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Dissertation

Über das Thema:

UNCERTAINTY AND MANAGERIAL DECISIONS FOR NEW TECHNOLOGY-BASED VENTURES

vorgelegt von
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aus
den Niederlanden

UNIVERSITÄT DER BUNDESWEHR MÜNCHEN

FAKULTÄT FÜR LUFT- UND RAUMFAHRTTECHNIK

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Tag der Prüfung:	30 Juni 2003

Mit der Promotion erlangter akademischer Grad: Dr.-Ing

Neubiberg, den 25 August 2003

"It is far better to predict without certainty, than never to have predicted at all"

Henri Poincaré, 1905

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LIST OF ABBREVIATIONS

ATM	Asynchronous Transfer Mode (broadband switching and transmission technology)
CEO	Chief Executive Officer
BPR	Business Process Re-engineering
DSS	Decision Support System
EBIT	Earnings Before Interest and Tax
Email	Electronic Mail
ERP	Enterprise Resource Planning
FTE	Full-time Equivalent
GAAP	General Accepted Accounting Principles
GDP	Gross Domestic Product
ICE	Information and Communication Enterprise Networks Department at Siemens Switzerland
IoS	Internet over Satellite
IP	Internet Protocol
IPR	Intellectual Property Rights
ISDN	Integrated Services Digital Network
LAN	Local Area Network
LRP	Long Range Planning
NASDAQ	National Association of Securities Dealers Automated Quotation – American automated system that trades over-the-counter stocks, traditionally home to stocks of technology-based firms

NTBV	New Technology-Based Venture
NYSE	New York Stock Exchange
OEM	Original Equipment Manufacturer
OTE	Hellenic Telecommunications Organisation
PBX	Private Branch Exchange (private telephone switchboard)
PC	Personal Computer
RBV	Resource-based View
R&D	Research and Development
ROI	Return On Investment
S&P500	Standard and Poor's 500 (Market Index)
WAN	Wide Area Network
VoIP	Voice over Internet Protocol
Win	Microsoft PC-Operating System Windows
WWW	World Wide Web (Internet)

ACKNOWLEDGEMENTS

Throughout the journey that resulted in the work presented here a great many people have contributed in terms of support and friendship. I would firstly like to thank Prof. Dr. Bernhard Katzy, for giving me the opportunity and guidance and making the whole process a challenging, inspiring, memorable but above all enjoyable experience. Secondly, many thanks to Prof. Mike Gregory from the University of Cambridge, whose institute I have been able to visit for an extensive period and for his willingness to be part of my examination committee. I would also like to thank the Dean of the Aerospace faculty at the University Bw Munich, Prof. Dr. J. Gwinner for both my years at the university as well as chairing my final examination.

Furthermore, my gratitude goes to Philippe Voirol who provided me with the necessary access to the case study data at Siemens ICE in Switzerland. In addition I would like to thank Laurent Bruelhart for his support and discussions during the development of the measurement software. Additionally I would like to thank David Probert for inviting me to be a visiting scholar at the Centre for Technology Management at the University of Cambridge, opening a world of valuable contacts and experiences.

Many of my colleagues became very good friend throughout my research project and I would like to express my gratitude. Dr. Guido Baltes for being like an older brother and making my life in Munich a great experience. Dr. Franziska Blindow, for the many long inspiring and enjoyable discussions, Dr. Mathias Müller, Dr. Lüder Tockenbürger and their families who never made me forget that there is an end to the tunnel and helped me to focus on just that. Scott Wilson for being my sparring partner in Cambridge and for throwing rocks in my pond of complacency. Thanks to Dr. Oliver Hugo and Dr. Noordin Shehabuddeen for their critical reviews and discussions. Also I would like to thank all my colleagues in both Munich and Leiden for their support. Furthermore I am grateful for the support from Helen Saunders in the write up phase of my dissertation.

In addition my thanks goes out to Frank van Loon, Arvid Fransen and Jelle Schutte, I highly value our longstanding friendship and appreciate your lasting support and discussions.

My love and thanks goes to my family whose interest and continuous support I have highly appreciated. Finally, I would like to thank Rachel Aston, my girlfriend without whom I simply would not have been able to do it and whom I love very much.

Marcel Dissel

1

INTRODUCTION

"Whenever we proceed from the known into the unknown we may hope to understand, but we may have to learn at the same time a new meaning of the word 'understanding'. We know that any understanding must be based finally upon the natural language because it is only there that we can be certain to touch reality, and hence we must be sceptical about any scepticism with regard to this natural language and its essential concepts."

Heisenberg, 1958

1.1 MOTIVATION AND OBJECTIVES

The objective of this dissertation is to explore managerial decision-making in new technology-based ventures and particularly the uncertainty surrounding such ventures. The Oxford English Dictionary defines a 'venture' as undertaking a risk, a risky enterprise or a commercial speculation. Venturing is a typical business firm activity. From this perspective, a venture is inherently associated with uncertainty. Uncertainty has also been a central focus for general management (Thompson, 1967). However, decision-making under uncertainty is especially evident in ventures where new technology-based innovations are exploited (Gold, 1971; Kay, 1997).

New technologies are prone to uncertainty a propos whether they will work, and if so, whether they can be turned into products for which there are markets to generate returns. As future applications of a given new technology have yet to be searched and discovered, it is difficult for management to make assumptions to base venturing decisions on. In MBA education, the 3M case (Bartlett and Mohammed, 1995) is used as an example. Specifically the case of 3M Post-it notes, which are based on a technology discovered in 1968: an adhesive that behaves differently to conventional glue in that it is less sticky. However it was five years before a successful application was found for this new technology and another 15 years before the technology was finally put to market. It was only when, rehearsing for the church choir one day and needing a marker in his hymn book, one of the 3M directors saw the benefits of an adhesive that could keep a piece of paper in place temporarily, leaving no trace. The results are well known and Post-it notes are now considered to be one of 3M's most successful ventures. It would have been impossible to assign probabilities or even anticipate the potential application for the technology during the first years of the technology's existence. It was only thanks to the innovation of one of the directors that the technology of the glue was patented and kept in house.

The topic of uncertainty for managerial decisions in new technology-based ventures (NTBVs) has received increasing attention at this time of writing (e.g. Courtney, 2001). Uncertainty-related problems for NTBVs are particularly visible and relevant at the present time. Since the market crash in April 2000, uncertainty for new technology-based industries has been reflected in the volatility and extreme fluctuations of stock prices. These fluctuations are disproportional and magnified in comparison to other industries (N. N., 1999a-c, 2001a-c). During a market crash, investors rapidly lose confidence in new technology industries as profitability prospects seem indefinitely delayed and new technologies face uncertain futures (N. N., 2001a-b). However, from a policy perspective, new technologies are essential for the economy. The European Commission recognised that technological development and innovation are by their nature uncertain, and it is a permanent challenge to assess the effects of new technological developments for future market dynamics and competitive conditions (N. N., 2002b).

Uncertainty as a managerial problem has been extensively researched and various techniques that have addressed decision-making under uncertainty are available. A prominent example of such an approach is decision theory (e.g. Raiffa, 1968; Markland and Sweigart 1987). Decision theory essentially helps decision makers to structure decision problems to the extent that statistical calculations can be performed to work out the probable outcomes of various decisions. The most common example is a risk-based calculation characterised by the availability of precise probabilities assigned to potential events, such as the outcomes of casting a dice. In dealing with uncertainty, however, these probabilities are less well known. Decision theory solves this by using so-called "subjective probabilities" or "best guesses" (Spencer, 1962; Raiffa, 1968; Dobbs, 1991), on which risk-like calculations can be applied. The success of such decisions thus depends on the accuracy of the assumptions of the decision maker.

Other approaches prescribe protection and avoidance techniques to help managers deal with uncertainty. Most prominently, Thompson (1967) suggested addressing uncertainty within the structure of the organisation and creating departments that shield the operative core of the firm from uncertainty. In that sense the marketing department addresses market uncertainties just as the Research and Development (R&D) department is a firm's response to technological uncertainty.

Another way of structuring the problem of uncertainty is to translate the uncertainty into a plan in which decision makers commit their resources to future activities. A decision is a specific commitment to action (Mintzberg *et al.,* 1978), mostly in terms of resources. The aim of such planning activities, according to Drucker (1959), is not to attempt to eliminate or minimise risk, but to commit present resources to future (uncertain) expectations (Drucker, 1959). The central problem, however, is again the accuracy of planner's estimate of the future (Koontz and O'Donnell, 1955).

These approaches have contributed a great deal to managers and their decision-making capabilities. Nevertheless, an added element of uncertainty that managers face when venturing new technologies is that it is not always clear *if* the technology will work, and *how* it will work. This stage precedes the applicability of the aforementioned methods, where reasonable assumptions on future states and their respective probabilities can be predicted by the decision maker.

An alternative perspective is provided in the literature that deals more with the input of the venturing process and the capabilities a firm should have. A prominent example is the proposal that a firm should have entrepreneurial capabilities. According to Schumpeter (1943), making the decisions related to bring about a unique event, or a venture, is a typical entrepreneurial activity. From this perspective, decisions rely on the entrepreneurial judgement (Penrose, 1959) which is often associated to the available experience in the firm (Penrose, 1959). Entrepreneurship seems to take a more input-oriented perspective to uncertainty. Rather than focusing on estimating the potential outcomes of decisions, literature on entrepreneurship describes what a firm requires in order to make good judgements.

In line with this example another input-oriented approach is emerging which is based on the capabilities a firm should have to change the resource base of a firm. Derived from this perspective, theories are emerging that address the typical turbulence present in new technology-based firms. Such firms require the capability to dynamically reconfigure the resource base (Teece *et al.*, 1997; Eisenhardt, 2000; Zollo and Winter, 2002), which is also referred to as a dynamic capability to optimally venture new technologies. A dynamic capability is thus the managerial capability to reconfigure the resources that make up the venturing organisation.

If this dynamic capability is prevalent in the firm, the firm is expected to have a competitive advantage, and thus arguably reduce some uncertainty. Such capabilities are ultimately an attempt to clarify the causal ambiguity that is apparent in the relation between the actions taken and the future outcome of these actions (or the performance) (Zollo and Winter, 2002). The main challenge from this resource-oriented perspective seems to relate to revealing potential causalities between the input (resources) and outcome (performance) of NTBVs.

These theories however are still in their early stages and are considered to be abstract (Teece *et al.*, 1997; Zollo and Winter, 2002). More empirical research and measurable results are called for (Teece, 1994; Teece *et al.*, 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002). The measurement of such intangibles requires exploration, and could prove beneficial to further the understanding of the impact such capabilities can have on the uncertainty surrounding the venturing process of new technology-based firms.

In this dissertation I will focus on new concepts that can support the measurement of intangible concepts and ultimately decision-making under uncertainty. In particular, I will explore new ways of dealing with the apparent ambiguity between the input or the output of the venturing process (Zollo and Winter, 2002). Within this context, this thesis sets out to use an analogy with Heisenberg's uncertainty principle that introduced a new conceptual way of understanding uncertainty using duality and probabilities that has been applied with great success in physics (Davies, 1989). This thesis will explore if and how this perspective can be adopted to enhance the understanding of uncertainty in NTBVs to the extent that it contributes to managerial decisions.

This thesis intends to adopt the conceptual understanding and implications derived from this uncertainty principle, in order to complement existing theories in understanding uncertainty for managerial decision-making. Analogous approaches based on concepts from other sciences have already provided valuable new insights in looking at organisational phenomena. Examples are biological theories, such as Darwin's theory of evolution to understand organisation development, and theories of physics, such as complexity and chaos theory (i.e. Gell-Mann 1995; Prigogine and Stengers, 1988) to understand organisational phenomena and the thermodynamics concept of synergy for self-organisation (Baltes, 2000).

The adoption of concepts from physics for social phenomena has received increasing attention (e.g. Ganley, 1995; Khalil, 1997; Overman, 1996; Mintzberg and Westley, 2000; Oliver, 1999; Fabian, 2000; Zohar, 1998; Zohar and Marshall, 1993; Evans, 1996; Barnard, 1996; Wheatley, 1999) and thus encourages this research direction. Within this context this thesis is a result of a dedicated research program developed at CeTIM that aims to explore such analogous approaches. Other examples as part of this program are the adoption of a synergy concept from thermodynamics to self-organisation (Baltes, 2000). As the results were encouraging, there seems to be potential to further the understanding using such concepts.

1.2 RESEARCH QUESTION

This thesis addresses the following two research questions:

- **What can a re-conceptualisation of uncertainty contribute to the understanding of uncertainty, in particular for managerial decision-making in new technology-based ventures?**

- **Can such an uncertainty concept be operationalised to complement existing pragmatic approaches and support managerial decision-making in new technology-based ventures?**

The first question aims to explore new ways of thinking about uncertainty by suggesting a re-conceptualisation of the understanding of uncertainty. Although uncertainty and managerial decision-making have been well discussed, the particular uncertainty residing in the venturing phases of new technologies still has potential for improvement. To this end, I will focus on the adoption of the conceptual understanding and a potential new way of dealing with the apparent limits of causality between decisions or actions and the outcome of such decisions. In order to deal with the unpredictability of this dichotomy I will adopt some of the ideas on probabilities, duality, methods and experiments first introduced by Heisenberg (1958).

The second question aims to explore a potential operationalisation of such a concept. This concept will predominantly focus on an alternative way of measuring and interpreting uncertainty within NTBVs. Similar to Heisenberg, who stressed the importance of experiments, I will operationalise and validate the conceptual insights in the context of NTBVs by proposing a candidate solution for measuring intangibles such as capabilities and study the impact these intangibles have on future outcomes. The subsequent results enable the evaluation of the potential contribution for managerial decision-making.

1.3 EXPECTED RESULTS AND CONTRIBUTIONS

The main academic contribution of this thesis is to raise the issue of the limits of causality when looking at uncertainty. This insight follows an analogous approach from the treatment of uncertainty as discovered in quantum theory. Research on this topic is time consuming and thus the expectations are not to provide a concrete solution but to initiate and explore this potential new research direction. As it took the physics community some three decades to come to terms with the unconventional ideas of Heisenberg in the Copenhagen interpretation (Heisenberg, 1958), so it is the expectation that research, as presented in this thesis, will need many years to evolve.

The conclusions are drawn on a conceptual level and aim to evaluate if this new way of looking at uncertainty can provide a potential contribution for managerial decision-making in NTBVs. This contribution is interdisciplinary as the main focus is in the area of technology and innovation management, which is at the confluence of engineering and management sciences (Lannes, 2001). This thesis does not claim that there is a new Heisenberg uncertainty principle to be found that applies to managerial phenomena. However, this thesis tries to raise awareness of the successful inquisitive methods and concepts Heisenberg applied and experimented with in order to explore potential pragmatic solutions for uncertainty in managerial phenomena.

The experiment described in this thesis is expected to provide a first indication of a new way of looking at and measuring uncertainty for NTBVs. The expectation is that based on these new insights future research streams will unfold from both a pragmatic as well as an academic perspective. The development of a measurement instrument in particular is expected to provide a fruitful starting point and has the potential to contribute to managerial practice and engineering sciences.

To engineering sciences, the expected contribution is to support system engineers in developing new methods and tools for managerial decision-making. The system design fuels the development requirements for information systems and provides a first validation of the applied conceptual advances made in this work.

To managerial practice, this thesis is expected to provide new insights on solutions to deal with uncertainty for managerial decision-making, especially in the context of NTBVs. The experimental results are expected to provide an increased understanding of the complex problems surrounding the uncertainty that managers face when venturing new technologies. This new understanding can benefit decision makers, such as board members, venture capitalists and general managers. The subsequent development of measurement systems therein is a potential way of dealing with these problems, and opens up an array of new ideas for future consideration.

1.4 RESEARCH PLAN

"...any concepts or words which have been formed in the past through the interplay between the world and ourselves are not really sharply defined with respect to their meaning; that is to say, we do not know exactly how far they will help us in finding our way in the world. We often know that they can be applied to a wide range of inner or outer experience, but we practically never know precisely the limits of their applicability."

Heisenberg, 1958: 51

The research plan reflects specific elements for conventional research approaches in both the social sciences and system engineering. Research in technology and decision-making typically crosses interdisciplinary barriers (Cheng, 1999). The interdisciplinary nature can be illustrated by describing technology as the process that enables a company to know how to apply science and engineering, clarifying what the technology does for the business instead of just stating what the technology is (Erickson et al., 1990). The research plan thus builds on the coalescence of engineering management (Lannes, 2001) and socio-economic perspectives.

In order to construct an appropriate research plan, the question of how reality can be known has to be addressed. This is the central question in the field of epistemology. Epistemology is the study of the nature of knowledge and justification (Audi, 1999). Philosophers have contemplated the numerous systems of belief by which reality can be known. For example, two prominent beliefs are the rational belief versus the empirical belief. From a rationalist's perspective, absolute truths, such as mathematics, are known a priori by pure cognition. This view was held by philosophers such as Descartes, Leibniz and Spinoza (Audi, 2000). In contrast, empiricists believe that the only way to know the truth is by experience. This view was predominantly held by philosophers such as Hume, Locke, Hobbes and Newton (Audi, 2000). Although both beliefs seem exclusive, a critical view emerged, notably by Immanuel Kant (1781), in a plea to align these two views. He suggested that these two types of knowledge, empirical and rational, co-exist. Some pieces of knowledge are rational and thus known *a priori*, e.g. that two and two makes four. Other knowledge can only be known through experience, e.g. the sun rising every morning (Heisenberg, 1958).

The epistemological position thus reflects the relation of the researcher to the object under study. Burrell and Morgan (1979) argued that knowledge can be viewed as either objectively or subjectively knowable. The first disposition, also referred to as a positivism, in which the phenomena under study is clear and an undeniable truth, is expected through a process of verification or falsification (Audi, 2000). The second disposition, the subjective view, is also referred to as social constructivism (e.g. Berger and Luckman, 1967; Weick, 1979; Guba and Lincoln, 1989). This view claims that knowledge on certain phenomena is the result of a process of social interaction, or socially constructed. This last view is appropriate in cases where the boundaries of the phenomena under study are unclear and an undeniable truth is not directly assumed.

In this dissertation, the boundaries between the phenomenon of "uncertainty" and the object under study, new technology-based firms, are not clear and thus require a constructivist approach. The exploration will thus be based on a research design that allows the researcher to experiment and learn from the findings in order to extend the knowledge base on the subject under study in an attempt to seek further clarification of the phenomenon rather than claim a new undeniable truth. To this end I follow Heisenberg's view, which advocates a continuous interplay between theory and experiment. Heisenberg (1958) built on the Kantian view but argued that what Kant defined as *a priori* knowledge can become obsolete when new empirical findings are made. An example of this is the law of causality which Kant viewed as rational and thus *a priori* knowledge. Heisenberg proved that the law of causality was no longer applicable on a quantum level and thus no longer an absolute truth. It is his belief that it is not possible to reach the absolute truth by pure reason alone; he therefore stressed the importance of listening to the experiment.

The research design of this thesis takes a constructivist approach in order to analyse and understand the phenomena under study. The design incorporates three distinct steps. Firstly, ideas are extracted from literature in order to come to an alternative treatment of uncertainty for decision-making in new technology-based venturing. Secondly, based on these conceptual ideas, an experiment is designed. This experiment takes the form of a set of cases in which the concept will be further explored. The experiment design will also incorporate a system engineering module to create an appropriate measurement tool. The third step is the actual testing and validation of the concept. The results of a critical longitudinal case study, where the concept will be tested in multiple sites, are expected to provide new insights into the understanding of uncertainty in new technology-based venturing.

An overview of the research design and its modules are as follows:

Idea Development

The idea development phase has three distinct modules that are based on an extensive literature analysis.

The first module addresses the literature on existing solutions for uncertainty and managerial decision-making. A vast amount of literature exists, examples of which have already been addressed in the introduction, such as decision theory and entrepreneurship. Nevertheless, as the introduction has shown, uncertainty is still a major challenge for managerial decision-making in

NTBVs in cases where decisions have to be made for which the consequences are not clear, or where there is causal ambiguity (Zollo and Winter, 2002).

In contrast to the existing solutions that regard uncertainty as a result of ambiguous casual relationships (e.g. the cause-effect relationship of decision-making and performance) uncertainty has been given a different meaning in physics. The second module will subsequently introduce an alternative approach adopted from physics where, notably, Heisenberg stood at the forefront of a powerful solution for uncertainty on a sub-atomic level. He proved the laws of causality were made redundant when dealing with this inherent uncertainty, and shifted the focus from causality to a probability approach. Although the subsequent method was highly disputed by the likes of Einstein, the application proved very successful in the years to come. The seminal work of Werner Heisenberg, 'Physics and Philosophy', will form the basis of this review (Heisenberg, 1958) that, in conjunction with supporting material on the history of physics, will be used to shed light on an new way of thinking about uncertainty.

In the third module I will propose a new way of looking at uncertainty for NTBVs analogous the conceptual approach used by Heisenberg. The re-conceptualisation follows a logical argument using an analogous approach adopted from Heisenberg's *uncertainty principle*, in looking for non causal elements that ultimately define uncertainty. This is also referred to as duality. Furthering the re-conceptualisation I will suggest a probability function that allows for a better prediction of this non-causal relationship. Finally the re-conceptualisation is compared to previous efforts that have used the philosophical implications derived from the discoveries in quantum theory as to position the results. The evaluation follows an analysis of the most prominent efforts where scholars and practitioners have used Heisenberg's uncertainty principle and its implications to study managerial phenomena. The evaluation aims to show similarities and gaps in previous works and will position the proposed re-conceptualisation within the existing literature.

The results of modules one and two are described in chapter two; module three is described in chapter three.

Experiment Design

The experiment design section incorporates two modules in order to effectively construct an experiment in which the new conceptual findings can be tested and validated.

The first module will further the research by developing an experiment that allows for an initial empirical validation on the potential contribution of the new insights on uncertainty and how it can benefit managerial decision-making in NTBVs. The experiment is developed using empirical case studies resulting in a first application aimed at operationalising the proposed concept. This candidate solution has been developed using practical insights on two new technology-based firms. More specifically, using case study research, requirements have been distilled in order to create a first application that, from a practical perspective, can operationalise the concept to benefit managerial decision-making.

Following these developments, these ideas are implemented in the second module in a software tool, to allow for appropriate measurements of the experiment. As part of the operationalisation, the applied concept has been implemented in a prototype measurement system that aims to model the new understanding of uncertainty. In addition, a method is developed that allows for the effective testing of the new concept. The section will close with the development of an initial "thought experiment". A thought experiment, or "Gedankenexperiment," is a device of the imagination used to investigate nature (Brown, 2002).

The case studies module is described in chapter 4; the system engineering module is separately described in chapter five.

Testing and Validating

In order to test and validate the experiment developed in the previous section, it will be carried out in a firm with multiple NTBVs. The concept and prototype system have been explored in a NTBV scenario of an Original Equipment Manufacturer (OEM) in the telecommunications industry. Using an exploratory longitudinal case study (Leonard-Barton, 1990) with two measurement sites, I aim to gain further insights into the potential contribution of the new way of looking at uncertainty in venturing new technologies and what it can contribute to understanding managerial decisions.

Based on this experiment I will discuss the contribution and implications on both a conceptual level as well as the lessons learned for future research experiments in this direction. This is illustrated in the research plan (figure 1) as a feedback loop to the respective sections.

The testing is reported in chapter six and the conclusions and implications are reported in chapter seven.

The distinct research methods are described at the beginning of each subsequent chapter; these will focus on how the data used has been selected and collected, how this data has been analysed and what the validity criteria are.

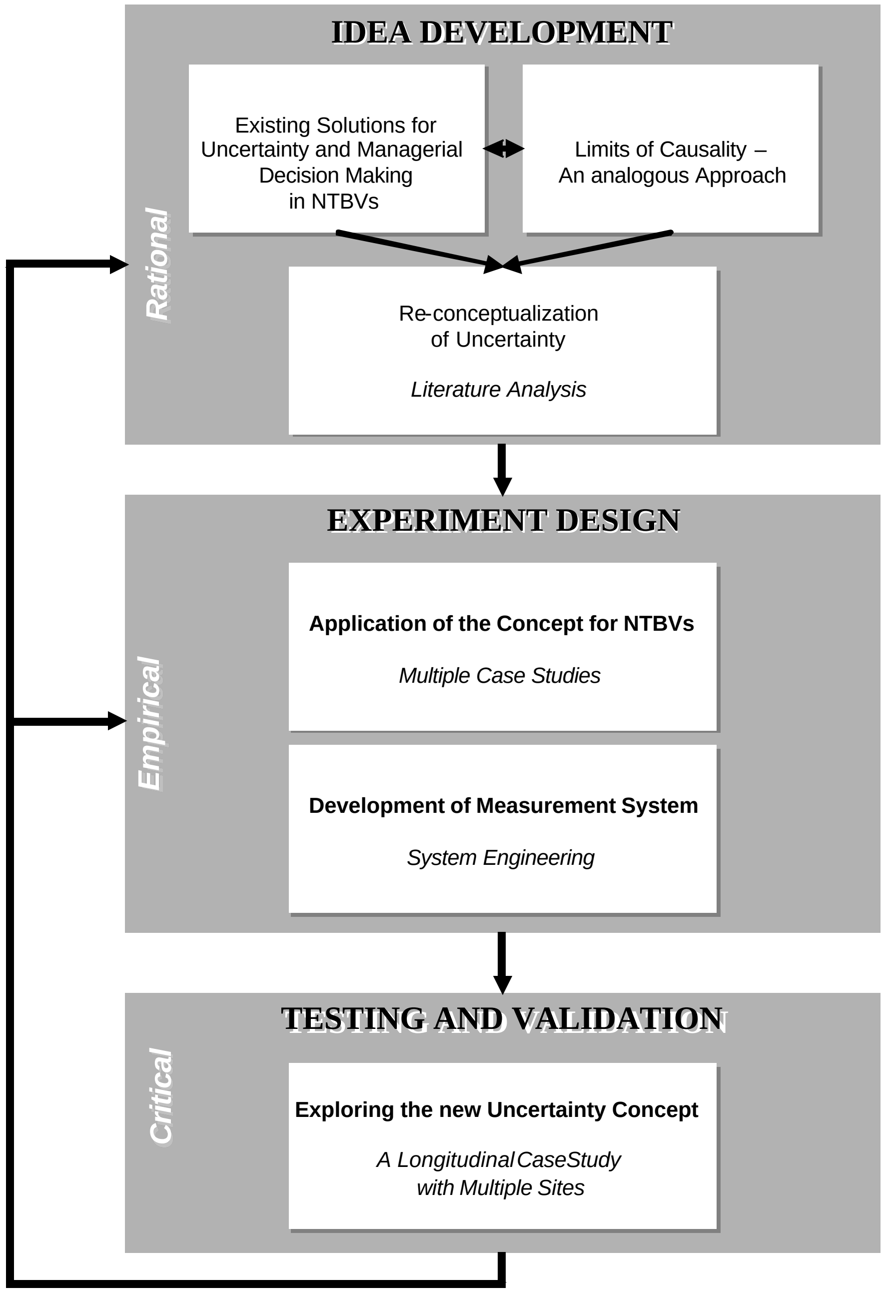

Figure 1: Research plan

2

DECISION MAKING UNDER UNCERTAINTY; A MATTER OF UNDERSTANDING CAUSALITY

2.1 INTRODUCTION

Uncertain. *(adj.)* **1** not certainly knowing or known ***(uncertain what it means; the result is uncertain*.,** **2** unreliable *(his aim is uncertain).* **3** changeable, erratic *(uncertain weather*).

Oxford English Dictionary

'Uncertainty' is the noun from the adjective 'uncertain', which in the Oxford dictionary is related to missing knowledge or unreliable and changing circumstances. Uncertain is the negative of 'certain', which stems from the Latin 'certus'. 'Certain' can also be taken to mean settled or determined, therefore the negative reflects a state of being unsettled or undetermined.

The process of venturing new technologies is often associated with such expressions. Venturing new technologies can bring many opportunities, but may also prove fruitless. The outcome of NTBVs is often not known at the outset. This has strong implications for managerial decisions and is complicated by the fact that the pre-investments needed to venture new technologies are often very high.

Uncertainty makes it difficult for managers to make good decisions and "settle" the technology venture, which is often complicated by a turbulent environment. The problem of uncertainty has been recognised in the literature and hence has been widely discussed. Examples can be found in decision theory and long range planning techniques. However, despite these solutions some uncertainty remains that is typically visible in new technology-based ventures. It is thus worthwhile revisiting the existing concept of uncertainty and managerial decisions to find complementary approaches to deal with this specific uncertainty.

This section will discuss the most prominent approaches in literature regarding managerial decisions under uncertainty, and evaluate how these approaches deal with the typical uncertainties in new technology-based ventures. I will then analyse an interdisciplinary framework that will form the basis of the evaluation of a potential alternative concept of uncertainty, by exploring an analogy with Heisenberg's treatment of uncertainty. This part follows a conventional literature research methodology. The literature study is based on the following steps:

1. Explorative scientific literature searches in libraries and electronic databanks on the concept of uncertainty and related topics. The search considered the title, keywords, abstract and full text, and focused on the hits related to the concept of uncertainty for managerial decision-making, with a particular focus on new technologies. Additionally the concept of uncertainty and analogies to physics has been explored.

2. Structuring of the hits in three levels:

   A. Managerial decision-making under uncertainty. The results stemmed from a semi-structured search within the existing body of literature. Specific focus has been given to the bodies of knowledge concerning technology and innovation management studies. The search continued throughout the duration of the study and was carried out at four university libraries[1], and also used intermediate electronic databanks[2]. In addition, a specific electronic search was carried out on the database of the Academy of Management. Three topics emerged: decision theory, strategy & organisation, a capabilities view of the firm. These will be discussed in sections 2.2 to 2.5.

   B. Literature on the evolution and treatment of the problem of uncertainty in physics (with emphasis on quantum theory and the conceptual and epistemological consequences). The results were predominantly based on a chronological search partly derived from similar sources to the first search level. They incorporated seminal and original works dealing with the conceptual and philosophical implications of the uncertainty principle and an outline of its history. This will be discussed in section 2.6.

   C. Literature on cross-references of Heisenberg's uncertainty principle in social sciences, in order to review existing analogies and references. The results stemmed from a direct search, using Proquest ABI/INFORM. This will be discussed in section 3.2.

This formed the basis of the literature review. The structuring of the specific search results has been carried out using the endnote database structure. For each search level (A-C) a separate database has been used to capture and summarise the articles. The selection criteria were twofold: the relevance to the research question and the quality rating of the publication. In the case of

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[1] Searches took place at the following libraries: Universität der Bundeswehr, St. Gallen University, University of Cambridge, Cranfield University

[2] Online databank sources: EBSCO's Business Source Premier, ABI/Inform Databank and the Emerald Databank.

journal articles, the articles predominantly stem from journals that have been classified as 'A,' according to the citation analysis on the technology and innovation management journals by Cheng (1999).

2.2 TO ASSUME AND TO ANALYSE: MAKING CALCULATED DECISIONS UNDER UNCERTAINTY

The literature study on managerial decision-making under uncertainty led to the field of decision theory. Decision theory reduces decision problems to a quantifiable set of decision outcomes and probabilities. By performing calculations on probabilities and outcomes, the most desirable decisions can be selected.

2.2.1 Using quantitative methods for decision-making under uncertainty

Decision theory finds it roots at the beginning of the 20th century when industrial engineers began to apply scientific techniques to reduce uncertainty in industrial problems (Markland and Sweigart, 1987). The first examples go back to the early 1900s when Frederick Taylor studied worker capacities and developed time standards for specific job functions, also known as time and motion studies (Taylor, 1911). This scientific approach has been furthered in a set of principles for scientific management (Fayol, 1949) theorising on all the elements required for a plan of action, such as the art of handling men, energy, moral courage, continuity of tenure, professional competence, and general business knowledge[3].

However it was not until World War II that these scientific methods for managerial decisions were enriched with statistical methods and became known as operational research (or operations research as the Americans have termed it). Notably, Thomas Edison had studied antisubmarine warfare during World War I and compiled statistics for determining the best methods for detecting and evading submarines (Markland and Sweigart, 1987). These ideas were taken up in World War II by the British army to scientific study military operations (Markland and Sweigart, 1987).

The new emerging operational research activities resulted in an improved decision-making capability for Winston Churchill and his team under the uncertainty of the war. For example, following a request for additional fighter squadrons a study was prepared graphing the daily losses and replacement rates (Beasley, 2001). This study indicated that additional fighter squadrons would

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[3] Fourteen general principles of management: division of work; authority; discipline; unity of command; unity of direction; subordination of individual interests to the general interests; remuneration; centralisation; scalar chain (line of authority); order; equity; stability of tenure of personnel; initiative; esprit de corps.

only deplete fighter strength, and thus the decision was made not to send any additional squadrons. This particular move has been coined one of the most important strategic contributions to the course of the war as a result of using operational research.

Operational research was found to be highly successful in decision-making in war scenarios where the objective was to find the most effective utilisation of limited military resources using quantitative techniques (Beasley, 2001). Notable achievements were made in determining how to protect a military convey, how to organise radar defences, and how to drop bombs effectively on submarines. Beasley (2001) reported the increase in probability of attacking and killing a U-boat from 2-3% at the beginning of the war to 40% at the end, which illustrates the relevance and importance of this technique.

The operational research method survived and rapidly expanded to support decision-making in post-war civilian practices and the associated uncertainties. Since the war, many different labels have been used to describe these practices, including decision theory, management science, operations research, decision analysis, decision science, cost-benefit analysis and system analysis (Raiffa, 1968). The essential treatment of uncertainty is similar throughout all these. It is thus not necessary in the context of this thesis to discuss all the nuances and differences between these labels. Henceforward, I will refer to these scientific approaches of dealing with uncertainty as 'decision theory'.

Decision theory is applied in many areas to support managerial decision-making. As a survey about Fortune 500 firms in the U.S. (Fabozzi and Valente, 1976) shows, mathematical methods are predominantly used in production management (determining product mix, production and scheduling), and in financial and investment planning (e.g. capital budgeting, cash-flow analysis, portfolio analysis, and cash management).

However, the specific types of problems that are subject to decision theory are not similar to the uncertainty elements in new technology-based ventures. For example, the military decision problems are of a different calibre to the decision problems encountered in new technology-based ventures. In wartime, the potential outcomes can be reasonably predicted, the extreme example being: to kill or to be killed. In addition, the decision options that lead to these outcomes are reasonably well known, the extreme example being: to attack or not to attack. As this chapter will show, quantitative methods are ideally suited to such decisions. However, such approaches have their limitations when it comes to venturing new technologies. In the typical venturing process the outcomes and decision options are neither predictable nor clear cut. For example, it is not always clear what outcomes a new technology will have. It may bring a product or something completely different. The purpose of a new technology may only be found much later, or even not at all.

Although many examples are available that illustrate the uncertainties of venturing new technologies, a well-known example is the Post-it case at 3M. In 1968 Spencer Silver, a lab scientist at 3M, discovered an adhesive that acted in a peculiar way. Instead of forming a film, this adhesive turned into clear spheres that “kind of sparkled in the light” (N. N., 2002: 38). Over the next few years, Silver sought a suitable application for the adhesive but to no avail. Five years after his discovery, Art Fry, a company director, found an application for the adhesive by coincidence whilst rehearsing for the church choir (N. N., 2002). As he turned the pages of his songbook his scrap paper bookmark fell on the floor, and he started wondering how he could get the bookmark to stay in place (N. N., 2002). It was then that the adhesive found its application, but it was another 15 years before the application was finally commercialised in the now popular Post-it notes (N. N., 2002). During this time it could not have been predicted that the technology would ultimately transform the firm, nor how the reasonable decision options available could have arrived at these unknown outcomes.

2.2.2 Subjectively assigning probabilities to potential future outcomes

Decision theory uses a method that is primarily based on assigning probabilities to potential outcomes. Instead of relying solely on intuition, experience or causal observation, decision theory incorporates the basic elements of a scientific method and thus facilitates a rational, systematic way of problem solving (Markland and Sweigart, 1987). Without this approach, decisions are believed to be unsystematic and highly subjective (Markland and Sweigart 1987).

In decision theory, four types of decision-making situations can be distinguished (see table 1). In cases of uncertainty, a lack of knowledge about potential future states is apparent. The decision-maker has to accept this limitation, and is required to guess the probabilities of these future states. Based on these guesses, decisions can be made using calculations similar to those applied in situations of risk.

FOUR TYPES OF DECISIO N-MAKING		
	Type	***Example***
1	***Decision-making under certainty*** The decision maker knows the state for each decision alternative with certainty. In other words there is perfect information available to the decision maker.	With a typical investment of €100, where a building society guarantees 4% interest and a bank guarantees 7%, it is easy to make the decision to put the money in the bank.
2	***Decision-making under risk.*** In this case the decision maker does not have perfect information, but knows the probability of an occurrence for each state of nature with certainty	Casting a dice where the state is not certain but each state has a 1/6 chance of being reached.
3	***Decision-making under conflict*** . Two or more decision makers are competing and thus have to make decisions under conflict. In this case the decision makers have to consider not only their own decision but also the decision of the competitor. This type has been discussed by von Neumann and Morgenstern (1947) Game theory.	The prisoner's dilemma, in which there are two players each having two choices: to co-operate or defect. Each player gains a little when both co-operate. However, if one of them co-operates and the other one defects, the latter will gain considerably more, whilst the first will lose (or gain very little). If both defect, both lose (or gain very little) but not as much as the co-operator whose co-operation is not returned.
4	***Decision-making under uncertainty***. The decision maker does not know the probabilities associated with the various states of nature. In this case the decision maker has to guess the probabilities, before a calculation can be made. Decision theory has addressed various criteria which a decision maker can use to make his guess.	Examples of these criteria are: maximax (take the most optimistic probability), maximin (take the most pessimistic probability), realism (take a compromise), equally likely (assume the probabilities are equal), minimax (minimise opportunity losses, also known as Savage criterion). However, in each case, it is assumed that the decision maker can reasonably estimate all future states. The criteria then describe the various attitudes the decision maker can take in guessing the probability of that state to occur and thus make a decision. In other words, rather than looking at the expected monetary value of each decision, the decision maker chooses a utility criterion and aims to optimise the utility rather than the monetary value (von Neumann and Morgenstern, 1944).

Table 1: Decision-making under certainty, risk, conflict and uncertainty (Markland and Sweigart, 1987)

However, it can be difficult to take full advantage of decision theory techniques in the case of NTBVs as such guesses are hard, if not impossible, to make. As previously stated, because both the outcomes and the decision options of NTBVs are mostly unknown, it is difficult to speculate on what the outcome may be and what the probability is that this will occur. In order to optimally benefit from decision theory, the problem should have a minimal degree of predictability on potential future states and their probabilities in order to make fair assumptions on their values.

This can be illustrated by examining the method of structuring available data combined with subjective assumptions as used in a decision tree. The graphical model of the decision tree illustrates where decision theory requires assumption. A decision tree can be used to map each stage of the decision-making process by showing its logical progression (Markland and Sweigart, 1987). Furthermore, a decision tree facilitates calculations. An example of a decision tree is depicted in figure 2. It is obvious that the decision maker should have some information or an idea of potential future states (or attitudes towards these future states) and the probabilities that these states will occur. In other words, the uncertainty in such models resides ultimately on the accuracy of the assumptions and subjective probabilities assigned to the various states.

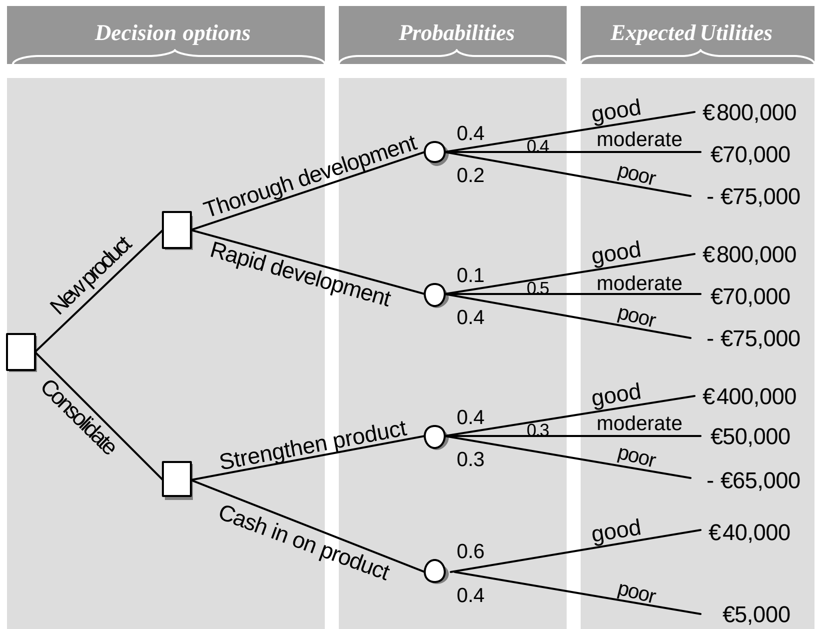

Figure 2: Decision trees: assumptions on decision options, probabilities and expected utilities

The accuracy of the subjective judgements is thus a very important condition for decision-making in decision theory. Raiffa (1968) schematically depicted the judgemental gap between output of the models used and the real world (figure 3). However, Raiffa also recognised that this judgemental gap might be "…so wide that the analysis does not pass the threshold of relevance; the analysis may fall short of furnishing meaningful insights into the problem." (Raiffa, 1968: 296). So the uncertainty shifts from the actual calculation and decision to the assumptions on which the decisions are made.

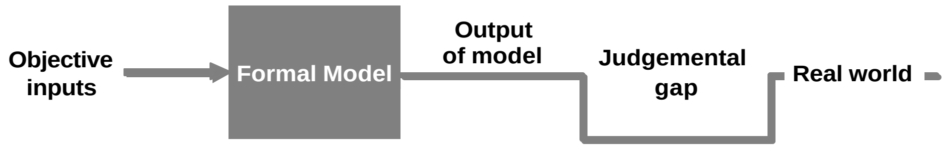

Figure 3: Decision theory: decision models and judgemental gaps (Raiffa, 1968)

Decisions regarding new technology-based ventures often have a judgemental gap that is too wide and thus renders decision theory obsolete. Decision theory only becomes useful when the outcome of a new technology is relatively predictable. As the example in figure 2 shows, the outcome of the new technology could be a product. When it is clear that this is the case, decision options can be established and decision theory becomes an effective method to reduce the uncertainty surrounding this new product. However if the outcome of the new technology is not yet known, a different class of uncertainty emerges.

2.2.2.1 Measuring subjective perceptions on uncertainty

A stream of literature has attempted to measure subjective perceptions of uncertainty (e.g. Burns and Stalker, 1961; Lawrence and Lorsch, 1967; Downey and Slocum, 1975; Downey and Hellriegel 1975; Miles and Snow, 1978; Hrebiniak and Snow, 1980; Snow and Hrebiniak, 1980; Wernerfelt and Karnani, 1984; Buchko, 1994; Koberg, 1987; Milliken, 1987; McMullen and DeCastro, 2000). The literature elaborates on the concept of perceived environmental uncertainty and has developed a variety of scales to measure this. The scales are based on the perceptions that a firm or individual managers have about uncertainties in the environment (Downey and Slocum, 1975).

A seminal example is a study by Lawrence and Lorsch (1967), who associated uncertainty with specific functions within an organisation, such as marketing, sales and R&D. Based on this classification, three sublevels of perceived uncertainty were derived: lack of clarity of information; general uncertainty about causal relationships; and time span and feedback about results. The study was a single examination of 10 U.S. industrial firms. The researchers accepted the operationalisation of uncertainty based upon the face validity of the concept and the instruments. However, extended studies into this operationalisation did not provide the replication necessary to support their argument (Tosi *et al.*, 1973; Downey and Slocum, 1975).

These measurement scales of perceived uncertainty implied that the uncertainty can be understood by taking the average of all individually measured perceived uncertainties (Buchko, 1994; Milliken, 1987; Miles and Snow, 1978; Downey and Slocum, 1975). However, the literature also demonstrates the difficulty in establishing such unanimous measures for perceived uncertainty. In particular, replication of these scales in additional studies proved unsatisfactory and the conceptualisations of these measures were not used consistently (Buchko, 1994). This illustrates the problem with using the subjective perspectives of decision-makers. If the perception of this level of uncertainty is already difficult to generalise, this means each decision-maker has a distinct view on his or her assumptions towards potential future states and probabilities.

Downey *et al*. also noted that there is tremendous inconsistency and confusion about how a construct of uncertainty is defined and used; hence the concept of uncertainty itself is surrounded by a lot of ambiguity (Downey and Slocum, 1975). However, additional attempts to operationalise these uncertainty concepts improved the scales and dimensions. For example Miles and Snow (1978) provided scales based on the predictability of the conditions in the environment. This has been extended by various other researchers (Milliken, 1987; Buchko, 1994), but the main conclusions derived from these studies were not so much on the validation of the operationalisation, but on the unstable perceptions of uncertainty itself (Buchko, 1994). Although it received a lot of attention from the 1970s through to the 1990s, interest in the topic seems to have been lost in the approaches to comprehend environmental uncertainty.

From this perspective, it would thus be more relevant to study measures on the judgmental capabilities available to a firm, rather than taking a normative measure for the apparent uncertainty in the environment. The measurement of uncertainty thus remains a challenge. In cases where quantitative research is less applicable (Raiffa, 1967), new approaches to understand the intangible aspects of this uncertainty might be useful for increasing the judgmental capabilities of the decision maker and ultimately improving decision-making under uncertainty.

2.2.2.2 Infomation gathering to make better judgements

One approach for enhancing the decision-makers judgement is to get more information. Information technology systems are typically designed to accommodate this. Based on the belief that the uncertainty is based on the level of accuracy of the assumptions that can be made, it thus seems important to gather as much information as possible to get a better feeling for the associated assumptions.

Information technology has contributed to the quantitative modelling of problems for decision-making. Particularly in situations where the problems are too complex for human computation, computers systems have been used to better inform and facilitate managers in decision-making under uncertainty. Some examples are Management Information Systems (MIS), such as enterprise resource planning systems (i.e. SAP, JD Edwards, BAAN etc.) and decision support systems.

The interface between MIS and decision theory, in particular, has received increased attention. Management information systems are computer-based systems for collecting, analysing and reporting information to managers (Markland and Sweigart, 1987) that aim to increase the accuracy of the assumptions made by decision-makers. Next to the enhanced computation abilities, MIS provide input data to support quantitative modelling efforts (Markland and Sweigart, 1987). Another type of information system that evolved from these developments is a Decision Support System (DSS). A DSS attempts to provide timely and accurate information to the decision maker and allows the decision maker to interact and change the model to ultimately enhance the decision-making process.

Although the accumulation of information using sophisticated systems supports decision-making under uncertainty, information systems alone do not seem sufficient to deal with uncertainty in NTBVs. For example, information overload has also been seen to destroy the creativity necessary for innovation (Sethi *et al.,* 2002), and thus might not fit the class of problems associated with decision-making under uncertainty for new technology-based ventures, as this is typically based on innovation (Drucker, 1959). In addition, whilst information systems are important to decision theory for developing a better-informed assessment or judgement on probabilities, they do not necessarily add to the knowledge on potential outcomes of new technologies, nor do they necessarily contribute to the decision-maker's capabilities to make good judgements. In the 3M case, more information, either from the market, previous business ventures or financial situation, would have contributed little to an enhanced understanding of the future outcomes of the new technology. In general, information on past data does little to enhance the knowledge on future outcomes of new technologies and innovations, as innovations can change the future itself (Drucker, 1959).

2.2.2.3 Using a real options perspective

A recent and promising development has addressed the relevance of uncertain future outcomes by taking a so-called 'real options' perspective. Option contracts represent small investments which yield the opportunity to purchase an underlying security at a later date (McGrath, 1996). When an investor holds an option, the investor can exercise the option and buy the underlying security. In essence the investor only carries a limited downward risk (the price paid for the option – which is a fraction of the price of the underlying security), without losing access to the opportunity (McGrath and MacMillan, 2000).

Real Option theory is receiving increasing attention, and the application areas are widespread (Miller and Park, 2000). Real options provide an essential framework, extending current practices in decision theory. Options provide access to opportunities at lower costs, and create an additional decision option: waiting (McGrath, 1996).

However, whilst real options are a promising new direction (Anderson, 2000; McGrath, 1999; McGrath and MacMillan 2000; Miller and Park, 2002), the uncertainty classification with respect to new technologies has not changed significantly. For real options to become a valid method, some initial idea on the future potential has to be apparent in order to apply the mathematical scheme and make calculated decision on these options. There is a difference between the uncertainty addressed in real option theory and the uncertainty associated with NTBVs, where these options are not readily available.

Real options thus seem better equipped in the phases when the uncertainty starts to diminish and technological applications start emerging (Bollen, 1999), or in other words, when the uncertainty is starting to settle. This thesis focuses on understanding the uncertainty before it is settled, and tries to identify how it can best cope in the unsettled phases. The Real Option framework will be discussed further as part of the entrepreneurship literature (McGrath, 1999), in section 2.3.

2.2.3 Calculating decisions in NTBVs – a problem of judgement

In summary, the uncertainty in calculation-based decision models such as decision theory, resides in the subjective probabilities assigned to decision-outcome relationships. This implies there is at least some knowledge available on the potential decision options and outcomes so that decision problems can be solved using risk-based calculations based on the assumptions made stemming from this knowledge (Choi, 1993).

As I have argued throughout this chapter, in the venturing process of new technologies, such decision-outcome relations are not known yet. The uncertainty in NTBVs thus resides in the outcome not in the probability of a potential outcome. NTBVs thus deal with a different class of uncertainty, where these assumptions are difficult, if possible at all. In NTBVs it is not known what the future state of the technology might be, if the new technology will actually work, let alone that any reasonable probabilities can be calculated.

Unlike the uncertainty in decision theory, therefore, uncertainty in NTBVs lacks a clear causal relationship between decision and outcome. Decision theories reflect systematic methods that support the rational structuring of decision problems in potential cause-effect relationships. By making assumptions on the probability of each potential relationship happening, the outcome and the most optimal decision can be calculated. In NTBVs, however, knowledge on these causal relationships is not available.

2.3 TO PLAN AND TO PROTECT: SOLUTIONS AND GUIDING MODELS FOR UNCERTAINTY

New technologies can cause disruptive and discontinuous changes to the firm and the market (Drucker, 1959). As shown in the first section, the outcome of new technologies is often not known and thus can render quantitative modelling techniques obsolete. To illustrate this, take again the 3M case, where the new technology (the glue) subsequently transformed the organisation that started out as the Minnesota Mining and Manufacturing Company. It is obvious that these changes could not have been reasonably predicted at the time, and thus decision theory could not have added much to the decision-making process at that time.

In order to better prepare the firm for these uncertain changes other approaches have been developed such as planning and organisational design solutions. This section will briefly discuss these approaches and evaluate their potential for this specific uncertainty in new technology-based ventures.

2.3.1 Planning for the future: capturing uncertainty

During the 1960s the realisation emerged that, in uncertain environments, firms require a systematic planning system (Ansoff, 1988). Previously, managers applied so-called ad-hoc management, or logical incrementalism (Quinn, 1978), in which decisions were made in an incremental reactive manner, without having a centrally planned strategy behind it (Ansoff, 1988). However, Ansoff (1988) noted that ad-hoc management is appropriate only in situations where the demand and technology in a firm's market continue to evolve incrementally. If the rate of change does not exceed the firm's ability to react then ad-hoc management is appropriate. In other environments with a higher level of uncertainty this is not sufficient (Ansoff, 1988).

Systematic approaches were called for to enable firms to enhance managerial decision-making in these uncertain environments of rapid growth. Such environments, where the firm is not always able to adapt to the rate of change, are often referred to as turbulent (d'Aveni, 1994; Katzy and Schuh, 1997). The solution resides in the fact that managerial decisions depend on the ability of managers to create a mental vision of the future. Uncertainty is attributed to managers having incomplete knowledge of the future, or bounded rationality (Simon, 1957). Managerial decisions thus depend on their ability to create a mental vision of the future (Spencer, 1962). This vision cannot be verified in a quantitative manner alone (Spencer, 1962).

New technology-based firms thus require a strategy in order to prepare for this uncertainty. In the words of Ansoff (1965): "In the absence of strategy, there are no rules to guide for the search of new opportunities, both inside and outside the firm. Internally, the Research and Development department has no guidelines for its contribution to diversification... Thus the firm as a whole either passively waits for opportunities, or pursues a 'buckshot' search technique" (Ansoff, 1965: 102).

Uncertainty in this sense is related to time, as the longer you want to plan the more uncertain the future is. A formal or systematic approach of achieving this mental vision is also referred to as the plan or strategy (Mintzberg, 1994). The first widely accepted systematic planning system was referred to as Long Range Planning (Ansoff, 1988). The name Long Range Planning (LRP) includes a time factor, and its initial intent was to enhance a firm's operations management in uncertain environments of rapid growth (Ansoff, 1988). Later on it also developed as a planning discipline for R&D (Koontz and O'Donnell, 1955; Drucker, 1959; Salveson, 1959), where the plan guides the decision maker in exploiting opportunities created by, for example, new technologies.

The central problem for good planning remains the accuracy of the planner's estimate of the future. LRP introduced a systematic approach to guide the planner in achieving a better estimate. Drucker (1959) suggested that the essence of good planning is to bring about a unique event or innovation that changes probabilities, rather than to try to forecast the future. Subsequently this innovation is rewarded with a profit. LRP does not eliminate risk or even attempt to minimise it; instead it commits present resources to future (uncertain) expectations (Drucker, 1959). Hence LRP takes a risk-taking and decision-making perspective and can be seen as a strategy for innovation in technical industries (Salveson, 1959; Mintzberg, 1994).

The uncertainty is now encapsulated in the plan and depends on the manager's visionary abilities and the quality of the plan. The question remains whether the plan will work. If the quality of the plan is good then the subsequent decisions based on the plan will also be good. If the plan is not good, the subsequent decisions are doomed to fail. In this sense, the plan can guide and protect the firm from uncertainty, but is itself still very uncertain. This is because the quality of the plan can only be determined in hindsight. In a similar way, great visionaries like Werner von Siemens, Karl Benz, Isambard Kingdom Brunel or Henry Ford were only recognised for their brilliance after their achievements were visible, not before.

2.3.2 Protecting the firm from outside uncertainty

Another approach is to protect the firm from the uncertainty by creating a structure. As the innovation or technological core is important for the future existence of the firm, Thompson (1967) argued, from an organisational point of view, that it is this core in particular that requires protection from uncertainty. Uncertainty is related to the unpredictability of future performance of the technological core of the firm, so by protecting this core from uncertainty, the firm effectively reduces uncertain elements in the venturing process. This could be done by building administrative boundaries that interface with the sources of uncertainty (Thompson, 1967). For example, an R&D department can protect the firm from the technological uncertainty; similarly a marketing department can offer protection from market uncertainty, and so forth.

By this logic, a firm's capability to deal with uncertainty can thus be measured by the number of specialist departments it has. In essence, these structural strategies to design organisations (e.g. Selznick, 1957; Thompson, 1966; Galbraith, 1973; Mintzberg, 1979) take a protective stance towards uncertainty. The main assumption within these approaches is again that the outcome of the new technology is more or less known, and by applying avoidance and blocking strategies the outcome is protected. In Thompson's case, the technological core (or the operational heart) of the firm is the product of the new technologies and thus requires this protection.

However, as previously discussed, in NTBVs the outcome is often not known. During this phase it is not yet appropriate to either build an organisation around the new technology, as it is not yet known what the threats of the uncertainty are. Such unsettled phases require additional and complementary measures and conditions necessary for effective managerial decisions. Unlike incremental improvements made on existing products or service, new technologies create discontinuous changes and thus a different kind of uncertainty applies. Firms that venture new technologies encounter these changes on a routine basis (Moore, 1998) and therefore have to be prepared to understand and deal with the associated uncertainty.

2.3.3 Guiding models for technology, products and markets

In addition to planning and protection approaches, models have been developed that describe typical patterns in the venturing process in order to gain more insight into the behaviour of the technology in the market and identify the typical areas where uncertainty is most visible. Such models can be useful to shape the decision-maker's judgement. The limitations of these models stem from the manner in which these models have been constructed. The models are derived from information collected over long time spans (such as a year) and are therefore useful for understanding typical long-term patterns. When venturing new technologies, a long-term perspective is obviously important. However, on a firm level the exploitation opportunities often occur in short timeframes (months). To demonstrate this, some dominant models will be briefly discussed: the technology adoption model, product and technology life cycles and the technology S-curve.

2.3.3.1 Uncertainty in adopting new technologies

Technology adoption is essential for venturing new technologies. Moore (1998) emphasised this problem by adapting the technology adoption model of Rogers (1962), which is essentially set of five categories that represent different attitudes towards new technologies. These categories show a continuum of attitudes in terms of a willingness to adopt new technologies, and are described in table 2.

Based on Rogers's categories a normal distribution applies as to which extent an innovation is diffused. Basically the model shows that the first 2.5% of people that adopt an innovation have the characteristics of the *innovator*. *Early adopter* characteristics are observable in the next 13.5%.

Early majority and *late majority* characteristics can be identified in the next consecutive 34% of each group. Finally, characteristics conforming to the *laggard* category are identifiable in the remaining 16% of the market.

CATEGORY	TECHNOLOGY ADOPTION CHARACTERISTICS
INNOVATORS	Venturesome – eager to try out new ideas
EARLY ADOPTERS	Respecting – opinion leadership in trying out new ideas
EARLY MAJORITY	Deliberate – adoption of new ideas just before the average member of society
LATE MAJORITY	Sceptical – new ideas are approached with caution, and adoption only after a majority has done so already
LAGGARDS	Traditional – suspicious, adoption when idea is already superseded

Table 2: Technology adoption characteristics (Rogers, 1962)

Moore (1998) extended this model by claiming that for NTBVs the uncertainty is most visible during the transition in adoption characteristics from early adopters to early majority. He refers to this as the problem of crossing the "chasm" (figure 4). Whereas 2.5% of the market is immediately prepared to adopt new technologies (and some are even willing to pay a premium to do so), followed by the 13.5% of early followers, it is much more difficult to address the early majority. The transition is thus a very unsettled phase. The gap also implies a change in market attitude towards the innovation. Whereas early adopters are interested in business opportunities, the early majority is more conservative and is only interested in improvement from a productivity perspective.

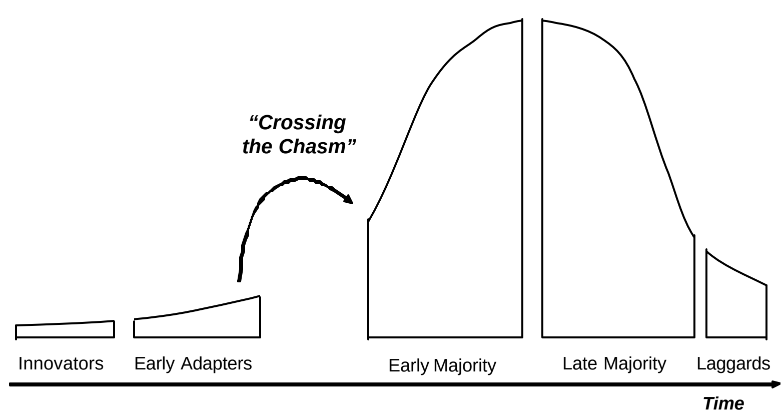

Figure 4: Adapted technology adoption cycle (Moore, 1998)

Evidently as new technologies are ventured, new technology-based firms have to be able to change their venturing approach from a technologist or innovator perspective (the enthusiast) towards the early majority market perspective. According to Moore this is vital for the existence of the venture, for the profit margin gains are at the top of the technology adoption cycle. In order for a firm to be successful it thus has to be able to change the venturing process in line with the attitudes of the potential customer.

This model provides valuable insights into the behaviour patterns of technology adoption, however because it takes a macro-perspective it does little to support firm level decision-making. Particularly as outcomes of new technologies are often unknown, and thus can change complete market structures and industries (for example, the internet), no predictive power or conclusions can be derived from models for venturing new technologies. The foundations of these models are grounded in a long-term data analysis (Rogers, 1962) and thus reflect a hindsight pattern of technology adoption. New technologies have the potential to change these underlying patterns; thus there are limitations in using these models for predicting and decision-making in NTBVs.

2.3.3.2 Uncertainty in the life cycles of products and technologies

Uncertainty in NTBVs can also be identified when looking at the behaviour of technologies versus products. A model that illustrates the market uncertainty from a product point of view is the Product Life Cycle (PLC) (Levitt, 1965). The PLC is a model that is derived from marketing literature and focuses on four distinct phases: introduction, growth, maturity and decline. These are the stages a product encounters during its life span and each phase has distinct and predictable characteristics. The PLC is depicted in figure 5.

The first stage in the PLC is the product *introduction*, and commences at the launch of a new product (Levitt, 1965). Typical characteristics during this phase are low sales volumes, high costs per customer and negative profits. Following the introduction is the *growth* stage. During this stage the characteristics of the product are rapidly increasing sales volumes with more customer numbers. Cost per customer figures are decreasing, profits start rising and more competitors enter the market (Levitt, 1965). After growth, the product starts to reach a certain level of *maturity*. A peak in sales and profits, low cost per customer, and a stabilisation of the number of competitors characterise this stage (Levitt, 1965; Afuah, 1998). During the final phase the product starts getting 'old' and hence profits start to *decline*. Characteristics of this phase are decreasing sales volumes and profits, increasing cost per customer, and a decline in the number of competitors (Levitt, 1965; Afuah, 1998).

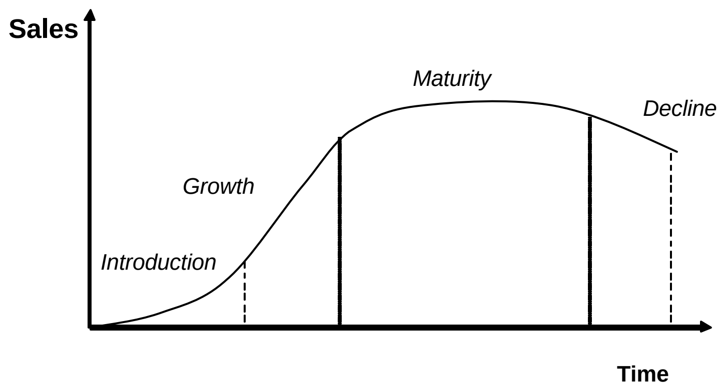

Figure 5: The product life cycle (Levitt, 1965)

The introduction and growth phase are the more unsettled phases from a product perspective. However, the PLC does not lend itself to effective prediction of future outcomes of new technologies. A PLC is only verifiable on hindsight, which means the uncertainty about the outcome of new technologies remains unsolved

Only when it is clear what application of the new technology could potentially become a dominant design, does a predictive pattern emerge. This is derived from the dominant design model formulated by Abernathy and Utterback (1994). This model extends the life cycle analogy and claims that market structures are influenced by the technology life cycles and the accumulated product and process knowledge available to the firm (see figure 6). Particularly in the early phases, before the dominant design is determined, the situation is unsettled, or to use Utterback's word, "fluid".

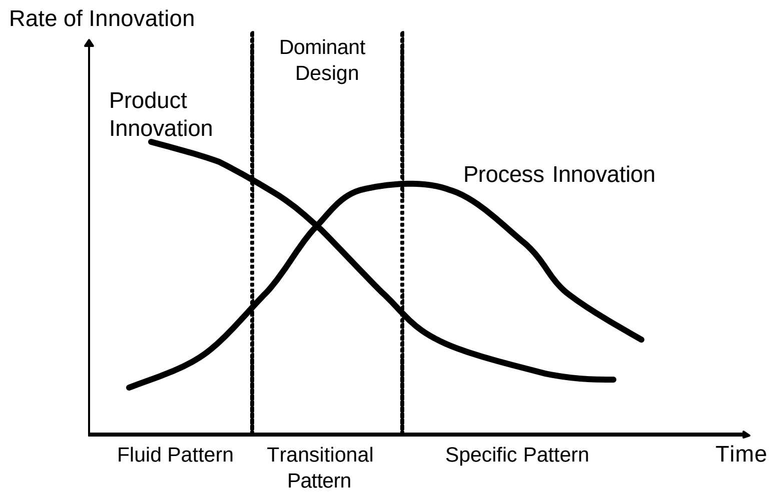

Figure 6: Dominant design model (Adapted from Utterback, 1994)

The dominant design model prescribes strategies in the various phases (Utterback, 1994). Using a similar characterisation as the technology adoption model, four innovation strategies emerge from a firm perspective. These strategies range from when the technology is unexplored and thus new, to when the technology has reached maturity and is fading out. The strategies relate to the characteristics of the roles invention leaders, innovation leaders, early followers and late followers. It seems that, compared with the technology adoption characterisations and Moore's chasm, the more unsettled phases are again those preceding the dominant design. After the dominant design, the number of firms will decline (Utterback, 1994) and new technologies and dominant designs will emerge.

2.3.3.3 Uncertainty and switches in technologies

The uncertainty relating to switching dominant designs and new technologies has also been referred to as technological uncertainty. This uncertainty is internally oriented and relates to issues concerning the level of unpredictability and speed of changing technology (Afuah, 1998). Such switches in technologies have been modelled using an S-curve (Foster, 1986). The S-curve (figure 7) is a forecasting tool that argues that the rate of advance of a technology is a function of the amount of effort put into it. Observed over time, the curve takes the shape of an S (Foster, 1986; Afuah, 1998). The technological progress has a slow start, but there follows a period of exponential increases. As the physical limit of the technology is approached, the progress starts to diminish. As the return on the efforts at the end of the curve becomes extremely small, a new technology is required that can overcome the physical limitations of the old technology.

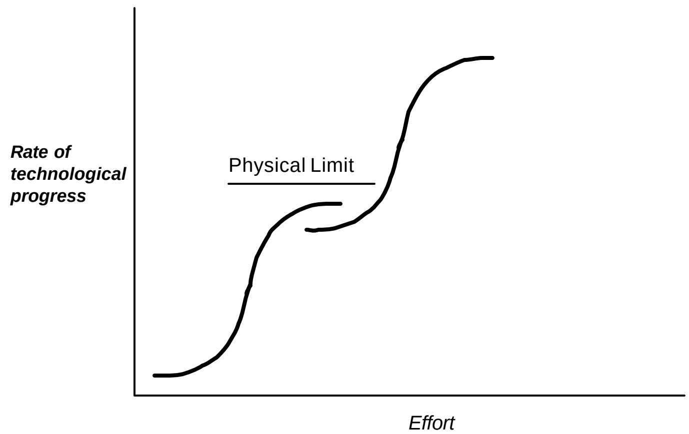

Figure 7: S-curve (Foster, 1986)

The technological uncertainty resides in the substitution of an older technology with a newer one. The S-curve shows patterns of alternating periods of incremental innovation (such as new product versions) and periods of radical change, implying a change of underlying technology. Making the right decisions in order to accommodate these switches is thus particularly important in order to profit from the technology.

The model implies that firms are required to switch technologies and products at the right time. This uncertainty is highly visible, particularly in firms dealing with new technologies that emerge and disappear rapidly (Moore, 1998). Such firms are more dependent on making the right decision to switch, and have to do this on a more frequent basis, than firms that are based on traditional offerings, such as the furniture or clothing industry. In comparison with traditional firms, such new technology-based firms are characterised by a high frequency of S-curves. Such firms thus have to deal with more unsettled environments, and more unsettled technologies.

Whilst the importance of switching technologies becomes apparent, the model has limitations on a firm level in predicting the potential outcomes of new technologies. As such models can only be constructed using longer time spans, prediction and decision-making rests upon the accuracy of the extrapolation and expectations derived from these hindsight perspectives; thus judgement remains an important factor.

2.3.4 An overview on planning and protecting approaches and guiding models for uncertainty

Managerial decision-making is supported by an array of approaches and models. In order to illustrate the applicability and limitations of these approaches and models, I have elaborated on some of the guiding models that enhance the understanding of how technologies, products and market tend to behave and how these models can ultimately serve decision-making by utilising planning and protection approaches.

The guiding models show innovation patterns that help firms in understanding and predicting market and technological trends. The patterns also identify the areas where there is more uncertainty; hence the firm has to be more alert. These predictions can ultimately help firms to understand and direct decisions towards reducing these uncertainties by, for example, instigating long-range plans and creating protective structures around the firm.

The 3M example can again be used to evaluate the application and limitations of these models. As previously argued, at 3M a different type of uncertainty still remains visible. When the new type of glue was made available, but the application area was not yet clear, the only plan that emerged in the mind of one of the directors was to maintain the technology in-house, despite the lack of direct application. Also, when the application emerged, it still took some 15 years before exploitation commenced.

During these stages, protection was limited to keeping the technology in-house. No particular structural arrangements could be prepared, as the future exploitation potential was simply not known. Planning and projecting future product life cycles only became of importance after the exact application of Post-it notes was found. Thereafter the structural arrangements can become relevant. However, the managerial decisions made before this stage required a different type of insight.

Additionally, planning approaches in the preceding phases could hardly have foreseen the future potential of the technology. With planning it is presumed that there are some causal patterns visible or that can be envisioned in a plan. However, in the case of 3M (N. N., 2002), this was not the case. The uncertainty in 3M stemmed from the fact that it was simply not known what the future was going to bring, so no plans or patterns were yet applicable, let alone that any sort of quantitative model which supported managerial decision-making could be applied.

Finally, existing guiding models also show limitations commonly associated to life cycle analogies. As Penrose (1959: 154) aptly noted, "Life cycle analogies make no provision for abrupt discontinuities and changed identity…Ecological analogies have trouble with unpredictable change". Firstly, these are generalised models. On a more product specific level, the patterns might be recognisable but they vary from product to product (Afuah, 1998). Secondly, the time-cycles for NTBVs are often very short (Moore, 1998), with the result that such patterns can be created only in retrospect.

Hence these models have limits to the actual understanding of the uncertainty when making decision for NTBVs, especially in cases when limited time is available. Decision-making in NTBVs is, on the one hand, a long-term strategic activity, but on the other hand a series of short-term commitments to concrete actions that have to be made at a certain point in time.

In the above examples uncertainty seems only interpretable using these models after the unsettled events took place. However the firms need to perform in the short run and thus require additional capabilities that allow them to take advantage of short-term opportunities, whilst not losing sight of the long-term implications and trends.

One the one side firms require some structure and plans to venture their technologies (e.g. Thompson, 1967; Ansoff, 1988), however within these structures a firm needs to be capable of acting on short-term opportunities. This concept of capabilities can be found in literature concerned with entrepreneurship and takes an inward resource perspective.

2.4 A CAPABILITIES PERSPECTIVE TO UNCERTAINTY

"The more I practice, the luckier I get!"

Gary Player (champion golfer)

The previous perspective for managerial decisions was predominantly focused on the potential outcome of the decision and its probability. Another stream of literature is more concerned with what a firm requires, or the input of the venturing process. Two theoretical frameworks stand out here: entrepreneurship and the resource-based view of the firm. These approaches prescribe what a firm needs to be capable of in order to achieve a sustainable competitive advantage. The contribution of these capability perspectives is described below.

2.4.1 Entrepreneurial capabilities for decision-making under uncertainty

Various definitions of entrepreneurs and entrepreneurship exist. Low and MacMillan (1988) specifically addressed the creation of new ventures as the essence of entrepreneurship. Schumpeter (1934), however, saw innovation as the essence of entrepreneurship and defined it as the creation of "new combinations of resources."

Venturing innovations, such as new technologies, is seen as a creative response to the establishment (Schumpeter, 1950). Schumpeter argued from an economic perspective and noted that "...whenever the economy, or an industry or some firms in an industry do something else, something that is outside of existing practices, we may speak of creative responses" (Schumpeter, 1950: 222). The main growth factor of national economies stemmed from entrepreneurs who produce innovations (Schumpeter, 1950). From this perspective, innovations from new technologies are one of the main determinants for the growth of the economy (Schumpeter, 1943; Sundbo, 1998).

Entrepreneurship is the driving force behind any successful venturing process. Whereas inventors merely create something new, entrepreneurs are concerned with the implementation of these new things (Frank, 1998). This is an essential element of new technology venturing. Innovation can therefore be seen as an entrepreneurial act essential for economic growth (Schumpeter, 1950). From a financial perspective, entrepreneurs are those who undertake uncertain investments for which the future returns and probability distributions are unknown (Knight, 1921; Amit *et al.*, 1993). New technology-based industries are highly uncertain and it is thus the entrepreneur who has the highest threshold to act in these uncertain times.

With reference to entrepreneurs, Knight (1921) referred particularly to uncertainty instead of risk. For risk, the probability that something might happen is known; for uncertainty this is not the case. A risk-based perspective would be inappropriate for evaluating markets because markets would ultimately be organised for contingent claims on these risks (Amit *et al.*, 1993). This notion of risk is similar to the risk in decision theory. Knight (1921) argued in his seminal work on uncertainty that the major inhibitor of entrepreneurship is not risk aversion but uncertainty aversion. Entrepreneurs are more willing and able to handle this ambiguity.

New technology-based firms thus require entrepreneurial capabilities in order to enhance the decision-making judgement. Penrose argued that the problem of judgement "involves more than a combination of imagination, 'good sense ', self confidence, and other personal qualities" (Penrose, 1959: 41). Entrepreneurship "leads to the question of effects of risk and uncertainty on, and the role of expectations in the growth of the firm" (Penrose, 1959: 41).

Entrepreneurial capabilities require an understanding of the actions-reward relationship in order to respond to opportunities. As this is often unpredictable, Schumpeter argued that these can only be understood *ex post* (Frank, 1998). Uncertainty thus relates to the fact that it is not known, *ex ante*, why some new technology-based ventures fail whilst others succeed (Amit *et al*., 1993).

As previously mentioned, the real option framework has recently received greater attention in the context of entrepreneurship, and could potentially enhance entrepreneurial capabilities (McGrath. 1996; McGrath, 1999; McGrath and MacMillan, 2000). The alignment of options thinking, which is output (reward) oriented, with entrepreneurship, which is input (action) oriented, provides a potential method from which decision-making techniques could be derived. The essence of real options reasoning on an entrepreneurial level is that entrepreneurs should make investment decisions with a limited downside and learn whether a future investment is warranted (McGrath and McMillan, 2000). This technique is seen to be especially relevant in new product introduction where the rewards can be huge but equally so can the losses. Essentially the technique prescribes a step-by-step approach of go/ no-go decisions where the uncertainty is settled in a sequential manner (McGrath and MacMillan, 2000).

However, as previously argued, the real options technique still takes a stance where there is a reasonable availability of knowledge on the probable outcomes. Nevertheless, there is still uncertainty in the phases preceding the knowledge on this outcome. A venture for a short-term opportunity can benefit greatly from real options, as it allows for incremental learning guiding the decision-maker's options. However, on an organisational (firm) level, uncertainty still exists on the outcome of the next venture, and uncertainty remains from a long-term perspective. Can the technology base provide additional future ventures or is this going to be the last successful venture for the firm? 3M is again a good example. The stationery industry was new to 3M, and was opened up only by the merits of the new adhesive technology. In their own words, only their tolerance for "tinkerers" led them to this new unexpected industry, which became one of the most important fields for 3M (N. N., 2002). The development of techniques such as real options is expected to contribute to enhancing entrepreneurial capabilities within a firm. However, it has so far failed to address the capabilities that are required *before* options become apparent.

2.4.2 Exploring capabilities from a resource-based perspective

A firm can be viewed as a pool of resources that delivers productive services in order to pursue a productive opportunity. "Thus a firm is more than an administrative unit; it is also a collection of productive resources the disposal of which between different users and over time is determined by administrative decision" (Penrose, 1959: 24). A resource can be seen as "a bundle of possible services" (Penrose, 1959: 67). Resources consist of the tangible elements (i.e. plant, equipment, raw materials, stock etc.) and human resources (unskilled and skilled labour, clerical, administrative, financial, legal, technical and managerial staff) (Penrose, 1959). The input of the production process, however, "is never resources themselves… but only the services that the resources can render." (Penrose, 1959: 25).

The motive for providing these services is the desire to increase long-run profits or, "...its general purpose is to organise and use of its [the firm's] 'own' resources together with the resources acquired from outside the firm for the production and sale of goods and services at a profit" (Penrose, 1959: 31). An essential notion, from a Schumpeterian point of view, is that the ambition that drives a firm to take advantage of opportunities (or productive opportunities, as Penrose calls them) stems from the entrepreneurial services provided by the firm's entrepreneurs.

Entrepreneurial services are contributions to the operations of a firm that relate to the introduction and acceptance of innovations (both organisationally and technologically) by the firm (Penrose, 1959). Whereas entrepreneurial services identify and take advantage of the productive opportunities available to the firm, managerial competence is "a function of the quality of the entrepreneurial services available to it." (Penrose 1959: 35).

Entrepreneurial services, from a new technology-based venturing view, are thus the driving force behind the necessary changes to venture new technologies as productive opportunities. Uncertainty in this respect is addressed by Penrose as the entrepreneur's subjective judgement on the productive opportunities required for predicting the outcome of actions (Penrose, 1959). The subjectivity is determined by the sum of the entrepreneur's confidence and the information available to him. Uncertainty "refers to the entrepreneur's confidence in his estimates or expectations" (Penrose, 1959: 56).

Whereas Penrose provides a lens for viewing the process of growth within a firm, others have elaborated further on the internal resources of the firm and introduced conditions that firms should meet in order to have a competitive advantage. The ability to reconfigure the available resources in a firm is a focal point for managing uncertainty in a proactive dynamic manner. This stream of thought produced the resource-based theory of the firm (Wernerfelt, 1984; Barney, 1991; Barney, 1994; Barney *et al.*, 2002).

The resource-based view of the firm is primarily concerned with how firms can secure the factors needed to create capabilities that form the basis for establishing and sustaining competitive advantage and address the strategic management of organisations (Burgelman and Maidique, 1988). The resource-based view is an influential theoretical framework for understanding how competitive advantage within firms is achieved and how that advantage might be sustained over time (Barney 1991; Barney, 1994; Barney 2002; Nelson 1991; Teece *et al.* 1997; Eisenhardt and Martin, 2000).

With respect to the venturing process, the resource-based view has provided a set of conditions that the firm's resources should comply with to in order to reduce the uncertainty and achieve a sustainable competitive advantage. Sustainable refers to the possibility of the competitive advantage being duplicated by competitors (Barney, 1991). Barney (1991) points out that for a firm to have this sustainable competitive advantage, the firm's resources must have 'VRIN' attributes. The resources (a) must be *valuable*, by either exploiting opportunities or neutralizing threats from the environments, or both, (b) must be *rare* amongst competitors, (c) can only be *imitated imperfectly*, and finally (d) should be *non-substitutable* (Dierickx and Cool, 1989; Barney, 1991; Conner and Prahalad, 1996; Nelson, 1991; Eisenhardt and Martin, 2000).

Within the context of decision-making, the resource-based view focuses on what managers require (input) in order to get the output, often referred to as competitive advantage. Penrose (1959) goes one step further by stating that such output ultimately links to a profit motive. Unlike the output-oriented approaches, such as decision theory, that aimed towards concrete potential outcomes, this set of theories focuses on prescribing input variables that could potentially produce a general outcome of long-term sustainability. When firms have resources that comply with these prescriptions they are better equipped to create a competitive advantage, or in other words are likely to be better prepared for uncertainty.

2.4.3 Changing the resource-base under uncertainty: dynamic capabilities

The resource-based view of the firm has influenced an additional perspective that focuses on markets and technologies which are more dynamic and thus more uncertain. Dynamic markets show rapid and unpredictable change (Eisenhardt and Martin, 2000). These changes are either a result of, but also allow for, shifts in the competitive landscape. This is typically the case in new technology-based industries which operate in environments of rapid technological change. The resource-based view has provided various dynamic concepts which focus on the capabilities a firm should possess to approach uncertainty and maintain competitive advantage.

From this resource perspective it is argued that organisations need to have capabilities that will enable them to act and respond to unpredictable changes (Nelson and Winter, 1982). These capabilities are described as *dynamic capabilities* in that they enable a firm to reconfigure its resource base and adapt to changing market conditions in order to achieve a competitive advantage (Teece *et al.* 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002).

The framework of dynamic capabilities that has emerged has received increasing attention over the last decade (Teece and Pisano, 1994; Madsen and McKelvey, 1996; Teece *et al*., 1997; Deeds and DeCarolis, 2000; Eisenhardt and Martin, 2000; Luo, 2000; Madhok, 2000; Carpenter *et al.,* 2001; Galunic and Eisenhardt, 2001; Rindova and Kotha, 2001; Zollo and Winter 1999; Zollo and Winter, 2002). The dynamic capabilities framework can be used to analyse "the sources and methods of wealth creation and capture ... private enterprise firms operating in environments of rapid technological change" (Teece *et al.*, 1997: 509). This perspective does not enhance the understanding of what uncertainty actually is, but does provide a prescription of the necessary capabilities believed to enable a firm to operate in uncertain environments.

The emerging literature on dynamic capabilities draws on the resource-based view of the firm (e.g., Grant, 1996; Iansiti, 1994; Teece, 1994; Teece *et al.,* 1997; Nelson, 1991; Eisenhardt, 2000) that states that the firm's resources are an essential structure for innovation. Dynamic capabilities are the antecedent organisational and strategic routines by which managers alter their resource base (acquire and shed resources, integrate them, and recombine them) to generate new value-creating strategies (Grant, 1996; Pisano, 1994). In line with Teece, Pisano and Shuen (1997), dynamic capabilities in this sense are defined as follows: "Dynamic capabilities are what enable a firm to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments. Dynamic capabilities are the firm's processes that use resources to match and even create market change. Dynamic capabilities thus are the organisational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die" (Teece *et al*., 1997: 515)[4].

Focusing on a firm's dynamic capabilities can be seen as a condition for a better approach to uncertainty. Dynamic capabilities consist of specific organisational and strategic processes that create value for firms within dynamic markets. These processes allow for the manipulation of resources into new value-creating strategies (Eisenhardt and Martin, 2000). Such capabilities can be observed by empirical research.

2.4.3.1 Dynamic capabilities and changes in the markets

The dynamic new technology markets are characterised by blurred industry structures and high velocity. In these industries, dynamic capabilities are arguably experiential unstable processes. By rapid creation of new knowledge and iterative execution, adaptive but unpredictable outcomes are produced (Eisenhardt and Martin, 2000). Table 3 shows the distinction between dynamic capabilities observed in moderately dynamic markets (low uncertainty) as opposed to high velocity markets (high uncertainty) (Eisenhardt and Martin, 2000). Dynamic capabilities differ according to: the nature of the market, the evolutionary patterns, how these capabilities have been executed, how stable the capabilities are, what the outcomes are and what the key is to effective evolutions.

	MODERATELY DYNAMIC MARKETS	HIGH VELOCITY MARKETS
MARKET DEFINITION	Linear and predictable change, stable industry structure, defined boundaries, clear business models, identifiable players	Nonlinear and unpredictable change, ambiguous industry structure, blurred boundaries, fluid business models, ambiguous and shifting players
PATTERN	Detailed, analytical routines that rely extensively on existing knowledge	Simple, experiential routines that rely on newly created knowledge specific to the situation
EXECUTION	Linear	Iterative
STABLE	Yes	No
OUTCOMES	Predictable	Unpredictable
KEY TO EFFECTIVE EVOLUTION	Frequent, nearby variation	Carefully managed selection

Table 3: Dynamic capabilities and types of dynamic markets (Eisenhardt, 2000)

The strategic challenge of dynamic capabilities in high velocity markets is again maintaining competitive advantage. When the duration of that advantage is inherently unpredictable, time is an essential aspect of managerial decision-making and the dynamic capabilities that drive competitive

[4] The term "dynamic" in this context is not used in the sense of multi-period analyses but refers to situations where there is rapid change in technology and market forces, and "feedback" effects on firms (Teece *et al.* 1997).

advantage are themselves arguably unstable processes that are challenging to sustain (Eisenhardt and Martin, 2000).

In order to deal with this uncertainty, new technology-based firms should have the capabilities to innovate (Nelson, 1991; Teece, 1994; Teece *et al.*, 1997; Iansiti, 1994; Zollo and Winter, 1999). Merely having processes for producing certain products or services is not sufficient from a strategic perspective. Having the capabilities to innovate requires appropriate organisational and managerial routines, which enable these organisations to take economic advantage. Dynamic capabilities, from a Schumpeterian perspective, must enable a firm to innovate, and to make that innovation profitable over and over again (Nelson, 1991).

An alternative view on the stability of the dynamic capabilities is proposed by Zollo and Winter (2002: 340) who define dynamic capabilities as "...a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness". Dynamic capabilities arise from a learning process and are the systematic methods available to the firm for modifying the operational routines (Zollo and Winter, 2002). Similar to Penrose, the learning mechanism makes a distinction between the operating routines (or productive base) of the firm and the dynamic capabilities that allow for the effective modification of the operational routines (the changes induced by the entrepreneurial function and managed by the administrative control).

In contrast to the view that dynamic capabilities are unstable processes (Eisenhardt and Martin, 2000) that are emergent and evolving (Rindova and Kotha, 2001) in turbulent and volatile environments, Zollo and Winter (2002) argue that dynamic capabilities are actually structured and learned patterns. Zollo and Winter argue that in such turbulent environments, where uncertainty emerges because changes are rapid and unpredictable and variable in direction, "...dynamic capabilities and even the higher order learning approaches will themselves need to be updated repeatedly". Leonard-Barton (1992) adds to this view that in absence of the regular updating, or second order dynamic capabilities, the firm will turn the core competencies into core rigidities".

The need for fast responses in dynamic markets brings its own particular challenges. As Leonard-Barton (1992) explains, firms have the pitfall of core rigidities to avoid. Core rigidities are defined as the flip side of core capabilities. They are thought to emerge when firms become insular, due to sustained periods of success, or when they fall prey to extremes by overshooting the optimal levels of best practice. They can be avoided by the regular evaluation and deconstruction of a firm's business systems in order to overcome static processes.

From an organisational perspective, dynamic capabilities can be seen as tools that manipulate resource configurations (Eisenhardt and Martin, 2000). In dynamic markets such as the high tech industry these capabilities rely heavily on new knowledge created for specific situations (Eisenhardt and Martin, 2000). This knowledge should be rapidly gained by experimental activities – such as prototyping, real-time information, multiple options and experimenting – that generate immediate knowledge for rapid replacement of the outdated knowledge (Eisenhardt and Martin, 2000).

This means that managers can focus on these tools to increase their decision-making capabilities when venturing new technologies. The formalisation and systematisation of the concept of dynamic capabilities implies that dynamic capabilities can ultimately be acquired or developed by a firm. The effect of having dynamic capabilities is assumed to be an enhanced competitive advantage, and thus a reduction in the uncertainties associated with dynamic markets.

2.4.3.2 Dynamic capabilities and changes in technological architectures

The dynamic capabilities framework has also been addressed through the lens of the uncertainty associated with the changes in technology. Traditionally, changes in technologies have been categorised as either *incremental* innovation, such as the introduction of new product versions, or *radical* innovation, such as changing to a new underlying technological base. Categorisations of uncertainty in terms of incremental and radical innovation are well established (Henderson and Cockburn, 2000; Baldwin and Clark, 1997). Incremental innovation introduces relatively minor changes to the existing product, exploiting and reinforcing the potential of the established dominant design (Henderson and Clark, 1990). Radical innovation introduces new technologies based on a different set of engineering and scientific principles and often opens up whole new markets and potential applications (Henderson and Clark, 1990). An example of a radical innovation is the shift from record players to CD players.

In terms of uncertainty, radical innovation often creates greater difficulties for established firms but can provide the basis for the successful entry of new ventures, firms or even the redefinition of an industry (Henderson and Clark, 1990). NTBVs are in principle concerned with such radical innovations. The uncertainty thus relates to questions of *if* the new technology will work, *when* it will work and *how* potential problems can be solved. A combination of both internal and external perspectives provides a better picture for understanding this.

This perspective has been sharpened by Henderson and Clark (1990), who introduced two additional categories by breaking technological innovations down to a component level. These additional insights focus on the relation of the component interfaces of the technology as well as the newness of the technology itself (Baldwin and Clark, 2000; Henderson and Clark, 1990). New technologies are often a combination of individually linked components (Baldwin and Clark, 2000; Baldwin and Clark, 1997). A component is defined as a physically distinct portion of the product that performs a well-defined function (Henderson and Clark, 1990) and embodies a core design concept (Baldwin and Clark, 1997; Baldwin and Clark, 2000). This implies that two types of knowledge are important: knowledge of the component and knowledge about how the component interfaces with the overall system. The latter is also referred to as architectural knowledge (Henderson and Clark, 1990). Four kinds of innovation can now be distinguished (figure 8).

Linkages between Core Concepts and Components	Core Concepts: *Reinforced*	Core Concepts: *Overturned*
Unchanged	Incremental Innovation	Modular Innovation
Changed	Architectural Innovation	Radical Innovation

Figure 8: A framework for defining innovation (Henderson, 1990)

The two additional kinds of innovation refer to the changes in the linkages between components. Modular innovations are innovations where the components change (the core concept is overturned), but where the linkages or interfaces of the components with the core design remain unchanged (Henderson and Clark, 1990). Architectural innovations are innovations where the core concepts of the technologies used in the system remain the same, but the linkages or *architecture* of the system change (Henderson and Clark, 1990).

These additional perspectives provide a sharper view of where uncertainty arises. Uncertainty in modular innovation resides in the knowledge, or rather the lack of knowledge, about the components (Baldwin and Clark, 1997; Henderson and Clark, 1990). Uncertainty in architectural innovation resides in the unsettled architecture between components and is related to changes in the architecture. Hence, specific knowledge about the architectural level of the system is important (Henderson and Clark, 1990). As the architecture of, for example, new products changes, it is essential to redesign the architecture of the components and thus the linkages or interfaces between the components. This requires knowledge on the coordination of these interfaces (Henderson and Clark, 1990).

The uncertainty of architectural innovations is not only visible on a technological level but also on an organisational level (Gulanic and Eisenhardt, 2001). As the architectural innovation resides in the changing links and coordination on the product or technological level, several studies have extended the concept of architectural innovations by examining on which level the innovation occurs (Henderson and Clark, 1990; Galunic and Eisenhardt, 2001; Baldwin and Clark, 1997). At the core of this research is the notion that, while firms may possess or could develop the competencies required to develop new product architecture, they often fail to recognise the way in which organisational competencies must be reconfigured to successfully sustain it on a business level. Existing organisational structures and routines operate to preserve current component linkages and thus raise cognitive barriers to the development of new architectures (Henderson and Clark, 1990; Nelson and Winter, 1982; Katzy et al., 2001).

From this perspective, dynamic capabilities are suited to deal with architectural innovations more effectively, or in other words to create architectural competencies (Henderson and Clark, 1990; Henderson and Cockburn, 1995). Dynamic capabilities typically address the reconfiguration of the organisational processes in order to allow for architectural innovations (Galunic and Eisenhardt, 2001).

2.4.4 Dynamic capabilities: reducing causal ambiguity in action-performance relationships

The dynamic capabilities framework provides a relevant conceptual lens to evaluate some necessary conditions for the input of the venturing process, which subsequently sets expectations, albeit ambiguous, on the outcome. Within the dynamic capabilities framework, uncertainty is associated with causal ambiguity (Zollo and Winter, 2002). Causal ambiguity is the ambiguity concerning causal relationships between actions and outcome (Lipman and Rumelt, 1982; Mosakowski, 1990; Reed and DeFillippi, 1990; Coff, 1999; Zollo and Winter 2002). Zollo and Winter (2002) have integrated the concept of causal ambiguity as a major concern for dynamic capabilities.

Zollo and Winter (2002) address the causal ambiguity of action-performance linkages and make a distinction between the short and long-term rewards from respectively operating routines and dynamic capabilities. Operating routines involve "...the execution of known procedures for the purpose of generating current revenue and profit" (Zollo and Winter, 2002: 341). Dynamic capabilities, on the other hand, seek to "...bring about desirable changes in the existing set of operating routines... for the purpose of enhancing profit in the future" (Zollo and Winter, 2002: 341).

The dynamic capabilities framework provides a mechanism that can potentially clarify the ambiguous, or uncertain, causal nature of action-performance relationships. This is especially important in high-level change environments, such as NTBVs. Zollo and Winter (2002) argue that in such cases, dynamic capabilities should focus on the articulation and codification of lessons learned in previous experiences.

The concept of dynamic capabilities is relatively new and not yet operationalised. Some also consider the concept idiosyncratic in their details (Eisenhardt and Martin, 2000) and abstract (Teece, *et al.*, 1997). This may well be as currently dynamic capabilities are predominantly observed by academia (Zollo and Winter, 1999; Teece *et al.*, 1997; Teece, 1994; Nelson, 1991; Deeds, 2000; Iansiti, 1994; Majumdar, 2000).

However, in a similar sense to Penrose's notion (1958) that a firm is an ambiguous entity, dynamic capabilities are also ambiguous. Subsequently so are the potential measurements that relate to the outcome of dynamic capabilities as competitive advantage. Penrose already noted that the "profit motives" of firms are ambiguous and interpretable in many forms (Penrose, 1959:27-28). This does not mean, however, that it would not be valuable to create a measure that approximates this competitive advantage. This is also true for the dynamic capability (Teece, 1998). The lack of a uniform measure does not mean that it is not worthwhile attempting to create an approximation of the dynamic capabilities residing in the firm.

In summary, whilst dynamic capabilities are believed to be indirectly linked to firm performance (Zott, 2000) and thus increase the probability of a firm achieving a sustainable competitive advantage, dynamic capabilities themselves are still intangible constructs for which no uniform measurement exists (Teece, 1998). The framework can be seen as a potentially effective approach to the specific uncertainties prevailing in this venturing process, from an input perspective. The ability to recognise such dynamic capabilities in a firm, albeit subjectively, therefore provides the potential for enhancing the predictability of uncertain events. It is essential to evaluate the implications of action-performance links in a process of experience accumulation, knowledge articulation and codification.

2.5 An Overview – Better Assumptions, Information or Judgements to Deal with Uncertain Causality

When examining the current literature streams that deal with managerial decisions for NTBVs, it becomes apparent that the underlying nature of uncertainty is derived from a lack of knowledge about the assumed causal relationships between the actions/decisions and their future outcomes/rewards (see table 4). The main assumption is that in the real world, causal relations do exist, but there are apparent limits (or boundaries) in human rationality to comprehend them (Simon, 1957).

The solutions described show various ways of dealing with these boundaries. Decision theory sees its limits in the judgemental gap (Raiffa, 1968). In cases of uncertainty, the calculations are based predominantly on assumptions and best guesses on the probabilities and future states. Based on these assumptions, risk-like quantitative modelling techniques can then be used to identify the best possible option, and thus recommend a decision. The uncertainty however remains visible in the quality of the assumptions.

In order to achieve better assumptions, management information systems have been introduced to better inform managers. Such systems typically support managers in either gaining more data or enabling complex computations following mathematical programming and decision theory techniques. Nevertheless, within the context of new technology-based firms, a specific class of uncertainty remains visible, as more information does not necessarily lead to better assumptions in this field. Uncertainty can even emerge in the overload of information fed to managers.

Planning and protection solutions have been also been elaborated which focus on protecting the firm from outside uncertainty. These solutions have been particularly valuable in traditional industries, where changes are continuous. However, new technology-based ventures typically deal with rapid environments of discontinuous change. In these cases it is relatively difficult to protect or to plan the future potential of a new technology, as the 3M case has shown.

These perspectives all have in common that they are focused towards a potential outcome. In order to apply decision theory it is essential to have some idea about potential or desirable future states. The essence however with new technology-based ventures is that, especially in the earlier stages, these outcomes are often unknown.

In contrast, input-oriented approaches exist focusing on the essential capabilities an organisation requires to reduce uncertainty and create a competitive advantage. This perspective advocates the utilisation of uncertainty by responding creatively and reconfiguring the resources that are available to the firm. Technology-based ventures are typically situated in this field of opportunities. This field generally focuses on the characteristics of entrepreneurship and especially the judgemental capabilities that enhance decision-making under uncertainty. This typical entrepreneurial mindset is especially equipped to judge potential causalities in future, and hence makes decisions by taking on the uncertainty rather than avoiding it.

Examples of such capabilities can be found in literature on entrepreneurship and notably the work of Penrose (1958). Penrose provides a new way of conceptualising the firm by looking at the resources available to it. This has resulted in the formulation of the resource-based view of the firm (Wernerfelt, 1984). Example contributions of this view are prescriptions for firms regarding the nature of the firm's resources (Barney, 1991). The assumptions can then be that having such resources would increase the chances of an enhanced competitive advantage, and thus reduce uncertainty.

Based on this resource-based view, a specific condition has been addressed that specifically benefits new technology-based firms. Such firms require dynamic capabilities to deal with the uncertain and rapidly changing technologies and environments. These dynamic capabilities are said to reduce the causal ambiguity of the action-performance relationships (Zollo and Winter, 2002), and thus improve managerial decisions under uncertainty.

Both input and outcome oriented perspectives on new technology-based venturing seem to imply the existence of a causal relationship, albeit ambiguous, between the two. The existing theories predominantly focus on ways to reduce the ambiguity in these causal relationships in order to improve managerial decisions. The reason why this is not so easy is often attributed to the limited knowledge managers have about the complexity of the situation. Simon (1957) coined the term 'bounded rationality', which implied the limits of human rationality. The efforts described above all seem to focus on improving this rationality aspect by proposing the use of input-oriented conditions or output-oriented assumptions.

This complexity is furthered by the dilemma of the timeframe of the prescribed conditions that are assumed to provide long-term competitive advantages, whilst maintaining short-term operative returns. In essence, decision makers who invest in building long-term capabilities can only do so if capital is generated from short-term operative returns.

When reviewing the literature it appears that the treatment of the relationship between decisions and outcomes always strives towards a certain degree of causality. However, measures to establish this causality do not exist, as the concepts are predominantly of an intangible nature. Although concepts such as dynamic capabilities are recognisable when carrying out longitudinal studies, no measures yet exist for such intangible assets of the firm. Measures for these intangible capabilities are thus required in order to better understand the uncertainty residing in the underlying relationships between the input and outcome of the venturing process in new technology-based firms.

This thesis will propose alternative measures for treating this uncertainty by losing the argument of causality. A problem that also concerned the lack of knowledge on assumed causal relationships occurred in quantum physics at the beginning of the 20th century. Quantum physics and the findings of prominent scientists such as Werner Heisenberg rendered the law of causality obsolete when measuring on a sub-atomic level. Although these developments shook the very foundations on which traditional physics was built, it has been applied with astonishing success.

FIELD	EXAMPLE TECHNIQUES	FOCUS ON	EXAMPLE AUTHORS	LEVEL OF CAUSALITY
DECISION THEORY	• Quantitative modelling • Games Theory • Operations research	***Output orientation:*** Assumptions on future uncertain outcomes	Bayes, von Neumann and Morgan, Raiffa	Mathematics and information processing to reveal causal relationships
STRATEGY AND ORGANISATIONS	• Long range planning • Organisation design	***Output orientation:*** Planning to visualise future outcomes and Structural and avoidance strategies to prevent negative unknown effects	Loasby, Mintzberg, Ansoff, Thompson	Causality assumed in planning and protection strategies, often fuelled by guiding models based on hind-sight information
CAPABILITIES	• Creative responses • Experience • Dynamic Capabilities	***Input orientations:*** Capabilities required to enhance entrepreneurial judgement and reduce uncertainty	Schumpeter, Penrose, McGrath, Wernerfelt, Barney, Dierickx & Cool, Nelson & Winter, Teece, Zollo, Eisenhardt	Capabilities to increase knowledge on Action-performance linkages and thus focusing on reducing causal ambiguity
QUANTUM THEORY	Quantum Mechanics	Uncertainty Relation	Heisenberg	Probability function however causality is lost

Table 4: Uncertainty approaches and causality

The next section will elaborate on the demise of the law of causality from a physics perspective and explore analogous approaches that are potentially beneficial for the treatment of uncertainty in NTBVs.

2.6 TREATING UNCERTAINTY BY LOSING THE CAUSALITY ARGUMENT

2.6.1 Introducing an analogy

This section will elaborate on the changing perspective on causality within physics to explore the adoption of the concept of treating uncertainty by losing the causality argument for managerial decisions and uncertainty.

2.6.1.1 Causality and Newtonian physics

In order to establish a conceptual basis for uncertainty in physics, the well-known 'arrow of Zeno' paradox can be used[5] as an illustration. In the 5th century B.C., the Greek philosopher Zeno of Elea introduced one of the first notions of uncertainty by elaborating on the paradox that emerged when attempting to explain an arrow in flight (figure 9). When observing an arrow in flight (or motion) the arrow seems to be moving continuously through space. However, Zeno discovered a paradox when he wanted to determine the position of the arrow at one instant in time. In this instant, an arrow can only occupy a region of space exactly equal to its size. The arrow cannot occupy a larger or a smaller space. In other words the arrow is not moving at that instant. However, if the arrow is not moving at one instant and the arrow cannot exist in two different places at the same time, how can the arrow have moved at all? Zeno challenged this concept of time and motion by elaborating that if the arrow moves, the next instant or position follows immediately and there is no time between one instant and the next. He argued that it appeared as though that if the arrow is at some particular position at one instant, it is impossible for the arrow to arrive at a new position at the next instant.

This paradox between position and time can be seen as one of the earliest traces of the understanding of the concept of uncertainty. Physics is the study of matter. It encompasses all levels of analysis from the smallest particles, such as electrons and quarks, to the largest bodies, such as galaxies (Ohanian, 1989). Physics is concerned with the measurement of space, time and mass of this matter. Phenomena happen at points in space and at points in time (Ohanian, 1989). As illustrated in Zeno's arrow, uncertainty can relate to the inability to measure and thus understand the arrow's position (in other words its point in space) at a specific point in time.

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[5] Source: Physics department, Trinity College Dublin,h
Http://www.tcd.ie/Physics/Schools/what/atoms/quantum/uncertainty.html

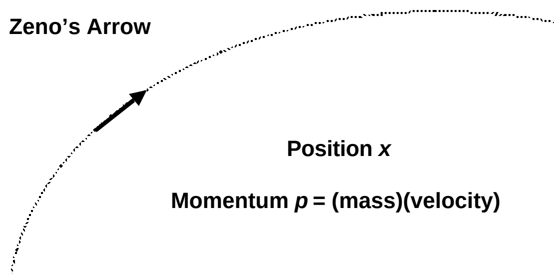

Figure 9: Zeno's arrow

The understanding of the uncertainty related to the arrow paradox of Zeno was solved three centuries ago, with the introduction of Newtonian physics. Using causal relationships and infinitesimal numbers, Newton developed laws that could exactly explain and predict the flight of the arrow. Newton introduced three laws of motion (the law of inertia, the law of action and reaction, and the law of acceleration proliferation – table 5) that led to the foundation of physics. By applying infinitesimal calculus, developed simultaneously by Leibniz and Newton in the 17th century, the arrow paradox could now be solved. The laws of motion explain uncertainty in areas such the behaviour of objects on the surface of the earth as well as the orbits of the planets around the sun, and the moon around the earth. These laws form the basics of mechanics (Gribbin, 1991).

Newton's method for understanding uncertainty was thus based on exploring causal relationships. The behaviour of a particle could be exactly predicted on the basis of its interactions with other particles and the forces acting on it. This has also been referred to as Laplace causality laws. "If an intellect were to know, for a given instant, all the forces that animate nature and the condition of all objects that compose her, and were also capable of subjecting these data to analysis, then this intellect would encompass in a single formula the motions of the largest bodies in the universe as well as those of the smallest atom; nothing would be uncertain for this intellect, and the future as well as the past would be present before its eyes." (Laplace, P.S. in Ohanian, 1989: 123). If the exact position and velocity of a particle at a given point in time is known, it is possible to calculate its position and velocity at any future moment (Cassidy, 1991).

NEWTON'S LAWS OF MOTION
The **first law of motion** is the law of inertia that states that every body will stay in a state of rest or uniform motion in a straight line unless that state is changed by forces impressed upon it, whereby all motion is composed of two parts: speed and direction. The combination of speed and direction is velocity, and a change in motion is acceleration.
The **second law of motion** states that the size of acceleration is directly proportional to the force applied, and inversely proportional to the mass of the body. Further, the acceleration will take place in the same direction as the force applied (F= m*a, where F= force applied to the body, m= mass of the body, and a= acceleration the body experiences in response to the force applied). An example of the second law is the force of gravity.
The **third law of motion** brings together the first and second laws and states that for every force applied to a body, there is an equal and oppositely directed force exerted in response. Or in other words: to every action there is an equal and opposite reaction.

Table 5: The foundation of physics: 3 laws of motion (Ohanian, 1989)

2.6.1.2 Challenging causality

A notable shift in the approach to uncertainty in physics stemmed from the concept of time. Whereas Newton's laws were completely reversible as far as time is concerned, experiments showed this is not always the case. For example, when a falling brick hits the floor the energy of its motion is converted into heat. However, if one heated the stone on the floor the stone would not move back up into the air (Gribbin, 1991). This problem could be explained using thermodynamics. The second law of thermodynamics states that in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state (Hawking *et al*., 1996). This has also been referred to as entropy. Entropy is a measure of disorder. Because natural processes always move towards a state of disorder, entropy is always increasing.

The concept of entropy led to a statistical approach for understanding uncertainty. Using the example of the falling brick, Boltzmann's addition to the second law was that it *could* happen that the stone would go up again whilst heated, although this was very unlikely (Gribbin, 1991). The introduction of the possibility of a particular random movement means that, whilst it was very probable that entropy always increases, it is not an absolute certainty (Gribbin, 1991). "Boltzmann's statistical approach involved cutting energy up into mathematical chunks and treating these chunks as real quantities that can be handled by probability equations" (Gribbin, 1991: 40). This is also known as the statistical interpretation of the second law of thermodynamics.

In physics, the idea of statistical interpretations for the explanation of phenomena such as entropy was received with great reluctance (Gribbin, 1991). Nevertheless, this idea eventually led to the introduction of "quanta". Max Planck, a German scientist, though strongly disagreeing with the use of statistics in physics, eventually derived his theory by applying a similar concept to Boltzmann's to understand the uncertainty related to the smallest particles. Planck discovered that the only way to explain the behaviour of light was to assume that the atoms and molecules in materials could only change energy in discrete units or "quanta"[6] (Heisenberg, 1958; Davies, 1989; Cassidy, 1991).

The idea that energy could be emitted or absorbed only in discrete energy quanta could not be fitted into the traditional framework of physics. Planck, renowned to dislike the conclusions of his own findings, endeavoured several times to reconcile his hypothesis with the older laws of radiation but his experiments all had similar results (Heisenberg, 1958). New ways of understanding this uncertainty were required.

2.6.1.3 Discovering the limits of causality: a duality

The existence of complete causality was disproved by the emergence of a contradiction. Einstein (1938) explained the observations by suggesting that the behaviour of light consists of quanta (or photons) of energy travelling through space. Light could either be interpreted as consisting of light quanta (particles), *or* as consisting of electromagnetic waves (Heisenberg, 1958). According to Einstein the apparent duality that emerged would be understood only much later.

The implications of the uncertainty surrounding this paradox emerged on the level of the observer (Cassidy, 1991). Only prescriptions of reality, in for example mathematical interpretations, could enable the development of concepts on the behaviour of the atomic world. Understanding observation and measurement became of central concern to quantum physics (Cassidy, 1991).

Prediction becomes limited as only by observation is it possible to know either the position or momentum of an atom, and the act of observation itself might affect what is being measured. A seminal example has illustrated this idea, by levitating the microscopic problem into a macroscopic setting. It is based on a thought experiment developed by Schrödinger, so-called Schrödinger's Cat (Gribbin, 1991). The thought experiment describes the situation of a cat in a steel chamber. In the chamber is a device that includes a Geiger counter and a tiny bit of radioactive substance. This portion is so small that, according to quantum theory, in the course of one hour one of the atoms might decay. But there is also an equal probability that this does not occur. If one of these atoms decays, the counter tube discharges and, through a relay, releases a hammer that breaks a flask of hydrocyanic acid. This would poison and kill the cat. If this system was left alone for an hour, the cat could be alive or dead depending on whether one of the atoms had decayed. Before opening the

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[6] As the metal is heated, the object loses energy in the form of light. Planck suggested that the colour of light emitted is determined by the size of the quanta of energy lost by the material. The measurement used for the colour of the light is "frequency", *v*. The constant of proportionality between the energy of the quantum, *E*, and the frequency of the light is a new physical constant – Planck's constant. The formula is $E=hv$ where E= Radiation (energy) related to v= frequency *h* is Planck's constant, the denominator of quanta $6.6 * 10^{-35}$ Joule seconds. (source: Physics department, Trinity College Dublin).

box, the state of the cat is represented by a probability function and it is impossible to determine with certainty the state of the cat. Only opening the box will prove if one of the atoms has decayed or not. This sub-atomic indeterminacy is now reflected in a macroscopic indeterminacy. This can only be resolved by direct observation. The superposition of possible outcomes (the cat is dead, alive or dying) exists simultaneously at a microscopic and at a macroscopic level (Gribbin, 1991).

The paradox is also observed in particle-wave duality. In essence it seems that particles show wave-like behaviour and waves show particle behaviour. The example of Zeno's arrow[7] can again be used as an illustration, but the uncertainty is now apparent on a sub-atomic level. In Zeno's arrow, the uncertainty emerged from the comprehension that the arrow could not be in two places at one point in time, so two options emerge. The first is to study the motion of the arrow through space, concentrating on the rate at which it passes a point (measured by its momentum). The second option is to study the position of the arrow at some instant during the flight. However, these two perspectives are mutually exclusive.

This is the essence of what is known as Heisenberg's *uncertainty principle*. Heisenberg's seminal paper on uncertainty stated that, "The more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa" (Heisenberg, 1927). If the position (q) of a particle is measured precisely, no information is given about its momentum (p). Alternatively if the momentum is measured precisely, no information is available about its position[8] (Heisenberg, 1930). The relationship between these two variables is uncertain. Furthermore, Heisenberg stated that not one or the other variable is uncontrolled alone, but both are uncontrolled in a reciprocal way (Cassidy, 1991).

Moreover, Heisenberg showed that these uncertainty relations are not just mathematical abstractions, but that the relations are consistent with actual experiments. He dubbed this uncertainty relationship as *anschaulich*. The German word *anschaulich* defies an unambiguous translation into other languages; however is possibly best described as 'intelligible' or 'intuitive' (Hilgevoord and Uffink, 2001).

Due to this uncertainty, determinism or the mechanical causality of physical systems is equally lost (Heisenberg, 1958). This has also been referred to as the principle of indeterminacy, showing that the old concepts fit nature only inaccurately (Heisenberg, 1958). The uncertainty between particle and waves could not be solved with traditional theories. Despite numerous experiments, the paradox in quantum theory did not disappear. In fact, the physicists got more used to this phenomenon (Heisenberg, 1958).

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[7] Source: Physics department, Trinity College Dublin,
http://www.tcd.ie/Physics/Schools/what/atoms/quantum/uncertainty.html

[8] The mathematical expression of the uncertainty relation is: $\Delta p \Delta q \geq h/4\pi$, where Δp is the uncertainty in measurement of the position and Δq is the uncertainty in the measurement of the momentum. $h/4\pi$ relates to Planck's constant divided by 4π. If for example the position is measured, and hence has a very small uncertainty, the uncertainty in the momentum becomes greater and vice versa. A similar version of this formula incorporates energy (E) and time (t).

2.6.1.4 A new method to understand the uncertain duality

The uncertainty seemed undeniable and could not be explained with classical methods – a new method was required. Based on a number of consecutive developments and experiments, a solution was developed that enabled physicists to deal with this uncertain duality in the form of quantum mechanics. Quantum mechanics provided a mathematical solution through transformation of the physical problem in space and time into a mathematical configuration space.

In other words it established a mathematical link between the symbols of the familiar classical world and the symbols of the quantum world of the atom (Heisenberg, 1958).

The dualism between particles and waves was not solved, but merely hidden in mathematical schemes (Heisenberg, 1958) by using probabilities. The introduction of probability implies the existence of a degree of knowledge of the actual situation (Heisenberg, 1958). Heisenberg noted this was a quantitative version of the old concept of 'potentia' in Aristotelian philosophy. "It introduced something standing in the middle between the idea and the event, a strange kind of physical reality just in the middle of possibility and reality." (Heisenberg, 1958: 11).

The concept considers the particle and wave duality as two complementary descriptions of the same reality (Heisenberg, 1958). There is a limitation to both perspectives, which leads to contradictions. However, taking these limitations into account, which in this case can be expressed by the uncertainty relations, these contradictions lose significance.

The uncertainty principle denies the strict formulation of the causal law (see figure 10). As soon as the phenomena are explained in terms of causal relationships (expressed by mathematical laws), a physical description of the phenomena in space-time is impossible (Heisenberg, 1930). The only calculation that can be made is a range of possibilities for the position and velocities of the electron in any future time. The laws and predictions of quantum mechanics are in general only of a statistical type. Uncertainty and indeterminacy can only be reversed by statistical approximations.

This means a balance should be struck between the abstract mathematical accuracy of measuring and the correct interpretation in space and time. The quantum theory stands out in that it renders the possibility of a consistent mathematical representation obsolete, by the uncertainty relation imposed on the object under study. The strength of the quantum approach to this uncertainty is the use of contradicting concepts (e.g. classical physics and probability waves) that ultimately explain the uncertainty relation (Heisenberg, 1958). This approach isolates and idealises the object under study in order to clarify the uncertainty (Heisenberg, 1958). However "…even if complete clarity has been achieved in this way, it is not known how accurately the set of concepts describes reality" (Heisenberg, 1958: 64). Idealisations form part of the human language. In this respect Heisenberg even compares these idealisations with different styles of art (architecture, music). The rules defined in art "can perhaps not be represented in a strict sense of mathematical concepts and equations, but their fundamental elements are very closely related to the essential elements of mathematics" (Heisenberg, 1958: 65).

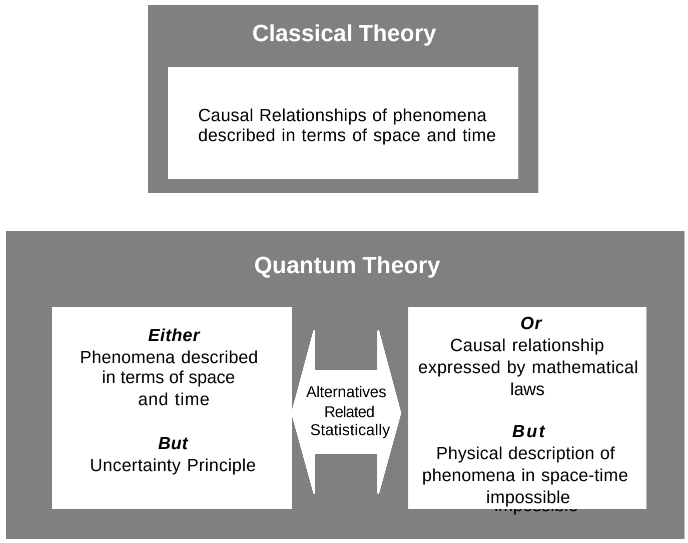

Figure 10: Classical versus quantum theory
(Heisenberg, 1930)

This led Heisenberg to elaborate on the theoretical interpretation of an experiment (Heisenberg, 1958), and identify three distinct steps required to merge probability with classical physics:

Constructing an Experiment	
Step 1.	The translation of the initial experimental situation into a probability function. A necessary condition here is the fulfilment of the uncertainty relations.
Step 2.	The following up of this function in the course of time. This step cannot be described in terms of classical concepts; there is no description of what happens to the system between the initial observation and the next measurement.
Step 3.	The statements of new measurement to be made to the system, the result of which can be calculated from the probability function. This step allows the change over again from the possible, to the actual (determinism) situation.

Table 6: Theoretical interpretation of an experiment (Heisenberg, 1958)

By adopting these three steps a potential probability function can be explored and evaluated on its potential to contribute to the understanding of the uncertainty in new technology-based ventures.

2.6.2 An analogous approach for managerial decisions in NTBVs

In Heisenberg's seminal essay on uncertainty, he suggested that the content of a physical theory may be recognised not by its mathematical formulation but by the new concepts it gives rise to. To take the example of quantum mechanics, the motion of an electron could previously be described by noting its position and velocity at any given moment. However, as Heisenberg noted in his essay, such concepts are meaningful only when they are referred to or defined by the actual experimental operations used to measure them. The physicist cannot know any more than what he or she can actually measure. The transition from the possible to the actual takes place during the act of observation. In quantum mechanics this implies that what happens in an atomic event can only be described with reference to the observation, not the state of affairs between observations.

The above synopsis on the evolution of the concept of uncertainty in physics showed that the focus on causality has been abandoned at the beginning of the 20th century, notably based on discoveries by Werner Heisenberg. Heisenberg showed that the law of causality, as it had prevailed for three centuries in classical physics, did not apply on a quantum level. Despite numerous attempts to falsify this insight, his uncertainty principle remained valid, and usable.

Heisenberg (1958) realised that the uncertainty was hidden in paradox relations. This has been formulated in the Copenhagen interpretation, which is considered to be the first complete description of quantum theory. The Copenhagen interpretation commences with a paradox: any experiment (from phenomena in daily life to atomic events), is to be described in the terms of classical physics (Heisenberg, 1958). Classical physics forms a common language, by which a description can be made of the arrangement of our experiments and results (Heisenberg, 1958). These classical concepts do not have to be replaced nor improved. However the uncertainty relation limits the application of these concepts (Heisenberg, 1958). This limitation has to be acknowledged when applying classical concepts.

The limitations placed on classical concepts had severe consequences for theoretical physics. Critics of the quantum theory from a mathematical and physical perspective have always existed. A prominent example is Einstein's comment, "God does not play dice" implicitly assuming that new developments will prove to be just a step towards an even better understanding of the physical world. Others, such as Bohm, regarded physics as an ongoing development with no end since new dimensions will be discovered (Bohm and Hiley, 1993). Another more recent example is a dialogue between Hawking and Penrose on quantum theory, in which they have a similar debate on the implications of the uncertainty principle (Hawking *et al.*, 1996). These illustrations show that there is no consensus amongst physicists about the epistemological implications of the loss of causality following the uncertainty principle on a sub-atomic level, although nobody has yet proven Heisenberg wrong.

The new workable solutions of quantum mechanics for understanding and managing uncertainty proved very successful. The Copenhagen interpretation formed the basis for many successful developments. Quantum theory has yielded a range of technological advances based on research in areas such as: sub-atomic particles (the evolution of the universe); nuclear physics (bombs, medical uses and power); atoms and molecules (materials and technology); and quantum optics (quantum computing, semiconductors, lasers, communications, quantum cryptography)[9]. Applying quantum mechanical mathematical transformation and abstraction can therefore be seen as ambiguous in its theoretical formulation but highly successful for its application in atomic research.

As for the philosophical implications of the Copenhagen interpretation, I quote Heisenberg on the potential of its applicability: "These new results (- the concept of matter and the inapplicability of classical physics to describe the smaller parts -) had first of all to be considered as a serious warning against the somewhat forced application of scientific concepts in domains where they did not belong. The application of classical physics, e.g. in chemistry had been a mistake. Therefore one will nowadays be less inclined to assume that the concepts of physics, even those of quantum theory, can certainly be applied everywhere in biology or other sciences. We will, on the contrary, try to keep the doors open for the entrance of new concepts even in those parts of science where the older concepts have been very useful for the understanding of the phenomena. Especially at those points where the application of the older concepts seems somewhat forced or appears not quite adequate to the problem we will try to avoid rash conclusions." (Heisenberg, 1958: 138-139)

With respect to the research question and the potential contributions that can be derived from the Heisenberg approach, great care should be taken in applying quantum theoretical concepts in other sciences. Nevertheless, this does not advocate complete ignorance and neglect of concepts from other sciences. As the evolution of quantum theory itself shows, many other concepts have been applied to enhance the understanding of the phenomenon under study. Others already have advocated actively pursuing investigations into managerial phenomena using principles that follow this new quantum way of understanding the world (Zohar, 1998; Zohar and Marshall, 1993; Wheatley, 1999; Katz and Gartner, 1988). Where current concepts on uncertainty remain ambiguous (Buchko, 1994), the conceptual advances and appreciation of uncertainty relations might prove useful as an alternative approach.

Even though the current state of affairs in social sciences is not as refined and clear in terms of understanding uncertainty as in physics (Parkhe, 1993), embarking on a thorough exploration in a similar fashion to the way physics evolved appears appropriate. No advanced mathematical uncertainty relations have been established in social sciences and the abstract language that guides social sciences is not as unequivocal as in mathematics. However the new conceptual findings and approach to uncertainty in quantum theory does provide alternative new ways of looking at the concept of uncertainty, which may prove beneficial in other areas.

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[9] Source: Physics department, Trinity College Dublin, http://www.tcd.ie/Physics/Schools/what/atoms/quantum/uncertainty.html

A necessary condition that has to be satisfied is the fulfilment of an uncertainty relation. Obviously, the current state of social sciences is not yet ready to come to a sophisticated uncertainty relation as that formulated by Heisenberg, since social science is not at such an advanced stage (Parkhe, 1993). Nevertheless, by *treating* the input-outcome relationships of new technology-based ventures as a non-causality, initial dualities can be proposed. Following this duality, the initial situation, or current state of affairs, can be translated in a probability function. This will form the starting point of the experiment which follows in the remainder of this thesis.

The next chapters will address three main issues. The first step is to explore potential uncertain relationships, relevant for new technology-based ventures. Such dualities ought to reflect a potential uncertainty relationship between two existing perspectives on the new technology-based firms. Secondly, a first attempt is made to suggest how a potential probability function can be formulated to understand this duality. The potential probability function will form the basis for the development and execution of an experiment (section 4.6), to test and gain insight into the potential contribution such an approach can provide for managerial decision-making. The third step evaluates previous efforts to adopt or refer to Heisenberg’s uncertainty principle in social sciences in order to position the contribution presented here.

3

UNCERTAINTY AND VENTURING NEW TECHNOLOGIES: TOWARDS A PROBABILITY FUNCTION

"In effect, we have redefined the task of science to be the discovery of laws that will enable us to predict events up to the limits set by the uncertainty principle."

Stephen Hawking, 1988

3.1 TOWARDS A PROBABILITY FUNCTION FOR UNCERTAINTY IN NTBVS

When looking at the existing approaches for dealing with uncertainty in managerial decision-making, it appears that an underlying causal relationship is always assumed to exist. For example, even though statistics are an effective tool for supporting the decision-making process, the underlying assumptions (or subjective data) necessary to fuel the calculations under uncertainty always seem directed to the best causal interpretation available to the decision maker. For new technology-based ventures this approach has its limitations.

Uncertainty in NTBVs emerges on the confluence of the building of long-term capabilities, which should give a competitive advantage, and short-term business opportunities, which provide concrete returns. In these cases the assumptions necessary to make decisions become very important as new technologies have neither clear-cut potential future states nor clear-cut probabilities that can be assigned to a suggested future state. The literature on entrepreneurship in particular has argued that the quality of such assumptions and the resulting decisions depend on the quality of the entrepreneurial judgement.

Based on the conceptualisation of the firm as a bundle of resources (Wernerfelt, 1984; Barney, 1991; Eisenhardt, 2000), it becomes apparent that on a firm level, dynamic capabilities (Teece *et al.*, 1997; Eisenhardt, 2000; Zollo and Winter, 2002) are essential in cases of venturing new technologies and in dealing with the associated turbulence. Dynamic capabilities enable the firm to reconfigure their resource base to improve performance and dynamically adapt to new productive opportunities in the market. Essentially, Zollo and Winter (2002) argue that these dynamic capabilities are a learning process that aims to enhance the causal ambiguity in the action-performance relationships.

However even though the relationships are clearly ambiguous, they are treated as though an underlying causality, that can be known, is still present. These solutions are geared towards the notion that increasing clarity on this relationship will benefit the company. From a managerial decision point of view, it thus appears that firms that have such dynamic capabilities are better equipped to make the correct and timely decisions (actions) that should result in a better outcome (performance).

However if you no longer look at this concept in terms of causality, a process model emerges (figure 11). Instead of treating the input and the output as a causal relationship – or a contingent relationship, depending on situational factors – the input-output can be regarded as a stochastic relationship.

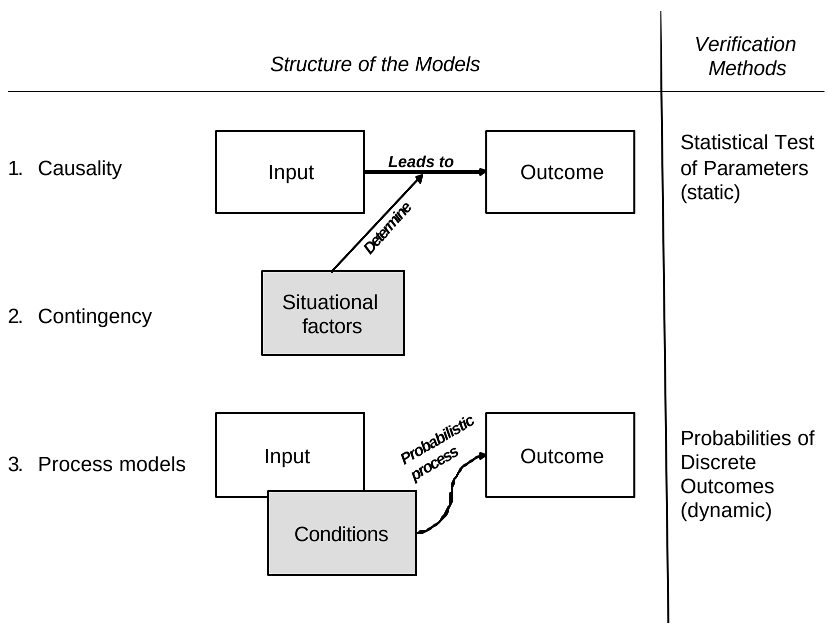

Figure 11: Causality, contingency or process models

The use of statistics in this case differs from decision theory approaches, as the essential new understanding is that the relationship is not causally related. Decision theory, for example, uses subjective probabilities to calculate the most appropriate decision that would lead to the desired future states. The underlying relationship between decision options and resultant future states are assumed to be casually related, but as there is a lack of knowledge, probabilities are distributed subjectively over the various options, compensating for the causal ambiguity. The process model, on the other hand, does not assume this underlying causal relationship nor does it describe decision options. Instead it aims to evaluate if a certain condition is apparent and if there is an increased chance of reaching the desired outcome. In some cases it will be, in others it won't. This remains a matter of observation. However, knowing there is a significant probability can influence the process of decision-making and thus enhancing the decision maker's judgement.

Measuring the intangible aspects of this relationship can thus be regarded as a useful starting point in for gaining understanding. The previous chapter has shown that we are able to describe managerial phenomena related to venturing new technologies. An example is the capabilities view of the firm, which takes an input-oriented approach to venturing, and conceptualises firms as bundles of resources that form the basis of any venturing process (Penrose, 1959; Wernerfelt, 1984) However, it became clear that the relation between the input and the eventual outcome of the venturing process is far from apparent, and concepts such as dynamic capabilities remain abstract.

By applying the experimental method to uncover such potential probabilities between two dual uncertain perspectives, a re-conceptualisation can be achieved that potentially forms the basis of a new understanding about the relationship between intangible capabilities and potential outcomes.

3.1.1 Duality for new technology based venturing – capabilities versus performance

Venturing new technologies is distinctly uncertain, as the future outcome is not known. However, as literature shows, the input can be conceptualised as committed resources. The effective reconfiguration of the resources is seen as the entrepreneurial act necessary for venturing new technologies. Nevertheless, the ability to conceptualise the input of the venturing process as resources still provides little insights into the outcome. This is the starting point for a potential duality in NTBVs.

Although the outcome of venturing new technologies is often not known, the main aim of venturing is creating value for the firm. Penrose's profit motive shows that a decision maker's ultimate goal is to create value out of resources, such as new technologies (Penrose, 1958). Therefore, business performance can ultimately be seen as the driver for the venturing process of new technologies. However, how new technologies come to create value (the outcome) is not known. New technology alone does not lead automatically to business performance.

Necessary conditions have been formulated, such as the dynamic capabilities framework, which should have a positive effect on the input-outcome relationship. Scholars believe that the effective allocation of resources has a positive impact on the corporate performance, for example by diversification (i.e. Rumelt, 1982; Harrison *et al.*, 1993). By applying diversifying strategies the risk return ratio of the business is lowered (Amit and Livnat, 1988) and this reduced business risk has a positive effect on profitability (Amit and Wernerfelt, 1990). It is also argued that such a resource perspective on diversification can help determine the direction of the firm's future expansion (Chatterjee and Wernerfelt, 1991). However, such studies take a wide time-span and do not consider the immediate uncertainty of new technologies. It is not yet known what the outcome is and thus it is not yet known if business risk can be reduced via diversification. Only after 3M found an application for the new adhesive, and it was proven to be successful, did diversification become a decision option.

When the relationship between the capabilities, by which a firm controls its resources, and the performance or profits they create, are imperfectly understood this is often attributed to causal ambiguity (Barney, 1991). However, contrary to Barney, I propose taking a non causal approach in the case of new technology-based venturing. As I have argued, in the case of new technology-based ventures it is simply not known what the outcome will be and thus a non causal approach seems more appropriate.

A duality emerges with a capabilities-based perspective on the one hand and a performance perspective on the other (figure 12). The capabilities perspective is input oriented. The performance perspective is outcome oriented. Venturing new technologies sees an uncertainty on the confluence of this relationship, where it is impossible to determine with certainty the outcome of any resource commitment to a certain technology venturing process. Whereas the dynamic capability of reconfiguring resources implies an enhanced chance of long-term competitive advantage, short-term performance is not necessarily granted. Vice versa, creating extraordinary performance or value from one new technology-based venture does not imply that the firm can repeat this action and have a long-term competitive advantage.

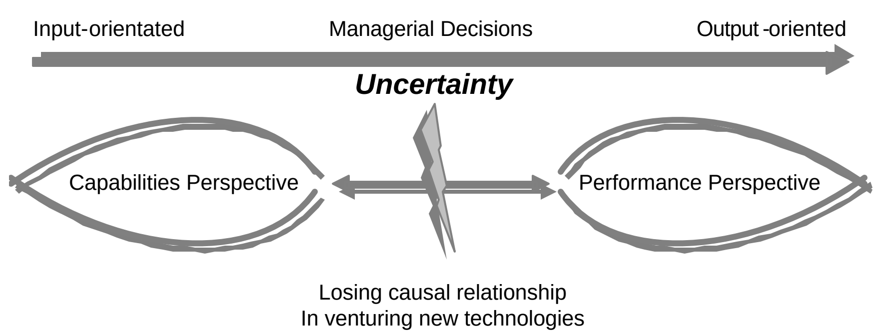

Figure 12: Duality: capability versus performance perspectives

Although literature has pointed towards arguing for a potential probability relationship between such capabilities and outcomes, no measures yet exist to explore such a relationship. In order to explore potential measures it is important to understand these two perspectives.

3.1.2 A performance perspective

The outcome of the process of venturing new technologies is ambiguous. On the one hand, it has been argued that having a distinct competitive advantage over competitors is important in order to survive. This is often seen as a long-term perspective for a firm's survival for which no measures exists. Competitive advantage is important for firms, especially how this competitive advantage can be created *ex ante* (Cockburn *et al.,* 2000). However, how competitive advantage can be achieved is still ambiguous. Coff (1999) argued for a distinction between rent creation and the appropriation of the rent created. Another perspective on this outcome, for which some measures are available, is performance or profit. Penrose (1958) argued that this profit motive can be seen as the ultimate driver to venture new technologies.

Business performance is traditionally measured using financial accounting standards, and becomes visible when looking, for example, at a firm's profit and loss account, balance sheet and cash flow statement (Tracy, 1996). These financial statements present the achievements of the company in monetary terms. The main financial imperatives of any business are: making profit (reported in the income statement), generating cash flow (reported in the cash flow statement), and maintaining financial health (reported in the balance sheet) (Tracy, 1996).

However, as this thesis shows, in NTBVs it is difficult to predict future performance. The existing models that help understand and predict future growth returns from this perspective, such as net present value, discounted cash-flows, and more recently, real options, are predominantly based on decision theory. However, these models all depend on the availability of reasonable assumptions about the return ratio. In the absence of such reasonable assumptions other perspectives are required.

The information that becomes available through conventional financial reporting systems always reflects a hindsight perspective of the business venture. Although such projections are helpful in conventional industries with stable business patterns, the dynamism of new technology industries means that these figures alone do not suffice for effective managerial decision-making. For example, 3M's existing financial reports contributed little to the managerial decisions regarding the new technology of the glue (N. N., 2002). The key to venturing new technology, as discussed in the previous chapter, is attributable to the entrepreneurship that can produce a creative response within conventional industries.

3.1.3 A capabilities perspective

Capabilities are an important input in the decision-making process when venturing new technologies. As seen in the literature review, from an entrepreneurship perspective the motor for growth and improved business performance rests on the decision-making capabilities of the entrepreneur. Decisions in this sense relate to committing resources to certain ventures. Resources are seen to have the ability to provide productive services (Penrose, 1959). Managerial decisions are thus focused towards the effective configuration of these resources so as to create on the one hand innovation (entrepreneurial contribution), by focusing on reconfiguring the existing pool of resources, whilst on the other hand managing the existing resources (what Penrose calls operations) that already produce output (Penrose, 1959).

As noted by Penrose (1959), an essential question about the entrepreneurial function of the firm addresses the "effects of risk and uncertainty on, and the role of expectations in the growth of the firm" (Penrose, 1959: 41). This suggests that for firms to create superior business performance, they need to understand the effects of risk and uncertainty on the potential outputs rendered by the productive services. Furthermore, based on the resource-based view of the firm, conditions emerge that are appropriate to NTBVs. A prominent description for these conditions that apply to NTBVs has been conceptualised in the dynamic capabilities framework (Teece *et al.,* 1997; Zollo and Winter, 2002).

The framework of dynamic capabilities (Zollo and Winter, 2002) focuses on understanding the relationship between the actions taken in a firm and the performance rendered through these actions. Dynamic capabilities can thus be understood as a necessary condition when venturing new technologies, as they potentially reduce the causal ambiguity within action-performance relationships (Zollo and Winter, 2002).

In order to determine whether a firm has such dynamic capabilities, the evolution of these capabilities needs to be addressed. Currently the evolution of dynamic capabilities has been observed via empirical research (Eisenhardt and Martin, 2000). Teece and Pisano (1994) identified three classes of factors that determine how a firm's dynamic capabilities evolve:

- processes: managerial, technological and organisational routines
- positions: current endowments of technology, customer bases and suppliers
- paths: available strategic alternatives.

The paths and positions shape the processes of the firm (through for example projects) and ultimately build the dynamic capabilities. Competitive advantages and competitive disadvantages (Moss-Kanter, 1994) of firms are seen as resting on distinctive managerial and organisational processes (ways of coordinating and combining), "shaped by the firm's specific asset positions (internal and market) and moulded by the evolutionary and co-evolutionary path(s) it has adopted or inherited" (Teece *et al.*, 1997). Managerial and organisational routines are referred to as a firm's routines or patterns of current practice and learning. Positions are defined as current specific endowments of technology, intellectual property, complementary assets, customer base, and the external relations with suppliers and complementary partners. Paths are the strategic alternatives available to the firm, and the presence or absence of increasing returns and attendant path dependencies. The firm's processes and positions collectively encompass its competencies and capabilities. The competitive advantage of the firm is seen to be sustainable at firm level through repeatedly creating short-term business.

Dynamic capabilities are the result of the co-evolution of a learning mechanism. "Dynamic capabilities arise from learning, they constitute the firm's systematic methods for modifying operating routines" (Zollo and Winter, 2002: 340). The operating (or organisational) routines relate to the "execution of known procedures for the purpose of generating current revenue and profit" (Zollo and Winter, 2002: 341), and thus can be seen as the company's productive base. However, in high velocity environments these routines require regular updating, which can be done by reconfiguring the resources that form the basis of the productive services rendered in the operating routines. The second order routine of updating the operating routines is the dynamic capability and "…seeks to bring about desirable changes in the existing set of operating routines for the purpose of enhancing profit in the future." (Zollo and Winter, 2002: 341).

This suggests that dynamic capabilities can be observed. Adapting the operating routines in an organisation is a systematic process, and can for example be seen in R&D processes, restructuring and re-engineering efforts and post-acquisition integration processes. Such dynamic capabilities are believed to stem from three main learning mechanisms.

Firstly, the process of experience accumulation. This is the central learning process by which operating routines have been thought to develop (Zollo and Winter, 2002).

Secondly, the articulation of knowledge derived from these experiences. "…articulation efforts can produce an improved understanding of the new and changing action-performance links, and therefore result in adaptive adjustments to the existing set of routines or in enhanced recognition of the need for more fundamental change" (Zollo and Winter, 2002: 342). The articulation of experiences is said to be limited compared to the amount of available articulated knowledge (Zollo and Winter, 2002). Examples of articulated knowledge can be found in discussions among employees, debriefing sessions and performance evaluation mechanisms (Zollo and Winter 2002).

The third mechanism identified is that of knowledge codification. Codified knowledge relates to the formal capturing of the articulated knowledge in, for example, manuals and process specific tools (Zollo and Winter, 2002). Codified knowledge provides a potential supporting mechanism for the knowledge evolution process and facilitates the generation and development of project proposals to change the operating routines (Zollo and Winter, 2002). These three mechanisms form the basis of the evolution of dynamic capabilities and the operating routines (figure 13).

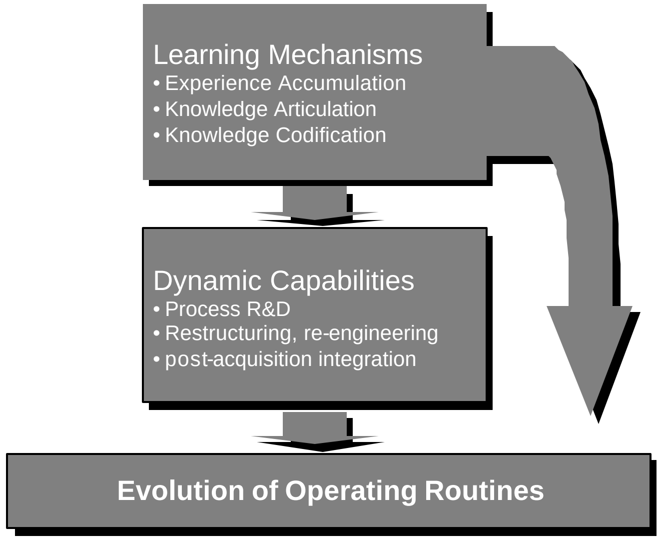

Figure 13: Learning, dynamic capabilities, and operating routines (Zollo and Winter, 2002: 340)

It thus seems possible to observe and perhaps even deliberately implement dynamic capabilities by focusing on the learning mechanisms and underlying change efforts undertaken by the organisation. However, little empirical research exists on the observation and measurement of the intangible concept of dynamic capabilities (Teece, 1998).

3.1.4 Complementary perspectives – a duality

Both the capability and the performance perspective provide a relevant picture of the firm. Performance, and especially financial performance, has always been of major concern to managerial decisions. However, complementary to this financial perspective, the rise in literature that relates to a firm's capabilities has received increasing interest. Especially in the last decade, literature has addressed such concepts as competences, capabilities, routines and a resource-based view of firms, which has provided a new perspective on managerial decisions.

Nevertheless, how these two perspectives relate remains uncertain. A causal relationship between the two cannot be determined due to a lack of measures. This is further complicated by the varying time spans of the above perspectives. On a venture level, the decisions relating to the commitment of specific resources to one new venture, and the following reconfigurations (changes) in these resource allocations can be seen as an input. These decisions are specifically designed to create a return, which often can be considered as a short-term return, and can typically be measured on hindsight using some form of monetary indicator (e.g. profit). However, from a long-term firm level perspective, new technology-based firms require the necessary capabilities to be able to venture new technologies on a continuous basis. These dynamic capabilities, however, do not directly create a short-term profit, but are believed to contribute to the long-term competitive advantage of a firm. The specific decisions that lead to the stimulation and creation of such dynamic capabilities are not yet clear, nor are the measures to evaluate them.

As dynamic capabilities refer to the manner by which a firm is able to make changes in the resource configuration, measuring these changes over time would potentially provide a picture of these capabilities. This would entail measuring the changes in the resource base for a particular new venture. Nevertheless, even if such a measure was apparent, it is not yet clear if this would imply the existence of future returns, or even contribute to predictions on future returns.

In contrast, the performance perspective only gives a description of the (financial) achievements of the venture. Such measures thus provide historical information that relates to decisions made in the past. The uncertainty between them becomes especially apparent when both perspectives are taken at one point in time (figure 14).

It thus seems that managerial decisions can be based on both the complementary information from the input-oriented capability perspective and the outcome-oriented performance perspective. Nevertheless, how these two perspectives relate is unclear. Whereas performance can be measured using arbitrary monetary values such as profit, no measures for dynamic capabilities exist. Even if these measures existed, and were executed at the same time, the capabilities indicator would relate to performance in the future, whereas the financial parameter typically reflects decisions made in the past. Uncertainty remains therefore, but it is perhaps possible to interpret this relationship in a probability function.

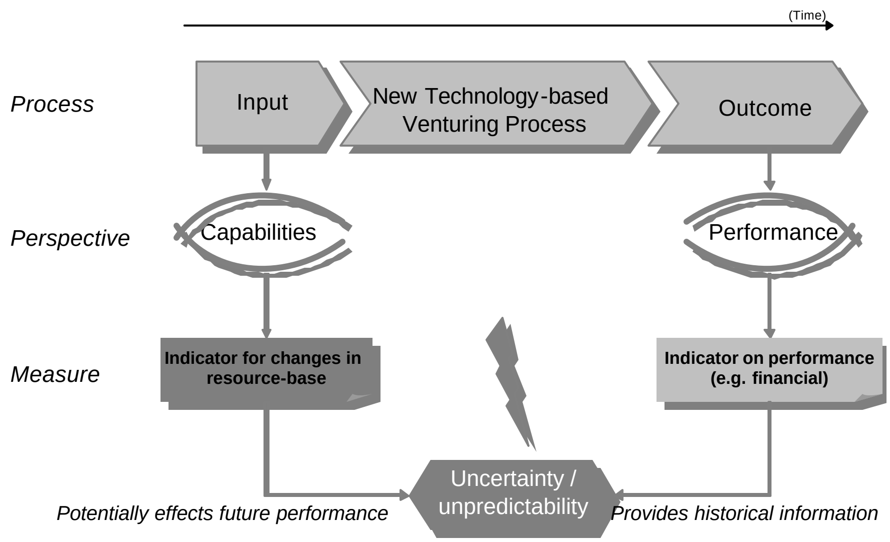

Figure 14: Uncertainty and the dual perspectives for the new technology-based venturing process

3.1.5 Dynamic capabilities for improved performance – towards a probability function for NTBVs

An initial exploratory probabilistic process model can now be modelled (figure 15). The main assumption is that if new technology-based ventures have dynamic capabilities, the likelihood of a positive business performance increases. Obviously this is a premature statement which opens up many different research avenues. However, in the spirit of Heisenberg, this thesis will provide a first experiment to evaluate the potential of such an approach.

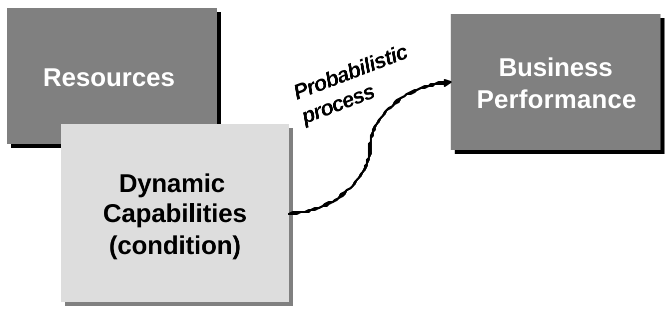

Figure 15: A process model for uncertainty in NTBVs

As a starting point, in its most simplistic form, it can be assumed that new technology-based ventures will have a higher probability of an increase in performance under the condition that dynamic capabilities exist, than they would if dynamic capabilities do not exist. Dynamic capabilities in this case would have a settling effect on the typical uncertainty in new technology-based ventures.

A probability function is a function that specifies the probability that a random variable takes on a specific value. Based on the dual perspectives between performance and capabilities, the outcome state of an improved performance can be interpreted as a random variable. In this assumption the dynamic capability can be seen as a variable that can be controlled.

This potential conditional probabilistic process (1) can be expressed in statistical terms for new technology-based ventures:

$$P\,(X \mid DC) > \mathrm{P}(X \mid \overline{DC}) \qquad (1)$$

Where: X = Increase in Performance

DC = Dynamic Capabilities

In order to test this condition, an experiment is required in which the controlled variable of dynamic capability can be varied. This will enable exploration of how and whether dynamic capabilities relate to increases in business performance. Ultimately this may lead to a probability function that creates better visibility on predicting the likelihood of future performance based on the existing dynamic capabilities. The dynamic capability can become a requirement for new technology-based firms that should be deliberately stimulated and implemented in a firm to reduce this uncertainty. Managerial decisions are in this sense not only directed towards the action-performance relation, but also focus on the underlying dynamic capabilities that a firm requires in order to enhance this process. These can be influenced by, for example, introducing process engineering methodologies and rapid prototyping (Eisenhardt and Martin, 2000).

Nevertheless, it is very early days and a complete probability function is not the anticipated result of this thesis. Developing and verifying such a probability function would be extremely time consuming and require a vast amount of further research and experimentation.

In line with the research question of this thesis, at the outset of the experiment is the question of whether there is a contribution to be gained at all from such efforts. The experiment following this chapter should thus be regarded as a first trial of an exploratory nature. The intention is not to conclude with a universal probability function that satisfies the expected condition presented in this chapter, but to learn lessons on potential ways to explore this probability function. To this extent the Heisenberg method will be followed.

The first hurdle to cross is to translate the abstract theoretical underpinnings of dynamic capabilities in a workable measure. Such a measure is not expected to be universal or applicable in any industry, as dynamic capabilities can take many forms (Eisenhardt and Martin, 2000).

Being intangible, these dynamic capabilities are difficult to measure (Teece *et al.,* 1997; Teece 1998). Dynamic capabilities are explained using qualitative research and no mathematical formulation is currently available to measure them in numerical form.

Nevertheless, Teece (1998), who initiated the term 'dynamic capability', argued that the challenge is to measure these intangible dynamic capabilities *quantitatively.* The key is to find a proxy that represents the dynamic capabilities.

In chapter 4, using a qualitative developmental case, I will propose a potential proxy for dynamic capabilities. Based on this proxy an experiment will be designed for which a specific measurement tool has been engineered. The system engineering process has been described in chapter 5. In chapter 6, an initial experiment will be carried out in a setting where all variables are relatively stable, and where the controlled variable of dynamic capabilities is changed. By triangulating (Jick, 1979) both qualitative data from an extensive set of interviews, and quantitative data from the measurement tool, I will draw conclusions on the proposed process model and provide an initial validation of the proxy, and a preliminary evaluation of the probabilistic process.

3.2 A NEW WAY OF LOOKING AT UNCERTAINTY

In order to position the contribution of this thesis, a literature analysis has been carried out to determine how Heisenberg's uncertainty principle has been used so far in social sciences. Two electronic database searches on the keyword "Heisenberg" have been performed in order to evaluate the field. The first search was done on EBSCO's[10] Business Source® Premier database. This resulted in a total of 479 hits on articles that used the keyword "Heisenberg" in both the title and full text. From this search 74 hits were filtered for their relevance and appropriateness to social sciences. Relevance in this sense related to the respective status of the journal (predominantly scholarly journals) and the nature of the journal (obviously the greater number of hits consisted of journals in physics and related fields). The second search using ABI/Inform[11] resulted in an additional 12 articles that were found to be relevant, but not included in EBSCO. In total 86 articles have been analysed on their specific reference to Heisenberg's uncertainty principle in social sciences.

The articles have been categorised in their respective fields of interest. Six dominant fields have been distinguished. These fields are: economics, organisation & management, public administration, statistics & decision theory, sociology, and psychology. The majority of the articles could be categorised into the first two fields: economics and organisation & management. An overview of the distribution is provided in figure 16.

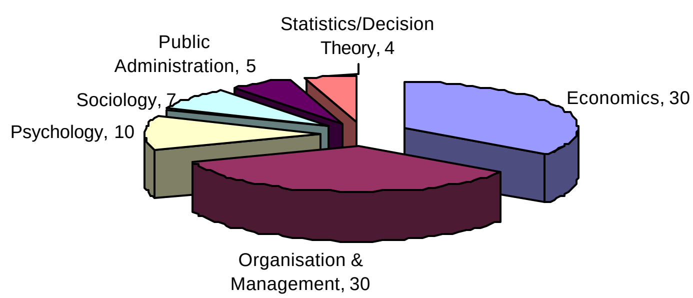

Figure 16: Pie chart distribution of search results on analogy in social sciences

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[10] EBSCO Business Source Premier is a full-text online database containing 2828 relevant full-text scholarly journals and business periodicals. The URL is http://www.epnet.com

[11] ABI/Inform is similar to EBSCO, with approximately 1200 periodicals.

The analysis showed that there is already a strong appreciation for Heisenberg's findings in social sciences and a variety of different usages of the underpinnings of the Heisenberg principle exist. Only one article explicitly rejected the notion of comparing the uncertainty discovered by Heisenberg with uncertainty visible in financial markets (Beed and Kane, 1991). The remaining 85 articles all deemed a potential analogy as appropriate or at least worthwhile for exploration.

Nevertheless, the majority of these articles were unsubstantiated efforts to adopt Heisenberg's uncertainty principle. Of the 86 articles, 68 made reference to the Heisenberg principle and established a comparison, but did not provide additional substantiation on the underlying conceptual or mathematical implications. The main aim of these articles was not to establish a comprehensive analogy of the Heisenberg principle, as laid out in this thesis, but merely to compare certain phenomenon to the Heisenberg uncertainty principle. However, the main aim (albeit not necessarily the only aim) of the remaining 18 articles was to directly adopt ideas from Heisenberg.

Furthermore, the majority of the articles do not provide a workable solution based on the assessment of Heisenberg principle. The majority (73) of the articles only emphasised the philosophical implications of the Heisenberg's uncertainty principle. Only a few (11) take the underlying mathematical statistics into consideration, and even less (2) adopt a combined effort. Particularly in the field of organisation & management, in which this thesis finds its centre of gravity, no mathematical considerations were apparent.

Various aspects of the works of Heisenberg have been addressed. The main point of Heisenberg's work can be seen as the loss of causality. This indeterminacy can be attributed to two features (Audi, 2000: 766). Firstly, the irreducibly statistical nature of quantum theory seems to be a feature of the apparent breakdown of determinism. I will refer to this as indeterminacy. Secondly, the apparent breakdown of observer-independence and the fundamental role of measurement is seen as a feature of the loss of causality. I will refer to this second feature as observer-interference.

Most prominently, in 36 articles, a link has been drawn from the observer-interference dilemma. One of the considerations that can be derived from Heisenberg's findings is that the observer interferes with the object under study and thus changes the results. In other words, observation means influencing and changing the observed, and therefore the results are never fully objective. This has been attributed to Heisenberg (1958), with the implication that one cannot observe nature itself, only nature exposed to the methods of observation. Some even compared the observer-interference with the Hawthorne effect – the effect that people change their behaviour when being observed – as its social science equivalent (Rosser, 1993; Atkinson and Shaffir, 1998). However, the notion of observation-interference has also been regarded as a simplified, albeit useful, representation of the underlying implications of Heisenberg's uncertainty principle (e.g. Capon, 2001).

The other main feature of Heisenberg's findings, referred to in 25 articles, is indeterminacy. Although the observer-interference dilemma holds its ground when examining Heisenberg's work, it is not the only lesson that can be learned from it. Heisenberg showed that the relationship between position and momentum was inherently uncertain, and could not be understood without appreciation for this uncertain relation. This indeterminacy has been compared to a variety of social and managerial phenomena, and was found to provide potential insight into these.

This thesis has so far argued that the uncertainty faced by NTBVs can be considered in the existence of non causal relationships. This is similar to the indeterminacy principle. Indeterminacy has led Heisenberg to accept the loss of the laws of causality, and find an alternative, probabilistic approach to solve this. This indeterminacy on a venture or firm level has an impact on managerial decisions, but has also been recognised on a market level.

Additional references to Heisenberg were made in articles that related the observer-interference argument to the indeterminacy argument (seven articles). Based on my own analysis of Heisenberg's work I am of the opinion that this is a more complete interpretation of the concept. Interestingly enough, only three (Khalil, 1997; Dreschler, 2000; Szira, 2000) elaborated on this as an analogy; all are in the field of economics. The remaining four articles merely made reference to this (i.e. O'Hara, 1995; Smith and Smith, 1996; Khalil, 1997/98; Bergmann Liechtenstein, 2000).

The remainder of the articles used the Heisenberg principle in a variety of ways. Some used it as either a token of appreciation towards a new way of thinking (i.e. Katz and Gartner, 1988; Barnard, 1996; Evans, 1996; Kober, 1997; Fabian, 2000; Gleisler, 2000; Mackenzie, 2000; Bogason, 2001). Others, which I will elaborate on later in this chapter, focus on dualities and paradoxes in order to understand social and managerial phenomena (i.e. McLarty, 1990; Bygrave and Hofer, 1991; Frosch, 1996). Some articles have compared the evolution of the developments in physics to the evolution of theories in economics, or organisation & management (i.e. Karsten, 1990; Ganley, 1995; Calkins and Vezina, 1996; Chia, 1997). Israel (1999) referred to Heisenberg to stress the importance of language from a sociology perspective, and finally, Leonard (1995) aligned statistics and the influences of Heisenberg probabilities on game theory. An overview of the articles and the respective classifications is provided in table 7.

In order to provide a concise overview of the use of Heisenberg's uncertainty principle and to position this thesis, each area in which references to Heisenberg have been found will be discussed in brief.

	ECONOMICS	ORG. & MNGT.	PSYCH.	SOCIO.	PUBL. ADMIN.	STATS.	TOTAL
ANALOGY	7	7		1	2	1	**18**
REFERENCE	23	23	10	6	3	3	**68**
TOTAL							**86**
OBSERVER-INTERFERENCE	11	14	6	4	1		**36**
INDETERMINACY	10	7	2	2	1	3	**25**
BOTH FEATURES	5	1	1				**7**
EVOLUTION	3	1					**4**
CRITICS	1						**1**
APPRECIATION		5			3		**8**
DUALITY		2	1				**3**
LANGUAGE				1			**1**
PROBABILITY						1	**1**
TOTAL							**86**
PHILOSOPHICAL	24	30	9	6	4		**73**
MATHEMATICAL	4		1	1	1	4	**11**
BOTH	2						**2**
TOTAL	**30**	**30**	**10**	**7**	**5**	**4**	**86**

Table 7: Overview literature analysis on uncertainty-analogy in social sciences

3.2.1 Analogy in economics

Uncertainty has been a central topic in economics and financial markets. Within this broad field, comparisons have been made between the uncertainty residing in these markets and the uncertainty in quantum physics. Investors in financial markets deal with uncertainty and demand a so-called risk premium for the uncertainty associated with the investment.

George Soros notably addressed the "*uncertainty principle*" in the financial field (N. N., 1993/94; Cross and Strachan, 1997). Soros is considered to be one of the most influential and successful investors and an acclaimed guru in the investment world (Nicolas, 1999). His financial strategy is based on an insight, borrowed from Heisenberg, about the distinction between appearance and reality – and thus falls into my category of observer-interference. His alternative investment vehicle is aptly named after Heisenberg's uncertainty principle: "the Quantum fund"[12].

The basis of his reference to Heisenberg and financial markets is the principle of market equilibrium. He refuted the existence of market equilibrium by arguing that it is "inherent in the imperfect understanding of the participants. Financial markets are inherently unstable, and the idea of a theoretical equilibrium …is itself a product of our imperfect understanding." (Soros, in Nicolas, 1999: 10). He argues that beliefs about reality alter reality itself, which in turn alters beliefs held by investors.

This is in Soros' view equivalent to the apparent observer-interference. The analysis shows that this view of Heisenberg's uncertainty principle is popular in economics, as a total of 11 articles refer to this (i.e. Jordan, 1992; Rosser, 1993; N. N., 1993/94; O'Hara, 1995; Carter, 1996; Wagner, 1996; Strachan, 1997; Atkinson and Shaffir, 1998; Stanley, 2000; Capon, 2001; Cross and Strachan, 1997; Phillips and Kaplan, 2001). Nevertheless, as the analysis shows, all the articles that mention observer-interference only use it as a side reference, which highlights the need for a more refined interpretation (Khalil, 1997)

Others recognise the similarities between the uncertainty in the financial markets and the uncertainty in quantum physics, but highlight indeterminacy as the most pertinent result of Heisenberg's uncertainty principle (i.e. Buchmiller, 1993; Benhabib and Farmer, 1994; Benhabib and Perli, 1994; Benhabib and Rustichini, 1994; Kaas, 2001; Ravetz, 1994/95; N. N., 1997; Raftery, 1998; Bazard, 2000; Singh and Dey, 2002). Again, however, it is in most cases used merely as a side reference. Raftery (1998) however shows a similar appreciation of the Heisenberg principle as presented in this thesis, and elaborates that causality seems to be replaced by indeterminacy, which has implications for the methodologies used in economics. His view is that this impacts the precision in prediction. A notable difference with the uncertainty in this thesis is that whereas he describes a loss of precision in prediction, I attribute Heisenberg-like characteristics to complete uncertainty in the outcome of new technology-based ventures, and hence in cases where no prediction can be made at all.

Recognition of similarities between economics and natural sciences have also been expressed and point especially to the notion that complexity and chaos perspectives may apply to financial markets as well (Ravetz, 1994/95; Singh and Dey, 2002). In these articles, chaos and complexity theory are seen as most beneficial for improving the understanding of how markets work. Ravetz (1994/95) in particular argues that economists should focus on chaos theory as an extension of Heisenberg's principle, implying that Heisenberg's considerations are a mere step towards the

[12] The Quantum Fund is a so-called Hedge Fund. A Hedge Fund is an alternative investment vehicle that seeks to create an absolute return, independent of market trends. The vehicle, by its structure, is enabled to utilise a variety of techniques (amongst which is *hedging*) to reduce the underlying risks of a security (Nicolas, 1999). Hedge funds can thus be considered as a vehicle that ultimately wants to eliminate virtually all uncertainty whilst creating an absolute return.

powerful framework of complexity and chaos, developed by the likes of Prigogine (1988) and Gell-mann (1995).

Khalil (1997) argues that there is a distinct difference between the uncertainty residing in the chaos in the market equilibrium and the uncertainty that stems from evolutionary, developmental activities. He argues that the two are irreconcilable, because they do not deal with the same aspect of the phenomenon (Khalil, 1997). According to Khalil there is a fundamental difference between two kinds of changes: developmental processes and dynamical fluctuations. Changes that refer to developmental activities refer to developmental processes and are expressed in the evolution of division of labour, technology and institutions, exemplified by, amongst others, Nelson and Winter (Khalil, 1997). Changes as dynamic fluctuations in markets are of a different order. Dynamical fluctuations in market equilibrium stem from market oscillations arising from "autofeeding expectations exemplified in the application of theories focusing on chaos" (Khalil, 1997).

Khalil (1997) advocates a similar notion of uncertainty to that proposed in this thesis in the entrepreneurial developmental processes of NTBVs. The indeterminacy of developmental processes stems from the inherent uncertainty (i.e. Knight, 1921; Keynes, 1973) of what can be known through experience and our senses and hence is arguably analogous to Heisenberg's principle of uncertainty.

This uncertainty is of a different order than the indeterminacy of dynamic fluctuations, which according to Khalil (1998/1999) is based on a limited computational ability and thus follows a similar methodology as scientists who use chaos theory to model weather patterns. Khalil compares this with the laws of thermodynamics. According to Khalil the laws of thermodynamics are not fundamental laws as they do not apply to single molecules – similar to how the laws of market equilibrium only apply to collective activities of agents (Khalil, 1997). This has itself even been seen as a duality – between stable equilibrium and development (N. N. 1997).

New technologies typically fall into the category of developmental processes and entrepreneurship (Khalil, 1997). Within this class, Heisenberg's uncertainty principle can be seen as potentially useful. Such developmental processes are non linear, and thus the past is not enough to predict the future (Boulding, 1966; O'Hara, 1995)

Finally the development of economic theory itself has been compared to the radical developments in physics. At the beginning of the twentieth century, neoclassical economics was driven by outdated physics. Ganley (1995) argues that institutional economics should be re-examined as it is clearly independent of the neoclassical paradigm (which followed the outdated physics model). Institutional economics followed both natural and social sciences. Ganley concludes that new efforts by modern institutionalists should provide a more productive path to travel in the history of economic thought (Ganley, 1995). In addition to Ganley, Calkins and Vezina (1996) argued of a similar shift in paradigm in economic theory. Whilst both perspectives do not provide new workable solutions to economic theory, a strong appreciation for the developments in physics, in comparison to developments in other fields (in this case economics), is apparent. I propose similar treatment for theories on innovation.

3.2.2 Analogy in organisation & management

General appreciation of influences from quantum physics has been expressed within the field of organisation & management (Katz and Gartner, 1988; Barnard, 1996; Fabian, 2000; Gleisler, 2000; Mackenzie, 2000). These articles argue for future research that should be directed to applying new ways of exploring phenomena in the field of organisation & management and thus confirm that it is worthwhile exploring the potential applicability proposed in this thesis.

In organisation & management four categories can be distinguished where references and analogies emerge. Firstly quantum theory, where Heisenberg's uncertainty principle is explained as an observer-interference issue, the measurement problem has been addressed on a general level, but also more specifically on the level of research methodologies. Secondly, from an indeterminacy perspective, the uncertainty principle has been referred to in cases of general appreciation and also links to chaos theory. The third perspective shows how quantum theory relates to the epistemological understanding of social construction. Finally quantum theory is used as a general reference to research confronted with uncertainty and paradoxes.

3.2.2.1 Uncertainty: measuring, methodology and observer-interference

Within the field of organisation & management, references to Heisenberg predominately concerned observer-interference and were used to explain how the act of measurement itself directly affects the results (i.e. Lingle and Schiemann, 1996; Thomson and Hunt, 1996; Glazer, 1998; Dove, 1998; Webster, 1998; Kogan *et al.,* 1998; Oliver, 1999; Mintzberg and Westley, 2000; Holbrook, 2001). Hence this interpretation highlights the limitations in the techniques available for making measurements. These studies attribute Heisenberg-like characteristics to the notion that an observer interferes with the subject under study. Although this was an implication of quantum theory, it was not the essential point. Heisenberg showed the relationship between position and momentum was inherently uncertain, and could not be understood without appreciation for this uncertain relation. For example, as Schrödinger's Cat demonstrated, it was not the observer who causes the uncertainty, but the notion that only *after* an observation can the state of a cat be determined, not before. As in the field of economics, the fundamental principle of this indeterminacy is not fully absorbed by the theories outlined above.

Although this notion of observer-interference contributed to the respective fields, it does not convey a full understanding of the implications of quantum physics. Such works are characterised by a limited explanation of the quantum theory itself. The full potential of the findings in quantum physics have not been applied.

Within the context of the observer-interference interpretation, a notable reference has been made in the resource-based view of the firm (Scarbrough, 1998). However, the only point that Scarbrough makes relating to the Heisenberg principle is that observing means change. As this is the only article that directly expounds one of the main perspectives of this thesis, it confirms the relative newness of the contribution made in this thesis. A similar assumption on observation and change has been made by Kleiner and Roth (1997)

A more concise elaboration of quantum theory relates to fundamental methodologies in social sciences. For example, Ledford relates Heisenberg's principle to action research[13] (Ledford and Mohrman, 1993). He refers to Reason who points out that action research abolishes the separation between the knower and the known that is central to the practice of conventional science. Subjects become co-researchers who not only know the purpose of the research, but also help to shape the research. Reason argues that since conventional objectivity is lost, the old quality standards are lost as well (Ledford and Mohrman, 1993). Ledford in reply argues that because the methods of social science are not truly objective this does not mean that such methods are now meaningless standards. By analogy he uses quantum theory of sub-atomic particles, in that the particles as subjects react to attempts to measure them (Ledford and Mohrman, 1993). He further points out that physicists continue to make progress without abandoning methodological standards and without adopting a new epistemology (Ledford and Mohrman, 1993). A similar notion has also been expressed by Bradbury and Bergmann-Liechtenstein (2000).

Ledford argues that qualitative research methodologies, such as action research, should be followed, thus embracing rather than rejecting the notion that an observer influences the situation. This interpretation follows the observer-interference argument, but provides new methodologies for dealing with it, without changing the epistemological underpinnings.

In organisation & management it has been argued that research should be more flexible in its choice of technologies (methods) (Parkhe, 1993). Unlike natural sciences, which are more mature[14] and where theory outpaces practice, organisation and management science is still in its infancy and theory is struggling to catch up with practice (Parkhe, 1993).

[13] Action research is a methodology for participatory research. Within an action research cycle four phases can be identified: (1) Diagnosis and problem analysis, (2) Action Planning, (3) Action Intervention, (4) Learning (Warmington, 1980).

[14] A chronology of commencement dates of leading journals in management exposes the discipline's infancy: Administrative Science Quarterly, 1956: Academy of Management Journal, 1958; Journal of International Business Studies, 1970: Academy of Management Review, 1976: Strategic Management Journal, 1979; Organisation Science, 1990. These dates may be contrasted, for example, with leading journals in medicine (e.g., New England Journal of Medicine, 1812) and science (e.g., Scientific American, 1845; Science, 1880) (Parkhe, 1993).

Hence, Parkhe argues for more empirical methodologies and a greater emphasis on qualitative (what he refers to as "soft") issues; this is still very rare, as studies have shown[15]. He illustrates his point by suggesting that Heisenberg's principle of uncertainty attained a precondition for physics. Nevertheless such preconditions seem to rest on a deep understanding of central phenomena which he considers may be distant in social science (Parkhe, 1993). His carefulness in attaining such limits however does not rule out a more flexible stance in organisation & management.

These methodological implications seem to confirm the potential value of research that is not purely based on outside observation. As the remainder of this thesis will show, the proposed experiment deals with similar problems of accuracy and subjectivity, both from the methodological point of view in designing the experiment (merging case study research and a process approach in system engineering), as well as with regard to the experiment itself.

3.2.2.2 Uncertainty: chaos, complexity and indeterminacy

Within the analysis, most notably McKelvey (1999) has addressed the potential of stochastic processes. However, he emphasises the use of complexity theory rather than Heisenberg alone. Heisenberg is seen as one step in the evolution of the physics. "During the twentieth century the uniformity assumption gave way to a *stochastic idiosyncrasy* assumption in natural sciences, in which particle or microstate behavior is assumed to consist of idiosyncratic microstates which have some probability of occurrence" (McKelvey, 1999: 297, referring to Prigogine, 1962). McKelvey continues by noting that all sciences are slow in switching to stochastic assumptions, and refers back to Boltzmann's suicide caused by the lack of acceptance of his statistical theory in thermodynamics.

Whilst chaos theory can also be seen as a potentially relevant avenue to use for social phenomena, for uncertainty in NTBVs I follow Khalil (1997) who states that entrepreneurial uncertainty is a developmental evolutionary process and thus is of a more quantum theory oriented nature. Whereas the statistical approaches of thermodynamics are ideally equipped for areas such as self-organisation and management (Baltes, 2000; Bergmann Liechtenstein, 2000), Heisenberg's uncertainty principle provides the additional notion of inherent uncertainty, and the fact that we simply do not know what the outcome will be, not just because everything is so complex.

Within this context, Bygrave and Hofer (1991) make an interesting distinction regarding how chaos theory and quantum theory can contribute to entrepreneurship. "Chaos theory produces models in which outcomes are incredibly sensitive to changes in the initial conditions. As such it has the feel of entrepreneurship… As an example: If Fred Terman had not fallen ill with tuberculosis when

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[15] Parallel statistics were cited in recent papers addressing other areas of Academy of Management as well. Schwenk and Dalton (1991) found that over 72% of research in strategy relied on archival and questionnaire data. Noting that "One category may be notable by its near absence," they concluded, "We recommend greater use of qualitative methods" (1991: 297). Quoted from Parkhe (1993).

vacationing in Palo Alto, there might not be a Silicon Valley today." (Bygrave and Hofer, 1991: 20). This elaboration implies that causal relationships are still the underlying reason for future states. On quantum mechanics they take a more observer-interference perspective and state, "Quantum mechanics is able to deal with systems that make sudden transitions. Among other things, it is able to predict the appearance of particles, and explain how particles tunnel through seemingly impenetrable barriers. Again, it has charming parallels to entrepreneurship. Recently, Baumol (1991) suggested that rather as the Heisenberg uncertainty principle imposes limits on observing quantum events, so too there are limits on observing mega-entrepreneurial events of the kind that create new industries. Each one is unique. If you could describe it completely, you could replicate it and it would become management instead of entrepreneurship." (Bygrave and Hofer, 1991: 20). Whilst the observer-interference explanation of quantum mechanics, as previously discussed, has its weaknesses, the duality that emerges between management and entrepreneurship becomes apparent. From this perspective it seems that the equilibrium oriented chaos theory (Khalil, 1997) seems more oriented towards managerial activities in the sense of Penrose (1959), whereas the entrepreneurial activities, such as venturing new technologies, seems to bear stronger comparison with the inherent uncertainty in quantum mechanics. Frosch (1996) stressed a similar duality between operations and development and referred to Heisenberg to point out that coordination is an important factor. In other words, for new technology-based ventures, as soon as the relationships between action and performance are clear, managerial activities seem to apply, however if the causality does not exist yet, the entrepreneurial function is paramount.

From an indeterminacy point of view, a general appreciation of the use of quantum theoretical concepts is apparent. This stems not only from the short references (i.e. DeTienne, 1994; Coates, 1995; Barnard, 1996; Grint 1997; Mutch, 2000), but also from more refined elaborations which advocate this kind of research (Parkhe, 1993; McDaniel and Walls, 1997; McKelvey, 1999). This appreciation supports the efforts laid out in this thesis.

However, taking the existing references and analogies together, they all seem to argue from a philosophical perspective and stop at the point where they promote looking into these areas. Nevertheless, in physics Heisenberg's uncertainty principle proved particularly valuable as a workable solution, despite the philosophical debates, which can be seen in numerous applications such as materials, bombs and quantum computing.

On the philosophical side, questioning the nature and existence of true uncertainty, the debate is still ongoing. The literature analysis shows that this is indeed the first thesis that aims to take the Heisenberg principle a step further and explore a potential and workable solution for uncertainty associated with NTBVs.

3.2.2.3 Uncertainty: emerging new perspectives

One of the essential differences between classical physics and quantum theory is the denial of the objective reality of the external world by the Copenhagen interpretation (Davies, 1989). Or as

Heisenberg puts it: "In the experiments about atomic events we have to do with things and facts, with phenomena that are just as real as any other phenomena in daily life. But the atoms or elementary particles themselves are not as real; they form a world of potentialities or possibilities rather than one of things or facts" (Heisenberg, 1958). This is in contrast with the classical scientists who believe their investigations refer to something real 'out there'.

In contrast to the social constructivist view, the positivist view in organisation science aims to study organisations as a reality 'out there'. Pugh stated that the "universe is replete with regularities and ultimately, the appeal to empirical 'data' is fundamental to the enterprise of organisational analysis." He makes the ontological assumption that people and organisations exist as relatively concrete entities (Pugh 1983, quoted in Chia, 1997: 694). He argues that, in comparison to nuclear physics, this meta-debate does not add to the functionalist aspects of theory development. Pugh compares it to the situation of a nuclear physicist telling a materials engineer that a steel bar is just a series of pulsating energy waves when the latter just wanted to calculate the stresses and strains to see how it holds up the roof (Chia, 1997). The most significant product of these initiatives in organisational analysis has been the development and articulation of the contingency approach (Chia, 1997).

Chia, who compares the evolution of physics to a paradigmatic shift in social sciences, disagrees with this view. He argues that as a consequence of the challenges posed by quantum theory to our understanding of particle physics, the positivist way of thinking fell out of favour in the natural sciences with the introduction of Einstein's relativity and more pointedly with Heisenberg's principle of indeterminacy and Bohr's quantum postulate. Chia refers to Bohr, who writes: "...the quantum postulate implies that any observation of … phenomena will involve an interaction with the agency of observation not to be neglected. Accordingly, an independent reality in the ordinary physical sense can neither be ascribed to the phenomena nor to the agencies of observation … an unambiguous definition of the state of the system is naturally no longer possible, and there can be no question of causality in the ordinary sense of the word." (Bohr, in Chia, 1997: 696).

For new technology-based ventures, this implies that they should not deal with new technologies when it is absolutely uncertain what the outcomes of such technologies are. I follow Chia, that this comparison between nuclear physicist and mechanical engineer can be disputed as having no functionality. Pugh's assumption taken to the extreme would seriously hamper creativity and radical innovation from new technologies, as he seems to advocate only considering technologies that already have a reasonably predictive outcome and thus a functionality.

Bohr's statement above shows similarities with the social constructivist perspective and its underlying ontology. Since the state cannot be described, there is no state. The only state that exists is the state that is socially constructed in experiments. Miller and King (1998) point out a similarity between the uncertainty principle and the work of Giddens on social construction. In addition, DeTienne (1994) argues that the next generation of organisation study scholars show an increasing appreciation for concepts taken from physics, for instance, as a number of researchers are embracing theories such as chaos theory and Heisenberg's uncertainty principle.

DeTienne relates this to an increase in support for contingency-like theories in other physical sciences (DeTienne, 1994). The natural scientists seem to be moving further and further away from an agreement on a paradigmatic theory. He concludes that time will tell whether these will be short revolutions into less-functionalist paradigms or if physical scientists will turn to a less paradigmatic approach (DeTienne, 1994). However, as previously discussed, contingency theories still assume underlying causal relationships. To fully adopt the Heisenberg uncertainty principle is to lose this causality, which results in probabilistic processes.

Another view that elaborates on the emergence and potential of a new paradigm based on a comparison to quantum theory has been expressed by Zohar and Marshall (1993). Their work comprises a comprehensive explanation of quantum theory, on which they build principles for the new science of society (Zohar and Marshall, 1993; Zohar, 1998). They intend to open up possibilities for developing a true democratic community, securely grounded in the quantum theory understanding of matter and potential that arose from those same experiments (Evans, 1996). Zohar and Marshall present their concept of the quantum society as a fundamentally new social reality to replace the mechanistic model.

These works show an initial appreciation for perspectives taken from quantum theory and for further exploratory research. Though reviewed as not being utopian (Evans, 1996) but thought provoking, the contents of the work and analogies made between physics and society lack the strength of direct application. Quantum theory and the fundamental implications became successful by the quantum mechanic applications. Zohar and Marshall do not provide concrete applications to implement their quantum society vision.

3.2.2.4 Uncertainty: paradoxes and duality

An interesting example of increased similarities between quantum theory and organisation & management approaches is the emerging appreciation of paradoxical relationships. The acknowledgement of contradicting perspectives and bridge building has also been compared to Heisenberg's concept. This was noted in the discussion on relating quantum theory to other natural sciences (Fabian, 2000). Discomfited by the realisation of contradictory assumptions about the nature of the world, Fabian argues for more debates on understanding these models and paradoxes for managerial phenomena (Fabian, 2000).

The appreciation for paradoxes in social sciences has strongly increased over the past decades. A paradox was also the starting point for the Copenhagen interpretation (Heisenberg, 1958). Paradoxes occur in the simultaneous existence of two inconsistent states, such as innovation versus efficiency, collaboration versus competition, or new versus old (Eisenhardt, 2000).

Organisation and management sciences show a shift away from compromising between the two (i.e. contingency theories) towards the acceptance of simultaneously holding the two states (Eisenhardt, 2000). As Eisenhardt argues, "This duality of coexisting tensions creates an edge of chaos, not a bland halfway point between one extreme and the other. The management of this duality hinges on exploring the tension in a creative way that captures both extremes, thereby capitalizing on the inherent pluralism within the duality" (Eisenhardt, 2000: 703).

Cameron and Quinn claimed that by exploring paradoxes, researchers might move beyond oversimplified and polarised notions to recognise the complexity, diversity, and ambiguity of organisational life (Quinn, 1988; Quinn and Cameron, 1988). They argue for thinking in paradoxes as this offers a potentially powerful framework for examining the impacts of plurality and change, aiding understandings of divergent perspectives and disruptive experiences (Lewis, 2000). Such paradox perspectives favour conceptions of change and pluralism that are more consistent with non-linear notions like chaos and complexity, as opposed to a more Newtonian view of the world (Eisenhardt, 2000). The use of paradoxes appears increasingly in organisation studies, often to describe conflicting demands, opposing perspectives, or seemingly illogical findings (Lewis, 2000)[16].

This stream of research complements what the Copenhagen interpretation did for quantum theory. However the acceptance and appreciation of paradoxes in organisation and management sciences has not yet explored the potential of the successful conceptual contribution of quantum mechanics within the context of enhancing the understanding of uncertainty. Nevertheless, a first attempt has been noted on a potential duality that has similarities to the Heisenberg principle, from an R&D perspective on vision and operations (Frosch, 1996). Although he mentioned it as a mere reference and potentiality, it indicates an increasing appreciation for the use of dualities in understanding phenomena in social sciences.

3.2.3 Analogy in other fields

The remainder of the literature reveals references and analogies to Heisenberg in the fields of sociology, psychology, public administration and statistics. Most of these articles showed similar considerations to those discussed in the field of economics and organisation & management. For example, in psychology the dominant interpretation of the Heisenberg uncertainty principle stems from the observer-interference dilemma (i.e. Bleedorn, 1993; Montgomery *et al.*, 1993; Vinten, 1994; Hayes, 1997).

Notably, Johnson and Cassell (2001) and Lawson (1994) elaborate on the methodological and epistemological implications of this observer-interference dilemma. For example, in organisational

[16] This appreciation in the community of organisation and management sciences is also highlighted by the prestigious Academy of Management 'Best paper' award given to Lewis for her comprehensive guide in exploring paradoxes.

psychology, Johnson claimed it would seem that social constructivism has a longer history in the natural sciences. He suggests social constructivist ideas were already expressed by Heisenberg's (1958) uncertainty principle – that it is impossible to study something without influencing what is seen. What a scientist observes is not independent of the process of observing but is an outcome of the scientists' methodological interaction with, and conceptual constitution of, objects of knowledge (Johnson and Cassell, 2001). Smith and Smith (1996) extend this notion and relate it to Lewis's (1963) well known field theory, but deny an analogy, because "...the interbehavioral field provides for objective observation which may or may not involve self-reference whereas the quantum field, which uses the interbehavioral field for its framework, insists on experimental procedures involving self-reference exclusively" (Smith and Smith, 1996: 18). Nevertheless, they do point out that the field approach in psychology requires some unconventional thinking, similar to relativity and quantum mechanics in physics. An example of a recurrent methodology in psychology that shows similarities with quantum theory is the so-called Q-methodology (Knight, 1994; Goldman, 1999), which "...attempts to cultivate a science of subjectivity where self-reference became a locus for understanding the human condition" (Goldman, 1999: 589). Based on these methodological efforts, statistical approaches have been applied in the field of psychology to understand this subjectivity.

Similarly, the analysis shows that in the field of sociology the observer-interference dilemma reigns as the ultimate interpretation of Heisenberg, although it has only been expressed as a side reference (King and Suford, 1996; Miller and Fox, 2001; Roberts, 2000). Smith (1995) extended this to propagate chaos theory rather than Heisenberg, as we have seen in economics and organisation & management. The more extensive interpretation of Heisenberg in indeterminacy has only found ground in works by Boulding (1996) and Mueser (1990), but these references are simply an appreciation rather than an attempt to application.

In public administration, the emphasis is on the appreciation of the conceptual ideas of Heisenberg, and seems to rest in a comparison to post-modernism philosophy and (i.e. Overman, 1996; Bogason, 2001; Evans, 1996). In addition Miller and King (1998) compare it to Giddens' social construction theory, and Kober's (1997) interpretation leans towards a principle of tolerance for the unknown.

Finally, in the field of decision theory and statistics, Bordley examined a link between Heisenberg and the human violations of the probabilities. The influences of Heisenberg have also been discussed within the qualitative versus quantitative research debate. It is illustrated that both quantum physics and behavioural decision theory appear to have similarities in the manner in which an uncertain event cannot be decomposed into sub-events without changing the overall probability assigned to that uncertain event (Bordley, 1998). "These results suggest that the structuring phase of decision analysis - which specifies how various events are decomposed - helps share the subjective probabilities which will ultimately be assigned to those events" (Bordley, 1998). However, as we have seen, the uncertainty residing in new technology-based ventures does not yet have these subjective probabilities on expected outcomes. This implies that tolerance towards approximations and accuracy has to be taken into account in understanding new technology-based ventures.

The remaining articles that address statistics merely refer to Heisenberg, showing appreciation but no direct application. On the confluence of economics and statistics, Lo (2000) elaborates on the randomness of financial markets and suggests a duality between the limits of future price changes if the forces of self-interest are at work. Leonard (1995) discussed the work of von Neumann on game theories and stated that von Neumann drew an implicit parallel between the probabilistic nature of social interaction and probabilities in physics. "A substantial part of von Neumann's work at the time, culminating in his 1932 Mathematical Foundations of Quantum Mechanics, involved constructing a mathematical basis for Heisenberg's theory. Now, with the minimax theorem, the prevailing probabilistic view of the world in physics was being reflected in von Neumann's theory of human interaction. This is our first hint of the extent to which von Neumann's view of the application of mathematics to the social domain was conditioned by the philosophy and standards of physical science." (Leonard, 1995: 734).

It seems as though the discussion on uncertainty has come full circle, where the decision theory approach is able to integrate the sophisticated quantum mathematical approaches to enable better prediction of social phenomena. However, as I have argued in chapter 2, decision theory and subjective probabilities such as minimax do not yet apply for new technology-based ventures, as the outcome itself is still uncertain. The references made here seem to provide a fruitful alignment of probabilistic processes for understanding social phenomena, and thus this work can be positioned as an initial step towards a potential new mathematical scheme.

3.2.4 Implications and critics

Despite the increasing appreciation for using quantum theory perspectives in social sciences, implications emerge on the level of analysis. The epistemological implications derived from the uncertainty principle in physics only apply to the micro-world and the sub-atomic level. It does not work in the macro-world, nor does it dispute classical physics. Hofstadter noted, "It is a total misinterpretation of Heisenberg's uncertainty principle to suppose that it applies to macroscopic observers making macroscopic measurements" (Hofstadter, 1985). Similarly, the notion has been expressed that the implications of the uncertainty principle "do not justify the attribution of post-hoc meanings to measurements" (Korunonda, 1996).

Nevertheless, from the perspective of a concept for uncertainty, it appears that physics has a much stronger foundation to sustain the division of the micro and macro level. Newtonian physics still applies on a macro level, and allows for many predictions concerning macro-events in the dimensions of time, space and motion. However, as Parkhe pointed out, social sciences do not have such a strong traditional framework as the classical physics laws that sustained over 300 years (Parkhe, 1993). This becomes more apparent in the existing notions of uncertainty, which are still ambiguous (Buchko, 1994). To assume that the physical macro-world is similar to the social macro-world is thus not appropriate.

The level of analysis also becomes significant in the economics debate on equilibrium versus evolution. The uncertainty residing in fluctuations on the equilibrium in macro economy is based on statistical probabilities that only apply to a collective set of agents, but not to individuals (Khalil, 1997). Similarly, in thermodynamics, the patterns are arguably not fundamental as they do not apply to single molecules (Khalil, 1997). However, thermodynamics was the first area in which physicists introduced a statistical concept (Gribbin, 1991). Furthermore, the use of statistics in physics proved the key to resolving indeterminacy on a micro-level.

Nonetheless, physicists themselves expressed their discomfort at applying the conceptual underpinnings of the uncertainty principle with the uncertainty residing in markets (Davies, 1989). There is an ongoing debate in physics regarding whether uncertainty is as real as Heisenberg and the Copenhagen interpretation imply. A similar debate surrounds the evolution of physics and economics. Knight noted, without reference to Heisenberg, that there is a distinct difference between risk and uncertainty (Knight, 1921). This however is not necessarily a general rule held by other economists. The evolution of the two fields thus seems to have parallels (Ganley, 1995).

3.2.5 Positioning of proposed uncertainty concept

The articles studied in the analysis show a tendency towards an increased appreciation for the use of concepts from physics, and more specifically quantum theory, in social sciences. With respect to the research question of this dissertation, a foundation exists with initial notions and ideas concerning the use of the Heisenberg *Uncertainty Principle*, and the increasing appreciation shows potential future research directions.

However, the analysis does not show any works addressing the specific uncertainty related to NTBVs. In fact, most articles did not go as far as to propose a workable solution and explore how a potential contribution might appear, but rather stopped by elegantly quoting Heisenberg and pointing out some philosophical similarities. Many works take a philosophical interpretation of Heisenberg’s propositions. This thesis on the other hand attempts to duplicate some of the success Heisenberg’s method had in making predictions under uncertainty. As mentioned, it is not the aim of this work to create a fully comprehensive mathematical scheme to uncover the specific uncertainties in new technology-based ventures, but rather to open up the field of workable solutions based on his work.

4

CONSTRUCTING AN EXPERIMENT USING MULTIPLE CASE STUDIES

"We have to remember that what we observe is not nature in itself but nature exposed to our method of questioning."

Werner Heisenberg, 1958

4.1 EXPERIMENTAL MEASUREMENT REQUIREMENTS

This chapter aims to evaluate uncertainty in technology venturing from an empirical perspective in order to construct a first experiment to explore a potential probability function. The experiment should follow the probabilistic process, proposed in the previous chapter, as a function of time. For new technology-based firms, the expectation is that, *ceteris paribus*, having dynamic capabilities increases the likelihood of improved firm performance.

Performance can be relatively easily measured in terms of a certain chosen value indicator such as money. In line with the profit motive, the chosen indicator can be any relevant outcome that can be expressed using financial valuations. Examples are net profit, earnings and cash flow, but it can also be expressed in terms of other strategic expectations that a firm wishes to achieve. Based on case studies in the telecommunications industry this chapter will propose a particular financial parameter which can be used to develop and explore the probability function for uncertainty set out in chapter 3.

It is however more difficult to establish equivalent numerical expressions for the abstract concepts of resources and dynamic capabilities (Teece, 1998). These concepts, by their nature, stem from the qualitative observations or subjective lens through which a firm can be conceptualised (i.e. Penrose, 1959; Wernerfelt, 1984; Teece *et al.,* 1997; Eisenhardt and Martin, 2000; Zollo and Winter, 2002). This means that any numerical expression of such concepts would imply a concession to the very nature and objectivity of the concepts themselves. Nevertheless, in line with Parkhe (1993), by using approximations based on empirical investigations this chapter aims to approach such numerical expressions, with the recognition that these expressions are not unilateral but limited to the context within which they have been created.

This chapter aims to sharpen the probabilistic process based on a multiple case study, and suggest a first potential measurement for the qualitative concept of dynamic capabilities. As the process model aims to study the effects on financial performance when this control variable is changed, it is necessary to ensure that the indicators used to measure dynamic capabilities are closely monitored against the current qualitative interpretations of this concept.

4.2 CASE STUDY DESIGN

The research design requires empirical data that supports the exploratory nature of the topic. Compared to other methodologies, case study research is better equipped to deal with the form of the research question as well as the limited control of the behavioural events and the focus on contemporary events (Yin, 1989). Case study allows the investigation of real-life events such as individual life cycles, organisation and managerial processes, and change (Yin, 1989). Case studies are defined as empirical inquiries where (Yin, 1989:23):

- Contemporary phenomena are investigated
- The boundaries between phenomenon and context are not clearly evident
- Multiple sources of evidence are used.

In order to come to a workable solution for this measurement problem, a multiple case study methodology has been applied in two comparable settings where new technologies are ventured (figure 17). I follow Yin (1989), who has established an accepted multiple case study design. The multiple case study design follows a replication-logic in order to provide convincing evidence. In this case the replication is focused on the development of a suitable measure for dynamic capabilities, by investigating the venturing process of new technologies in two independent firm settings. The cases are conducted independently, using data such as interviews, observations and internal documents that apply to the context of each case. Following a comparison of these studies, cross-case conclusions can be drawn.

The cases are developmental in nature. Based on these cases, the next chapter (5) will develop a system that supports the proposed measurement. Finally, a first validation case (chapter 6) will be conducted. Yin stated that "…a major insight is to consider multiple cases as one would consider multiple experiments" (Yin, 1989: 53); thus these case studies can already be regarded as a first qualitative exploration of a potential probability function.

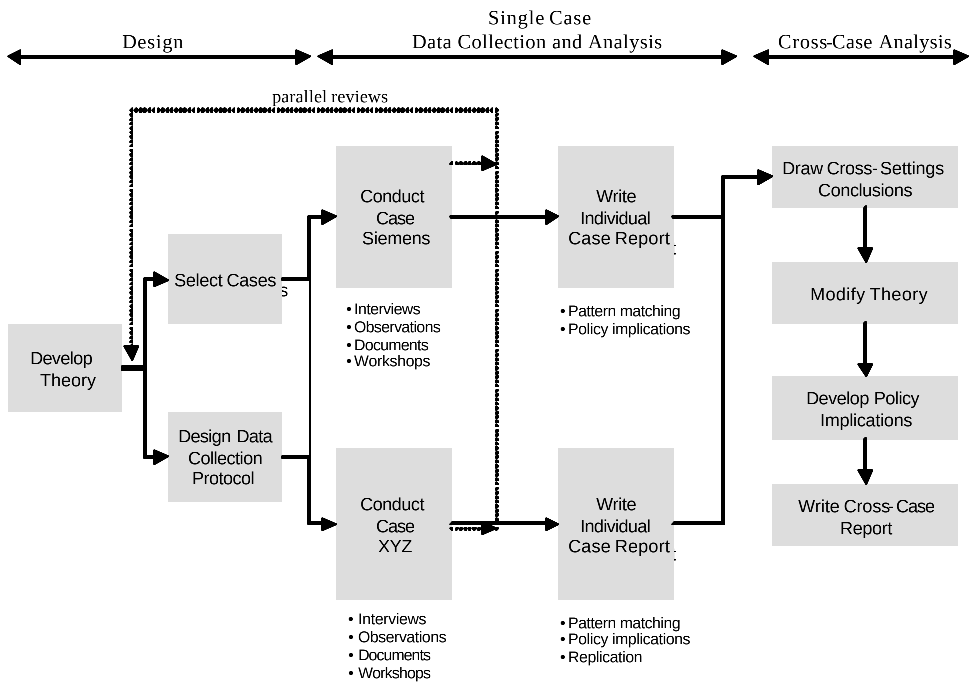

Figure 17: Case study design (adapted from Yin, 1989: 56)

4.2.1 Case selection

Within multiple case study design it is vital to select comparable cases. Two large electronics manufacturing firms in the telecommunications industry were selected to provide requirements for the system development: Siemens and Company XYZ [17]. The cases chosen are both divisions of these multinational telecommunications firms. Both divisions encompass the complete venturing process, from introduction and exploitation to phase-out of innovations.

The divisional level was chosen because a division represents a stand-alone firm with all the basic functionalities, within a larger conglomerate. Furthermore, following Penrose (1959), a productive opportunity requires a productive base which can provide that opportunity. The two divisions chosen already have an established productive base. The ideal experiment takes a case where the dependent variable dynamic capability changes *ceteris paribus*. In order to develop such an approximation, it is more appropriate to take a more established new technology-based venture

[17] For confidentiality, one of the companies will remain anonymous.

instead of a start up firm. This is not to deny, however, that for such ventures this uncertainty is equally or perhaps even more important; this remains an area for future research.

The following selection criteria were applied:

- ***The cases operate in comparable new technology-based industries***

  Both firms operate in the telecommunications industry.

- ***The cases have similar innovation characteristics***

  Both companies use new technologies in their output, such as telephone equipment, data equipment, satellites and underlying components. The character of the innovations of the two firms are comparable, and of an architectural nature. The (uncertain) outcomes of these new architectural configurations can be classified as products, services and solutions. In both cases these new configurations often result in changing business models, which can be innovations in their own right.

- ***The cases have similar environmental conditions***

  The firms are comparable as they both have a high market share in their respective operating environments (Switzerland and Greece). Despite potential cultural differences, both firms operate in comparable environment. Both Switzerland and Greece recently liberalised their telecommunications markets. Previously, both divisions were the main electronic suppliers to the respective national telephone operators (Swisscom and OTE). Liberalisation allowed new entrants into the market, which opened new opportunities but also imposed new threats on the divisions. As a consequence both divisions had to become more competitive.

- ***Adequate access is granted to the researcher and a sufficient quantity of external data is available***

  This is true for both cases, as described in the data collection section (4.2.2).

4.2.2 Data collection

Having selected the cases, relevant data sources need to be identified that are required for gaining in-depth insight in the phenomenon of uncertainty. There were six sources of evidence used here; these are listed in table 8 together with examples. The use of multiple sources of evidence, such as these, is a necessary condition for the effective execution of case study research (Yin, 1989).

SOURCES OF DATA	EXAMPLES
DOCUMENTATION	Internal memoranda, intranet and internet publications, internal and external presentations, agenda and minutes of meetings, internal and external reports, press releases and administrative documents (proposals, progress reports, administrative forms).
ARCHIVAL RECORDS	Service records, organisational records (charts, budgets, HR documentation), lists of names, records on previously documented projects, personal records.
INTERVIEWS	Semi-structured interviews, informal interviews, open ended interviews.
DIRECT OBSERVATION	Site observation including workshops, meetings, corporate conferences.
PARTICIPANT-OBSERVATION	Workshop attendance, dedicated workshop facilitation.
PHYSICAL ARTEFACTS	Technologies, products as well as operational support devices.

Table 8: Multiple data sources and examples

To ensure replication, data was collected using a variety of sources and methods for each individual case (Yin, 1989). An overview is provided in table 9.

				DATA SOURCES	
DATE	METHOD	TECHNOLOGY	POPULATION	SEMI-STRUCTURED INTERVIEWS	SECONDARY DATA SOURCES
Oct 00 - Jan 02	Case Study 1 Research	Enterprise Network Products and Services	Upper-level Management Project Managers Sales Presales Product Managers Engineers Process Engineers	*N* = 2 *N* = 1 *N* = 2 *N* = 1 *N* = 1 *N* = 2 *N* = 2	Archival Personal Observation Attendance at Meetings Attendance at Workshops Informal Discussions Cross Case Workshops
Oct 00 - Jan 02	Case Study 2 Research	Design Development Programmes Department and Sales & Marketing Department	Upper-level Management Project Managers Sales/Marketing Engineers R&D Liaisons Process Engineers	*N* = 2 *N* = 2 *N* = 2 *N* = 2 *N* = 2 *N* = 2	Archival Personal Observation Informal Discussions Cross Case Workshops

Table 9: Description of methods used: timeline and data sources[18]

[18] The data collection phase of this study took place in the context of the EU -funded Genesis Project.

4.2.3 Data analysis: validity, reliability and generalisability

The qualitative data has been analysed in order to derive an initial measurement procedure for dynamic capabilities. The results are "grounded" in the data analysis (Eisenhardt, 1989; 1991; Glaser, 1967), which is characterised by a continuous comparison of the data collected against the existing theories. Given the early stages of theory development on dynamic capabilities, the logic of this comparative approach is best suited to support an exploratory study. This method has already been successfully used in the emergent field of continuous innovation (e.g. Burgelman, 1991; Leonard-Barton, 1995; Brown, 1997), and it is consistent with the challenges of theory development in the field of organisational capabilities (Verona, 1999). It can be hard to develop normative prescriptions on capabilities from cross-sectional studies (Henderson, 1990). Organisational capabilities are the result of complex processes involving the accumulation of small decisions and actions undertaken over many years in a situation of great uncertainty.

The purpose of case studies is to provide rich contextual evidence that, in combination with the theoretical constructs, can create conceptual advances for enhancing our understanding of uncertainty and managerial decision-making in NTBVs. The nature of this research is exploratory, and follows an instrumental approach where the cases play a secondary and supportive role to the concept building process (Stake, 1998). Nevertheless it is important to have sufficient quality criteria to ensure that validity can be achieved. Yin defines the quality criteria for case study research on four levels: construct validity, internal validity, external validity and reliability.

The construct validity relates to the establishment of "correct operational measures for the concepts being studied" (Yin, 1989: 40). Yin specified two distinct steps that have to be met in order to satisfy the construct validity: (1) "select the specific types of changes that are to be studied", and (2) "demonstrate that the selected measures of these changes do indeed reflect the specific types of changes that have been selected." The literature review reported in chapter 2 and the conceptual advances derived from this study (chapter 3) specify the critical changes in new technology-based venturing where uncertainty is observed. In addition to this review, this chapter will follow the tactics set out by Yin in using multiple sources of evidence to further develop these ideas. The construct validity of the developments prepared in this chapter will be evaluated using a longitudinal case study in chapter 6.

Internal validity relates to the establishment of causal relationships. Yin argues that internal validity does not apply to exploratory research, as such studies do not involve making causal statements. Nevertheless, Leonard-Barton, who advocates the longitudinal case study with multiple sites as an effective methodology for exploratory research, does address the issue of internal validity (Leonard-Barton, 1990). The specific methodological combination of a longitudinal single site, and retrospective multiple sites (used in chapter 6) provides an additional advantage derived from the ability to move back and forth between the two settings and thus "formulating theory in one setting and then immediately placing the embryonic ideas in the context of the other kind of study for potential disconfirmation" (Leonard-Barton, 1990: 259). This research project applies an adapted logic, and the designated technique of pattern matching (Yin, 1989) by engaging in the exploration of potential probability relationships rather than confirming or rejecting a proposed causal relationship.

External validity establishes the domain to which the findings can be generalised (Yin, 1989). Case study research is a qualitative methodology as opposed to quantitative methodology using statistical techniques. Case studies therefore produce only limited generalisation opportunities (Yin, 1989). Case studies are similar to experiments in that they are "generalisable to theoretical propositions and not to populations or universes" (Yin, 1989: 21). The generalisation thus takes an analytical rather than a statistical generalisation (Yin, 1989).

The generalisation or external validity of this research project relates to the multiple case studies executed on the topic of uncertainty. Nevertheless, as the theory is in an embryonic state (Leonard-Barton, 1990), the exploratory nature of the study does not aim to create a general theory. Instead this research project sets out to explore conceptual contributions to the understanding of uncertainty within the framework of dynamic capabilities, for which the contribution at this initial stage can be attributed to local theory (Eisenhardt, 1989). Thus the replication logic, albeit existing, has no priority over the evidence required to explore the research question.

Finally, the reliability of the study relates to the extent to which the study design demonstrates that the operations of the study can be repeated with the same results (Yin, 1989). Yin advocates two tactics for increasing reliability: using a case study protocol, and using a case study database. As previously mentioned, the exploratory nature implicitly led to a more reflexive and hence less systematic approach to data analysis (Tesch, 1990). Nevertheless, this research project has introduced more systematic data collection mechanisms such as the establishment of process models according to a specified methodology (N. N., 2000a) to allow for the effective capturing of data that is essentially repeatable. More details on this approach are provided in chapter 4. Furthermore, the conceptual developments preceding the case studies are based on a systematic literature review and are thus also repeatable. Furthermore, numerous reports have been written throughout the length of the study, leaving a paper trail that allows for effective auditing (Yin, 1989). Finally, most interviews have been transcribed and maintained in a database.

The validity, reliability and generalisability arguments will be further addressed in chapter 6, which reports on the validation.

4.3 BACKGROUND OF THE CASES

4.3.1 Case 1: Siemens Enterprise Networks division Switzerland

Siemens is a multinational electrical engineering and electronics company employing over 440,000 employees in over 190 countries. Siemens qualifies as an innovative firm as 80 % of their offerings have been developed over the past five years. Furthermore the investments made in R&D exceed €5 billion and approximately 49,000 employees are engaged in R&D. The revenues stem from six business segments: energy, industry, healthcare, transportation, lightning, and information & communications.

The case specifically focuses on one of the high tech subsidiaries of Siemens, namely Siemens Enterprise Networks in Switzerland. Enterprise Networks is part of the Information & Communications (I&C) business unit. Siemens Switzerland head office is located in Zurich and employs 3900 people. The annual turnover of Siemens Switzerland was €1.1 billion in 1999, with the Enterprise Networks department accounting for an annual turnover of €160 million. The turnover rose 69% in the accounting period from September 1998 to September 1999. During this time, the Enterprise Networks department employed approximately 500 people. The department provides tailor-made information and communication solutions in five major areas: Voice Networks, Data Networks, Application (Hardware and Software) Services, and recently Converged Networks (Voice over Data Networks).

Traditionally the national subsidiaries of Siemens are sales outlets of Siemens Group. However, the I&C division in Switzerland is different in that it also strongly engages in R&D activities:

- The R&D budget is €51 million
- €8 million is allocated to the Information and Communication Enterprise Networks division (ICE) at Siemens Switzerland, especially in the Voice-over Internet Protocol (VoIP) section.

4.3.2 Case 2: Company XYZ

The second company that took part in the case study for system design will be referred to as company XYZ. XYZ is the largest manufacturer of telecommunications equipment and information systems in Greece. In co-operation with its business partners, consisting of manufacturers, suppliers, sub-contractors and engineering offices around the world, the company provides products and services to the Greek public and private sectors, while developing a significant international presence. The company currently employs 2300 people.

XYZ's activities are mainly focused on three business sectors: Telecommunications, Energy Management and Defence Electronics. Within this framework, the company provides products as well as integrated services for design, manufacture, turn-key project implementation and support in the areas of Public Telecommunication Networks, Public Telephony Systems, Telecommunication Systems Software, Integrated Business Networks, Operations Support Systems, Digital Satellite Technology, Terminal Equipment, Telematic Applications and Defence Systems.

In the Greek market, XYZ is the main telecommunications hardware and software supplier of the Hellenic Telecommunications Organisation (OTE). Internationally, XYZ concluded various agreements in 1999 with established organisations in Romania, Moldova and Armenia and undertook the construction of telecommunications infrastructure networks in Ukraine and Bulgaria. Additionally, by establishing joint ventures and subsidiaries, the company has strengthened its presence in Russia, Romania, Bulgaria, Moldova, Albania, Cyprus, the USA and Middle East.

The company's sales during the period 1995-1999 came to €1.05 billion and are expected to reach €3.8 billion in the period 2000-2004. At the same time, the 1995-1999 exports amounted to €300 million (29% of sales in 1999). At present, XYZ's products are sold in over 40 countries. The company's objective is to boost exports to €1.5 billion or 40% of its sales in the next five years.

XYZ's local and global business activities are conducted in co-operation with its business partners, consisting of customers, suppliers, contractors and engineering offices around the world. Its business processes related to these activities cross local enterprise boundaries to interact with other related activities of organisations within XYZ's Global Partners Network. Operating within such an enterprise network means facing an increasingly changing environment, as well as managing a large variety of products and processes and a vast amount of information spread across the different business units.

4.4 CROSS CASE ANALYSIS: A RESOURCE-BASED PERSPECTIVE TO NEW TECHNOLOGY-BASED VENTURING

This section describes the integrated findings of the case studies. Both case studies were carried out simultaneously, and some joint development workshops have been carried out, which provided additional data that is not classifiable to either one case. Therefore the joint findings are directly reported and the individual findings have been integrated as illustrations where relevant.

4.4.1 Main phases of the new technology-based venturing process

The venturing process in both cases is characterised by three main phases (figure 18). Based on an extensive process analysis in both cases it appeared that the venturing process can be split up into three distinct phases. The first phase represents the conversion of new technologies into business ventures. In both cases, the technological innovations can be regarded as architectural innovations. The second phase represents the insertion of the new technology-based venture into the main operational system of the division (i.e. the operations and sales processes). The third phase represents the exit of the venture from the operational process, which instigates either a spin-off, or the end of the venture's life cycle.

4.4.1.1 Phases of new technology-based venturing at Siemens

For Siemens these phases became apparent when analysing the new technologies in the field of voice and data components. A dedicated VoIP competence centre existed in which the new technologies were developed alongside R&D facilities in Palo Alto and Munich.

Within the division, potential innovations were explored in conjunction with the new business development department. These innovations are characterised by the new business models they gave rise to. For example, an innovation that could be used as a highly efficient tool for call centres allowed a direct interface between the phone calls being made, and the underlying database containing customer details. Such solutions typically required their own specific venturing process, which was tested in phase one. The early customers for such architectural innovations can be compared with the innovators category from Rogers (1962). During this phase the development centre worked in close co-operation with the client in order to develop the new architecture.

Following these tests, and in a relatively short time these architectural innovations had to be expanded and adopted by the operational processes of the organisations. The innovations followed one another in quick succession and their average life cycle was not more than 9-12 months, according to internal documents. This fast turnaround was essential if any margin was to be gained on these products at all. This integration process was thus highly important for the success of the venture but also for the overall performance of the division.

The final phase represented the phase-out of such innovations from operational processes. In Siemens' case this usually meant the end of the innovation's life cycle.

4.4.1.2 Phases of new technology-based venturing at XYZ

At company XYZ a similar pattern emerged. One example is the development of an innovation that provided internet access over satellite (IoS). Again, the nature of the innovation rests in the architecture, rather than the individual components. Both satellite technology and internet technology already exist, but advances in the individual technologies allowed for a new architecture to exploit these technologies in a new innovation. The venturing process of IoS can be conceptualised in similar phases.

The development was instigated by an entrepreneur within the firm, who was also referred to as "the professor". Similar to the 3M case, the innovation of IoS in the first phase was predominantly technology oriented and, in a large R&D project, developed together with potential user firms.

This resulted in a typical business venturing process, which was subsequently taken up for exploitation by the large sales and marketing division. It soon became apparent that the innovation was successful enough and ready for scalability. A separate new division was created to establish the innovation in its own right. During the interviews it emerged that this process was a typical innovation pattern at XYZ.

4.4.1.3 New technology-based venturing from a resource perspective

When analysing these three phases from a resource-based perspective the following characteristics emerge (figure 18):

Phase 1 represents the development phase where new technologies are applied in new products, services or solutions (henceforward called innovations). Within this phase resources are allocated to develop processes that support the effective exploitation of newly developed innovations. This phase typically reflects the entrepreneurial services to the firm, where the creative response rests in new architectural configurations of advanced technologies. This results in a diverse range of new potential ventures. The outcome at this stage is not a certainty as the potential configurations are unknown, as is the value that can be created out of these new ventures. Investments are typically very high during this phase.

Phase 2 represents the integration phase, where the new ventures are introduced to the operational processes. From a Penrosian perspective this represents the phase where the entrepreneurial services contribute new ventures to the operations of the firm, or what Penrose calls the productive base (Penrose, 1959). The ventures potentially address a new productive opportunity. Whereas the operations of the firm typically require managerial competences, the entrepreneurial services require changes in the operations. These changes are frequent and thus the uncertainty is high. This uncertainty resides predominantly in the transfer of the architectural knowledge of the new innovations to the operational processes. Examples of problems found in the case studies relate to the restricted knowledge about new innovations. This knowledge is difficult to transfer to the people working in the operational processes as it is based on the complexity of the new architectural structures of the innovations. The operational side of the business remains reluctant to use these new innovations as the existing offerings are easier to sell and often more profitable in the short term.

Phase 3 represents the "phase-out" of an innovation, were the critical interface resides in the effective resource reconfiguration in order to support the phase-out. In the phase-out two dominant options exist: 1) the innovation reaches the end of its life cycle and is replaced, or 2) the innovation gives birth to a long-term strategic opportunity and resources are allocated to build a new main operational process. Examples of the latter situation are apparent in the creation of new departments (for ventures such as IoS) or innovations in the service and consulting area.

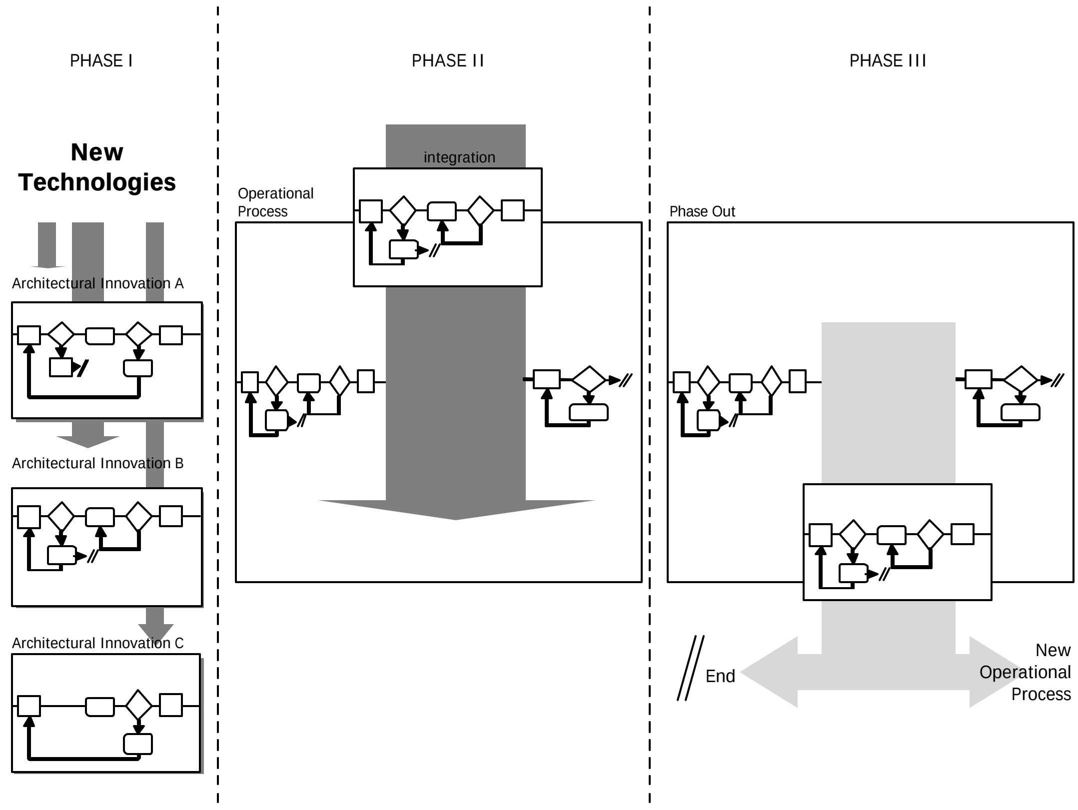

Figure 18: Three distinct phases in the new technology venturing process

In both the firms in the case study, it is shown that the uncertainty regarding the outcome of new technologies plays an important role within the divisions. A typical dilemma in both divisions is that although long-term competence development is important for the sustainability of the division, on the other hand the business opportunities arise in very short cycles and thus need to be dealt with appropriately and dynamically to prevent jeopardising the division's existence. The venturing of a new technology typically relates to these short-term business opportunities.

Both firms are engineering driven and the technological side of the innovations was not usually the main cause of failure. The uncertainty often resided in the architectural reconfiguration of the technologies (Henderson and Clark, 1990; Henderson, 1993; Christensen *et al.*, 1995), which was reflected in the new business models it gave rise to. The interviews confirmed that the uncertainty of these new technologies-based ventures rested in the changes required for integrating these business ventures into the mainstream business, and thus developing new business architectures. The divisions required to integrate these ventures time and again in the existing operating processes are similar to what Penrose (1959) referred to as the operating routines. Changes in these routines were essential if the venture was to have a chance of succeeding.

4.4.2 Dynamically reconfiguring the resource-base as a requirement

The three phases from the case studies show that resource reconfigurations across functional boundaries are essential. The organisational structure is mainly split up into two areas: the operating side that effectively sells and implements innovations at customer sites, and the development side, responsible for producing new innovations. Resource reconfiguration and the effective transfer of knowledge about new innovations are hindered by these functional separations.

The most important reconfigurations are those associated with the intellectual capital of the firm. This knowledge is mostly embodied in the individual employees. It was seen as essential to reconfigure the resources in new more efficient constellations in order to create an organisational advantage. Hence the managerial decisions on reconfiguring this intellectual capital are essential for the commercialisation of new technology-based ventures (Kogut and Zander, 1992; Kogut and Zander, 1996; Nahapiet and Ghoshal, 1998; Teece, 2000).

The interviews show that the challenge for the management is to effectively shift these resources between the various functional areas in a continuous manner in order to optimise the exploitation potential. In cases of architectural innovation a firm has to continuously redeploy its existing knowledge (Itami and Roehl, 1987). However the nature of these firms, as divisions of larger multinational firms, did not allow for ongoing and rapid shifts in function and formal positions. Despite this restriction employees did informally work in all parts of the processes and on various innovations, even though this was often unsupported by the formal processes and generally inefficient. The organisational structure alone is not a sufficient vehicle to capture information about which resources operate in which processes, since the processes cut right across these organisational boundaries.

From a managerial decision perspective the uncertainty arises from the challenges in the effective and continuous resource (re-) configurations. This can be interpreted from a dynamic capabilities perspective. Dynamic capabilities are seen as the processes by which a firm can achieve new resource configurations (Teece *et al.*, 1997). Interviews with the decision makers confirmed the importance of the existence of such processes, as this is seen as essential to not only the short-term, but also long-term sustainability to the firm.

In order to arrive at a better understanding of the changes in the venturing process, a more in-depth analysis of the operating processes has been prepared. Three main sub-processes and their respective resource distribution (R) have been distinguished as follows:

- Sales and customer oriented processes – $R_1(T)$
- Specific innovation related processes – $R_2(T)$
- Installation and after-sales processes – $R_3(T)$

The total resource distribution of these processes is the sum of the individual resources allocated to these sub-processes.

1. **Sales and customer-oriented processes**

   The first part of the process represents the activities that concern the customer, such as sales, customer relations and lead creation. These processes are mainly concerned with motivating existing customers as well as getting new customers interested in the firm's offerings.

   In comparison to the pilot activities in the development phase, which address technology enthusiasts such as the innovators and early technology adopters, these processes are concerned with scaling the technology adoption to a wider market, and exploiting the opportunity productively. Typically these processes depend on the customer base the firm already possesses. The study revealed that, for one firm, only 5% of the volume of sales came from new customers, whilst 95% were from existing customers.

2. **Specific innovation-related processes**

   The second set of sub-processes of the specific venture activities are those representing the new business model. These sub-processes are integrated into the operational process. Functions that are active in these processes are typically characterised by a high knowledge on architectural and component level, and often have been involved in the development phase. Employees working in such functions include system engineers, sales engineers, consultants, project managers and bid managers.

3. **Installation and after-sales processes**

   The third set of sub-processes relates to the actual installation of the new innovation at customers' sites, and the after sales and service processes. Employees typically involved in these sub-processes are technicians, after-sales agents, project managers, logistics personnel and consultants.

Inefficiencies that arose from the process analysis in this part of the operational process were often a legacy from interface problems earlier in the process. For example, feedback loops (identifying that a certain process has to be repeated), which generally cost the firm a lot of money, were found in these sub-processes, but led back to interface mistakes earlier on in the process.

The first interface problem emerges between the interface of these customer oriented processes and the actual innovation knowledge. The interviews confirmed that individual sales targets, rather than the effective exploitation of new innovations, generally drive these customer-oriented processes. Obviously the targets were more easily met by replicating sales pitches for existing offerings than indulging in time consuming learning processes to gain new knowledge about new products.

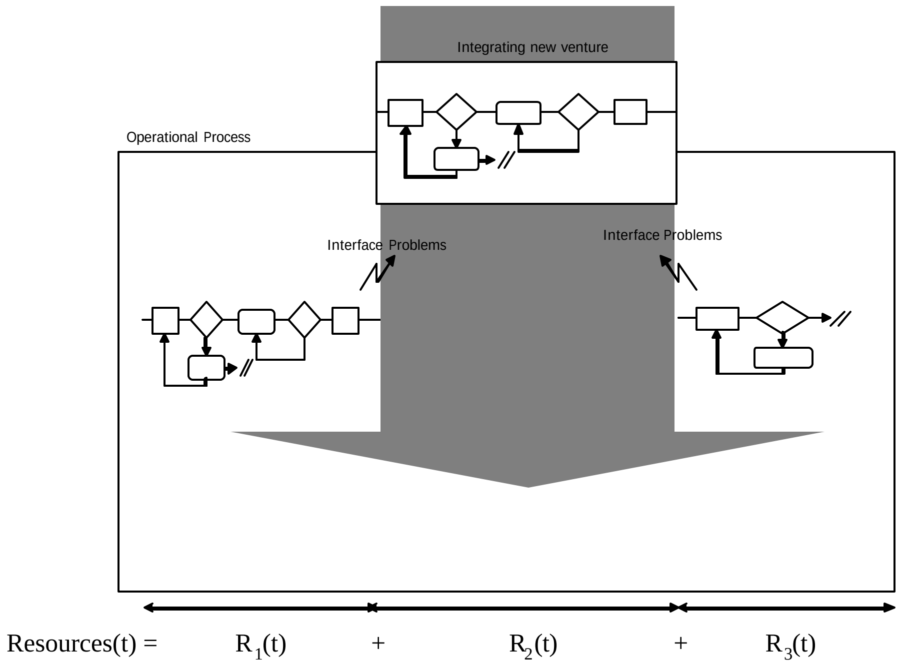

Figure 19: Operational process – interface problems between three main sub-processes

The sub-processes were seen as unsettled as the division's offerings (i.e. new products or services) changed continuously. Both cases showed that the routine implementation of their new innovations and subsequent processes (developed in phase one) formed the main hurdle in successful exploitation of these innovations (figure 19).

The case studies revealed that the main source of this unsettledness related back to the managerial decisions regarding the resource distribution in these sub-processes. The interviewees were asked to estimate how much time they each spent on each sub-process. With particular regard to the resource distribution over the three processes, the interface problem emerged on the confluence of functional positions (i.e. sales, presales, system engineers, technicians, etc.) and their actual resource distribution over the processes. The many feedback loops between these functional elements showed that the individual competencies were not optimally co-ordinated, and a lot of time was spent 'fire fighting' and in communication at other than the designated sub-process. For example, sales people were found to be unintentionally involved in the back-end of the process (system implementation at customer site), due to miscommunication throughout the process. Also technical expertise was often not utilised early on in the process, which led to poor judgements on the offers made to customers and resulted in high resource allocation in the correctional activities. As a consequence, technicians and engineers found themselves heavily involved in unnecessary administrative procedures, which in some cases took up more than 40% of their time.

These problems are reflected in poor productivity. The transfer of knowledge from the developmental phase into the operational phase left much to be desired, with the sales side of the operational processes reluctant to accept new ways of working, and development staff and project managers not having the means or resources to effectively integrate these processes.

The speed of innovation and new product introduction made matters worse. The interface problems were not seen as temporary but structural, as new innovations entered the system on a continuous basis. Learning processes were not in place in order to allow for an effective knowledge transfer given the limited time-span of these innovations.

Since integrating ventures into the operational processes is a routine effort (figure 20), the monitoring of changes in the resource distribution on a routine basis was seen as an essential measurement for this productivity problem. The decision to go ahead with either a sale or the integration of a new product into the sales process was dominated by the sales force and often non negotiable with the other participants in the process. Project leaders, identifying themselves as "customer care" employees, were quoted as saying, "…we cannot make a go/no-go decision; we just simply receive the project and have to deal with it, even if we know up front it will not be profitable."

This led to a great number of inefficient projects for a variety of reasons. Concrete examples of the problems were a lack of feasibility studies and a lack of communication with technicians before a proposal was sent out to a customer (resulting in a high rate of inappropriate equipment being found when the technicians went on site for installation). Many projects faced difficulties and often did not create a satisfying return.

As the sales force was dominating the input of the venturing process, little pressure was imposed on them to venture innovative products and services, as the existing "older" products were easier to sell. This meant little incentives were available to make the necessary process changes to integrate new ventures into the operating system.

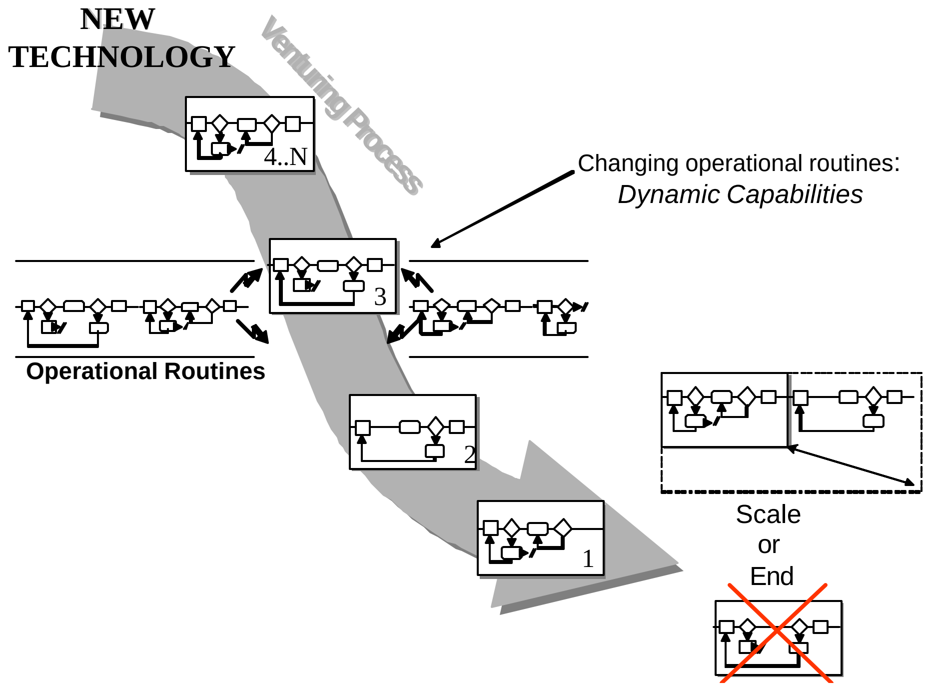

Figure 20: Continuous flow of new technology-based ventures in the productive base of the divisions

This illustrates from a pragmatic perspective the need for dynamic capabilities. New ventures of innovative products should be continuously introduced and subsequently phased-out of the firm's main operating processes. The development processes (phase one) build and provide the venture groups which are successively integrated into the operations department. The operational process should exemplify a single source of competence in, for example, marketing and selling towards the customer. The subsequent processes should then be continuously updated to allow the integration of new innovations.

A coordination mechanism was required to make such integration decisions more effectively. This coordination mechanism should allow for a negotiation between the technological and the sales competence of the firm in order to determine what combination of technologies would suit the customer best. The venturing process should support this negotiation and decision-making procedure.

This can be seen as a confirmation that dynamic capabilities are required and thus supports the probabilistic process, albeit from a qualitative perspective. Based on this analysis it appears that managerial decisions should be geared towards building dynamic capabilities. Although the outcome of new technology-based ventures remains unknown, building dynamic capabilities seems to enhance the hit rate of commercialising these ventures successfully.

4.4.3 Venturing for performance: effective exploitation of the short-term business opportunities

Although the management of the divisions often regarded the outcome of the venturing process of new technologies as uncertain, it was clear what the owners (the holding company) wanted to see: a profitable division. Because of the frequency with which new technology-based ventures are integrated into the operating processes, it was important to have as many ventures as possible to create a profit margin that was satisfactory to the owners.

In order to realise this ongoing stream of short-term profitable ventures, managerial decisions should revolve around coordinating the integration of new ventures into the operational system, also known as new business development. However as the interviews showed, managerial decisions were often based on prior experiences in integrating new technologies into the operating processes. Before liberalisation this was generally considered to be a stable, well-organised process. However after liberalisation, this turned out to be a tremendous challenge because of the competitive pressures. The case studies suggest that, as a result of liberalisation, the economic advantage orientation in the telecommunications industry moved from sales-based accounting to earnings-based accounting.

New technology-based firms often face decisions regarding the trade-off between increasing operating profits now, and investing in innovation to allow for profits in the future. Earnings are a firm-level performance measure. However, direct costs reduce earnings before interest, tax, depreciation and amortisation (referred to as 'EBITDA'). Earnings will therefore increase if the organisation is able to quickly integrate component competencies, such as knowledge and skills or technical systems, into firm-level solutions.

The increased pressure on earnings also arose out the rapid changes in the telecommunications industry. The holding companies of both departments were listed on stock exchanges, and hence subject to the scrutiny and measures used by investors. Stockholders of publicly owned companies are predominantly interested in two ratios: earnings per share (EPS) and price/earning ratios (P/E) (Tracey, 1996). EPS is net income divided by the number of common stock shares outstanding (Tracey, 1996). P/E is the current market price of a stock divided by EPS (Tracey, 1996). Hence the pressure is on the firm to provide quarterly figures that express profit and a solid P/E ratio, as such figures will be scrutinised in their published quarterly reports.

Although new technologies may have to mature before adequate ventures can be built, the existing ventures still should produce enough capital to support this expensive endeavour.

Whilst maintaining a highly innovative portfolio, it is thus important to keep each venture as productive as possible. The outcome of each individual venture relates to the long-term financial outcome. Based on the specific financial strategic considerations and targets from the holding firm, it would seem essential that the majority of the individual ventures create value.

In terms of a potential measurement for the outcome requirements, a certain managerial discretion is still required. During liberalisation, in both cases a shift of focus from volume to earnings emerged, which implied a changing perspective on the expected bottom line outcome. Holding firms may impose different performance indicators to express their subjective perspective on the anticipated value created. The value measures, as derived from the two case studies, were pointing towards earnings or profit but it has to be noted that these can vary from firm to firm. The requirements for the measurement system should thus include a flexible and subjectively interpretative value measure as the preferred output of the venturing process.

4.5 DEVELOPING A POTENTIAL MEASURE FOR DYNAMIC CAPABILITIES

The main requirements concerning a measurement for the uncertainty in the venturing process were driven by three dimensions: financial performance, dynamic capabilities and time. The uncertainty was pinpointed on the unpredictability between the input of the operational processes (resource configurations) and the output of the operational processes (finance). Although this relationship could be determined *ex post* when financial figures come in, *ex ante* no predictability exists. Furthermore, the changes in the resource configuration varied from venture to venture. Measuring these changes over time can contribute to understanding the dynamic capabilities of the firm.

These three dimensions taken together can be used to interpret the productivity of the venturing process. The productive base of the firm is essential to venture new innovations effectively, therefore, new ventures require a productive base (Penrose, 1959). In new technology-based firms, the changes made to the venturing process to accommodate rapid innovations can hence be measured by looking at the productivity of the operational process with respect to new ventures entering the productive base.

The dilemma interpreted from a pragmatic view is to preserve or improve productivity without losing the innovative capability. Productivity is a concept that allows measurement of performance and is regarded as being of vital importance for organisations (Drucker, 1991). Nevertheless, by innovating and trying new things, the control over productivity is effectively lost, as the future outcome of the innovation is uncertain. This has been regarded as an important dilemma, particularly in the dynamic environments of the case companies, where existing management information systems do not provide salience.

A new measure has been defined which has been coined alternative productivity. This measure has been confirmed during a number of workshop sessions with the respective divisions. As previously shown, the input of the process at t=1 is not directly related to the output of the process at t=1, as the input renders productive services that will only be reflected in output later on.

For both parameters, however, set expectations can be identified. In order to achieve better productivity the resource allocation should decrease relative to the financial outcome. In the venturing process, when the venture enters the operational processes, it is expected that the amount of resources allocated to this venture will be high, and the financial performance will be low. Over time, however, the expectation is that the resource allocation should decrease while the financial performance should rise, due to the integration of the venture and optimisation of the productive base of the company (see figure 21).

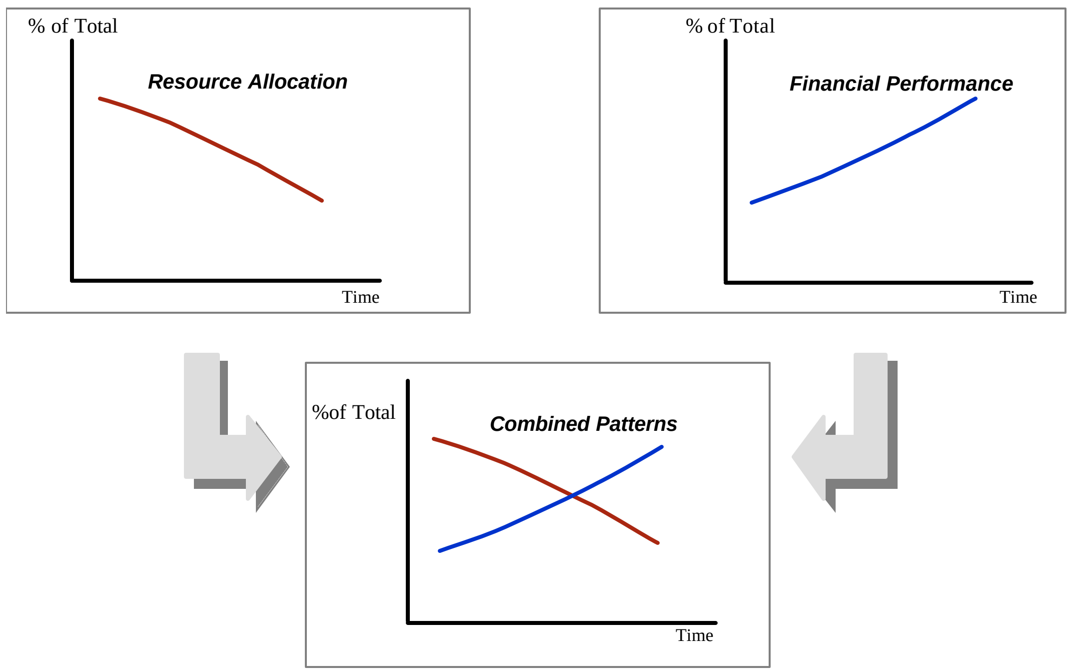

Figure 21: Resource allocation versus financial performance over time

A pattern can thus be created by combining both measures at certain points in time (productivity ratios) that together show a trend. Productivity typically describes a relationship between the output and the input over time. The basic productivity formula of the venturing processes for venture A can thus be described as follows.

$$PR_A(t) = \frac{Output_A(t)}{Input_A(t)} \qquad (2)$$

Where:	PR	= Productivity Ratio
	A	= New Technology-based Venture A
	t	= time
	Output	= Financial Performance
	Input	= Resources Allocated

As indicated by the case studies, the productivity ratio has now a defined output (a financial or value driven performance measure) and input (amount of resources spent on the new technology-based venturing process).

In order to measure resources, a value factor has been assigned. In both cases the cost factor of the resources was seen as most important. To allow for the fact that some resources are more valuable than others, a value factor has been incorporated, which brings a subjective element into the calculation of the firm. This value factor reflects the direct value consumed by the process under investigation and can be defined on a case-by-case basis. The value element that is of importance for a specific organisation can vary from the direct costs to the specific ranking or exclusive qualities a certain resource can bring into to the process. For example, there may be only one employee who has vital expertise in a certain activity; they will thus be more valuable to the firm than others.

The value of the resource-input reflects the amount and cost of the resources consumed by the new venture during the integration period. This means that measurements can represent the amount of resources consumed by the NTBV over this specific period as a percentage of the total resources available to the firm. When these resources become more effective this should be reflected in an increase in productivity. For example, development staff are often needed to support the initial introduction of a new offering, although they would obviously be more productive in the development processes. The cases showed however that these people’s time is mostly taken up with fire-fighting problems in the operational processes as a result of poor integration efforts. If they were able to rapidly redistribute their efforts to the developmental processes a productivity increase could be achieved, providing of course that the performance of the venture remains intact.

This measurement is an initial proposition for the effective translation of the resource-based view to a numerical parameter. Although the resource-based view comprises many intangible factors, the case studies have shown that the most important measurement, in terms of monetary values, can be seen as the direct investment made to the individual processes in which the resources deliver their productive service.

The output is taken as a strategic financial indicator attributed to the output of the new technology-based venture. Again an allowance has to be made, as the value indicator is defined on a subjective basis, and stems from targets given by their holding firms. These output or performance indicators are typically financial in nature. Examples are profit, net contribution, revenue, financially driven key performance indicators and benchmarks of the new venture.

Using these two measures over a (short) timeframe, which represents the integration of the new venture into the operations, produces a trend. I will refer to this trend as the alternative productivity trend (figure 22). Following the expectations emphasised during the case studies, the pattern should reflect an increase in financial performance related to a decrease in resource allocation.

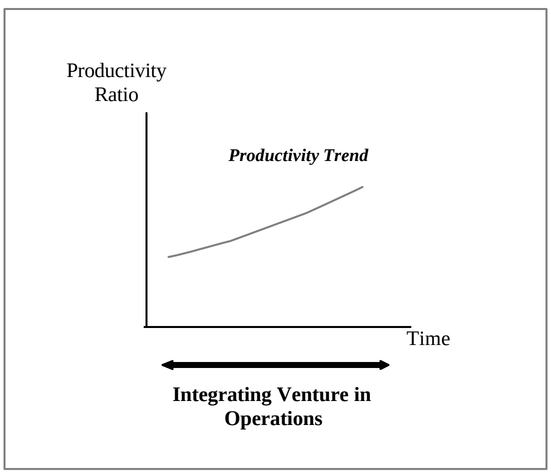

Figure 22: Productivity trend expectations

This measure allows managers to dynamically determine the productivity trends of specific ventures. However, according to the probabilistic model, the uncertain outcome of new technologies suggests a dependence on the level of dynamic capabilities, with a more long-term perspective. As proposed in chapter 3, dynamic capabilities do not guarantee short-term profits but should be regarded as a long-term competence of the firm. Firms that possess such capabilities show an ability to dynamically reconfigure the productive processes so as to enable exploitation of new ventures on a continuous basis. In other words, creating one successful venture (or one with a satisfactory performance) out of new technologies is important, but equally so is the ability of firms to replicate this success.

In order to test the probabilistic process, a proxy for dynamic capabilities is required. Following the alternative productivity trend, an experimental measure has been developed using the case study material, and validated by both firms in workshops, to interpret a dynamic capability by comparing multiple ventures.

In order to explore a measure of dynamic capabilities, the alternative productivity trends of sequential new ventures can be compared and examined over time. A pattern can thus be created that potentially indicates if the firm is improving the integration process, or in other words, if a firm utilises a dynamic capability.

A comparison between productivity trends shows the relative productivity ratios of a selection of new ventures that have been integrated in the operational processes. This can be done by taking, for example, a ratio from two consecutive ventures that are integrated in the operations during a similar timeframe. As a starting point, we can take the point when the venture is integrated into the new firm, usually referred to as 'kick-off'.

The case studies identified the first few months as crucial for the venture's existence. Comparing these periods in the respective cases thus allows us to see any improvements made in the integration process itself. For example, a comparison can be made between venture A, with a critical phase from t=1 to t=5, and venture B, with a critical phase from t=6 to t=10, by creating a graph overlapping A(t) and B(t) in A(1-5) and B(6-10). It is essential that the respective points in time represent seemingly identical phases in the innovation life cycle.

A ratio can now be calculated using the productivity indicator A and B at time (t):

$$DC_{A\text{-}B}(ph) = \frac{PR_B(t) - PR_A(t)}{PR_A(t)} \qquad (3)$$

Where:

DC	= Dynamic Capability Ratio
PR	= Productivity Ratio
A	= New Technology-Based Venture A
B	= New Technology-Based Venture B
t	= time
ph	= Integration phase

In order to measure two phases, it is important to remember that the dynamic capability relates not to a specific point in time, but to a specific phase of the integration process (ph). For example, if venture a starts at t=1, and venture B start at t=6, then ph represents the phase resembling both t=1 and t=6. As this is the first measurement point that is compared we can thus say:

ph=1, for t=1 and t=6.

In the example the following calculations can than be made:

$$DC_{A-B}(1) = [\, PR_B(6) - PR_A(1)]/\, PR_A(1)$$

$$DC_{A-B}(2) = [\, PR_B(7) - PR_A(2)]/\, PR_A(2)$$

$$DC_{A-B}(3) = [\, PR_B(8) - PR_A(3)]/\, PR_A(3)$$

$$DC_{A-B}(4) = [\, PR_B(9) - PR_A(4)]/\, PR_A(4)$$

$$DC_{A-B}(5) = [\, PR_B(10) - PR_A(5)]/\, PR_A(5)$$

The five ratios can now be converted back into a trend that effectively compares the two productivity trends (see figure 23).

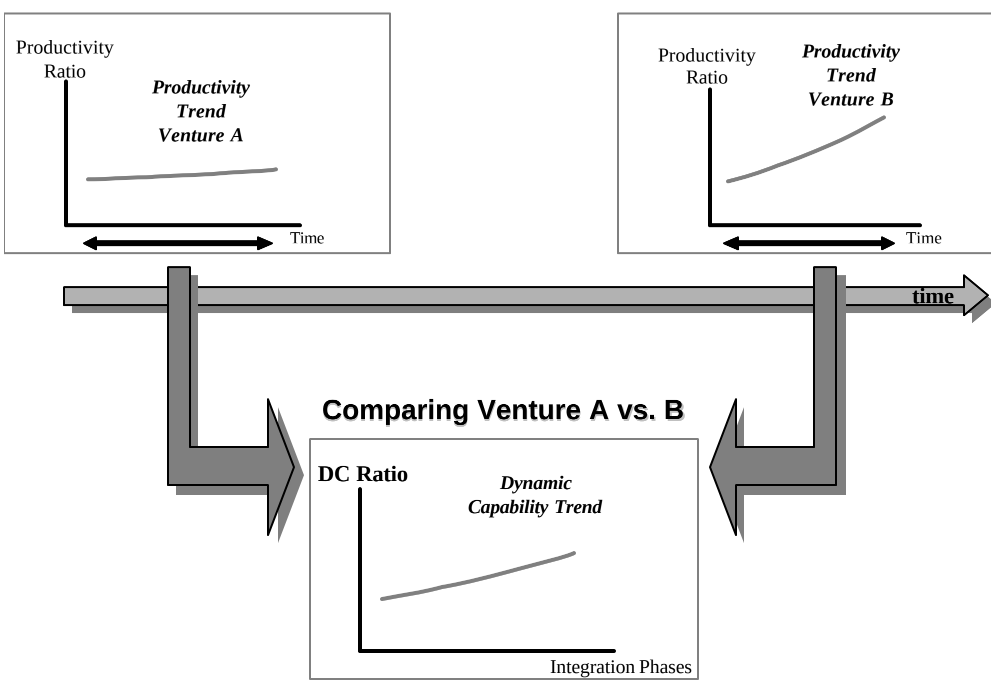

Figure 23: Dynamic capability trend

The dynamic capability proxy can now be interpreted on a managerial level. When the trend is horizontal, the expectation is that this represents a stable dynamic capability, between the respective measurement periods. When the trend moves diagonally upwards to the right it is expected that dynamic capabilities have been built or improved during the periods between measuring ventures A and B. Finally when the trend shows a chaotic or declining pattern this is expected to represent a lack of dynamic capabilities.

4.6 IMPLICATIONS FOR AN INITIAL EXPERIMENT

The proposed proxy for dynamic capabilities has obvious limitations and implications, as is the nature of any experimental measure. The line suggests that each venture follows a similar path into the integration of the operational processes. This can however vary as the nature of new ventures may vary. Some ventures can be implemented more easily into the operational system than others. If these are measured in the way shown above, the representation would not be an adequate one. It is thus essential for the experiment to select two ventures of both comparable size and nature, where real resource reconfiguration efforts are required, and new processes are introduced.

Furthermore, the mathematical elegance of the proxy could be improved. The proxy for dynamic capabilities proposed here is kept as simple as possible. However this does not rule out future improvements by more refined efforts, by for example testing and applying different ratios and performing statistical analyses.

These measures have been developed in conjunction with the two case firms, who both acknowledged their potential relevance during three sequential workshops. Even though clear limitations are already apparent, a next step is to carry out a first experiment to learn from these measures.

Nevertheless, the proxy is only relevant in the context in which it has been created, and thus generalisation cannot be expected yet, especially since the important resource configuration in the case studies was predominantly of a singular nature. In cases where multiple resources play an equally important role – such as production facilities, equipment, stock, raw materials, or any other resources – the proxy will inevitably become more complex.

The next section will describe the development of a system that aims to support the described measurement concept. Based on this system, an experiment has been conducted in which the probabilistic process model will be evaluated. However, in order to do so, it is also essential to evaluate the proxy for dynamic capabilities. Using qualitative analysis the existence of the dynamic capabilities in the experiment can be compared to the proxy. As this is the first experiment, lessons are expected to be learnt about the proxy as well as with regard to the probabilistic process model for uncertainty.

5

DEVELOPMENT OF PROTOTYPE MEASUREMENT SYSTEM: XTREND

5.1 INTRODUCTION

In order to explore the proposed probabilistic process model, a supported prototype system (XTrend) has been developed for effective data collection and measurement in an initial experiment. Existing performance measurement information currently available to management is predominantly based on accounting, supplier management or quality management systems. Such systems utilise past data that may only become available to managers on a monthly or quarterly basis.

However, managers of new technology industries have to make decisions in order to meet new business opportunities, for which the historical performance data may not be enough. As the literature study has shown, for such decisions managers rely on their judgement of these dynamic situations.

Furthermore, literature has pointed to the importance of technology-based firms having the capability to dynamically reconfigure their resource-base in order to meet these new business opportunities that often occur and disappear in short cycles. Firms with such dynamic capabilities are expected to have a long-term competitive advantage over their competitors. However, there are limited measurement systems available that provide information on the relation between the firm's ability to change dynamically and the performance created out of this ability. Moreover, there is no measure yet available that approximates a firm's dynamic capability, so as to test the probabilistic process model.

Based on the requirements from the case studies of chapter 4, this chapter will describe a prototype measurement system that aims to measure this dynamic capability, using a real-time dynamic information collection protocol.

5.1.1 System design

The prototype system design follows a typical system engineering approach (Machol *et al.,* 1965; Dandy and Warner, 1989; Blanchard, 1991). XTrend has been developed in order to complement existing information systems. The prototype development process is depicted in figure 24 and addresses the three main steps: requirement analysis, system development, and system measurement and evaluation.

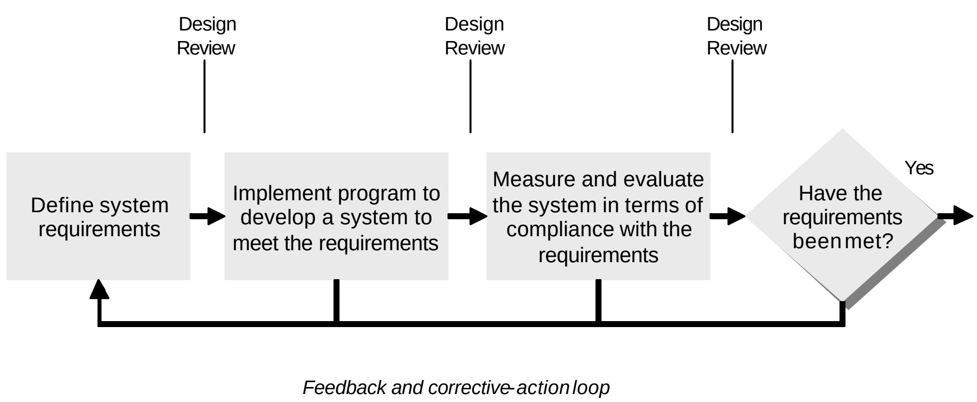

Figure 24: Prototype system design approach (Blanchard, 1991)

The first step in the system engineering approach reflects the requirement analysis. The data for the requirement analysis is derived from the case studies in chapter 4. The requirement analysis is aimed at supporting an experiment to explore potential measures for dynamic capabilities. Both case studies have actively participated in providing the relevant requirements through interviews and workshops.

Following the requirement analysis a process has been developed to support the data collection required to measure the proposed proxy for dynamic capabilities. As the data required for the experiment was not obtainable through the existing information systems at either site a new data collection process was required. Additionally, a software system was developed to support the data collection for the experiment.

Finally an initial experiment has been carried out in conjunction with key players from both firms to measure and evaluate the system with respect to the initial requirement analysis. This experiment is based on fictional simplified data, verified by the partners, in order to simulate a possible scenario. The simulation allowed the system to be effectively tested and evaluated. An iterative cycle of action and reflection has been applied in order to complement the more traditional data collection methods, such as documentation, interviews and observations. Three consecutive workshops have been held with both firms to develop and refine the measurement procedures.

5.1.2 Validity: feasibility, usability and utility

To ensure the validity of the research approach of this section of the work, a set of output criteria have been adopted, stemming from a process approach (Platts, 1993). Platts argues for three criteria by which the process created (in this thesis the data collection process) can be judged and assessed. These criteria are feasibility, usability and utility. Feasibility addresses whether the process can be followed, usability relates to how easy the process was to follow and utility concerns to the question of whether the process provides a useful step in strategy formulation.

These criteria have been applied in order to establish the validity of the data collection method for the experiment. The main aim is to ensure the relevance of the chosen parameters and the measurement approach from a firm perspective. Focusing on the potential applicability in practical situations and thus integrating this pragmatic perspective in the exploratory conceptual context creates a solid basis for future research that is directed towards more workable solutions. The criteria for assessment are thus essential to evaluate the outcome of the data collection process and subsequent system, albeit in a preliminary prototype version. The criteria are embedded in the system engineering approach and the requirement analysis.

Feasibility is achieved by repeating the process in different settings (Platts, 1993). This has been an integral part of the workshops and several test sessions at the two case companies. In addition, various experts from both academia and industry have facilitated similar workshops to generate greater confidence in the measurements and the data collection process.

Usability has been achieved through use of independent testing panels at both firms and an external reviewing board. These help to ensure a minimum level of usability and allow for refinements throughout the development of the process.

Finally, utility is achieved by the evaluation of a direct as well as an indirect output of the process. The direct output has been evaluated on the basis of the development and evaluation of a thought experiment (reported in section 5.4). The indirect output relates to the subjective perspective of the potential users, and was validated here through the execution of a number of interviews with the potential users.

The validity criteria have been applied in order to ensure an acceptable level of validity to the development of the prototype measurement system in order to optimally enable the exploratory longitudinal study reported in chapter 6. The resulting prototype also provides a basis for potential future research in new ways of measuring intangible aspects of business and managerial decision-making.

5.2 REQUIREMENT ANALYSIS

Some initial general requirements, based on the findings and the discussion in chapter 4, are predominantly oriented to the operationalisation of the proposed measurements and proxy in a practical real life setting.

Firstly, because of the short timeframes in which new ventures are introduced, integrated and disbanded, it is essential that the system captures the data in real-time. It is also essential that the data is captured in a dynamic and continuous fashion. Therefore regular short intervals should be selected as the respective measurement points. For this experiment the intervals have been set on a monthly basis.

A second requirement is the effective measurement of the allocation of individual resources to the processes. For example, instead of simply assuming that a developer spends the most of his time in development, this should actually be monitored. This requirement was also motivated from the employee perspective. Technicians, for example, did not like the fact that in some cases they spent 40% of their effort in administration-related processes. The function description is thus not a guarantee for the productivity of the processes. The measurement of the resource allocation to the organisation's processes should be performed on an individual level, rather than working with general averages and expectations that are based on the organisational structure and function descriptions alone.

The XTrend measurement system should therefore incorporate a technology that allows employees to easily submit their estimates of their percentage of effort spent on the venturing process being measured, against the other processes. An employee can thus allocate 100% of effort spent in specific processes and sub-processes, one of which is the new venture.

In addition to the effort percentage, a value factor on what this effort is worth to the company needs to be incorporated. Obviously, the effort of a director or senior engineer is worth more than the effort of secretarial workers. During the case studies it became apparent that the value factor could be taken in two ways. The value could either be a cost factor representing a certain monetary value, or it could be seen as being relative to the total resources measured. By multiplying this value factor with the effort indicator an indicator emerges. This indicator (hereafter termed resource indicator) will serve as the input for the productivity formula 2 from section 4.5.

Based on the initial requirements and the measurement proxies set out in chapter 4, the following data collection process has been developed.

5.2.1 Data collection process

In order to obtain the relevant data for the construction of the measurements from the case studies, a data collection process has been developed. As described above, the data collection process has a dynamic real-time character.

Two roles have been distinguished within firms for the purposes of this study: management and employees. Management data is concerned with two elements: set-up of the system, and input of the financial indicator. The resource allocation data comes from the employee side. Following the divisional character of the case studies, each division can be seen as a separate firm on its own, and is administrated like a profit centre.

The data collection process is depicted in the figure below.

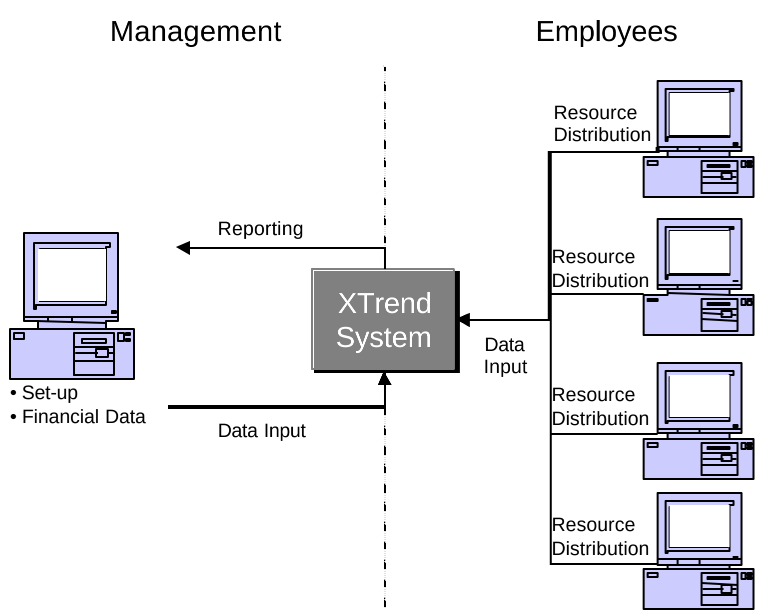

Figure 25: Roles structure for data collection

The system requirements reflect the flexible nature of the measurement requirement. The system should allow managers or administrators to create a variety of definitions for both the resource indicator and the financial indicator. As long as these parameters are in line with the uncertainty relation, the operators of the system should be able to work flexibly.

The analysis of the data collection revealed a cyclical process structure with the following main activities:

- Set-up of the system, identification of: active periods, innovations (new products/services/solutions), the operational process structure, functions, departments, locations, relevant employees active or influencing the processes, and table of rights of usage for the system

- Data input by Employees – resource distribution

- Data input by Managers – financial distribution

This process contains regular feedback loops based on the firm's input requirements. The system should allow for flexible data collection at regular predefined intervals, i.e. data collected each month, week or day. This feedback loop implies a maintenance activity within the structure of the system, so that it allows for people leaving the firm, new people coming in, or the addition of new processes and innovations.

To obtain regular data input an important requirement was the user friendliness of the system for both the employees and management. Ease of use for employees implied that it should take them no more than five minutes to fill in the data sheet.

Furthermore, to prevent the system being misused – in terms of employees providing false information – employees are asked to distribute their time in percentages over all processes identified in the system. A major concern was that employees could manipulate the accuracy of the data by providing a resource distribution that was favourable to their own situation. In particular it was evident that people would not reveal any personal in-efficiencies by allocating the percentage of their time spent on processes such as coffee drinking or surfing the net. In the interviews it was stated that, "…it should be prevented that employees get the feeling of being watched by big brother".

Allocating resource distribution in terms of percentages allows employees to more easily provide an estimate of their real time distribution that may vary from their contractual obligations. No link should be made to employee appraisals, or why they worked on a particular innovation when they should be doing something different. The system's main intention is to create real estimates rather than exact figures, in a flexible manner, to create an understanding of how the operational process base is really used.

The data collection process is depicted in the following picture:

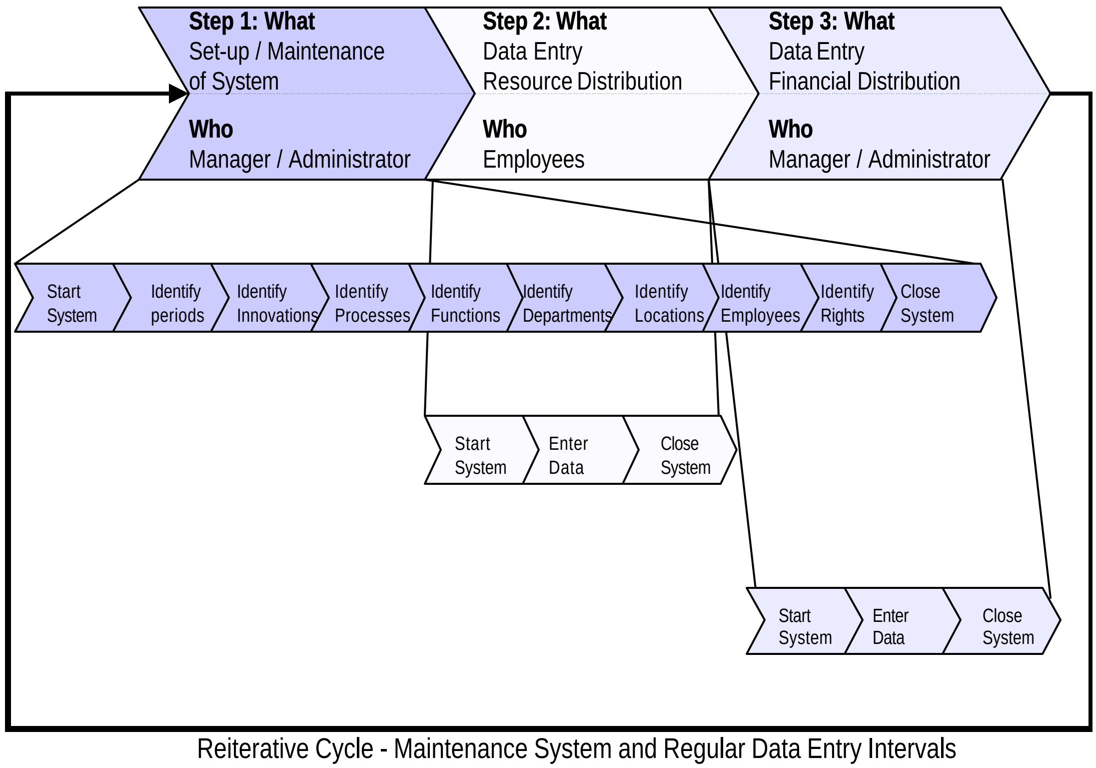

Figure 26: Detailed process structure for data collection

5.2.2 Process step 1: set-up/maintenance of system

The first step in the data collection process is the set-up of the system. To create a flexible approach, the system should allow the manager or administrator to define the specific characteristics of the division.

The logical order for this is as follows. Firstly, the manager should define the periods for which the system should be active. The manager should then identify the innovations in the integration phase (whether new products, solutions or services) and define the periods for which they should be open for measurement.

Furthermore the process structure is defined. This structure represents the minimal three phases of the operational process stemming from the operational analysis. The division's structure can be broken down into functions, departments and locations. This forms the basis for the identification of all relevant employees working in the system. Finally a table of rights should be issued to allow one or more persons extended access to the system (for example, process owners or department managers could be granted access to their specific reporting data). For confidentiality reasons, the manager should be able to define rankings instead of real values to indicate the financial resources and the resource distribution values.

5.2.3 Process step 2: data entry resource distribution

The second process step represents the data entry for the resource distribution. All employees have access to the system and individually allocate their 100% time over the predefined innovations and processes. This user interface should be particularly easy to use and should take no longer than five minutes per employee.

It is important to note here that the employees provide their own subjective judgement on the time spent on the relevant processes. In the case study it became apparent that it would be more useful to have their “thumb-feeling” of the resource allocation rather than striving for absolute correctness in the measure.

Each employee will be issued with a username and password (defined by the manager in step 1), as to allow them to enter the data entry side of the system.

5.2.4 Process step 3: data entry financial distribution

The third process step represents the data entry for the short-term performance of the venturing process. The manager or administrator can provide a value indicator to each predefined venture (termed ‘innovation’ in the system) as part of the total. An example could be total profit and profit allocated specifically to the innovation under investigation in a certain time period. During the set-up process the manager has the authority to identify whether the nature of the value indicator is financial (profit, revenue, etc.) or otherwise.

The data collection process is an iterative process and is repeated on regular intervals. The set-up process takes the form of a maintenance process, so that changes to the process base, product base and organisational structure can be dynamically integrated.

5.2.5 Organisational requirements

The organisational requirements for the system relate to the level of detail by which data can be collected and processed. In addition to the measurements defined in the operational analysis, the cases indicated the need for more in-depth analysis of the results in case they varied from expectations. The in-depth analysis reflects the level of detail described in the set-up process step 1, where the complete organisation and process structure can be broken down.

A breakdown of the data allows the companies to provide the resource distribution over the sub-processes related to one specific innovation, and thus to optimally benefit from the data collected.

The three elementary sub-processes that have been distinguished in chapter 4 form the basis of this breakdown.

Comparing deviations in the resource allocations over these three sub-processes over time will allow the manager or process engineers to identify potential problematic areas that require improvement. Large resource variations in the sub-processes can thus endorse specific action for change.

This organisational requirement brings a third measurement level to the system that is oriented to support the effective building of new processes. An in-depth analysis to the resource configuration can pinpoint sources of uncertainty related to the resource configuration of the productive base of the organisation. This has formed a sub-element of the investigation of the research question that is primarily concerned with the enhanced understanding of uncertainty. It is not however directly related to the uncertainty relation concept and hence will receive only limited attention throughout this thesis. However, the implications derived from this analysis for future research is important and hence it is included.

5.2.6 Technical infrastructure requirements

Next to the operational and organisational requirements, the system infrastructure of the cases plays an important role in the development of the prototype. These requirements stem from the legacy systems available in the divisions as well as the complexity of the computer infrastructure. The following main requirements have been identified:

- The system should run on the organisation's Local Area Network (LAN). The system should be a networked version and run on the central server of the organisation's LAN, to enable accessibility for all employees and managers concerned.

- The system should be compatible with a wide variety of Windows platforms, from Windows 98 to Windows XP and NT versions.

- The system should be simple, with allowances for future interfaces to integrate existing Information Systems and a variety of databases such as Oracle and XML.

5.2.7 Summary of the requirement analysis

The requirement analysis provides the main system requirements for the development of the IT-supported data collection tool. With respect to the alternative uncertainty concept, the uncertainty relation between the process and finance parameters has been further defined. The operational process analysis identified more detailed measurements which confirm the complexity and issues residing in the two telecom cases. In addition, the organisational and technical requirements provided the elementary system requirement for the prototype design of the data collection process and reporting capability of the tool, with a specific focus on the usability and infrastructure demands.

The main requirements derived from the analysis are:

- **Flexibility for customised interpretation of the performance.** By issuing a flexible parameter, firms are able to define their main strategic driver in terms of the value output of the venturing process. This could be earnings, profit, net contribution, revenue and so on.

- **Resource distribution as the main parameter for process performance.** The input of the processes is predominantly dependent on the (human) resources allocated to this process. Multiplied by the value (costs) of these resources, a distribution of the resources per individual over a selected amount of innovations and processes can be recorded. The sum of these distributions depicts the overall resource distribution and defines the second elementary parameter of the uncertainty relation.

- **Time element is essential to determine trends.** There is no direct relationship between the input and output of the two parameters at one point in time. However the behaviour of these two variables at similar points in time can create a pattern that serves as a basis for developing a ratio.

- **Alternative productivity as a measure.** Alternative productivity is the output divided by the input at a certain point in time. By taking this measure at various points in time a pattern is created that represents the uncertainty relation. These patterns can be reported and interpreted to enhance understanding of the uncertainty.

- **Comparing the alternative productivity patterns creates a dynamic capability trend.** A comparison of a number of these patterns provides insight into the dynamic capabilities embedded in the firm.

- **The measures should be applied to that part of the venturing process where an innovation is integrated in the main operation process**. This represents the most critical phase in the venturing process, and the patterns created during this phase visualise the uncertainty related to the innovations and the process portfolio.

- **Real-time measures are required**. Whereas most traditional information systems only allow for such projections in hindsight, the system should collect and report the patterns on a real-time basis.

- **Frequent measurement points are essential**. Short interval periods should be set to allow the creation and interpretation of these patterns to enhance understanding and create more predictability in the evolution cycles of these patterns.

- **A comprehensive data collection process should be incorporated** Data is collected from two sources: employees and managers. Both play an essential role in the effective data collection process, and should be enabled to do so in a time-efficient and straightforward manner.

- **From an organisational perspective, it is essential to allow for a breakdown of the measures in the various elements of the organisation structure (functions, departments, location).** Such resource configurations can reveal problem areas and hence enhance the understanding of what causes unpredictable patterns. The implications derived from such an in-depth analysis can contribute to future research implications.

- **Technical requirements for the system architecture**. The system should be easily integrated into the existing systems of the company. The system should be accessible by all relevant parties from the LAN, and should be supported by the main versions of the Windows operating system.

5.3 PROTOTYPE SYSTEM DESIGN – XTREND

This section describes the core elements of the system's architecture and functionalities using the process model. The system is a specifically designed software application that supports the data collection and reporting process of the alternative uncertainty concept. This section is split into two parts. Firstly, a description of the technical elements of the system will be discussed. Secondly, the data collection process and the functioning of the system will be elaborated, illustrating the functionalities of the system for each process step.

5.3.1 System architecture

The XTrend application is developed using WINDEV 7. WINDEV is a software development environment for Windows. WINDEV works with Windows 3.1 as well as Windows 95, 98, XP and NT. An important point for the ease of development and maintenance is that the source code is the same for all five Windows environments. WINDEV interfaces with most programming languages such as C, C++, Java, VB, Pascal, COBOL, and FORTRAN.

XTrend is based on Client/Server architecture (see figure 27). Client/Server architecture means that the data is stored on a "server" computer, but can be accessed (read/write) from a "client" computer. The application and all data are stored on the server. When the user starts the application, it is loaded into the local memory of the PC. In a network environment all users thus access the same databank. However, it is also possible to install the application locally on the PC.

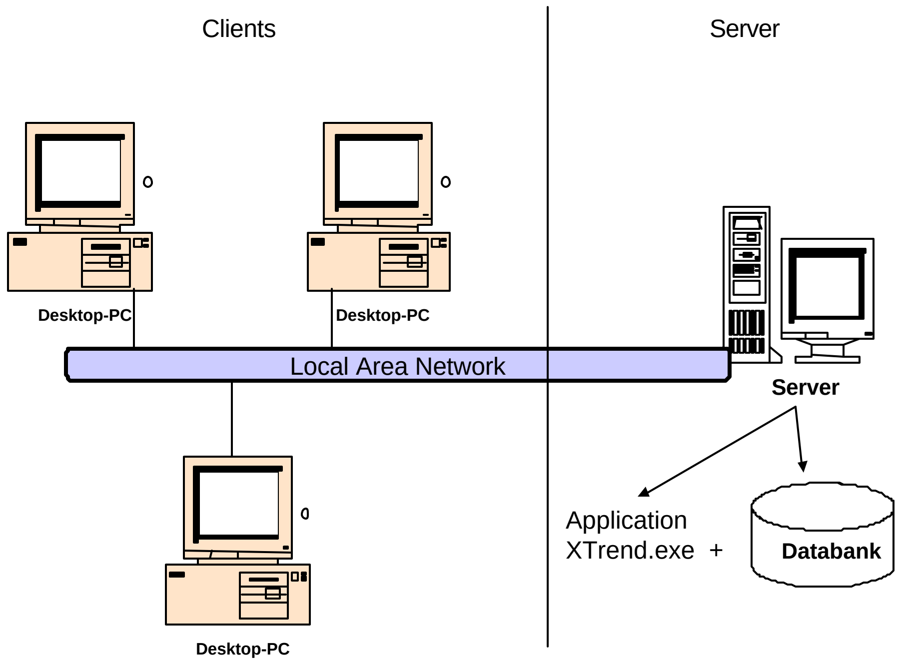

Figure 27: Client/server architecture XTrend

The database engine is integrated with the development environment. At any time, all information regarding a file or a field can be accessed and altered. The integration of the user interface and database allows for easier and more compact programming and limits the risks of bugs while easing maintenance. WINDEV's database engines (Hyper File and xBase) manage the databases on a network, with potential locking facilities at the record and file level. WINDEV's database engine supports large-scale networks of 200 PC workstations and more[19].

The file works independently from the server, regardless of the server type (LanManager, Novell, NT). The XTrend application is developed for multi-users, but will also function on a single machine. The data structure is depicted in figure 28.

[19] 200 is an indication, not a limit; the theoretical number of PCs is infinite (source: http://www.windev.com).

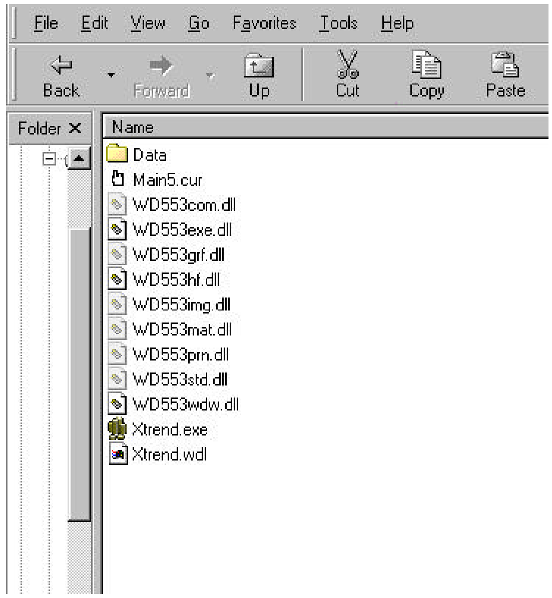

Figure 28: Example file structure XTrend

5.3.2 Process supported application: XTrend

Using the process model from the requirement analysis this chapter will provide an overview of the main functionalities of the prototype application XTrend. Following the three basic steps I will discuss the main functional elements and how they relate to the requirements.

5.3.2.1 Process step 1: system set-up

Process step 1 consists of 10 sub-processes that set the specifications of the firm's characteristics.

Sub-process 1: start-up

The first sub-process is similar for all main process steps and concerns the start-up of the program from the LAN server. Each employee and manager has been allocated an employee identification name and a password (figure 29). Furthermore, the employee can select a preferred language: German, French or English.

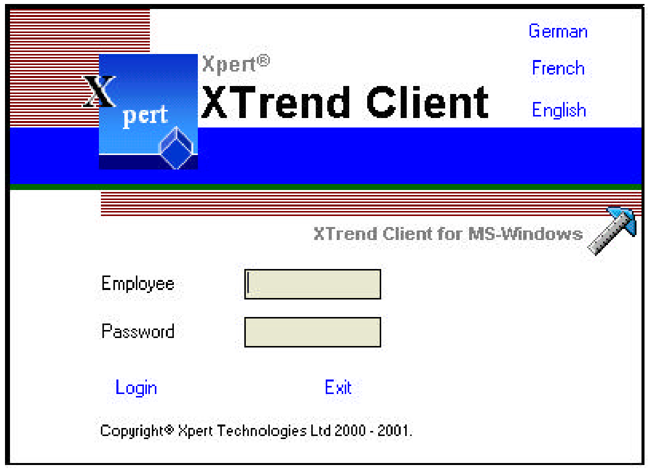

Figure 29: Entry screen XTrend

Based on the user specific settings, the employee or manager will be directed to the relevant data entry or reporting screen.

The main entry screen for the administrator/manager is depicted in figure 30 and comprises the following core elements: navigation, performance measurement reporting menu, period selection bar, and a set-up menu.

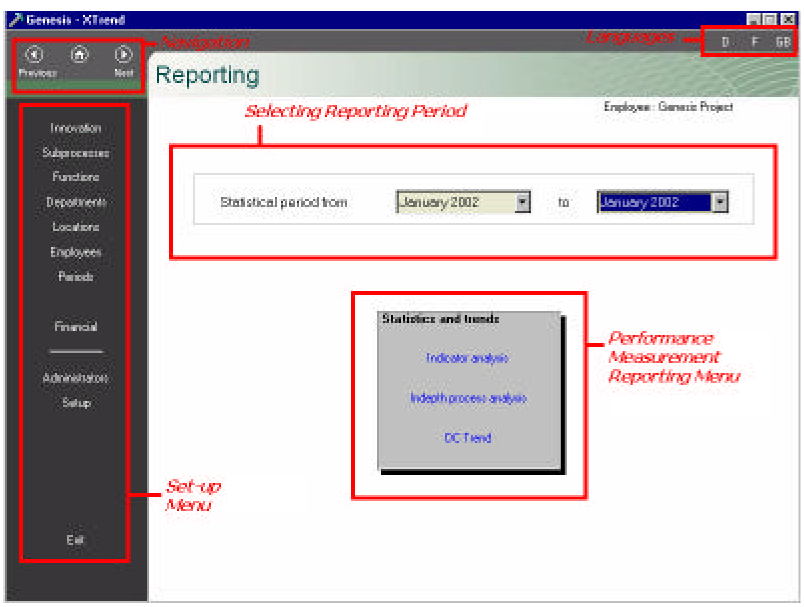

Figure 30: Master reporting screen

Sub-process 2: identify periods

The period section allows the administrator to define the measurement period (figure 31). The period reflects the overall activity of the system. The period selector is aligned with the date/time properties as set up on each individual PC. The amount of intermediate periods defined here represents the reporting frequency. It is entirely up to the administrator what to choose, i.e. months, weeks, or even days.

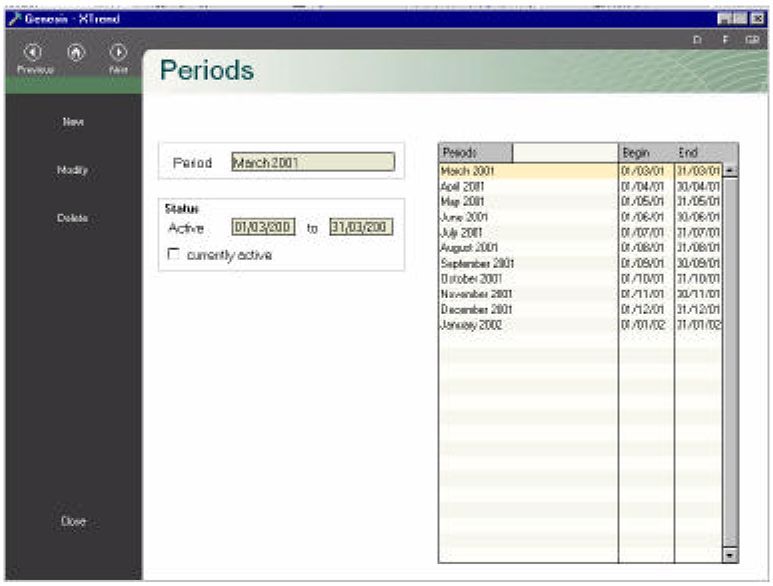

Figure 31: Period identification screen

Sub-process 3: identify innovations

The first parameter to be defined is "innovation" and reflects a typical new technology-based venture. The definition of innovation (figure 32) in this context is the embodiment of the new technology in a business model of a new product, service, contract or any other form of deliverable the company is offering. The administrator can define the innovation portfolio that requires monitoring. This is particularly useful in the telecommunications industry, since in this industry at least three categories of operation can be distinguished: 1) end products consisting of a multitude of parts, which in turn are built out of thousands of components; 2) service offerings, which can be defined and integrated as in the product offering; and 3) large, customer-specific developments which can represent innovation projects. The administrator is free to choose his or her preferred measurable operation.

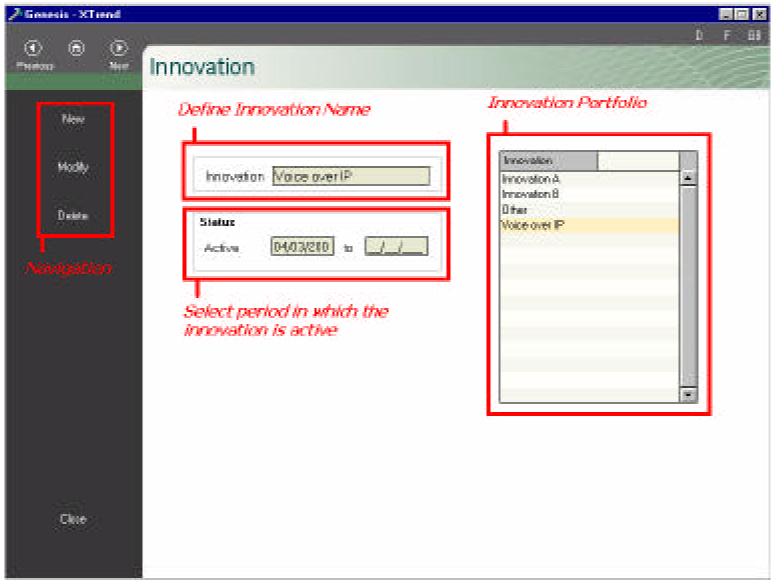

Figure 32: Innovations identification screen

Using the navigation menu, the administrator can add, modify and delete new innovations. Each innovation is accompanied by a period in which the innovation is "active," meaning this is the period that the administrator desires to open up the innovation for measuring (for example, the first five months after introduction).

Sub-process 4: identify processes

In sub-process 4 the administrator integrates the company specific processes linked to each innovation (figure 33). The prototype version of XTrend allows for two hierarchical levels of process definitions. The figure below depicts the input-window for the administrator in the field "Processes". In the left-hand column the overall process is depicted whereas in the right-hand column the respective sub-processes can be inputted. In addition, the period in which the various processes are active (and therefore require measurement) can be defined by the administrator.

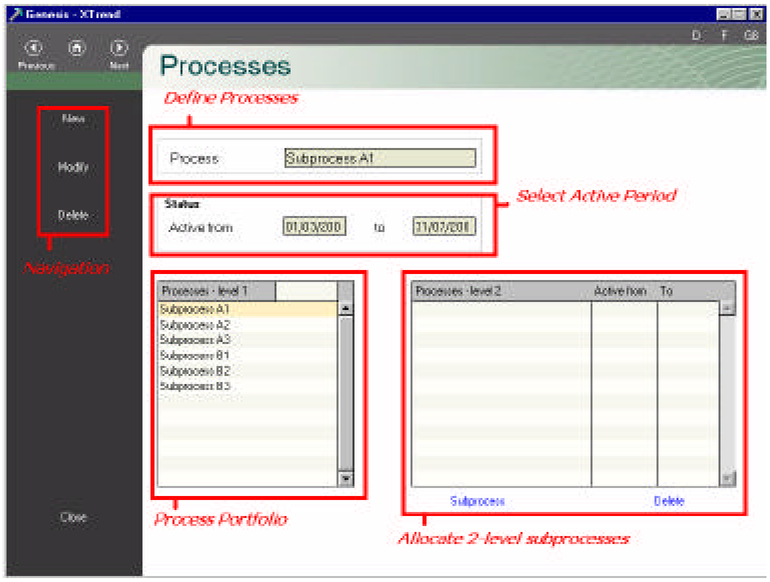

Figure 33: Process identification screen

Sub-process 5: identify functions

The prototype system XTrend can be modified in order to pinpoint data from various areas such as functions, departments, and locations. It allows the administrator to define the various 'functions" that are active within the organisation. These functions are similar to the employees who have to provide the data. In the venturing process these could be: Sales, Marketing, Pre-sales, R&D managers, Product managers, System engineers, Team assistants.

Sub-process 6: identify departments

Departments can be defined in a similar way. This section allows the administrator to define the various departments under measurement. This is done to provide the heads of the departments with their individual performance figures. In the innovation process departments that are under investigation could be R&D departments, Marketing departments or Intellectual Property Rights (IPR) departments, but also Sales departments and Operational departments.

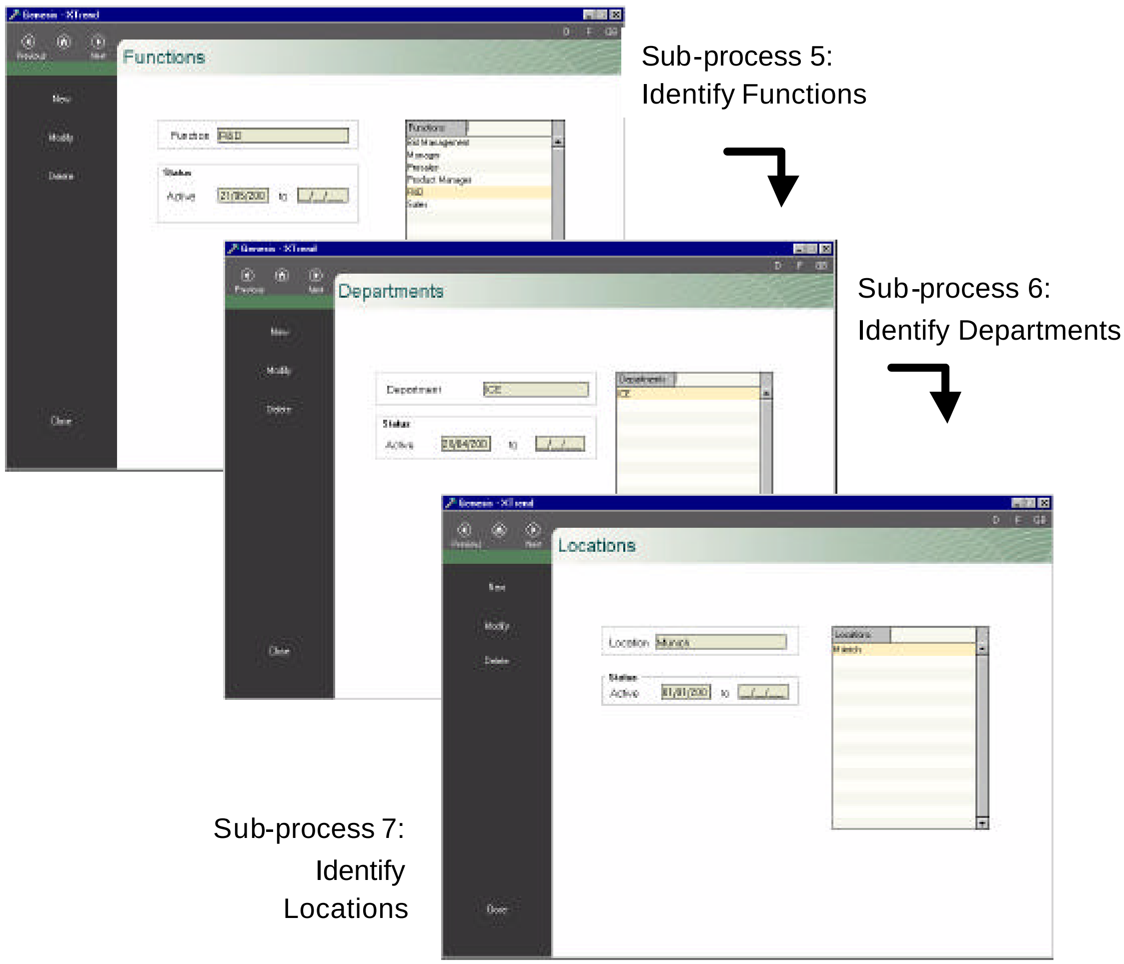

Figure 34: Identifying functions, departments and locations

Sub-process 7: identify locations

With respect to co-development and the virtual structures that emerge in technology companies, a section on location has been integrated to effectively measure the performance of location specific teams.

Sub-process 8: identifying employees

In sub-process 8 the administrator can identify and define the employees who partic ipate in the organisation and who are subject to process controlling. All relevant information about each employee can be inputted, including the FTE (full time equivalent) percentage, personnel costs and overheads.

To accommodate the fact that some organisations do not allow salary costs to be disclosed, the system also supports the use of rankings (i.e. CEO=10, Manager=6, Staff=3). By doing so the relative value aspect of each employee is still factored into the calculations.

In this section the administrator also defines the access passwords for the respective employees.

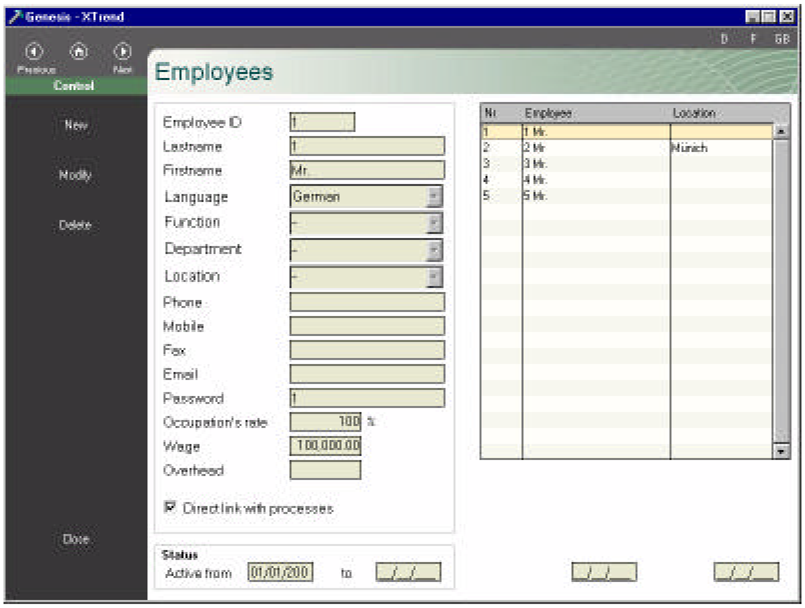

Figure 35: Employee identification screen

Sub-process 9: Identify table of rights

In order to support larger, more complex organisations, more administrators can be defined. Each administrator can be allocated certain rights to either set up parts of the system or view results. Blocking screens can limit an administrator's views, to protect confidential information. The table of rights (figure 36) focuses on each of the sub-processes outlined in the set-up process.

Sub-process 10: close system

Similar to all three main processes, the last process is to exit the system. A proper exit from the system is required for the information to be sent to the main database.

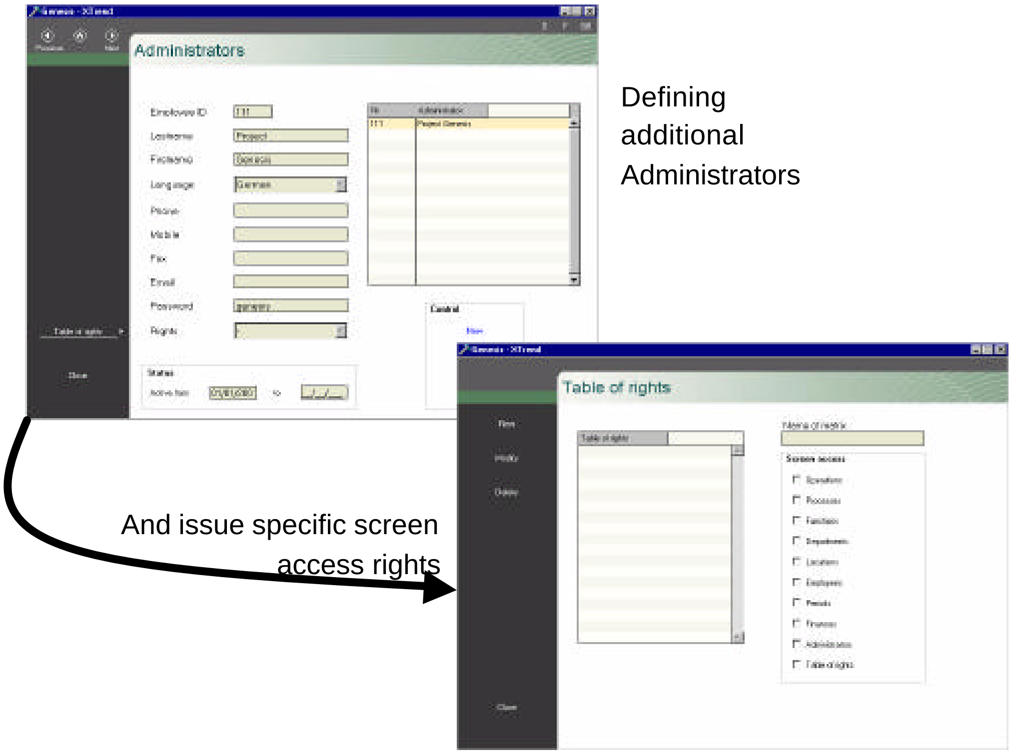

Figure 36: Defining administrators and access rights

5.3.2.2 Process step 2: data entry resource distribution

The second process step in the data collection process is data entry for resource distribution. All employees identified in the system can now access the system and allocate 100% of their effort spent on the predefined innovations and processes. XTrend has two levels of resource data entry (figure 37). The first screen shows the selection of available innovations from which the employee can make their choice. By clicking on the respective innovation the employee is enabled, through a user-friendly interface, to select the percentage of their effort (of a total of 100%) to the available innovations. For example if the systems aims to measure the venturing of an innovation X, the system will ask the employees to how much effort each individual has spent on this innovation in the measurement period. Assume that in this case a sales engineer has worked 70% of his time on the existing product portfolio, and spent 30% on innovation X. The first data entry step will collect this information from the sales engineer.

The second data entry level is concerned with the effort spent on the specific sub-process that belong to the innovation under measurement. In this case the relative distribution of the effort allocated to the innovation in total of each employee is divided over the predefined sub-processes. In order to encourage usage, the employee does not have to make the calculation but again can allocate a full 100% over the sub-processes. In the example, assume three sub-processes (A, B and C) are relevant for innovation X. In step 2, the sales engineer is asked to allocate his efforts over these three sub-processes. The sales engineer does not have to start from his initial 30%, but can start from a 100%. He can thus allocate for example 20% to sub-process A, 50% to sub-process B and 30% to sub-process C.

During the development it was found that this way it is easier and quicker for the employees to use the system, as the mathematical breakdown is done by the system. Tests revealed that the system requires a maximum of five minutes input time per period for each employee. Employees are thus not unnecessarily burdened with additional administrative tasks which ultimately encourages participation.

As previously described the start-up and close down of the system is similar as in process step 1.

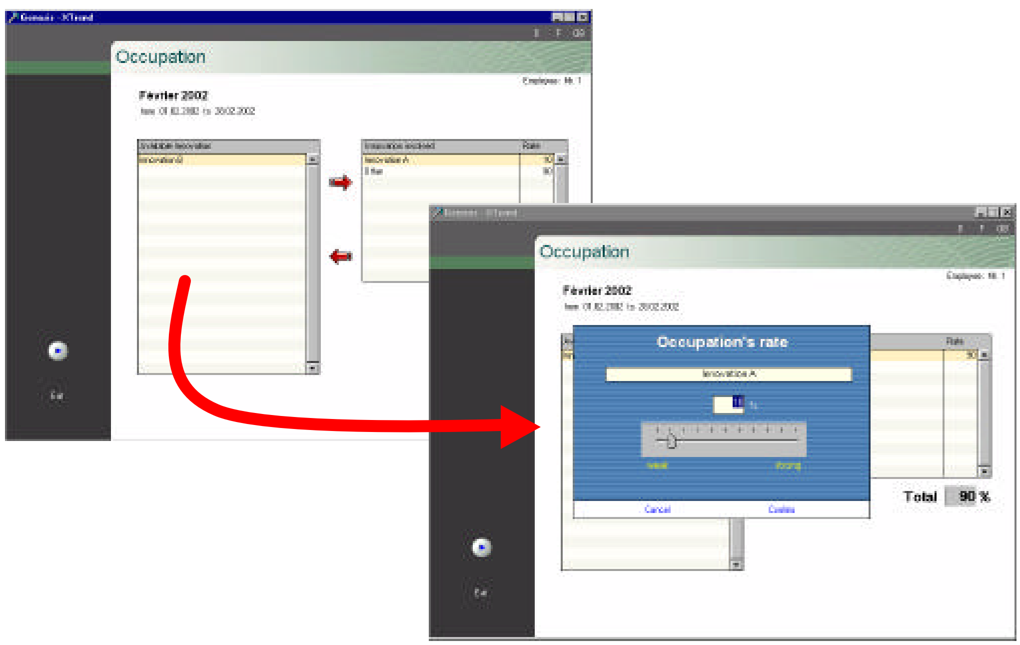

Figure 37: User friendly interface to allocate resources

5.3.2.3 Process step 3: data entry financial distribution

Process step 3 relates to the collection of the data concerning the relative financial performance or rent created out of a specific innovation. This indicator should be taken as relative of the total rent created in a predefined context (e.g. a division or firm). The administrator is responsible for the precise definition of the context and input of this figure. For example, a manager of a technology-based firm can decide to measure the earnings of innovation A against the total earnings created by the firm over a predefined period. This can for example be in the first month of introducing innovation A to the market the earning created out of this innovation is 10% of the total earnings that period. The frequency is similar to the data collection for the resource parameter so comparable trends can be constructed.

An optional set-up process is integrated in the system that allows the administrator to define the financial indicator in the various possibilities. In the set-up menu a dedicated window exists for defining the indicator (figure 38). This setup menu also allows for redefining the term innovation (in case a division only works with products or services in which case the term innovation might cause confusion).

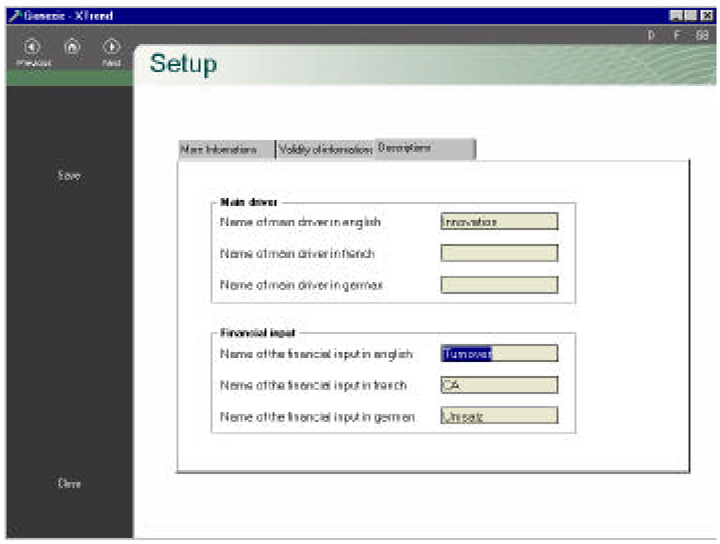

Figure 38: Optional set-up for redefinition of innovation and financial Indicator

The value input for the indicator is depicted in figure 39. The administrator can define the nature of this indicator based on its relevance to the firm. In cases where this information is sensitive, a value ranking can also be given that still produces a relative result. Nevertheless, it is important to bear in mind that the performance indicator should reflect the rent created from the efforts spent on a particular innovation, and it thus seems appropriate not to add any additional indirect costs.

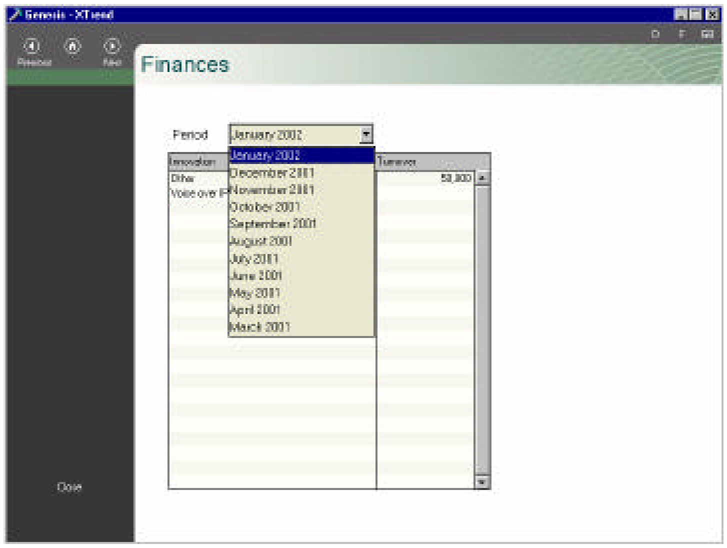

Figure 39: Finance data entry screen

The system is developed to allow for future interface capabilities (for example with SAP), in order to minimise the effort. However, in the prototype stage it was decided that a manual data entry was preferred.

5.4 PRELIMINARY SYSTEM TEST – A THOUGHT EXPERIMENT

Together with the two case companies, a "thought experiment" has been constructed to test the system's reporting capabilities. A thought experiment is an experiment that is based on fictional, simplified data, though this data has been confirmed as a realistic representation of reality by the case companies. The validity of the simplified thought experiment stems from the iterative development of the experiment. Furthermore, interviews and discussion with an external review board have been held and incorporated in the construction of the thought experiment. This review board was made up of consultants, academics, other industry players and funding bodies[20]. This thought experiment will be used to introduce the mathematical underpinnings of the system.

The thought experiment is constructed using an example of a fictional company X and its respective innovation patterns and venturing process. Company X takes the characteristics as identified on a divisional level in large high technology companies, where new products/service/businesses (hereafter called "innovations") are developed on a dynamic and continuous basis.

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[20] The workshops and review board formed part of the "Genesis" project, funded by the EU under the IST 5th Framework program.

The data selected for testing the system are interpreted as to reflect a situation whereby company X is building a dynamic capability in the venturing process. The underlying assumption is that company X can only create value out of innovations by rapidly exploiting these innovations.

The thought experiment follows the introduction of two consecutive innovations, A and B, over a period of five months each. The complete measurement period of the experiment is 11 months, with innovation A being introduced into the early adopter market in March 2001 and innovation B introduced in September 2001. Measurements are executed on a monthly basis.

The input and output parameters have been defined following the alternative productivity formula. The input variable used in the experiment is total resources used per innovation (A and B) in relation to the rest of the business (other). Resources in this case are the value of the allocated time to the processes of innovation A and B. In order to simplify the underlying principles, the example considers only five people actively working in company X, consisting of five full-time employees. The output variable is based on a concrete financial measure related to profit. The main indicator for company X has been defined as the net contribution per innovation on a monthly basis, as a part of the total net contribution.

$$PR_A(t) = \frac{NetCon_A(t)}{ResAl_A(t)} \qquad (4)$$

Where:

PR = Productivity Ratio for Company X

A = New Technology-Based Venture A

t = time

NetCon= the output defined as net contribution of A as a percentage of total net contribution of firm

ResAl = the input defined as resources allocated to the venturing processes of A as a percentage of total resources available to the total process portfolio

The sub-processes in the example reflect the three critical sub-processes observed in the integration phase. Each innovation has been allocated three sub-processes. These sub-processes are labelled accordingly, for innovation A as: A1, A2, A3, and for innovation B as: B1, B2, B3. This data will be used to perform the in-depth process analysis.

5.4.1 The expectations for company X

Company X has a set of expectations related to the active building of dynamic capabilities. Since the venturing process is now better managed and changed, company X expects better performance in the vital introduction of an innovation onto the market, and the successful take up of this innovation.

These expectations are similar to those set out in the development of the proxy for dynamic capabilities. In the first period the company expects high resource allocation to a particular innovation. In addition, not a lot of profit will be made in this first period and hence the financial indicator – the net contribution of the innovation – will be low in the first periods. However over the course of the product life cycle of this innovation, the expectation is that resource allocation will go down. The dynamic capability provides the company with the capability of dynamically building, reconfiguring and streamlining the process portfolio of the company; hence it should not take the company long to utilise these processes. Furthermore, the net contribution is expected to rise due to increased sales.

In addition, company X also expects to see not only improvements on the basis of one innovation, but also a progressive trend for future ventures. In other words innovation B ought to show a better productivity trend compared to innovation A.

It is important to note here that the system measures one perspective of the innovation process concerned with understanding the specific commercialisation uncertainty high-tech companies face. Obviously there are numerous other factors that can influence the performance of the processes. The system does not aim to provide direct decision-making advice, but aims to help understand one part of this uncertainty. If trends appear that do not support the above straight-line thinking, it is important that explanations can be found why the trend deviates from the expectation. For example when the system is monitoring a strategic development – whereby a high investment is required to prepare a new market – a different pattern might be expected (more resources invested, less direct returns). This anticipation should be reflected in the trends produced by the system, thereby clarifying the measurement.

Performance measures should always be complemented by the managerial judgement or qualitative view of the situation. To illustrate this important matter, take the example of a car. In a car, various performance measurement instruments tell the driver something about the drive, but the driver is bound to end up in trouble if they only stare at one of these dials. There is a similar situation for performance measures in companies. Only when the decision maker takes in the full spectrum of interpretations and its context can a judgment been made. The measures proposed here should thus also be regarded as complementary to existing measures.

Finally, with respect to the in-depth understanding and location of where uncertainty resides in the sub-processes, the in-depth analysis has been tested. The aim is to identify the potential of such in-depth understanding in the light of the case study findings.

In summary, based on detailed data set, three levels of analyses will be reported using the prototype XTrend. Firstly the productivity trends will be presented and discussed. Secondly, an elaboration on the in-depth analysis will further the evaluation of the process performance. The testing phase will conclude with the evaluation of the experimental dynamic capability trend and the interpretation to the expectations set out in this experiment.

A comprehensive data set has been constructed to simulate the thought experiment. The data set comprises of all the values that have been entered into the system in order to produce the subsequent trends. The data set is split up in three sections:

- Resource allocation data on the level of the venturing process of an innovation in the integration period, compared to resources allocated to the rest of the process portfolio

- Resource allocation data on the level of the sub-processes of the venturing process

- Financial Data (net contribution) on the level of the innovations as a percentage of the total net contribution generated by the firm.

The first two levels address the input of the employees, whereas the last set is concerned with the data input on the management level.

Based on this data set, XTrend allows for the effective reporting of the measurement proxies of resource allocation, net contribution, productivity trend and dynamic capabilities, as well as a sub-process analysis. Firstly, a resource allocation trend is created over time, to identify the behaviour of the resource distribution in the critical phase of the venturing process. Secondly, a financial performance allocation trend shows the return on the innovations. Thirdly, these two patterns are combined to establish a coherent view of how each of the two patterns behaves over time and how they compare. Finally, the alternative productivity formula is used to produce the dynamic capability trend.

The next sections will discuss the respective data sets of the thought experiments, the calculations and the XTrend reports in the following order:

- Resource Allocation
- Net Contribution
- Productivity Trend
- Dynamic Capability Trend
- In-depth sub-process analysis

5.4.2 Resource allocation

5.4.2.1 Data set and calculations for resource allocation

The values for the data concerning the resource allocation on the level of the innovation are based on a collection of all individual inputs of the employees. In the thought experiment five employees have been identified: Mr. 1, Mrs. 2, Mr.3, Ms. 4, and Mr. 5. These employees have entered the data in the first access screen after starting up the application.

These five employees in total have entered five values for each innovation, over the five months that these innovations have been monitored. In total, 10 values per person (two lots of five periods) have been defined. An overview is provided in table 10 for innovation A, and table 11 for innovation B.

INNOVATION A			PERIOD				
	COST (€) / YR	COST (€) / MONTH (CE)	MAR-01	APR-01	MAY-01	JUN-01	JUL-01
MR. 1	100,000	8,333.33	**20%**	**20%**	**15%**	**15%**	**20%**
MRS. 2	50,000	4,166.67	**40%**	**35%**	**30%**	**30%**	**30%**
MR. 3	150,000	12,500.00	**30%**	**50%**	**45%**	**40%**	**30%**
MS. 4	120,000	10,000.00	**20%**	**10%**	**20%**	**20%**	**20%**
MR. 5	80,000	6,666.67	**15%**	**15%**	**15%**	**15%**	**10%**
TOTAL	500,000	41,666.67	10,083.33	11,375.00	11,125.00	10,500.00	9,333.33
RELATIVE RESOURCE ALLOCATION			**24.2%**	**27.3%**	**26.7%**	**25.2%**	**22.4%**

Table 10: Resource allocation for innovation A

INNOVATION B			PERIOD				
	COST (€) / YR	COST (€) / MONTH (CE)	SEP-01	OCT-01	NOV-01	DEC-01	JAN-02
MR. 1	100,000	8,333.33	**20%**	**20%**	**15%**	**15%**	**15%**
MRS. 2	50,000	4,166.67	**30%**	**30%**	**30%**	**30%**	**25%**
MR. 3	150,000	12,500.00	**50%**	**50%**	**30%**	**25%**	**15%**
MS. 4	120,000	10,000.00	**15%**	**10%**	**20%**	**20%**	**20%**
MR. 5	80,000	6,666.67	**15%**	**15%**	**10%**	**10%**	**10%**
TOTAL	500,000	41,666.67	11,666.67	11,166.67	8,916.67	8,291.67	6,833.33
RELATIVE RESOURCE ALLOCATION			**28%**	**26.8%**	**21.4%**	**19.9%**	**16.4%**

Table 11: Resource allocation for innovation B

The first column represents the five employees. The second column represents a weighting factor. Each employee has been attributed a weighting, which in this case is reflected by their yearly salary costs. This information is provided by the manager/administrator during the set-up of the system. Furthermore, each person represents a full time employee. In this simplified experiment the assumption is made that no alterations took place on the individual level concerning their salary or time.

The third column represents the value per interval period. In order to create the monthly value of the time allocated, the salary is divided by the amount of intervals over the yearly salary. In the experiment, monthly intervals have been selected, which results in a monthly value per person of salary divided by 12. For example salary costs for Mr. 3 are set at €150,000. Per month these costs are €12,500.

The total cost of all employees can be calculated as the sum of all individual monthly costs:

$$C_{total} = \sum_{e=1}^{n} C_e \qquad (5)$$

Where,
C_{total} = Total Costs of Employees
C_e = Cost of Employee (e)
n = number of employees

In the experiment for both innovations this is €41,666.67.

The remaining columns represent the actual data from the employees in each respective month the innovation was monitored. For example Mr. 1 spent 20% of total his time on innovation B in September 2001, 20% in October, and 15% in November, December and January.

The figure used for the respective graphs is represented by the bottom row, *relative resource allocation*. This row represents a calculation of the percentage allocated to each innovation per month and thus equals ResAl(t). The cost per month of each employee is taken into account as to allow for a proper weighting of the various employees and their relative values. Obviously, a secretary costs less than a top engineer, and hence this should be reflected in the total percentage allocated.

The calculation is based on a formula that multiplies the monthly percentage of resource allocation by the cost per month. The formula is as follows:

$$ResAl(t) \quad \frac{\sum_{e=1}^{n} [R_a C_e]}{C_{total}} \qquad (6)$$

Where, R_a = Resource allocation to innovation (a) as a percentage of total (employee input)

a = Innovation

ResAl = percentage of total value of resources spent

t = Time

For example, the resource allocation for innovation B in September is calculated as follows:

$$\frac{[(20 \text{ x } 8{,}333.33) + (30 \text{ x } 4{,}166.67) + (50 \text{ x } 12{,}500.00) + (15 \text{ x } 10{,}000.00) + (15 \text{ x } 6{,}666.67)]}{41{,}666.67} = 28$$

The resource allocation to innovation B in the month September 2001 is thus 28 % of the total resources allocated from the sample. These percentages form the first concrete sets of measurements for the productivity measurement.

5.4.2.2 XTrend reporting on resource allocation – *resource indicator*

The resource indicator visualises the behaviour pattern of the relative changes in resource distribution to innovation A and innovation B. Both innovations are measured in their respective time period, the critical phase in the venturing process. Innovation A is measured from March 2001 to July 2001, and innovation B from September 2001 to January 2002. Five intervals have been set to compare the data. The graphs of innovation A and innovation B are depicted in figure 40.

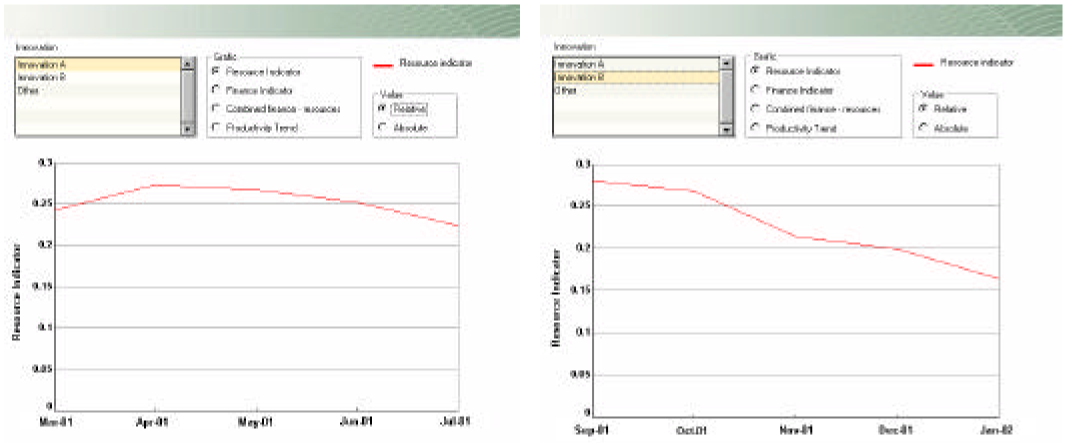


Figure 40: Resource indicators for company X

Following the general expectations set out in the thought experiment, both patterns follow a declining line. During the integration phase of a new innovation in the productive base of the organisation, it is expected that at first a lot of resources will have to be allocated to the integration of the innovation in the main operational process. As routines start to develop, a reduction of resources spent on a particular innovation can be expected.

Furthermore, a first observation regarding the differences between A and B shows that innovation B has a steeper decline than innovation A. Company X is under the assumption that dynamic capabilities are being developed. Following this assumption, a preliminary statement might be that, since the organisation is better able to handle this critical phase the second time round (with innovation B), the pattern of resource allocation should be more favourable and predictable in comparison to innovation A. Nevertheless this only provides half the picture, as there are numerous other reasons why this pattern might be as it is. For example, it is possible that because the financial returns are not showing any result, the company is spending less time on innovation B and slowly letting it exit their system.

Other external factors can also have an influence on the behaviour of this pattern. Although the thought experiment follows a simplified simulation of the venturing process, it is necessary to acknowledge that resource allocation alone does not provide the full story on the integration capabilities of the company. Hence uncertainty still remains if this graph is interpreted on a standalone basis.

5.4.3 Net contribution

5.4.3.1 Data set and calculations for net contribution

The management input required to establish the data set relates to the net contribution an innovation has made as a percentage of the total net contributions of the product portfolio. The administrator/manager inputs this data. In the thought experiment the following simplified values have been selected.

Financial Performance Innovation A					
Period	Mar-01	Apr-01	May-01	Jun-01	Jul-01
Net Contribution of Innovation A (in €)	20,000	30,000	30,000	40,000	35,000
Total Contribution of Product Portfolio (in €)	100,000	100,000	100,000	100,000	100,000
Relative Net Contribution (as % of Total)	**20%**	**30%**	**30%**	**40%**	**35%**

Table 12: Net Contribution of innovation A

Financial Performance Innovation B					
Period	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02
Net Contribution of Innovation B (in €)	20,000	25,000	35,000	40,000	50,000
Total Contribution of Product Portfolio (in €)	100,000	100,000	100,000	100,000	100,000
Relative Net Contribution (as % of Total)	**20%**	**25%**	**35%**	**40%**	**50%**

Table 13: Net contribution of innovation B

These values form the output values for the productivity formula to calculate the productivity and dynamic capability trends.

5.4.3.2 XTrend reporting on financial performance– *finance indicator*

XTrend provides direct reports of the financial performance patterns of both innovations over time. Based on the data entries made by the manager/administrator, a pattern is created to evaluate the fluctuations of the performance over the period. Both patterns are reported over a similar time span as the resource indicator, with similar measurement intervals. The graphs are depicted in figure 41.

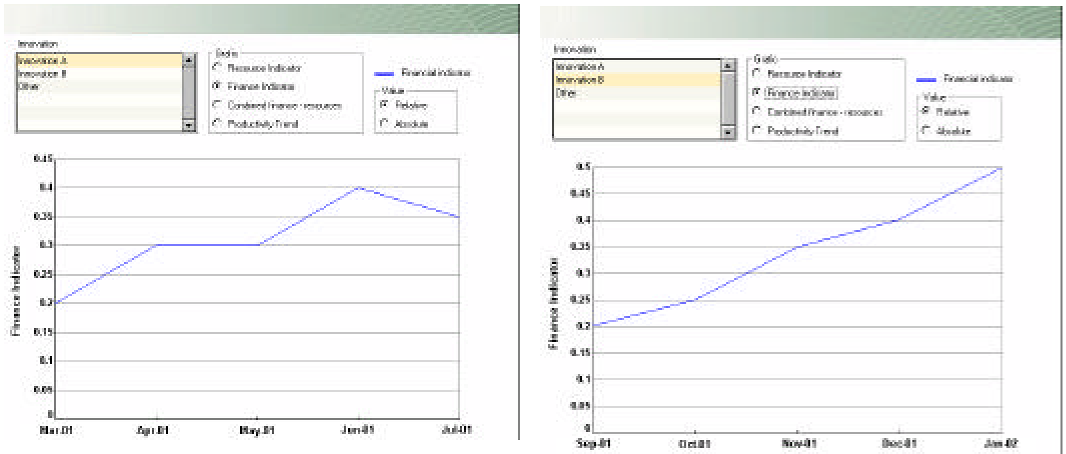


Figure 41: Financial indicators for company X

The patterns in the financial indicator graphs both show increasing financial performance. This is according to the expectations of company X. As the venturing process utilises the productive base of the firm, more profitable markets are reached and thus the net contribution of the innovations increases.

A comparison between A and B again projects a line that follows the assumptions made about the installation of dynamic capabilities. The line for innovation B is smoother and steeper than the line of innovation A. Nevertheless, similar to the resource indicator, a standalone interpretation is not sufficient to draw any meaningful conclusions with respect to the comprehension of the uncertainty in this critical phase.

5.4.4 XTrend calculations and reports on productivity trend

Based on the above data set, the proxy for productivity can be calculated. Firstly, however, a combination graph can be reported to see how the respective finance and resource indicators relate to each other. This has been included to provide managers with a *feel* for how the two trends relate to each other.

5.4.4.1 Combined finance -resource indicators

The third trend projects both the resource and financial indicators in their respective time frames. This graph is referred to as the combined finance-resource indicator. The trend allows for a combination of the two lines, to see how the financial indicator of net contribution (output of the processes) relates to the value of resources allocated to the processes (input). The graphs of both innovation A and B are depicted in figure 42.

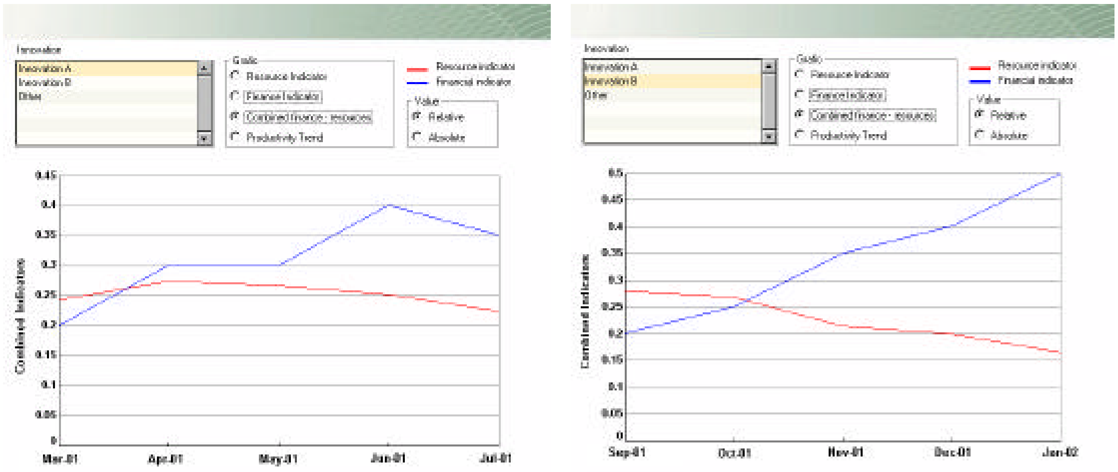


Figure 42: Combined Finance-Resources indicators for Company X

Here it becomes apparent how the input and output relate to one another. Both lines follow the initial expectation that resource allocation to a newly introduced innovation to the market will decline whilst financial performance (net contribution) per month will increase. As noted in the previous graphs, the curves of innovation B are steeper and smoother than innovation A.

5.4.4.2 Productivity ratios and trend

Based on this data the productivity ratios, $PR_A(t)$, can be calculated using formula (4) in section 5.4. In numerical form the ratios have been calculated as follows:

INNOVATION A	PERIODS				
	MAR-01	APR-01	MAY-01	JUN-01	JUL-01
FINANCIAL INDICATOR (F)	20%	30%	30%	40%	35%
RESOURCE INDICATOR (R)	24.2%	27.3%	26.7%	25.2%	22.4%
PRODUCTIVITY RATIO (F/R)	**0.83**	**1.10**	**1.12**	**1.59**	**1.56**

Table 14: Calculation of the productivity ratios for innovation A

INNOVATION B	PERIODS				
	SEP-01	OCT-01	NOV-01	DEC-01	JAN-02
FINANCIAL INDICATOR (F)	20%	25%	35%	40%	50%
RESOURCE INDICATOR (R)	28%	26.8%	21.4%	19.9%	16.4%
PRODUCTIVITY RATIO (F/R)	**0.71**	**0.93**	**1.64**	**2.01**	**3.05**

Table 15: Calculation of the productivity ratios for innovation B

The table shows the calculations based on the data set provided in the previous chapters. The productivity ratio (output divided by the input) is calculated at one point in time, so as to visualise the relation between these parameters. This trend effectively visualises the uncertainty relation between the measures to evaluate the pattern.

For example, for innovation B in September 2001, the relative financial indicator was calculated as 20%, and the resource indicator as 28%. The relative productivity ratio that follows is 20/28, which equals 0.71. This ratio on its own has little meaning, as the underlying values can vary enormously. However projected over time, it does show how this interpretation of productivity behaves as a trend (figure 43):

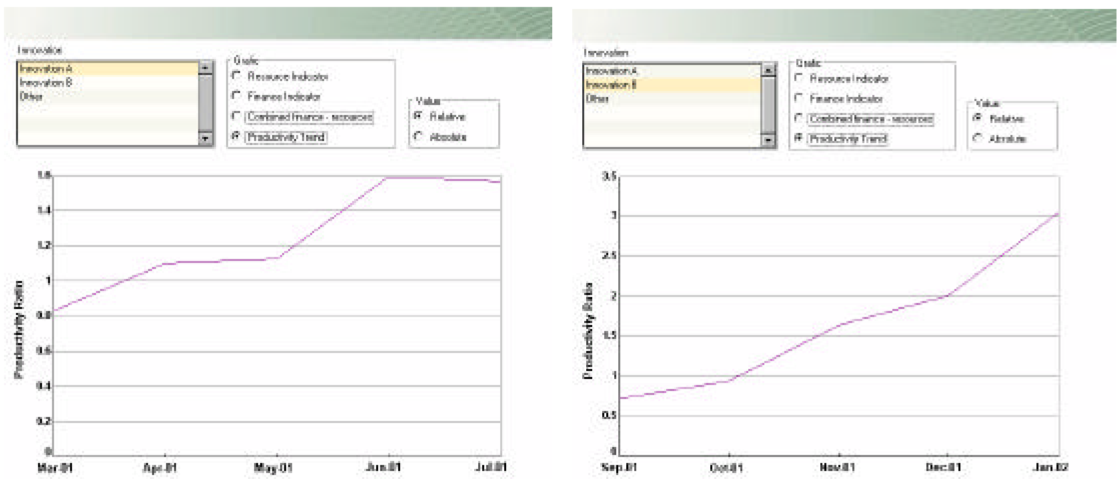


Figure 43: Productivity trends for innovation A and B

This simulation is now based on dynamic subjective figures of input and output. These subjective elements taken together are aimed at sharpening the judgement of the decision maker about the uncertain relationship between resource commitments versus performance of specific technology ventures.

In the thought experiment, the simulation shows that both trends represent an increase in productivity. Innovation A sees an increase in the ratio of approximately 0.8 over five months, whereas for innovation B an increase in the ratio of approximately 3.2 has been achieved.

A typical evaluation of the above data and graphs shows how the venturing process improved. In other words, the expectations are met in that the pattern of innovation B shows a more rapid and steeper increase in comparison with innovation A.

Applied to a variety of innovations over a wider time span (or measurement intervals) these trends enable the company to better understand this pattern. The productivity pattern projects whether or not the company possesses the capability to commercialise the innovations effectively and according to a (short-term) plan and external factors. If the pattern shows a deviation from the company's expectations, actions can be taken towards a deeper analysis in order to understand the underpinnings of the behaviour of the pattern.

As with any interpretation of data, it is important to note that these graphs do not make a decision or suggest making any statements by claiming there is a direct causal link between short-term performance and the quality and effectiveness of process management. The data provides a basis on which interpretation and expectations can be valued and monitored, and hence provides additional and complementary measures.

5.4.5 XTrend calculations and reports on dynamic capability trend

The final analysis is the DC Trend (or Dynamic Capability Trend). The DC Trend aims to provide the organisation with an understanding of their capability to change their process portfolio on a routine basis. The concept stems from a theoretical background set out in the requirement analysis phase.

In the thought experiment, following innovations A and B, the DC Trend can be constructed by comparing the two innovations' active periods, and measuring the difference in behaviour. An overview of the values based on the calculations is provided in table 16.

DC TREND					
INNOVATION A	1	2	3	4	5
SELECTED PERIOD RANGE	MAR-01	APR-01	MAY-01	JUN-01	JUL-01
PRODUCTIVITY RATIO (F/R)	0.826	1.099	1.124	1.587	1.563
INNOVATION B					
SELECTED PERIOD RANGE	SEP-01	OCT-01	NOV-01	DEC-01	JAN-02
PRODUCTIVITY RATIO (F/R)	0.714	0.933	1.636	2.010	3.049
DC TREND [(B-A)/A]	**-0.136**	**-0.151**	**0.456**	**0.266**	**0.951**

Table 16: Calculation of the dynamic capability trend for company X

The DC-Trend compares the two productivity ratios used to calculate the productivity trend. Firstly, the five monthly measurement points are compared as follows:

DC TREND PHASE (PH)	*TIME (INNOVATION A)*	*TIME (INNOVATION B)*
1	t = 1 = March 2001	t = 7 = September 2001
2	t = 2 = April 2001	t = 8 = October 2001
3	t = 3 = May 2001	t = 9 = November 2001
4	t = 4 = June 2001	t = 10 = December 2001
5	t = 5 = July 2001	t = 11 = January 2002

Table 17: Defining comparable critical phases for the DC Trend

The DC Trend ratio is calculated as the Productivity Ratio (PR) of innovation B minus the PR of innovation A, divided by the PR of innovation A (following formula 3 from section 4.5). As a reminder, the formula is as follows:

$$DC_{A-B(ph)} = \frac{PR_B(t) - PR_A(t)}{PR_A(t)} \quad (3)$$

For example, in phase 1, the relative DR of innovation A equals 0.826. The DR of innovation B in the same phase equals 0.714. The dynamic capability ratio now equals [(0.714-0.826)/0.826] which is –0.136.

The pattern created is referred to as the Dynamic Capability Trend (see figure 44).

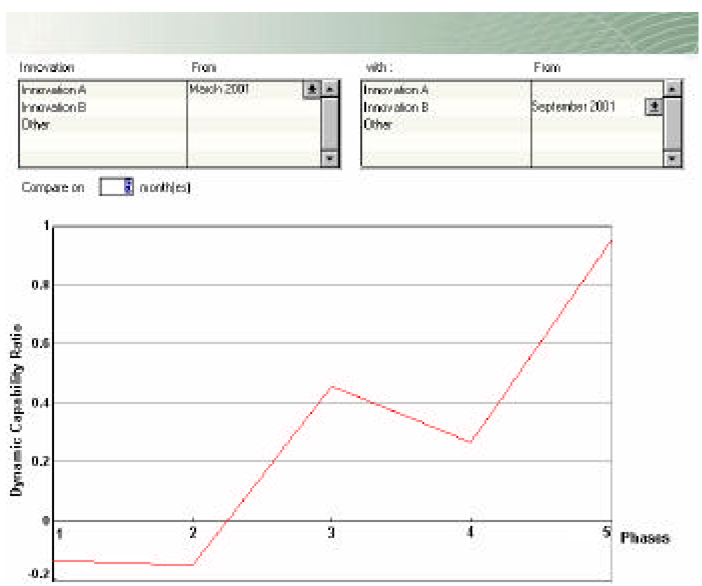


Figure 44: Dynamic capability trend for company X

The graph represents the dynamic capability ratio in the respective phases of the integration of a venture into the operational system. This graph shows a relative increase in the alternative productivity of innovation B against innovation A. The line is positive and hence can be interpreted in the context of the thought experiment as indicating an increase in dynamic capabilities.

However as mentioned previously, the line produced here does not unilaterally state that the company is doing a good job, nor is this line the only possible outcome, as the inputs are subjectively defined. Other factors play a major role, such as the comparability of the innovations (some are expected to have a longer life-span than others). Furthermore the trend is subject to strategic implications, for example introducing new products and services can also be a strategic investment for the company. In such cases, losses are often anticipated and accepted as other objectives are seen as temporarily more important (e.g. creating a large market share).

The next section will evaluate the proxy as well as the system by comparing it to a qualitative analysis of dynamic capabilities in order to determine if the representation is similar as the qualitative data suggests. Furthermore, if this is the case, the measure shows fluctuations in the dependent variable of dynamic capabilities in the probabilistic process model. This would imply that the existence of dynamic capabilities, as identified by the proxy, should have increased the likelihood of overall good performance.

5.4.6 In-depth sub-process analysis

Further to the productivity and dynamic capabilities trend, that aim to provide the measures for the uncertainty relation in a more generic fashion, an in-depth analysis has been integrated into the XTrend application as a starting point for pinpointing and evaluating seemingly troublesome sub-processes. The level of detail used in the thought experiment relates to the main three sub-processes, as specified during the requirement phase.

- sub-process 1: Sales and customer oriented processes
- sub-process 2: Specific innovation related processes
- sub-process 3: Installation and After sales processes

XTrend allows for a further breakdown into detail, by the dimensions of department, location and function. These requirements have been integrated based on the importance stressed in the case studies.

During the case studies, it was identified that particularly in sub-process A (comparable to the sales and customer relation management processes) there was over-proportional resource allocation. In one of the cases this was also location specific. After close examination, it was found that in one region the greatest efforts were invested in the sales and customer relation management process, compared to the other sub-processes, but this did not bring about any additional results. In stark comparison, another region created much better results without the extreme investment in these specific processes. This was interpreted by management as a lack of process efficiencies in the under performing region and subsequent actions to resolve this matter were instigated.

The company immediately reinforced proactive process engineering activities in order to change and improve the process efficiency of the sub-processes of sales and customer relation management.

Based on this observation, the development of the prototype incorporates a potential breakdown of the resource allocation to the sub-processes.

5.4.6.1 Data set and calculations for in-depth analysis

In addition to the relative resource distribution to the respective innovations, the employees are asked to provide their resource allocation on the sub-processes for both innovations. In order to simplify this process for the employees, they can distribute their total effort (100%) over the various sub-processes per innovation. In other words, if an employee allocated 15% to an innovation, this number does not have to be carried forward and split between the three sub-processes. In the thought experiment the situation is simplified since the innovations do not overlap each other.

An overview of the data set values of the resource distribution as selected for the thought experiment is presented in table 18 for innovation A, and table 19 for innovation B.

SUB-PROCESS A1			**Resource Allocation** (Re)					**To Sub-process A1** (X)				
Employee (e)	Cost /yr	Cost/month (Ce)	to Innovation A (a)					Resource Allocation to Sub-process A1 (SubA1) at month (t)				
			Mar-01	Apr-01	May-01	Jun-01	Jul-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01
Mr. 1	100,000	8,333.33	20	20	15	15	20	**10%**	**10%**	**5%**	**5%**	**0%**
Mrs.2	50,000	4,166.67	40	35	30	30	30	**20%**	**25%**	**20%**	**70%**	**100%**
Mr. 3	150,000	12,500.00	30	50	45	40	30	**90%**	**90%**	**90%**	**90%**	**90%**
Ms. 4	120,000	10,000.00	20	10	20	20	20	**50%**	**60%**	**65%**	**60%**	**55%**
Mr. 5	80,000	6,666.67	15	15	15	15	10	**60%**	**80%**	**80%**	**80%**	**80%**
Total (C_{total})	500,000	41,666.67						5,475.00	7,556.25	7,475.00	7,437.50	6,258.33
Total(ResAl)								**13%**	**18%**	**18%**	**18%**	**15%**

SUB-PROCESS A2			**Resource Allocation** (Re)					**Sub-process A2** (X)				
Employee (e)	Cost/yr	Cost/month (Ce)	to Innovation A (a)					Resource Allocation to Sub-process A2 (SubA2) at month (t)				
			Mar-01	Apr-01	May-01	Jun-01	Jul-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01
Mr. 1	100,000	8,333.33	20	20	15	15	20	**50%**	**40%**	**50%**	**30%**	**30%**
Mrs.2	50,000	4,166.67	40	35	30	30	30	**50%**	**40%**	**45%**	**15%**	**0%**
Mr. 3	150,000	12,500.00	30	50	45	40	30	**5%**	**5%**	**5%**	**5%**	**5%**
Ms. 4	120,000	10,000.00	20	10	20	20	20	**25%**	**20%**	**15%**	**15%**	**10%**
Mr. 5	80,000	6,666.67	15	15	15	15	10	**40%**	**5%**	**5%**	**5%**	**5%**
Total	500,000	41,666.67						2,754.17	1,812.50	1,818.75	1,162.50	920.83
Total (ResAl)								**7%**	**4%**	**4%**	**3%**	**2%**

SUB-PROCESS A3			**Resource Allocation** (Re)					**Sub-process A3** (X)				
Employee (e)	Cost/yr	Cost/month (Ce)	to Innovation A (a)					Resource Allocation to Sub-process A3 (SubA3) at month (t)				
			Mar-01	Apr-01	May-01	Jun-01	Jul-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01
Mr. 1	100,000	8,333.33	20	20	15	15	20	**40%**	**50%**	**45%**	**65%**	**70%**
Mrs.2	50,000	4,166.67	40	35	30	30	30	**30%**	**35%**	**35%**	**15%**	**0%**
Mr. 3	150,000	12,500.00	30	50	45	40	30	**5%**	**5%**	**5%**	**5%**	**5%**
Ms. 4	120,000	10,000.00	20	10	20	20	20	**25%**	**20%**	**20%**	**25%**	**35%**
Mr. 5	80,000	6,666.67	15	15	15	15	10	**0%**	**15%**	**15%**	**15%**	**15%**
Total	500,000	41,666.67						1,854.17	2,006.25	1,831.25	1,900.00	2,154.17
Total (ResAl)								**4%**	**5%**	**4%**	**5%**	**5%**

Table 18: Resource distribution sub-processes for innovation A

SUB-PROCESS B1			**Resource Allocation** (Re) to Innovation B (a)					**Subprocess B1 (X)** Resource Allocation to Sub-process B1 (SubB1) at month (t)				
Employee (e)	Cost/yr	Cost/month (Ce)	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02
Mr. 1	100,000	8,333.33	20	20	15	15	15	**10%**	**10%**	**5%**	**5%**	**0%**
Mrs.2	50,000	4,166.67	30	30	30	30	25	**20%**	**25%**	**20%**	**70%**	**100%**
Mr. 3	150,000	12,500.00	50	50	30	25	15	**50%**	**70%**	**60%**	**50%**	**35%**
Ms. 4	120,000	10,000.00	15	10	20	20	20	**50%**	**60%**	**65%**	**60%**	**55%**
Mr. 5	80,000	6,666.67	15	15	10	10	10	**60%**	**80%**	**80%**	**80%**	**80%**
Total	500,000	41,666.67						4,891.67	6,254.17	4,395.83	4,233.33	3,331.25
Total (ResAl)								**12%**	**15%**	**11%**	**10%**	**8%**

SUB-PROCESS B2			**Resource Allocation** (Re) to Innovation B (a)					**Subprocess B2 (X)** Resource Allocation to Sub-process B2 (SubB2) at month (t)				
Employee (e)	Cost/yr	Cost/month (Ce)	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02
Mr. 1	100,000	8,333.33	20	20	15	15	15	**50%**	**40%**	**50%**	**30%**	**30%**
Mrs.2	50,000	4,166.67	30	30	30	30	25	**50%**	**40%**	**45%**	**15%**	**0%**
Mr. 3	150,000	12,500.00	50	50	30	25	15	**40%**	**15%**	**30%**	**45%**	**35%**
Ms. 4	120,000	10,000.00	15	10	20	20	20	**25%**	**20%**	**15%**	**15%**	**10%**
Mr. 5	80,000	6,666.67	15	15	10	10	10	**40%**	**5%**	**5%**	**5%**	**5%**
Total	500,000	41,666.67						4,733.33	2,354.17	2,645.83	2,302.08	1,264.58
Total (ResAl)								**11%**	**6%**	**6%**	**6%**	**3%**

SUB-PROCESS B3			**Resource Allocation** (Re) to Innovation B (a)					**Subprocess B3 (X)** Resource Allocation to Sub-process B3 (SubB3) at month (t)				
Employee (e)	Cost/yr	Cost/month (Ce)	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02
Mr. 1	100,000	8,333.33	20	20	15	15	15	**40%**	**50%**	**45%**	**65%**	**70%**
Mrs.2	50,000	4,166.67	30	30	30	30	25	**30%**	**35%**	**35%**	**15%**	**0%**
Mr. 3	150,000	12,500.00	50	50	30	25	15	**10%**	**15%**	**10%**	**5%**	**30%**
Ms. 4	120,000	10,000.00	15	10	20	20	20	**25%**	**20%**	**20%**	**25%**	**35%**
Mr. 5	80,000	6,666.67	15	15	10	10	10	**0%**	**15%**	**15%**	**15%**	**15%**
Total	500,000	41,666.67						2,041.67	2,558.33	1,875.00	1,756.25	2,237.50
Total (ResAl)								**5%**	**6%**	**5%**	**4%**	**5%**

Table 19: Resource distribution sub-processes for innovation B

In order to calculate the distribution of the resources over the specific sub-processes, the cost factor has to be taken into account (C_e), as well as the individual resource allocation to the innovation related to the processes (R_e). As previously mentioned, the employees only have to allocate 100% over the sub-processes. No further breakdown is necessary.

For example, take the sub-process B1 in the period September 2001. The employees have inputted the following data: 10%, 20%, 50%, 50%, and 60%. These are the percentages allocated by the employees to sub-process B1 from the total of 100% over B1 to B3. The first consideration is similar to the calculation of the resource distribution over a particular innovation, that each employee has a cost factor (C_e). This is the total cost of the employee in that month. Secondly, the employees have not worked for the full 100% in the sub-processes B1-B3, but according to the resource allocation to the innovation B, only a percentage of their time (R_e). In this case this was, R_{Mr1}=20%, R_{Mrs2}=30%, R_{Mr3}=50%, R_{Ms4}=15, and R_{Mr5}=15, for the month of September. These individual percentages are taken from the resource distribution input of the employees to innovation A.

The formula is as follows:

$$ResAl_{Xe}(t) = \frac{\sum_{e=1}^{n} [(C_e/100)R_{ae}Sub_{eX}]}{C_{total}} \qquad (7)$$

Where, $ResAl_{Xe}$ = Percentage of total value of resources allocated to a subprocess X of Innovation a

Sub_{eX} = Percentage of total resources allocated to sub-processes X, by employee e (employee input)

R_{ae} = Resource Allocation to Innovation a of employee e, (employee input)

C_e = Costs of employee e

C_{total} = Total Costs of Employees

n = number of employees

t = time (a specific month)

In the example this would work out as follows:

$$\frac{[(83.33 \text{ x } 20 \text{ x } 10) + (41.67 \text{ x } 30 \text{ x} 20) + (125 \text{ x } 50 \text{ x } 50) + (100 \text{ x } 15 \text{ x } 50) + (66.67 \text{ x } 15 \text{ x } 60)]}{41{,}666.67} = 12$$

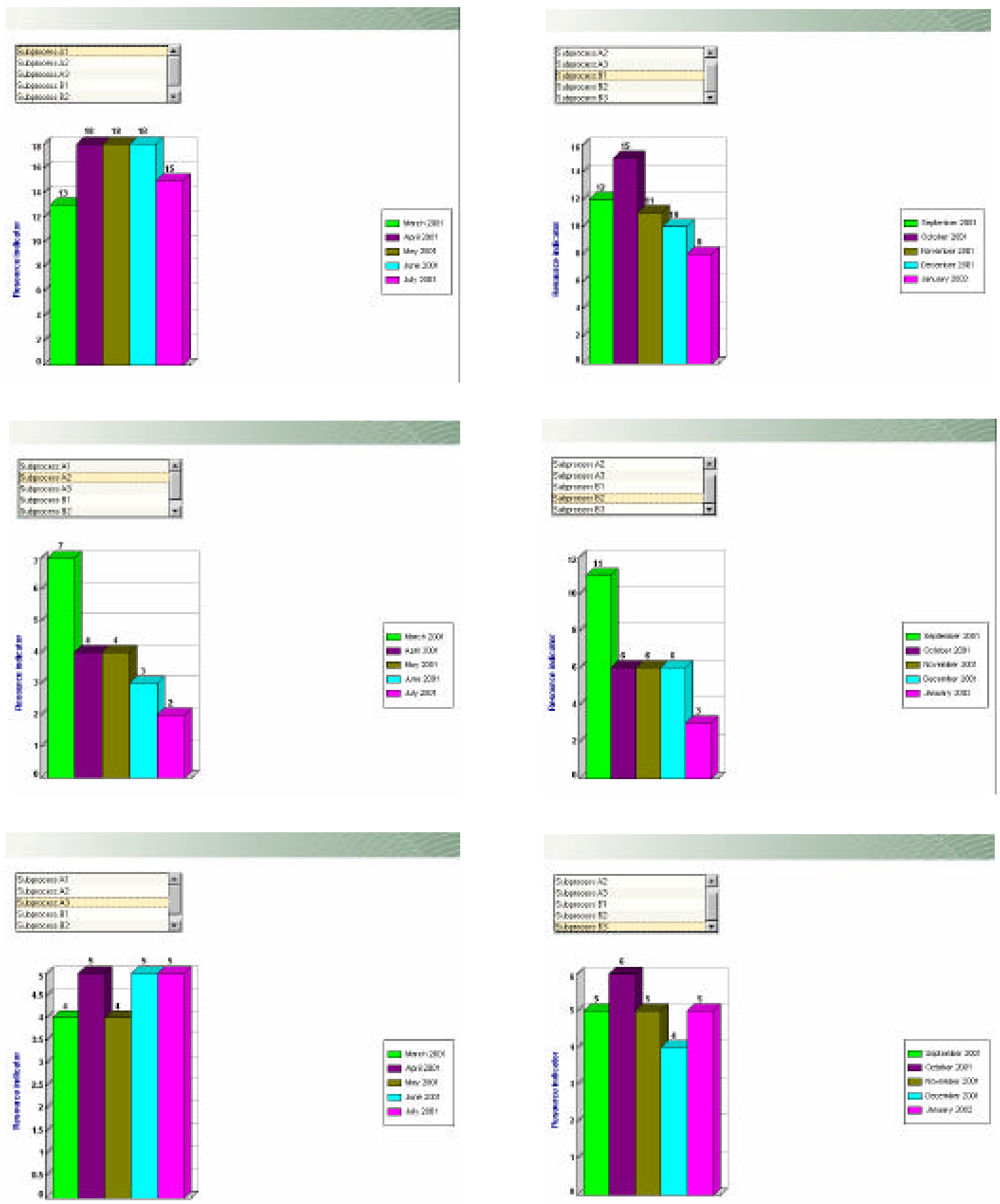
So, $ResAl_{Xe}(t)$= 12%, which indicates that 12% of the total value of the available resources have been distributed to sub-process X = A1 of in the venturing process of Innovation a= A, at t= September 2001. These values are allocated on the bottom row of each individual sub-process table and together make up the trend that will be reported in the in-depth analysis.

5.4.6.2 The in-depth process analysis and interpretation for company X

The graphs are construed based on the information given by the individual employees on their relative resource allocation to sub-processes ($ResAl_{Xe}$). The results of this analysis following the data set of the thought experiment are depicted in figure 45.

The graphs show a more even distribution of the resources in the venturing process of innovation B compared to the venturing process of innovation A. Whereas innovation A, especially in sub-process A1, shows no decline in resource allocation, this is the case in innovation B. An interpretation of this could be that, especially in the first customer oriented processes, changes are being made and less effort is apparently required to exploit new innovations.

In summary, the in-depth analysis provides complementary indicators. The graphs provide an easy overview of the resource allocation behaviour over the sub-processes, and can indicate weaknesses portrayed as over-distribution or under-distribution. This analysis adds value in that it enables uncertainties, detected in the previous analysis, to be pinpointed. Unusual patterns can now be more easily detected and subsequently addressed. The uncertainty can thus be interpreted in on a deeper, more detailed level.



Resource allocation sub-processes innovation A *Resource allocation sub-processes innovation B*

Figure 45: In-depth analysis company X

5.5 OVERVIEW AND EVALUATION OF THE PROTOTYPE SYSTEM XTREND

The prototype application developed in this chapter attempts to operationalise the proxies for productivity and dynamic capabilities by providing real-time models of concrete innovation patterns and behaviours. Managers are thus able to understand these patterns as they emerge and not on hindsight, thereby increasing the predictive power of these patterns.

The XTrend application is new in that such data would normally only become available at the end of a formal financial reporting period. Furthermore the data used to create the various reports stems from individual estimations rather than from exact hindsight analysis. The accumulation of these estimations allow for the dynamic measurements. Using this system managers are empowered to rationalise and act upon inefficiencies from a process perspective, by monitoring the various trend reports – and are alerted to these before conventional management information systems could provide such information.

The prototype application XTrend fulfils the requirements to effectively collect and create the patterns for this new insight. The alternative uncertainty concept on the basis of the proposed uncertainty relation can be measured using XTrend in real-time. The assumption is that such patterns allow for a more predictable behaviour once interpreted in the abstract concept of dynamic capabilities, with the ultimate goal of enhancing the understanding of the underlying uncertainty in the critical phases of the venturing process in high technology companies.

This experiment is the first one of its kind aimed at transforming the abstract conceptual ideas from dynamic capabilities into a measurable interpretation for the purpose of enhancing the decision-maker's judgement. This is particularly so as it is based on hard data derived from systematically measuring accumulated individual subjective interpretations. Nevertheless, it should be acknowledged that the chosen ratios are not necessarily the only correct ones.

It is too early to give a precise meaning to the productivity and dynamic capability ratios because, as previously argued, the numerical outputs are not expected to be causally related within the measured time frame. The experiment in the next chapter will further elaborate on the interpretation that can be given to both these numerical outputs, to evaluate the potential of what these calculations can contribute to developing a proxy for the intangible concept of dynamic capabilities and how this eventually can assist in drawing conclusions towards a more probabilistic treatment of decision-making under uncertainty.

The next chapter aims to incorporate the XTrend tool in creating an enhanced insight into the probabilistic process model as well as an evaluation of the selected proxies. Following a longitudinal case study in a division that typically ventures new technologies, uncertainty and dynamic capabilities are evaluated based on existing concept. These findings will be compared with the findings of two retrospective case studies in which patterns are created using the XTrend application. The discussion will be of an exploratory nature, so as to evaluate the potential of this new approach to understanding and measuring decision-making under uncertainty.

6

Case Study – Siemens Switzerland Enterprise Networks Division

6.1 Understanding Uncertainty in NTBVs – A Longitudinal Case Study with Multiple Sites

Following a longitudinal case study at Siemens, this chapter aims to gain more insight into the proposed probabilistic process model on uncertainty which has been operationalised in the previous chapters. The study is an instrumental case study which is suited to enhancing conceptual insights (Stake, 1998). The state of theory development on the topic of uncertainty using dynamic capabilities as a central focus is relatively new; hence an instrumental case study is most appropriate (Stake, 1998).

The longitudinal character of the case study ensures a comprehensive data set in the context of new technology-based venturing firms. The study was held at the Enterprise Networks division (ICE) of Siemens, a large German multinational that has its main expertise in electrical manufacturing. The study has been carried out over a period of three years and followed in excess of 150 semi-structured interviews with all levels of the organisation and over 25 workshops with top management. Furthermore, access was granted to numerous internal reports and the company Intranet, which added to the dataset of the case.

6.1.1 Case study design

The case design (figure 46) follows a case study methodology that combines a real-time longitudinal case study with two retrospective case studies about the same phenomenon (Leonard-Barton, 1990).

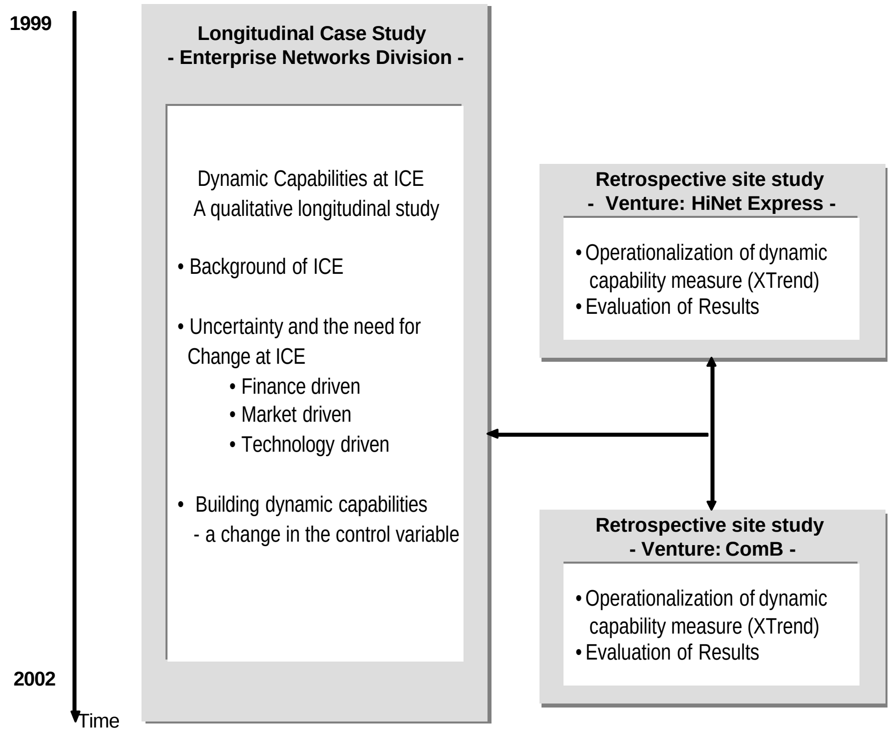


Figure 46: Structure and context of case study – longitudinal case study with multiple sites

The longitudinal study provides a close-up view of patterns concerning the phenomenon of uncertainty and the impact of dynamic capabilities on this uncertainty as they evolve over time. The longitudinal case study has been carried out on the level of the Enterprise Network division. Following accepted data collection methods (i.e. Yin, 1989), the longitudinal study evaluated why and how dynamic capabilities were introduced in the department.

The case study elaborates on a distinct reaction of the division to the imposed uncertainty. The need for this reaction is finance-, market- and technology-driven. The subsequent reaction can be interpreted using the dynamic capability framework. The understanding of uncertainty in relation to the strategy of the company for dealing with uncertainty in terms of their dynamic process base is discussed by analysing the evolution of such dynamic capabilities (Teece *et al.,* 1997; Eisenhardt and Martin, 2000).

The qualitative study on the evolution of dynamic capabilities in the division approximates a change of the proposed control variable of dynamic capabilities in the probabilistic process model. This qualitative perspective can be compared to the proposed proxy for dynamic capabilities using the XTrend system.

6.1.2 Site selection

In order to utilise the prototype measurements two comparable new technology-based ventures within the division have been selected. These ventures represent the retrospective case studies (Leonard-Barton, 1990) and are typical examples of the processes whereby new technologies are formed in a business venture and integrated into the operational processes of the organisation.

The cases represent the integration of a new innovation into the main productive base of the division (figure 47). This confirms the second phase identified during the system development and deals with the process changes necessary to support the integration. These case sites offer the opportunity to identify patterns indicative of dynamic processes, with the aim of gaining more insight into the measurement concept and system. Using initial quantitative material from the measurement system, a first evaluation of the proxy for dynamic capabilities is made.

The ventures, HiNet Express and Com-B, are comparable in that they concern a typical architectural innovation for the business. The first case relates to a new Voice over Internet Protocol (VoIP) system, HiNet Express; the second case concerns an architectural innovation relating to a reconfiguration of the business architecture of telephone systems, Com-B. Both cases were, at the time of their development, considered to be the main strategic way forward for the division; hence implementation scales were comparable. For both cases, process engineering initiatives have been executed to support the integration of the innovation in the system

6.1.3 Data collection

The cases have been measured during two sequential five-month periods, representing identical phases of the venturing process (figure 48). The two sites can hence be seen as a microscopic view on a venture level that allows for a comparison with the data found in the overall longitudinal case study. The measurement periods are identical in their starting nature, taking the innovation from the competence centre or business development centre to the operational processes, and are measured on a monthly basis.

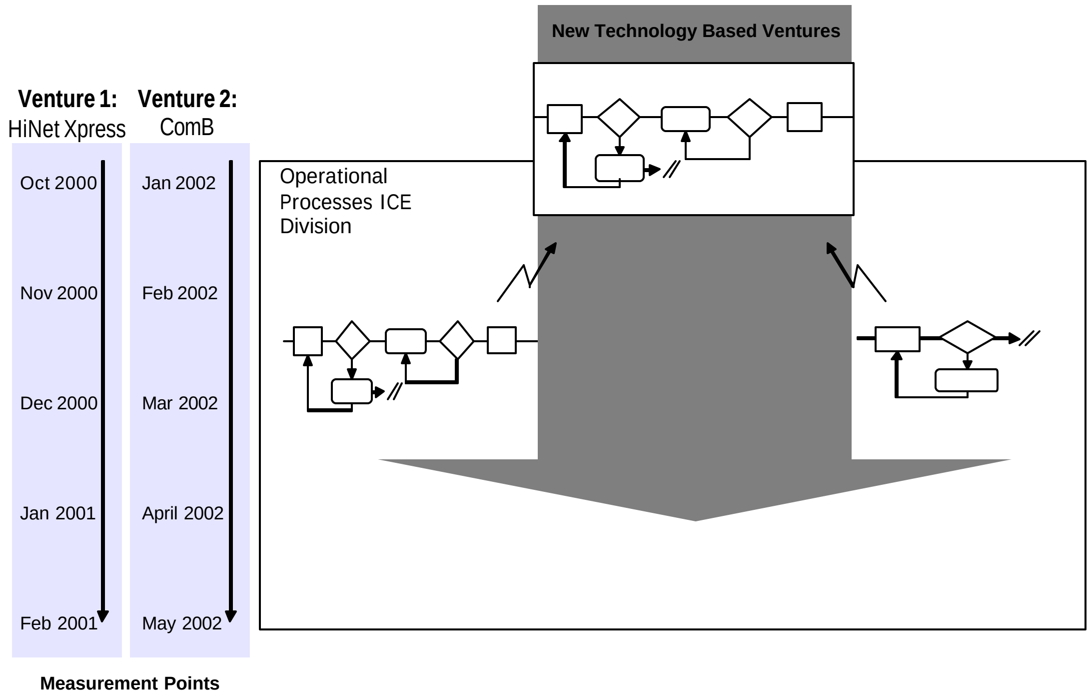


Figure 47: Two multiple site cases of integrating new innovations in the operational system of ICE

Data has been collected using a variety of sources and methods for each individual case as well as for the overall longitudinal study. An overview of the methods used, including the timeline and data sources, is provided in table 20. The division is located in Switzerland and covers five regional areas that are operated from local offices in Zurich, Bern, Basel, Renens and Lugano. The longitudinal case was carried throughout all five regions, whereas the multiple site cases focused on one particular region.

				Data Sources		
				Interviews		
Date	Method	Technology	Population	Semi-Structured	Un-structured	Secondary Data Sources
1999-2002	In-depth Longitudinal Instrumental Case Study	Enterprise Network Products and Services	Upper-level Management	*N* = 5	*N* =12–15	Archival
			Project Managers	*N* = 18	*N* = 2–4	Personal Observation
			Sales	*N* = 40	*N* = 4–8	Attendance at Meetings
			Presales	*N* = 46	*N* = 6	
			Technicians	*N* = 54		Attendance at Workshops
			Product Managers	*N* = 8	*N* = 1–2	Informal Discussions
			Team Assistants	*N* = 5	*N* = 2–4	
			System Engineers	*N* = 15		
			Logistics	*N* = 11	*N* = 3–5	
			Finance	*N* = 4	*N* = 2	
			Key Customers	*N* = 9		
Oct00 – Feb01	First of Multiple Retrospective Case	HiNet Express (Integrating Data [IP] and Voice [PBX])	Upper-level Management	*N* = 2	*N* = 2	Archival
			Product Manager	*N* = 2	*N* = 1–2	Attendance at Meetings
			Project Manager	*N* = 2	*N* = 2–4	Informal Discussions
						XTrend
Jan02 – May02	Second of Multiple Retrospective Case	Com-B (Integrating new business partner for sales)	Upper-level Management	*N* = 2	*N* = 2–4	Archival
			Business Developers	*N* = 2	*N* = 3	Attendance at Meetings
			Project Managers	*N* = 2	*N* = 1	Informal Discussions
						XTrend

Table 20: Description of methods used: timeline and data sources

6.1.4 Data analysis: a critical approach

The longitudinal case study generates a substantial amount of data that allows for a critical review of the probabilistic model. The problem with multiple data sources is that the richness of the data can endanger the efficiency of the research (Leonard-Barton, 1990) and abundant data can obscure the process patterns. Therefore the data has been structured following a specific classification, so as not to lose sight of the phenomenon under study.

The data sources for case study research can be classified over four dimensions: internal, external, primary, and secondary (Yin, 1989). Internal data refers to data collected from the main unit of analysis, the firm. External data relates to sources outside of the firm, such as independent newspaper articles, interviews with customers and competitors, government sources, etc. Primary data refers to data gathered specifically for the research project and phenomena under study, whereas secondary data refers to data collected that could have other purposes (Yin, 1989). Table 21 provides an overview of the sources of data used for the research project and their respective classification.

	PRIMARY	SECONDARY
INTERNAL	• Interviews (with personnel of firm) • Participant Observation	• Internal Documentation • Internal Archival records • Direct Observation • Physical Attributes
EXTERNAL	• Interviews (with customers and external experts such as consultants and academics)	• External Documentation • External Archival Records

Table 21: Classification of data sources

In addition, a process modelling technique has been applied to allow for a more formal and systematic analysis of the data and to examine the underlying processes of the cases. This has been developed at CeTIM and allows for the effective visualisation of the process activities and co-ordination link (N. N., 2000a). Using participant observation and facilitation in the form of workshops, process plans have been created which were accepted throughout the case firm. The purpose of these plans was to complement the data set by deconstructing the firm’s underlying venturing processes and to identify uncertainty within these processes compared to the literature.

Finally the measurement approach has been applied to generate quantitative data in order to explore the probabilistic process model. The quantitative data is generated by XTrend and systemises patterns regarding the candidate solution for a dynamic capability proxy for uncertainty.

These patterns are reinterpreted against the qualitative data analysis of the longitudinal case study in order to draw conclusions and make initial statements on the potential contribution of dynamic capabilities on a managerial decision-making level for new technology-based ventures. This process is also known as triangulation (Jick, 1979). The data from the longitudinal case study is of a purely qualitative nature, whereas the data from the respective case also incorporates the quantitative measure. Triangulation allows for cross-validating the results and strengthens the validity of the results (Jick, 1979).

The qualitative data analysis was partly based on a reflective process (Tesch, 1990). A reflective process involves disciplined thinking and is ideally suited to exploratory work for gaining further insight into a phenomenon (Stake, 1998). The reflexive process was necessary to select the retrospective case studies.

Although a reflexive analysis does not have any explicit formal systematic data analysis techniques or processes, the data analysis for this study does entail some systematic and verifiable elements. A database has been set up with the transcripts of the semi-structured interviews. Furthermore, a collection of numerous internal documents, such as process models, press releases and internal reports, has been stored in a database. Patterns and consistencies can then be identified using the database. Pattern matching allows analysis of data that has been obtained from multiple perspectives and levels (Leonard-Barton, 1990: 249) and can thus be used for the specific process of building explanations between these various perspectives (Yin, 1989; Campbell, 1975; Miles and Huberman, 1984).

The aim is "to analyse the case study data by building an explanation about the case" (Yin, 1989: 113). The goal of this exploratory study is not so much to draw conclusions but to develop new ideas for further study (Yin, 1989), or hypothesis generation (Glaser and Strauss, 1967). In this research project, the phenomenon of uncertainty is the thread that winds through the case study reports to evaluate the initial ideas proposed in this thesis, and to recommend future research.

Obvious limitations to the generalisability of the results are apparent. However, the current state of the theory and the exploratory nature of the study the approach and case selection is a logical start. The vast amount of data collected within the context of the experiment will contribute to identifying further areas for research that could further enhance the generalisability of this alternative way of understanding uncertainty.

6.2 BACKGROUND OF CASE OBJECT – SIEMENS

The case object of this study is Siemens, or more specifically, the Enterprise Networks department (ICE) in Switzerland. The outline of this case has already been discussed in the development part of this thesis (chapter 4). As the development and operationalisation of a potential probabilistic process model incorporates many individual organisation-dependent factors (the parameters for resources, the critical venture phases etc.) it seems appropriate to carry out the first experiment in this setting.

6.2.1 Organisation structure of ICE

The organisation structure of ICE went through several changes during the longitudinal study, indicating that there was in fact a need for change in its own right. At the start of the study the department was involved in a post-merger integration of a recently acquired data division. The complexity in the organisation was further exacerbated by the high frequency of new technologies and subsequent offerings that the division maintained in its portfolio.

The changes discussed in the following study will show how managerial decisions were realised in order to make the organisation more dynamic and anticipate the unsettled environment. To this extent the main commitments that have been made relate to the changes in the division from a structural division to a process division. The main building blocks of the organisation consisted of the sales, logistics, maintenance and services, new business development, product management, marketing, finance and R&D competence centres. The study will show how the organisation rationalised these main ingredients in order to become a more process-oriented organisation.

6.2.2 Initial identification of uncertainty for ICE

At Siemens, the progression from new technological ideas to profitable businesses has already been acknowledged as important but difficult, with lots of uncertainty (Scheepers *et al.,* 1999). This problem is not only visible on a corporate level, but is also particularly important for the day-to-day operations and managerial decisions of the various divisions.

In addition to the brief outline provided in chapter 4, the case study focuses on the business segment of information & communications (I&C) in the Enterprise Networks division (ICE) in Switzerland. Traditionally, the national subsidiaries of Siemens are sales outlets of the Siemens Group. However, the I&C division in Switzerland is different in that it also strongly engages in R&D activities (the total R&D budget is €51 million, of which €18 million is allocated to the ICE division), especially in the VoIP section.

Some initial facts indicate that uncertainty is a potentially major problem for the division[21]:

- The sharp fall in prices is expected to see the first margins drop under 10%.
- The central processes still appear to be the consequence of the previous co-operation with the company owned by the federal state that held the legal monopoly.
- The cost of capital, which was at around 9% in the early 1990s, was approaching 15% at the start of the study in 1999.
- In 1990, the development of technological innovation of average importance cost €5 million; today, it costs more than €11 million. This rise is due to the increasing complexity of the market requirements.
- Whereas in 1990 the cost of activities inherent to the marketing of a product amounted to about 20% of the proposed price, today it reaches around 55%.

All these developments required the division to take action. The next section will elaborate on the financial, market and technological underpinnings of the requirements for change at ICE.

6.3 UNCERTAINTY AND THE NEED FOR CHANGE AT SIEMENS ICE

6.3.1 Finance-driven change

At Siemens, one of the main drivers for change emerged as a consequence of the turbulence in the financial markets. Although the impact of this turbulence on the division was highly visible, the division on its own is not able to influence financial markets, as its own financial results are consolidated in a global conglomerate of companies under the holding company Siemens AG.

Nevertheless the management of both Siemens Group and the division perceived these externalities as uncertain. Numerous interview and archival data has shown that the finance-driven uncertainty was regarded to be very high. The uncertainty stemmed from two major factors: the introduction of Siemens AG at the New York Stock Exchange (NYSE), and the turmoil in the financial markets resulting from the downturn in the technology sector. Both events emerged in the timeframe of the longitudinal study and had a major impact on the business.

The next section will discuss these two factors and elaborate on the uncertainty and managerial decisions the division faced.

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[21] Sources: MSM, Siemens AG, Munich, Siemens Switzerland, Marcom.

6.3.1.1 Stock exchange listing at NYSE

The globalisation drive of the holding company resulted in the listing of Siemens on the New York Stock Exchange (NYSE). Siemens' NYSE listing took place on 1 October 2000. In several press releases, von Pierer, CEO of Siemens Group, made it clear that improvement of profitability is top priority (Birnstiel, 2000).

The company aimed at an EBIT margin (Earnings Before Interest and Taxes as a ratio of sales) trend in the range of a 20% increase per annum from operations. To achieve these new goals, six drivers have been defined: improving business excellence; growth through innovation; continued optimisation of the business portfolio; strengthening synergy management; transforming Siemens into an e-company; and global market penetration, with a focus on the U.S. and China. As von Pierer noted, "Our goal is clear: we want to put each of our activities in a leading market position" (Birnstiel, 2000).

Siemens aims to be a leader in both innovation and market position (Ramelsberger, 2001). The company's owners should have a yield on their Siemens investment that measures up to the best in the industry. The company hopes to be a global player with a global presence – "strong in Europe, the company's home market; strong in the U.S., the world's most important electrical market; and strong in Asia, which has the highest growth rates" (Ramelsberger, 2001).

Siemens chose the NYSE rather than NASDAQ[22] because nearly all of its direct competitors are listed on the NYSE (Ramelsberger, 2001). NASDAQ – traditionally home of the stocks of technology-based companies – is primarily attractive to small and medium-sized companies with strong growth rates and levels of profitability that are often still very low. In von Pierer's words, "Siemens is a company characterised by technology-driven growth businesses coupled with the well-established structures and experience that come from more than 150 years of corporate history – in other words, by New Economy with substance"(Ramelsberger, 2001).

Nevertheless, the technology burst on the financial markets brought about high levels of uncertainty for the company, as stock prices plummeted. In figure 48 the stock price performance of Siemens AG on the NYSE is compared to the S&P 500[23]. The decline at Siemens was magnified in comparison to the S&P 500 companies.

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[22] National Association of Securities Dealers Automated Quotation

[23] Standard and Poor's 500 is an index consisting of 500 stocks chosen for market size, liquidity, and industry group representation. The S&P 500 is one of the most commonly used benchmarks of the overall stock market (source: http://www.investopedia.com/terms/s/sp500.asp)

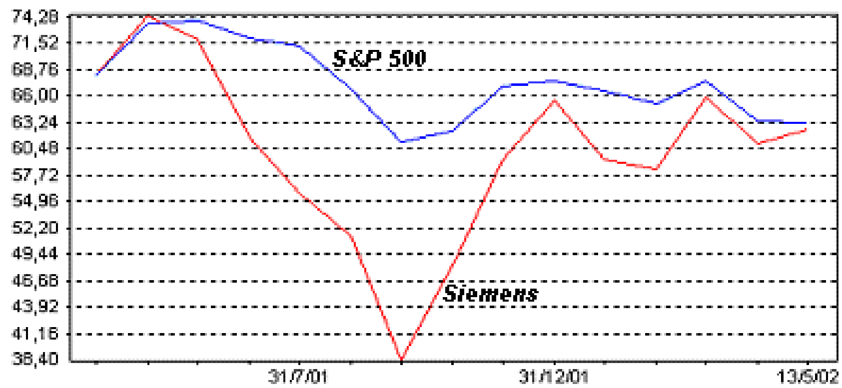

Figure 48: Siemens stock price against the S&P 500 trend from 30/3/2001 to 13/5/2002
(source: FLife AG)

The impact of these events had resonance for the ICE division in Switzerland.

6.3.1.2 Impact on the ICE division

Subsequently to the stock listing, financial reporting had to be converted from the German GAAP[24] to the US GAAP. For the ICE division this implied a change from turnover oriented reporting to EBIT reporting. While turnover reports volumes, EBIT is based on margins. Sales revenues are diminished by the process cost and therefore link revenue growth with process efficiency gains. The new accounting standards have strong impact on external and internal performance criteria for the entire company and its business units, as well as for individual managers.

The targets for the local divisions, such as ICE, changed accordingly and new EBIT margin targets have been set. The EBIT margin targets are in the range of a 20% increase per annum from operations. Additionally, Siemens made the overall targets public for the first time, creating a high level of reporting transparency (Birnstiel, 2000) and increasing the exposure to further uncertainties in the financial markets.

The holding company started to scrutinise all divisions carefully. Before the stock listing the group's business areas were relatively profitable, so the next level, the divisions, were now up for scrutiny (Birnstiel, 2000). "Some are highly profitable while others have yet to exploit their potential" (von Pierer). Siemens announced that it would quickly prune out weak spots. No division would be kept on life-support at the cost of others, and although the Group was seen as a good

[24] General Accepted Accounting Principles, the common set of accounting principles, standards and procedures which companies are required to follow.

performer overall, some of its divisions were seen to have over-capacity and would require restructuring (Birnstiel, 2000).

All these externalities instigated higher levels of perceived uncertainty throughout the management board of the ICE division. They faced decisions with the trade-off between increasing operating profits now and investing in innovation in order to allow for profits in the future (Katzy and Dissel, 2001). The division clearly realised it had to change and be more agile in order to create profit out of innovation quickly and on a routine basis.

6.3.2 Market-driven change

ICE operates in the telecommunications enterprise network market. The customers are enterprises for which tailor-made information and communication solutions are provided in five major areas: Voice networks, Data Networks, Application (Hardware and Software) Services, and recently Converged Networks (Voice over Data Networks). Table 22 shows a brief overview of this market and some product examples.

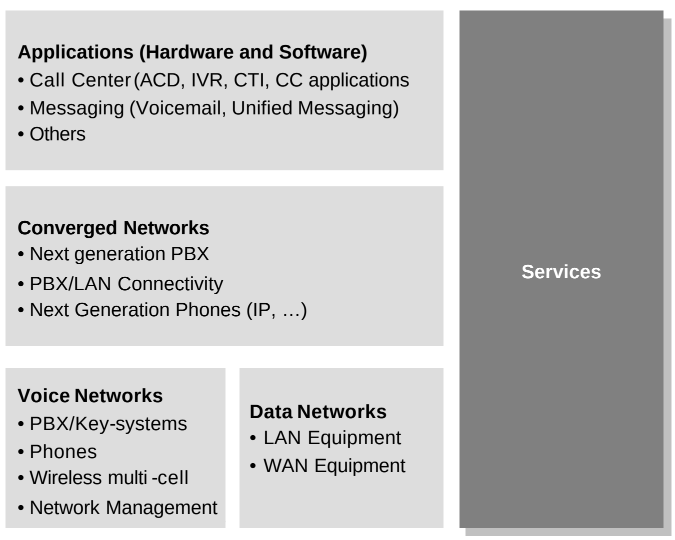

Table 22: Enterprise Network market

Using the product life cycle (Levitt, 1965) Siemens found a profound change in the pattern of new technology-based ventures. Based on the 1995 figures, this curve shows a product life cycle of three years, with investments of approximately €10 million per product. Figure 49 depicts the traditional curve that shows that the product has a positive cash-flow during the maturation phase of the life cycle. This implies the existence of so-called cash-cow products (Katzy *et al.*, 2001). Cash cows can be defined as products that generate cash for the firm and where the products are seen to be in the maturity stage of their life cycle.

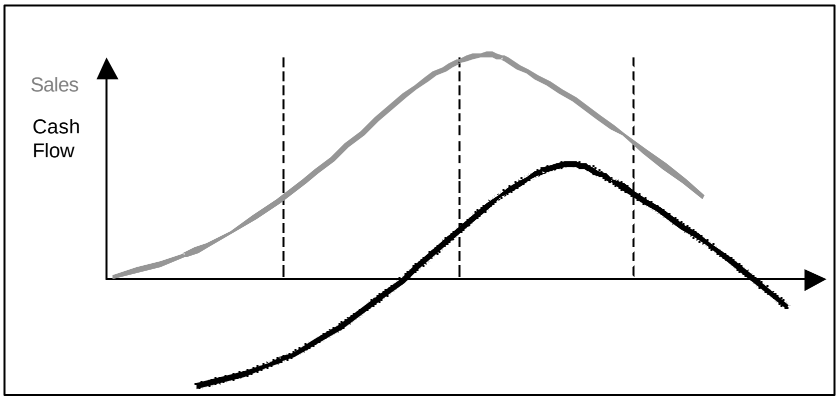

Figure 49: The traditional product life cycle

This representation of the business was valid until 1995. In the telecommunications industry, a range of factors have been reported which can cause drastic changes in the life cycle of the products.

Compared with the traditional curve, the market-life cycle has shortened to nine months, and the required pre-investments have more than doubled. An example of the new life cycle is depicted in figure 50 and shows a study of a wireless device made by Siemens.

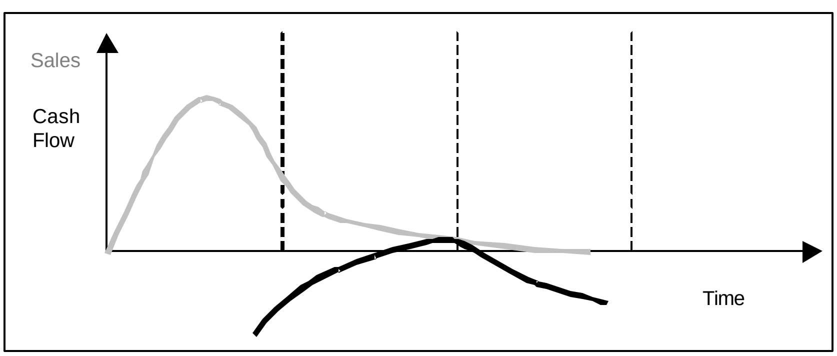

Figure 50: The present life cycle on the telecommunications market
(Example of the new Wireless generation) [25]

[25] Source : Department of Marketing and Finance of Siemens Switzerland, Swisscom.

With the disappearance of the cash cow, rapid integration of technologies into the operational processes becomes a requirement. The need to enhance productivity in the integration phase of new ventures in the operational process is paramount as the pre-investments become higher as well, and thus require a countermeasure. The division needs to capitalise on these technologies quickly in order to meet the EBIT targets.

In the course of this analysis it became clear that the ICE division needed new organisational competencies. During an interview session, the following diagram (figure 51) was produced to show the competence required to quickly move from one product life cycle to the next. It shows that the organisation has to be able to quickly switch from innovation to innovation, rather than to rely on the cash cows. In addition to the corporate strategy a separate business strategy was required for the division, to deal with the flow of new business opportunities and sustain competitiveness.

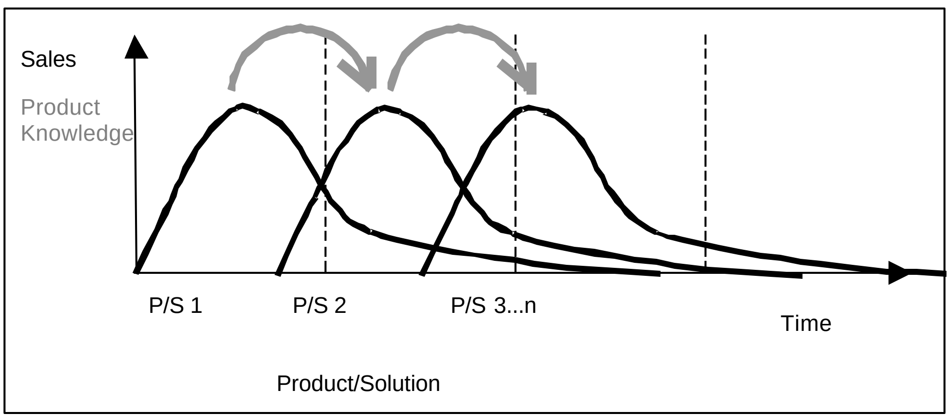

Figure 51: Switching business opportunities

6.3.3 New technology-driven change

The third driver for change at the division stems from the technological underpinnings and complexity of the offerings. The uncertainty from a technological perspective at the ICE division relates to the changing architecture of both the component structure and the business model. The telecommunications services market is increasingly outperforming the telecommunications equipment market in volume. This development is driven by the trend of increased demand for comprehensive, customised solutions.

From an innovation point of view, the complexity of the products within the division increased dramatically. The traditional component innovations (e.g. PBX[26], Internet) occurred with high

[26] Private Branch eXchange (private telephone switchboard).

frequency and the mixture of the components became more and more important. The mixture of traditional and IP-based networks and the stronger penetration of software applications is visible in converged products where 'Voice' is digitally routed over 'Data' networks. These typical architectural innovations led to the increased importance of architectural competencies of the business unit.

This is particularly true for VoIP where voice technology and LAN technology come together for one product. IP telephony and VoIP are key themes in the telecommunications industry. IP is an acronym for "Internet Protocol" – a network level data transfer protocol which is often used for networking PCs and accessing the Internet.

The benefits offered by IP telephony are to cut the cost and investments of communication between various business sites. The innovation came in the form of IP telephony gateways which no longer link individual terminals such as PCs via the Internet, but rather connect entire communication systems located at different sites. This ensures that the infrastructure familiar to the user (telephone, features, and dialling behaviour) would remain intact. At the same time, new possibilities can be offered, for instance the call can be routed (transparently for the user) by the telecommunications system via an IP telephony gateway and the Internet by means of the Least Cost Routing functionality.

VoIP innovations are typical architectural innovations (Henderson and Clark, 1990), where the components do not change but the architecture between these components does. Voice components such as the PBX (communication servers) and Data networks are integrated. An example of a VoIP system and the different components that are integrated into the new product structure is provided in figure 52.

The increased product complexity requires a more solution-oriented approach by the vendors. The share of enhanced services revenues generated by integrating converged systems and applications is strongly outperforming the share of revenues made with traditional voice-based systems. The lack of human skills associated with the topics convergence (of voice, data and media), IP networking and application development leads to increasing service costs and new business opportunities for hardware suppliers in the services business.

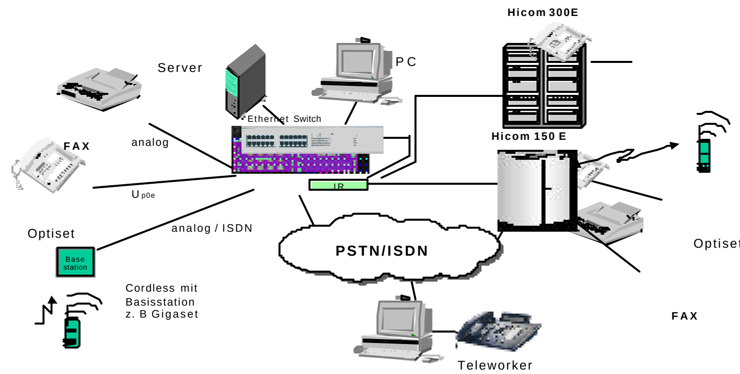

Figure 52: Example of the architecture of a network solution integrating Voice and Data technologies

The challenge of these architectural innovations is the ability to create and integrate these resources in such a way that the ventures are successfully integrated into the operational business of the firm. The changing links and coordination on the product level relate to the respective changes on the business level. In the case of VoIP, for example, transmission without time delay is essential for good audio quality, but less crucial in the transmission of text or graphics of an Internet web page. Several studies have extended the concept of architectural innovations by examining on which level the innovation occurs in a product. At the core of this research stream is the notion that, while firms may possess or could develop the competencies required to develop new product architectures, they often fail to recognise the way in which organisational competencies must be reconfigured to successfully sustain it on a business level (Henderson and Clark, 1990). Existing organisational structures and routines operate to preserve current component linkages and thus raise cognitive barriers to the development of new architectures.

6.3.4 Impact of the uncertainties on the division

The above mentioned changes had implications for the management of the division, which had to make decisions to overcome the associated uncertainty that emerged from these changes. Interviews confirmed that the uncertainty was predominantly observed in the venturing process, where new technology-based ventures are integrated in the productive base of the division driven by the operational processes. Although the division's competencies in the information and communication technologies proved very competitive (a variety of awards on the technological advances were granted to Siemens), the organisational assets caused inefficiencies. These inefficiencies emerged on the interface between the new product/solution development department and the sales and marketing department. The division's management board perceived the interfaces between the small entrepreneurial ventures (new businesses) and the large sales organisation as unsatisfactory (i.e. long lead times, inefficiencies, dissatisfaction of employees).

At ICE it was evident that the incubation of new ventures in the various competence centres was sufficiently supported. For example, the VoIP competence centre was led by a board member of the division who also acted as an entrepreneur (previously owner of a company) and therefore able to create a small venture within the company. This venture brought together the backgrounds of both data and voice engineers, and focused on developing new technology-based solutions, with own projects.

Nevertheless, these processes of the independent centres were not adapted to the existing sales and marketing department. This department was characterised by two distinct channels supporting the two technologies of voice networks (telephone) and data networks (computers, Local Area Networks).

The malfunctioning of this post-acquisition integration of the data and the voice side was perceived to be a result of two existing cultures. Siemens is a traditional telecoms producer and has telephony competencies. In 1996 the need for data communication led to the decision to buy a data company (employing approximately 90 people). A separate data division, Siemens Nixdorf, initially bought the company. In 1998 this division (approximately 120 people) integrated with the ICE division. However, the different technology orientations implied a degree of culture conflict. The voice side, which used to work with over 95% of Siemens-made products, now had to collaborate with a data organisation, which used to work with more than 95% of products and components from external suppliers. In general, the observations revealed that the culture from the data side is more flexible in nature due to co-operation with relatively young and flexible organisations such as Cisco and 3com, which the employees considered as having a more flexible and autonomous stance towards the innovation process.

The ICE division ran two separate order management systems, and the ordering process of putting in an offer and delivering the goods and services required over 23 transaction systems. The incompatibility of the two IT worlds and their legacy systems led to the need for increasing coordination efforts to be put in place when customers ordered data, voice and converged equipment and solutions.

The incompatibility stems from the division’s history, in that it (the voice side) used to deal with fairly stable customers, like the national phone operator. However due to the liberalisation, deregulation and privatisation trends in 1998, the market has become more competitive (N.N., 1999d). More customers, and thus competitors, came on the scene. Previously the organisation received clear-cut orders (from the voice side of the business) from well-known customers with relatively well-known products. However the environment changed to the provision of more complex innovations to a diversified market.

Increasingly complex innovation problems were observed due to a decentralised organisation. The technological knowledge of the new (converged) products could not be diffused in the regionally organised department. Switzerland has three dominant regions with their own language and culture (French, German and Italian). Whilst appropriate from a customer relation point of view (as it presents one regional face to the customer), the technological knowledge of these complex businesses is not available in all parts of the country. In an interview, a presales consultant confirmed this, "…sometimes I have to spend up to two days to find the best supplier for a particular cable, even though I am almost certain that the same problem has already been solved somewhere else in the organisation."

Customers also perceived this lack of knowledge transfer in the sales process. One customer, who ordered Swiss-wide PBXs and telephone-sets, came to the conclusion that the installation differed in Lugano (Italian region) from the one in Basel (German region). Due to the enhanced and more complex features of the products, his employees, who travelled frequently between the two sites, had to learn how to operate the same equipment twice, because the installation was not standardised.

The lack of knowledge transfer was not limited to the different regions within the same function (presales, technicians), but equally occurred cross-functionally. Interviewees demonstrated that diverging sales strategies withhold Siemens from optimising the sales of new products. For instance, customers told of several occasions where they were aware of new Siemens products before the sales-force knew about them.

Internal reasons for the lack of knowledge transfer were further limited by the organisational competencies and the motives of the sales-force to concentrate on old and familiar products instead of innovative solutions. A salesman quoted, "Why would I spend a day on trying to sell one VoIP system, whilst I can sell three PBX systems in the same time?"

Traditionally the sales-force was specialised in selling products, which required little additional effort. At Siemens this was also referred to as the "sales of boxes". This was typically a result of their traditional supplies to the national phone operator. The national phone operator employed people with similar technological competences as the Siemens employees. Therefore the sales process was one between two specialists both having extensive knowledge of the technical underpinnings of the product, and the customer just wanting to have the best technology available without any additional services or installation requirements. However, as another business customer put it, "I do not care what kind of PBX is in my cellar, I just want to make a phone-call".

The above mentioned process implications were further rooted in the commission mechanisms. The commission scheme was sales oriented (regionalised) and depended on individual sales volumes. Established products generate better sales than new products. Although new businesses have been explored using pilot projects, specialists and the use of so-called competence centres, there were no clear rewards for sales staff to invest in building their sales competence on new products. Moreover, the product and solutions managers, who were responsible for the introduction of these new ventures, were organised as support functions and seen as overhead costs rather than part of the direct value creation process. This caused more motivational glitches and, as a result, the information flow of new product information was seen as unsatisfactory by the sales organisation.

Such interface problems between the development oriented departments and the sales department culminated when large nationwide projects were to be realised. These projects require the co-operation of numerous employees from different departments and regions. In practice this resulted in insufficient accessibility by phone, lingual barriers and a lack of readiness to co-operate.

6.4 MANAGERIAL DECISIONS TO CHANGE: REALISING DYNAMIC CAPABILITIES

It was evident to the management board of the division that changes had to be made. This lead the board to embark on a multitude of efforts to make the divisions better prepared for the uncertainties arising from new technologies.

These efforts were executed under an initiative which was known throughout the division as the ICE2000 project. This initiative was the most prominent division-wide project held during the length of this study. As the following sections will show, this project can be interpreted as a sequence of managerial decisions that resulted in, what I refer to as, an enhanced level of dynamic capabilities within the firm. These actions represent, from a qualitative perspective, a change in the controlled variable of the probabilistic process model on uncertainty

6.4.1 Rationalising the productive activities

The division's board decided to engage in a process change management initiative. Before the case study commenced, ICE had already undertaken three Business Process Re-engineering projects, all of which were unsatisfactory. The last project (the so-called GPO project) resulted in a description of the processes within the ICE division, but the organisation was not able to implement any recommendations for improvement of the processes. This led them to start the ICE2000 project in January 2000, which aimed to check the current processes against the results of the GPO (which ended in June 1999) and furthermore improve the processes.

The project was the first step in creating a new process concept that aimed to rationalise the malfunctioning interfaces between the technology push (i.e. new ventures) and market pull factors (i.e. the sales and operations processes). An in-depth process analysis revealed the weaknesses as described above and based on these weaknesses the division entered a bottom-up consensus approach in order to establish the new process concept to optimise new innovation introduction to the productive base. The board decided to radically alter the existing ways of working, and create one coherent process in which this would be possible. This process concept is depicted in figure 53.

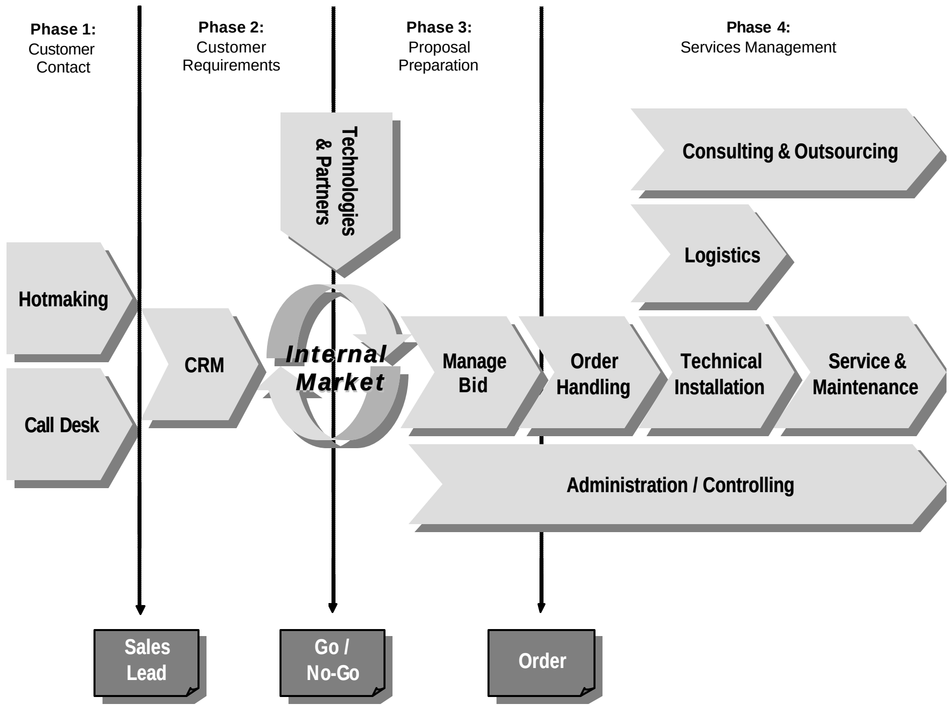

Figure 53: New process concept ICE

The main decision that arose from this new process concept was the definition of four distinct phases: customer contact, customer needs and requirements, proposal preparation and services management. The interfaces between these four phases were seen as critical for enabling profitable venturing of the division's product and services base. Furthermore, these phases are valid for the complete portfolio of the division's offerings. Whereas previously each specific technology (such as voice and data) maintained their own specific processes, the new process concept rationalised a new way of working that integrated these approaches, and made the division realise that there were coherent and technology-independent ways of working.

Phase one represents the customer contact. The input for this phase focuses on informing and establishing potential customers. As a result of the increasingly competitive markets, the former sales activities have been redefined. Formerly sales representatives mainly focused on maintaining the existing customer base. As the national operator, the department's main customer, faced more competitors, this meant that more active sales actions to be taken by the division. This led to the creation of a new process coined "Hotmaking" (making potential customers interested). The output is defined as a sales lead, which is the input for the phase two, Customer Relations Management.

The second phase aims to create a clear customer requirement. Customer Relations Management receives the sales lead from Hotmakers, the call desk, or requests for tenders from existing customers. The task is to turn these sales leads into clear business opportunities. This phase is characterised by a high customer focus, in which the customer requirements and needs will be defined. The output is a clear business opportunity that will be presented to the internal market.

Phases three and four are the actual bid management and the service management processes (including distribution, installation, maintenance and consulting). These processes are predominantly technology oriented.

The internal market represents the negotiation between the sales pull and technology push activities. The previously described process implications and incompatibilities led to the common understanding of having an internal market structure within the order mechanism. Internal market is a metaphor for switching. The rules of the game can be interpreted as a means to generate the dynamic capability of getting new ventures into operational processes of the division.

Two main changes resulted from this new process concept. Firstly, the organisation structure required more flexibility and working in virtual teams. Secondly, the internal market should actively support continuous process (re-)engineering for the new technologies based ventures, confirming the four distinct new technology-based venturing phases.

6.4.1.1 Internal market and virtualisation

In order to increase exploitation of the opportunities arising from new technologies, the management board decided to restructure the division so as to support an entrepreneurial spirit. Whereas previously the division was split up into a multitude of small organisations working independently within the division, deploying their own island solutions and processes, the division now consisted of two main elements: development and operations. With respect to the interface inefficiencies identified during the project between the product/solution development departments and the operational side of the business (e.g. marketing, sales, presales and installation and services) the division aimed to create better co-ordination between these two functions by allowing internal business ventures to grow. The focus for this analysis is based upon the process for large innovative projects.

Firstly, the development side in the division created the so-called 'business house', in which new ventures are incubated. The business house is a combination of the previous product management and solution management departments. Engineering specialists together with business experts develop new product/solution combinations in dedicated business venture groups. The venture leaders are responsible for producing a business plan in order to shift the focus from product development to business development. In addition to development activities the venture groups have the objective to start pilot projects with selected customers to test the commercialisation of the innovations. The business house supports these venture groups. They serve as an incubator, providing the necessary funding and facilities to start-up business ventures.

Secondly, the sales side of the operations is structured in customer areas instead of regional areas. The sales/customer relations management departments now cover specific customer groups such as hospitals and banking and insurance companies. Where it was previously this department's role to produce a concrete sale, the main output is now a concrete customer requirement.

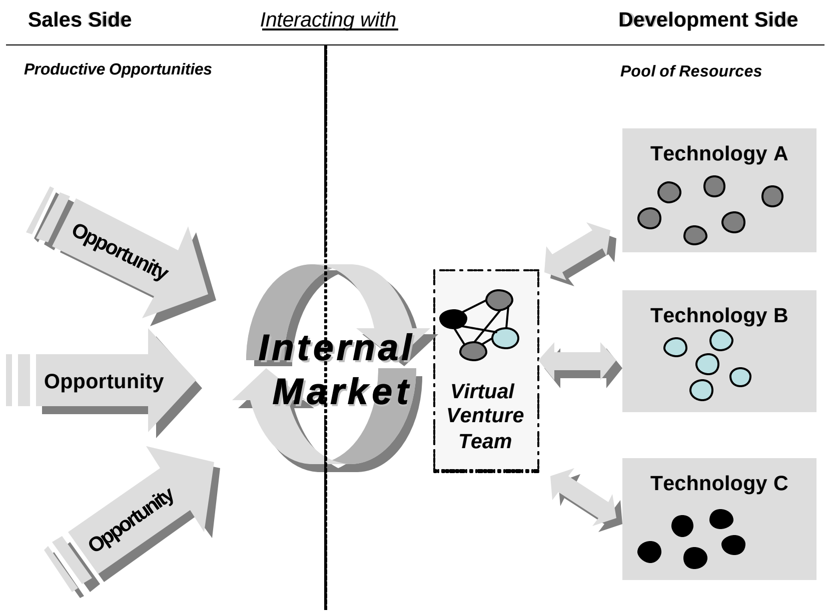

Figure 54: Internal market and virtual venture teams

The division has introduced a new coordination mechanism in order to allow for more rational go/no-go decisions (figure 54). This mechanism is based on network co-ordination where the project manager is able to compose virtual teams by negotiating with the several specialist areas. The virtual team becomes a project-oriented team, built up out of pools (ventures) of specialists. Co-ordination is based on the internal market in which negotiations can take place within certain rules, which are being defined.

6.4.1.2 Enabling the venturing process

The interface between the business house and the operations department can be explained with a revolver metaphor. The business house builds the bullets – the venture groups, which are successively inserted into the revolver – the operations department. The mechanism of a revolver consists of one barrel for several chambers of bullets. This is true for the operations department, which should portray a single source of competence in marketing and selling towards the customer. The coordination mechanism allocates each sales opportunity to the correct group of specialists (ventures).

When a start-up is successfully nurtured in the business house it will be integrated into the operational department. The team of specialists will then take the function of specialist in their field of expertise (e.g. VoIP) within the operational department. The sales/customer relations department is then able to feed this internal venture with business opportunities, by exposing the tested solution to the extensive sales network. The mechanism of systematically placing new ventures into the operational department can therefore be identified as a new dynamic routine.

In summary, when looking at the Siemens Division three distinct phases for the ventures can be identified (Katzy, *et al.*, 2003), each requiring their own specific capabilities (figure 55). Firstly, the incubation phase, where the new venture is nurtured to make a business out of an innovation. Secondly the venture is grafted into the existing operational processes, by systemically and continuously reconfiguring the organisation. Thirdly, in the exit phase the resources of ventures are either recycled or scaled up, depending on the nature of the venture.

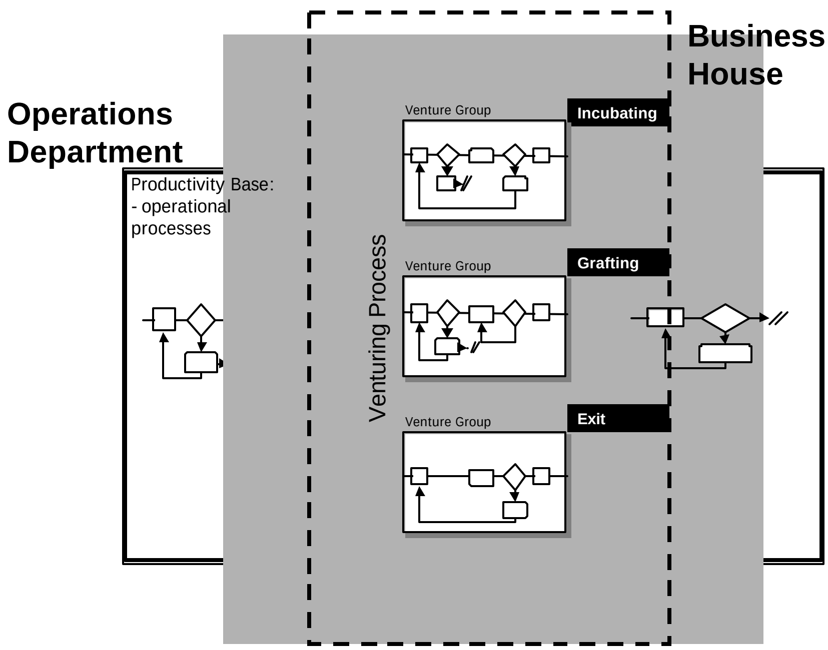

Figure 55: Incubating, grafting and exit capabilities (Katzy, et al., 2003)

In the first phase the emphasis is on the capability of the division to develop or incubate new technologies into ventures. In the business house new ventures are created which act like entrepreneurial “start-ups”. This means that each venture is supported, next to the solution development and product management activities, in writing a business plan. This phase of the venture is referred to as the incubation phase, where the business provides the necessary competencies, budget and support for these “start-ups”.

In the second phase of the venturing process, the division requires the capability to “graft” the new venture into the operating part of the organisation. When new ventures are ready to be exposed to the sales network of the division, the ventures can be integrated into the sales/operations department. This change is an organisational one, for the venture is no longer strictly dependent and supported by the business house, but interfaces with different departments. This is the second phase in the entrepreneurial venturing process, which is termed grafting. Grafting means the successful installation of a venture into the sales/operations department. The division requires the ability to reconfigure the resource base of the firm to accommodate the changes in these two phases of the venturing process; in other words, the division requires dynamic capabilities.

The final stage depends on the division's capability to successfully organise an exit for matured new ventures. The venture process ends with the exit of an innovation from the department. There are two options available: firstly the venture group could function as a stand alone department i.e. a spin-off; secondly the venture group might reach the end of its life cycle and cease to exist.

6.4.2 Evolution of the dynamic capabilities at the division

Parallel to the three venture phases, capabilities can be observed that evolved in the organisation. The dynamic capability framework (Teece *et al*., 1997) elaborates on the evolution of dynamic capabilities and can be used to position the proposed changes in the division within the perspective of dynamic capabilities. The framework suggests that paths shape the specific asset position of the firm, which in turn shapes the processes. Subsequently these processes build the dynamic capabilities.

Applying these three lenses to Siemens ICE shows the evolution of the dynamic capabilities. By identifying the paths, positions and processes at Siemens ICE, the evolution of the above-mentioned capabilities becomes apparent.

Two major paths can be identified that relate to the specific incubation, grafting and exit capabilities. Firstly the technological trend where the telecommunications industry integrated the data networks (local area networks). This trend extends to the current trend of the convergence of voice and data solutions. Secondly, the changes in the telecommunications market, the increasing R&D pre-investments required, and the decreasing product life cycle can be identified as a major path dependency. The new product life cycle curve shows the need for a constant capability to switch and diffuse new architectural knowledge on the products and solutions throughout not only the new product development but also the new business development process, with increased pace.

Furthermore the specific asset position of the firm is apparent in the architectural nature of the innovations on both a product and a business level. In accordance with Teece, Pisano and Shuen (1997), the case shows how these changes contributed to the current specific asset position at ICE (figure 56). Firstly the technological position, as determined by the previous path dependency of the architectural innovation, is interpreted as a lack of architectural knowledge and a deficiency in the diffusion of innovations between the voice and data sides of the division. Although the technical inventions appeared to be successful, the diffusion of this knowledge did not reach the sales organisation.

Instead of benefiting from the complementary assets brought by the extensive sales network and the business house (e.g. award winning inventions), the two did not meet. They were opposing each other and the lack of coordination had a negative influence on the processes.

The lack of diffusion of the architectural knowledge of the VoIP innovations throughout the organisation resulted in inefficient process co-ordination. The case study shows a range of examples that illustrated these inefficiencies. This was particularly visible at the interface between the sales organisations (both voice and data side with independent order mechanisms), and the new product/solution developments and successful technology-oriented competence centres.

The initiation of the ICE2000 project allowed both sides to acknowledge these inefficiencies. The learning effect created a shared mental model throughout the division, resulting in a new process concept including a new coordination mechanism between the operational side and the R&D side of the division. In addition, the organisation became aware of the necessity not only to re-engineer the processes to their current asset position, but also to systematically update its routines and the organisation as they move forward.

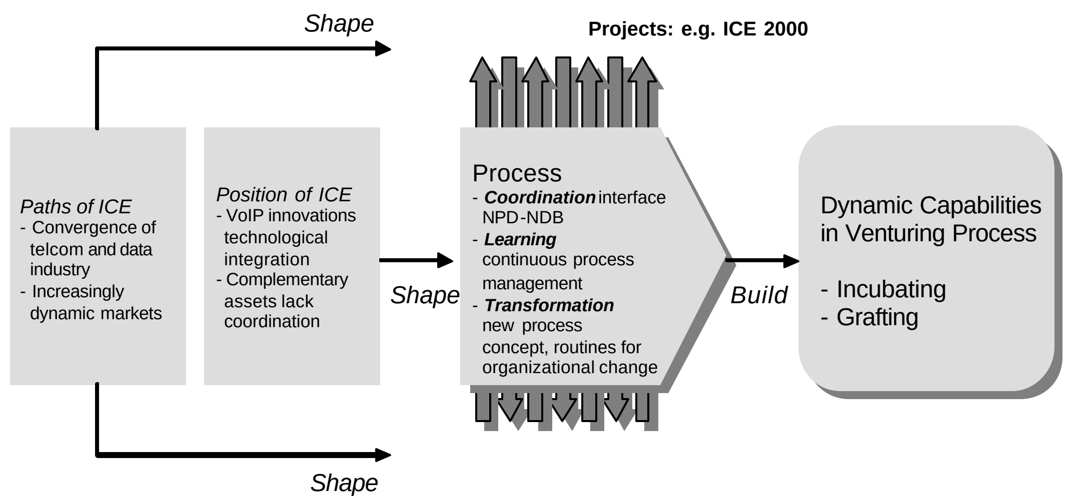

Figure 56: Building of dynamic capabilities at ICE (Katzy et al., 2003)

6.5 IMPROVED DYNAMIC CAPABILITIES AT ICE: CHANGING THE CONTROLLED VARIABLE

The subsequent results of this (ongoing) learning process within the division led to the transformation of the organisational routines at the interfaces in question. The decisions that followed can be interpreted as the deliberate building of dynamic capabilities within the firm.

In the course of the case it can be observed how the dynamic capabilities for the venturing process were built in order to cope with the uncertainties. Nevertheless, not only are the processes of incubation, grafting and exiting essential, but so is the fact that the division is able to change on a routine basis, or what Zollo and Winter (2002) would term ‘second order dynamic capabilities’.

6.5.1 Visible improvements in the division’s dynamic capabilities

In the Siemens case the commitments to a variety of actions to improve the dynamic capabilities within the firm were visible in various activities. From an organisational perspective, dynamic capabilities can be regarded as tools that manipulate resource configurations (Eisenhardt and Martin, 2000) in order to deal with the uncertainty and create competitive advantage. In dynamic markets these capabilities rely heavily on new knowledge created for specific situations (Eisenhardt and Martin, 2000).

Following Eisenhardt (2000), dynamic capabilities are processes that can be observed in the firm, such as rapid prototyping, process engineering and alike. The decisions following the ICE2000 project were geared to install a number of such processes. These decisions are visible in the actions taken to support the incubation and especially the grafting phases of the new venturing process.

At Siemens dynamic capabilities became visible by the installation of a dedicated team responsible for the ongoing changes necessary in the processes. This team was dubbed the “change management crew”. They reported directly to the board and were under supervision of both the business house and the operations division. The team consisted of a core group of five people, with an external expert to provide the change consulting.

The team raised its profile within the organisation over the course of the study. Interviews confirmed that the team was seen as the dominant factor and the basis of all process engineering activities within the organisation, and as such was respected for its activities. The team worked closely with the board in order to meet strategic challenges, but was not responsible for any performance targets itself. Instead, the role of the team was typically to provide a coaching and supporting function to help management change the organisation. As one director noted, “Change management is a core competence, just as selling telephone equipment is. We do not have this competence, and thus we outsource it, by hiring an independent external consultant that leads the internal change management crew.” The team was seen as the driving force for the learning process at the division.

The team's main activities were facilitating workshops and moderating meetings according to business process re-engineering techniques (e.g. Davenport, 1993; Hammer and Champy, 1993; Elzinga *et al.*, 1995; Mueller, 1999; Tockenbuerger, 2000). This can be seen as a typical process of dynamic capabilities.

However, in addition to these existing techniques, the team also indulged in R&D efforts that were specifically designed to test and improve new methods and tools. The team established many links to academic institutions and was open to adopt and validate new and improved methods for process management. This can be seen as the second order dynamic capability (Zollo and Winter, 2002) where the division has not only got existing processes to change, but also changes these learning process continuously to maintain the state-of-the-art.

This learning process emerged as a continuous interaction between the evolving technology and markets. The aim was to adapt processes to evolutions in technologies and markets on a continuous basis (see figure 57). Continuous iterations with technologies and markets ensure business processes that meet environmental requirements.

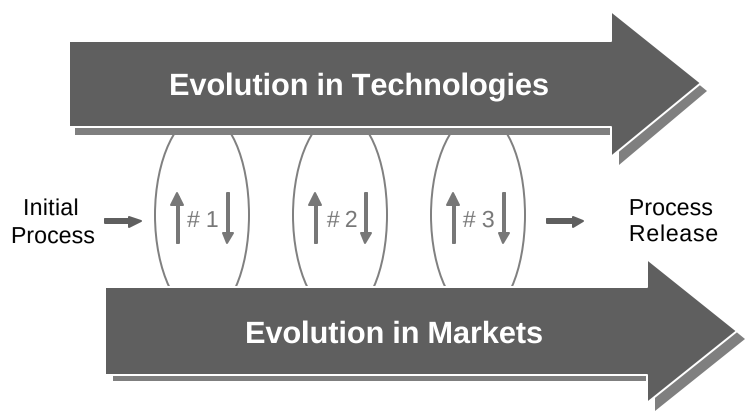

Figure 57: Process engineering approach (Katzy *et al.,* 2001)

The change management crew adapted and developed a dedicated change cycle in order to effectively re-engineer processes. This cycle can be interpreted as a stable pattern or routine in its own right, with the aim of updating the operating routines on a continuous basis.

This learning process followed a dedicated cyclical approach of plan-do-check-act (Deming, 1986). An illustration of this process is depicted in figure 58. Following this cycle the team was able to dynamically adapt processes. Based on change requirements from the introduced new technology (innovation), the team identified new core processes and set process objectives. Following this, detailed processes were designed and implemented, focusing on established BPR[27] methodology. The last phase represented the process controlling activities in which a variety of measurements were used to evaluate the quality of the process.

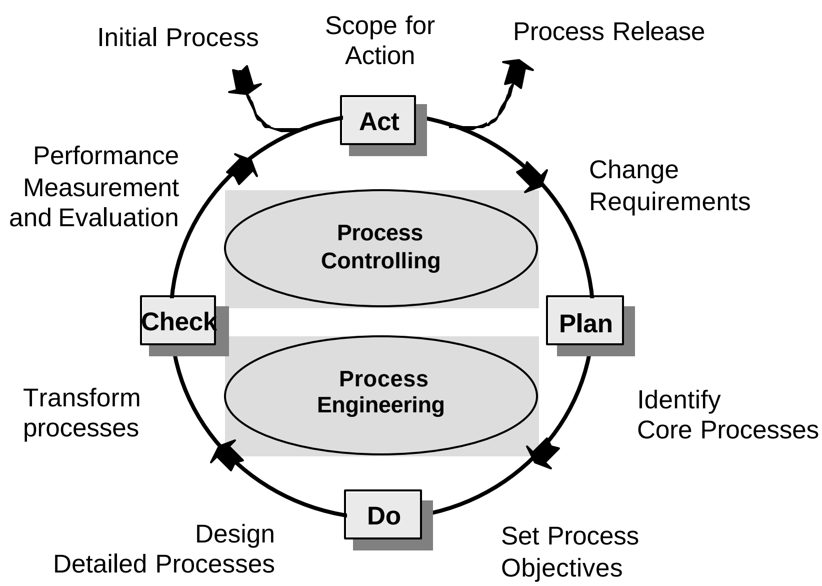

Figure 58: Learning cycle (Katzy *et al.,* 2001 after Deming)

From this perspective the dynamic capabilities, as embedded in the learning cycle routine, follow a similar process to that stipulated by Zollo and Winter (2002). The cycle intrinsically incorporates three learning mechanism phases on specific parts of the processes: experience accumulation, knowledge articulation and knowledge codification. These three phases become apparent when examining the process. The process exhibits the learning mechanisms of experience accumulation and knowledge articulation, as in interviews, workshops and reviews, when the processes were discussed individually and groups. The articulation focused predominantly on the weaknesses and strengths of the process base in an attempt to reveal the best way forward. Furthermore this articulated knowledge on the processes was captured in various reports and process plans, handbooks and working documents. These artefacts can be seen as a clear act of knowledge codification.

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[27] Business Process Re-engineering.

However during the three-year study, the process of creating this knowledge was refined by the introduction and testing of various methodologies and tools to achieve this. The process team articulated and refined the learning cycle continuously, and subsequently reported the results to the rest of the division. During the longitudinal study the process team evolved into a central node within the structure of the division. This became apparent as the team and its results became increasingly central to internal dissemination activities such as conferences and on the Intranet. In Zollo and Winter's interpretation this can be seen as second order dynamic capabilities (Zollo and Winter, 2002).

6.5.2 Evaluation of dynamic capabilities and understanding uncertainty

The study has revealed a set of distinct decisions that can be attributed to the subsequent building of dynamic capabilities. Hence this can be regarded as a deliberate change in the controlled variable of dynamic capabilities, which has been confirmed on a qualitative level, through the interviews and observations. As previously mentioned, the ICE2000 project was the main factor of change within the division at the time of this study. Obviously other initiatives had been developed and implemented, but not with the same impact and awareness throughout the division. Moreover, most initiatives that did change the organisation were direct results of the ICE2000 project. For example, 18 project teams were created to support the changes in the process base.

The longitudinal study clearly shows two patterns concerning dynamic capabilities. Firstly, the conditions of dynamic capabilities were essential to enable the division to remain competitive within its high velocity market. The emerging dynamic capabilities focused in this sense on the incubation and grafting phases of the venturing process, where the interfaces of the existing productive base need to be adapted or changed in order to integrate new ventures so as to quickly shift business opportunities and benefit from short life cycles.

In the course of the three-year study the process changes instigated by the change management crew were the most prominent changes made in the division. No other initiatives or decisions created the impact of ICE2000 and the change management crew. This can thus be regarded as an approximation to a *ceteris paribus* situation, where the building of dynamic capabilities is the dominant changing variable, and other variables remain relatively unchanged. No indications of this or alternative decision drivers were observed or elaborated in the interviews.

These dynamic capabilities can be recognised when looking at the installation of a process team (also known as the change management crew), whose job is to change and maintain the process base of the division. Furthermore, the methods and tools applied by this team represent a pattern of change that is evolving into a stable but effective approach to change the operational routines.

Furthermore, these routines of dynamic capabilities evolved themselves throughout the study. Updated and new methodologies were applied and more dissemination and training activities were developed to ensure high impact. Another interesting observation is that at the start of the study, the process team was very dependent on top management support to convince the division that this was required. However at the end of the study, the process team was an established entity within the division that was actively being used by the whole organisation. This shows that the dynamic capabilities themselves evolved, and confirms the assumptions of Zollo and Winter, and Teece *et al.*, that dynamic capabilities can take the form of more stabilised patterns.

From the perspective of uncertainty, the dynamic capabilities observed in the case study are based on routinely changing the process base of the organisation as a strategy for uncertainty. However, these dynamic capabilities only become apparent when reviewing the organisation from an academic abstract perspective. The actual evaluation of the dynamic capabilities and the potential effects these may have had on the competitive advantage of the firm can only be done in hindsight. No measures were in place to see the effect on the uncertainty or having a more predictive power in order to strategise *ad hoc*. As mentioned in a workshop, "we are now able to produce processes quicker that allow for innovations to enter the market, however we do not know if we are only getting better in producing crap processes quicker, or if there is a real effect in terms of profitability and competitive advantage."

One of the main uncertainties stemming from the above case study was the pressure put on the department to operate profitably. However the profit figures only followed later, so there was no indication of whether the new processes actually fulfilled this requirement. The uncertainty relation proposed in this thesis between resources as an input and financial performance as an output remains uncertain.

The probability function, from a qualitative perspective is thus approximated in that the control variable of dynamic capabilities changed, where other variables remained relatively stable and thus approaches the initial conditions set out for the experiment. Nevertheless, the uncertainty was still apparent as no measure or indication could be given yet to support the probability function and the expectation that this situation should result in an increased likelihood for better performance.

In order to explore this probability function, the next step in the experiment is to evaluate the proxy for dynamic capabilities.

6.6 EXPERIMENTAL MEASURES: TESTING THE SYSTEM IN TWO VENTURING CASES

The evidence from the longitudinal case study confirms that the evolution of dynamic capabilities is apparent. The next step in the exploration phase is to compare these results to the proxies of productivity and dynamic capability for new technology-based ventures.

Two comparable ventures within the division have been selected to test the proposed proxies of productivity and dynamic capabilities. The cases represent the introduction of the HiNet Express platform and the Com-B business model. The venturing initiative of HiNet Express was the first VoIP application to enter the mainstream market. Com-B was a business architecture that ventured the combined technologies of telephone and data equipment together with a carrier network provider.

The underlying new technologies of these two ventures stems predominantly from the merging of distinct voice and data technologies. The next section will briefly describe the underlying new technologies in more detail, as well as the background of the HiNet Express and Com-B ventures.

6.6.1 New technologies at Siemens: HiPath

The technological platform of the Enterprise Networks division during the length of the study was dependent on the emergence of the converging technologies on voice and data. The Siemens 'Enterprise Convergence Architecture', called HiPath, aimed to strengthen business communications by enabling a company's existing voice and data infrastructures and applications to interoperate globally over all networks. This innovative approach is based on open standards and distributed architectures.

HiPath technology is an enterprise convergence architecture that provides a flexible, affordable and rational migration path to the IP-world of highly integrated communications and applications. It provides customers with choices regarding when and how they implement applications whilst protecting and evolving their current infrastructure and application investments. Potential offerings include customer relationship management, web-based call centres, e-business, and support for internal co-operation, virtual teams and mobile working.

The HiPath technology brought about uncertainty in that the future potential was hard to predict. Whereas some scenarios had been drawn up by, for example, the Gartner Group, these should be seen more as beacons to the future than the only right way of venturing this technology. This became apparent with the Com-B venture that introduced a whole new dimension on the new technologies which was not predicted at the start of the study. The introduction of VoIP systems and its expected technology life cycle was projected in 2000 (Vandermate, 2000) using the "hype cycle" of the Gartner Group (figure 59). The hype cycle charted a typical progression of a technology from ‘over-enthusiasm’ through a period of ‘disillusionment’ (based on the inevitable failures that arise fom inappropriate application) to an eventual understanding of its relevance and role.

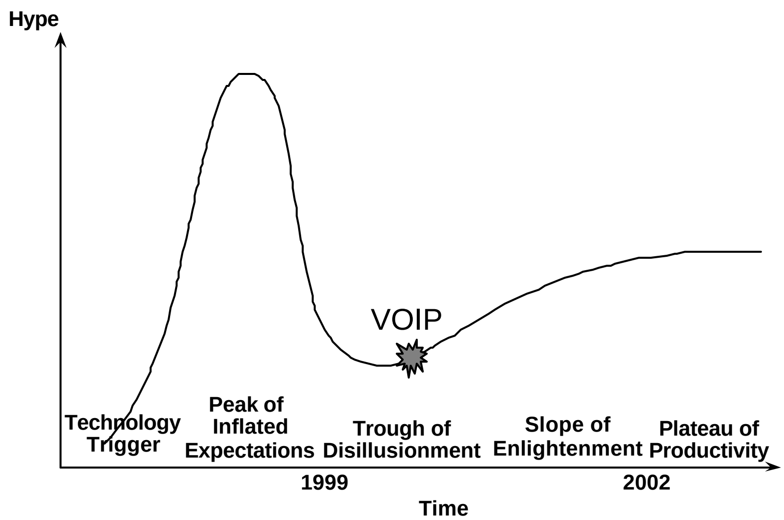

Figure 59: Technology hype cycle VoIP (Gartner Group, taken from Vandermate, 2000)

Siemens was a superior provider of this new technology. Ken Landoline, vice president and director of telecom research at the Robert Frances Group, stated in 2000, “IP technology is still an early adopter solution and widespread deployment will take place over several years, due to scalability, interoperability, quality of service, security and latency issues” adding, “Siemens’ HiPath is one of the most comprehensive architectures that we have seen to date to address many of these key issues” (N. N., 2000).

From a strategic perspective this new technology was seen as essential. “Siemens’ HiPath architecture ensures the protection of current and future Hicom and HiNet investments,” said Landoline. “Additionally third-party vendors’ products and solutions can interoperate with solutions based on the HiPath architecture” (N. N., 2000). This strategy was based on market projections from the Infotech Group (Vandermate, 2000), which saw the convergence of voice and data markets gain more and more market share (figure 60).

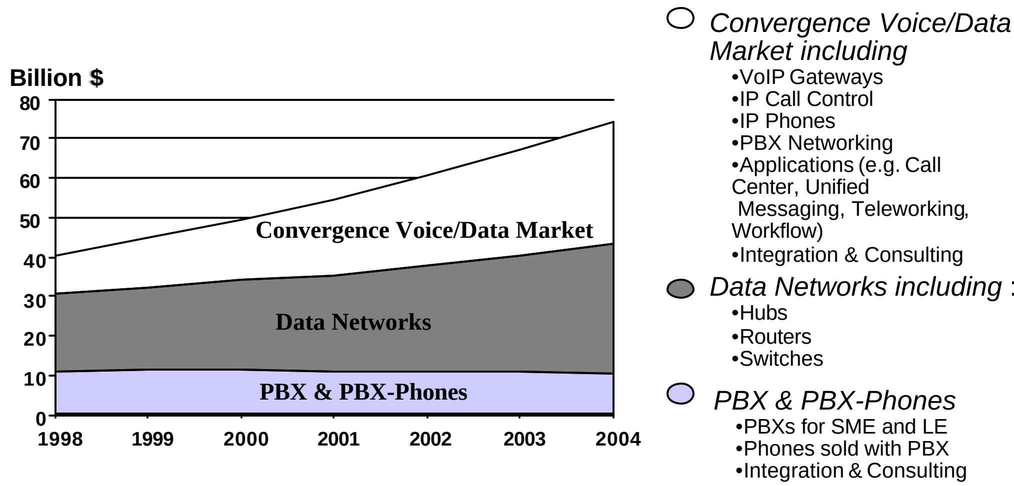

Figure 60: Expected market trend for Voice/Data convergence (Infotech taken from VanderMate, 2000)

The first venture based on this new technology arrived in 2000 under the name HiNet Xpress. In 2000, Siemens introduced new IP products, including a flexible IP gateway, enhanced IP phones, IP-based workflow applications and an IP-based communication and application platform, called HiNet Xpress.

This was followed in 2002 by the integration of fixed network providers, the Com-B venture. Fixed network providers represent the so-called carrier networks that offer communication channels between users (for example the landline phone networks), whereas Enterprise Networks provide the communication platform within enterprises.

6.6.1.1 New technology-based venture 1: HiNet Xpress

HiNet Xpress replaces traditional server based communication systems and combines fax, e-mail and telephony features on a client desktop PC. From a technical perspective both voice and data are processed in the same manner based on the Internet protocol and, as such, the user has access to all applications from a standard user interface. Intelligent call distribution enables not only telephone calls but also fax, e-mails and voice messages to be routed. In addition, in a call centre for example, e-mails are not allowed to pile up in a mailbox to be subsequently processed, as previously was the case, but are forwarded directly to the screen of the next free agent. The call centre supervisor can view the status of e-mail processing on screen at any time and help avoid bottlenecks. This allows call centre systems to be used with greater efficiency aims to reduce costs across the entire work process.

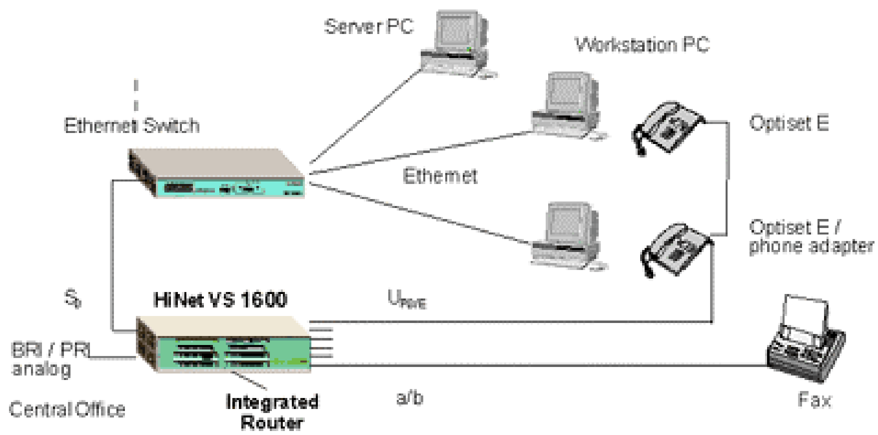

Figure 61: Example of HiNet Xpress configuration

HiNet Xpress does not simply translate the existing PBX architecture into a VoIP system, but is a true architectural innovation. The traditional PBX architecture consists of telephones, with very limited processing power, connected via a separate network to a central PBX. This central server takes care of all communication processes. Because HiNet Xpress runs on multimedia PCs, processing power is no longer a bottleneck. This means that no central intelligence is needed to direct the company's communication processes. Instead of a central server, the distributed HiNet Xpress software processes calls and generates features locally. Because it does not rely on a central feature server this architecture makes the HiNet Xpress system not only more robust than server based PBXs, it is also much more scalable than traditional PBXs, especially in conjunction with the use of teleworking clients.

The venturing model stemmed from the initial results derived from the ICE2000 project activities. The process model was driven by the internal new process concept and the internal market to support the effective take up of the new venture. Effectively this meant a post-merger integration of the voice and data processes at the division.

6.6.1.2 New technology-based venture 2: Com-B

Com-B is an innovative solution offered by Siemens together with an external carrier network partner. Com-B takes over a business model from the mobile communications market where customers can get a mobile phone for free while using a specific telecommunications provider for a specific time period. Siemens transferred this business model to the small- and medium-sized enterprises (SME) market. An SME can get state-of-the-art telecommunications equipment (including internet access) for free while using a specific carrier network provider. Siemens provides the equipment and maintenance during a 36-month contract.

The technological innovation in this construction is the follow-up innovation of HiNet Xpress from the HiPath family. The architectural innovation from a technical perspective still applies, as Com-B is the combination of this offering with an external network provider.

The emphasis of this new venture base is on the new business architecture. In the previous case of HiNet Xpress, the emphasis was on integrating the coordination of, and architectural knowledge about, data and voice technologies in the venturing process. Within Com-B a similar architectural knowledge transfer is necessary to create the venturing process of this new business model, whereas HiPath is complemented with carrier network technologies.

The architectural innovation of Com-B has been illustrated by a new core process concept (figure 62). The customer orders, pays and receives the equipment from Siemens under the Com-B co-operation contract. The cost is a fixed amount that is included in the contract obligations together with the carrier network contract. Siemens delivers the goods and their part in the process is complete. The carrier network provider, who then deals with the maintenance and service of the technology, will also pay out a discount to the customer since they use the Com-B construction.

This new business architecture stemmed from a process engineering effort that was a follow up of the methods, tools and techniques utilised to produce the new process concept of the internal market. The result described here was the second version of the business architecture. In the first run, the business architecture was structured that the customer got the equipment virtually for free (all payments went through the carrier provider), however this business model did not work to the satisfaction of both partners.

The architectural implications of the above described core process were significant in that it had to fit on both sides (Siemens and the carrier network operator) with the operational processes and systems for the ordering and delivery contracts. Numerous interfaces between these two processes had to be reviewed to align the processes in order to market this construction.

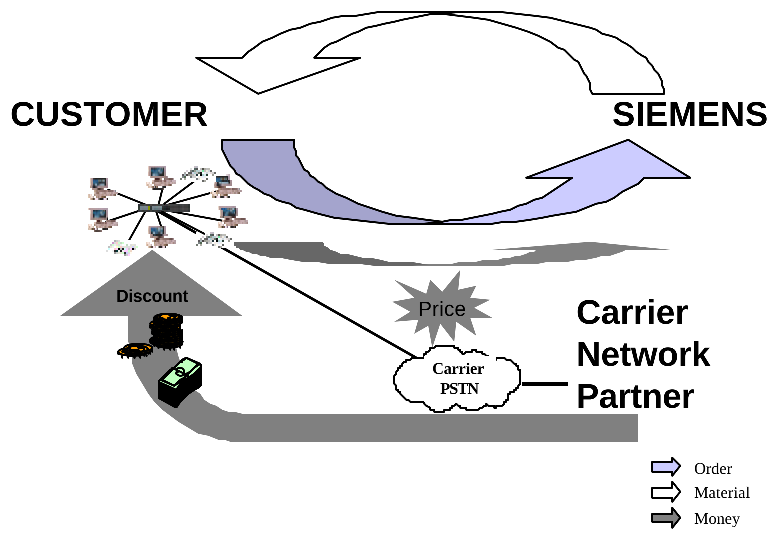

Figure 62: Com-B business architecture

6.6.2 Comparability of the two ventures

In order to use these ventures in the experiment it was essential that they were relatively comparable. Obviously each venturing case has its own specificities with respect to the underlying technologies, the market, and the organisation. Nevertheless in order to carry out the experiment, it is necessary to have a certain degree of comparability to experiment with the proposed proxies and measurement system.

The cases are comparable in three aspects: strategic intent, scale, and level of architectural integration. The comparability has been verified through both the interviews and workshops.

Both cases were regarded as the main strategic driver for the future, at the time of their implementation. Internal communication patterns show similar behaviour in the announcement of the venture as the way forward for the business. Furthermore interviews with top management and the process team confirmed that both were seen as equally important strategic business opportunities.

Secondly, the scale of the two cases is comparable as both involved a division-wide rollout, and the business opportunities covered the whole division. The division was also a similar size at the time of the rollout of both ventures. Both cases were highly marketed at conferences such as the leading CeBIT conference in Germany, and received national newspaper attention (e.g. N. N., 2001). Furthermore, as the test results revealed, a comparable amount of resources were committed at the start of both ventures (approximately 70% of total resources available).

Thirdly, both ventures consisted of radical new architectures in both technological and business terms. The architectural integration of the two innovations had comparable implications from a process perspective. The technology of HiNet Express was the first architectural innovation of VoIP. Com-B was more oriented towards co-operation with an external network provider in a new architecture. The implications for process engineering on the architectural level were similar, as both ventures had to deal with two groups of *component* providers (HiNet Express: Voice and Data providers; Com-B: VoIP and Fixed Network Providers) that required integration.

As mentioned in the previous section, during the study efforts have been made to enhance venturing of the new technologies. These efforts represent the evolution of the observed elements of the dynamic capabilities within the division driven by the change management crew. Examples are the use of advanced methodologies and tools for process engineering activities, and training modules to ensure knowledge transfer and implementation. For both ventures two distinct process engineering efforts can be identified.

6.6.2.1 Process engineering for HiNet Xpress

As previously mentioned, the HiNet Xpress case was set in the context of the ICE2000 initiative. The process engineering activities represent the start of building an ongoing capability in the division to establish productive processes. From this perspective the HiNet Xpress venture can be seen as the first venture that could benefit from this commitment.

When analysing the process engineering activities carried out before the introduction of HiNet Xpress it became apparent that the division had improved its ability to design processes. Before the start of the ICE2000 continuous process management programme (effectively, the installation of a dynamic capability within the division), efforts to align processes failed to produce any concrete results. The last project run in 1998 was internally organised. This effort took a year and the result was two large folders full of processes, without implementation potential.

The HiNet Xpress process engineering approach was split into three phases: conceptual, implementation and measurement. The conceptual phase of the process engineering effort took five months (from January to May 2000). The implementation phase took nine months (from July 2000 to March 2001). The measured phase (process controlling) commenced afterwards, but it was soon found that no existing measures were effective enough to actually pursue this. Here it is interesting to note that the lack of measures occurred as a result of a lack of specific process related real-time data. The proposed measures developed in this thesis became the preliminary impetus for this new raw data in terms of real-time process based measurement, and thus executes the triangulation (Jick, 1979) and cross validation of the work. An overview is depicted in figure 63.

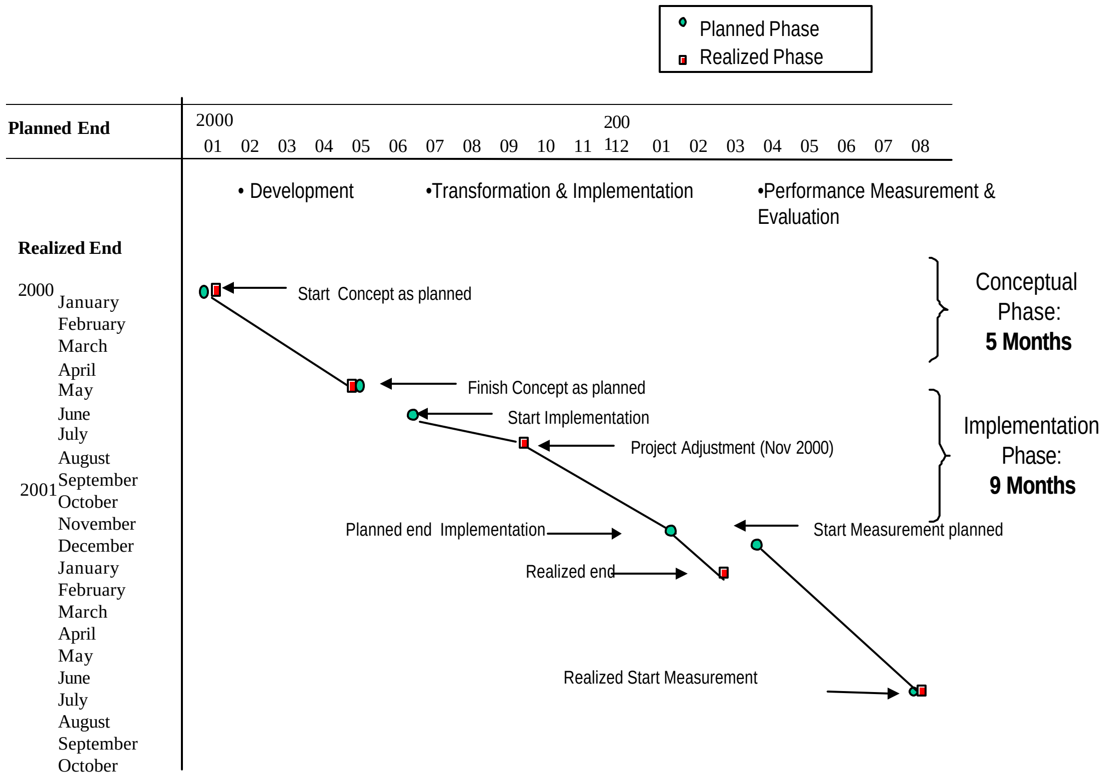

Figure 63: Process engineering for HiNet Xpress

6.6.2.2 Process engineering for Com-B

The process engineering efforts for the Com-B processes showed a clear improvement in comparison to the HiNet Xpress processes (figure 64). The conceptual phase for the process engineering of the Com-B innovation took one month (August to September 2001). This is an improvement of 80% in comparison to HiNet Xpress. Furthermore the implementation took five months (October 2001 to March 2002), which implies an improvement of 44%. Com-B was introduced to the market in January 2002, and an amendment to the business architecture was made in March 2002. In total, the combined phases of development and implementation of Com-B saw an improvement of 57% in comparison with HiNet Xpress.

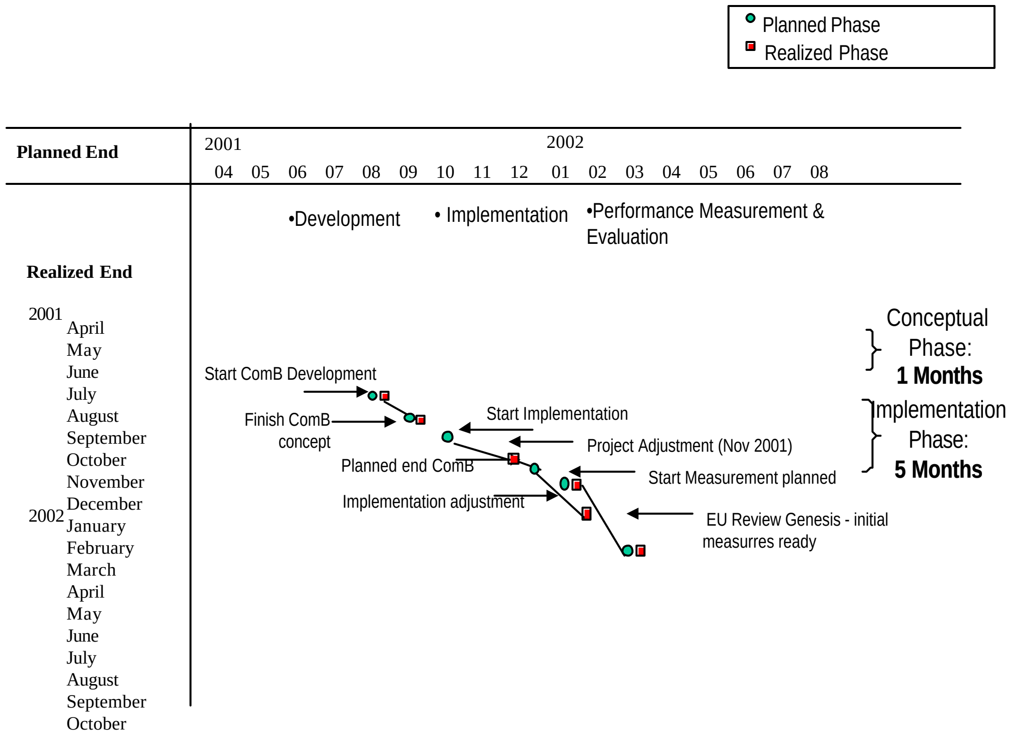

Figure 64: Process engineering for Com-B

On this level of innovation the changes confirm the evolution of the division's dynamic capability. The improvements show that the division, with the installation of a dedicated team for process engineering and the methods and tools, were able to more effectively engineer new venturing processes for new innovations.

6.6.3 Productivity measurement – XTrend measures

The question remained whether this had any impact on the performance of the division. The improved process engineering efforts result in a decrease of process development time. Nevertheless, no measurements were available to evaluate these efforts to real business performance.

Uncertainty for the management board of ICE was not reduced, which became apparent during a division wide rollout of the processes at a yearly conference. Although the 160 employees present at the rollout were enthusiastic about the new processes and keen to implement them, the board of Switzerland Group (the effective owners of ICE) needed more convincing performance related results. These were however not available.

During the case it became apparent that a probability function does not only contribute to managerial decisions, but if it holds true, even in approximated form, could have provided convincing arguments for the investors in the division as well. The initial concept thus provides a basis on which further operationalisation can be built, and the need for a real-time performance measurement system.

This observation appears to open the doors for an interpretation of theoretical interpretations of capability and direct resource commitments (decisions) geared to support the active operationalisation of these capabilities. This will be further addressed in the conclusion. This section aims to test the initial candidate solutions.

Retrospectively, data has been collected to evaluate the developed proxies with the collection tool XTrend. Based on interviews and data available from internal systems, a recollection could be made for the concrete measurement-points resource allocation and financial contribution.

The measurement took place in a sample region of the division, which represents a comparable sample of the total division. The figures given are relative, to conform to confidentiality agreements.

Both ventures have been measured in the venturing process from the point of their respective introduction in the operational process and thus have comparable starting points. The starting point has been chosen as the point when the venture left the development stage (business house) and entered into the process engineering phase to be taken up by the operational system (the operations department), which have been identified by the director of the business house.

The cases have been measured for a period of five months; HiNet Express was integrated into the operations department in October 2000, and Com-B was introduced in January 2002. The results of the measurements taken in these cases are provided below. Using XTrend, five measurements have been taken in each case to examine the relationship between the resource distribution and the financial indicator[28]. The graphs represented here will present and discuss the proxy for alternative productivity in the individual ventures and the expected increase in the dynamic capability proxy, and will compare this to the qualitative analysis of the longitudinal study.

6.6.3.1 Productivity measurement HiNet Xpress

HiNet Xpress has been measured over the period of October 2000 to February 2001 (five consecutive measured points). The “combined finance and resource indicator” graph (figure 65)

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[28] For confidentiality reasons, the scales of the graphs presented are relative. The data has been classified as retrospective as the numbers were provided by means of interviews with top management. Nevertheless, the numbers were based on previous existing management systems, which the author had access to, and the results resemble real-time data.

shows the timeline on the X-axis. The Y-axis depicts the resource and finance indicators of HiNet Xpress. The indicators multiplied by a hundred create the respective percentages.

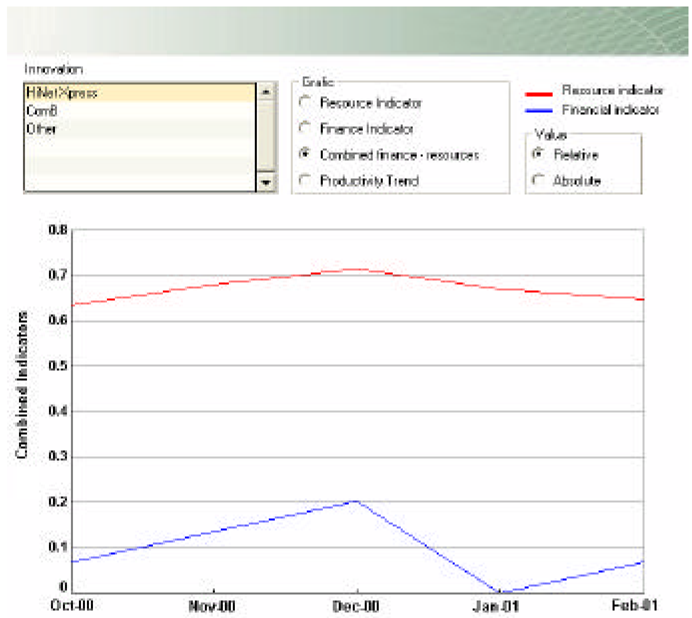

Figure 65: Combined finance-resource indicator HiNet Xpress

The resource distribution varies between 0.63 (63%) and 0.71 (71%) and the fluctuation patterns are balanced. From the resources input perspective no major changes are visible either up or down. This can be confirmed from a qualitative perspective which revealed that little restructuring efforts were executed within these critical five months.

The 63% to 71% of the total resources of the sample that has been invested in venturing HiNet Xpress rendered a return of between 0-20% of total returns. The efforts put in the additional product portfolio did not require an equally high investment to venture the rest of the financial results.

The fluctuations and the behaviour of the relative returns are more volatile than the resource inputs, particularly in measurement point four, where no significant returns on venturing HiNet Xpress have been reported. These figures confirm the uncertainty as perceived on board level. Despite the tremendous amount of process efforts poured into the division, the returns were still perceived as poor and uncertain. Only in the first three months can a positive impact be seen, where returns gradually increase from 6.7% to 20% of total returns. This is followed by a drop to 0% of financial returns on the venturing efforts of HiNet Xpress, which illustrates the high uncertainty.

Combining the measurements according to the productivity ratio produces a graph that shows heavy fluctuations (figure 66). When analysing the productivity ratio, the graph clearly shows a turbulent path in the first five months of introduction. The first three measurement points show an increase in the productivity ratio from 0.11 to 0.28. However, due to the zero returns in measurement point four, productivity rapidly decreases to zero, only to pick up again in measurement point five to 0.1.

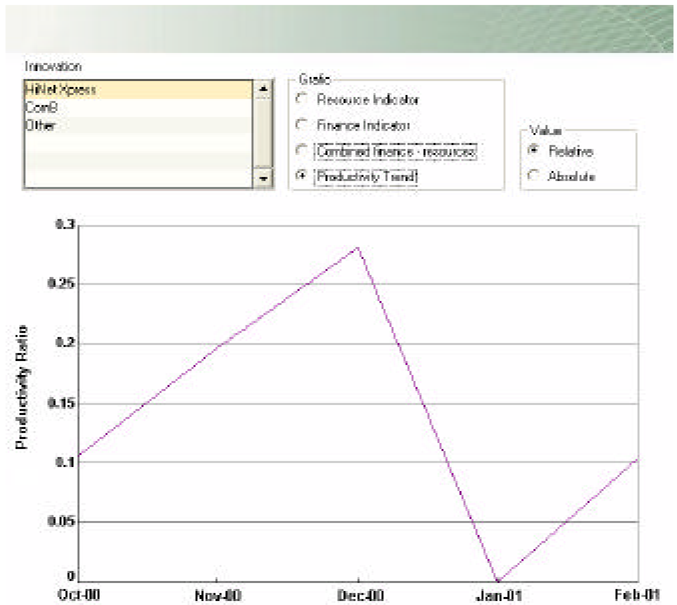

Figure 66: Productivity trend HiNet Xpress

Based on the productivity ratio in the HiNet Xpress case, no patterns have been presented to support the expectation that the process engineering efforts that preceded the measured venturing process had any significant effect on productivity improvement as calculated using the alternative productivity ratio. Although support can be generated from the first three measurement periods, the fourth measurement period does not confirm the expected productivity pattern. However, measurement point five shows an increase in the productivity ratio of 0.1 from period four. This quick recovery implies rejection of potential interpretations from this measurement for understanding the venturing process of new technologies is not the immediate conclusion.

Compared to the longitudinal data, it appeared that there was uncertainty with respect to the commitment of resources towards the new venture and the new profitability targets set by the Siemens Group. Based on past data, several months later the division stated an interim strategy to pursue existing products rather than VoIP to boost profits. It also indicates that at the time no understanding of the underlying uncertainty relation was available. This resulted in a higher exposure to the risk of falling in the chasm and losing out as one of the main players in Switzerland to enter this market (referring back to the Gartner expectations in figure 64).

In spite of these developments, the division did not give up the efforts related to the effective building of dynamic capabilities within the division. Although the action-performance relationship was not satisfactory and led to a change in strategy – back to the old technology base in order to boost profits – the department still acknowledged the importance of exploiting new technologies.

6.6.3.2 Productivity measurement Com-B

Com-B has been measured in the time period from January 2002 to May 2002, comparable to the time period of HiNet Xpress. Again the “combined finance resource indicator” and the alternative productivity indicator have been used to interpret the patterns in the light of dynamic capabilities and the respective uncertainty in the venturing process between the performance and the resource commitments (figure 67).

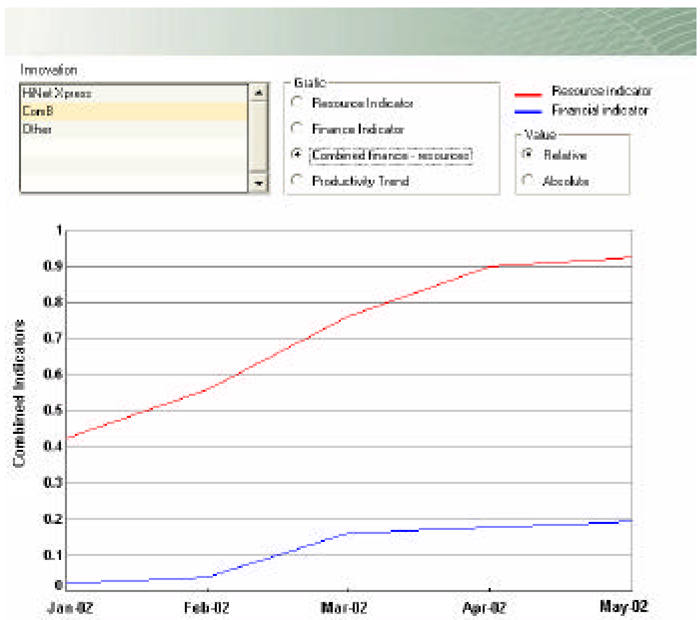

Figure 67: Combined finance-resource indicator Com-B

The relative amount of resources spent on the venturing process as compared to the total shows a variance between 0.42 (42%) and 0.92 (92%). The increase is relatively stable but flattens in measurement point four. Compared to the resource indicator of HiNet Xpress, it can be noted that at the start of the Com-B introduction relatively less resources have been used (42% for Com-B against 63% for HiNet Xpress). Additionally, whereas with HiNet Xpress a decrease in resources committed to this venturing process is visible from measurement point three, no decrease at all is apparent in Com-B. Com-B only shows a flattening of the resources committed to the venturing process. Compared to the thought experiment expectations, this arguably suggests that based on the resource input alone, HiNet Xpress follows the expectations of the behaviour of relative amount of resources allocated to a new venture more than does Com-B. Nevertheless, a different perspective emerges when comparing the resource indicator patterns against the performance patterns.

The performance pattern of Com-B shows a stable increase from 0.02 (2%) to 0.19 (19%) of total performance. The trend appears more balanced than HiNet Xpress, which could indicate that the relationship follows a more predictable path from the time of introduction. Both ventures have seen a relative return maximum of approximately 19-20% in the five-month measurement period. However, the performance trend of HiNet Xpress was characterised by a much more volatile behaviour compared to Com-B. The venturing process of Com-B shows an initial return of 2% of the total returns in period January 2002. However, four periods show a stable increase of approximately 2% per month, with the exception of the increase from period two to period three, which approximates to 12%. In all measurements, however, the trend is upwards, not downwards as was the case with HiNet Xpress in period three. This implies that although a higher investment in resources in Com-B was visible from the resource indicator, this paid off in terms of performance. As the resource indicator flattens in the last month, the financial indicator is still increasing steadily.

Translating these measurements into the productivity ratio, a more stable pattern emerges (figure 68). Although the productivity ratio at one point for HiNet XPress reached 0.28 (period three), which is 0.07 higher than any of the measurement points in the Com-B venture, the overall pattern of Com-B is much more settled and shows a predominantly increasing trend. Whereas in the case of HiNet Xpress, a chaotic pattern characterised the initial venturing phases with a drastic drop from period three to four of 0.28, no such fluctuations appear in the productivity trend for Com-B. Com-B seems to settle faster and more closely resembles the path as developed in the thought experiment (chapter 5). Only a slight decline of 0.01 from measurement point three to four is visible. The qualitative study has shown that this can be attributed to a modification in the business architecture of Com-B and the line picks up again in month four.

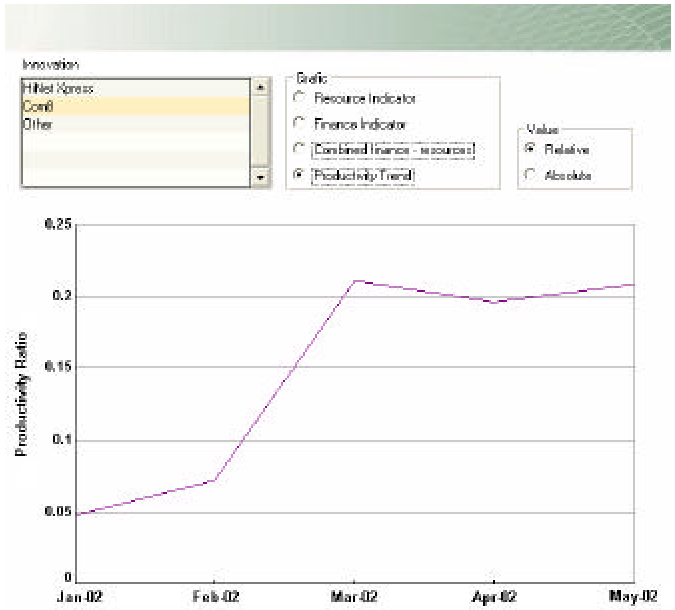

Figure 68: Productivity trend Com-B

The findings of the qualitative analysis, which suggested that the division improved its capability for integrating new ventures into the operations department, seem to be supported by the productivity ratios and trends, which show a change from a volatile (HiNet Xpress) to a more predictable and settled trend in productivity (Com-B). Overall, the Com-B trends seem to suggest that the integration of this venture in the operational base of the division by effectively engineering the processes seems to behave in a more predictive manner, especially when taking into account the increase in productivity of 57% in process engineering and the subsequent reduced investments (time and effort of process engineering are not included in the measurement) that have been made to introduce Com-B in comparison to HiNet Xpress.

Based on the patterns derived from the alternative productivity measure, it seems that the division was able to perform better the second time around. Nevertheless, it has not yet explained why the peak in the productivity ratio of 0.28 in month three of HiNet Xpress was not replicated with the Com-B venture. As with any measure, these measures also are very much dependent on the context in which they have been created. To this extent the triangulation with the qualitative data seems to suggest that the fluctuations of the productivity line in Com-B can be better explained, understood and perhaps even be used to predict future performance than was the case with the measurements with HiNet Xpress. For example, the conclusion drawn about the slight drop from March 2002 to April 2002 for Com-B appears to be related to changes in the business model

It also has to be acknowledged that, with regard to the productivity ratios, although the process activities were the main changing variable during this experiment, other factors could still have had an impact on the development of these measurement results. Also the extended timeframes of the two introductions of the ventures into the operational systems and the frequency of measuring can potentially produce a different perspective or interpretation of the changing behaviour of the resource commitment versus performance relationship. This can indicate that there is a need for more empirical research on a division level. From a pragmatic perspective however it also opens up more potential, in case extended measurement does enable better interpretation and prediction of the venturing process, and these measures could serve to indicate and interpret external influences on the productivity trend of the new venture.

6.6.4 Dynamic capabilities proxy: HiNet Xpress versus Com-B

The final measure has been referred to as the dynamic capability trend. The dynamic capability trend sets out to explore a potential measurement of a firm's level of dynamic capabilities according to the uncertainty relation as applied in this thesis. In this case, and according to the expectations set out in the qualitative study, the dynamic capability proxy should show an effect that resembles a positive increase.

This experiment aims to evaluate the proposed proxy for dynamic capability by applying it in a comparison of HiNet Xpress and Com-B. The dynamic capability measure, as developed in XTrend, takes a ratio over similar periods of introduction (five months each) and attempts to visualise the assumptions made during the retrospective evaluation of the "combined finance resource" trend and the alternative productivity trend. Using the XTrend measurement system the following pattern has been created (figure 69).

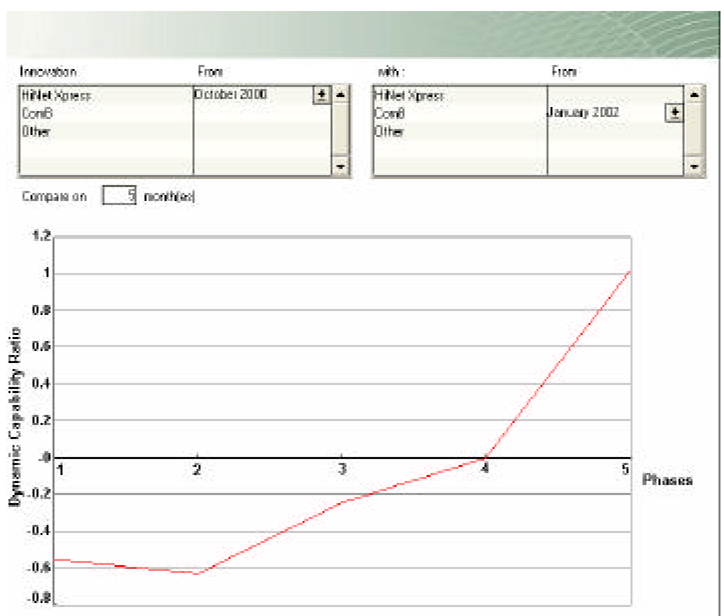

Figure 69: Dynamic capability trend HiNet Xpress versus Com-B

The dynamic capability ratio is derived from the expectation that a dynamic capability can be seen when an improvement in the productivity ratios is visible over time. This has been done to reflect the expectations of a long-term capability by measuring and subsequently comparing short-term business opportunities (in this case the ventures Com-B and HiNet Xpress).

The formula compares the two productivity ratios of two consecutive ventures. In the comparison this difference is taken as a percentage of the productivity ratio of the first venture. This implies that the dynamic capability ratio will show positive if the second venture outperforms the first, and thus an improvement is visible. A negative dynamic capability ratio would imply that the productivity ratio of the first venture was favourable to the second venture. Nevertheless, additional to the individual measurement points, the dynamic capability ratios combined give a trend that aims to reflect the firm's capability to change during the venturing process.

The first assumption that has been made is that the relative venture introduction periods are comparable. In this experiment this means that the periods from month one to five for HiNet Xpress are similar in the performance and resource allocation expectations to the periods from Com-B in their characteristics. A ratio can thus be prepared that compares the first productivity measurement point of HiNet Xpress to the first productivity measurement point of Com-B. The measure reflects the relative difference in percentages between the productivity ratios of Com-B (0.05 in period one) to HiNet Xpress (0.11 in period one). Com-B then shows a difference of -0.55 (or -55%) against HiNet Xpress. This indicates that the productivity in similar timeframes (period one) is better in the HiNet Xpress Case, compared to Com-B.

Period two shows a relative decrease of this proxy of -0.64 (or -64%). Again HiNet Xpress seems to outperform Com-B when considering the productivities of both ventures over comparable periods. The dynamic capabilities proxy shows a 9% decrease from phase-1 to phase-2, which would indicate that the dynamic capability of the division has declined instead of improved, and thus would imply the proxy does not support the findings of the qualitative data.

Period three again shows a negative comparison of the productivity of Com-B against the productivity of HiNet Xpress. The proxy shows a negative difference of 25%. Although this negative difference could again imply that the dynamic capability proxy does not reflect the situation as established by the qualitative data, the pattern that emerges from the dynamic capability trend is a fast increase of 39%. This could also imply that an improvement has been made in the dynamic capabilities of the firm as the productivity of Com-B has increased from the last measurement period compared to HiNet Xpress.

This pattern also holds true for period four, where the proxy implies that both the productivity of Com-B and HiNet Xpress are similar, or approximate to zero. Nevertheless an increase of the dynamic capability is implied, as the productivity of Com-B again improves on average 25% more than that of HiNet Xpress, in a similar phase of the venturing process.

Finally, in period five, the proxy shows for the first time that the productivity ratio of Com-B outperforms the productivity of HiNet Xpress, with a relative increase of 102%. This means that in a similar period (month five) after the introduction of the new technology venture, productivity of Com-B improved 102% compared to that of HiNet Xpress.

This would indicate that the dynamic capability proxy, especially the trend in the latter phases, indeed reflects the assumptions made from the qualitative data analysis. This analysis showed that an improvement in dynamic capabilities is apparent. In the comparison of the cases HiNet Xpress and Com-B the dynamic capability trend shows an ever-increasing upward line, except for period one. The dynamic capability trend shows an average increase of 39% over the first five months of introducing a new technology-based venture into the operational processes (table 23). This line thus seem to confirm the results that emerged from the longitudinal case study which showed that, after the division had actively created dynamic capabilities, the division can change more rapidly and with better results in terms of performance against resource commitment.

	PHASES				
	1	**2**	**3**	**4**	**5**
DC RATIOS	-0.55	-0.64	-0.25	0	101
CHANGE (2-1)	***-0.08***				
CHANGE (3-2)		***+0.39***			
CHANGE (4-3)			***+0.25***		
CHANGE (5-4)				***+1.01***	
AVERAGE CHANGE	***+0.39***				

Table 23: Changes in dynamic capability ratios

These insights suggest the measures seem promising for interpreting intangible aspects such as capabilities within a firm. Taken from the perspective of the individual monthly comparisons, only periods four and five would support this as only in these phases was the productivity of Com-B similar or better than HiNet Xpress. However when comparing the relative changes in the dynamic capability ratio, only period two denies a positive change of the dynamic capability of the firm, where the proxy shows a slight decrease (-0.08) as compared to the previous measurement. Over a period of five months an effect of 39% improvement in this ratio is visible.

The dynamic capability ratio thus seems to be helpful in measuring and interpreting the observations made during the longitudinal case studies. The graph reflects a positive impact, which indicates that dynamic capabilities are being built within the division. The proxy could be a first step towards potential ways of measuring intangible processes such as dynamic capabilities. The graphs and interpretations presented here reflect what Zollo and Winter (2002) would refer to as a knowledge codification of the action-performance relationships. The system actively supports the knowledge articulation (the survey style data collection) and codification (the reports). Future research can be directed towards further exploration of the managerial contributions that such systems can provide.

6.7 CONCLUSIONS AND IMPLICATIONS OF THE CASE STUDY

Based on this longitudinal case study and the measurements of the two sites, some initial conclusions can be drawn concerning dynamic capabilities and the respective measurement of these capabilities using the XTrend prototype system.

6.7.1 A longitudinal study on dynamic capabilities

The case study has provided an initial insight into how dynamic capabilities can be measured to fuel potential statements on a probabilistic process model for uncertainty. The nature of this study is instrumental, and aims to provide further insight into the phenomenon of uncertainty and the relevance of using uncertainty relations to enhance the understanding of uncertainty. Hence limited attention has been given in this initial phase to replication of the results. Nevertheless, the assumption made throughout the thought experiment in chapter 4 seems to be confirmed by the two cases, which opens areas for future research.

Two main findings can be derived from the qualitative study. Firstly, the longitudinal case implied that dynamic capabilities could be deliberately implemented in an organisation. Although most literature on dynamic capabilities still portrays them as intangible assets of a firm that have only been understood on an abstract level and observable mostly in hindsight by interpreting their evolution (i.e. Teece, 1994; Teece *et al.*, 1997; Eisenhardt, 2000; Zollo and Winter 2002), the Siemens case shows that the characteristics of such dynamic capabilities can be intentionally implemented. Siemens actively endorsed some of the techniques and processes expected to form dynamic capabilities, such as continuous process engineering activities and rapid prototyping (Eisenhard, 2000). This would imply that dynamic capabilities can be deliberately and actively implemented, and thus become part of the managerial decision-making process.

Secondly, the Siemens case showed that the problems arising from the long-term effects of such dynamic capabilities relate to the exploitation of short-term business opportunities, and on this confluence an uncertainty emerges on the level of managerial decision-making. Capabilities are understood to provide a long-term competitive advantage (Teece *et al.*, 1997), and evolve over time; it thus takes time and investment to build them up.

However, a paradox emerges where these capabilities are prescribed for organisations that are engaged in turbulent environments (Teece, 1994; Zollo and Winter, 2002). The Siemens case showed that in these turbulent times, business opportunities are characterised by their short timeframes (for instance, an internal study has shown that product life cycles declined from three years in 1995 to no more than nine months in 2000). In order to survive, it is essential that these business opportunities are exploited effectively, which subsequently implies a strong focus on short-term results when making decisions.

6.7.2 Measuring dynamic capabilities

Within the case study, however, and supported by the experiment, Siemens ICE did not abandon the long-term plan of building dynamic capabilities, and subsequent investments, in favour of short-term results. In contrary, the division aimed to establish a separate change management crew that would deal with the change demands of the division, effectively embodying the dynamic capabilities, which can then be measured and evaluated using the XTrend system, providing short-term dynamic performance results.

This situation provided the required grounds to experiment with the developed proxies on productivity and dynamic capability. The longitudinal case study and the retrospective cases confirm that the division was able to increase their dynamic capability to change, which can be interpreted as the effective building of dynamic capabilities. These capabilities addressed the incubating and grafting of new ventures into the productive base of the firm.

Triangulation of the quantitative and qualitative data shows an encouraging result in three of the four measurement periods, confirming the expectations made at the outset of the experiment and the qualitative analysis.

Measuring the productivity of the process engineering activities has already revealed the impact of the investments in the building of the dynamic capabilities. The process engineering activities, as part of the new business development for Com-B, showed an improvement in time of 57% compared to HiNet Xpress.

However, the longitudinal case studies confirm the literature (Zollo and Winter, 2002) in that such improvements are not enough to enable decision-making towards the long-term competitive advantages expected to result from dynamic capabilities. Instead, the short-term action-performance relationships – described in this thesis as resource commitment (decisions) versus performance relationships – are related to the dynamic capabilities and thus also require improved understanding. This meant that these two perspectives were measured simultaneously, and by using the XTrend system, allowed for the creation of patterns reflecting such resource commitment versus performance trends, albeit in a real-time fashion.

The proposed proxy for dynamic capabilities showed an effect of 39% as an average increase per month over the first five months of grafting new ventures into the operational process base. During the longitudinal case study, this effect has been confirmed by the qualitative data gathered throughout the division via observations, workshops and interviews. The triangulation of these results shows that the proxy provides a potential contribution to increasing the understanding of dynamic capabilities

As previously indicated, for this first experiment the system has been applied with retrospective cases. As the experiment required a comparative amount of qualitative data, which would confirm a change in the observable dynamic learning processes within the division, the two cases of HiNet Xpress and Com-B have been measured using retrospective data. This data was provided by an existing system, complemented by direct information from the board of the division.

In addition to the proxy evaluation, on a system level some initial insight emerged on the in-depth process analysis. The development of the system has been done in close co-operation with the division, who, irrespectively of the cases presented here, carried out some independent tests, especially concerning the in-depth analysis. The in-depth analysis is concerned with the resource allocation to sub-processes, which has been referred to as process-based costing. From this perspective, the experiment provided the division with a tool that allowed the management to actively monitor and predict resource allocations based on the process measurements.

Within the experiment, the data provided by these efforts resulted in some interesting findings concerning apparent discrepancies with respect to the resource base and the services rendered by these resources. In particular, a comparison between two regions under similar circumstances showed that one region was able to render more productive services with the available resources than the other region.

These insights led the management of the division to focus the process re-engineering activities on the under performing division. As such, the tool was directly used to make decisions concerning the commitment of resources to the process engineering activities. The knowledge codified by the system actively supported the division in utilising the change management resources optimally. In this sense, and conforming Zollo and Winter's (2002) argument on the importance of experience accumulation, knowledge codification and knowledge articulation for the evolution of dynamic capabilities, these results suggest the system itself contributed to the evolution of the dynamic capabilities at the division.

Although no comprehensive data set is yet available to evaluate the exact impact of these results, the contribution of the system from a pragmatic perspective was regarded as very relevant. These unexpected benefits have been confirmed in various interviews with both users and decision makers. Furthermore, plans have been made to test the system on a division wide level.

6.7.3 Implications and future research

This also has implications for future research. The combination of performance measurement and process engineering seems a promising avenue. More empirical research is required to learn how such process oriented performance measurements can benefit process engineering activities, and the deliberate commitments required to build dynamic capabilities within an organisation.

Finally, future research should be directed to expand on these results and on the instruments and methods proposed in this thesis. Further cases should be held to see if the ratios are replicable or need revision. Furthermore an implication arises with respect to the timelines used (five months) and the comparability of these timelines. Future research should amplify the case in a real time, instead of retrospective, study. This can also support the evaluation of the potential managerial benefits of this approach and real-time data collection. Here the sub-process measures could add to the enhanced resource reconfiguration capabilities of the firm.

With respect to the probabilistic process model set out in chapter 3, the first results as detailed in this chapter show encouraging signs for further research in this area. The proxy as such could thus be a first candidate solution to evaluate the likelihood of dynamic capabilities enhancing performance.

The study also provides some first qualitative indications that dynamic capabilities, as described in this thesis, seem to improve the organisation's performance on a long-term basis. Notably, halfway through the study a division wide conference was held as part of the process engineering activities in order to roll out some of the new processes. Although staff present at this conference were enthusiastic about the results presented by the management, the board of I&C (the respective owners of the division) were less impressed as the new processes and all the efforts invested in them did not yet show that the division would come in on target. This resulted in accumulated pressure on the management of the division and high levels of uncertainty about the future of the division. The management however persisted in the change activities. Two months later, the official financial results showed the division had outperformed all other division by at least 20% and was most in line with the agreed targets. This can be regarded as an initial indication that the dynamic capabilities did increase the likelihood of increased performance for the division.

This implies that whilst the experiment has indicated that constructing such a probability function is a time consuming effort, the results derived from this particular study should be regarded as an encouraging start. Especially with regard to the co-evolution of both the theoretical underpinnings of the input and output variables as well as the framework of dynamic capabilities, the probability function is likely to evolve in conjunction with these areas. This study has merely commenced operationalising these abstract theoretical frameworks in the light of understanding uncertainty within NTBVs.

7

CONCLUSIONS AND IMPLICATIONS

7.1 SUMMARY AND OVERVIEW OF THE RESULTS

This thesis aimed to address the uncertainty faced by managers when making decisions concerning NTBVs. I have argued that such decisions are difficult but important for management to comprehend and thus a relevant topic to explore.

7.1.1 Input versus output: uncertainty and venturing new technologies

Uncertainty can be conceptualised when looking at the outcome versus the input of the new venturing process. From the outcome perspective, existing approaches are helpful when more refined knowledge is available or can be assumed. Nevertheless, the outcome of venturing new technologies is uncertain, not only to the extent that the performance, such as profit, of a potential future state should be judged, but also that it is yet unclear what the actual potential future states might be. When the latter is known, existing frameworks such as decision theory, planning activities and real options planning can provide potential solutions to conquer such decision queries. Nevertheless, the uncertainty this thesis focuses on does not have this level of knowledge and as such requires a different approach.

On the input side of NTBVs, existing theoretical frameworks have addressed various views that all point towards the importance of the capabilities a firm needs to increase the chances of a long-term competitive advantage. Specifically, with the dynamics involved in venturing new technology-based ventures, I have argued that the emerging framework of dynamic capabilities seems to be appropriate as it addresses the problems associated with venturing new technologies.

Decisions, within this context, are commitments of resources to achieve future returns. Within the process of venturing new technologies, the condition of being able to reconfigure these resources in a dynamic manner (a dynamic capability) is seen as essential to create a competitive advantage. Nevertheless, this concept does not make a claim on future returns other than the assumption that it enhances the competitive advantage or that it is indirectly related to firm performance (e.g. Henderson and Cockburn, 1994; Iansiti and Clark 1994; Zott, 2000). Dynamic capabilities are believed to address the so-called action-performance linkages (Zollo and Winter, 2002) and are claimed to reduce the causal ambiguity between these linkages. This seems impossible, however, when looking at the specific uncertainty of new technologies.

The prevalent uncertainty for new technology-based ventures seems to hinge on the ambiguity surrounding the decisions made and the outcomes rendered by these decisions. The problem seems associated to the fact that although capabilities are required to make managerial decisions that result in long-term competitive advantage, the short-term decisions are of equal importance, as business opportunities need to be exploited in very short cycles. Long-term performance becomes more and more dependent on an organisation's ability to exploit short-term business opportunities on a continuous basis, and thus continuously create performance from new business development.

The analogy used in this thesis has treated this uncertainty by conceptually losing the argument of causality when looking at the input-outcome uncertainty for new technology-based ventures. This thesis proposed exploring an alternative perspective for this problem and adopting a method to deal with this uncertainty based on the treatment of uncertainty on a sub-atomic level. The use of probabilities and experimenting to understand and measure probabilities proved particularly successful in dealing with uncertainty in quantum theory.

Others have already suggested the exploration and use of such insights for managerial phenomena, but no analogy yet exists to solve the specific uncertainty encountered when venturing new technologies. This thesis has shown that, from a rational perspective, such approaches are becoming more and more favoured by scholars for understanding managerial phenomena. Nevertheless, many of these works remain on an abstract philosophical level or only note that this is a potential way forward. Furthermore, various interpretations have been granted to the essence of the uncertainty principle, but very few have focused on the method that afterwards proved so successful. As such, this thesis contributes a new perspective by providing a first operationalisation of the treatment of uncertainty, using an analogy to Heisenberg's concept and methods.

7.1.2 Losing causality: towards a probabilistic process model

Losing causality, in this sense, means losing the assumption that there is an underlying causal relationship between the input and outcome of the new technology-based venturing process. As it is an ambiguous relationship, the underlying causality is replaced by a probability. Whereas current approaches are still focused on uncovering potential causal relationships, this approach implies a need to start looking for potential predictions without this underlying causality. Such an approach is distinct from, for example, decision theory as it does not assume likelihoods in a causal sense but aims to understand likelihoods in non-causal relationships, where some uncertainty remains, but perhaps becomes more manageable.

Based on this idea, a first probabilistic process model has been constructed to reflect an uncertainty that resides between the input-capability perspective and the output-performance perspective. Within this process model it is argued that a duality exists between the resource input and the performance output of the new technology-based venturing process. Although current theories from a capabilities perspective argue that the existence of the right capabilities would ultimately increase the chances of an enhanced competitive advantage, there is no certainty that this will actually happen.

A new way of exploring the duality between capability and performance is to explain the relationship in terms of likelihoods instead of ambiguous causal relationships. Having so-called dynamic capabilities within the firm increases the likelihood of improved performance, which has been expressed as a conditional probability. Using dynamic capabilities as a variable, the expectation would be that organisations that have a dynamic capability are more likely to generate increased performance from new technologies than organisations that do not have this capability.

Unlike conventional quantitative research, it was not the aim to validate a potential causal relationship between dynamic capabilities and performance based on positive correlations. Instead, the aim was to explore how this uncertainty can be explored in order to understand and support managerial decisions. If there are indications that there is a higher probability of increased performance when dynamic capabilities are present, this would encourage the decision-making process to focus and monitor all factors attributed to the constitution of such dynamic capabilities, and complement existing decision-making approaches. For example, resource commitments (decisions) under this specific uncertainty can be made to deliberately establish and nurture the elements that constitute a dynamic capability within the organisation. In essence, the aim is to provide managers with a new way of looking at this uncertainty.

7.1.3 Towards a proxy for dynamic capabilities

Exploring a potential probability, however, is time consuming, particularly as no measures yet exist for the intangible dynamic capability (Teece, 1994). A first step is thus to develop a proxy for dynamic capabilities. The experiment commenced by exploring a potential metric. As the aim is to support managers, the proxy should have empirical validity. A multiple case study has been carried out in order to construct a candidate solution.

The proxy was based on a conceptualisation of where dynamic capabilities reside in the new technology-based venturing process. This conceptualisation is derived from three distinct phases of the venturing process, whereby the second phase, the effective integration of new technology-based venture into the productive base of the firm, was identified as most important and relevant.

7.1.4 Designing a measurement instrument

Based on this conceptualisation, a measurement instrument has been developed to enable the evaluation of the proxy. This development of the system contributes an alternative real-time way of capturing process based resource allocation information. Instead of using completely accurate hindsight information, which often is made available too late to use for decision-making purposes, the system allows for real-time estimations to be made by the staff on their individual resource distribution on a process level. The employees are asked to provide their resource distribution to the processes related to the new technology-based venture as a percentage of their total effort. The system tracks the changes and reconfiguration of the resource-base of the firm over time.

This information can then be used to compare the performance of the new venture to the overall firm performance. The system allows for easy collection of the two data sets and calculates a ratio that represents the productivity of the new venturing process. The usefulness of this ratio has been tested and validated in the two case companies.

By comparing the productivity measures of sequential new technology-based ventures, a proxy emerged that has been identified as a potentially relevant representative of dynamic capabilities. By comparing the productivity ratios in similar phases of the new venturing process, a ratio emerged that has been termed the dynamic capability ratio. The system provides a graphical interface in order to depict the trends of the productivity and dynamic capability ratios over time.

Evaluating these productivity and dynamic capability ratios requires experimentation. The expectation is that systems that can produce such real-time ratios could ultimately support managers in making better predictions on future performance based on measurements of the current capabilities. In this context, the ratios presented here should be regarded as first candidate solutions and have been trialled at one new technology-based firm.

7.1.5 Testing the dynamic capabilities proxy in a longitudinal case study

Using a longitudinal case study at the Enterprise Networks division of Siemens, a qualitative study identified the evolution of dynamic capabilities within the organisation. The study provided insights into how specific decisions can lead to an enhanced level of dynamic capability. The evolution of dynamic capabilities was observed through specific learning routines that have been installed by the division.

At Siemens, managers realised the importance of dynamically reconfiguring the available resources and the operational processes. A dedicated change management crew was assigned to continuously update and re-engineer the process base of the division. In addition, a dedicated process engineering methodology and process development tool were applied and further developed throughout the study. These efforts resulted in a clear process engineering improvement of 57% of development time when comparing the process development phases of two NTBVs: HiNet Xpress and Com-B.

In addition to the longitudinal study, the two NTBVs were also studied using the measurement system. The measurement system has been applied in order to evaluate the productivity ratios and the dynamic capability ratio. The productivity ratio appeared to be volatile in the HiNet Xpress venture. However, in the Com-B venture this trend was more settled. This can be taken as a first confirmation of the evolution of dynamic capabilities in the firm, as the venturing process seems more stable due to enhanced process engineering activities. However, HiNet Xpress showed the highest productivity at one point (0.28), which has not been replicated in the Com-B case (which reached a maximum of 0.21). More data is required to explore possible reasons for this.

The study showed promising results concerning the dynamic capabilities proxy, where an effect of 39% was measured over a five-month period. The dynamic capability ratio was negative in three out of five points, due to the higher productivity ratios in HiNet Xpress. This would imply that the dynamic capability ratio does not appear to reflect the results of the longitudinal study. However, when the rate of change is studied, it appears that an average increase of 39% occurred in the dynamic capability ratio over the full five months. Especially in the last phase, the Com-B venture outperformed HiNet Xpress, which supports the longitudinal results. Alongside the qualitative observations and data analysis, these results are encouraging for future research.

Furthermore the measurement system itself seemed to contribute to these deliberate efforts of building a dynamic capability. In addition to serving as a measurement instrument, the information and insights based on an analysis of the resource allocation to sub-processes management contributed towards some specific decisions regarding changing apparent process inconsistencies. This indicates a potential new area of research to further develop and test the system as a tool that has the potential of assisting organisations in building dynamic capabilities.

Finally, the experiment confirmed the expectation that studying potential probabilistic process models is time-consuming, and though the study yielded some promising initial results, future research is necessary in order to further these results.

7.2 DISCUSSION ON IMPLICATIONS AND FUTURE RESEARCH

7.2.1 An alternative understanding of uncertainty

The main contribution of this thesis has been to raise the issue of non-causality when looking at uncertainty. Following an analogous approach based on Heisenberg's uncertainty principle, this thesis has argued for the introduction of three factors that could potentially enhance the understanding of uncertain phenomena.

Firstly, uncertainty can be identified as part of a relation. This is also referred to as a duality – a relationship between two observable parameters that cannot be explained. Instead of treating uncertainty as a collection of unknown elements or sources (such as environmental uncertainty, or technological uncertainty), uncertainty can be identified between two such parameters. It is important to note that this thesis does not claim the existence of uncertainty principles within other phenomena. Even the uncertainty principle itself was disputed by the likes of Einstein, who described this concept as an intermediary step in uncovering the quantum world with certainty. However, the conceptual underpinnings of this principle, such as the notion of duality, offer a potential new way of exploring uncertain phenomena.

This follows from the second factor identified in this thesis, which is the treatment of this duality by using probabilities. Instead of attempting to clarify the causal ambiguity within such dualities, a new way of understanding them is to explore the relationship between the parameters in terms of potential likelihoods, without assuming causality. In other words, when there is no understanding of what happens between two measurement points in the duality, the focus can be on uncovering potential likelihoods without assuming an underlying causality.

To this extent this thesis provides a point of departure in the quest for alternative ways of dealing with uncertainty. As Henri Poincaré aptly noted, "To undertake the calculation of any probability, and even for that calculation to have any meaning at all, we must admit, as a point of departure, a hypothesis or convention which has always something arbitrary about it. In this choice we can be guided only by the principle of sufficient reason. Unfortunately this principle is very vague and elastic" (Poincaré, 1905). This seems true for the study and explains the prevailing qualitative nature required in order to interpret the first results.

The third factor relates to the experimental research method for exploring such potential probabilities. As pointed out earlier, exploring probabilities is a time consuming and arbitrary process. To this extent this thesis can be regarded as a first experiment in which an uncertain relationship is tested on potential likelihoods between the parameters. This study should be regarded as a point of departure. The interpretations of the duality and ratios chosen in this dissertation to measure this duality to construct a potential probability model are still arbitrary at this stage and the experiment should be regarded as a trial. This indicates the necessity for future research. Following Parkhe (1993) it is essential to accept approximations, especially in this early stage.

Whilst the results of the experiment in this thesis show encouraging signals and areas for improvement, the underlying concepts are not necessarily limited to the context of this experiment. The fundamental new way of understanding uncertain relations by losing the causality argument could potentially benefit other areas in which relationships can be identified that are persistently ambiguous and uncertain. The appreciation of the conceptual underpinnings should be on the applications derived from the treatment of such uncertain relations in terms of enhancing the ability to predict, even without certainty.

7.2.2 Dynamic capabilities and performance: a matter of likelihoods

This thesis has explored these alternative conceptual underpinnings of uncertainty in the field of venturing new technologies. To this end I have proposed and evaluated an experiment that looks at the specific uncertainty of new technology-based ventures relevant for managerial decisions. In this context this thesis draws attention to the potentiality of making a decision that might not result directly in the preferred outcome or result but does however increase the likelihood of a favourable future outcome.

Within this context, this thesis draws on the dynamic capability framework, and the uncertain relation between dynamic capabilities and performance. Focusing on elements that enable the organisation to better reconfigure the resources for new technology-based venturing might not prove immediately successful. However, having this capability potentially increases the likelihood of increased performance the next-time round and therefore could increase the chances and thus the predictability of improved future performance.

7.2.2.1 Implications for academia

This work contributes to the academic community a way to develop an operational concept based on the dynamic capabilities framework. This concept is applied by developing a proxy and measurement instrument that aims to translate the conceptual abstraction into a more pragmatic measurement. The singular validation of the concept in a longitudinal case study helps to meet the empirical research demands (Teece, 1998), and promotes further research in this area. The study thus contributes to the empirical research base of the resource-based view of the firm and the dynamic capabilities framework, an area which has been characterised by a slow accumulation of solid empirical research (Dosi, Nelson and Winter 1999).

The experiment in the longitudinal case study has limitations, however, as the concept has been specifically developed and trialled in the context of the telecommunications industry and the enterprise network market. This niche is characterised by multi-products with short cycles dominated by architectural technological changes. Furthermore this market has been influenced by an influx of competitors due to recent liberalisation legislation.

The results are thus not generalised within a broader context, and have to be seen as local developments and concepts. Further research could focus on exploring the proposed new understanding of uncertainty in other fields of technology, such as biotechnology or nanotechnology, and other industries such as the semiconductor industry and also the more traditional industries such as car manufacturing. This could enable the development of different models and measurements for dynamic capabilities and managerial decisions.

Variations on, and improvements to, the here presented concept and measures are expected. For example, with regard to the definition of the resources, additional types of resources to human resources could be incorporated to measure the changes and reconfigurations in the resource base.

Following Penrose (1959) these could be tangible elements such as plants, equipment and stock. Incorporating measures for changes in these tangible resources might imply the need for revisions to the data collection process, as well as the system. Furthermore, such alterations could also have consequences for the definition of both ratios.

Research could also be oriented towards exploring variations in the definition of (financial) performance or outcome indicators. In the Siemens case it was obvious that EBIT was the most important indicator, and managerial decisions within the division were geared towards improvements relating to this indicator. However, for other industries alternative outcome indicators may be preferred. Whilst the prototype system allows for such flexibility in defining various types of performance or outcome-oriented measures, such variations still could have an impact on the calculation of the ratios. Additionally, research could focus on clarifying the implications of these various ways of defining the performance of a firm. A continuum of measures is apparent prescribing a firm's focus on outcome from both a long-term perspective with competitive advantage and a short-term perspective with profit. There still seems to be some ambiguity inherent in these definitions, which is further complicated by the various terms that exist to define potential parameters (such as monetary, value, and rent).

Furthermore, the study incorporated two sites measured on a monthly basis over a five-month period. Future research could be directed towards scaling up the number of sites, measurement points and extending the measurement periods. The additional results should again be compared to qualitative data in a process of triangulation. This could potentially improve and sharpen the chosen productivity and dynamic capability ratios and the measurement instrument, and provide insights into whether or not the here presented results are replicable. Additional results also are expected to provide further insights in the critical time-span of the venturing phases.

The expectations are that the co-evolution of the existing input and outcome concepts and theories will further fuel the exploration of new ways of understanding the underlying uncertainty for managerial decisions. On the one side, the concept of dynamic capabilities is at an early stage. More empirical work, in conjunction with the specific operationalisation efforts of this thesis, could further the understanding of the input of the venturing process and ultimately enhance the meaning of the proposed process model. On the other side, emerging frameworks such as real options planning are acting on the confluence of input and output of the venturing process. More empirical research is required in order to explore how these two developments compare.

7.2.2.2 Implications for practitioners

The aim of the operationalisation of dynamic capabilities was to complement traditional approaches for managerial decisions under uncertainty, with the aim of creating better predictability for managers albeit without certainty. The instruments created for the experiment, as well as the concepts of the three venturing phases and subsequent types of capabilities (incubating, crafting and exit), are vehicles that can encourage managers to enable the more deliberate creation of dynamic capabilities within an organisation.

The experiment identified what deliberate commitments are needed for the effective building of dynamic capabilities. The current literature has predominantly addressed the evolution and observation of dynamic capabilities (Teece, *et al.* 1997; Zollo and Winter, 1999), and little work has yet been done on the operationalisation of the concepts with a more pragmatic stance. Eisenhardt (2000) was the first to identify distinct processes, such as rapid prototyping and process engineering, as constituents of dynamic capabilities. The empirical findings of this thesis confirm this and show that direct action can be taken in order to consciously improve this dynamic capability within the firm. Future potential could eventually elevate this concept to a more pragmatic application level, similar to the use of applications such as Total Quality Management and Business Process Re-engineering in the past.

From a pragmatic perspective, the new insight that the relationship between a firm's dynamic capabilities and the performance rendered by its operations can possibly be understood in terms of likelihoods could have direct implications for managerial decisions. If the preliminary results can be replicated and further proof can be found for the probabilistic process model, this would imply that, for firms that venture new technologies, the creation of dynamic capabilities should become an essential part of the decision making process.

Especially in unsettled times, it appears that most decisions are granted on the basis of their potential to create a direct return on investment. In declining economies, in particular, this implies that the focus should be on schemes to cut costs and lower overheads as much as possible. Nevertheless, the new understanding presented in this thesis could imply that pursuing investments to build dynamic capabilities within the firm, reflected in activities that are often related to the overhead costs of a firm, increases the likelihood of improved performance.

Currently, the lack of both more concrete evidence that dynamic capabilities have a positive effect on firm-level performance, or even measures for assessing this, is reflected in managerial decisions. Activities that endorse the active building of dynamic capabilities are often dismissed or ignored as it cannot be explained how these dynamic capabilities can have an impact on performance. However, embracing this lack of causal understanding, and interpreting the relationship in terms of likelihoods could arguably change this perspective.

New ways of data collecting and reporting, whereby dynamic collection and real-time estimations are more important than complete accuracy on hindsight, could spur developments in this direction. The XTrend prototype measurement system provides an example of such a new way of measuring, where the emphasis is on processes, rather than functions, and the data collected is based on employee estimations of their division of effort over these processes, instead of timesheets. By coupling this data with performance measures, alternative indicators become available which can further enhance the understanding and shape judgements for managerial decisions.

7.2.3 Exploratory experiments

Finally some initial implications can be derived from the development and execution of the experiment. The experiment consisted of a combination of two distinct interdisciplinary research methodologies. Further research could be directed to explore such interdisciplinary action-oriented research methodologies as trialled in this thesis.

The research design combined qualitative case studies with a system engineering module. In order to trial the probabilistic process model, it was necessary to create an instrument that allowed for the measurement of the proxy developed for the productivity ratios and dynamic capability ratio. The result was a hybrid, action-oriented research approach. The system and data collection process subsequently became part of the qualitative case study. The implication of this approach is that the measurement instrument interfered with the study. This became particularly apparent in the case studies as the qualitative data confirmed that the system itself was also seen to be valuable as a tool that can encourage the evolution of dynamic capabilities within the organisation under study.

Although the interference can influence the actual outcome of the chosen measures, it also proved to render some valuable preliminary pragmatic results. An initial conclusion that can be drawn is that the system was found to be useful not only for collecting the quantitative data for the experiment, but also as a tool that has the potential to enable managers to be more efficient in making decisions concerning the reconfiguration of the resource base of the organisation. Further research should be directed to support the practical side of this application, and initial interest has been shown in taking up this development.

This thesis invites more reiterative cycles of exploratory experiments in order to further explore the conceptual advances proposed here. For example, future research of a more quantitative nature could provide a wider data set which, through a process of constant triangulation with the qualitative data, could enhance the meaning of the concept and the underlying mathematical construction, as these are expected to change and co-evolve over time. Future research could also be directed to explore the use of more advanced mathematics to further examine the ratios and develop the probabilistic model in conjunction with the qualitative interpretations.

Finally, within the context of the CeTIM research programme, this thesis has provided an additional example of the potential of adopting concepts from modern physics in exploring social phenomena. As shown in this thesis, this research direction is receiving increased attention; this thesis is thus an encouraging contribution towards any future explorations of this kind.

BIBLIOGRAPHY

Abernathy, W. J., Utterback, J. M. (1978), *Patterns of Industrial Restructuring*, Technology Review, 80 (7), 1-9

Afuah, A. (1998), *Innovation Management; Strategies, Implementation and Profits*, Oxford: Oxford University Press

Amit, R. Livnat, J., (1988), *Diversification and the Risk-Return Trade Off*, Academy of Management Journal, 31(1), 154-165

Amit, R., Wernerfelt, B. (1990), *Why do firms reduce business risk*, Academy of Management Journal, 33(3), 520-533

Amit, R., Glosten, L., Muller, E. (1993), *Challenges to Theory Development in Entrepreneurship Research*, Journal of Management Studies, 30(5), 816-834

Anderson, T. J. (2000), *Real Options Analysis in Strategic Decision Making: an applied approach in a dual options framework*, Journal of Applied Management Studies, 9(2), 235-255

Ansoff, H.I., (1988), *The New Corporate Strategy*, New York: Wiley and Sons

Atkinson, A., Shaffir, W. (1998) *Standards for field research in management accounting*, Journal of Management Accounting Research, 10

Audi, R., (2000), *The Cambridge Dictionary of Philosophy*, 2nd Edition, Cambridge: Cambridge University Press

Baldwin, C. Y., Clark, K. B. (1997), *Managing in an Age of Modularity*, Harvard Business Review, 75 (4), 84-93

Baldwin, C. Y., Clark, K. B. (2000), *Design Rules - The Power of Modularity*, Cambridge, MA: MIT Press

Baltes, G. (2001), *Synergiemanagement in Vernetzeten Organisationen – Synergetische Koordination durch Intranet-Gestützte Geschäftsprozesse, Gezeigt am Beispiel des Einkaufs eines Internaltionalen Großunternehmens.* München: Dissertation Universität der Bundeswehr München

Barnard, J. M. (1996), *The Management of Crisis*, Economic Development Review, 14 (3), 53-55

Barney, J. (1991), *Firm Resources and Sustained Competitive Advantage*, Journal of Management, 17(1), 99-120

Barney, J. (1996), *The Resource-based Theory of the Firm*, Organization Science, 7(5), 469

Barney, J., Wright, M., Ketchen Jr., D.J. (2001), *The resource-based view of the firm: ten years after 1991*, Journal of Management, 27, 625-641

Bartlett, C. A., Mohammed, A. (1995), *3M: Profile of an Innovating Company*, Harvard Business School Cases

Bazard, P. (2000), *Sidgwick and Edgeworth on indeterminacy in the labour market,* European Journal of the History of Economic Thought, 7(3), 350-362

Beasley, J.E. (2001), *OR Notes*, Imperial College: http://mscmga.ms.ic.ac.uk/jeb/or/

Beed, C., Kane, O. (1991), *What is the critique of the mathematization of economics?*, Kyklos, 44(4), 581-612

Benhabib, J., Farmer, R. E. A., (1994), *Indeterminacy and Increasing Returns ,Journal of Economic Theory*, 63(1), 19-41

Benhabib, J., Perli, R. (1994*), Uniqueness and Indeterminacy: On the Dynamics of Endogenous Growth*, Journal of Economic Theory, 63(1), 113-142

Benhabib, J., Rustichini, A. (1994), *Introduction to the Symposium on Growth, Fluctuations, and Sunspots: Confronting the Data*, Journal of Economic Theory, 63(1), 1-17

Berger, P. L., Luckman, T. (1967), *The Social Construction of Reality*, Garden City, NY: Doubleday Anchor

Bergmann Lichtenstein, B. M. (2000), *Valid or Vacuous? A Definition and Assessment of New Paradigm Research in Management*, American Behavioral Scientist, 43(8), 1334-1366

Best, M. H., Garnsey, E., (1999) *Edith Penrose, 1914-1996*, The Economic Journal, 109, 187-201

Birnstiel, C. (2000), *Siemens: Record earnings in fiscal 2000 only an interim step*, Report, 14 December 2000, Siemens AG Corporate Communications, Munich, 5

Blanchard, B. S. (1991), *System Engineering Management*, in: Stewart, R. D. (ed.), New Dimensions in Engineering, New York: John Wiley & Sons Inc.

Bleedorn, B. D. (1993), *Toward an integration of creative and critical thinking*, American Behavioral Scientist, 37(1), 10-20

Bogason, P. (2001), *Postmodernism and American Public Administration in the 1990s* Administration & Society, 33(2), 165-193

Bohm, D., Hiley, B. J. (1993), *The undivided universe; An ontological interpretation of quantum theory*, London: Routledge

Bollen, N. P. (1999), *Real Options and Product Life Cycles*, Management Science, 45(5), 670-684

Bolman, L. G., Dealt, T. D. (1991), *Reframing Organizations: Artistry, Choice, and Leadership*, San Francisco: Jossey-Bass.

Bordley, R. F. (1998), *Quantum mechanical and human violations of compound probability principles: Toward a generalized Heisenberg Uncertainty Principle*, Operations Research, 46(6), 923-926

Boulding, K. E. (1966), *The Economics of Knowledge and the Knowledge of Economics*, American Economic Review, Papers and Proceedings, 56, 1-13

Boulding, K. E. (1996), *The Fallacy of trends: On living with Unpredictability*, National Forum, 76(4), 69-71

Bradbury, H., Bergmann Liechtenstein, B. M. (2000), *Relationality in Organizational Research: Exploring The Space Between*, Organization Science, 11(5), 551-564

Brown, R. V. (1970), *Do Managers find decision theory useful?,* Harvard Business Review, 48(3), 78-89

Brown, S. L., Eisenhardt, K. M. (1997), *The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations*, Administrative Science Quarterly, 42 (1), 1-34

Brown, J. R. (2002) *Thought Experiments*, The Stanford Encyclopedia of Philosophy (Summer 2002 Edition), Edward N. Zalta (ed.), URL = http://plato.stanford.edu/archives/sum2002/entries/thought-experiment/

Buchko, A. A. (1994), *Conceptualization and Measurement of Environmental Uncertainty: An assessment of the Miles and Snow Perceived Environmental Uncertainty Scale*, Academy of Management Journal, 37 (2), 410-425

Buchmiller, J. (1993), *The 24 commandments of the G-30*, Corporate Finance, 106 (37)

Burgelman, R. A., Maidique, M. A. (1988), *Strategic Management of Technology and Innovation*, Illinois: Homewood

Burgelman, R. A. (1991), *Intraorganizational ecology of strategy making and organizational adaptation: Theory and field research*, Organization Science, 2, 239-262

Burns, T., Stalker, G. M. (1961), *The Management of Innovation*, London: Tavistock Publications

Bygrave, W. D., Hofer, C. W. (1991), *Theorizing about entrepreneurship*, Entrepreneurship: Theory & Practice, 16(2), 13-22

Calkins, P., Vezina, M. (1996), *Transitional paradigms to a new world economic order*, International Journal of Social Economics, 23(10/11), 311-328

Campbell, D.T., (1975), *Degrees of Freedom and the Case Study,* Comparative Political Studies, 8 (2), 178-193

Capon, A. (2001), *Mass in motion,* Institutional Investor, 35 (1), 111-113

Carpenter, M. A. S., Wm. Gerard; Gregersen, Hal B. (2001), *Bundling Human Capital with Organizational Context: The Impact of International Assignment Experience on Multinational Firm Performance and CEO Pay*, Academy of Management Journal, 44 (3), 493-511

Carter, A. P. (1996), *Scholarship and recognition: Reflections on the contributions of P.N. Mathur*, Economic Systems Research, 8(3), 203-208

Cassidy, D. C. (1991), *Uncertainty: the life and science of Werner Heisenberg*, New York: W.H. Freeman and Company

Chatterjee, S., Wernerfelt, B. (1991), *The link between resources and type of diversification: theory and evidence*, Strategic Management Journal 12(1), 33-48

Cheng, C. H., Kumar, A., Motwani, J. G., Reismann, A., Madan, M. S. (1999), *A Citation Analysis of the Technology Innovation Management Journals*, IEEE-TEM, 46 (1), 4-13

Chenghu Ma (2000), *Uncertainty aversion and rationality in games of perfect information*, Journal of Economic Dynamics & Control, 24(3), 451-482

Chia, R. (1997), *Essai: Thirty years on: From organizational structures to the organization of thought*, Organization Studies, 18 (4), 685-707

Choi, Y. B. (1993), *Paradigms and conventions: uncertainty, decision making, and entrepreneurship.* Ann Arbor: University of Michigan Press

Christensen, Clayton M., and Richard S. Rosenbloom (1995), *Explaining the attacker's advantage: technological paradigms, organizational dynamics, and the value network*, Research Policy, 24, 233-257

Coates, J. F. (1995), *Fight the Schriesheim Uncertainty Principle*, Research Technology Management, 38 (3), 11

Cockburn, I. M., Henderson, R. M., Stern, S. (2000), *Untangling the origins of competitive advantage,* Strategic Management Journal, 21, 1123-1145

Coff, R. W. (1999), *When competitive advantage doesn't lead to performance: The resource-based view and stakeholder bargaining power*, Organization Science, 10(2), 119-133

Conner, K. R., Prahalad, C. K. (1996), *A resource-based theory of the firm: knowledge vs. opportunism*, Organization Science, 7(5), 477-501

Courtney, H. (2001), *Making the Most of Uncertainty*, McKinsey Quarterly Newsletter, October, 38-47

Cross, R., Strachan, D. (1997), *On George Soros and economic analysis*, Kyklos, 50(4), p. 561-574

Dandy, G. C., Warner, R. F. (1989), *Planning and Design of Engineering Systems*, London: Unwin Hyman

Davenport, T. H. (1993), *Process Innovation: Reengineering Work through Information Technology*, Boston: Harvard Business School Press

d´Aveni, R. A. (1994), *Hypercompetition: Managing the Dynamics of Strategic Manoeuvring*, New York: The Free Press

David Smith, R. (1995), *The inapplicability principle: What chaos means for social science*, Behavioral Science, 40(1), 22-40

Davies, P. (1989), *Introduction*, in: Heisenberg, W. (ed.), *Physics and Philosophy*, New York: Harper & Row Publishers

Deeds, D. L., DeCarolis, D. (2000), *Dynamic Capabilities and New Product Development in High Technology Ventures: An Empirical Analysis of New Biotechnology Firms*, Journal of Business Venturing, 15 (3), 211-228.

Deming, E. (1986), *Out of the Crisis*, Cambridge MA: Report, Massachusetts Institute of Technology, Center for Advanced Engineering Study

DeTienne, K. B. (1994), *On procuring a paradigm*, Academy of Management Review, 19 (4), 640

Dierickx, I., Cool, K. (1989), *Asset stock accumulation and sustainability of competitive advantage,* Management Science, 35: 1504-1511

Dobbs, I. M. (1991), *A Bayesian Approach to Decision-making under Ambiguity*, Economica, 58, 417-440

Dove, R. (1998), *A Knowledge Management Framework*, Automotive Manufacturing & Production, 110 (1), 18-20

Downey, H. K., Hellriegel, D. (1975), *Environmental uncertainty: the construct and its application,* Administrative Science Quarterly, 20(4), 613-629

Downey, H. K., Slocum, J. W. (1975), *Uncertainty Measures, Research and Source of Variation*, Academy of Management Journal, 18(3), 562-577

Dreschler, W. (2000), *On the possibility of quantitative-mathematical social science, chiefly economics*, Journal of Economic Studies, 27(4/5), 246-259

Drucker, P. F. (1959), *Long Range Planning*, in: Ewing, D. W. (ed.), Long Range Planning for Management, New York, Harper & Row, 7-20

Drucker, P. F. (1991), *The new productivity challenge,* Harvard Business Review, 69(6), 69-79

Einstein, A., Infeld, L. (1938), *The Evolution of Physics: from Early Concepts to Relativity and Quanta*, New York: Simon and Schuster

Eisenhardt, K. M. (1989), *Building Theories from Case Study Research*, Academy of Management Review, 14 (4), 532-550

Eisenhardt, K. (1991), Better Stories and Better Constructs: The Case for Rigor and Comparative Logic, Academy of Management Review, 16 (3), 620-627

Eisenhardt, K. M., Schoonhoven, C. B. (1996), Resource-based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms, Organization Science, 7(2), 136-150

Eisenhardt, K. M. (2000), *Paradox, spirals, ambivalence: the new language of change and pluralism*, Academy of Management Review, 25 (4), 703-705

Eisenhardt, K. M., Martin, J. A. (2000), *Dynamic Capabilities: What are they?*, Strategic Management Journal, 21, 1105-1121

Elzinga, D. J., Horak, T., Lee, C-Y, Bruner, C. (1995), *Business Process Management: Survey and Methodology*, IEEE Transactions on Engineering Management, 42(2), 119-128

Erickson, T. J., Magee, J. F., Roussel, P. A., Saad, K. N. (1990), *Managing Technology as a Business Strategy*, Sloan Management Review, 31(3), 73-78

Evans, K. G. (1996), *Chaos as opportunity: Grounding a positive vision of management and society in the new physics*, Public Administration Review, 56 (5), 491-494

Fabian, F. H. (2000), *Keeping the tension: Pressures to keep the controversy in the management discipline*, Academy of Management Review, 25 (2), 350-371

Fabozzi, F.J., Valente, J. (1976), *Mathematical Programming in American Companies: A Sample Survey*, Interfaces 7(1), 93-98

Fayol, H. (1949), *General and Industrial Management*, New York, Pitman Publishing Corporation

Foster, R. N. (1986), *Innovation; The Attacker's Advantage*, London: MacMillan

Frank, M. (1998), *Schumpeter on Entrepreneurs and Innovation: a Reappraisal*, Journal of the History of Economic Thought, 20 (4), 505-516

Frosch, R. A. (1996), *The customer for R&D is always wrong!*, Research and Technology Management, 39 (6), 22-25

Galbraith, J. (1973), *Designing Complex Organizations*, in: Schein, E. H., Beckhard, R., Bennis, W. G. (eds.), Organizational Development, Reading (WA), Addison-Wesley

Galunic, D. C., Eisenhardt, K. M. (2001), *Architectural Innovation and Modular Corporate Forms*, Academy of Management Journal, 44 (6), 1229-1249

Ganley, W. T. (1995), *Institutional economics and neoclassicism in the early twentieth century: The role of physics*, Journal of Economic Issues, 29 (2), 397-406

Geisler, E. (2001), *Good-Bye Dodo Bird (Raphus cucullatus) Why Social Knowledge Is Cumulative, Expansive, and Nonevolutionary*, Journal of Management Inquiry, 10(1), 5-15

Gell-mann, M. (1995), *What is Complexity?* Complexity, 1(1), 16-19

Giddens, A. (1976), *New Rules of Sociological Method*, New York: Basic Books

Glaser, B. G., Strauss, Anselm L. (1967), *The Discovery of Grounded Theory: Strategies for Qualitative Research*, London: Weidenfeld and Nicholson.

Glazer, R. (1998), *Measuring the Knower: Towards a Theory of Knowledge Equity*, California Management Review, 40 (3), 175-184

Gold, B. (1971), *Explorations in Managerial Economics: Productivity, Costs, Technology and Growth*, London: MacMillan

Goldman, I. (1999), *Q Methodology as Process and Context in interpretivism, Communication, and Psychoanalytic Psychotherapy Research*, Psychological Record, 49(4), 589-604

Grant, R. M., (1996), *Towards a Knowledge-based theory of the firm*, Strategic Management Journal, Summer Special Issue 17, 109-122

Gribbin, J. (1991), *In Search of Schrödinger's Cat*, London: Transworld Publishers

Grint, K. (1997), *TQM, BPR, JIT, BSCs and TLAs: Managerial waves or drownings?*, Management Decision, 35(9/10), 731-738

Guba, E. G., Lincoln, Y. (1989), *Fourth Generation Evaluation*, London: Saga

Hannan, M. T., Freeman, J. (1989), *Organizational Ecology*, Cambridge, MA: Harvard University Press

Hammer, M., Champy, J. (1993), *Reengineering the Corporation: A Manifesto for Business Revolution*, New York: Harper Business

Harrison, J. S., Hall, E. H., Nargundkar, R., (1993), *Resource allocation as an outcropping of strategic consistency: Performance Implications,* Academy of Management Journal, 36(5), 1026-1051

Hawking, S., Penrose, R., Atiyah, M. (1996), *The Nature of Space and Time*, New York: Princeton University Press

Hayes, L.J. (1997), *Understanding Mysticism,* Psychological Record, 47(4), p. 573-596

Heisenberg, W., (1927), *Zeitschrift für Physik, 43* (1927), 172-198, received 23 March 1927 (*Gesammelte Werke / Collected Works*, vol. A1, p. 486). translated into English by Wheeler, J. A., Zurek, H. (1983) *Quantum Theory and Measurement*, wheeler and Zurek, eds., Princeton: Princeton Univ. Press, 1983, 62-84

Heisenberg, W. (1930), *The Physical Principles of the Quantum Theory*, New York: Dover Publications

Heisenberg, W. (1958), *Physics and Philosophy*, New York: Harper & Row

Henderson, R., Clark, K. B. (1990), *Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms*, Administrative Science Quarterly, 35, 9-31

Henderson, R. (1993), *Underinvestment and incompetence as responses to radical Innovation: evidence from the photolithographic alignment equipment industry,* RAND Journal of Economics, 24 (2), 248-270

Henderson, R., Cockburn, I. (1994), *Measuring Competence? Exploring Firm Effects in Pharmaceutical Research*, Strategic Management Journal, 16 (1), 63-84

Henderson, R., Cockburn, I. (2000), *Measuring Competence? Exploring Firm Effects in Drug Discovery*, in: Dosi, G., Nelson, R. R., S.G., W. (eds.), The Nature and Dynamic of Organizational Capabilities, Oxford: Oxford University Press, 155-161

Hilgevoord, J., Uffink, J. (2001), *The Uncertainty Principle*, The Stanford Encyclopedia of Philosophy (Winter 2001 Edition), Edward N. Zalta (ed.), URL: http://plato.stanford.edu/archives/win2001/entries/qt-uncertainty/

Holbrook, M. B. (2001), *The Millennial Consumer in the Texts of Our Times: Exhibitionism*, Journal of Macromarketing, 21(1), 81-95

Hrebiniak, L. G., Snow, C. S. (1980), *Industry Difference in Environmental Uncertainty and Organizational Characteristics Related to Uncertainty*, Academy of Management Journal, 23 (4), 750-759

Iansiti, M., Clark, K. B., (1994), *Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe Computers*, Industrial and Corporate Change, 3(3), 557-605

Israel, J. (1999), *Language as Praxis*, International Review of Sociology, 9(3), 269-281

Itami, H., Roehl, Thomas W. (1987), *Mobilizing Invisible Assets*, Cambridge, MA: Harvard University Press

Jick, T. D. (1979), *Mixing qualitative and quantitative methods, triangulation in action,* Administrative Science Quarterly, 24(4), 602-611

Johnson, P., Cassell, C. (2001), *Epistemology and work psychology: New agendas*, Journal of Occupational and Organizational Psychology, 74 (2), 124-144

Jordan, J. L. (1992), *Private forecasting and government policy stability*, CATO Journal, 12(1), 107-117

Kaas, L. (2001*), Indeterminacy of intertemporal equilibria under imperfect competition*, Economic Theory, 17(2), 307-323

Kant, I., (1781), *Kritik der reinen Vernunft / Critique of pure reason*, translated from the German by Norman Kemp Smith 1st ed., 2nd impression with corrections, reprinted Macmillan; St Martin's Press, 1963

Karsten, S. G. (1990), *Quantum Theory and Social Economics: The Holistic Approach of Modern Physics serves better than Newton's Mechanics in Approaching Reality*, American Journal of Economics & Sociology, 49(4), 385-400

Katz, J., Gartner, W. B. (1988), *Properties on Emerging Organizations*, Academy of Management Review, 13 (3), 429-441

Katzy, B. R., Schuh, G. (1997), *The Virtual Enterprise*, in: Molina, A., Sanchez, J. M., Kusiak, A. (eds.), *Handbook of Life Cycle Engineering: Concepts, Methods and Tools,* New York: Chapman & Hall

Katzy, B. R., Dissel, M. C. (2001), *Earnings vs. Innovation; Measuring Architectural Competencies*, in: Society, I. E. M. (ed.), Proceedings of the Engineering Management (IEMC), Change Management & the New Industrial Revolution, Albany, NY: IEEE

Katzy, B. R., Dissel, M. C., Blum, M. (2001), *Measuring Value - Creating Value; A Solution for Process Innovation in High-tech Company Networks*, in: Proceedings of the eBusiness e-Work Conference, Venice

Katzy, B. R., Dissel, M. C., Blindow, F. S. (forthcoming), *Dynamic Capabilities for Entrepreneurial Venturing; the Siemens ICE Case*, in: Zedtwitz, M. v., Haour, G., Khalil, T., Lefebvre, L. (eds.), Management of Technology: Growth through Business, Innovation and Entrepreneurship, Oxford: Pergamon Press

Kay, N. M. (1979), *The Innovating Firm; a Behavioural Theory of Corporate R&D*, Thethford: MacMillan Press Ltd.

Kern, D. (2002), *Content and Trends in Engineering Management Literature*, Engineering Management Journal, 14(1), 43-48

Keynes, J. M. (1973), *A Treatise on Probability,* The collective writings of John Maynard Keynes, volume 8, London: MacMillan

Khalil, E. L. (1997), *Chaos theory versus Heisenberg's uncertainty: Risk, uncertainty and economic theory*, American Economist, 41 (2), 27-40

Khalil, E. L. (1998/1999), *The Janus Hypothesis*, Journal of Post Keynesian Economics, 21 (2), 315-342

King, P. M., Shuford, B. C. (1996), *A multicultural view is a more cognitively complex view*, American Behavioral Scientist, 40(2), 153-164

Kleiner, A, Roth, G. (1997), *When Measurement Kills Learning*, Journal for Quality and Participation, 20(5), 6-15

Knight, F. H. (1921), *Risk, Uncertainty and Profit*, Boston: Houghton Mifflin

Knight, M. (1994), *Darwinian functionalism: A cognitive science paradigm*, Psychological Record, 44(2), 271-287

Kober, S, (1997), *The Spirit of Humility*, CATO Journal, 17(2), 235-242

Koberg, C. S. (1987), *Resource Scarcity, Environmental Uncertainty, and Adaptive Organizational Behavior*, Academy of Management Journal, 30 (4), 798-807

Kogan, A., Sudit, E. F., Vasarhelyi, M. A. (1999), *Continuous Online Auditing: A Program of Research*, Journal of Information Systems, 13(2), 87-103

Kogut, B., Zander, U. (1992), *Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology*, Organization Studies, 3, 383-397

Kogut, B., Zander, U. (1996), *What do firms do? Coordination, identity and learning*, Organization Science, 7: 502-518

Koontz, H., O'Donnell, C. (1955), *Principles of Management*, New York: McGraw-Hill

Lannes, W. J. (2001), *What is Engineering Management?*, IEEE Transactions on Engineering Management, 48 (1), 107-110

Lau, F. (1997), *A Review on the Use of Action Research in Information Systems Studies*, in: Lee, A. (ed.), Proceedings of the IFIP 8.2 Working Group Conference: Information Systems Research: Information Systems and Qualitative Research, Philadelphia, IFIP

Lawrence, P., Lorsch, J. (1967), *Organization and Environment*, Boston: Harvard Business School

Lawson, D. (1994), *Identifying pretreatment change*, Journal of Counseling & Development, 72(3), 244-248

Ledford, G. E. J., Mohrman, S. A. (1993), *Looking backward and forward at action research*, Human relations, 46 (11), 1349

Leonard, R. J. (1995), *From parlor games to social science: Von Neumann, Morgenstern, and the creation of game theory 1928-1944*, Journal of Economic Literature, 33(2), 730-761

Leonard-Barton, D. (1990), *A Dual Methodology for Case Studies: Synergistic use of Longitudinal Single Site with Replicated Multiple Sites*, Organization Science, 1 (3)

Leonard-Barton, D., (1992), *Core capabilities and core rigidities: A paradox in managing new product development*, Strategic Management Journal, Summer Special Issue, 13, 111-125

Leonard-Barton, D. (1995), *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*, Boston (MA), Harvard Press

Levitt, T, (1965), *Exploit the Product Life Cycle*, Harvard Business Review, 43 (6), 81-94

Lewis, M. W. (2000), *Exploring Paradox: Towards a More Comprehensive Guide*, Academy of Management Review, 25 (4), 760-776

Lingle, J. H., Schiemann, W. A. (1996), *From balanced scorecard to strategic gauges: is measurement worth it?* Management Review, 85(3), 56-61

Lipmann, S. A., Rumelt, R. P., (1982), *Uncertain imitability: an analysis of interfirm differences in efficiency under competition,* The Bell Journal of Economics, 13, 418-438

Lo, A. W. (2000), *Finance: A Selective Survey*, Journal of the American Statistical Association, 95(450), 629-635

Low, M. B., MacMillan, I. C., (1988), *Entrepreneurship: Past Research and Future Challenges*, Journal of Management, 14(2), 139-161

Luo, Y. (2000), *Dynamic Capabilities In International Expansion.*, Journal of World Business, 35 (4), 355-378

Machol, R. E., Tanner Jr, W. P., Alexander, S. N. (1965), *System Engineering Handbook*, London: McGraw-Hill

Mackenzie, K. D. (2000), *Throwing tradition to the wind: The Processes and Results of the Writers' Workshop*, International Journal of Organizational Analysis, 8(1), 4-15

Madhok, A. (2000), *The International Biotechnology Industry: A Dynamic Capabilities Perspective*, Journal of International Business Studies, 52 (2), 325-335

Madsen, T. L., McKelvey, B. (1996), *Darwinian Dynamic Capability: Performance Effects of Balanced Intrafirm Selection Processes*, Academy of Management Proceedings, 26-30

Makadok, R. (2001), *Toward a Synthesis of the Resource-Based and Dynamic-Capability Views of Rent Creation*, Strategic Management Journal, 22 (5), 387-401

Majumdar, S. K. (2000), *Sluggish Giants, Sticky Cultures, and Dynamic Capability Transformation.*, Journal of Business Venturing, 15 (1), 59

Markland, R.E., Sweigart, J.R., (1987), *Quantitative methods: applications to managerial decision making*, New York: John Wiley & Sons

McDaniel, R. R., Walls, M. E. (1997), *Diversity as a management strategy for organizations*, Journal of Management Inquiry, 6(4), 363-375

McGrath, R, G, (1996), *Options and the entrepreneur: toward a strategic theory of entrepreneurial wealth creation*, Academy of Management Proceedings 1996

McGrath, R. G. (1999), *Falling Forward: Real Options Reasoning and Entrepreneurial Failure*, Academy of Management Review, 24(1), 13-30

McGrath, R. G., MacMillan, I. (2000), *The Entrepreneurial Mindset: Strategies for Continuously Creating Opportunity in the Age of Uncertainty*, Boston: Harvard Business School Press

McKelvey, B. (1999), *Avoiding complexity catastrophe in coevolutionary pockets: Strategies for rugged landscapes*, Organization Science, 10(3), 294-322

McLarty, M. H. (1990), *An examination of modern psychology through two philosophies of knowledge*, Psychological Record, 40(2), 273-288

McMullen, J. S., DeCastro, J. (2000), *Entrepreneurial Decision Making and Risk Assessment in the Midst of Environmental Uncertainty*, Academy of Management Proceedings, ENT:F2

Miles, M., Huberman, M. (1984), *Qualitative Data Analysis*, London: Sage.

Miles, R. E., Snow, C. C. (1978), *Organizational strategy, structure, and process*, New York: McGraw Hill

Miller, H. T., King, C. S. (1998), *Practical theory*, American Review of Public Administration, 28 (1), 43-60

Miller, H. T., Fox, C. J. (2001), *The Epistemic Community*, Administration & Society, 32(6), 668-685

Miller, L. T. (2002), *Decision Making Under Uncertainty – Real Options to the Rescue?* The Engineering Economist, 47(2), 105-150

Milliken, F. J. (1987), *Three Types of Perceived Uncertainty About the Environment: State, Effect, and Response Uncertainty*, Academy of Management Review, 12 (1), 133-143

Mintzberg, H., Raisinghani, D., Theoret, T. (1976), *The Structure of "Unstructured" Decision Processes*, Administrative Science Quarterly, 21, 246-275

Mintzberg, H. (1979), *The Structuring of Organizations - A Synthesis of the Research*, Englewood Cliffs: Prentice-Hill

Mintzberg, H. (1994), *The Fall and Rise of Strategic Planning*, Hemel Hempstead: prentice Hall International

Mintzberg, H., Westley, F. (2000), *Sustaining the institutional environment*, Organization Studies, 21, 71-94

Montgomery, D., Bull, K. S., Baloche, L. (1993), *Characteristics of the creative person*, American Behavioral Scientist, 37(1), 68-78

Moore, G. A. (1998), *Crossing the Chasm*, Oxford: Capstone.

Mosakowski, E., (1990), *Entrepreneurial Diversification and Causal Ambiguity: A Dynamic Analysis of Entrepreneurial Firms in the Computer Industry*, Academy of Management Proceedings, 64-68

Mueller, M. (1999), *Prozessorientierte Veränderungsprojekte: Fallbeispiele des Unternehmenswandels*, Bamberg: Difo-Druck OHG, Dissertation St. Gallen University, No. 2233

Mueser, P. (1990), *A rhetoric in defense of formalism in the social sciences: Comment on McCloskey*, American Sociologist, 21(1), 20-25

Mutch, A. (2000), *Contested Knowledge (Book Review)*, Journal of Management Studies, 37(3), 467-469

Nahapiet, J., Ghoshal, S. (1998*), Social capital, intellectual capital, and the organizational advantage*, Academy of Management Review, 23(2), 242-266

Nelson, R. R. (1991), *Why Do Firms Differ, and How Does It Matter?* Strategic Management Journal, 12, 61-74

Nelson, R. R. Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*, Cambridge (MA): Belknap Press

N. N. (1993/1994), *Take me to your leader*, in: The Economist, 329, Dec 25-Jan 7, 21-25

N. N. (1997), *Part I. Appendix A--a new research programme (paradigm) as the foundation of the new economics of stable equilibrium*, International Journal of Social Economics, 24(5), 509-526

N. N. (1999a), *Financiers call the tune*, FT-Survey in: Financial Times, 29-09-1999

N. N (1999b), *FT500 Youngest Industries are the winners*, FT-Survey in: Financial Times

N. N. (1999c), *FT Survey Introduction*, FT-Survey in: Financial Times, 29-09-1999

N.N. (1999d), *Economic Survey of Switzerland*, July 1999, Organisation for Economic Co-operation and Development, Economic Surveys

N. N. (2000a), *Process Co-ordination in Networks*, Handbook, CeTIM gGmbH, version 19-01-2000

N. N. (2000b), *Siemens Unveils HiPath Architecture for Next-Gen Enterprise IP Communications*, http://www.tmcnet.com/tmcnet/newsit/it1000735.htm

N. N. (2001a), *Global Investing*, FT-Survey in: Financial Times, 6-10-2001

N. N. (2001b), *Meltdown, but the strongest keep their cool*, FT Global500 in: Financial Times, 1-06-2001.

N. N., (2001d), *Sunrise und Siemens wollen mit „Geschenken" Kasse machen*, Basler Zeitung, 14.09.2001, 21

N. N. (2002), *A Century of Innovation: The 3M Story*, 3M Company

N. N. (2002), *Productivity: The Key to Competitiveness of European Economies and Enterprises,* Communication from the Commission to the Council and The European Parliament, Brussels: COM 262 Final

Ohanian, H. C. (1989), *Physics*, New York: W.W. Norton & Company

O'Hara, P. A. (1995), *The Association for Evolutionary Economics and the Union for Radical Political Economics: General Issues of Continuity and Integration*, Journal of Economic Issues, 29(1), 137-159

O'Hara, S. U. (1995), *Valuing socio-diversity*, International Journal of Social Economics, 22(5), 31-49

Oliver, R. W. (1999), *The Red Queen Rules*, The Journal of Business Strategy, 20 (3), 8-10

Overman, S. E. (1996), *The New Sciences of Administration: Chaos and Quantum Theory*, Public Administration Review, 56 (5), 487-491

Parkhe, A. (1993), *'Messy' research, methodological predispositions, and theory,* Academy of Management Review, 18 (2), 227

Penrose, E. T. (1959), *The Theory of the Growth of the Firm*, Oxford: Basil Blackwell.

Phillips, D., Kaplan, P. D. (2001), *The Greatest Return Stories Ever Told*, Journal of Investing, 10(3), 94-96

Poincaré, H. (1952), *Science and Hypothesis*, New York: Dover Publications, Inc., unabridged republication of the first English translation published in 1905 by the Walter Scott Publishing Company Ltd.

Prigogine, I., Stengers, I. (1988), *Entre le temps et l'éternité*, Paris: Fayard

Pisano, G. P. (1994), *Knowledge, integration, and the locus of learning: an empirical analysis of process development*, Strategic Management Journal, 15(8), 61-78

Platts, K.W. (1993), *A Process Approach to Researching Manufacturing Strategy,* International Journal of Operations and Production Management, 13 (8), 4-17

Quinn, J. B., (1978), *Strategic Change: "Logical Incrementalism"*, Sloan Management Review, 20(1), 7-21

Quinn, R. E. (1988), *Beyond Rational Management; Mastering the Paradoxes and Competing Demands of High Performance*, London, Jossey-Bass

Quinn, R. E., Cameron, K. S. (Eds.) (1988), *Paradox and Transformation; Towards a Theory of Change in Organization and Management,* Cambridge, MA: Harper & Row

Raftery, J. (1998), *From Ptolemy to Heisenberg: Quantitative Models and Reality*, Construction Management & Economics, 16(3), 295-302

Raiffa, H. (1968), *Decision Analysis: Introductory Lectures on Choices under Uncertainty*, Reading, MA: Addison-Wesley

Ramelsberger, E. (2001), *Siemens lists in New York*, Report No. AXX 200103015 e, 12 March 2001, Siemens AG Corporate Communications Press Office, New York, 5

Ravetz, J. (1994/95), *Economics as an elite folk science: The suppression of uncertainty,* Journal of Post Keynesian Economics, 17(2), 165-184

Reed, R., DeFillippi, R. J. (1990), *Causal Ambiguity, Barriers to Imitation, and Sustainable Competitive Advantage*, Academy of Management Review, 15(1), 88-102

Rindova, V. P., Kotha, S. (2001), *Continuous 'Morphing': Competing through Dynamic Capabilities, Form and Function*, Academy of Management Journal, 44 (6), 1263-1280

Roberts, M. (2000), *Rethinking the postmodern perspective: excavating the Kantian System to Rebuild Social Theory*, Sociological Quarterly, 41(4), 683-698

Rogers, E. M. (1962), *The Diffusion of Innovation*, New York: The Free Press

Rosenbloom, R. S. (2000), *Leadership, Capabilities, and Technological Change: The Transformation of NCR in The Electronic Era*, Strategic Management Journal, 21 (10/11), 1083-1103

Rosser Jr., J. B. (1993), *Belief: Its role in economic thought and action*, American Journal of Economics & Sociology, 52(3), 355-368

Rumelt, R.P. (1982), *Diversification Strategy and Profitability*, Strategic Management Journal, 3(4), 359-369

Salveson, M. E. (1959), *Long-Range Planning in Technical Industries*, Journal of Industrial Engineering, Sept-Oct

Scarbrough, H. (1998), *Path(ological) Dependency? Core Competencies from an Organizational Perspective*, British Journal of Management, 9(3), 219-232

Schepers, J., Schnell, R., Vroom, P. (1999), *From Idea to Business – how Siemens bridges the innovation gap*, Research Technology Management, 42(3), 26-31

Schumpeter, J. A., (1934), *The theory of economic development: an inquiry into profits, capital credit, interest, and the business cycle*, Cambridge, Mass.: Harvard University Press

Schumpeter, J. A. (1950), *Capitalism, Socialism and Democracy*, New York: Harper Torchbooks

Schwenk, C. R., Dalton, D. R. (1991), *The changing shape of strategic management research*, Advances in Strategic Management, 7, 277-300

Selznick, P. (1957), *Leadership and Administration; A Sociological Interpretation*, New York: Harper and Row

Sethi, R., Smith, D. C., Park, C. W. (2002), *How to Kill a Team's Creativity*, Harvard Business Review, 80(8). 2-3

Simon, H. A. (1957), *Administrative Behavior*, New York: Free Press

Singh, J. P., Dey, P. (2002), *Risk Measurement, Nonlinearities, and Chaos*, Singapore Management Review, 24(2), 47-58

Smith, N. W., Smith, L. L. (1996), *Field theory in science: Its role as a necessary and sufficient condition in psychology*, Psychological Record, 46(1), 3-19

Snow, C. C., Hrebiniak, L. G. (1980), *Strategy, Distinctive Competence, and Organizational Performance,* Administrative Science Quarterly, (25)2, 317-336

Spencer, M. H. (1962), *Uncertainty, Expectations, and Foundations of the Theory of Planning*, Academy of Management Journal, 5 (3), 197-206

Stake, R. E. (1998), *The Art of Case Study Research*, London: Sage Publications, Inc.

Stanley, T. D. (2000), *An empirical critique of the Lucas critique*, Journal of Socio-Economics, 29(1), 91-107

Sundbo, J. (1998), *The Theory of Innovation: Entrepreneurs, Technology and Strategy*, Cheltenham, UK: Edward Elgar

Szira, T. (2000), *The illusion of exactness*, Journal of Economic Studies, 27(4/5), 495-508

Taylor, F. W. (1911), *The Principles of Scientific Management*, New York: Norton & Company

Teece, D. J., Pisano, G. (1994), *The dynamic capabilities of firms: An introduction*, Industrial and Corporate Change, 3 (3), 537-556

Teece, D. J., Pisano, G. P., Shuen, A. (1997), *Dynamic Capabilities and Strategic Management*, Strategic Management Journal, 18 (7), 509-533

Teece, D. J. (1998), *Research Directions for Knowledge Management*, California Management Review, 40(3), 289-292

Teece, D. J. (2000), M*anaging Intellectual Capital: Organizational Strategic and Policy Dimensions*, Oxford: Oxford University Press

Tesch, R. (1990), *Qualitative Research: Analysis Types and Software Tools*, New York: The Falmer Press

Thompson, J. D. (1966), *Approaches to Organizational Design*, USA: University of Pittsburgh Press

Thompson, J. D. (1967), *Organizations in Action*, New York: McGraw Hill

Thomson, R. C., Hunt, J. G. (1996), *Inside the black box of alpha, beta, and gamma change: Using cognitive-processing model to assess attitude structure*, Academy of Management Review, 21(3), 655-690

Tockenbürger, L. W. (2000), *Controlling prozessorientierter Restrukturierungen*, Aachen: Sharer Verlag, Dissertation St. Gallen University

Tosi, H., Aldag, R., Storey, R. (1973), *On the Measurement of the Environment: An Assessment of the Lawrence and Lorsch Environmental Uncertainty Scale*, Administrative Science Quarterly, 18, 27-36

Tracy, J. A. (1996), *The Fast Forward MBA in Finance*, New York: John Wiley & Sons Inc.

Trist, E. (1977), *A Concept of Organizational Ecology*, Australian Journal of Management, 2, 162-175

Utterback, J. M. (1994), *Mastering the Dynamics of Innovation. How Companies can Seize Opportunities in the Face of Technological Change,* Boston, MA: Harvard Business School Press

VanderMate, J. (2000), *VOIP Market Update*, Just_Us Conference 2000

Verona, G. (1999), Note: *A resource-based view of product development*, Academy of Management Review, 24 (1), 132-142

Vinten, G. (1994), *Participant Observation: A Model for Organizational Investigation?*, Journal of Managerial Psychology, 9(2), 30-38

Von Neumann, J. Morgenstern, O., (1947), *Theory of Games and Economic Behavior*, 2nd Ed, Princeton, N.J.: Princeton University Press

Wagner, R. B. (1996), *Walking that Lonesome Valley*, Journal of Financial Planning, 9 (4), 28

Warmington, A. (1980), *Action Research: Its Methods and its Implications*, Journal of Applied Systems Analysis, 7, 23-39

Webster, J. (1998), *Desktop videoconferencing: Experiences of complete users, wary users, and non-users*, MIS Quarterly, 22 (3), 257-286

Weick, K. E. (1979), *The Social Psychology of Organizing*, Reading (MA): Addison- Wesley

Weick, K. E. (1982), *Administering Education in Loosely Coupled Schools*, Phi Delta Kappan, 673-676

Wernerfelt, B. (1984), *A Resource-Based View of the Firm*, Strategic Management Journal, (2), 171-181

Wernerfelt, B., Karnani, A. (1984), *Competitive Strategy under Uncertainty*, Academy of Management Proceedings, 42-46

Wheatley, M. J. (1999), *Leadership and the New Science; Discovering Order in a Chaotic World*, San Francisco: Berret-Koehler Publishers

Yin, R. K. (1989), *Case Study Research - Design and Methods*, Newbury Park: Rev. Ed. Sage Publications.

Zohar, D., Marshall, I. (1993), *The Quantum Society*, London: Bloomsbury

Zohar, D. (1998), *What would a quantum organization look like?* Management Review, 87 (3), 56-58

Zollo, M., Winter, S.G. (1999), *From organizational routines to dynamic capabilities*, INSEAD Working paper series, 99/48/SM

Zollo, M., Winter, S. G. (2002), *Deliberate Learning and the Evolution of Dynamic Capabilities*, Organization Science, 13(3), 339-351

Zott, C. (2000), *Dynamic capabilities and the emergence of intra-industry differential firm performance differential firm performance: insights from a simulation study,* Insead working paper