AN INVESTIGATION INTO THE TREATMENT OF UNCERTAINTY AND RISK IN ROADMAPPING: A FRAMEWORK AND A PRACTICAL PROCESS

This thesis is submitted for
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ABSTRACT

This thesis investigates roadmapping in the context of its application to strategic early-stage innovation planning. It is concerned with providing an understanding of how uncertainty and risk are manifested in roadmapping in this application, and with developing and testing a roadmapping process that supports appropriate treatment of uncertainty and risk.

Roadmapping is an approach to early-stage innovation planning, which is strategic in nature. It is seeing increasing application in practice and receiving growing attention in management literature. There has, however, been a noticeable lack of attention to uncertainty and risk in roadmapping theory and practice (and generally in strategic planning and at innovation's early-stages). This is despite the awareness that uncertainty and risk are fundamental to strategy and innovation (i.e. application domains of roadmapping), and that roadmapping is meant to deliver, as part of its benefits, the identification, resolution and communication of uncertainties and risks. There is very limited theoretical or practical direction on what this entails. It is this gap that the research reported in thesis addresses.

The research is divided into two phases. The first phase explains the manifestations and mechanisms of uncertainty and risk in roadmapping. It also introduces 'risk-aware roadmapping', a concept of roadmapping that includes a conscious and explicit effort to address uncertainty and risk, and points out what the process would entail in terms of necessary steps and procedures. The research here is designed using mixed methods (a combination of experience surveys, archival analysis, and case studies). The second phase provides a practical risk-aware roadmapping process. This practical process is developed based on the results of the first phase, and is designed according to procedural action research.

This thesis contributes to the fields of roadmapping, early-stage innovation and organisational sensemaking. It is found that factors related to the content, process and nature of roadmapping interact to influence the perception and treatment of uncertainty and risk. Characteristics of organizational sensemaking as theorized by Weick (1995) are

explored in the light of the findings and challenged. Aspects of early-stage innovation including the generation and selection of innovation ideas are explored in the context of uncertainty and risk and important paradoxes and constraints at innovation's early-stages.

DEDICATION

To father,

Professor James Atane Ilevbare.

You made this possible.

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I thank God for giving me the opportunity to embark on my PhD journey, and the provision, soundness of body and of mind to complete it.

I am forever grateful to my wife, Ayomikun, for her support through every step of the way, her encouragements to me, her prayers for me, and her strength of mind. Ayomikun, your love and strength saw me through this, and I am joyful I can share this achievement with you. I love you.

My family contributed immensely to this achievement. Dad, thank you for the training by which you prepared me for this, and the strength of your belief in me to get me on my way. Mum, thank you for your love, your prayers, and for constantly looking out for my health and well-being despite the thousands of miles between us. Gabriel, thank you for being my vanguard into Cambridge, for teaching me what to do and making my student life a lot more comfortable than it otherwise would have been. Joshua, you have been a great spiritual and moral example to follow. Thank you for opening the doors of your home to me to rest my head during my holidays. Elijah, thank you for the strength of heart and mind you show. You kept me inspired and focused throughout my journey. Emmanuel, your patience and doggedness taught me not to give up. Thank you. Osen, you kept looking out for me whenever we were apart. I thank you for that and for your provision, support and encouragement each time I visited home on holidays. Aima, you inspired me and spurred me on with your excellence and your maturity (which is far beyond your years). I am grateful to Folusho, Chris, Seun and Gerard for their support.

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Thank you all!!!

PREFACE

Except for commonly understood terms and accepted ideas, or where specific reference is made, the work reported in this thesis is my own and does not include the outcome of work done in collaboration. No part of the dissertation has been previously submitted to any university for any degree, diploma or other qualification.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1 – INTRODUCTION

1.1 Research background

Roadmapping is an approach to strategy that is seeing increasing application in practice and receiving growing attention in management literature. It is also particularly useful for drawing up and articulating innovation plans and required activities. Uncertainty and risk are fundamental aspects of strategy formulation and innovation (Noy, 1998; Ruefli et al., 1999), and there is increasing awareness that strategic planning and innovation should incorporate a more rigorous treatment of these issues (Euchner, 2011). This also applies to roadmapping, which is particularly relevant to planning at the early-stages (or front-end) of innovation that involves making decisions that are strategic in nature under an uncertain and complex outlook (Phaal et al, 2008). It has been pointed out that roadmapping should deliver as part of its benefits, the identification, resolution and communication of uncertainties and risks surrounding the strategic issue it focuses on (EIRMA, 1997; Bruce & Fine, 2004; Petrick & Provance, 2005).

However, a general lack of attention to uncertainty and risk has been noted across roadmapping practice and literature. This lack of attention is also visible in strategic planning and the early stages of innovation. Only limited attention has been given to the assessment and management of risk in strategic planning (Noy & Ellis, 2003) and risk had been neglected in most of formal strategic thinking (Wickham, 2008). Similarly, it has been indicated that there is a need to understand the mechanisms of risk management and how to respond to different kinds of uncertainty in early stages of innovation (Euchner, 2011). Similarly, in roadmapping there has been minimal consideration of uncertainty and risk issues and available roadmapping guides provide limited or no practical direction on how to address these issues. The lack of guidance is demonstrated by the results from a review (carried out as part of this study), which showed that only in 3.4% of roadmaps were explicit measures taken to manage uncertainty and risk. There have been attempts to show how roadmapping may be enhanced for use under situations or uncertainty (Lizaso & Reger, 2004; Strauss & Radnor, 2004), but these provide insufficient guidance and suggested processes show limited consideration of the routines and peculiarities of roadmapping. These issues highlight a need for better understanding of uncertainty and risk in roadmapping and a roadmapping process that would explicitly consider and manage uncertainty and risk surrounding the issues it focuses on. These needs are also pertinent to strategic planning and early-stage innovation planning. The early-stage of innovation (also called the front-end of innovation) is the first stage of innovation, in which opportunities for new products are first identified and analysed. In this stage, product ideas are generated and selected, thereafter leading to product conceptualisation and product development projects. This stage of innovation is often unstructured, but can be formalised through strategic planning (Koen et al., 2002). Planning at the early-stages of innovation is strategic in nature because it has a long-term impact on the organisation (Phaal et al, 2008). While innovation is generally uncertain, the early-stage of innovation is particularly so (and therefore particularly open to risk) because there is much less focus and there are less precise goals and objectives at this stage (Koen et al, 2002). Therefore, the consideration of uncertainty and risk in roadmapping, in its application to strategic early-stage innovation planning is pertinent.

1.2 Research aims and objectives

This research was carried out to meet the needs, as identified above, for:

- An understanding of uncertainty and risk in roadmapping in its application for strategic early-stage innovation planning, and
- Guidance for a roadmapping process that pays attention to the treatment of uncertainty and risk within itself.

To meet these needs, the following research objectives were drawn up and addressed:

- To develop a preliminary framework that considers the implications of uncertainty and risk for roadmapping and captures the relevant factors that should be considered if uncertainty and risk are to be appropriately addressed in roadmapping for strategic early-stage innovation planning

- To propose a roadmapping process (a step-by-step approach) that incorporates (and trades-off) the factors (and their implications) identified from the framework
- To develop and refine the process and framework based on the views of roadmapping experts and tests them for robustness using in-company case studies

1.3 Research approach

The overall research was approached in two main phases: the development of a preliminary framework that explores the mechanisms of uncertainty and risk in roadmapping, and application of learning from the framework to create a roadmapping process that is aware of these mechanisms and responds to them appropriately. In the first phase of the research, input from literature and practice, which included the use of archival analysis, interviews of roadmapping experts and case studies, were combined to develop the preliminary framework. From these, relevant issues to consider in addressing uncertainty and risk in roadmapping were drawn out. Useful steps to take, and methods to apply in addressing these issues were also identified. In the second phase of the research, a roadmapping process was developed to recognise the issues identified in the preliminary framework. This process was first created by integrating appropriate methods into a baseline roadmapping process, and was subsequently refined based on the appraisals of practitioners. It was then tested (and further refined) through five in-company case studies. The second phase of the research was carried out in line with principles of action research.

1.4 Structure of the thesis

The remainder of this thesis is organised into eight chapters (as shown in Figure 1.1).

Chapter 2 provides an important foundation for the research through the review of relevant literature. It introduces roadmapping and examines it in the contexts of strategic planning and early-stage or front-end innovation. The concepts of uncertainty and risk are also discussed, first generally, and then in the contexts of roadmapping.

Chapter 3 discusses research methodology applied to meet the research objectives. It describes the stages of research and justifies the research methods. Chapter 4 focuses on the development of the preliminary framework, using input from literature and roadmapping practice. Chapter 5 presents a roadmapping process that is incorporated with procedures to address uncertainty and risk. This process is built based the understandings of the framework (i.e. by recognising its implications and addressing them appropriately). Chapter 6 reports the appraisal of the process by strategic planners and roadmapping experts, and the refinements made to it (and preliminary framework). Chapter 7 reports the testing of the revised process in five companies and the refinements made to the process as a result of the tests. Chapter 8 presents and discusses the research findings, drawing out both practical and theoretical contributions. Chapter 9 summarises and concludes the thesis, pointing out areas for further the research.

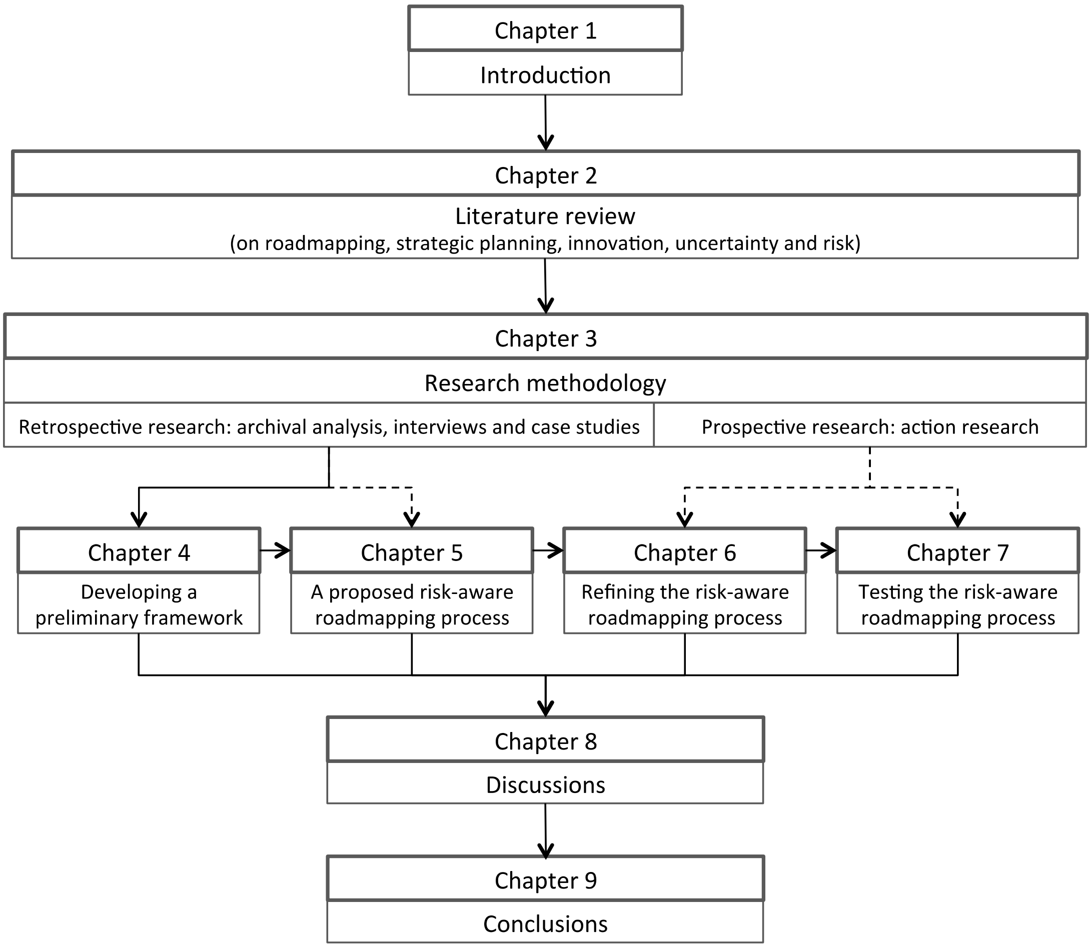

Figure 1.1 – Structure of the thesis

Chapter 2 – LITERATURE REVIEW

This chapter aims to provide a foundation for the research carried out and reported in this thesis in subsequent chapters. It is split into four main sections.

Section 2.1 focuses on roadmapping. It introduces roadmapping and shows the different types, and by so doing helps to point out that roadmapping can be applied to planning. Importantly, this section also explains the roadmapping framework and process, whose understanding is central to achieving the research objectives. In addition, it points out the characteristics of roadmapping, which set it apart from other planning routines.

Section 2.2 establishes roadmapping in the context of strategic planning and innovation (the contexts in which roadmapping is explored in this research). To do this, it first positions roadmapping within wider strategic planning (and strategic management), and points out its significance to strategic management research. It also characterises roadmapping according to the forms (or models) of strategic planning. The section explains how the purpose of roadmapping (and strategic planning) ties to value creation in the firm and logically links to the application of roadmapping as an approach to front-end innovation planning. Importantly, it is demonstrated here that the generic roadmapping process conforms to those of strategic planning and front-end innovation and this further strengthens the understanding (from practice) that roadmapping can be seen as an approach to these. To further establish the relevance of this research to theory and practice, the usefulness (and application) of roadmapping across various states of organisational environment, whether stable or uncertain, is ascertained. Overall, the explanations given in this section are significant as they can be regarded as useful perceptions that strengthen roadmapping literature.

Section 2.3 focuses on providing an understanding of uncertainty and risk, first in the context of strategic management and then in the light of roadmapping and strategic planning. It also shows the generally accepted process for addressing uncertainty and risk (i.e. the risk management process), and importantly, how risk management relates to the objective of value creation in the firm, especially in the light of roadmapping.

Section 2.4 then examines the management of uncertainty and risk in roadmapping (and its associated applications of strategic planning and front-end innovation) and exposes the gap in theory and practice, which subsequent chapters focus on bridging.

Thus, in bridging this gap, this study focuses on an overlap between roadmapping (and strategic planning and innovation), uncertainty and risk, within the context of strategic management research (Figure 2.1). The study is inspired largely by a practical problem and relevant literature is explored corresponding to the bodies of knowledge represented in Figure 2.1. In examining literature, links are made to some perspectives, namely bounded-rationality, knowledge-based theory of strategic management and strategy-as-practice perspective as found applicable to the study focus.

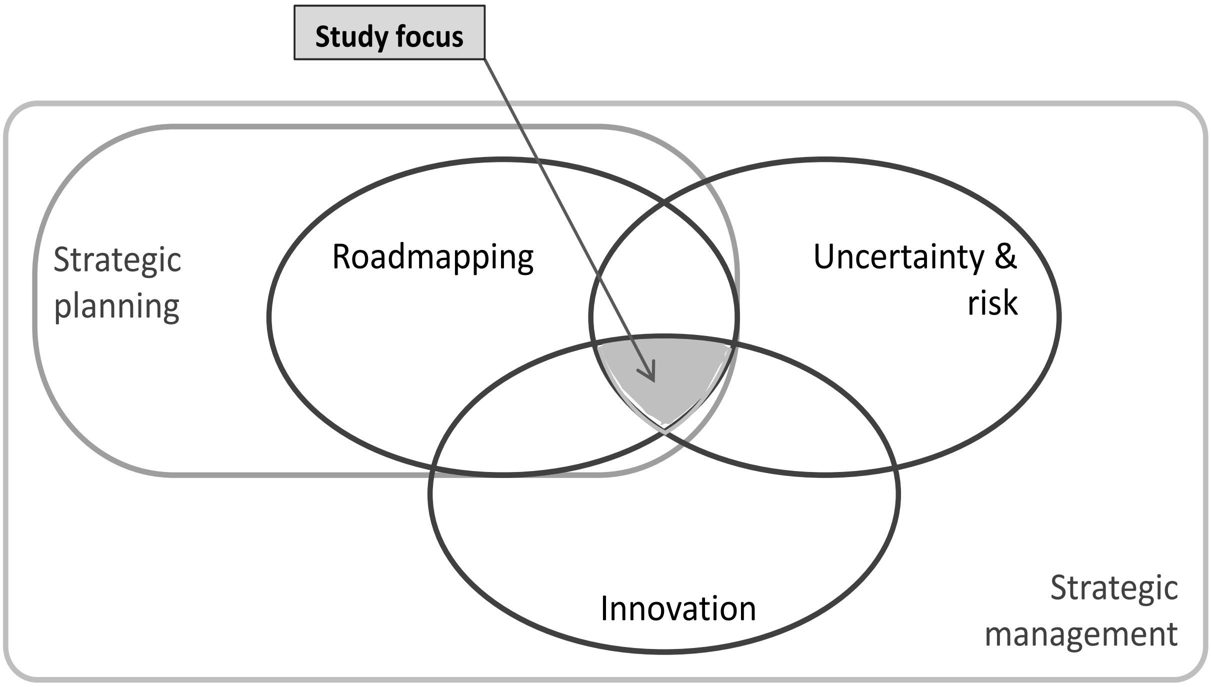

Figure 2.1 - Focus of study

2.1 An overview of roadmapping

2.1.1 Introduction to roadmapping

Roadmapping is an approach to strategy formulation and innovation planning, and has become a widely used management method for these purposes (Phaal & Muller, 2009). It can simply be described as the process of developing roadmaps (Garcia & Bray, 1997; Kappel, 2001; Kostoff & Schaller, 2001). A roadmap is a visual representation that provides "an extended look at the future of a chosen field of inquiry drawn the collective knowledge and imagination of the groups and individuals in that field" (Galvin, 2004, p 101). It identifies objectives for a set of product needs, and helps to focus resources on the critical technologies required to meet those objectives (Garcia & Bray, 1997).

The origin of roadmapping is not precisely known, but as identified by Beeton (2007), the earliest form of a roadmap was published in 1945 (Massel, 1945). Contemporary application of roadmapping took root in science and technology. It was championed in the 1970s by Motorola (Willyard & McClees, 1987), and its application to product technology planning there provided the foundation for subsequent application and development of the approach (Probert & Radnor, 2003). Roadmapping has conventionally been applied to identify technological solutions (de Laat & McKibbin, 2001; Garcia & Bray, 1997). As a result, the term *technology roadmapping* has been used more dominantly to describe the approach. However, Phaal et al. (2003) pointed out that technology is only one aspect of roadmapping, and that the terms 'business', 'strategic', or 'innovation' roadmapping may be more appropriate to qualify it. Thus, to avoid the confusion which may arise from the usage of the different qualifiers, the term 'roadmapping' is adopted throughout this thesis.

Roadmapping fits within the broader corporate, technology and innovation planning of the firm (Bruce & Fine, 2004; Garcia & Bray, 2004; Willyard & McClees, 1987). It is applicable to a wide range of issues including capability planning, programme planning and knowledge asset planning (Phaal, et al, 2010). However, roadmapping is particularly relevant to the early stages of innovation, which involves making decisions that have a strategic impact on the organisation (Phaal et al., 2008).

2.1.2 Types of roadmaps and approaches to roadmapping

Roadmapping's wide applicability has made it difficult to assign a single or standard definition to the word 'roadmapping', and a way scholars have tried to overcome this challenge is by classifying roadmaps (and roadmapping) (Kappel, 2001).

Albright & Schaller (1998) provided four classes of roadmaps based on the organisational level at which roadmaps are applied (i.e. domain of application) and the various objectives for creating them (Figure 2.2). The four classes are: a. science and technology (S&T) roadmaps, b. industry technology roadmaps, c. corporate or product-technology roadmaps, and d. product/portfolio management roadmaps. These span different levels of application, from product (or project) and firm levels to industry and cross-industry levels. Kappel's (2001) classification is also based on two dimensions: roadmapping purpose (similar to Albright & Schaller's (1998) 'objective' dimension) and roadmapping emphasis (Figure 2.3). The purposes for creating roadmaps identified by Kappel (2001) (industry understanding and local coordination) are however different from those by Albright & Schaller (research/understanding, technology development and administration), indicating difference of views on the uses of roadmaps. Roadmapping emphasis refers to whether the roadmap is created to consider business environment trends and align relevant ones with targets and corresponding actions, or used to establish and communicate future expectations. By crossing these two dimensions, Kappel (2001) identified science/technology roadmaps, industry roadmaps, product-technology roadmaps and product roadmaps as the four classes of roadmaps. Kappel (2001) also explained that roadmaps combine elements of foresight (i.e. anticipation of the future, which could be exploratory or goal-oriented in nature) and planning (i.e. setting out goals and action steps to the anticipated future).

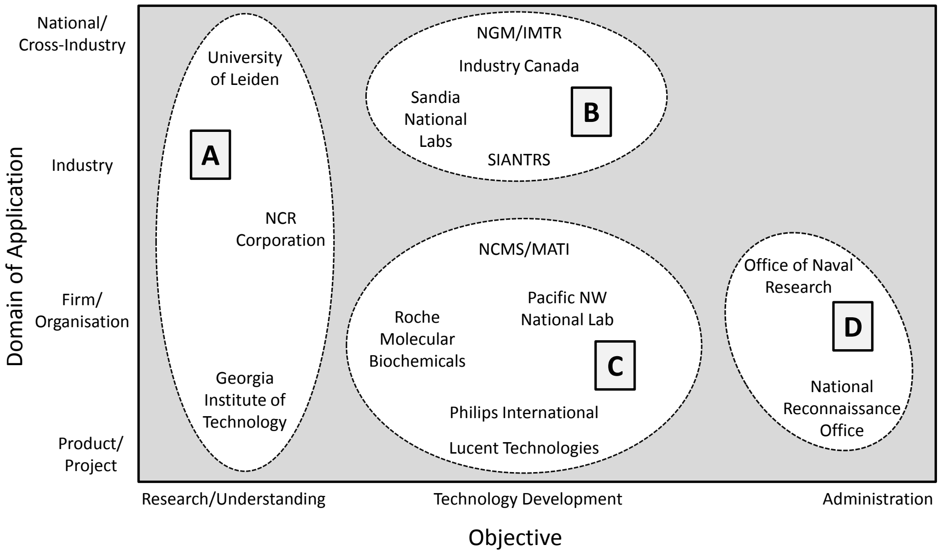

Figure 2.2 - Taxonomy of roadmaps (Albright & Schaller, 1998)

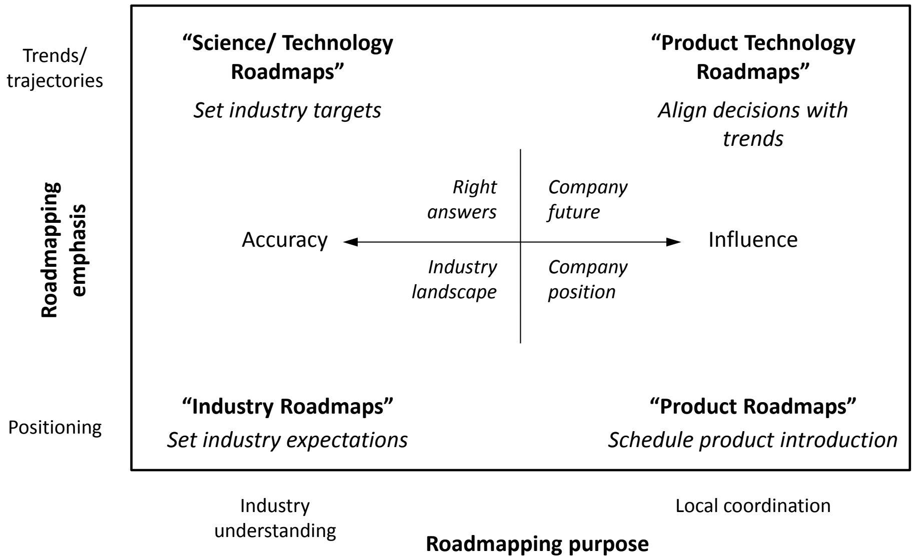

Figure 2.3 - Roadmapping taxonomy (Kappel, 2001)

Figure 2.4 is a depiction of Bruce & Fine's (2004) classification of roadmaps (which is supported by Beeton (2007)). It expands the foresight aspect of roadmaps. Bruce & Fine (2004) and Beeton (2007) identified four classes of roadmaps based on their technology [foresight] scope (whether exploratory or target-driven in nature) and participation scope (i.e. number of organisations involved in the creation of the roadmap, which shares similarities with Kappel's 'roadmapping purpose' and Albright and Schaller's 'domain of application' dimensions). Bruce & Fine (2004) pointed out that there is no strict demarcation between exploratory roadmapping and target-driven roadmapping, but a transition between one and the other, and the eventual scope of a roadmap is usually a mix of exploratory and target-driven aspects. However, emphasis could shift from exploration to having a target-driven focus, and this may be affected by the maturity of product or technology that the roadmap focuses on.

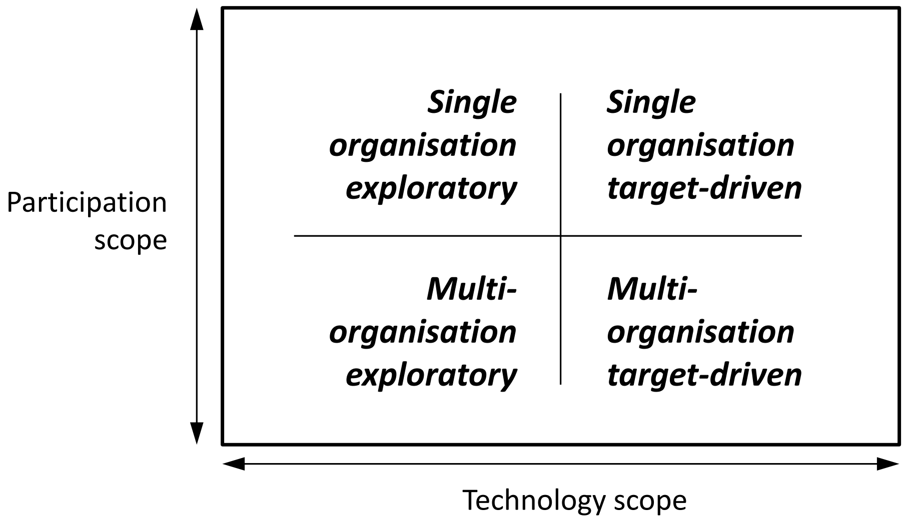

Figure 2.4 - Taxonomy of roadmaps (Bruce & Fine, 2004; Beeton, 2007)

Figure 2.5 integrates the three aforementioned taxonomies into one. It shows that roadmaps possess foresight and planning elements (as suggested by Kappel (2001)), that the foresight element can either be exploratory or focused and target-driven (as suggested by Bruce & Fine (2004) and Beeton (2007)), and that a transition in emphasis exists between these elements. It also shows that roadmaps can be created at several organisation levels (as indicated by Albright & Schaller (1998)). The emphasis or purpose of roadmapping at these organisation levels would be, at one extreme, to anticipate or 'understand' the future, and at the other, to create action plans.

This thesis focuses on roadmapping that aligns more with the right-hand side of the taxonomy, since it concentrates on roadmaps used to create strategic and innovation plans.

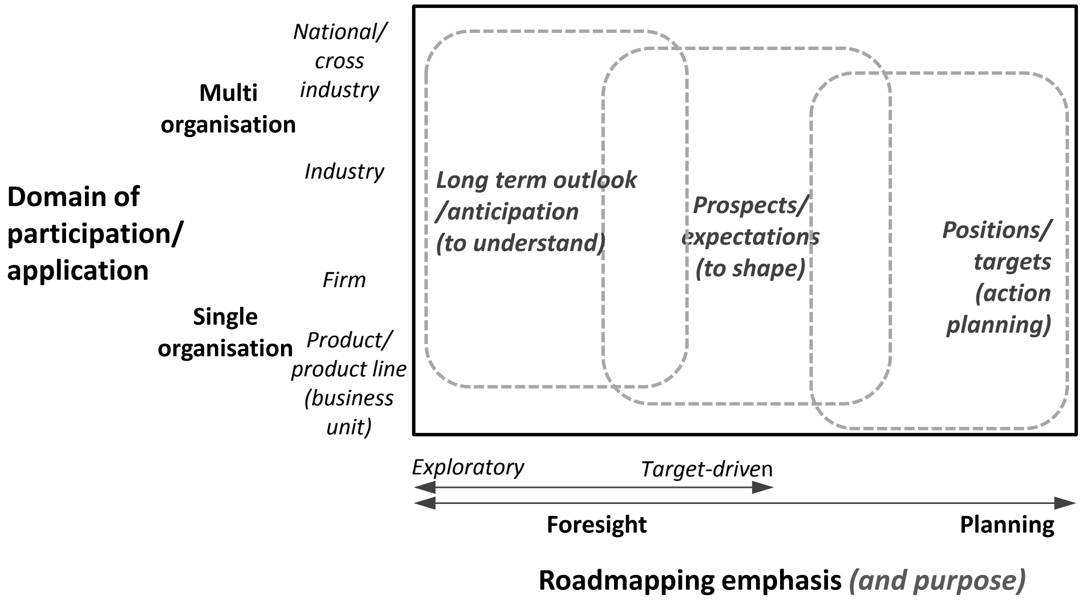

Figure 2.5 – Integrative roadmapping taxonomy

Aside from the two-dimensional taxonomies described above, there are other classifications of roadmaps. Garcia & Bray (1997) identified three types of roadmaps: the product technology roadmap, emerging technology roadmap and the issue-oriented roadmap, and as shown in Figure 2.6, Phaal et al. (2001b) provided a classification of roadmaps according to their purpose and visual format. Despite these various taxonomies, the principles underpinning roadmapping, in terms of the architecture of the roadmap and the development process, are generic. These are discussed in the following section.

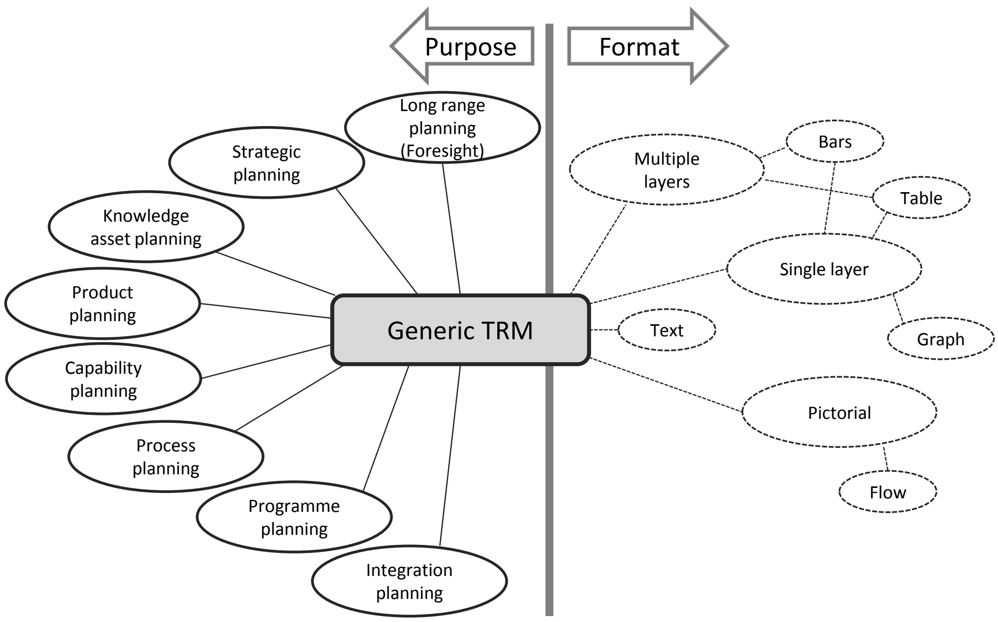

Figure 2.6 – Types of roadmaps: purpose and format (Phaal et al., 2001b)

2.1.3 Roadmap framework and roadmapping process

A. The roadmap framework

The roadmapping approach is flexible, both in the structure of roadmaps and the process followed in development (Probert et al., 2003). However, the most common format of roadmaps is the multi-layered time-based format (Phaal et al., 2001b). This format is captured by the generic roadmap framework proposed by EIRMA (1997) (Figure 2.7). It consists of a number of layers (external influences, deliverables, technology, science, skills and know-how, and resources), which are laid out over time. Building on this, Phaal et al. (2003) provided a reconfigured framework (which will be used through this thesis) around three major layers (Figure 2.8):

- The 'know-why' – These layers, usually topmost in the roadmap architecture, relate to present and future influences that indicate future needs of the market (e.g. external market and industry trends and drivers: social, technological, economic, environmental, political, infrastructural, etc., and the business vision and policy).
- The 'know-what' – the middle layers focus on the key opportunities, objectives or deliverables pertaining to the strategic/innovation issue under consideration, usually in the form of products and services. It is through these strategic opportunities (or value propositions) that the needs of the market are met.
- The 'know-how' - The bottom layers are concerned with the technology, capability and other resources necessary for actualising the objectives and deliverables contained in the know-what layers.

The exact composition of these layers (i.e. in terms of their sub-layers) depends on the specific application of the roadmap (Probert, et al., 2003). It is useful to point out the presence of a fourth layer – the To Do (or actions) layer – which is implied in Phaal et al.'s (2003) know-how layer, but made explicit by Albright (2009) (Figure 2.9). The inclusion of a 'to-do' layer explicitly brings out the *planning purpose* of roadmapping indicated on Figure 2.5. This layer points out the steps to be taken to acquire and apply necessary technologies, capabilities and resources for the achievement of objectives and deliverables.

Figure 2.10 consolidates these views from EIRMA (1997), Phaal et al. (2003) and Albright (2009). This time-based multi-layered structure drives data gathering and analysis during the roadmapping process. The time dimension makes explicit three important questions an organisation developing a plan should answer: *where are we?, where do we want to go?, and how can we get there?,* (Phaal, et al., 2003). The multi-layered structure facilitates an alignment of the interacting themes contained in these three layers, which enables the making of sound actionable decisions (Gindy et al., 2006).

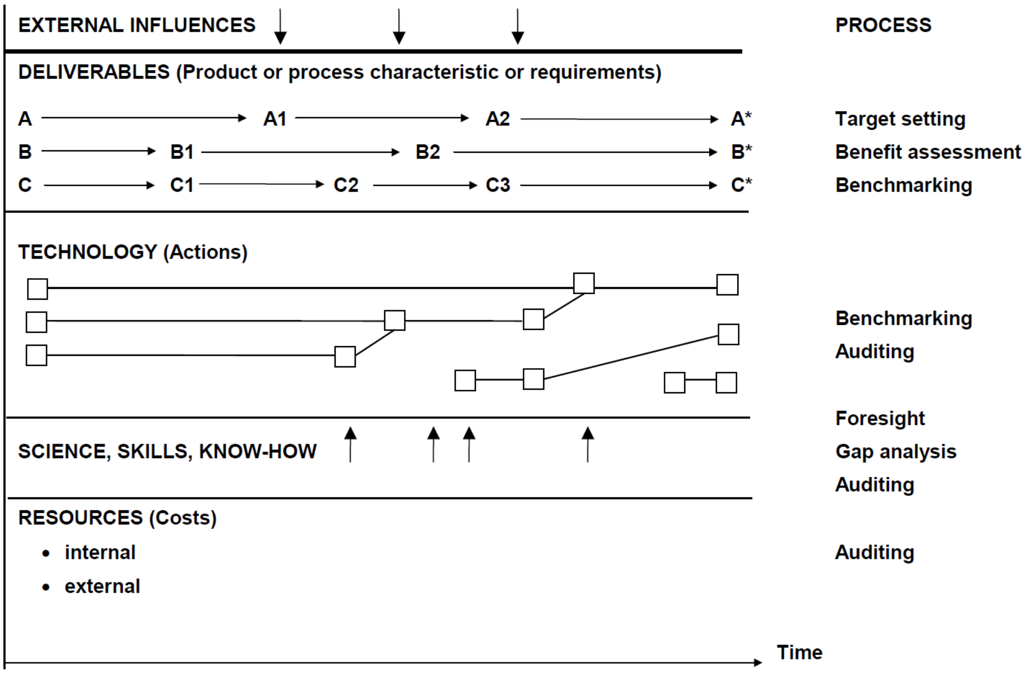

Figure 2.7 – The generic roadmap framework (EIRMA, 1997)

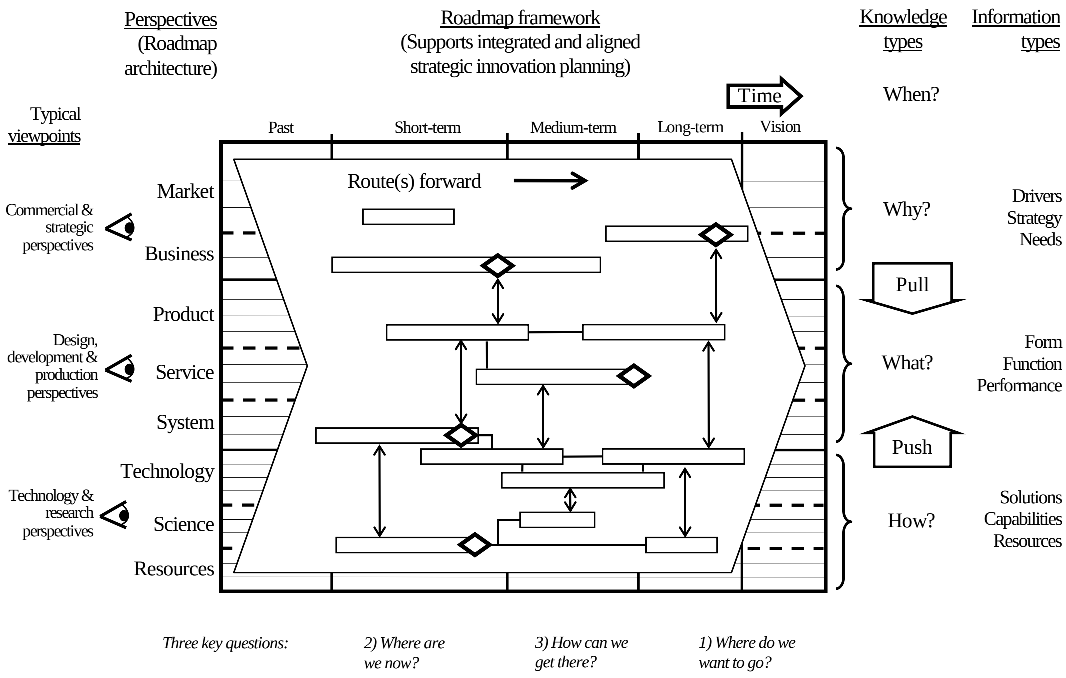

Figure 2.8 - The roadmap framework (Phaal et al., 2003)

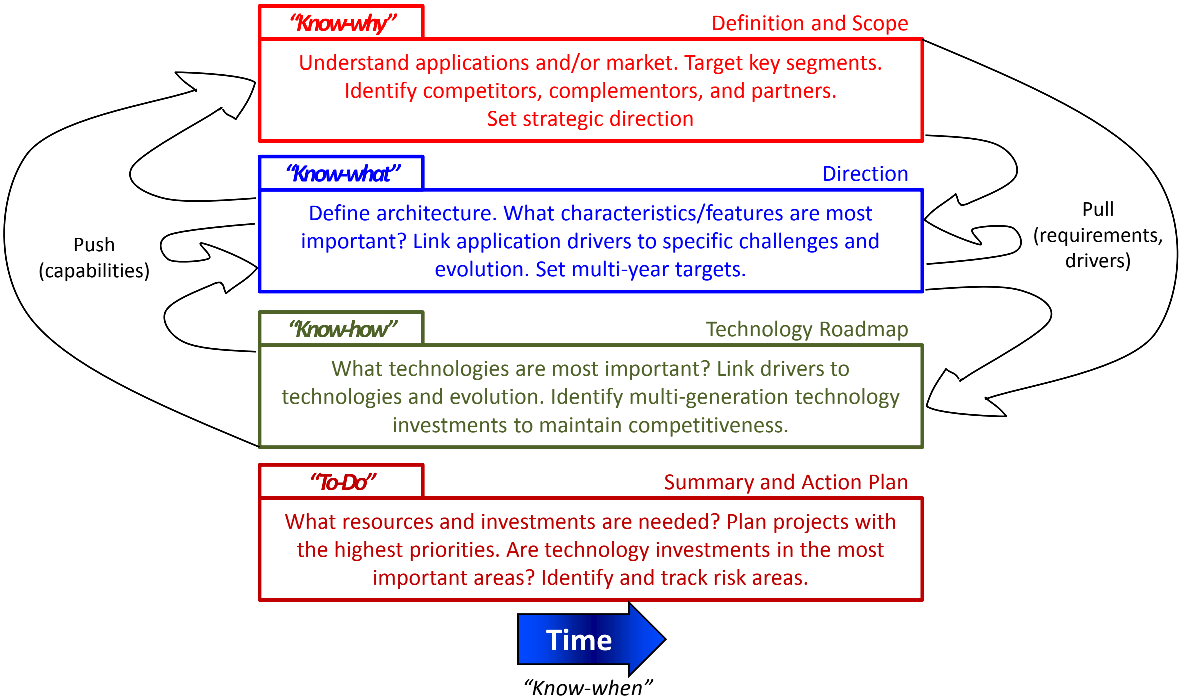

Figure 2.9 – The generic roadmap framework (Albright, 2009)

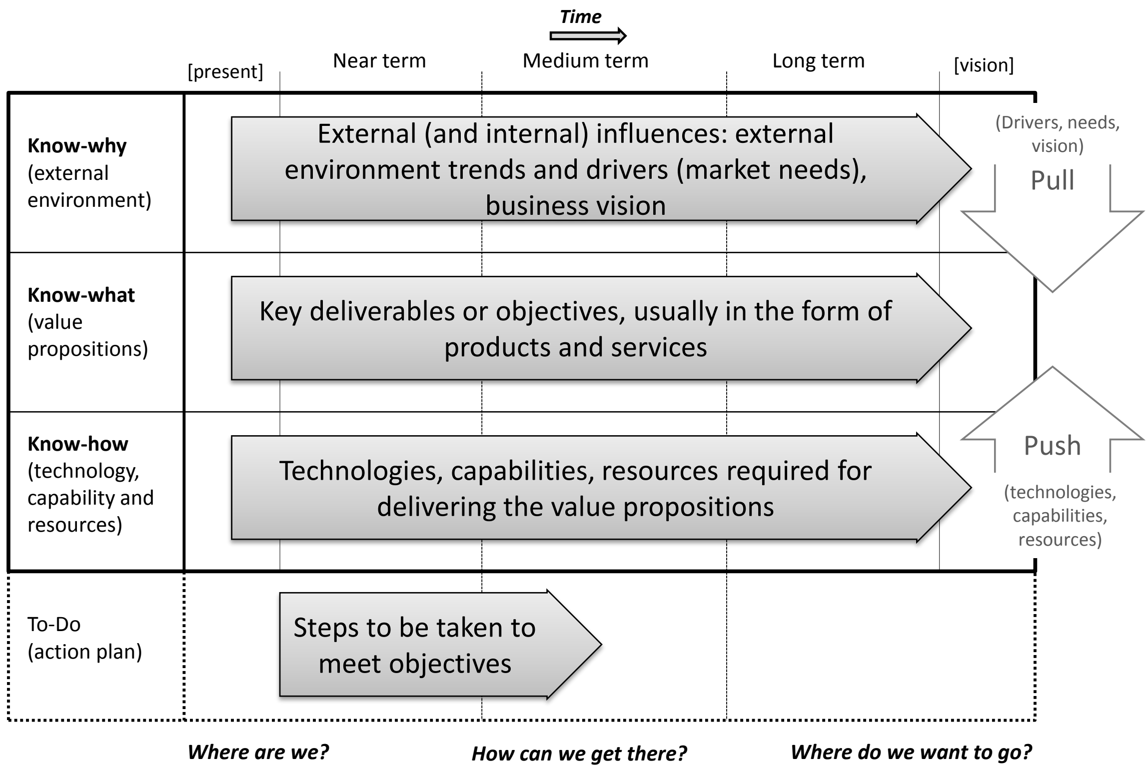

Figure 2.10 – The generic roadmap framework based on a combination of EIRMA (1997), Phaal et al. (2003) and Albright (2009)

B. The roadmapping process

Kostoff & Schaller (2001) pointed out two fundamental approaches to roadmapping: expert-based approach and computer-based approach. The expert-based approach places emphasis on drawing on the knowledge and experience of a team of experts in developing the roadmap, which may or may not be supplemented with information from relevant reports or databases. The computer-based approach applies data extracted from large textual databases using computer techniques to develop the roadmap. Even though this approach is more objective than the expert-based approach (since it does not directly rely on the subjective knowledge and experience of humans), it is limited by the difficulties faced in its implementation (e.g. availability of databases with the relevant information, and the ability to successfully apply computer-based information extracting tools) (Kostoff & Schaller 2001). It is also disadvantaged by the absence of interaction among experts – a vital aspect of the roadmapping process (Strauss et al., 1998). In addition to these two approaches, Kostoff & Schaller (2001) indicated a third approach -

the hybrid approach. It combines the expert-based and computer-based approaches, which helps in overcoming some of the limitations identified with the individual approaches. Yoon et al. (2008) reported its application, in which text mining was used as a computer technique to extract information from databases, which was then used in a morphological analysis-based roadmapping process. This thesis, however, places emphasis on the expert-based approach.

In terms of process, there is no single universally accepted or best method for roadmapping (de Laat, 2004; Phaal et al., 2010), but four generic stages are identifiable in literature. These are: 1) initiation and planning, 2) input and analysis, 3) roadmap synthesis and output, and 4) implementation (or integration) of the roadmap. The various approaches presented by scholars and practitioners can be captured in these stages as shown in Tables 2.1 and 2.2.

- In planning, the need for the roadmap is defined (Garcia & Bray, 1997) and thought is given to the structural elements of the roadmap (Kostoff & Schaller, 2001). Also, participants are identified and selected for the input and analysis stage of the roadmapping process.

  In the planning phase, the structure and nature of content of the subsequent phases is determined.
- At the input and analysis stage relevant knowledge is captured, structured and shared (Phaal, et al., 2003).
- Roadmaps have to be interpreted correctly or implemented to fulfil their objectives of either providing an ‘understanding’ of the future or achievement of specified goals (Beeton, 2007; Gerdsri et al., 2009).
- Updating a created roadmap has been identified as good practice to “keep it alive” and as part of the organisation’s planning activities (EIRMA, 1997).

Generic process	Garcia & Bray (1997)	Bruce & Fine (2004)	Beeton (2007)	Gerdsri et al (2009)
Initiation and planning	Preliminary activity	Planning	Planning	Initiation
Data input and analysis	Development of roadmap	Input	Insight collection	Development
		Analysis	Insight processing	
Roadmap synthesis and output		Roadmap output		
Implementation	Follow-up activity		Interpretation/ implementation	Integration (as an on-going process)

Table 2.1 - Generic steps in roadmapping according to the identified authors

The input and analysis stage is usually carried out in workshop forums[1]. Workshops are an important part of roadmapping, since they are the main means by which stakeholders and domain experts relevant to the focus of the roadmap are brought together to capture, share and structure knowledge (Phaal et al., 2007; Kerr, et al., 2012). Workshops provide an opportunity for interaction and collaboration between the experts and stakeholders for the purpose of group cognition, i.e. integration of their cognitive (or mental) efforts, consensus and collective action (Kerr et al., 2012). Since roadmapping is centred on the workshop, and the primary task of the participants is to generate a roadmap, the workshop itself may be regarded as a microcosm of the overall roadmapping process. Its inputs and outputs are aligned with the overall roadmapping initiative (Phaal et al., 2010).

As shown in Figure 2.11, the input and analysis stage follows a series of divergence-convergence iterations (Phaal & Muller, 2009; Kerr et al., 2011). Divergence refers to capturing and exploration of knowledge and information, and convergence refers to the analysis and reduction of that knowledge to the most essential and beneficial for the issue the roadmap focuses on.

[1] It is not unusual for the input and analysis to start before the workshop, as the latter part of the planning process.

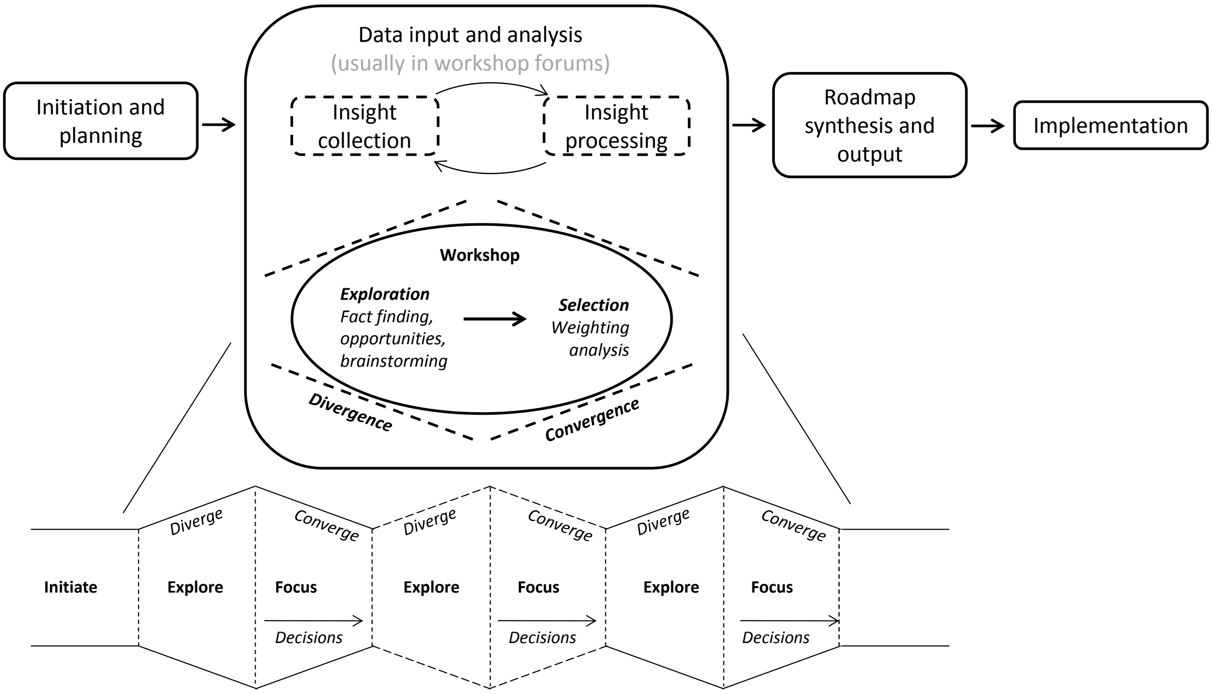

Figure 2.11 - Generic roadmapping process showing the overall divergence and convergence phases (and the series of divergent-convergent iterations) at the input and analysis (adapted from Phaal et al., 2008 and Kerr et al., 2011)

Generic phase	EIRMA (1997)	Groenveld (1997)	Garcia & Bray (1997)	Australia (2001)	Phaal et al. (2007)	Beeton (2007)
Initiation and planning	1. Pre-project phase	1. Problem recognition by management	1. Initial conditions of need and availability of relevant stakeholders for roadmapping activity as well as roadmap leadership/ sponsorship	1. Confirm the scope of the roadmap, vision and strategic goals	1. Plan: define objectives, focus and boundaries: i. Design the roadmap architecture and process. ii. Identify stakeholders that will participate. iii. Plan the logistics of the workshop event	1. Establish steering committee 2. Articulate need for the roadmap
	2. Setting up the team	2. Development of provisional roadmap	2. Define the scope and boundaries of technology roadmap			3. Set system boundaries
	3. Preliminary plan for the roadmapping project		3. Identify the focus of roadmap			4. Design the roadmap architecture 5. Recruit experts
Data input and analysis		3. Roadmap discussion and information gathering by a small team	4. Identify the critical system requirements and targets	2. Identify the technology barriers and alternatives	2. Roadmapping workshop process a. Strategic landscape activity to outline market trends and drivers, products and services, and identify a list of priority topics to focus upon.	6. Workshop introduction and overview 7. Strategic landscape i. Brainstorming ii. Capture insights iii. Populate the roadmap
		4. Workshop(s) with multi-disciplinary participation to draft roadmaps	5. Specify major technology areas which will help in achieving the system requirements and technology drivers and targets 6. Identify the technology alternatives and their timelines	3. Identify the technology alternatives for technology areas based on the critical product or service	b. Explore key topics identified in the landscape activity in more depth: i. Summarise key drivers, constraints and assumptions ii. Clarify vision and objectives iii. Summarise current situation iv. Map a route forward v. Highlight key risks, enablers, barriers, decision points and knowledge gaps	
	4. Processing the inputs	5. Upgrading of roadmaps and their format	7. Recommend technology alternatives that should be pursued.	4. Prioritise the technology alternatives according to their ability to overcome	c. Present topics for discussion and review in order to agree on which to further pursue	8. Voting and rank key issues
Roadmap synthesis and output	5. Compression to a working document		8. Create, critique and validate the technology roadmap	5. Create the roadmap	3. Create a report (or presentation or both) containing a summary of outputs	9. Collation and transcription into a working document
Implementation	6. Checking, consulting, communication planning 7. Formulation of a decision document	6. Improvement of supporting tools	9. Develop an implementation plan	6. Implement and review technology roadmap		
	8. Update	7. Stimulation of learning	10. Review and update the roadmap			

Table 2.2 – Roadmapping procedures according to the identified authors positioned over the generic stages identified in Table 2.1

C. Characteristics and benefits of roadmapping

Roadmapping is an analytical process for planning (Bruce & Fine, 2004), and it deals with strategic levels of information, which means it has to navigate through high uncertainty (MoD, 2006). However, the key distinctive feature that sets roadmapping apart from traditional planning routines is the visual aspect it brings to strategic decision-making (Bruce & Fine, 2004; Phaal et al., 2009, Albright, 2009). This visual aspect is embodied by the roadmap framework itself (Figure 2.10). Roadmap visuals are always time-based and the explicit (and visual) linkage of elements contained in a plan to a time dimension also distinguishes roadmaps from other strategy maps or documents (Kappel, 2001). The visual aspect of roadmapping should be seen not just as an attractive way to communicate the outcome of the process, but as a powerful enabler of the planning process (Eppler & Platts, 2009). The visuals provide the means for multiple interacting themes to be represented in a structured format, thereby aiding the understanding of inter-dependencies between the themes and promoting communication and discussion among decision-makers during the process.

Another characteristic of roadmapping is that it is usually carried out as a collaborative and social process involving a group of people who are experts in the field of the issue under consideration (Bruce and Fine, 2004; de Laat & McKibbin, 2001; Garcia & Bray, 1995, Kostoff & Schaller, 2001). The roadmapping process depends on the cognitive effort of the group which usually serves as the primary (or initial) source of data and the means of its analysis. Roadmapping processes are usually carried out to spur action towards innovation. Therefore they tend to be driven towards achieving consensus between participants to increase the likelihood that the decisions reached will be executed (Burer & Glaze, 1995; Garcia & Bray, 1995; Bruce & Fine, 2004).

2.2 Roadmapping in the context of strategy and innovation

Within the field of strategic management, roadmapping is still a relatively young subject area that has developed mainly through practice (Willyard & McClees, 1987; Kostoff & Schaller, 2001). As such it does not have its own strong theoretical underpinnings. However, it is considered that by placing roadmapping in the context of more established models and theories from strategy and innovation (which are areas most relevant to roadmapping), an appropriate theoretical base can be created to support understanding generated by research on roadmapping. A useful point to begin would be to have an overview of how research in the field of strategic planning has evolved and the position roadmapping occupies within it.

2.2.1 The evolution of strategic planning (and management) research and roadmapping's position within it

The history of research in strategic planning is intertwined with broader strategic management and therefore both are presented together here. The emergence of roadmapping is positioned within this evolution of strategy research (see Figure 2.12 for a summary). Following scholars such as Rumelt et al. (1994), Herrmann (2005), Furrer et al. (2008), the account of the evolution of strategic management (and strategic planning) is divided into three broad eras:

a. Pre-history and birth of strategic management (before 1970s)
b. Separation of the strategic management field into strategy content and strategy process research (and the era of competitive advantage) (1970s – 80s)
c. Emergence of contemporary strategic management theories (1990s – present)

A. Prehistory and birth of strategic management (and initial prominence of strategic planning)

Strategy has its roots in the military. The term 'strategy' derives from the Greek 'strategos', which means 'general of the army'. It was the responsibility of the 'strategos' to give advice about managing battles to win wars (Blackerby, 1994). In the prehistory of strategic management, studies were mainly concerned with the interaction of economics and the organisation (Rumelt et al., 1994). Examples are Taylor's (1947) "science of work" in the organisation and Barnard's (1938) study on how managers can make work efficient and effective.

The works of Chandler (1962), Ansoff (1965) and Learned et al. (1969) are credited for the birth of the strategic management field. They established the foundations of the field and the first definitions of strategy within it, at a time when there was no dominant paradigm (Rumelt et al., 1994). Chandler (1962) showed how executives laid out long-term strategies concerning their enterprises and modified organisational structure to make the strategies work. Learned et al., (1969) suggested a framework for strategy formulation based on the appraisal (from the perspective of the CEO) of the organisation's internal strengths and weaknesses as well as the external environment's opportunities and threats (which became known as SWOT analysis). Ansoff's (1965) view of strategy emphasised corporate expansion and diversification within the product-market. These scholars defined strategy as follows:

"the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out the goals" p 13, Chandler (1962)

"the pattern of objectives, purposes, or goals and major policies and plans for achieving these goals, stated in such of a way as to define what business the company is in, or is to be in and the kind of company it is or is to be" p 3, Learned et al. (1969).

"[Strategy] is designed to transform the firm from the present position to the position described by the objectives, subject to the constraints of the capabilities and the potential" p 205, Ansoff (1965)

A common theme in these works is that they were interested in identifying best practices for managers and prescribing formal routines for developing strategy (Hoskisson et al., 1999). Thus, this period of strategic management birth and emergence was dominated by strategic planning. For this time, strategy could be described as *"a deliberate process,* *initiated by top management, based on an elaborate industry analysis and aimed at designing a cohesive grand strategy [plan] for the corporation"* (Volberda, 2004, p 36).

Even though roadmapping was not recognised as an approach to strategy in this era, it bears strong similarities with the views (and definitions) of strategy given above. It is deliberate in nature and can facilitate the determination of long-term goals, clarification of an organisation's present position and deciding its future according to its purposes and objectives. However, it does not necessarily aim at designing a grand plan for an entire corporation.

B. Separation of strategic management field into process and content research: the era of competitive advantage (and fall of strategic planning)

The 1970-80s witnessed the separation of strategic management research into descriptive studies of how strategies are formed and implemented (strategy process research), and studies to understand the relationship between strategic choice and performance of organisations (strategy content research) (Rumelt et al., 1994). Within process research, Mintzberg's (1978) 'emergent strategy' and Quinn's (1980) 'logical incrementalism' were presented as more accurate characterisations of how strategy is formed. These themes explained that strategy emerges or is formed gradually, and became predominant over the notion that strategy should be explicitly and formally decided in advance (as proffered by Chandler (1962) and Learned et al. (1969)). Nevertheless, overall strategy management research in this period was dominated by the content research, especially by Porter's (1980) work on organisational performance and competitive advantage (Herrmann, 2005). These views on emergent strategy coupled with Porter's work may have contributed to formal strategic planning losing its position at the forefront of strategic management research at this time.

In content research, theories developed around industrial organisational economics, inspired by Porter's (1980) five forces framework. These included *strategic groups* and *competitive dynamics* (Hoskisson et al., 1999), and their application included the prediction of relationships between similar organisations and the behaviour of competitors (Barnett & Burgelman, 1996; Grimm & Smith, 1997). *Transaction cost* *economics (TCE)* (Williamson, 1979) and *agency theory* (Demsetz, 1983) were other theories that emerged, under which studies conducted included examining the performance of different forms of organisations (e.g. joint ventures and multinationals) and the relationship between R&D investment and firm performance.

C. Contemporary theories and perspectives in strategic management (and the resurgence of strategic planning)

More contemporary theories emerged in strategic management, focussed on forming and maintaining systems that help firms to create and sustain competitive advantage or adapt to competitive change (Volberda, 2004). One of these is the *resource-based view (RBV)*, attributed to Wernerfelt (1984), who built on the work of Penrose (1959). Penrose (1959) initiated the viewing of firms as a collection of productive resources, which comprise material and human resources. The RBV rests on the idea that a firm sustains competitive advantage by developing and applying its distinctive resources (Hermann, 2005). The *strategic leadership and decision theory* (SLDT) and *knowledge-based view* (KBV) are extensions of RBV (Hoskisson et al., 1999). The SLDT views a firm's leaders (e.g. the CEO and directors) as unique resource and relates their characteristics to organisational performance (Miller & Droge, 1986). The KBV views the firm's stock of knowledge is viewed as a critical resource and capability, and determinant of competitive advantage (Kogut & Zander, 1992), and examines its acquisition, development, exploitation and diffusion (Herrmann, 2005).

As the 1990s witnessed the development of RBV and KBV, it also saw the resurgence of strategic planning and strategy process research. In its revival, strategic planning retained its formality, and its focus on the long-term (Camillus, 1997). However, it became renewed in purpose and structure (Bonn & Christodoulou, 1996; Carter, 1999). Rather than being the direct responsibility of the CEO as suggested by Chandler (1962) and Learned et al., (1969), it is now driven by a strong bottom-up component, which ensures that people important in its execution are part of its formulation (Carter, 1999). Most of planning responsibility has moved from top management to middle management, i.e. to the business unit managers who are charged with its implementation for the purpose of developing business lines (Wilson, 1994; Floyd & Wooldridge, 2000). Evidence of the resurgence of strategic planning (and strategy process research) is found in the emergence of *strategy-as-practice (SaP)* paradigm in the late 1990s, which shifts concern from core competencies of the firm to practical competence of managers and how they act and interact in strategy formulation processes (Whittington, 1996; Johnson et al., 2003).

<u>Emergence of roadmapping in strategic management research</u>

The resurgence of strategic planning explained in the last paragraph coincided with the emergence of roadmapping in strategic management as shown in Figure 2.12. Evidence for this can be drawn from the results of a full-text search of the Science Direct database for the term "roadmapping", (presented as an inset diagram in Figure 2.12), which indicates a trend of increasing popularity of roadmapping in strategic management research since the 1990s[2]. This further lends credence to the renewed (and increasing) importance of strategic planning to firms, and the realisation of the significance of roadmapping to it. The subsequent section explains how roadmapping can be characterised according to models (or theories) of strategic management and planning.

[2] It is important to note that all of the results produced in the search of these databases may not be specific to the form of roadmapping considered in this thesis.

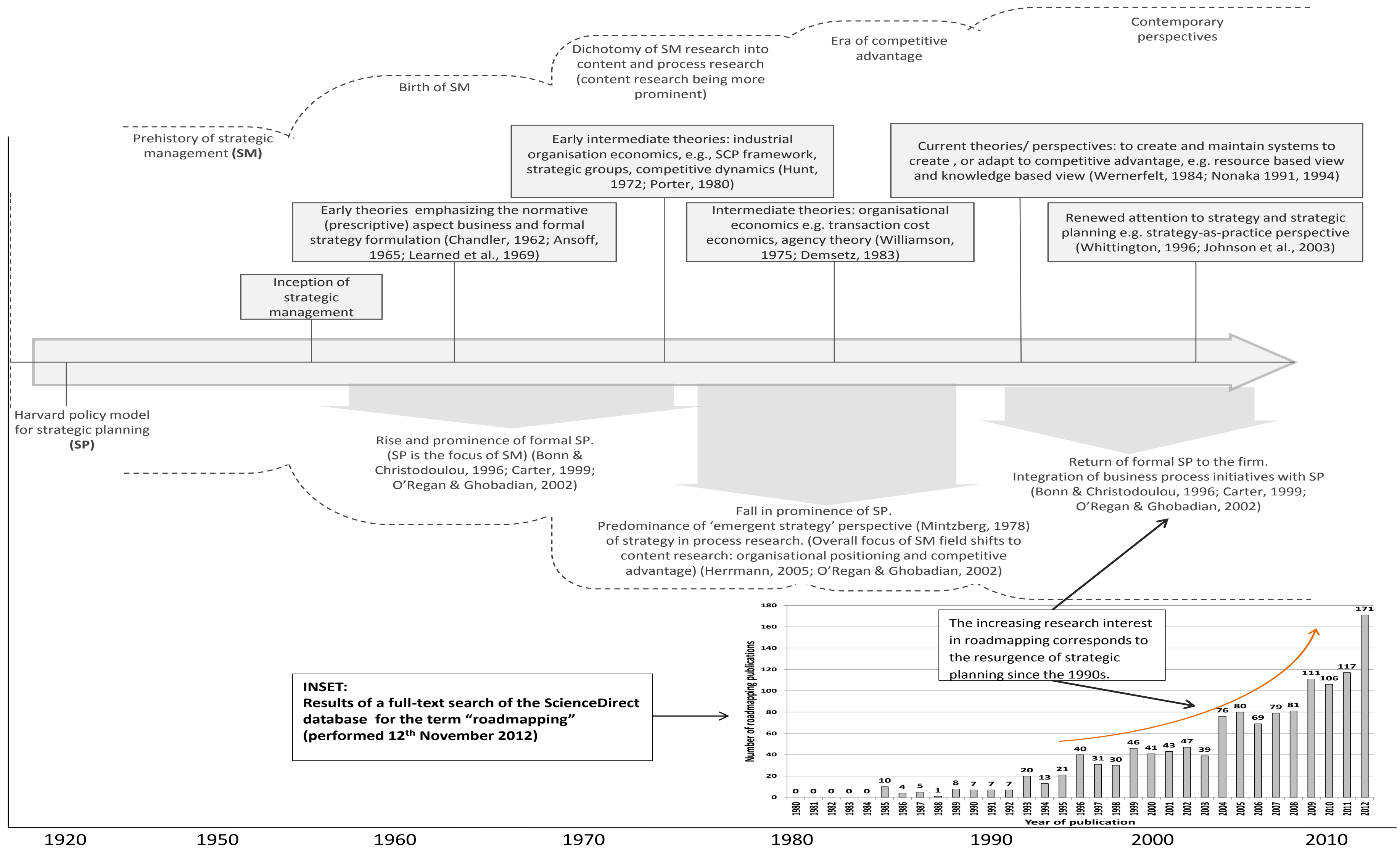

Figure 2.12 - Evolution of strategic management *(SM)*, strategic planning *(SP)* and the emergence of roadmapping (See Appendix 1 for an overview of separate versions of this evolution by different scholars)

2.2.2 Perspectives within strategic planning and strategic management for characterising roadmapping

A. Modes and models of strategy

This section focuses on strategic planning[3] and presents some of the frameworks that describe it. This is to identify frameworks that are relevant to roadmapping.

Strategic planning can be described as the activity of formulating strategy: *"[strategic planning] can be used as a synonym for the formulation (but not the achievement) of corporate [or business] strategy"* (Andrews, 1980 p viii). Ackoff (1970) explains that *"strategic planning is concerned with the formulation of goals and selection of the means by which they are to be attained"* p 4. Mintzberg (1994) describes planning as *"a formalised procedure to produce an articulated result, in form of an integrated system of decisions"* p12. These definitions describe strategic planning as an intentional process of determining goals and outlining the necessary steps to meet them. The steps are outlined with the expectation that they will be implemented, and therefore called intended strategy (Mintzberg, 1978). These descriptions apply to roadmapping, and roadmaps created from the process can be seen as intended strategy (as opposed to emergent strategy) (see Figure 2.13)[4].

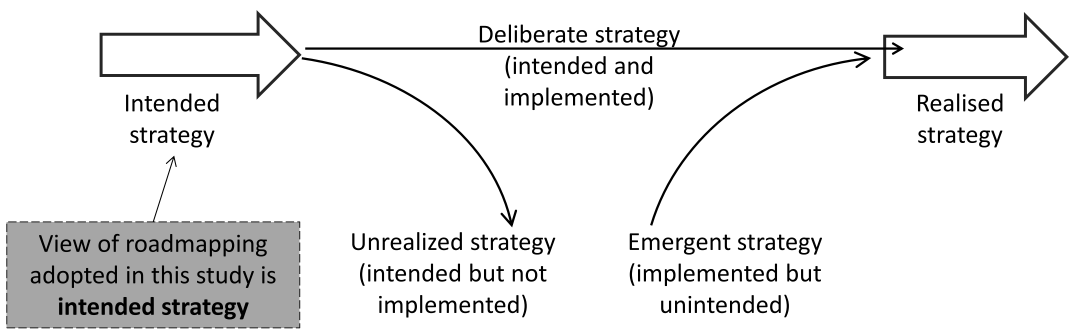

Figure 2.13 - Types of strategies (Mintzberg, 1978) (and the view from which roadmapping is explored in this study)

[3] Other terms used synonymously with strategic planning: strategy (Chandler, 1962), strategic decision-making (Hart, 1992), strategy formulation (Mintzberg, 1978), policy (Thomas, 1984).

[4] This study focuses only on the creation of roadmaps (i.e. the roadmapping process). It does not concern itself with the implementation (and realisation or 'unrealisation') of the created roadmap.

Additionally, Eisenhardt & Zbaracki (1992) identified three dominant models of strategic planning: *rationality and bounded-rationality, politics and power* and *garbage can* models

- Rationality and bounded-rationality: This has also been called the 'synoptic' or 'analytically comprehensive' model by Fredrickson et al. (1984) and it reflects the original concepts of strategy by Chandler (1962), Ansoff (1965) and Learned et al. (1969).The rationality model assumes that objectives are clear at the beginning of the process. To achieve the objectives a set of alternative courses of action or strategies are developed based on organisational information, and from these the optimal alternative is selected for implementation (Eisenhardt & Zbaracki, 1992). It has been recognised, however, that this process can only be boundedly-rational because of decision-makers' cognitive limitations[5], which makes it impossible to be truly comprehensive or exhaustive in identifying all the possible alternatives and subsequently selecting the most optimal. Thus, bounded-rationality has displaced basic rationality as a more realistic model (March, 1994). Nevertheless, bounded-rationality retains the generic phases of problem identification and goal formulation, alternatives generation, and evaluation and selection, proffered by rationality.

- Politics and power: The politics and power model explains that although individuals involved in decision-making share general goals such as the welfare of the firm, they also have conflicting preferences, which may be due to biases or clashes of ambition and interests. The decisions made therefore tend to "follow the desires and subsequent choices of the most powerful people" (Eisenhardt & Zbaracki, 1992, p 23) involved in the process. People engage in noticeable, but often covert actions and tactics such as lobbying and co-optation to enhance their power to influence decisions.

- Garbage can: this model describes decision-making in highly ambiguous settings called organised anarchies, in a complex and unstable world. The ambiguity that surrounds the organisation in this model is as a result of inconsistent and ill-

[5] March (1994) explained that decision-makers face serious limitations in attention, memory, comprehension and communication.

defined preferences of decision-makers, a loose understanding of underlying causes, and so learning is by trial and error, and the make-up of participation in the decision-making process is always changing.

Eisenhardt & Zbaracki (1992) pointed out that strategic planning is best described as a mix of boundedly-rational and political processes. The garbage can model is regarded as being of little relevance to strategic planning, since it was discovered to be less robust than the other two models from an observation of practice. Being an analytical, structured and stepwise process (Bruce & Fine, 2004), roadmapping lends itself to examination through the rationality (or bounded-rationality) model. Figure 2.14 and Table 2.3 together explain how the roadmapping framework combines two models of rational strategy formulation presented by Steiner (1997). Model 1 is supported by the top-down flow of the framework, while Model 2 is supported by the left-right time dimension of the framework.

Model 1		**Model 2**	
A	Develop inputs: Past history, major environmental trends, opportunities and threats, etc.	I	Where are we?
B	Evaluate alternative courses of action and define major objectives, e.g. sales, profits, product development, etc.	II	Where do we want to go?
C	Define major strategies and policies -Markets, products, finance -Employees, prices, technology, etc. Develop medium-range detailed plans and determine needed current decision	III	Can we get there? Which strategies will achieve which aims? What decisions must be made now to get there?

Table 2.3 – Models of rational planning (Steiner, 1997) (refer to Figure 2.14)

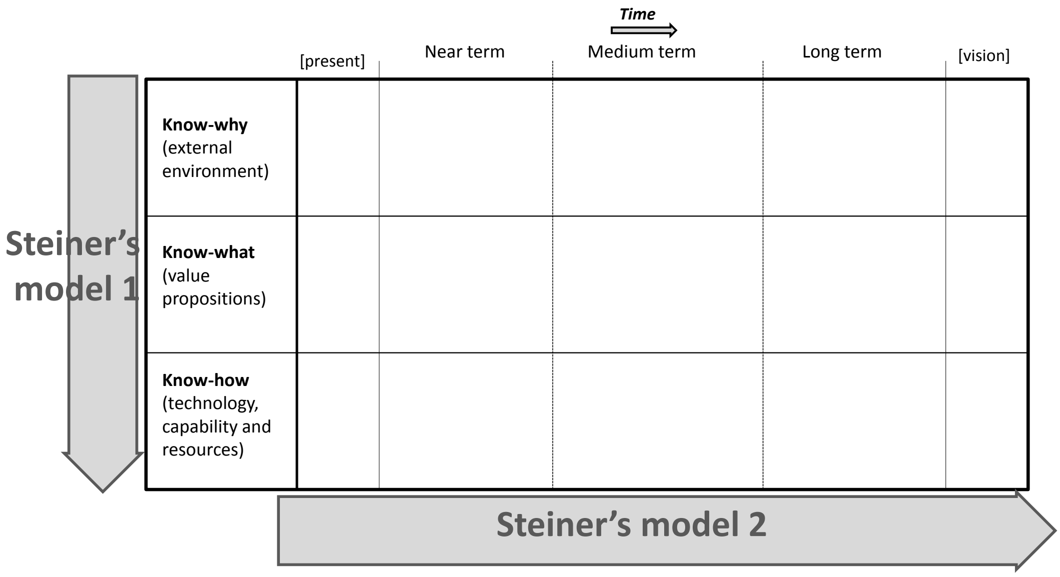

Figure 2.14 – The roadmapping framework combines rational strategic planning models (see Table 2.3)

In addition, since roadmapping is a social and collaborative process (Bruce & Fine, 2004; Kerr, 2012), and roadmapping workshops (which give participants the opportunity to interact and persuade one another into accepting each other's points of view) forms a crucial part of the process, politics and power model can be seen as an applicable model for roadmapping. Thus, in line with Eisenhardt & Zbaracki (1992), a combination of bounded-rationality and the politics and power models would be appropriate perspectives for investigating roadmapping.

The applicability of the rationality (or bounded-rationality) model in different types of organisational environments (e.g. simple, stable, and turbulent (and uncertain) environments) may however be called into question. Hart (1992) explained that the rational model is most suited a stable external environment with a low degree of change, while in a turbulent (dynamic and uncertain) external environment, the generative model (akin to Eisenhardt & Zbaracki's (1992) garbage can model) is more appropriate. However, Floyd (2011) countered this by showing that the rational model of strategic planning can be applied in all environments, whether stable or turbulent. The applicability of rational model in uncertain environments is further buttressed by the understanding that rational planning is typically used in environments in which managers are uncertain about the future (Ansoff, 1991). This makes rationality (or bounded-rationality) an appropriate model for roadmapping regardless of the nature of the environment in which the roadmap is being (or has been) created. It also suggests that roadmapping can be useful in both stable and uncertain environments.

B. The knowledge-based view (KBV) as an appropriate strategic management theory for investigating roadmapping

As explained in Section 2.2.1c, KBV is an extension of the resource-based view (RBV). The KBV views knowledge within the firm as a critical resource and examines its management, i.e. its acquisition, development, accumulation and exploitation (Kogut & Zander, 1992; Herrmann, 2005). Even though KBV is a variant of RBV, the KBV is more aligned with strategy process research while RBV leans towards strategy content research (Hoskisson et al., 1999). The RBV only helps to explain a firm's strategy in hindsight (i.e. to explain firm past activities seen to have had a strategic significance), but the understanding of how strategy (i.e. intended strategy) is built requires the KBV (Nonaka & Toyama, 2007). Also, KBV looks into how specialised knowledge is captured and integrated from different sources to create knowledge for product and service innovation (Eisenhardt & Santos, 2002)[6].

Knowledge can be explicit (expressible in words and numbers and shared in codified forms) or tacit (personal, difficult-to-codify knowledge that is deeply rooted in an individual's actions and experiences) (Polanyi, 1967). It can be transformed between these forms through knowledge conversion modes (Nonaka, 1994) (see Figure 2.15):

- From tacit knowledge to tacit knowledge, through *socialisation*, i.e. interaction between individuals
- From explicit knowledge to explicit knowledge, though *combination*, i.e. the exchange, combination and reconfiguring of existing information between individuals

[6] This applicability of KBV to intended strategy formulation and its relevance to innovation can be extended to roadmapping by virtue of the similarities between roadmapping, strategic planning (or formulation) and innovation. Section 2.2.3 explains the linkage (and similarities) between roadmapping, strategic planning and innovation.

- From tacit knowledge to explicit knowledge through *externalisation,* using metaphors and descriptors
- From explicit knowledge to tacit knowledge through *internalisation* i.e. reflection and action.

Nonaka (1994) further explained that interactions of explicit and tacit knowledge lead to the learning and the enrichment and enlargement of knowledge.

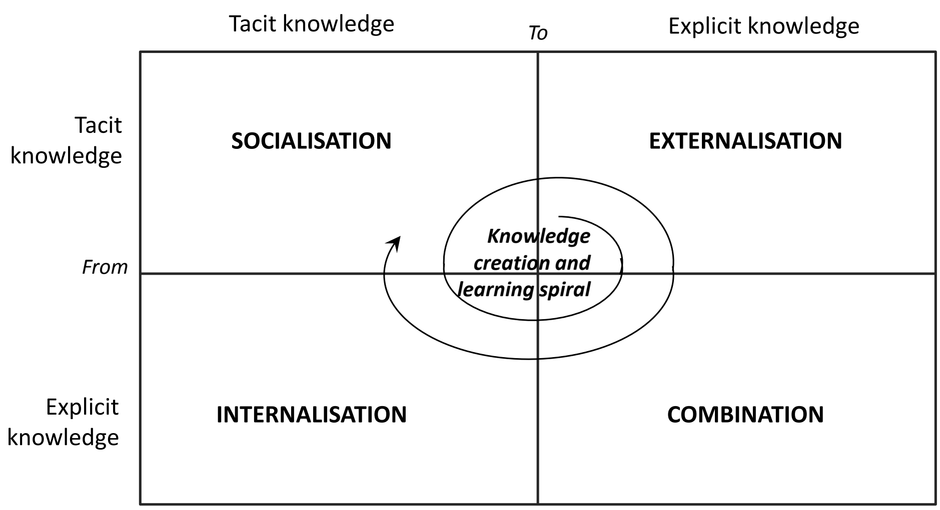

Figure 2.15 – Modes of knowledge conversion and creation (adapted from Nonaka (1994))

It is also important to mention Drew's (1999) classification of business knowledge, which highlights the interaction between knowledge content and knowledge awareness. There are four types of knowledge (Figure 2.16):

- What we know we know: knowledge which is stored, can be accessed and shared
- What we know we don't know: which can prompt further knowledge seeking
- What we don't know we know: which demands uncovering neglected, forgotten or tacit knowledge
- What we don't know we don't know: which may hold greatest threats or opportunities to the organisation

Knowledge content can be understood in terms of whether or not particular knowledge is available or present in the organisation, while knowledge awareness may be associated with the explicitness (or 'tacitness') of the knowledge to the organisation (as shown in Figure 2.16). Drew (1999) pointed out that firms should manage the knowledge types, especially by seeking ways to transform them into explicit and available knowledge.

Knowledge awareness	*Available knowledge*	*Unavailable knowledge*
Explicitness	**What we know we know**	**What we know we don't know**
Tacitness	**What we don't know we know**	**What we don't know we don't know**

Knowledge content

Figure 2.16 – Classification of business knowledge (knowledge portfolio) (adapted from Drew (1999))

According to Li & Kameoka (2003), the knowledge management (and creation) perspective provides a useful approach for examining roadmapping especially when looking to understand and further improve it. The knowledge creation perspective provides an understanding of roadmapping as "purposeful creation of value through the integration of different talents and efforts" (Li & Kameoka, 2003, p 389). Roadmapping has been credited with providing an avenue for capturing knowledge, both explicit and tacit, through the common ground it provides for interaction between decision stakeholders (Petrick & Provance, 2005). It facilitates the combination of explicit information from reports and databases, as well as tacit knowledge held individually by the experts. Tacit knowledge is shared and obtained through the interaction and socialisation that takes place during the workshop process (Strauss et al., 1998). Among other things, the visual aspect of roadmapping facilitates the elicitation and synthesis of knowledge from participants during the process, integrates different perspectives and assists in mutual understanding (Eppler & Platts, 2009). Through this knowledge capture and sharing process, new insight and learning is created for the organisation for the purpose of common anticipation, consensus and commitment to collective action (Phaal et al. 2010). The learning created for the organisation is both tacit (in the form of insight and understanding shared between the participants) and explicit (in form of the knowledge captured in text or visually on the roadmap) (Phaal et al., 2005).

C. Strategy-as-Practice as a perspective for studying roadmapping

The Strategy-as-Practice (SaP) perspective of strategic management provides a compelling and solid basis for studying roadmapping. It is able to encapsulate the boundedly-rational, intended strategy perspective and the knowledge management theory of strategic management described above. Strategy as Practice looks at "what people do in relation to strategy and how this is influenced by, and influences their organizational and institutional context" (Johnson et al., 2007, p. 7). Strategy, in SaP, is not seen as something possessed by organisations, but in terms of the strategic activities carried out by its members. It concerns itself with how managers 'do strategy' and how they act and interact in strategy making (Whittington, 1996; Johnson, et al., 2003). Its focus is on activities that have largely been invisible to strategy research, but have significant consequences for organisations (Johnson, et al., 2003). This focus and application of the SaP perspective becomes particularly relevant in the light of the realisation that the descriptions of what people should do as suggested by prescriptive models of strategy do not always agree with the evidence of what they actually do (Johnson et al, 2003), and that the social and physical features of context in everyday activities shapes how actors interact and perform in strategy creation (Whittington, 1996). Thus SaP refocuses research attention on the actions and interactions of strategy practitioners.

i. SaP framework

The overarching conceptual framework of the linkage of practices, praxis and practitioners proposed by Whittington (2006) provides a coherent approach to the SaP agenda, and finds relevance to this thesis. Each one of these elements of the framework provides an analytical mode of entry into the study of SaP (Jarzabkowski, 2005). These terms are described below, according to the explanations given by Reckwitz (2002) and Whittington (2006). 'Practices' are the routines and behaviours consisting of interconnected elements such as *understanding and the state of knowledge,* and *activities (bodily or mental) and their applications*. These practices can be represented materially (e.g. Gantt charts, strategy templates, etc.), or non-materially in the form of processes (e.g. roadmapping process, brainstorming technique, etc.), thus encompassing tools, procedures, routines and sub-routines. The use of practices is connected to the 'doing' because they provide the cognitive, procedural and physical resources through which multiple actors are able to interact and accomplish a collective activity within a broader praxis. 'Praxis', as used by Whittington (2006), describes collective human action, but also includes the interconnection between the actions of different individuals and groups. Its application in this manner also indicates that a form of praxis may be operationalized at different levels in the organization. *Innovation* is an example of praxis (and a specific example relevant to the focus of this thesis is *front-end innovation (or early stages of innovation)*). 'Practitioners' are the actors who apply and coordinate these practices to act, and their ways of behaving, thinking and acting are consequential on organizational praxis and survival. Jarzabkowski et al (2007) explained, "strategizing occurs at the nexus between praxis, practices and practitioners". Research on strategizing can link all three, but there will be a dominant focus on specific element(s) or linkage(s) between the elements. This thesis examines practices of (and within) roadmapping in the context of its application by practitioners to innovation. This examination will involve the understanding of the practices of practitioners, what processes and tools and methods they use, especially in addressing uncertainty and risk within roadmapping in the context of front-end innovation.

ii. Theoretical perspectives within SaP research

Johnson et al. (2007) identified four theoretical underpinnings for the SaP research. These are: situated learning, institutional theory, actor network theory, and the Carnegie tradition. Situated learning focuses on how people learn in everyday activity, and encourages the understanding of what people actually do in organisations, and how strategy emerges from their behaviours. Institutional theory emphasizes institutional rules or cultural norms in the wider environment that define what and how organisations should be. The actor network theory attempts to understand the kinds of work involved in producing scientific and technical knowledge, the types of people who did it, and the types of skills and tools (and equipment) they use. The Carnegie tradition recognises the lack of perfect rationality in strategy formulation and insists on bounded-rationality as opposed to perfect rationality. Thus it links directly to the bounded-rationality mode of strategic decision making discussed in Section 2.2.2A. This tradition has two streams that are of relevance to research on doing strategy: organisational routines and organisational sensemaking.

1. Organisational routines and strategic episodes

The first stream of work discussed here is 'organisational routines'. Organisational routines may be rules of thumb (Nelson & Winter, 1982) or specific performances in specific times and places (Feldman & Pentland, 2003). Akin to the description of routines as 'specific performances' is the concept of 'strategic episodes', which was introduced into SaP research by Hendry & Seidl (2003). Strategic episodes are sequences of strategic communication or events structured in terms of a beginning and an ending, which is its key characteristic. These episodes can range from being formal to informal in nature, and examples, as mentioned by Hendry & Seidl (2003), include weekly pub lunches, board meetings, annual strategy reviews, awaydays and strategic workshops. Since workshops form an integral part of roadmapping, it is important to consider 'strategic episodes' as a theme to which research on roadmapping can contribute. Hendry & Seidl (2003) provided a framework for the systematic study of episodes, consisting of three crucial aspects:

- Initiation: the setting up of episodes, and how they are decoupled from organisational structures
- Termination: the ways in which they are terminated and what mechanisms are necessary for recoupling their outputs with the organisational structures
- Conduct: the ways in which they are conducted, which focuses on the discourses and the types of reflection carried out in them, as well as the sub-routines developed within the episodes.

Studies of episodes can focus on any of these aspects, and the investigation carried out into roadmapping in this thesis focuses particularly on the conduct of roadmapping, looking specifically at how uncertainty and risk are dealt with (as will be further elaborated in Chapters 4, 5, 6 and 7). The study carried out thus provides the opportunity to contribute to understanding on how routines are actually performed, an issue which Johnson et al. (2007) pointed out as a research challenge in such organisational episodes. Hodgkinson et al. (2006), also pointed out that there is little academic knowledge on strategy workshops, even on basic details such as who gets involved, what ends they serve and the results they produce.

2. Organisational sensemaking

The second theoretical stream under the Carnegie Tradition is organisational sensemaking. Sensemaking simply means "the making of sense" (Weick, 1995, p 4). It is "the activity that enables us to turn the ongoing complexity of the world into a situation that is comprehended explicitly in words and that serves as a springboard into action" (Ancona, 2012, p 4). Thus, sensemaking refers to how we structure the unknown so that we can act within it. It is clear that there are various ways in which sensemaking can be applied, given that humans face complexity and the unknown in diverse ways. It therefore quite broad as a concept, and in fact, as a theoretical perspective, it is able to capture or encompass issues such as strategy, knowledge management, and strategic episodes, which have been discussed in the foregoing. For example, Johnson et al. (2007) explained that sensemaking can raise important questions for strategic planning, and

Gioia & Chittipeddi (1991) explained that a sensemaking perspective on practice could be used to explore the dynamics of strategy at particular times and places (i.e. strategic episodes).

Karl Weick, through his work "Sensemaking in Organisations" (Weick, 1995), provided a theory of organisational sensemaking. The theory discusses the seven properties of sensemaking, which embody the theory. These are: i. Sensemaking is grounded in identity construction, ii. Sensemaking is retrospective, iii. Sensemaking is enactive of sensible environments, iv. Sensemaking is driven by plausibility rather than accuracy, v. Sensemaking is social in nature, vi. Sensemaking is ongoing, vii. Sensemaking is focused on, and by extracted cues. Weick also identified that *ambiguity* and *uncertainty* are occasions that require sensemaking.

<u>a. Properties of sensemaking</u>

The seven properties are related, but each of them poses a self-contained set of research questions, meaning each can be examined individually as the focus of research. Four of these seven properties are considered to be of theoretical relevance for the research conducted in this thesis, and are explained below.

i. Sensemaking is grounded in identity construction:

   According to Weick (1995) the sensemaker's identity or definition of him/herself (or itself, as an organisation) will determine how he/she defines the situation perceived. Weick explained that sensemaking begins with the sensemaker and the need to have a sense of identity. This self-referential nature of sensemaking leads Weick to suggest that it is self, rather than the environment that may be in need of interpretation, and that the ramifications of a situation for any individual or organisation is dictated by the identity adopted by the organisation [toward that situation].

ii. Sensemaking is retrospective:

   Weick (1995) based this on the notion that people can only know what they are doing after they have done it. Sensemaking is based on experience and Weick explains that creation of meaning is a process of giving attention to what has already occurred. Weick ties this retrospective nature of sensemaking to Mintzberg's realised strategy, which relies on observed patterns on past decisional behaviour.

iii. Sensemaking is enactive of sensible environments:

Sensemaking creates a reality in environments in which action can be taken confidently, by enacting constraints and creating rules. The creation of rules and constraints, are in themselves actions taken consciously or unconsciously and these help in understanding and dealing with issues that may arise within the environments created by these rules. One of the examples given by Weick to illustrate this is the action by the USA in 1987 to put American flags on Kuwaiti Ships and surrounding it with US combat ships to deter attacks by Iran. Having American flags on those ships and surrounding them with US combat ships created a 'reality' for the US in which they could legitimately respond militarily to any attack on the Kuwaiti ship.

iv. Sensemaking is driven by plausibility rather than accuracy:

Sensemaking takes a relative approach to truth. Weick explained that sensemaking does not rely on accuracy and does not see it as necessary in offering explanations for complex situations. Reasons such as the limitedness of human cognition, the preference of speed over accuracy in most organisational action, the constantly changing nature of organisational relationships (this making it impossible to accurately tell what is going on at any time), were given by Weick to support this notion. Weick pointed out that instead of accuracy, what is necessary in sensemaking is a good story, an explanation that is coherent and reasonable.

<u>b. Occasions for sensemaking: ambiguity and uncertainty</u>

As presented by Weick (1995), the two occasions for sensemaking common in organisations are ambiguity and uncertainty. It is these occasions that trigger sensemaking. People resort to sensemaking when faced with ambiguity because they are confused by too many interpretations. Multiple plausible interpretations of a situation may result from a lack of clarity, high complexity, or contradictions, therefore, making it difficult to work out the situation in any simple way. Uncertainty is generally described in terms of insufficiency of knowledge necessary for addressing a situation, or the inability to predict something accurately (Milliken, 1987). Under uncertainty, people resort to sensemaking as a result of ignorance, or the inability to precisely foresee the consequences of future actions (Weick, 1995) (uncertainty will be further discussed in Section 2.3.1). Weick explained that there are differences in the nature of sensemaking required under occasions of ambiguity and uncertainty. Under ambiguity, "managers use language to share perceptions among themselves and gradually define or create meaning through discussion, groping, trial and error and sounding out" (Weick, 1995 p 99). Such issues are addressed through subjective opinions because objective data is not available, and where it is, it is unclear which part of it is relevant. Under uncertainty, Weick explained that sensemaking should be directed at collecting more information to combat ignorance. Weick (1995) therefore suggested that care must be taken in dealing with these two situations accordingly.

<u>iii. Relevance of SaP to this research</u>

Given that roadmapping is a strategic episode (i.e. it is an organisational routine), and it is studied within this thesis to examine how uncertainty (an occasion for organisational sensemaking) and risk are addressed within it, both aspects of the Carnegie Tradition theoretical perspective (organisational routines and organisational sensemaking) become relevant. The combination of these theoretical streams is therefore inevitable. The advantage of this combination is that it presents an opportunity to look at sensemaking within the context of a strategic episode within Strategy as Practice. The role of sensemaking in Strategy as Practice research has been generally examined, by authors such as Balogun & Johnson (2005) who examined the socially negotiated nature of sensemaking in strategy, and Stensaker & Falkenberg (2007), who studied the interaction between individual level and organisational level sensemaking. Strategic episodes such as strategy workshops (e.g. Hodgkinson et al (2006), who pointed to the mediums for planned emergence of strategy in strategy formation, and Whittington et al (2006), who examined the mastery of practices and craft skills in them) and strategy meetings (e.g.

Jarzabkowski & Seidl (2008), who examined their role in strategy practice) have been explored. However, the nature of sensemaking has not been explicitly examined within these episodes. Weick (1995), in his own admission, explained that his theory of sensemaking was generalised over various organisational processes and settings, and that it would be useful to know in where his theories hold and where they do not. The focus of this thesis, i.e. the study of the treatment of uncertainty and risk in roadmapping, provides an opportunity to do so.

2.2.3 Roadmapping in the context of strategic planning and front-end innovation

From a strategic planning perspective, the ultimate objective of the firm is to maximise economic return (Ansoff, 1965), to position itself for long term survival (Wind, 1979). To achieve this objective, the firm needs to create value (Goldratt & Cox, 2004). Innovation is a crucial to value creation[7] since value is created through the invention of new things using new methods, technologies, and/or raw materials (Lepak, et al., 2007). Thus, a central purpose of strategic planning is to describe how an organisation intends to create value (as confirmed by Kaplan & Norton (2004)) by innovation of products and services. According to Mintzberg (1990), strategic planning is most useful in periods of 'reconception' (i.e. when there is the need for 'total reassessment' such as when large resource commitments need to be made) and 'initial conception' (i.e. in a new venture, when a clear sense of direction is necessary). In the context of value creation and innovation, periods of 'reconception' and/or initial conception can be attributed to the initial, conceptual (early) stages (or front-end) of product (and service) innovation.

Thus, by being an approach to strategic planning, roadmapping becomes directly appropriate for innovation. While roadmapping is applicable at different stages of the innovation process, it is of particular relevance at the early-stages where innovation opportunities are identified and explored, which requires making decisions that have

[7] This argument is valid whether value creation is viewed from the perspective of the firm's stakeholders (i.e. in terms of profit creation) or customers served by the firm (i.e. in terms of providing them with useful products).

significant strategic and long-term impact on an organisation (Phaal et al., 2008). The link between the processes of roadmapping, strategic planning and innovation's front-end can be further reinforced by examining the processes. As shown in Figure 2.17, the divergence-convergence processes present in roadmapping (Phaal et al., 2008) (shown earlier in Figure 2.11), are found in the generic phases of formal strategic planning (in the form of the generation of strategic alternatives (divergence) and the evaluation and selection from the set of alternatives (convergence)) (see Table 2.4). The divergent-convergent cycle of idea generation (through knowledge exploration) and idea selection, also characterises the early-stages of innovation.

Mintzberg et al., (1976)	**Fredrickson (1984)**	**Schwenk (1984)**	**Nasi (1999)**
Problem identification (decision recognition and diagnosis)	Situation diagnosis	Goal formulation, problem identification	Determine the mission and objectives
Development (search and design)	Alternative generation	Strategic alternatives generation	Analyse the environment
Selection (screen and evaluate)	Alternative evaluation	Evaluation and selection	Analyse and then select the strategic alternatives
Authorisation	Decision integration	Implementation	Implement the strategies

Table 2.4 – Generic steps in rational strategic decision-making according to different scholars

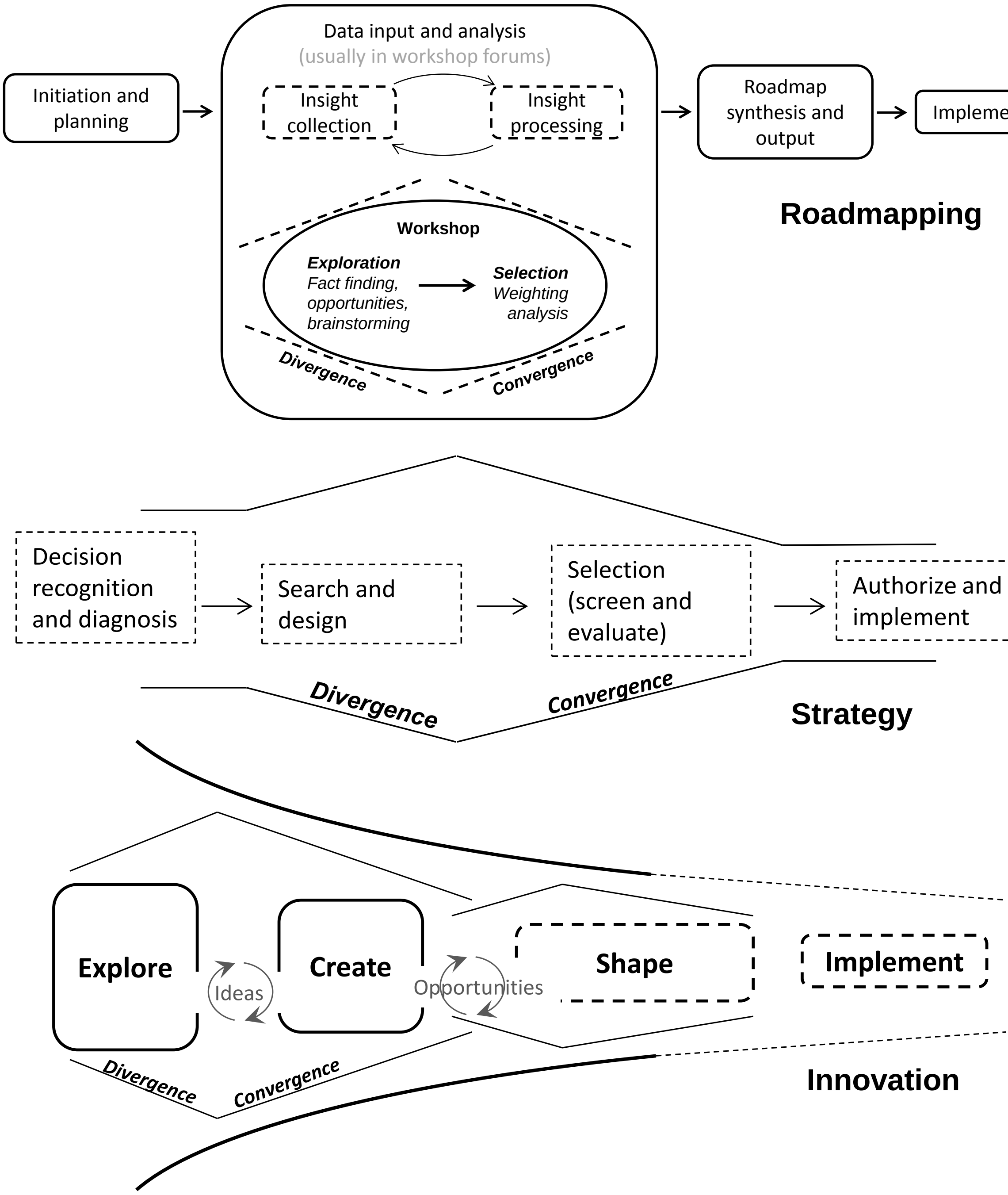

Figure 2.17 – Similarity of divergence and convergence phases shared by roadmapping, strategic decision-making and the front-end of innovation[8], based on Phaal & Muller (2009), Mintzberg et al. (1976), and Phaal et al. (2008) respectively.

[8] The depiction of the front-end of innovation by Phaal et al. (2008) presents a process of exploration and choice of ideas, which form the basis for the exploration and choice of opportunities. This is in agreement with the front-end activities of idea generation, ideas selection, opportunity identification, opportunity analysis and concept definition established by Koen et al.'s (2002).

2.3 Overview of uncertainty and risk

According to Bettis (1982) and Emblemsvag & Kjolstad (2002), most strategic management scholars indicate a distinction between risk and uncertainty, but then go on to disregard it by using the terms interchangeably. It has also been pointed out that there is a lack of consensus on the definition of uncertainty and risk in this field (Ring, 1989; Miller, 1992). Therefore, in strategic management, the relationship between uncertainty and risk is quite ambiguous and open to various interpretations. Nevertheless, it is important to establish a connection between these concepts.

2.3.1 Uncertainty

In simple terms, uncertainty can be described as the inability to predict something accurately due to a lack of necessary information or to distinguish between useful and irrelevant information (Milliken, 1987). According to Weber (2000), there are two categories of usage for the term 'uncertainty' in strategic management: perceived environmental uncertainty and decision-making under uncertainty these are discussed in the following paragraphs.

Environmental uncertainty, as described by Miles & Snow (1978), Milliken (1987) and Courtney et al (1997) refers to the lack of complete knowledge and unpredictability of the environment external to the organisation. Duncan's (1972) description of environmental uncertainty however considers it as the inadequacy of information concerning both the external environment and internal environment of the organisation. Miller (1992) provided a classification of uncertainties into general environment, industry-specific and firm-specific uncertainties, and this reflects a consideration of uncertainty across the boundaries of the organisation. The descriptions of uncertainty as 'incomplete knowledge' and 'unpredictability' bring to the surface two types of uncertainty as pointed out by Merna & Al-Thani (2005) and Meijer et al. (2006). These are:

- Epistemic or knowledge uncertainty, which reflects a lack of knowledge and may be reduced by knowledge creation and learning, and

- Aleatory or variability uncertainty, which arises from pure chance or unpredictability of the organisational environment, and cannot be reduced by seeking additional knowledge.

Both forms of environmental uncertainty relate to the imperfection of human knowledge (Weber, 2000).

The second category, decision-making under uncertainty, concerns choice-making circumstances where information necessary for proper consideration of all the relevant factors associated with a set of decision alternatives is incomplete. It is a result of insufficient knowledge about the alternatives and their consequences, caused by limitations of decision-makers in information gathering and analysis (Simon, 1997).

These categories of uncertainty in strategic management literature (environmental uncertainty and decision uncertainty) are related and no strict demarcation between them should be asserted. For instance, Milliken (1987) identified and linked three manifestations of uncertainty and these bring environmental uncertainty and decision uncertainty together. These are:

- state uncertainty: perceived uncertainty in the organisation's external ***environment***,
- effect uncertainty: uncertainty concerning the effect of the unknown aspects of the external environment on the organisation, and
- response uncertainty: uncertainty surrounding how to make ***decisions*** in reaction to effect uncertainty.

Uncertainty can also be said to abound in different levels of severity or seriousness, and perceived accordingly. Courtney et al. (1997) pointed out different levels of uncertainty especially in the context of strategic planning and the clarity of the future as perceived by planners or decision-makers (Figure 2.18):

- Level one : a clear enough future, in which precise, reasonable predictions can be made,
- Level two: alternate futures in which there are a few distinctive ways in which the future might evolve, each of which is more difficult to predict than in level one,

- Level three: a range of futures in which there is a range (a non-discrete number) of ways the future might evolve, and
- Level four: true ambiguity, in which even a range of ways in which the future might is unidentifiable and there exists no basis on which the future may be predicted.

While the level one uncertainty poses no real challenge, specific tools are required for managing the other levels of uncertainty. Level four uncertainty is quite rare and would quickly adjust towards level three unceratinty. Therefore, the mid-levels appear to be encountered more often in reality and therefore, are probably of greater interest to decision-makers.

The definition for uncertainty, based on Galbraith (1973) and Rowe (1977), is adopted for this study, since it encapsulates the various views above. *Uncertainty is the insufficiency or imperfection of the acquisition and application of knowledge critical to decision-making, concerning the past, present, or future events, or conditions within and surrounding an organisation.*

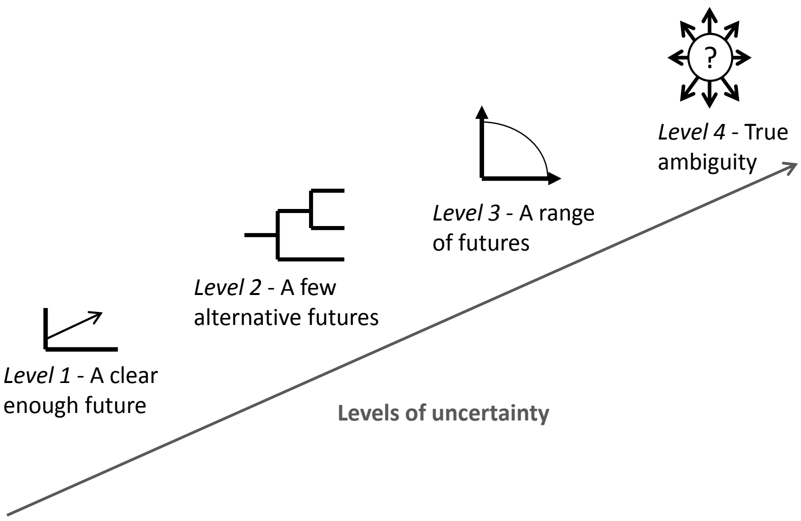

Figure 2.18 - Four levels of uncertainty (Courtney et al., 1997)

2.3.2 Risk

The word "risk" derives from the Latin word 'riscum', which denotes the danger created by a barrier reef to a sailor (Merna & Al-Thani, 2005)[9]. Baird and Thomas (1990) found several applications of the term 'risk' in strategic management. These include variability of returns, size and nature of outcomes, probability of loss, failure to attain targets, ruin and lack of information.

As it is in contemporary definitions, early definitions of risk (in economics and finance) included the element of (or were linked to) uncertainty. For example, Willet (1901) defined risk as "the objectified uncertainty regarding the occurrence of an undesirable event" (cited from Rowe (1977)). Knight (1921) defined risk by contrasting it with his understanding of uncertainty. According to Knight (1921), risk is a state of measurable uncertainty, wherein possible outcomes of events and their respective probabilities of occurrence are known or are measurable, while uncertainty exists if the probabilities are unknown or 'unmeasureable'. Even though Knight's definition became widely adopted by economists (Langlois & Cosgel, 1993), it has not been met with widespread acceptance in strategic management. Scholars concerned with organisational issues adopt definitions that are significantly different from Knight's, which are considered not to fit into the context in which managers make strategic decisions (March & Shapira, 1987; Bromiley et al., 2001). Managers conceptualise risks in terms of potential losses (Baird & Thomas, 1990), and therefore, their definitions are perhaps more inclined with Willet's.

Strategic management researchers have used the term 'risk' to mean "unpredictability or downside unpredictability of business outcome variables such as revenues, costs, profit, market share" p 261 (Bromiley et al., 2001). These descriptions of "downside unpredictability" and "unpredictability" point out two ways of approaching risk. The first relates to the possibility of the occurrence of an event with only negative consequences (e.g. Rowe, 1977; Rescher, 1983), and the other relates to the possibility of the occurrence of an event which could have both positive and negative consequences (e.g. March & Shapira, 1987; Damodaran, 2012). This second approach relates to the technical (financial or mathematical) definition of risk which explains that risk is related to both the

[9] Bernstein (1998) traces the origin of the word risk to the early Italian (or Latin?) word 'risicare' which means 'to dare'.

range of possible events and the chance of their occurrence, without a restriction on the nature of the events (i.e. whether positive or negative). Wickham (2008) explained that the technical (or formal) interpretation of risk can be traced back to the idea of what was fair in gambling (as indicated by Bernstein (1998)); that a fair price for a gamble (the risk) was the amount that might be won (the outcome or reward) multiplied by the chance of winning that amount (probability of outcome).

2.3.3 Risk in the context of strategic management research

The theoretical perspectives for risk in strategic management literature are often borrowed from economics, finance and psychology. Bromiley et al. (2001) indicate that Bowman's (1980) study, which has its theoretical underpinnings in finance and economics, is widely regarded as the starting point for risk research within strategic management. He discovered the *risk-return paradox*. The risk-return paradox goes against the norms of financial theory to show that organisations tended to experience higher rewards (or performance) under conditions of lower risk[10].

A great proportion of risk research in strategic management that followed Bowman's (1980) work has been largely focused on explaining the risk-return paradox and understanding organisations' strategic 'risk-taking' (i.e. strategic choice) behaviours and their linkage to firm performance (Bowman, 1980; MacCrimmon & Wehrung, 1986; Shapira, 1994). As pointed out by Bromiley et al. (2001), two main theories have been applied in strategic management to explain strategic risk-taking: behavioural theory and prospect theory. Kahneman & Tversky's (1979) prospect theory explains that people assess a risk situation relative to a reference point (their current wealth level), and avoid risk above the reference point, while they seek risk below it. In the light of strategic risk-taking, the prospect theory argues that low performing firms will seek risk and high performing firms will avoid risk. Cyert & March's (1963) behavioural theory explains that if a firm's performance exceeds aspirations (which is determined either by comparison to its past performance or to average performance across industry), the firm continues to

[10] Economic rationality in financial theory suggested that higher-risk project or investment will require a higher expected return or it will not be undertaken (Bowman, 1980).

operate as it was, but searches for ways to improve if its performance is lower than aspirations. Therefore, risk-taking increases as firms drop below industry average performance, and if the firm is above industry average, then its risk-taking would depend on the firm's performance relative to its recent past performance. Bromiley et al (2001) point out that prospect theory may not be appropriate for explaining firms' behaviours, as it originally emerged from the study of individual behaviours. They also recognise that the behavioural theory lends itself more to incremental changes in firm strategy rather than major shift or reconceptualisation of strategy (i.e. in situations of strategic planning) and does not predict the types or directions of strategies that firms can/will adopt. Therefore, these theories do not directly apply to strategic planning activities such as roadmapping.

However, from the psychology perspective, there has also been research that more directly examines attitudes and behaviours of managers and decision-makers when they are confronted with uncertainty and risk in complex decision situations. From this line of research, it has been observed that decision-makers apply heuristics and rules subjectively in decision situations, and the biases that emanate from them can affect the optimality of decisions made (Tversky & Kahneman, 1974; Barnes, 1984; Schwenk, 1984).

2.3.4 Risk and risk management in the context of roadmapping

There is a need to provide an explanation of risk in a way that relates meaningfully to the handling of strategic problems (Baird & Thomas, 1985), so that it is relevant for the setting of this study, i.e. roadmapping, and its application in the wider context of strategic planning.

Measurements of risk that have been used in strategic management research (to understand the risk-reward relationship in organisations - highlighted in Section 2.3.3) are *ex post* financial measurements of risk and performance (e.g. the variance and the average of return on equity (ROE) (Bromiley et al., 2001; Wickham, 2008)). These measures may be considered as objective since they are ex post in nature (i.e. based on observable facts). However, risks surrounding strategic issues that concern the future cannot be objectively measured or estimated. Emblemsvag & Kjolstad (2002) pointed out that strategic issues basically exist in a state of uncertainty and from this, strategic risks can emerge. They explain that strategic risks are fuzzy and difficult to assign probabilities to because the possible outcomes are not all knowable. Wickham (2008) explained that in contrast to the use of financial measures of risk in many strategic discussions, strategists think about risk in its common sense format (more about losses), described in ways that may be weakly related to numerical (or monetary) measures. Strategists' concerns go beyond money to things of non-monetary value (e.g. reputation). Thus, in the context of strategic planning (and roadmapping), in which the information applied concerns the future for which objective data or measures are not available, risk becomes subjective, and any risk-associated estimation would be dependent on the strategist's perception. Also, risk needs to be perceived and understood in the context of the issue being considered, the sources of risk pertaining to the issue (Miller, 1992) and the range of choices available within the context (Clementson, 1988).

Thus, this study takes on the strategist's view of risk as the concept of loss of value to the firm (which may not directly be monetary) associated with the presence of uncertainty (Baird & Thomas, 1990; Bromiley et al., 2001; Forlani & Mullins, 2000; March & Shapira, 1987). This is in line with the ISO 31000 (international standard for risk management) definition of risk as "the effect of uncertainty on a firm's objectives" (ISO, 2009) which is also adopted here. A firm's objectives are the creation of value and profitability (as pointed out in Section 2.2.3) and so this definition portrays risk as a derivative of the linkage between uncertainty and value creation in the firm. However, one must also consider the other aspects of subjectivity and context highlighted in the preceding paragraph. Together, as shown in Figure 2.19, these four issues have an influence on the concept of risk in roadmapping: uncertainty, impact of uncertainty (on value creation), subjectivity (of the people involved in the planning process) and the strategic context (innovation).

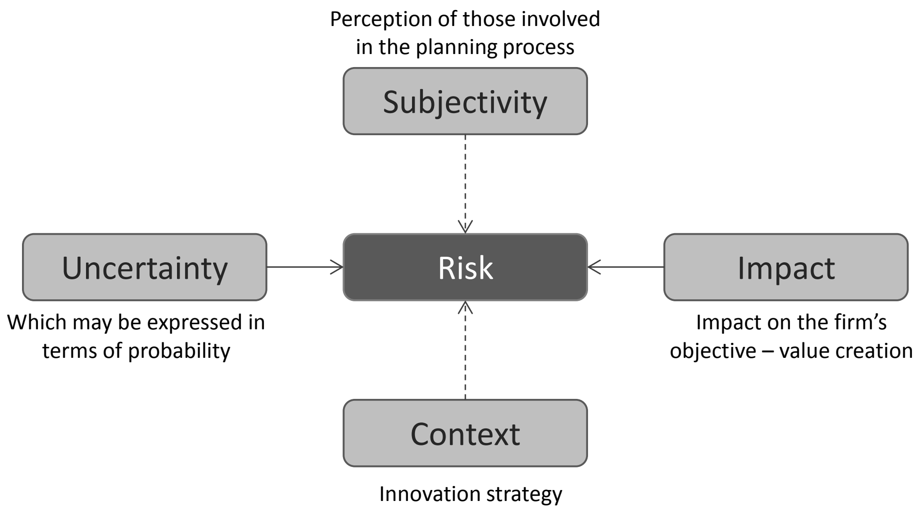

Figure 2.19 - Issues influencing risk in the context of roadmapping

Risk management provides a means of addressing risk – to reduce the likelihood of occurrence and to mitigate its effects if possible. There is consensus that risk management involves assessing (identifying, assessing and evaluating), treating (responding to) and monitoring risks (as shown in Table 2.5). However, the process applied in this study (Figure 2.20) is the one presented by the ISO 31000 (ISO, 2009). It includes a preliminary step – *establishing the context* – which serves as a planning step which other processes do not consider. In this step, the specific focus and scope of the process are clarified, and the external and internal environment contexts of the organisation are taken into consideration for the process.

It should be recognised that fundamentally, risk management should provide a logical and systematic means of dealing with uncertainty (Fowler, 2006). This understanding recognises the basic link between uncertainty and risk, and suggests that to manage risk, one must start by examining uncertainty. This is in accordance with Rowe (1977), that to have an understanding of risk, one must begin with a consideration of uncertainty and how it affects the firm in terms of value loss.

Author	Risk management process				
Rowe (1977)	Risk identification	Risk estimation	Risk evaluation (and response)		
IRM, AIRMIC, ALARM (2002)	Risk identification and description	Risk estimation	Risk evaluation	Risk treatment	Risk reporting and monitoring
PMBOK (2004)	Risk identification	Risk analysis		Risk response planning	Risk monitoring and control

Table 2.5 – Risk management processes

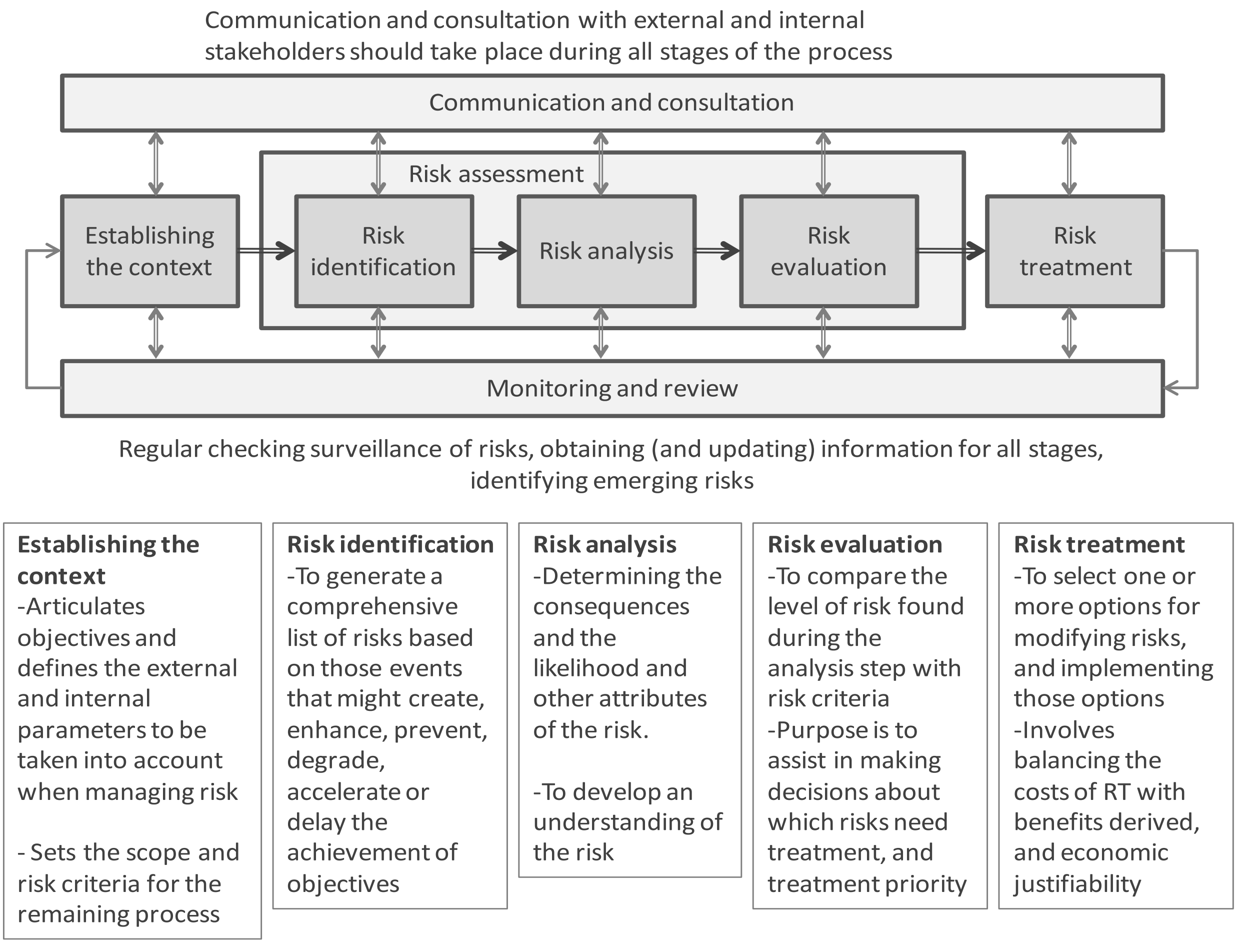

Figure 2.20 – The ISO 31000 risk management process (ISO, 2009)

2.4 Risk management in strategic planning, innovation and roadmapping

There is recognition that uncertainty is fundamental to strategic planning and decision-making (March, 1994; Weber, 2000). Yet, as pointed out by Noy & Ellis (2003), only limited attention has been given to the assessment and management of risk in strategic planning. Wickham (2008) explained that risk has been neglected in most of formal strategic thinking. From the perspective of practice, Funston & Ruprecht (2007) explained that individuals responsible for strategic planning in many organisations do not have an integrated view of risk in their planning exercises even though they admit it is a crucial part of strategy. They pointed out that many organisations, in formulating their strategy, traditionally treat failure as a taboo topic, and therefore shun the acknowledgement and understanding of risks that pertain to them. This is particularly crucial for innovative organisations since innovation is fundamentally uncertain (Emblemsvag & Bras, 2000), and this puts the strategic planning objective of value creation at risk.

Emblemsvag & Kjolstad (2002) presented a strategic risk analysis approach for decision situations at the strategic level using the SWOT framework suggested by Learned et al. (1969). These situations are not specifically strategic planning routines or directly related to innovation. However, the study highlighted and attempted to address the growing concern that risk management is being left out of strategizing. Also, efforts to integrate risk management into the innovation process have been largely limited to the management of projects at the latter stages of the innovation value chain, i.e. after innovation ideas have been turned into projects or become 'projectised' (as can be seen in Chapman & Ward, 2003; Cooper, 2001; Goffin & Mitchell, 2005). The management of risk at the front-end of innovation has not received such attention (Uher & Toakley, 1999; Euchner, 2011). This is despite the recognised difficulty associated with innovation and the uncertainties and inherent risks surrounding it (Euchner, 2011). This lack of attention to front-end innovation is not surprising since activities there bear strong similarities to the strategic planning process (as explained in Section 2.2.3 and shown in Figure 2.17). It therefore becomes clear, as identified by Noy & Ellis (2003) and Bromiley et al. (2001) and Euchner (2011), that there is the need to understand the mechanisms of risk management and how to respond to different kinds of uncertainties in early-stage of innovation and broader strategic planning.

Similarly, it is recognised that in roadmapping, uncertainties and risks associated with the issue under consideration should be identified, resolved and communicated (EIRMA, 1997; Bruce & Fine, 2004; Petrick & Provance, 2005). There is however a lack of practical guidance on how to carry this out in roadmapping literature. Available roadmapping guides, which detail steps to follow (some of which have been summarised in Table 2.2), do not provide clear (or practical) direction on how to address uncertainty and risk, or explain the ways in which they are manifested in roadmapping. Consideration of uncertainty and risk in roadmapping literature is also limited. Albright & Kappel (2003) presented an example of a risk roadmap "used to identify major 'risk events' for monitoring during execution of the roadmap" (p 38), but there is no explanation of the issues that should be considered in the practice of creating one. There have also been attempts to show how roadmapping may be enhanced for use under situations of uncertainty by combining it with techniques such as scenario planning and options thinking (Lizaso & Reger, 2004; Strauss & Radnor, 2004; Ilevbare et al., 2010). Again, these offer no or insufficient practical guidance. They show limited (or no) consideration of how uncertainty manifests itself within the roadmapping process, and what relevant practical concerns to consider in creating processes that are useful and widely applicable.

The absence of roadmapping guidance can be demonstrated by the identified lack of attention to uncertainty and risk across the majority of published roadmaps. As part of this study, 650 published roadmap reports available in the public-domain (Phaal, 2011) were examined[11]. As shown in Table 2.6, 64 of them acknowledged the presence of uncertainty and (or) risk, but only 22 (3.4%) took some measures to address the uncertainties and risks acknowledged. In addition, the communication of risk and uncertainty in roadmap visuals has been found to be generally lacking. From a sample of 369 roadmap visuals, uncertainties and risks surrounding the respective objectives and targets were presented on the visual in only 14 (3.8%). It was also noted that in contrast to the structured, common approach of roadmapping shared by many of the reports,

[11] Details of how this study was carried out are presented in Chapter 3 (methodology chapter) of this thesis.

there was no common or comprehensive approach for addressing uncertainty and risk issues faced or for visualising them on the roadmap. The lack of common guidance or understanding for addressing uncertainty and risk in roadmapping is therefore clear.

Exploration of roadmap documents		
Number of publications examined	650	
Number that took risk management-related measures to address the uncertainties or risks	22	3.4%
Exploration of roadmap visuals		
Number of visuals examined	369	
Number that showed risk and uncertainty explicitly	14	3.8%

Table 2.6 - Results from the exploration of roadmaps and their visuals, depicting the general lack of explicit attention to the consideration of risk and uncertainty within roadmapping

2.4.1 Summary of the research problem

There is an awareness that roadmapping should deliver as part of its benefits, the identification, resolution and communication of uncertainties and risks surrounding the strategic issue it focuses on (EIRMA, 1997; Bruce & Fine, 2004; Petrick & Provance, 2005). However there is no practical guidance on how this can be achieved or a conceptual understanding from literature of what the mechanisms of uncertainty and risk are for roadmapping. This concern is also pertinent to strategic planning and front-end (or early-stage) innovation routines, which share strong similarities with roadmapping. Given the fundamental nature of risk and uncertainty to strategy and innovation (which are the focus of roadmapping) it is important that these issues are addressed.

2.4.2 Research aims and approach

The aims of the research (which will be addressed in subsequent chapters of this thesis) can therefore be outlined as follows:

- To develop a framework that considers the implications of uncertainty and risk for roadmapping and captures the relevant factors that should be considered if uncertainty and risk are to be appropriately addressed in roadmapping in its application to strategic early-stage innovation planning,

- To propose a process that incorporates (and trades off) the factors (and their implications) identified from the framework, and
- To develop and refine the framework and process based on the views of roadmapping experts and test them for robustness using in-company case studies.

These aims are to be achieved in the context or roadmapping's application to early-stage innovation and would rely on a combination of relevant literature and empirical research. It is important that the fundamental ways in which uncertainty manifests itself in roadmapping are understood to address risk within it, since risk management should provide a logical and systematic means of dealing with uncertainty. As there are no known theoretical linkages between uncertainty (and risk) and roadmapping, perspectives used from literature are drawn from the overlap between risk literature and strategy and innovation. This overlaps (to be discussed in Chapter 4) are used to develop a conceptual view, which is then strengthened through empirical research.

2.5 Summary

This chapter has given an overview of roadmapping and uncertainty and risk, and positioned these within the contexts of strategy and innovation. It has also identified a gap in knowledge, concerning how uncertainty and risk are addressed in roadmapping, both in theory and practice. An insight into the proposed approach to bridging this knowledge gap through research has also been given. This approach will be discussed in greater detail in the following research methodology chapter.

Chapter 3 – RESEARCH METHODOLOGY

This chapter describes the methodology followed in the research carried out to bridge the gap in theory and practice identified in Chapter 2. It establishes the study's philosophical positioning (Section 3.1), selects an appropriate methodology (Section 3.2) and describes the research design (Section 3.3). Section 3.4 presents the research design considerations while Section 3.5 summarises the chapter.

3.1 Philosophical positioning of the research

The consideration and understanding of philosophical positions in management research is useful because it clarifies research design and methods appropriate for a study (Easterby-Smith et al., 2008). Philosophical issues concern the assumptions made regarding the nature of reality (in terms of accepted truths and facts - i.e. the ontology) and the appropriate way to inquire into that 'reality' to build knowledge (i.e. epistemology).

The two traditional philosophical positions in management research are positivism and [social] constructionism (or constructivism) (Easterby-Smith, et al., 2008; Gill & Johnson, 2010). Under positivism, reality is seen to exist externally in an objective sense, and accessible or understandable only through objective observation. Constructionism is based on the view that reality is not objective but that it is determined (or constructed) by people, and that the discovery of knowledge is dependent on the view (or interpretation) of the researcher (Bryman, 2001; Easterby-Smith, et al., 2008). Closely linked to these philosophical positions are two broad research traditions: quantitative research and qualitative research. These are associated with positivism and constructionism respectively (Cooper & Schindler, 2011; Robson, 2002), which are, in turn, related to the overarching research intentions of theory testing and theory building respectively (Bryman, 2001; Gill & Johnson, 2011).

A constructionist, qualitative approach, was followed in meeting the aims of this research. Constructionism is appropriate for research, as in this study, which concerns a relatively new area of investigation (Cooper & Schindler, 2011) and seeks to identify and understand the variables and their interacting mechanisms (Creswell, 2007). Also, a qualitative approach is highly appropriate for studying processes (in this case, the roadmapping process), which require detailed descriptions captured from people who have experienced it (Patton, 2002). This study was carried out to provide an understanding based on the reflection on experiences of roadmapping practice (in addition to insight from literature), formulating categories of observed issues, to produce explanations that extend (i.e. build) roadmapping theory.

3.2 Choice of research methodology and approach

Robson (2002) pointed out three methodologies for qualitative research: case studies, ethnography and grounded theory. In addition to these, there are narrative research and phenomenology as identified by Creswell (2007). These traditional five approaches are each explained in Table 3.1.

Characteristics	**Narrative research**	**Phenomenology**	**Grounded theory**	**Ethnography**	**Case study**
Focus	Exploring the life of an individual	Understanding the essence of the experience	Developing a theory grounded in data from the field	Describing and interpreting a culture-sharing group	Developing an in-depth description and analysis of a case or multiple cases
Type of problem best suited for design	Needing to tell stories of individual experiences	Needing to describe the essence of a lived phenomenon	Grounding a theory in the views of participants	Describing and interpreting the shared patterns of culture of a group	Providing an in-depth understanding of a case or cases
Data collection forms	Using primarily interviews and documents	Using primarily interviews with individuals, although documents, observations, and art may also be considered	Using primarily interviews with 20-60 individuals	Using primarily observations and interviews, but perhaps collecting other sources during extended time in field	Using multiple sources, such as interviews, observations, documents, artefacts

Table 3.1 - Contrasting the characteristics of the five approaches to qualitative research (abridged from Creswell (2007))

In preference to selecting and meticulously following one of the traditions highlighted in Table 3.1, the study here aligned itself with the view that the purpose of the research should be the primary consideration in deciding on a research approach (Patton, 2002). In addition, the research design must be pragmatic and developed with consideration of any imposed time constraints, and the opportunities and resources available for the research (Robson, 2002).

It was therefore important to revisit the research aims and purpose (outlined at the end of Chapter 2), to identify appropriate research approaches.

These are as follows:

- To develop a framework that captures factors relevant to the manifestations and mechanisms of uncertainty and risk in roadmapping, their implications, and how to respond to them in the context of strategic early-stage innovation planning.
- To propose a process that incorporates (and trades off) the factors and their implications identified from the framework and explicitly addresses uncertainty and risk in roadmapping
- To develop and refine the process (and framework) based on the views of roadmapping experts and test it for robustness using in-company case studies.

To meet these aims, the study was carried out in two phases, each phase answering one of the questions:

- How is uncertainty and risk manifested in roadmapping within the context of its application to strategic early-stage innovation planning, and what are their implications for roadmapping practice?
- How might roadmapping be carried out to incorporate explicit consideration of uncertainty and risk?

The first phase was designed to seek an understanding of uncertainty and risk in the roadmapping process, a method widely used in practice for innovation and strategic planning. By so doing, it would provide insight into an important problem of the general lack of attention to addressing uncertainty and risk in roadmapping practice. The second phase was to propose and refine a roadmapping process that explicitly addresses uncertainty and risk within itself, and thereby providing a solution to the identified problem.

Following the descriptions of categories of types of research by Patton (2002) (see Table 3.2), the first stage can be classified as applied research, as it was exploratory in nature and sought to provide understanding concerning the practical issue of uncertainty and risk in roadmapping. The second phase was built on the understanding developed in the first stage, and provided a practical solution, and therefore can be classified as action research.

Types of research	**Purpose**	**Focus**	**Desired results**
Basic research	Knowledge as an end it itself; discover truth	Questions deemed important by one's discipline or personal intellectual interest	Contribution to theory
Applied research	Understand the nature and sources of societal problems	Questions deemed important by society	Contributions to theories that can be used to formulate problem-solving programs and interventions
Summative evaluation	Determine effectiveness of human interventions and actions (programs, policies, personnel, products)	Goals of the intervention	Judgements and generalisations about effective types of interventions and the conditions under which those efforts are effective
Formative evaluation	Improve an intervention: a program, policy, organisation, or product	Strengths and weaknesses of the specific program, policy, product, or personnel being studied	Recommendations for improvements
Action research	Solve problems in a program, organisation or community	Organisation and community problems	Immediate action; solving problems as quickly as possible

Table 3.2 - Research categories and purposes (abridged from Patton, 2002)

It is important (and logical) to apply research techniques that help the achievement of research aims (as identified) and address the focus of the research (which in this case, is roadmapping) (Patton, 2002). Roadmapping is a form of strategic decision-making and according to Nutt (2001) strategic decision-making can be researched retrospectively or prospectively. In the retrospective approach, past examples of decisions that display the characteristics of interest (which for this study is roadmapping for strategic planning and early-stage innovation planning) can be examined. In the prospective approach, new process ideas are trialled and their results reported. Both approaches are applied in this study sequentially. The retrospective approach was applied in the first phase of the study (i.e. the applied research aspect), while the prospective approach was used in the second phase (which corresponds to (and confirms) the use of action research). The following section describes the research design in detail, covering both phases of the research, and outlining and justifying the choice research methods.

3.3 Research design

As identified in the previous section (and illustrated by Figure 3.1), this study was carried out in two phases. These are discussed in detail in the subsequent paragraphs, along with the research methods and techniques applied, chosen from the several approaches adaptable for qualitative research as identified by Cooper & Schindler (2011)[12].

[12] Cooper & Schindler (2011) point out some of the several approaches available for qualitative research: individual depth interviews, participant observation, filming and photography, projective techniques, case studies, ethnography, elite or expert interviewing, document analysis, proxemics/kinesics.

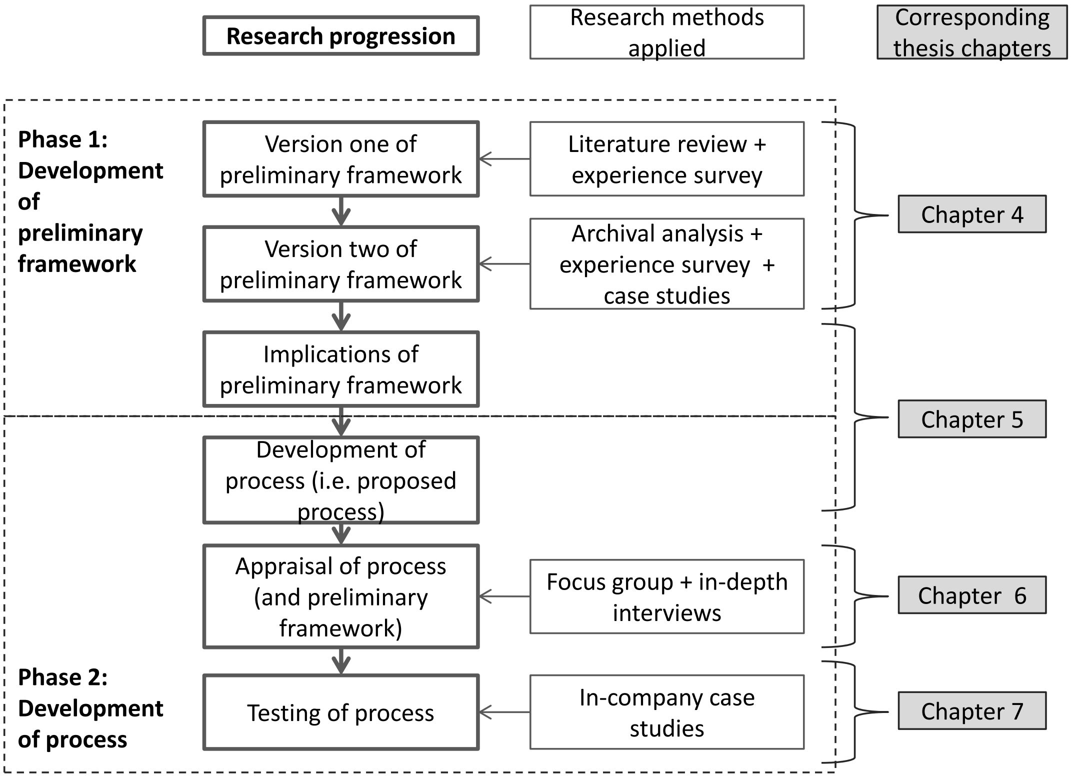

Figure 3.1 – Overall research design showing the two phases of the study

3.3.1 Phase 1: development of preliminary framework

The development of a preliminary framework in Phase 1 of the research was to answer the question:

"How is uncertainty and risk manifested in the roadmapping process within the context of early-stage innovation and strategic planning, and what are their implications for roadmapping practice?"

This question, since it concerns roadmapping - a decision-making process, can be answered by following a retrospective approach. Retrospective studies can involve case studies of the type of decision processes under study, having discussions with the author (or manager) and other key participants in the decision process, and real-time observations of decision-making events and activities (Nutt, 2001; Van de Ven, 1992). Other qualitative techniques applicable for this type of research are experience surveys and archival (or documentary) analysis (Cooper & Schindler, 2011). These techniques, i.e.

archival analysis, experience surveys and case studies, were combined (including literature review) in this phase of the study. These are explained briefly and then followed by a fuller description of the research carried out:

- Archival analysis: this is the evaluation of historical or contemporary confidential or public records and government documents, both to decide what needs to be done, and serve as an important source of data (Cooper & Schindler, 2011).
- Experience surveys: this involves seeking information from persons experienced in the area of study to seek ideas about important issues. It involves tapping into their memories and experiences to provide special insight (Cooper & Schindler, 2011).
- Case studies: these can illuminate a decision or set of decisions. They help to identify why and how they were taken and illustrate or explain the decision process as well as underlying procedures and motivations (Remenyi et al, 1998).

A. Stages of research within Phase 1

Literature review

Literature review linking roadmapping, uncertainty and risk (in Chapter 2) helped in identifying the gaps in existing theory and practice of roadmapping (and the treatment of uncertainty and risk within it). Further to the identification of research gaps, additional literature review was carried out (early in Chapter 4) to identify and understand key factors that might introduce and influence uncertainty- and risk-related issues in roadmapping. These factors were captured and grouped into categories, and depicted in the conceptual version of the preliminary framework. The framework was thereafter modified based on the findings from the archival analysis, experience surveys (i.e. interviews with roadmapping practitioners) and retrospective cases studies of specific roadmapping exercises.

Archival analysis

In the archival analysis, 650 publicly available roadmapping reports (referred to, in this thesis, as the corpus of roadmapping documents), published between 1994 and 2010 were examined. The corpus of roadmaps had been archived by Phaal (2011). The data obtained served two main purposes. It reinforced the knowledge gap identified from the literature review, by showing that a great percentage of roadmapping activities pay little or no attention to uncertainty within their processes (as shown in Section 2.4). The few documents that addressed uncertainty and risk explicitly were identified through the archival analysis and used to provide valuable insight in terms of the practical measures that could be followed in addressing uncertainty and risk in roadmapping.

Experience surveys

Experience surveys were used in two stages. The first stage provided a confirmation of the relevance of the study, and an expansion of the conceptual framework developed from literature. Several roadmapping practitioners were approached and six of them, affiliated with the Institute for Manufacturing, University of Cambridge, UK (IfM), expressed interest in the study and were interviewed to explore the research ideas. The interviews were semi-structured in format, covering issues relevant to uncertainty and risk in roadmapping, and also providing the flexibility in discussion which allowed the practitioners to share and reflect on personal experience to illustrate the insight they provided. The interviews lasted up to 60 minutes.

In the second stage, a wider range of roadmapping practitioners were approached. Five responded: three from the US, one from Thailand and one from the UK. These practitioners, known to be at the forefront of roadmapping research and practice, were identified and approached through academic contacts at the IfM. In-depth semi-structured interviews were conducted with them in which discussions were focussed on the detailed description and reflection on specific roadmapping exercises they conducted in the recent past. Insight gathered from these interviews was combined with the case studies subsequently conducted to provide a comprehensive view of the roadmapping process, and the manifestations and mechanisms of uncertainty and risk within it. Table

3.3 outlines the practitioners consulted (1-6 in the first stage, and 7-11 in the second stage).

Practitioner	Profile
1	UK-based independent consultant who applies roadmapping for developing innovative products and services for small and medium-sized manufacturers. Previously worked in new product development roles in a high-tech company.
2	Director of a UK technology management firm which provides organisations with technology roadmapping services.
3	Director and partner at a UK-based business performance consulting firm, applying roadmapping to support strategy and capability development for industrial corporations. Previously a senior executive at a leading multinational FMCG company with over 20 years of experience.
4	Principal of an independent UK-based strategic and technology management consulting practice. Previously a senior partner at a leading international management and technology consulting firm.
5	Senior partner at a UK-based management consulting firm that applies roadmapping and scenario planning in developing technology strategy. Spent 30 years with a global oil and gas company, and there rose to the position of vice-president.
6	Principal of a UK-based management consulting firm. Formerly the strategic planning director at a multinational industrial gas company.
7	Recently retired as group technical director of a global printing technologies organisation where roadmapping was applied to keep technical strategy aligned with the organisation's business objectives and vision.
8	Trainer and management consultant to several leading organisations in Thailand and the Asia-Pacific region, and conducts research on application of roadmapping within organisations.
9	Director of the technology and innovation management centre at one of US's leading universities. He actively promotes the use of tools such as roadmapping and scenario planning within new businesses in industry.
10	Founder and principal of a US-based consulting firm specializing in roadmapping, strategic planning, business model, process, and product development. Formerly director of global technology planning at a leading global car manufacturer.
11	Founder and principal of a US-based consulting firm that works with companies, industry organisations and government to develop their roadmaps, roadmapping processes, technology futures studies, and strategy.

Table 3.3 – Profile of practitioners who took part in the experience survey

Case studies

The use of case studies fulfilled the need to explore specific roadmapping activities. This was to help take into consideration the contexts in which roadmapping was carried out, to provide a holistic view of the issues (and their interrelationships) surrounding the treatment of uncertainty and risk within the roadmapping process. Five case studies were conducted. This multiple case-study approach was deemed appropriate according to the assertion of Carroll & Johnson (1990), that the understanding of a specific type of decision-making process requires the examination of multiple cases which share the same context. The common context for the case studies selected was early-stage innovation (strategic) planning.

The unit of analysis for the case studies was the roadmapping process. This type of unit of analysis (i.e. a decision-making process) lies within the group of less concrete cases identified by Yin (2009), as opposed to the more concrete ones, which include individuals, small groups and organisations. Each unit was bound in time by the point at which roadmapping preparation and planning began, and the point at which it ended, denoted by the creation of the roadmap document/report. Also, cases were situated within (or spatially bounded by) the organisation which facilitated the roadmapping process.

In addition to the cases being roadmapping processes developed for (or in) early-stage innovation (strategic) planning, other criteria for selecting the case studies were:

- The cases must have been (or were being) carried out by organisations that have considerable experience in roadmapping.
- The cases must have been completed recently within the last 2 years (for reliable recollection of events).
- The set of cases should cut across a range of industries.
- The researcher should be able to gain access to the organisation (primarily the facilitator) that conducted the case, as well as roadmapping reports and other documents.

To identify appropriate cases, several organisations with good roadmapping experience were approached (these were identified from the archival analysis carried out earlier). Access was obtained to five organisations each providing specific access to a roadmapping activity (see Table 3.4). Relative to the time of data collection, Case 5 was on-going, Cases 1,2 and 3 had been completed within 6 months, and Case 4 within 18 months. The cases belonged to 4 different industries of defence, energy, ICT and environmental sustainability.

Case Roadmapp	**Case 1 SST roadmap**	**Case 2 NWEE roadmap**	**Case 3 Green ICT roadmap**	**Case 4 NGNP roadmap**	**Case 5 LWEC roadmap**
Date created	2011	2011	2010	2009	2011
Performing/ facilitating organisation	Industry Canada, Canada	Bonneville Power Administration, USA	VTT Technical Research Centre, Finland	Idaho National Laboratory, USA	Institute for Manufacturing, UK
Industry	Defence	Energy	Environmental sustainability/ ICT	Energy	Environmental sustainability

Table 3.4 – Overview of case studies in Phase 1 of research

B. Data collection and analysis

The data collection techniques applied corresponded to the three sources of evidence of archival analysis, experience surveys and case studies. Interviewing and document analysis were applied for each case study. Semi-structured interviews were carried out with the facilitator of each roadmapping exercise studied. Also, documentation that emerged from the roadmapping exercise in form of reports of the roadmapping activities and output were also examined. In addition, participant observation was applied in one of the cases (i.e. the one that was on-going at the point of case access: Case 5), in which the researcher participated in the roadmapping process as part of the facilitation team while observing the exercise. The combination of these sources of evidence helped in combining their advantages to ease their respective limitations (as shown in Table 3.5). Each of the interviews (and case studies) conducted was guided by an interview protocol or case study protocol (see Appendices 2 and 3), which were important for maintaining consistency in data collection across the multiple interviews and cases carried out.

For the archival analysis, the entirety of the documents (all in electronic format) contained in the roadmapping corpus served as data. As done in content analysis

(Easterby-Smith et al., 2008), each of the documents was searched for a series of key phrases or words relevant to the focus of the study (e.g. 'uncertainty', 'risk'). This was facilitated by the application of an electronic search engine: Google Desktop™. Through this, textual references to issues concerning risk and uncertainty and how they were addressed in the roadmapping process were identified, extracted and examined for relevant insight. In addition to this, a set of roadmapping visuals, randomly selected from the documents were also studied for indicators of risk and uncertainty. Identified indicators were extracted and input into a spreadsheet for comparison and relevant insight (see Appendices 4a and 4b).

In the experience survey (and case studies), all the interviews conducted were recorded[13] and transcribed. For the case studies, these transcriptions were supported by the documentary evidence (and field notes (as in Case 5)). These were analysed using thematic analysis, using a hybrid of theoretical coding and inductive coding, which helped in identifying already recognised themes and uncovering new ones. A template of codes generated based on previously reviewed literature was first used and new themes emerging from the data were included as the analysis proceeded (Crabtree & Miller, 1999; Braun & Clarke, 2006). The analysis was carried out in two phases: open coding, first to extract pieces of data related to key ideas, and then axial coding, to organise these ideas into overarching themes. This organisation of ideas was particularly important for the case studies since it facilitated their comparison and identification of relevant similarities or differences.

[13] With the exception of Practitioners 2 and 6 who declined to be recorded.

Source of evidence	Strength	Weakness
Documentation	- Stable – can be reviewed repeatedly - Unobtrusive – not created as a result of the case study - Exact – contains exact names, references, and details of an event - Broad coverage – long span of time, many events, and many settings	- Retrievability – can be low - Biased selectivity, if collection is incomplete - Reporting bias – reflects (unknown) bias of the author - Access – may be deliberately blocked
Archival records	- Same as above for documentation - Precise and quantitative	- Same as above for documentation - Accessibility due to privacy reasons
Interviews	- Targeted – focuses directly on case study topic - Insightful – provides perceived causal inferences	- Bias due to poorly constructed questions - Response bias - Inaccuracies due to poor recall - Reflexivity – interviewee gives what interviewer wants to hear
Participant observation	- Same as above for direct observation - Insightful into interpersonal behaviour and motives	- Same as above for direct observations - Bias due to investigator's manipulation of events

Table 3.5 – Sources of evidence (and data collection techniques): strengths and weaknesses (abridged from Yin, 2009)

3.3.2 Phase 2: development of process

The objective of Phase 2 was to apply the findings of Phase 1 (captured in the preliminary framework developed therein) to develop a roadmapping process that explicitly considers and addresses uncertainty and risk. It sought to answer the question:

"How might roadmapping be carried out to incorporate explicit consideration of uncertainty and risk?"

As explained in Section 3.2, this question can be answered by following a prospective approach, and particularly action research, in which new process ideas are trialled and their results reported. The origin of action research is attributed to Kurt Lewin (1946) for whom its key attribute was its focus on the resolution of practical problems through realistic fact finding and evaluation of action. Action research was originally applied for social research (e.g. Lewin, 1946) and then education research (e.g. Hopkins, 2002). Its application to management research is also quite established in operations management (e.g. Coughlan & Coghlan, 2002) and for strategy development (e.g. manufacturing strategy (Platts, 1993) and strategic planning (Caetano & Amaral, 2011)). Within the context of management, action research helps to implement and validate new ideas and test whether ideas can create value within organisations (Kaplan, 1998). The application of action research in this study, to test and validate new theories and ideas for explicitly addressing uncertainty and risk in roadmapping, directly falls under its use in management (and specifically, strategy).

A. Research approach

Reason & Bradbury (2008) pointed out that there are several approaches to action research, each one based on the approach of Lewin (1946) of a "spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the results of the action" (p 38). Some of the approaches highlighted by Reason & Bradbury (2008) are: action science, action inquiry, clinical inquiry, appreciative enquiry, participatory learning and action, cooperative enquiry and action learning. The important thing in choosing an approach is that it is appropriate for the circumstances of the inquiry at hand. The approach chosen for this study is *procedural action research (PAR)*, which was pioneered by Platts (1993). PAR was created specifically for the development of strategy processes, which makes it suitable for this study.

The PAR methodology consists of three stages:

- Creating the strategy formulation process
- Testing and refining the process
- Investigating the wider applicability of the process by survey

The strategy formulation process (called *risk-aware roadmapping process* in this study), was created based on the findings of Phase 1. Testing and refining of the process was carried out in two stages. First, it was appraised at a subjective level, using a focus group of strategic planning professionals and interviews of experienced strategic management practitioners. This led to initial improvements in the process. Subsequently, it was tested at a practical level in a small number of companies (i.e. in-company case studies)[14]. The third stage of the methodology (investigating the wider applicability) which would have involved wider feedback on the use of the process was not carried out for practical reasons[15].

In testing and refining the process, Platts (1993) draws attention to three main considerations:

- Involvement of researcher
- Consistency of the process
- Choices of companies (and individuals for the focus group and interview-based appraisals)

The standpoint of the researcher in testing the process was that of a 'process facilitator' who structured and directed the process, not imposing his views on the company. However, to ensure objectivity of the testing process, two independent consultants facilitated two of the five cases carried out, in which the researcher only observed and served in a supportive role.

Regarding the consistency of the process, Platts (1993) highlights the choice between applying the process consistently throughout the testing process, and developing and refining the process as experience is gained. In this study, the process was developed and refined as experience was gained.

The selection of focus group participants (to take part in the initial appraisal of the process) can be carried out in two ways according to Bryman (2001):

- Selection of people unknown to each other, or
- The use of natural groupings (or pre-existing groups)

[14] This use of interviews (one-to-one and group (or focus group)) and case studies for data collection is appropriate for action research (Kitzinger, 1995; Hopkins, 2002).

[15] The investigation of wider applicability involves seeking feedback from a wide range (and large sample) of managers or practitioners who have put the process to use. The features and demands of roadmapping make this particularly challenging. Any roadmapping process usually takes months to plan, requires the convening of key participants and other logistical arrangements, and should be directed by an experienced facilitator. Meeting these demands with a large sample would not be pragmatic within the time constraint of the PhD.

This study drew 9 participants from a pre-existing group called the Visual Strategy Network (VSN)[16] (see Table 3.6 for participants' profiles). The VSN is a community of interest in roadmapping and other visual approaches to strategy and innovation, bringing together professionals from industry, academia and government. The choice of participants from the VSN conforms to the main guideline given by Bryman (2001) for selection of focus group members: "anyone for whom the topic is relevant can logically be an appropriate participant" (p 343). Strategic planning practitioners who were consulted for further appraisal of the process were selected because they were familiar with the specific roadmapping methodology (S-Plan, which is described in greater detail in Section 5.2) used in developing the process. Nine practitioners were consulted at this stage. Five of the 9 had taken part in the experience survey of Phase 1 of the study (see Table 3.7).

Focus group participants	
1	Managing director at a company that develops software for strategic roadmapping and planning
2	Technology strategy consultant at a company that develops software for strategic roadmapping and planning
3	Director of a technical consultancy specialised in technology roadmapping delivering technical strategy support to clients
4	Technology intelligence manager at an open innovation services provider that helps client companies develop and maximise value from their innovation programs
5	Innovation and growth leader at a global defence, aerospace and security company
6	Principal of a technology management and innovation consultancy offering services in R&D and technology strategy and product development
7	Industrial service manager in product and systems development and new technologies and innovative solutions for a power and automation company
8	Founder and principal of a company that develops and provides solutions that employ visual approaches to improve planning, organisation, innovation and collaboration
9	Strategic product director at a company that develops inkjet and laser printing solutions

Table 3.6 – Profile of focus group participants

[16] The VSN was started as LinkedIn group:
http://www.linkedin.com/groups?gid=2842050&trk=myg_ugrp_ovr

Practitioner	Profile
1	See Table 3.3
3	
5	
6	
7	
12	CEO of a consulting firm whose primary areas of expertise include strategy and innovation and business decision support. Previously served as strategy director in an aviation and aerospace company
13	Independent consultant who uses roadmapping and other strategic management tools with large companies to optimise and reconfigure their manufacturing strategy
14	Practitioner in roadmapping, global manufacturing network design and make-or-buy assessment, with leading global companies
15	Founder and director of a technology consulting firm based in Mexico, whose activities include roadmapping for strategic planning and foresight

Table 3.7 – Profile of practitioners consulted to appraise the proposed process

The identification of companies to take part in the in-company case studies was facilitated by the advertisement of the proposed process in the IfM roadmapping newsletter[17]. Eight companies indicated interest and 5 of these were eventually selected. Table 3.8 provides a brief overview of these companies (more details of the case studies are provided in Table 7.2). The main criterion for selecting the organisations was that they were at the early stages of development of new products (or product lines), and they required clarification of product ideas with a strategic, long-term outlook.

	Case A Company A	**Case B Company B**	**Case C Company C**	**Case D Company D**	**Case E Company E**
Industry	Coatings	Defence	Wall and floor coverings	Healthcare	Power generation
Corporate base	USA	UK	UK	UK	UK

Table 3.8 – Overview of case studies in Phase 2 of research

[17] Newsletter can be found at: http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/Roadmapping/Newsletter/Roadmapping_Autumn_2011.pdf

B. Assessing the process

As suggested by Platts (1993), three criteria were used for process assessment: feasibility, usability and utility (or functionality). Feasibility is demonstrated by the ability to follow the process as described, while usability refers to how well each stage of the process was organised. It also gives the opportunity to identify problems encountered in applying the process. Functionality refers to the usefulness of the process in generating action plans.

These criteria were applied in the focus group, the interviews and the in-company case studies. Questionnaires were administered to the focus group and case study participants (after the focus group and roadmapping sessions), while the interviews of practitioners were semi-structured in format, to discuss the process in detail. Questions contained in the questionnaires and interviews captured the three criteria, by breaking them down into sub-criteria (see Table 3.9). The questionnaires used a 5-point rating scale (see Appendix 10) and the feedback ratings were aggregated and assessed using statistical measures[18].

The number of changes (or improvements) to the process as the testing phase progressed was recorded to give an indication of how the process became more (or less) stable. As explained by Maslen & Lewis (1994), development cases should continue until either successive case studies provide only small improvements, or practical resource constraints limit further development. Figure 3.2 is an illustration by Platts (2010) of a process approaching stability as the number of changes made reduces with each additional in-company test carried out.

Criteria	Feasibility	Functionality	Usability
Sub-criteria	Logical flow Format	Integration Relevance Usefulness of process (or willingness to repeat process) Usefulness of individual design elements	Ease of application (analysis) Ease of application (of visual charts) Time sufficiency

Table 3.9 – Criteria and sub-criteria used in assessing the process

[18] Statistical measures used: arithmetic mean and interrater agreement (a measure of dispersion derived from the standard deviation of individual ratings)

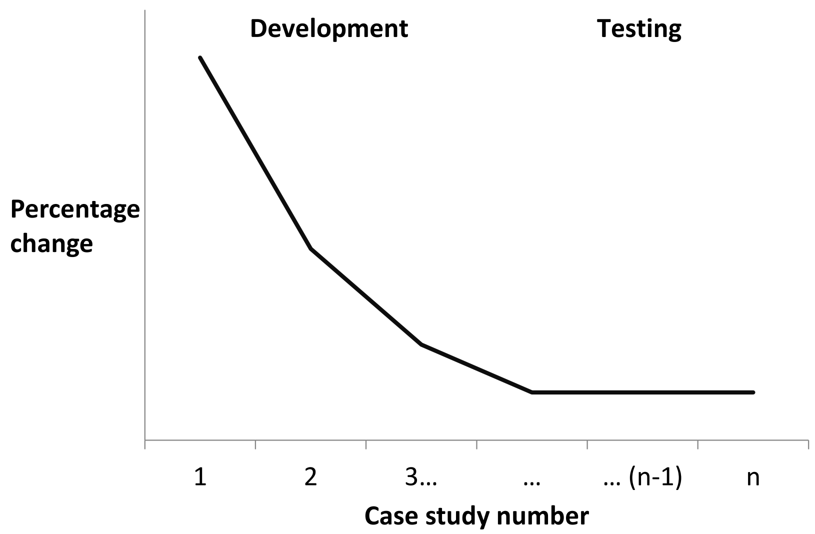

Figure 3.2 – Illustration of a process under development that is progressively becoming more stable (i.e. the number (or percentage) of the corrective changes made to the process reduce) with additional case studies for process development and testing (adapted from Platts (2010))

3.4 Research design considerations

3.4.1 Research quality

This research was guided by design principles commonly used to establish the quality of a research: validity and reliability. For the constructionist, qualitative approach to research (as followed in this study), there are different criteria under validity and reliability as outlined and explained in Table 3.10. The relevance of these criteria for the research and the steps taken to ensure the relevant ones are addressed are discussed in the following paragraphs.

This research, carried out to understand how uncertainty and risk are manifested in roadmapping with the view to creating a roadmapping process that allows their explicit consideration, can be described as both exploratory and descriptive in nature. It was also carried out by a single researcher. Therefore, the criteria of 'internal validity' and 'internal reliability' as identified in Table 3.10 were not significant for this study. The other criteria were fulfilled using recognised tactics or strategies.

Design principle	Explanation	Criteria	Explanation
Validity	Does the study properly reflect the experiences of those in the research setting?	Construct validity	Establishing correct operational measures for the concepts being studied
		Internal validity	For explanatory or causal studies only, and not for exploratory and descriptive studies: establishing causal relationships, showing how certain conditions lead to other conditions
		External validity	Degree to which the study's findings can be generalised to other situations beyond the immediate study setting
Reliability	Is there transparency about how sense was made from the raw data?	Internal reliability	When there is more than one researcher: showing consistency across members of the research team in what they observe
		External reliability	The degree to which the study can be replicated: demonstrating the procedures followed can be repeated to provide similar results

Table 3.10 - Design principles and criteria for constructionist, qualitative research (based on Bryman (2001), Easterby-Smith et al. (2008), and Yin (2009)[19])

As advised by Robson (2002) and Yin (2009), construct validity was maintained by using multiple sources of data to enhance the rigour of the research and reduce the impact of biases[20]. The research (specifically Phase 1) combined experience surveys, archival analysis and case studies (within which documentation, interviewing and participant observation were applied). This helped in inhibiting the potential for biased accounts from any single source of data. Also, the case studies selected were either on-going or recently completed at the point of data collection, to minimise the bias introduced by the difficulty of the case facilitators to recall events accurately (Remenyi et al., 1998). The main threat to validity for Phase 2 of the research (i.e. the action research) is the lack of impartiality on the part of the researcher (Coughlan & Coghlan, 2002). This was inhibited by consulting with various roadmapping practitioners as part of the process evaluation process and using external facilitators in 2 of the 5 in-company tests carried out. Across the two phases, the overall research was documented as it progressed (and reported in

[19] The criteria (or tests) of construct validity, internal validity, external validity and reliability identified by Yin (2009) were specifically for case study research, but have been similarly identified by other authors to cover qualitative research.

[20] Validity of research is threatened by respondent bias, researcher bias and reactivity (Lincoln & Guba, 1985). Remenyi et al (1998) pointed out that case study research (applied in phase one of this study) is usually fraught with the danger of subjectivity and bias.

this thesis) to clearly and logically link the research questions, findings, suggestions, evaluations and conclusions.

While the study primarily concerns roadmapping, the contexts in which it was examined and explored, i.e. strategic planning and early-stage of innovation, make it possible to generalise the findings to these perspectives. The case studies carried out and experiences shared by roadmapping practitioners were not constrained to a specific industry, so the findings may be regarded as not industry-specific.

To promote reliability, interview protocols and case study protocols (Appendices 2 and 3), and questionnaires (Appendix 10) were used to guide the collection of data, as suggested by Yin (2009). These also helped the researcher maintain consistency in data collection across the various cases studies and practitioner discussions carried out.

3.4.2 Ethical considerations of action research

The action research carried out involved applying the process suggested by the researcher in real company situations. This required the companies opening up confidential information on their product development plans to the researcher. This sensitive aspect of the research initially hindered case access and acceptability of the researcher to the organisations. To ease this difficulty, non-disclosure agreements where drawn-up to which the researcher was (and still is) bound. Thus, contents of the reports and visual charts resulting from the in-company cases (presented in this thesis as illustrations of process followed) have been stripped of information considered sensitive. Also, names of the companies and participants have been anonymised.

3.5 Summary

This chapter discussed the manner in which the research was designed and carried out. The study was designed according to the constructionist paradigm, and it followed a qualitative approach. It was carried out in two major phases. Phase 1 was in the form of applied research, in which an understanding of the relationships between the main concepts of the study, i.e. roadmapping, uncertainty, risk, innovation and strategic planning, was developed. Phase 2 took the form of action research, in which a *risk-aware roadmapping* process was developed and tested. These two phases conform to the two types of research conducted on strategy processes (which roadmapping is), which are retrospective studies and prospective studies (Nutt, 2001). Across the two phases, archival analysis, interviews (individual and group), participant observations and case studies were used to collect necessary data. Measures applied to maintain research quality were also discussed and the ethical issues surrounding study were pointed out. The following chapter presents Phase 1 of the research, in which an understanding of the links between roadmapping, uncertainty and risk is presented by examining relevant literature and a retrospective study of roadmapping practice.

Chapter 4 – DEVELOPING A PRELIMINARY FRAMEWORK

Chapter 2 identified a gap in existing literature of the lack of understanding of the mechanisms of uncertainty and risk in roadmapping (and related themes of strategic planning and front-end innovation planning). It also pointed out the absence of clear practical guidance on how to address uncertainty and risk in roadmapping.

Chapter 3 described and justified the research methods adopted for bridging these gaps in understanding and practice. It explained that a two-phase approach to the overall research would be necessary. These are:

- development of a preliminary framework that explains the manifestation of uncertainty (and risk) in roadmapping. This is to provide an understanding of the mechanisms of uncertainty and risk and factors that influence how these issues are addressed in roadmapping.
- applying learning from the developed framework to creation of a roadmapping process that embeds within itself conscious and explicit risk management procedures.

This chapter addresses the development of the preliminary framework. Central to the findings and learning here is the realisation that to carry out risk management, one must begin by understanding uncertainty and how it affects the firm and its objective of value creation (as discussed in Section 2.3.4). The findings here therefore highlight the manifestations of uncertainty (and risk) in roadmapping and how they may affect its central objective of value creation. Factors that influence how uncertainty and risk are addressed in roadmapping as well as measures that can be taken to address these issues in practice are also identified.

To start the chapter, Section 4.1 introduces and explains the concept of *risk-aware roadmapping* which is central to the rest of this thesis. Section 4.2 gives a brief examination of literature to identify broad themes to develop a preliminary framework subsequently built upon by research carried out and discussed in Sections 4.3 and 4.4. Section 4.3 draws insight from interviews with roadmapping experts and case studies of roadmapping exercises, while Section 4.4 provides the results of the examination of a corpus of roadmapping documents to see how uncertainty and risk were dealt with in them. Findings from Sections 4.3 and 4.4 include an identification of ways to visualise uncertainty and risk within the roadmapping process and for communication on the finished roadmap. Section 4.5 discusses the findings and presents the preliminary framework, while Section 4.6 summarises the chapter.

4.1 Introducing the concept of risk-aware roadmapping

'Risk-aware roadmapping', is a concept introduced here to represent roadmapping which involves a conscious and explicit effort to address uncertainty and risk. This process is conceptualised in response to the identified lack of attention to risk management in roadmapping. Presented in Figure 4.1, it aligns the generic risk management process (according to the ISO 31000) with the generic roadmapping process, to portray a roadmapping process in which uncertainty and risk are explicitly and properly managed. This high level representation is used at this conceptual stage when all factors that would influence and ultimately shape a detailed process are not yet fully identified or understood. The focus in subsequent parts of this chapter is to have an understanding of the mechanisms of uncertainty (and risk) in roadmapping, through qualitative empirical evidence from roadmapping experts and recently completed roadmapping exercises.

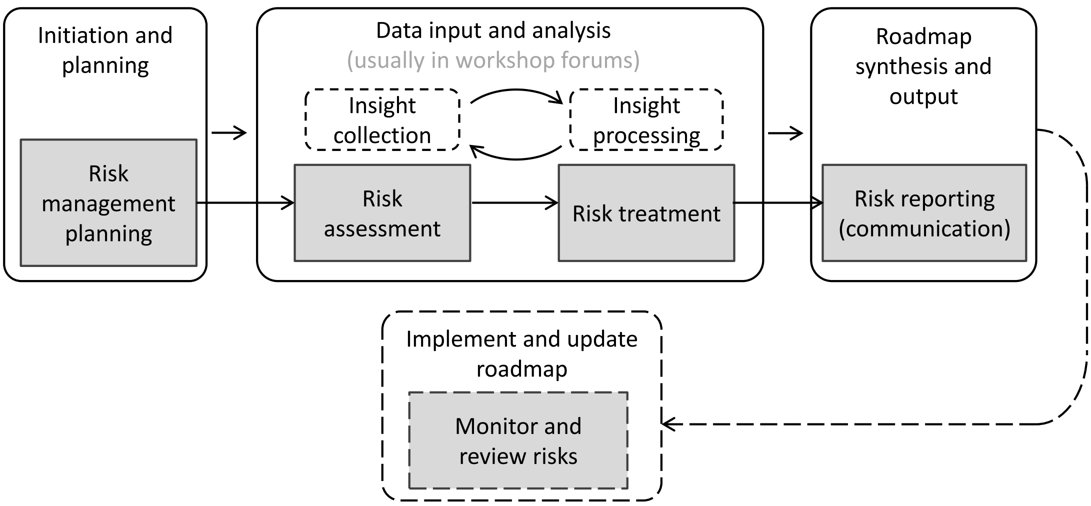

Figure 4.1 – An initial high-level conceptualisation of risk-aware roadmapping

4.2 Preliminary framework version 1: framework development based on literature and exploratory interviews

4.2.1. Identification of relevant factors from literature

Understanding the manifestations of uncertainty and risk in roadmapping involves having insight into their sources, and how these translate onto the roadmapping framework and the roadmapping process. This section first establishes broad themes to define a starting point for the provision of the preliminary framework by examining literature. The absence of literature and theory directly linking uncertainty, risk and roadmapping forces the search for initial insight outside roadmapping literature into related themes of strategy, innovation and decision-making psychology. The literature used here may not directly pertain to strategy formulation and front-end innovation planning (which serve as context for studying roadmapping here). However, useful and relevant themes for the study can be drawn from them.

Baird & Thomas (1985) identified factors that influence the treatment of risk in strategy with specific reference to a firm's *risk-taking* propensity. They identified the external environment, industry, organisational (internal) environment, strategic problem and decision-maker as the major factors. According to Keizer & Halman (2007), aspects that contribute to risk in innovation include the outcome uncertainty of innovation activities, and the level of control over the innovation process. Outcome uncertainty refers to the gaps between what is necessary and available in terms of knowledge, skills and experience. The level of control is the degree of influence that decision-makers anticipate they will have on the innovation process, to steer it towards success. Outcome uncertainty can be further broken down through Kim & Wilemon's (2003) view that uncertainty in innovation is related to the perceived complexity of innovation. Sources of innovation complexity include technological and developmental complexities, market complexities and organisational complexities (as shown in Figure 4.2).

These factors by Keizer & Halman (2007) and Kim & Wilemon (2003) are however considered to fall within those identified by Baird & Thomas (1985). The innovation tasks can be seen as the strategic problem. The technological, developmental, and organisational complexities fall within the internal environment factors, while the market complexities are captured by external environment factors. Level of control (or controllability) falls within decision-maker factors, as will be explained in subsequent paragraphs.

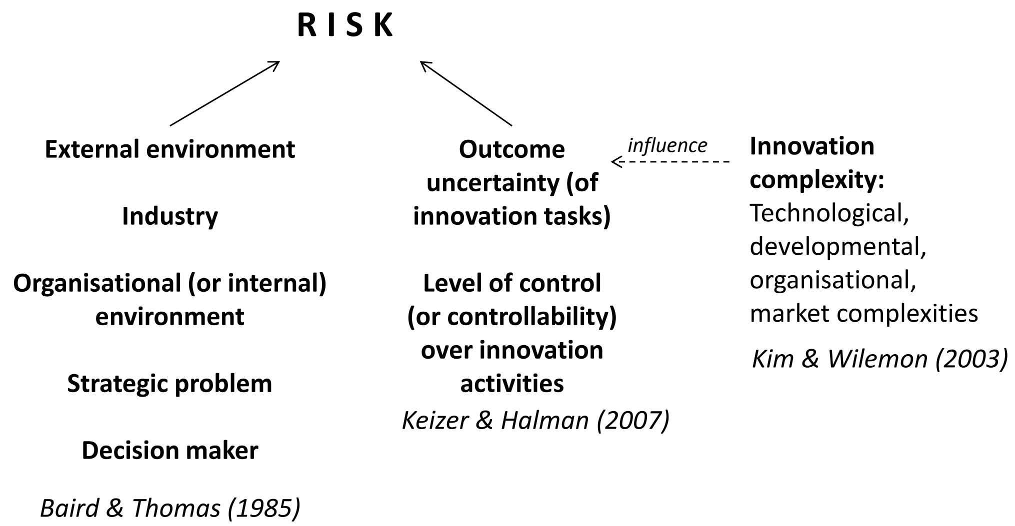

Figure 4.2 – Factors influencing risk (and how it is addressed) in strategy and innovation

Decision-maker factors include the cognitive processes of individuals, their experience and level of responsibility, and these contribute to how uncertainty is perceived and eventually addressed through risk management[21] (Downey & Slocum, 1975). Examples of cognitive processes (or cognitive simplification processes, or heuristics or biases) (Schwenk, 1984) help decision-makers simplify and 'get their heads around' the complex, ambiguous and incomplete information they have to integrate (and analyse) in making decisions. These simplification processes are required as a result of the limited (or bounded) cognitive capabilities (or rationality) of decision-makers (i.e. their inability to exhaustively acquire and process information, as discussed in Section 2.2.2). Some of the biases are explained below.

Prior hypothesis bias affects problem identification or goal formulation during a decision process and leads decision-makers to focus their attention only on objectives that appeal to their interests. This might cause them to ignore information about other worthwhile objectives (Das & Teng, 1999), and lead to 'solving the wrong problem'. *Illusion of*

[21] People perceive uncertainty and risk differently. This connects with the understanding that risk is subjective in nature as discussed in Section 2.3.4 and shown in Figure 2.19)

manageability (or control) bias leads to the downplaying of potential risk issues as a result of the overestimation of the ability to successfully execute a plan or reach an objective (Schwenk, 1984; Das & Teng, 1999). In a*vailability* bias*,* risk events that cannot be remembered or imagined are ignored and judged as improbable, while *hindsight* bias causes possibilities of which similar events that have happened in the recent past to be accorded a high degree of reoccurrence. *The desire for certainty* can result in the disregard of critical issues that may contribute to risk (Barnes, 1984). Since roadmapping involves a group of people (especially when the expert-based approach is followed – see Section 2.1.2), another issue that can be classified as a decision-maker factor is the *homogeneity of the decision team,* which affects uncertainty and risk perception and behaviour in group decision-making (Sitkin & Pablo, 2002). A common result of group homogeneity is *groupthink*, which can be explained as the decline in quality and efficiency of decisions due to in-group pressures (Janis, 1972).

The foregoing can be summarised under two broad categories (see Figure 4.4): roadmap (or strategy) content-related factors and process-related factors. The content-related factors deal more directly with the sources of uncertainty and risk, i.e. external environment, internal environment and strategic problem factors and their manifestation on the roadmap, while the process-related factors are those that influence how these manifestations of uncertainty and risk are addressed during the roadmapping process. Both these sets of factors would influence/determine how uncertainty and risk are addressed in the risk-aware roadmapping process. These individual factors have been positioned approximately on the roadmapping framework (Figure 4.4) and they are explained in this context:

- External environment factors (or macro-environment factors) over which the organisation does not have direct control. In the context of roadmapping within the firm, this will include industry factors (originally a separate factor within Baird & Thomas' framework). Examples would include social, economic, political, legislative, environmental, industry, and technology factors.
- Internal environment factors (or micro-environment factors) over which the organisation has more influence. Examples given by Baird & Thomas include

organisational structure, information and communication factors. However, in the context of the roadmapping framework, this would concern the capability of the organisation to address the strategic issues and muster necessary resources (e.g. human, capital, technology, etc) towards the fulfilment of objectives.

- Strategic problem factors, which characterise the strategic issue under consideration. These will include the complexity and ambiguity of strategic problem, rate of change of problem elements, etc.

- Decision-maker factors, i.e. characteristics of the stakeholders involved in the strategy activity, which will influence the way risk is perceived and addressed. These are cognitive factors, decision-maker characteristics (e.g. experience), and group dynamics (e.g. groupthink).

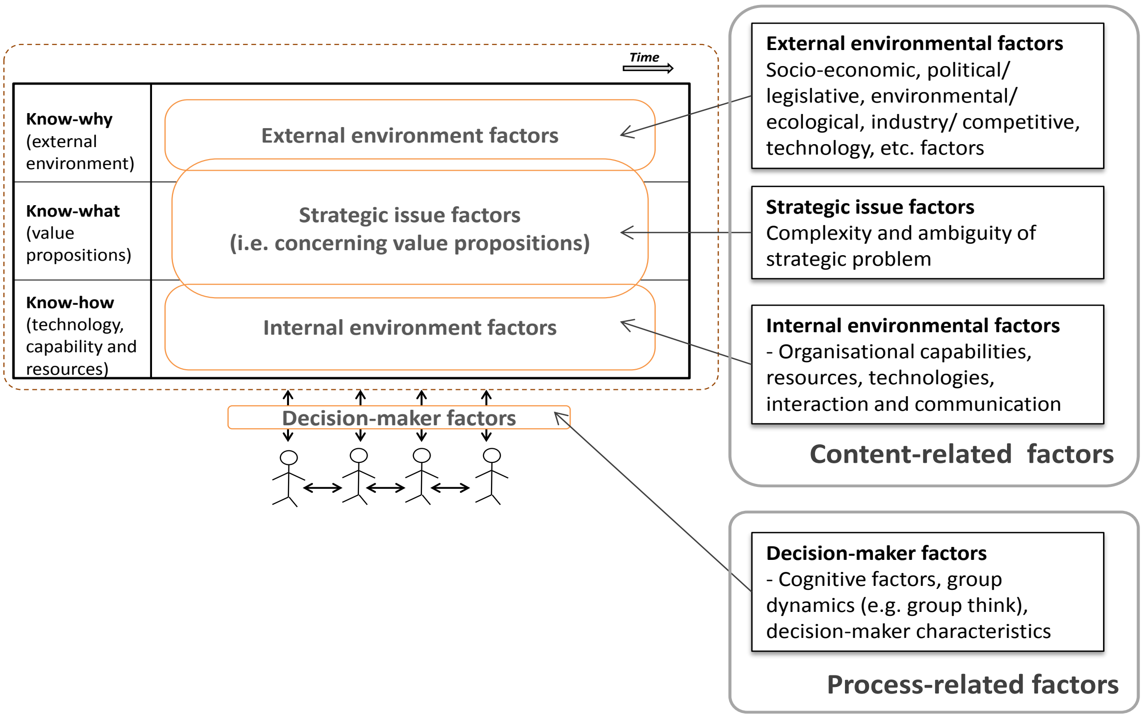

Figure 4.3 - Themes to consider in addressing uncertainty and risk in roadmapping

4.2.2. Preliminary consultation with roadmapping practitioners

Six roadmapping practitioners were consulted to ensure the factors identified from literature were consistent with roadmapping practice. The profiles of these practitioners were presented in Table 3.3 (practitioners 1-6). These consultations were in the format of semi-structured interviews, which enabled collection of insight beyond just the confirmation of the factors. Each interview covered a number of questions including establishing the relevance of the study undertaken to their roadmapping practices, key factors to be considered in addressing uncertainty and risk in roadmapping and suggestions on methods that can be applied for this. Following this the conceptual framework built from literature was presented to the practitioners. This prompted further discussion in which the roadmapping experts were encouraged to share past roadmapping experiences to illustrate the points they had earlier raised during the interview. These discussions provided contexts in which some of the factors identified on the framework were seen to manifest themselves in practice. These contextual insights are presented along with those received from further in-depth interviews with other roadmapping experts and a series of case studies in Section 4.3.

Reflection and learning from preliminary consultation

A summary of key learning points from the interviews, which are relevant to the development of the framework, is presented in Appendix 11G. Feedback from interviews showed that roadmapping practitioners thought dealing with uncertainty and risk is an important and necessary aspect of roadmapping, and that the roadmapping approach requires further development so that aspects of it explicitly address uncertainty and risk.

The practitioners agreed that the factors outlined in Section 4.2 were relevant to roadmapping and should be considered in addressing uncertainty and risk within it. No significant additions were made to the factors (see Figure 4.5). However, the importance of having a diverse group of expert contributors in a roadmapping exercise to counter groupthink (one of the decision-maker factors) was particularly stressed by the practitioners. It was also pointed out that while uncertainty can be manifest in the three roadmapping layers, the specific sources of uncertainty will depend on roadmapping purpose and the organisational context. Practitioners 1 and 6 indicated that the designated sub-layers on the roadmap (i.e. the details within the broader know-why, know-what and know-how layers) can hold specific sources of uncertainty, and each of these can therefore serve as risk indicators.

A notable addition was made to the risk-aware roadmapping process conceptualisation in form of an additional step of 'identifying and addressing ambiguity', which should be carried out as one of the first procedures in the roadmapping exercise. Practitioner 4 pointed out the case of a roadmapping activity he carried out with an automobile company. The company was faced with a considerably high level of uncertainty concerning information on future legislation on CO_2 emissions, which would be critical in shaping the future automobile market. The company was therefore unsure of the direction to take in its innovation strategy. To reduce the ambiguity associated with this critical information, scenario planning techniques were applied to build alternative, structured and internally consistent views of the future (i.e. scenarios):

> *I did a lot research and interviews with the executives of [automobile company] prior to the roadmapping workshop to try to understand what the issues were. And that's when it became clear that there were likely to be some quite big issues…If [a] particular roadmap has got issues that make the company uncertain, if those uncertainties will turn the whole answer you'd get on its head… for example, one of [automobile company's] uncertainties was government legislation on the maximum permissible level of carbon dioxide. If you start looking 10 years ahead, is it going to be 100mg/km, or 80 or 50? And the difference between those [values] is absolutely fundamental because if it 100, it is within known technologies, if it is 80 a number of people might conceive of it, if it is 50 nobody knows how to get to that level. So that degree of uncertainty and hence risk will change the outcome of the [roadmapping] workshop. So in a case like that, you'd have to consider it [uncertainty]. In other workshops it will have much less impact and therefore it is incidental not fundamental. So I think having a technique available that could deal with this is important, but it doesn't have to be deployed every time.*
>
> *In [automobile company] we drew up two scenarios. We got people to think about business as usual (nothing unexpected happening) and then we also got people to think about another scenario, which was a major shift into a more environmental conscious group of customers, and there, either as a result of natural disasters or government legislation, the emphasis on environmentally-friendly products was significantly higher than had been the trend in the past, and what impact that [will] have. That worked quite well because the groups naturally sort of divide into groups*

> *that felt environmental aspects were fundamentally important and those that felt they were a hindrance. And that helped, it focussed their minds, [and] they found it logical. (Practitioner 4)*

Practitioners 5 and 6 pointed to the application of scenario planning techniques in ways similar to that described above by Practitioner 4. Applying scenarios to clarify the future as an initial step in roadmapping under conditions of ambiguity (or high uncertainty) provided clearer views of the future and therefore, the creation of roadmaps with greater confidence. This helped in reducing a wide and unmanageable range of perceived possibilities to a few valid and manageable ones. With these clarified views of the future, subsequently identified risk events contained in the roadmap can then be more easily appraised and mitigated. Thus, the step "identify and address ambiguity" would help ensure that high uncertainty is identified where it exists and addressed if it is critical to the strategic concern of the roadmap. This is in agreement with the understanding that there are varying degrees of uncertainty as identified by Courtney et al. (1997) (as shown in Figure 2.18) and that certain techniques considered suitable for managing uncertainty at these different levels (e.g. scenario planning can be used to address uncertainty at higher levels of uncertainty).

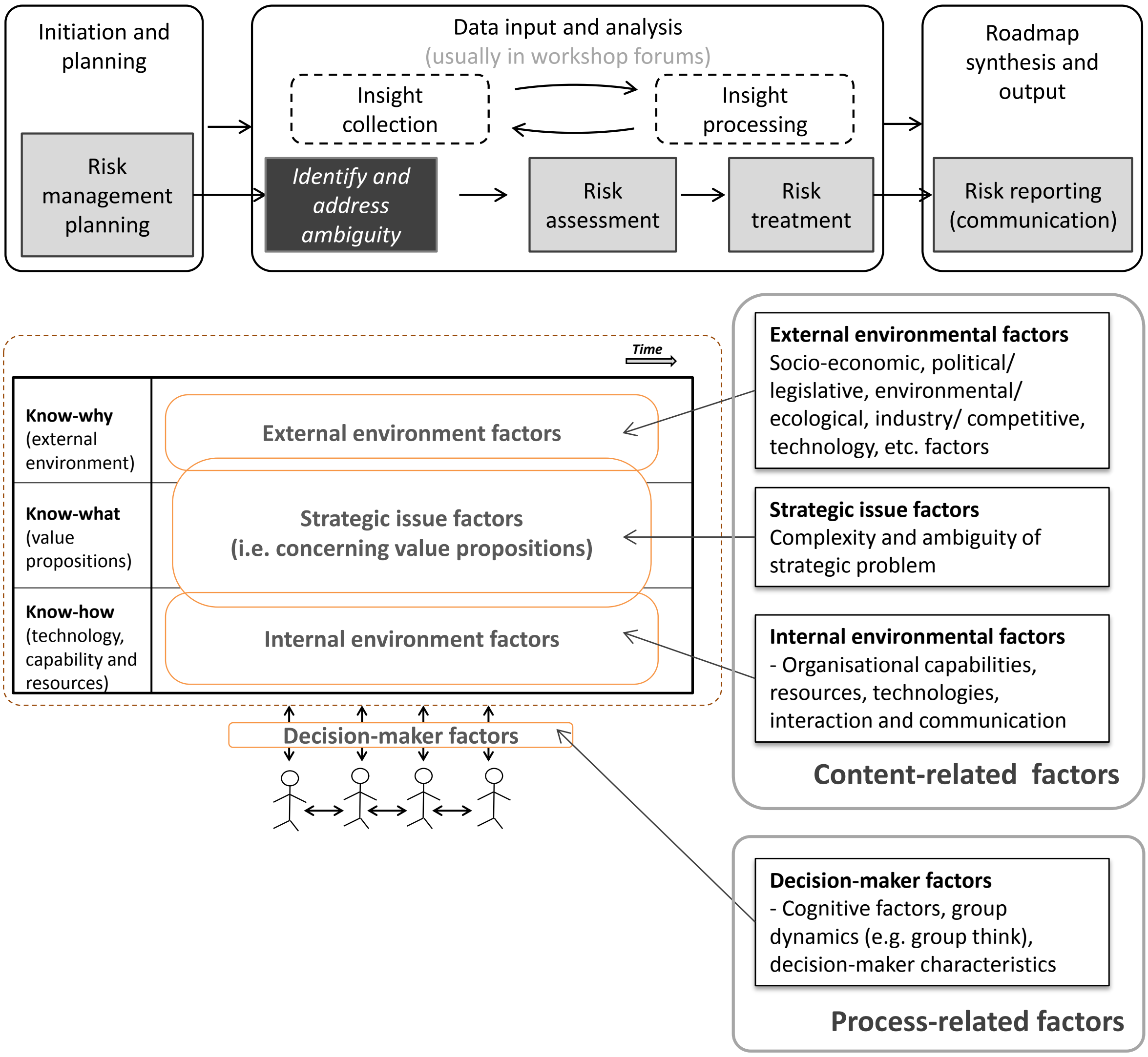

Figure 4.4 – Version 1 of preliminary framework of factors influencing risk-aware roadmapping

4.3 Preliminary framework version 2: further framework development based on additional practitioner interviews and case studies

4.3.1 Research approach and practitioner and case profiles

Further interviews were carried out with a different set of roadmapping practitioners (see Table 3.3 for practitioner profiles: practitioners 7-11). They were asked specifically to describe roadmapping exercises they recently carried out. In their descriptions, they were asked to reflect on issues they consider had an impact on the extent and nature of attention given to addressing uncertainty and risk within the exercises. As with previous consultations, the interviews were recorded and fully transcribed.

In addition to the practitioner interviews, in-depth examinations of five roadmapping exercises (by different organisations) were carried out (see Table 4.2 for the case profiles). Each of them centred on achieving specific objectives and targets in line with the vision of the respective organisations, and concerned the early stages of product/service innovation. In addition to interviewing the facilitators of the exercises, documents produced from the roadmapping processes were examined in all cases and participant observation employed in Case 5.

The data was analysed through thematic analysis. Factors associated with uncertainty and risk in roadmapping, and the steps and techniques applied in addressing them were identified. Elicitation of the factors was in two parts: the manifestation of uncertainty (and risk) in roadmapping (i.e. content-related factors) and those influencing how uncertainty (and risk) is addressed in roadmapping (i.e. process-related factors) in agreement with version one of the preliminary framework. A summary of that data collected from the practitioner discussions and case studies can be found in Appendices 11H and 11B respectively. The following section discusses them in greater detail.

	Case 1: SSTRM (2011)	Case 2: NWEE roadmap (2011)	Case 3: Green ICT roadmap (2010)	Case 4: NGNP roadmap (2009)	Case 5: LWEC roadmap (2011)
Performing/ facilitating organisation	Industry Canada, Canada	Bonneville Power Administration, USA	VTT Technical Research Centre, Finland	Idaho National Laboratory, USA	Institute for Manufacturing, UK
Industry	Defence	Energy	Environmental sustainability/ICT	Energy	Environmental sustainability
Orientation	Technology strategy	Technology strategy	Technology strategy	Technology strategy	R&D strategy
Reason for undertaking roadmapping process	To understand future technologies that might contribute to an enhanced soldier system that increases operational effectiveness.	To develop tactical R&D plans to meet strategic goals of the northwest of America regarding energy efficiency.	To point out a strategy for VTT by delivering a perspective on the optimal use of ICT for sustainability and offer an outlook of its potential developments.	To guide the development of technologies needed to achieve laid out strategic objectives for the NGNP project.	To develop strategic framework ensuring decision-makers have the necessary capabilities and resources to address environmental change.
Roadmap time horizon	Fifteen (15) years (2011-2025)	Twenty (20) years	Five(5) years	Twelve (12) years	Twenty (20) years

Table 4.1 – Profile of case studies

4.3.2 Reflection and learning: factors influencing the treatment of uncertainty and risk in roadmapping

Two dimensions of elicitation were pursued following on from version 1 of the preliminary framework (Figure 4.5): 1) the manifestations of uncertainty and risk within the roadmap framework (i.e. the roadmap content-related factors) and 2) roadmapping process-related factors that affect how and what risk management takes place. In addition, measures taken in response to these issues and the requirements (or tensions) that dealing with uncertainty and risk might place on roadmapping are pointed out. These are discussed in turn and illustrated using excerpts from the interview transcripts (some of the insight applied here has been taken from the first round of practitioner consultation introduced in Section 4.2.2).

A. Manifestation of uncertainty and risk on roadmap framework (roadmap content-related factors)

i. Manifestation of environmental uncertainty and risk on roadmap framework

The five case studies along with the practitioner interviews provide evidence on how elements of uncertainty and risk can be addressed. They demonstrate that uncertainty (and therefore risk) exists in each of the three generic layers of the roadmap. However, the nature of uncertainty emanating from them can be split across the two categories of uncertainty: environmental uncertainty and decision uncertainty.

The first category concerns uncertainty in the external and internal environments of the firm. In Case 2, uncertainty was encountered in the form of incomplete knowledge of the market environment (contained in the top (know-why) layer of the roadmap). This prompted a market intelligence activity to ensure market knowledge was as accurate as possible. This new information was then used to produce a revised, more complete version of the roadmap. Also in the top-layer, uncertainty was present in Case 5, in form of the unpredictable manner in which the future external environment under consideration could develop. There, scenario planning techniques were applied to provide a set of structured views of future conditions against which decisions could be made. This helped to improve the robustness of activities proposed by the roadmap, so they were adaptable and relevant to various future conditions. In Case 3, there was a brainstorming activity to directly identify potential risk events that could arise from the future external market and negatively affect the achievement of the innovation objectives (the value propositions) of the roadmap.

In the two other cases, steps taken addressed uncertainty and risk associated with the technologies and resources, i.e. in the bottom (know-how) layer of the roadmap. In Case 1, the choice of technologies to invest in (which would help achieve the value propositions) was faced with uncertainty. It was unclear and unpredictable which of them would offer the greatest benefit or would turn out to be successful (as there was the chance that the technologies would fail). Decisions made were inspired by an options thinking approach to promote flexibility of strategic action over a range of future eventualities. In Case 4, specific risk events that could adversely affect the acquisition and development of resources and technologies were identified and risk mitigation measures were included in the roadmap's action plan.

These uncertainties in the know-why and know-how layers of the roadmap relate to the imperfection of knowledge and unpredictability of the future market or the success (or availability) of technologies and resources needed to meet respective objectives. The uncertainty arising from these areas of the roadmap affects the know-what layer, in which value propositions (which embody the strategic/innovation objectives of the roadmap) are outlined. These value propositions are in the form of strategic objectives and targets, and in the case of innovation, new product ideas that will meet future market needs and serve as a source of value and profit for the organisation. With uncertainty from the external environment, there is the risk that the value propositions that go into the know-what layer will be misjudged for the future market. The uncertainties related to required technologies and resources arising from the know-what layer highlight the risk that the objectives and targets will not be achieved according to expectations.

ii. Manifestation of decision uncertainty and risk on roadmap framework

The other, perhaps more subtle, manifestation of uncertainty in roadmapping is embedded in the know-what layer. The set of value propositions contained on a roadmap are identified by going through exploration (search) and selection (choice) routines (see Figures 2.11 and 2.17).

Uncertainty surrounds this choice routine since it is not always clear which of the value propositions among a range of alternatives should be selected. The approach generally used by the practitioners to overcome the uncertainty is simple consensus (through democratic voting) of the process participants. This means of 'overcoming uncertainty through agreement or consensus' is however seen by some of the practitioners as an unreliable approach.

> *Every roadmap I've done has got some element of uncertainty, but largely, when people vote, there will be a commonly held view that will enable you to move forward. (Practitioner 4)*

> *So one of things we realised was that we didn't want to use dot-voting*[22] *for the final prioritisation. It is only good for back-of-the-napkin stuff, not good for anything other than a quick pass. So we did not feel that would be reliable; we needed something more robust. (Facilitator, Case 2)*

It was observed that the unreliability of using voting to deal with uncertainty stems from the combination of at least two factors: the cognitive limitations of the participants in bringing all the available information at their disposal to bear on voting for the most optimum alternatives, and the influence that a key member (e.g. a senior figure in the organisation) within the group can have on the manner in which the other participants vote:

> *Dot voting is generally not the way to go except you do blind dot-voting. And because what happens is that you get a room filled with these folks. Some of them are kind of rockstars within their field and if they go up and throw their votes on the wall first, they influence everyone else. Everyone starts putting dots where they have put dots. (Facilitator, Case 2)*

[22] Dot-voting is a commonly used means of choosing among value proposition alternatives in a roadmapping workshop. In dot-voting, each of the participants is allocated a number of sticky dots. The participants openly place their dots against their value proposition preferences. The value propositions chosen are the ones assigned the highest number of sticky dots (The Consulting Partnership, 2012)

Similar cognitive limitations and group influences can also introduce a lack of confidence that the set of value propositions identified in the preceding search process are optimal or the 'best possible'. There is the possibility that in the search for value propositions to meet the demands of the future market, the group's thinking is too constrained such that it focuses only on a narrow set. This might result in some very good ideas or alternatives not being considered at all, therefore resulting in missed opportunities of value capture for the firm:

> *In hindsight we can see there are things we did that were good ideas, and then there were things we didn't do that will have been very good ideas - good ideas missed. It is very, very important but the trouble is [that] there are no sanctions there, because it would have been a good idea but we did not do it. This is not normally thought about but we should recognise it. (Practitioner 7)*

This uncertainty highlighted in the search and choice routines can have the effect of the firm losing potential value as a result of missed value propositions (i.e. missed opportunities) that with better attention could have been identified and captured. It should be noted that these phases of search and choice for value propositions are themselves decision-making processes that are sub-routines of the overall decision-making process embodied by roadmapping. It depicts Simon's statement that: "each phase in making a particular decision is itself a complex decision-making process… there are wheels within wheels within wheels" (Simon, 1977, p 34).

Therefore, uncertainty is found on all layers of the roadmap structure, each introducing an element of risk of loss of value to the organisation. The top and bottom layers can hold uncertainty pertaining to the organisation's external and internal environment respectively, while the middle layer is affected by decision-making uncertainty surrounding the search and choice routines for value propositions it carries (See Figure 4.6).

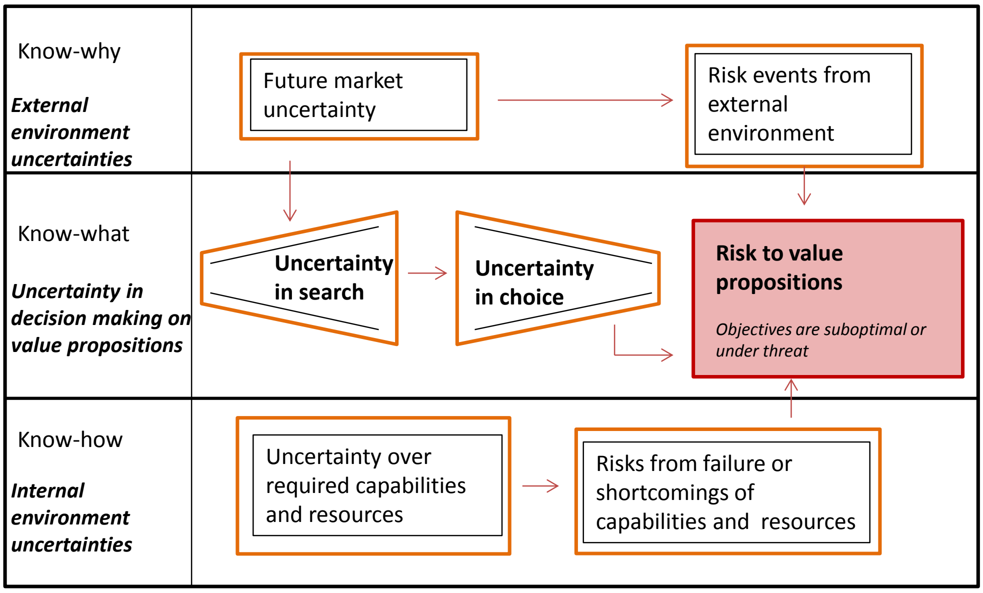

Figure 4.5 - Manifestations of risk and uncertainty on the roadmap framework (strategic content factors)

<u>B. Process-related factors</u>

i. <u>Quality and diversity of participation</u>

The quality of participants affects the quality/reliability of data in the roadmap. Each layer of the roadmap deals with specific types of information (e.g. market information, technical information) and requires people in the field with good levels of awareness of those issues to provide good quality and dependable data. The presence (or absence) of participants who are experts in their fields is an indicator of how certain or uncertain data can be regarded, and how relevant and complete the information provided is for the purposes of drawing up action plans.

> *… if we are going to use expert opinion, but the guy that we called in is not really an expert, it is an issue as well. (Practitioner 8)*

In addition to this, it was indicated that a lack of diversity of experts restricts the generation of knowledge that can be applied on the roadmap. The 'completeness' of knowledge can be affected by how diverse the group is. Having a group of people who have the same backgrounds (maybe they belong to the same department in the organisation) would have the tendency to limit the variation of views, the ideas generated, as well as risk-related issues raised, as one of the practitioners observed:

> *I think the first thing you need to try to get a grip on is: how complete is the information? … the more complete [it] could be, the less risk you then try to grapple with because you've got the information on the table and you are more likely to do something with it. Now, if you don't have a sufficiently diverse group, you might not get the possibilities, and then you might end up with a more risk-prone roadmap because people are not diverse enough in a way to feed off each other… (Practitioner 3)*

ii. ***<u>Biases brought into the roadmapping process</u>***

<u>Bias against dealing with uncertainty</u>

There are cognitive biases that roadmap participants might bring into the process that can affect how critically uncertainty and risk are examined. There might be a basic lack of desire of expert participants to confront uncertainty and risk. This, on one hand can be attributed to *optimism bias* or as a result of participants trying to avoid the complexity of thinking through uncertainty and risk:

> *People have a very difficult time dealing with uncertainty. That is just the human trait. People want certainty; [they] don't like to deal with the alternative consequences. It is a difficult thought process. (Practitioner 11)*

> *I think one of the things that would prevent efficient risk analysis is biased views, which are either vested interests or risk appetites of the individual or just borne out of experience. You have to think of ways to liberate people from those experiences. (Practitioner 3)*

<u>Illusion of manageability</u>

However, even when participants appear to take steps to address uncertainty and risk, there remains the tendency for them to be selective in the areas of the roadmap they focus on. Experts may find it difficult to see how things might go wrong in the areas of the roadmap that fall within their domain of expertise. This *illusion of manageability or controllability* was pointed out as a factor that affected the identification of risks (or bottlenecks, as they were called) in Case 3. Practitioner 11 also shared his experience on this:

Basically our experts were mostly engineers, and they tend not to see technology as a bottleneck. Technology is something that can be solved, so it is more of regulation, or some sort of context or general mind-set of people that is the bottleneck. That is why the bottlenecks [identified] were more of societal bottlenecks. (Facilitator, Case 3)

For each technology, we asked the subject matter experts to develop a one-page description of the technology and incorporate risk there, asking them: "what are the uncertainties in the approach you are taking, and the risks too?" The experience we had there was pretty mixed – people [had] difficulty talking about the uncertainties, particularly researchers who were convinced that their solutions will work, and theirs was the best. (Practitioner 11)

iii. <u>*The consensus-driven nature of roadmapping*</u>

In the light of addressing uncertainty and risk, the consensus-driven nature of roadmapping appears to come with a downside. Participants who have misgivings (e.g. uncertainties about the information used or decisions reached by the group) may tend to suppress their perceptions for the sake of maintaining group agreement. This was noted in Case 5, in which *after* a roadmapping workshop had been completed, five of the forty participants were observed to privately discuss some of the common scepticism they had felt concerning certain data applied in the roadmap. These issues were however not raised by these individuals during the process at the time the data was inputted and applied. This drive to achieve agreement in roadmapping could therefore lead to groupthink, preventing people from critically challenging the roadmap and identifying data gaps and assumptions. As such, uncertain and risk-laden issues may tend to be overlooked[23].

iv. <u>*Constraint of time and resources available (or allocated) for roadmapping*</u>

It was obvious from the cases that the volume and depth of analysis done in any roadmapping process is constrained by the time allocated for the process. The constraint

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[23] Motorola includes a 'minority report' in its roadmapping outputs in a bid to prevent useful information overlooked or neglected by the roadmapping group from being entirely lost (Willyard & McClees, 1987). While the 'minority report' was not presented specifically as a means of addressing uncertainty or risk, its use illustrates the recognition that the consensus-driven nature of roadmapping has downsides, and that it is appropriate to make an attempt to reduce them.

of time is particularly manifest in roadmapping workshops, in which strict agendas are followed due to the time and resources it costs the firm to bring experts together for the meeting (in terms of real costs and opportunity costs (Jones, 1985; Nutt, 2001)).

For example, in Case 1, it was possible to apply a range of methods to address uncertainty. This may be attributed to the time and resources made available for the process. Case 1 had a series of seven 2-day workshops and in addition, a wiki that served as a platform for virtual workshops after the face-to-face workshops, which gave time for further deliberation. Therefore, even when practitioners understand the need to manage uncertainty and risk in their roadmapping process, time and resource (or budgetary) constraints can hold them back, as made evident by Case 3 facilitator:

> *We have also tried to experiment with some of these risk management tools in some of our [other] workshops that we have more room to do. This roadmapping exercise was quite tight money-wise and that is why we had to very carefully make a selection of how to do the process. We tried to make the process in a very straightforward way [without the risk management tools] because of these limitations. (Facilitator, Case 3)*

4.3.3 Addressing uncertainty and risk in roadmapping

A. Application of techniques/methods

The techniques applied in the cases and by practitioners (or suggested based on their perception of good practice) are outlined in Table 4.5.

For biases that affect how risk is perceived and addressed, the advice is to look for ways to liberate participants from them (as can be seen in the earlier observation by Practitioner 3). The bias against confronting uncertainty and risk can be addressed by explicitly 'challenging' roadmap participants to reflect on such issues. This may be achieved by making sure that the visual templates used in the process, contain sections that directly request information relevant to uncertainty and risk, so that participants can consider and deliberate upon them.

> *To the classic know-why, know-what, know-how, in a sense we just add the dimension 'know what-if' layer. And so the idea is simply to raise the ideas about 'under what conditions would this not work?' And to try to challenge thinking saying 'how would something be different?' (Practitioner 9)*

Also, the application of devil's advocacy using "what if…?" questions that have been structured to suit the strategic issue (using SWIFT, see Table 4.5) can help to break down groupthink and the illusion of manageability which prevent the identification of risks.

The search and choice routines for value propositions are affected by cognitive limitations and individual or collective bias. Techniques that have a structured and systematic approach to search and choice were suggested for countering the subjectivities.

> *The more you can make the approach objective than subjective the better. Take out some of the subjectivity, break down the risk; maybe include some sort of scoring so it becomes more systematic. (Practitioner 6)*

TRIZ (theory of inventive problem solving) was identified as a systematic approach to help identify more and better quality innovative ideas and alternatives as opposed to the traditionally-applied brainstorming technique for searching out ideas. To overcome the susceptibility of dot-voting to groupthink in the choice routine, blind-voting was applied in Case 5 and, MCDA (multi criteria decision analysis) techniques (i.e. scoring models) were employed in Cases 2 and 4. Portfolio methods such as the risk-reward matrix have also been applied by some of the practitioners.

Apart from the application of specific techniques, the act of consistent reviewing and updating of a roadmap with new market information to fill previously identified gaps in knowledge is itself a means of dealing with uncertainty. Within this process of updating the roadmap, previously identified risks can also be monitored and reassessed, along with the newly identified ones.

Method/ technique	Application	Reference
Assumptions analysis	Suggested as way to identify risks by examining data assumptions made in the course of the roadmapping exercise.	Practitioner 9, 11
Brainstorming	Applied for risk identification.	All cases, all practitioners.
Checklists/ prompt lists	Suggested as a way of generating a list of risks by prompting roadmapping participants in possible risks associated with the strategic issue.	Practitioner 1, 2
Decision points (or trees)	Applied for visualising a set of alternative decision options on the roadmap in response to the uncertainty surrounding which one to follow. Also applied for quantification of risks associated with investment decisions.	Case 4 Practitioner 11
Devil's advocacy	A way of introducing structured and constructive dissent in the decision group to counter groupthink.	Practitioner 9,11
Multi-criteria decision analysis: MCDA	Applied for objective prioritisation and selection of focal issues in all parts of the roadmap. Also used to assess the severity of risk associated with a range of investment options.	Cases 2, 4 Practitioner 7, 10
Probability-impact assessment	A means of assessing the severity of identified risks.	Practitioner 4, 6
Real options thinking	Applied to help decide how to infuse flexibility into strategic actions concerning investment decisions where there is uncertainty on how well the investments will perform or how relevant they will be for the future.	Case 1 Practitioner 5
Blind voting methods	A revised way of voting for the top priorities, which reduces the influence of participants' votes on one another. Applied to counter the effects of groupthink.	Cases 2, 5
Risk-reward matrix	Applied for appraising investment choices based on the levels risk associated with them against the profit they are expected to generate if successful.	Practitioner 2, 3, 6
Rolling wave planning	A concept useful for outlining decision commitments when there still remains reasonably high uncertainty surrounding a technology's profitability. Decisions are broken into stages, and commitments are made only as far as the clear planning horizon.	Practitioner 9
Scenario planning techniques	Applied for structuring difficult to predict future environments by providing alternate views of how it might develop. Useful for identifying risks and stimulating creative thinking.	Case 5 Practitioners 4 - 11
SWOT analysis	SWOT (strengths, weaknesses, opportunities, threats) analysis can be applied for identification of risks according to the environmental threats and organisation weaknesses.	Case 1, Practitioner 9
TRL (technology readiness levels)	Applied to characterise levels of risk associated with the technologies being considered for action or investment.	Case 4
TRIZ	TRIZ (Theory of Inventive Problem Solving) was suggested as a structured means of stimulating creativity for ideas generation during roadmapping.	Practitioner 7
SWIFT (structured what-if technique)	Asking 'What-if' questions was suggested as a means of ensuring that the various uncertainties and risks and their effects on objectives are considered by participants.	Practitioner 8, 9, 11
Market (and technology) intelligence	Applied for filling gaps in market and technical knowledge contained on the roadmap.	Case 3 Practitioner 1

Table 4.2 - Methods identified from case studies and practitioners for addressing uncertainty and risk in roadmapping

B. The role of the process facilitator in addressing uncertainty and risk

Apart from applying techniques and visual templates that stimulate thinking on uncertainty, facilitators may need to get actively involved in the strategic discussions to bring risk issues into the open.

> *What I've found is that it becomes the role of the facilitator to ask those questions that the group may be too close to see. Asking those stupid questions that everybody thinks they know the answer to, or are afraid to ask. The role of the facilitator is to help bring those points out. (Practitioner 11)*

To be able to do this, i.e. to apply a technique such as SWIFT or take on the role of the devil's advocate to draw out risk issues, the facilitator may need to have a fair level of understanding of the strategic issue under consideration. As such he would act not only as a process facilitator (ensuring the smooth running of the process) but as an expert facilitator, helping the elicitation of knowledge from the participants. This role of the facilitator was also seen in Case 3, where the facilitation team was knowledgeable enough in the subject of the roadmap. They actively provided additional information to the participants to influence their discussion and appropriately steer it through the uncertainties that faced the participants.

C. The issue of potential complexity of the roadmapping process

The practitioners' accepted the importance of dealing with uncertainty and risk in roadmapping, but some were concerned that the inclusion of measures to explicitly address uncertainty and risk may lead to an overly complex roadmapping process. The inclusion of additional methods and analysis to address uncertainties and risks, in addition to existing procedures within roadmapping, could make the process too difficult for participants. There is therefore the need to find a balance of an '*appropriate'* amount of analysis of uncertainty and risk for roadmapping, so that the overall process is not stifled by the inclusion of risk management.

> *You've got to be also careful so you don't overwhelm people. Having a template of ten pieces of analysis would probably overwhelm people in a roadmapping exercise. You probably need maybe two or three, to allow people to get to grips with the bigger issues. (Practitioner 3)*

> *The balance to strike is on how heavy the [risk management] process compared to roadmapping [is]. You don't want the dealing with risk to overwhelm the*

discussion you are having on where you are going. Make sure that the ideas are incorporated but not to a point where they dominate. (Practitioner 11)

4.4 Further insight from investigation of a corpus of roadmap documents

4.4.1 Dataset description

The corpus of roadmap documents collected by Phaal (2011) was examined for ways in which uncertainty and risk might be addressed and visualised. The corpus contained 650 roadmap documents from the public domain. The review was carried out in two parts. The first part examined the 'document content', to identify, based on the account given in the document, how uncertainties and risks pertaining to the strategic issue were addressed within the roadmapping process. The second part examined the 'roadmap visual', to identify how uncertainty and risk were communicated (or depicted) on the roadmap visuals contained in the publications.

For the first part, the entire set of 650 documents served as data. To facilitate the examination of such a large number of publications, the documents were examined at two levels of detail (as shown in Figure 4.6). First, using Google Desktop™ search engine, the documents contents were searched for keywords 'uncertain', 'uncertainty' and 'risk' as well as their synonyms (e.g. 'complexity' and 'threat'). This initial screening helped the investigation focus only on documents that had made reference to 'uncertainty' and (or) 'risk'. Only 85 documents made such reference. Each of these was then examined in detail individually to understand the context of the usage of the terms 'uncertainty' and 'risk'. 64 were found to refer to risk and (or) uncertainty in a manner relevant to this study, i.e. of strategic relevance to the innovation objectives of the roadmap[24]. For the 64 documents, the extent to which uncertainty and risk were addressed was examined. 22 of the documents took steps to manage uncertainty and risk.

[24] The documents disregarded were those that used the terms only in an operational sense, e.g. risks encountered in general parlance of everyday-life, or those that used the words 'risk', 'uncertain' or 'uncertainty' in the narrative of the roadmap document, without any direct bearing on the strategic content of the roadmap.

The second part of the review examined 369 roadmap visuals from the corpus. Each one was examined for indicators of uncertainty and risk. Where found, uncertainty and risk indicators were classified as explicit or implied. Explicit indicators are those that clearly or directly mention or represent risk or uncertainty, while the implied were those from which the presence of uncertainty or risk within the roadmap could be deduced based on the constituents of the roadmap or how the visual information provided was structured.

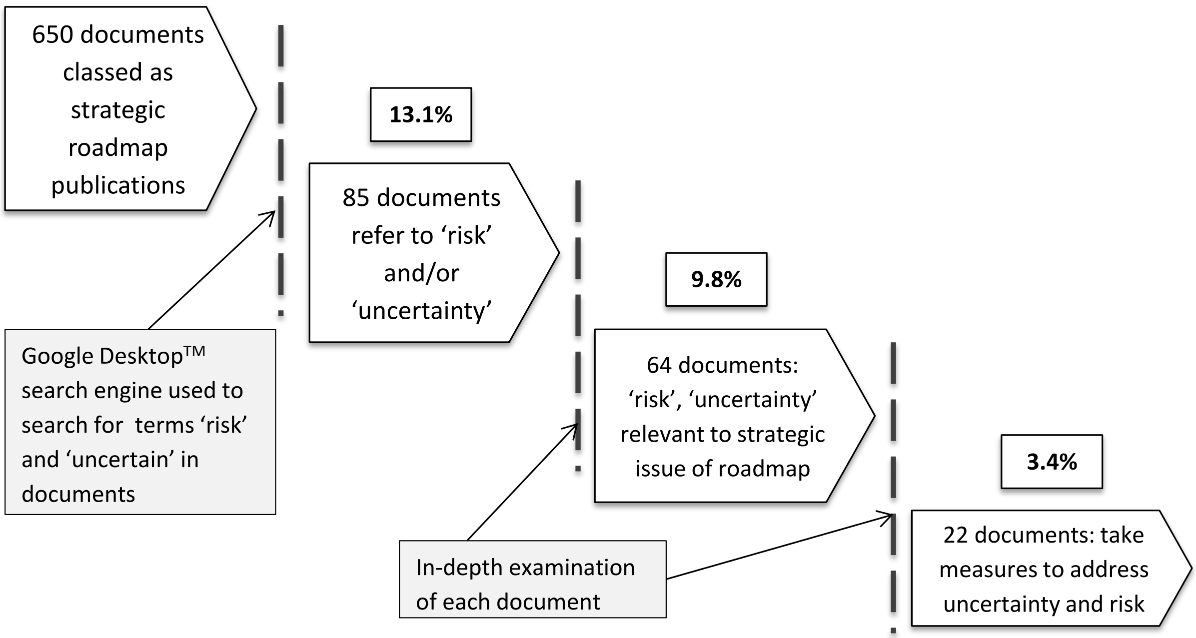


Figure 4.6 - Steps taken in reviewing the document content of the publications within the corpus

4.4.2 Findings

A. Document content exploration

Of the 650 documents examined, only 64 acknowledged the presence of uncertainty and (or) risk in roadmap development. Many of the uncertainties and risk identified stemmed from knowledge gaps in data or information used to build the roadmap. Some of these gaps were found in the trends characterising the future market environment related to the strategic issue. Specific uncertainties identified on the roadmaps fall into the categories of environmental uncertainty identified in the 5 case studies in the previous section, i.e. emanating from the market (or external) environment and the organisation (or internal) environment.

Of the 64 roadmaps that acknowledged the presence of these uncertainties (and risks), only 22 took definite steps to deal with them, through the application of risk management techniques. These 22 roadmaps are presented in Appendix 11A and the manner in which they addressed uncertainty and risk are outlined therein. 11 of the 22 applied *scenario planning* within the roadmapping process and built roadmap(s) to respond to the alternative future scenarios considered[25]. Appendix 11A.1 examines the two types of scenarios used within roadmapping for the purposes of reducing high uncertainty (or ambiguity) and identified how they are used differently. These are discussed in detail in **Section 8.3.1C**. Other risk management methods were used in the other 11. These include technology readiness level assessment and risk-reward analysis, generally confirming the methods identified by the practitioners as listed in Table 4.2.

B. Visualisation of uncertainty and risk on roadmaps

369 roadmap visuals were selected at random from the corpus, only 14 of these (3.8%) depicted uncertainty and risk visually. 10 (2.7%) out of these showed that the identified risks had also been addressed in some manner, either by indicating their severity (i.e. signifying that risk assessment had taken place), or by pointing out measures to counter the risks (showing that risk mitigation plans had been considered) on the map.

[25] This further reinforces or supports the included step of 'identifying and dealing with ambiguity' (using scenario planning techniques) in the risk-aware roadmapping process, as identified in Section 4.2b.

Some of the visuals that depicted uncertainty or risk also indicated how severe these identified risks were. The more common method for doing this was to use the traffic light colour-scheme[26], as shown in the first example in Table 4.3. In this example, green was used to depict lowest level of uncertainty, and then yellow, red and blue in increasing order, the traffic light system is used here for showing uncertainty in the data inputted into the roadmap based on views of the future. It can also be used to indicate specific risk events likely to impact on the roadmap and show the importance of each one, as indicated in the third example. There is also the use of decision points as shown in the second example. These decision points are used on the part of the roadmap that concerns the action plans. Decision points recognise there is uncertainty on what the directions to take, or whether a path of action would be continued after a period of time. Overall, there are no set rules or ways in which uncertainty and risk may be depicted, or how the roadmap may be structured to show these. The third and fourth examples are taken from Practitioner 11 and Case 3 respectively, and they provide examples of the differences depiction. Example 3 is wholly a risk roadmap developed as an adjunct to the main roadmap to show specific uncertainties and risk events associated with the main roadmap (on which plans are specified). Example 4 is in itself a main roadmap, which dedicates a layer to uncertainties and risk. While there are no set rules, what appears important is that issues of uncertainty and risk are clearly identified and presented, and if possible, their levels of importance or severity indicated.

[26] In the traffic light colour-scheme, green = low uncertainty/risk, yellow = moderate uncertainty/risk, red= high uncertainty/risk.

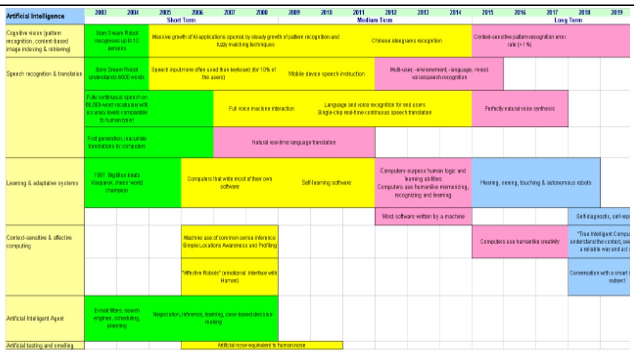
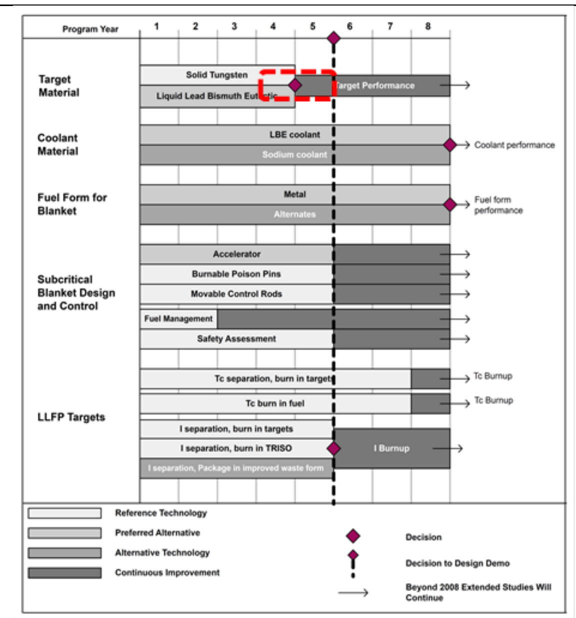
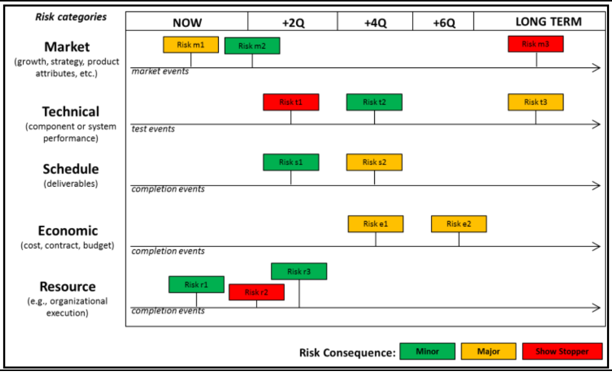
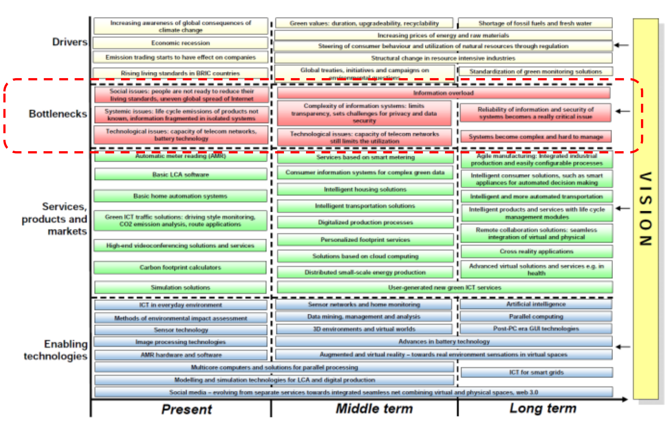
1		Technology roadmap for artificial intelligence (from corpus): use of *traffic light colour system* (to indicated level of uncertainty associated with milestones) Green = little uncertainty; yellow = moderate uncertainty; red = high uncertainty; blue= wishful thinking/science fiction.
2		A Roadmap For Developing Accelerator Transmutation Of Waste (ATW) Technology: use of *decision diamonds (depicting uncertainty in choice among two alternative routes)*
3		An example of a risk roadmap associated with a main roadmap, as created by Practitioner 11 during a roadmapping process. The risk roadmap shows identified risks and uses the traffic light colour scheme to denote their severity.
4		This is the roadmap visual created in Case 3, in which there is a layer of the roadmap dedicated to identifying risks (or bottlenecks) as written on the roadmap.

Table 4.3 - Examples of ways uncertainty/risk is depicted on roadmap visuals

4.5 Discussion and implication of findings: revision of preliminary framework version 1

This chapter has pursued the objective of exploring and understanding uncertainty and risk in the context of roadmapping, for the purpose of describing a preliminary framework upon which a risk-aware roadmapping process can be developed. It also pointed out practical measures that can be taken (in the form of tools and techniques) in response to them, thus identifying issues relevant for laying a foundation for risk management in roadmapping. These issues are particularly relevant for the application of roadmapping to front-end of innovation.

Figure 4.7 provides a diagrammatic representation of the issues. Factors influencing the treatment of uncertainty and risk in roadmapping fall into two categories: the manifestation of uncertainty and risk in the strategic content of the roadmapping process (bounded by the roadmap framework), and factors associated with the features of the roadmapping process. The content-related factors pointed out on the roadmap framework indicate sources of uncertainty (and therefore risk). However, the process-related factors would influence how these content-related issues are identified and addressed. Two types of uncertainty are present within roadmapping: environment uncertainty and decision-making uncertainty. These are interrelated (rather than being two separate constructs (as they have been treated in strategic management (Weber, 2000)). Together, they affect conception and actualisation of value propositions and have the potential to put value creation prospects within the firm at risk, since they can lead to the pursuance of sub-optimal and/or under-threat value propositions.

Some of the process factors concern the participants (or group of experts), through whom data is gathered and analysed in roadmapping. Quality and diversity of participation have important effects on 'completeness' and quality of information, and therefore the extent of uncertainty felt. However, regardless of the participants' quality and diversity, the cognitive biases brought into the process can affect how uncertainty and risk are perceived. These biases also create the tendency to limit the search for ideas (or value propositions), and distort the selection of the ones the organisation would focus on and develop through the innovation value chain. Biases of *ambiguity aversion* and *illusion of manageability* were identifiable in roadmapping. Ambiguity aversion is similar to *antiplanning bias* (or *deliberate ignorance*, i.e. resistance to confronting uncertainty and the possibility of failure) (Steiner, 1999; Kutsch & Hall, 2010). The tendency to limit the search for value proposition ideas is related to the bias of *focussing on limited targets (or exposure to limited alternatives)* (Das & Teng, 1999). Some of the identified tendencies can be strongly influenced and strengthened by groupthink (Janis, 1978), which in turn appears to be promoted by the consensus-driven nature of roadmapping. In addition to the aforementioned, the constraints of time and resources (budget) surrounding most roadmapping exercises limits how much additional risk management analysis can be taken on to address these uncertainties and seek ways to limit their potential impact.

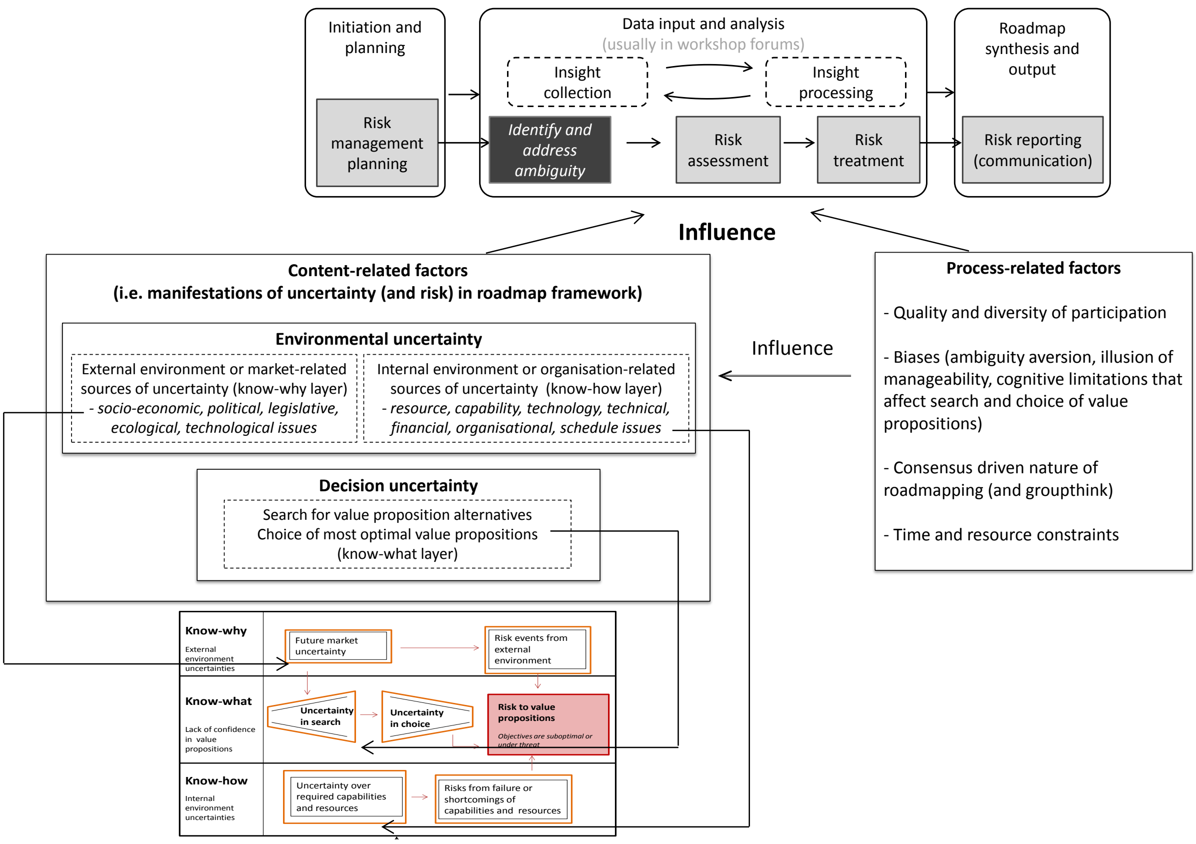


Figure 4.7 – Version 2 of preliminary framework of factors influencing risk-aware roadmapping

4.5.1 Implications for risk-aware roadmapping

Given the issues raised in the preceding sections and summarised in the above paragraphs, it appears that in the case of roadmapping, there is more to risk management than the standard procedure prescribed by risk management manuals (e.g. IRM, 2002; Chapman, 2003; ISO, 2009). Risk management in roadmapping should address both types of uncertainty manifest within it and this should include the factors that influence them. This means risk management should go beyond the identification, estimation and mitigation of discrete risk events to include the manner in which uncertainty and knowledge is managed. This means an active consideration of data sources (e.g. finding the right mix of participants to promote diversity and expertise) and how they contribute and analyse information so that the influences of their individual and collective biases (and subjectivities) are minimised. Not only should the uncertainties and risks emanating from market and organisation environment be considered, those affecting search and choice of value proposition should also be addressed, to reduce the risk of missing value propositions that otherwise could be of great worth to the firm. Thus, the initial conceptualisation of the risk-aware roadmapping process has been further updated to incorporate two additional procedures: "augment search (and creativity)" and "improve selection process" (Figure 4.8). Other activities, such as selecting a well-experienced and diverse set of participants are embedded in this process, which will be elaborated upon in the next chapter.

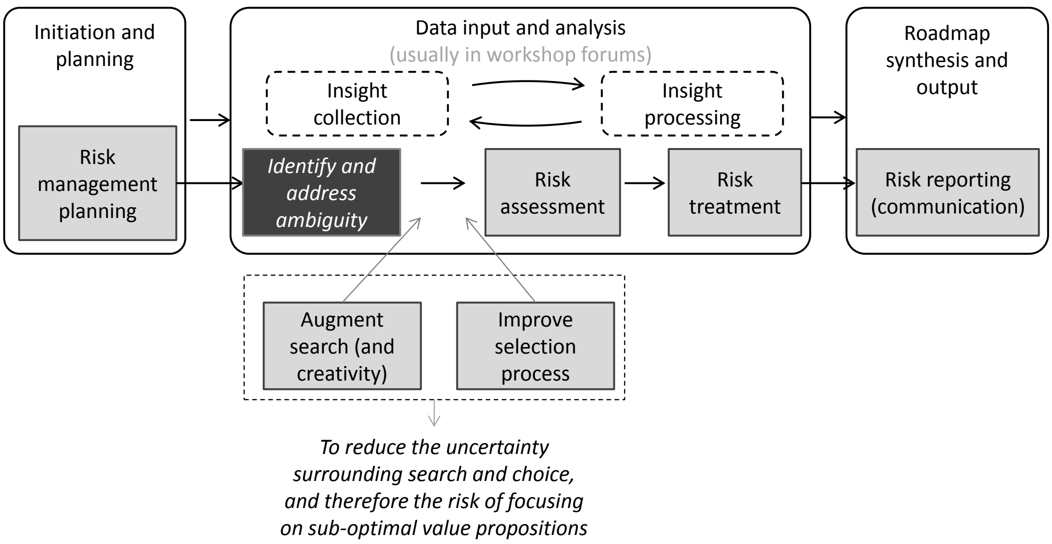


Figure 4.8 – Re-conceptualisation of risk-aware roadmapping

As one can reasonably expect, embedding extra procedures to address uncertainty and risk in roadmapping will require additional time and resources as it is bound to increase the amount and potentially, the complexity of analysis necessary. Organisations may be unwilling to commit this time and effort, but it must be recognised that a major requirement of risk management is the willingness to commit to it the necessary time and effort (Steele, 1989). On the issue of increased complexity, it is important to appropriately balance the additional effort required for risk analysis against the abilities of the participants, so that they are not overwhelmed. As identified by Varga-Hernandez et al. (2010), risk management is valuable for innovation but too much or inappropriate risk management might stifle innovation altogether, and this can be attributed to roadmapping as observed from the findings. On time and resource constraint, it is important to explore how to mould the techniques suggested here into easy-to-use, time-efficient, yet effective formats. Such formats can take forms that can be embedded in fast-start models of roadmapping (e.g. Phaal et al., 2001; Phaal et al., 2007) which were developed to, in part, overcome similar constraints of time and budget associated with the general application of roadmapping.

It should also be noted that some of the measures suggested by the roadmapping practitioners (for addressing uncertainty and risk) go against traditional views of roadmapping. For example the active involvement of the process facilitator in the participants' discussion to force the group to give attention to risk-related issues appears contrary to the norm of neutral facilitation (de Laat & McKibbin, 2002; Kerr et al., 2011). It is argued that the facilitator, by virtue of his/her position as the 'manager' of the roadmapping process, can influence the process and (perhaps, unwittingly) skew its outcomes to conform with his/her views. Another example is the introduction of dissent through devil's advocacy, to help to overcome groupthink, which might sometimes prevent the identification of risks. This has the potential of upsetting the consensus of the group towards collective action (Brunsson, 1982), which is one of the central attributes of roadmapping (see Section 2.1.3c). It therefore becomes important that risk is addressed in ways that do not destabilise the roadmapping process or undermine its essence and useful features.

Another critical feature of roadmapping is visualisation. As explained in Section 2.1.3c, visualisation plays an important role, both to support the process and in communicating the developed roadmap. It is important that this key feature is not only protected but used to the advantage of the risk-aware roadmapping process by using it in the step of risk communication procedure. Tables 4.7 and 4.8 give examples of how this can be done and it will be useful to apply some of these ideas in the risk-aware roadmapping process. For example, charts and visual structures with risk managing features can be used as process enablers (Eppler & Platts, 2009) to 'force' participants to provide relevant risk-related information, that otherwise would not have been supplied.

4.6 Summary

This chapter has provided a preliminary framework which shows the issues to consider in embedding risk management in roadmapping. The framework, which has been developed using input from theory and empirical research, identifies the manifestations of uncertainty in roadmapping and the effects on (or risks to) value creation in the firm that result from them. It also explains factors that influence how the uncertainties and risks might be addressed. By so doing it provides an understanding of the mechanisms of uncertainty and risk in roadmapping and sets a foundation for the creation of a risk-aware roadmapping process (which is the focus of Chapter 5 and the subsequent chapters).

Chapter 5 – A RISK-AWARE ROADMAPPING PROCESS

Chapter 4 developed and described a preliminary framework to provide understanding necessary for creating a roadmapping process that includes conscious and explicit risk management procedures (referred to as risk-aware roadmapping). The framework encapsulated factors that explain the manifestations of uncertainty and risk in roadmapping. Their implications for roadmapping were identified.

This chapter uses understanding from the preliminary framework to propose a detailed risk-aware roadmapping process. Section 5.1 indicates the desired features of the risk-aware roadmapping process based on the implications of the framework. Section 5.2 identifies (and gives an overview of) the baseline roadmapping method onto which relevant risk-managing tools and techniques will be integrated to give the risk-aware roadmapping process. Section 5.3 explains the tools and techniques to be integrated. Section 5.4 then provides a detailed description of the proposed risk-aware roadmapping process.

5.1 Desirable risk-aware roadmapping features based on factors and implications of the preliminary framework

Table 5.1 presents an outline of desirable features of risk-aware roadmapping in response to content-related and process-related factors that interact on the preliminary framework. The proper response to the environmental uncertainty is that potential risks (arising out of uncertainty) are identified, assessed and mitigated by drawing up appropriate responses to them. However, where ambiguity clouds the view of the future external environment, first, measures should be taken to reduce it. To address decision uncertainties which affect search and choice decisions of value propositions, measures that help in improving the structure and objectivity of these decisions should be introduced.

The quality and diversity of participation in the process directly affects the completeness and quality of information used to develop the roadmap, and the identification of uncertainties and risks pertaining to it. It therefore is important that in planning the risk-aware roadmapping process, reliable and diverse participants are selected and involved in the process as much as it is possible[27].

Influencing factors for risk-aware roadmapping		**Implications**	**Desirable features in risk-aware roadmapping.** Process should…
Content-related factors	Environment uncertainty (concerning external and internal organisational environments)	Ambiguity of future environment making the overall strategic direction of the roadmap unclear; Discrete risk events associated with the sources of environmental uncertainty that threaten the successful pursuance of value proposition(s).	clarify (or reduce) perceived ambiguity if it exists; identify uncertainties and potential risk events they introduce and address them
	Decision uncertainty (search and choice decisions regarding the roadmap's value propositions)	Uncertainty surrounding the search and choice of value proposition ideas may lead to sub-optimal value propositions.	improve (and structure) the decision processes
Process-related factors	Quality and diversity of participation	The 'completeness' and quality of information brought in and applied within the roadmapping process by participants (this also affects the ability to identify and address uncertainties and risks)	encourage the selection of diverse and reliable participation
	Biases: ambiguity aversion, illusion of manageability, prior hypothesis bias	Limited or distorted perception of uncertainty and risk (biases affect how environment uncertainty and decision uncertainty are addressed)	enhance/promote objectivity in the various procedures in the roadmapping process; 'force' participants to manage risk
	Consensus-driven nature of roadmapping (and groupthink)	This may strengthen biases (see above row) and lead to low quality decision (especially as a result of groupthink)	counter groupthink within the process but not at the expense of group consensus
	Time and resource constraints	Constraints place a limit on how much analysis can be carried out in roadmapping.	be designed to be relatively quick and easy to carry out
	Maintain essential features of roadmapping	Key features of roadmapping should not be eroded as a result of including risk management procedures	ensure features/benefits of roadmapping such as achievement of consensus and visualisation are maintained.

Table 5.1 – Summary of implications of factors identified from preliminary framework and desirable features of risk-aware roadmapping (in response to them)

[27] It is realised here that the selection of a diverse set of participants can be limited by the nature of the organisation (e.g. size of the organisation (or department)) that is undertaking the roadmapping exercise.

A diverse range of participants would limit the potential for groupthink, which can easily beset roadmapping due to its consensus-driven nature, to reduce the quality of decision reached and responsiveness to underlying risks and uncertainties. Other subjectivity-related issues such as biases that are identifiable in roadmapping can be countered by applying procedures that promote risk-awareness, structured thinking and objectivity. For example, visualisation (and other relevant techniques) should be made use of as much as possible, to confront participants with risk issues so that they are not ignored. All these must be traded-off against one another and the constraints of time and resource available for executing the roadmapping process, and the importance of keeping the overall process simple.

5.2 Roadmapping process used as baseline for creating the risk-aware roadmapping process

The high-level representation of risk-aware roadmapping (as shown in Figure 4.9) is an integration of risk management procedures into roadmapping. To operationalize this, it is necessary to identify a roadmapping methodology. As noted in Section 2.1.3b, there is no single universally accepted roadmapping method. Nevertheless, the need for a risk-aware roadmapping process that is easy-to-use, time efficient and effective (as noted in Section 4.5 and pointed out in Table 5.1) makes it necessary to choose a baseline roadmapping method that aligns with these characteristics. 'Fast-start' models of roadmapping (S-Plan and T-Plan developed and introduced by Phaal et al. (2007) and Phaal et al. (2001a) respectively) are flexible, scalable, rapid and efficient roadmapping methods which require minimal time and resource commitment, and therefore applicable in this context.

S-Plan roadmapping is appropriate for business level strategy[28] focusing on strategic challenges, exploring innovation opportunities and other critical issues. It is therefore suited to the front-end of innovation process. T-Plan focuses more directly on product-technology planning (for a single product) and attempts to detail a product's potential

[28] Also, S-Plan can be scaled up for application at the sector (industry or cross-industry) level. The Foresight Vehicle Technology Roadmap is an example of how S-Plan has been applied in this way (http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/Roadmapping/foresight_vehicle_v1.pdf). Phaal et al. (2007) records other examples of business level and sector level S-Plan application.

functions and features and the specific technology solutions for developing them (Phaal et al., 2010). The suitability of S-Plan to the front-end of innovation process makes it appropriate for use in developing the risk-aware roadmapping process, especially since the context of the research so far has been strategic and front-end innovation planning. As shown in Figure 5.1 T-Plan is applicable down the innovation funnel, to further develop a specific product idea.

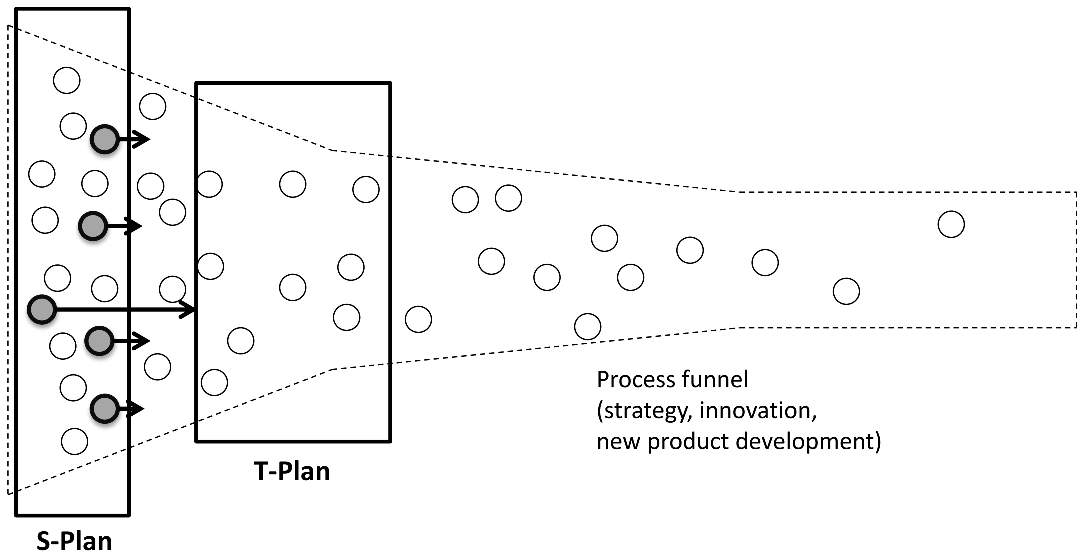


Figure 5.1 - Positioning of S-Plan and T-Plan roadmapping approaches (Phaal et al., 2010)

S-Plan relies on workshops, (usually a one-day workshop, but expandable to cover more days if so required), consisting of three steps:

- strategic landscape: the business is considered, using the roadmap framework to capture information from all the process participants as well as the identification and prioritisation (and choice) of value propositions (i.e. innovation opportunities or strategic topics) for further exploration
- topic exploration: the roadmap framework is used in small groups to explore and define each value proposition (or innovation opportunity) in greater detail and map out how they can be achieved

- review and way forward: topics are presented for discussion to agree on way forward for the roadmap in the context of strategic planning and innovation.

The workshop is preceded by a planning step and followed by an overall review process in which the learning from the process, the created roadmap and progress made in its implementation are re-examined (Figure 5.2). Time available for the workshop process can be maximised if some pre-work is done, specifically to gather information to be used for the strategic landscaping. This information can be gathered from the prospective participants themselves, to be presented and discussed at the beginning of the workshop[29].

The charts (visuals) applied in S-Plan are shown in Figures 5.3 (a step-by-step description of S-Plan is given in Table 5.8, alongside the details of the proposed interventions for addressing uncertainty and risk to create the risk-aware roadmapping process).

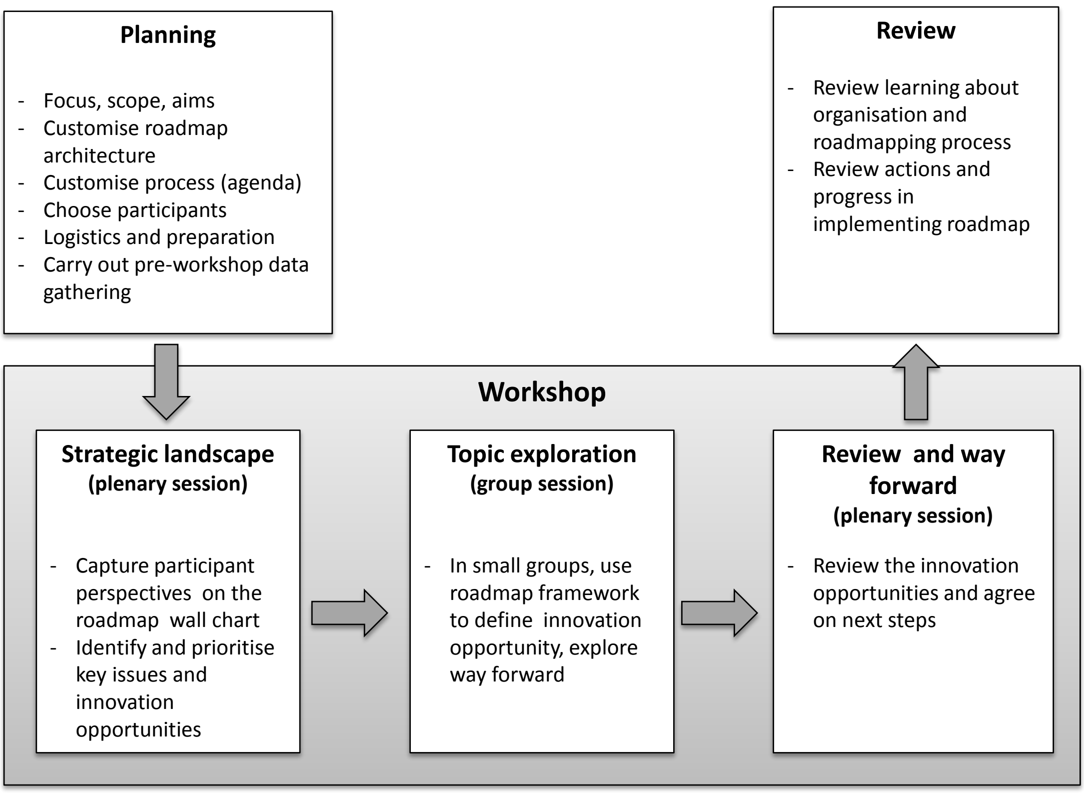


Figure 5.2 - S-Plan process (adapted from Phaal et al. (2007))

[29] This will save the time that would otherwise be spent during the workshop on brainstorming the information.

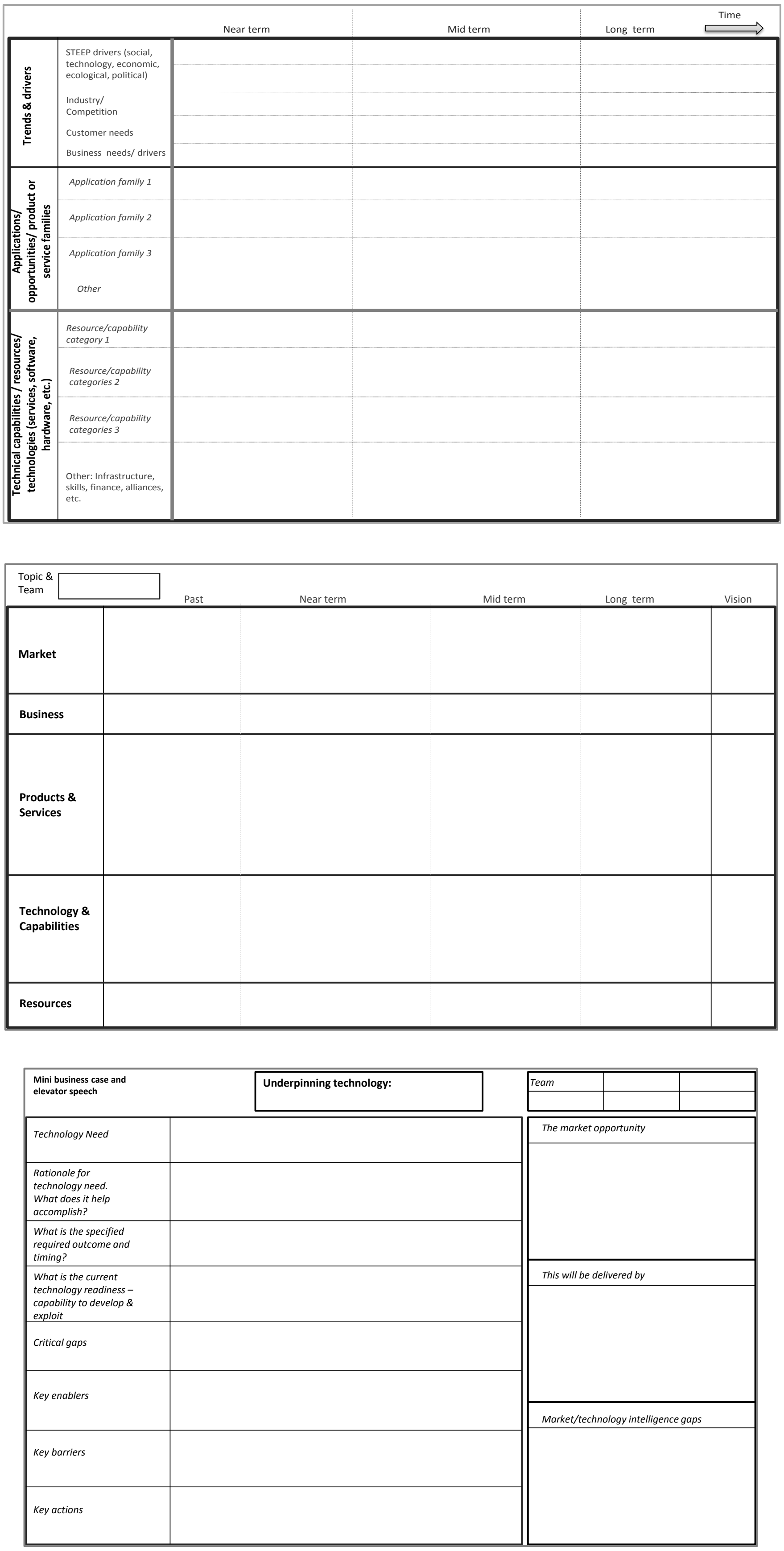


Figure 5.3 – Typical S-Plan strategic landscape (top), topic roadmap (middle) and feedback templates (adapted from Phaal et al., 2010)

5.3 Methods chosen for integration into S-Plan to develop risk-aware [strategic] roadmapping (RSRM) process

The choice of methods for integration into S-Plan to produce the risk-aware [strategic][30] roadmapping (RSRM) process is based on the suggestions of roadmapping practitioners (and observations from practice) as identified in Table 4.5. The methods are:

- Scenario planning
- Brainstorming (with prompt lists and PESTLE/SWOT analysis)
- Assumptions analysis (with devil's advocacy and SWIFT (Structured What-If Technique))
- Probability-impact assessment
- TRL-risk assessment
- Risk-reward assessment
- Real options thinking (with rolling wave planning)
- Decision trees
- Multi-Criteria Decision Analysis (MCDA)
- Blind-voting techniques
- TRIZ (theory for inventive problem solving)

Collectively, as shown in Table 5.2, these methods can help facilitate suitable responses to the desired features for risk-aware roadmapping summarised by Table 5.1.

However, the manner in which these techniques will be used within S-Plan (the baseline roadmapping process chosen) should not be construed as the only way in which they can be applied. Some of them are applicable in multiple formats. The following paragraphs give a brief explanation of these methods. This is followed by an explanation of the specific manner in which they are applied within S-Plan to create the RSRM process, which is designed to conform to guiding principles of strategic management toolkit design.

[30] The use of the term 'strategic' as a descriptor of the risk-aware roadmapping process developed reflects the usage of S-Plan as baseline roadmapping process. S-Plan provides a strategic outlook on innovation and this distinguishes it from other specific formats of roadmapping e.g. T-Plan which may take a more constrained product (or project)-specific outlook.

Desirable features in risk-aware roadmapping (taken from Table 5.1)	**Responses (procedures, methods or techniques)**
Clarify (reduce) ambiguity where it exists	Apply scenario planning techniques
Identify uncertainties and potential risk events they introduce and address them	Risk identification: brainstorming, assumption analysis, SWIFT, checklists/prompt lists, devil's advocacy, SWOT analysis Risk assessment: probability-impact assessment; risk-reward assessment, TRL assessment Risk treatment: real options thinking, rolling wave planning and standard risk treatment responses: such as risk avoidance and risk sharing
Improve the search for, and choice of, value propositions	Improvement of search routine: TRIZ; improvement of choice: MCDA, blind voting techniques
Encourage the selection of diverse and reliable participation	Careful thought should be put in choice of participants while planning the roadmapping process
Enhance/promote objectivity of the various procedures in the roadmapping process	Enhancement of objectivity: devil's advocacy, assumption analysis, SWIFT, MCDA, blind-voting techniques, TRIZ
Force participants to address risk and uncertainty	Use of visualisation (alongside other techniques) during the process to ensure risk issues are visible and addressed
Overall process should be quick and easy to carry out	Apply methods and techniques in simplified formats to avoid an overwhelmingly complex roadmapping process.
Ensure key features of roadmapping, e.g. consensus building and visualisation, are not eroded	Apply visualisation as much as possible in addressing uncertainty and risk; facilitator would need to balance the inclusion of techniques like devil's advocacy with maintaining group agreement (which is vital for roadmap implementation).

Table 5.2 - Responses to desired features for risk-aware roadmapping

5.3.1 Description of methods

Scenario planning

Scenario planning is an approach for taking into account uncertainty in making strategic choices. A key output of scenario planning is a set of *scenarios*, each of which is "an internally consistent view of what the future might turn out to be" (Porter, 1985, p 446). Scenarios give structure to the perceptions about the future and are especially useful under high uncertainty (Shoemaker, 1991). They do not accurately predict the future, but provide bounds to an uncertain and complex outlook, along with a range of plausible future states, as illustrated by the scenario funnel depiction of Timpe & Scheepers (2003) (Figure 5.4).

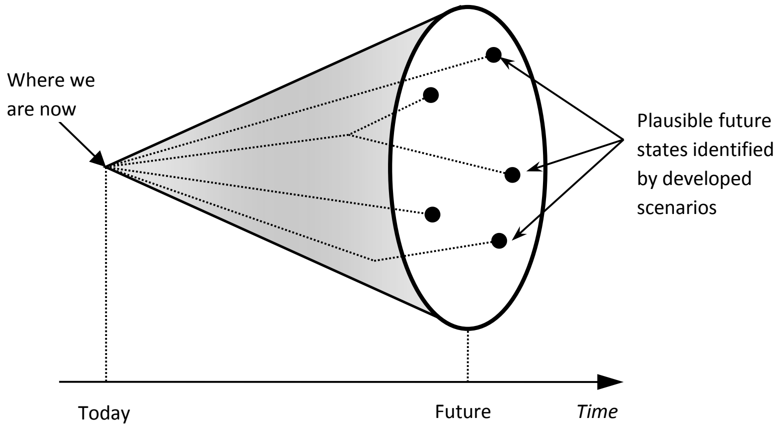


Figure 5.4 - Scenario funnel (Timpe & Scheepers, 2003)

It is important to draw out the difference between scenario planning and scenario building as pointed out by Chermack (2004). Scenario building is the construction of scenarios, and is only part of the larger scenario planning process. Schwartz (1991) provided a six-step process for building scenarios. These are: 1. Identify focal issue and strategic concerns, 2. Identify key factors and stakeholders in the environment, 3. Identify key environmental drivers, 4. Rank factors and identify critical uncertainties, 5. Select scenario logics, and 6. Flesh out scenarios. The scenarios, once created, are linked to strategic planning and decision-making. Wilson (2000) identified 4 ways in which scenarios may be used:

- Sensitivity/risk assessment: evaluating the resilience of a strategic direction against different business conditions (modelled according to the scenarios)
- Strategy evaluation: using scenarios as ‘test beds’ to evaluate the effectiveness of a strategy against the business conditions so as to modify the strategy and include appropriate contingencies

- Strategy development (using a ‘planning-focus’ scenario): selecting one of the scenarios created (the ‘most probable’ one), to focus the strategic plan while the others are used to make contingency plans
- Strategy development (without using a ‘planning-focus’ scenario): all scenarios developed are given equal level of importance as being equally likely, to create a strategy that is resilient across all the scenarios. Wilson (2000) explained that it is this fourth option that makes optimal use of scenarios.

Brainstorming

The brainstorming technique was not created specifically for risk management, but developed by Osborn (1957) as a means of idea generation (especially within a group). However, is particularly useful for identifying the risks associated with a new venture where there is no previous data (ISO 31010, 2009). The relatively unstructured nature of brainstorming makes is relatively quick and easy to set up and apply, but makes it difficult to ensure a comprehensive identification of risks (ISO 31010, 2009). Application of brainstorming with structures or frameworks such as prompt lists, and PESTLE framework (discussed in the following paragraphs) provides confidence that risk identification has been comprehensive across relevant risk categories.

- *Prompt lists (and checklists)*

  Prompt lists and checklists facilitate risk identification. Prompt lists indicate categories of risk e.g. economic, technological, social, technical, developmental etc. that are relevant to an issue under consideration. This makes them different from checklists, which provide a standard list of risks developed specifically for a procedure, usually drawn up based on experience of the organisation in carrying out that procedure (or based on a particular industry’s standards). Prompt lists are more flexible than checklists since they allow the inclusion of previously unidentified risks and issues, and are therefore considered more suitable for ill-defined problems as would be seen in strategic planning (Merna & Al-Thani, 2005; ISO 31010, 2009).

- *PESTLE (and SWOT) analysis*

  The PESTLE framework provides a structured approach to risk identification; especially external (or market-related) risks and may be used in this manner as a generic prompt list. It focuses on political, economic, sociological, technological, legal and ecological issues. PESTLE may be used in conjunction with the SWOT (strengths, weaknesses, opportunities, and threats) framework (Hopkin, 2010), which has its origins in the works of Learned et al. (1969) (as initially indicated in Section 2.2.1). SWOT can be used as a stand-alone tool and basis for strategic planning, but also as a framework for identifying risks internal and external to the organisation, when used in conjunction with brainstorming techniques (Hopkin, 2010).

<u>Assumptions analysis</u>

In assumptions analysis, knowledge assumptions made in developing a plan are identified and assessed to understand the impact they would have on the outlined plan (and its objectives) if they turned out to be false assumptions (Merna & Al-Thani, 2005). Those assumptions that would negatively impact the objectives provide an indication of risks. The assumptions underlying a proposed plan are not always obvious, which can make them difficult to identify. Methods such as devil's advocacy and SWIFT (structured what-if technique) can help in identifying them.

- *Devil's advocacy*

  Devil's advocacy is a means to introduce formalised dissent and debate into decision-making, especially when premature consensus might inhibit the challenging of assumptions (Schwenk, 1984). It is most useful in major strategic decisions in uncertain environments where the decision outcomes are often subjective (Herbert & Estes, 1977). The role of the devil's advocate is taken up by a person, to examine a strategy by identifying the underlying assumptions to the plan, critique these assumptions and provide alternative strategies based on the critique (Cosier, 1981). Thus, logical faults, misconceptions and inaccuracies (and risks) can be identified and rectified or mitigated.

- *Structured What-If Technique (SWIFT)*

  SWIFT is especially suitable in a facilitated workshop, to help a decision-making group to identify assumptions and risks. The application of SWIFT requires the use of prompts, phrases, or words in 'what-if' questions by the workshop facilitator to encourage participants. SWIFT can be applied very rapidly and requires minimal preparation by the team who are to respond to the what-if questions for major risks to be identified (ISO 31010, 2009).

<u>Probability-impact assessment</u>

Probability-impact assessment is used to rank risks, by combining their qualitative or semi-quantitative ratings of impact and probability to indicate the severity of the risks (ISO 31010, 2009). It is used as a screening tool to determine which risks are most critical and need further detailed analysis or treatment, and which ones are mild enough that they can be retained or neglected. The probability-impact assessment is usually carried out using a probability-impact matrix (see Figure 5.5). The probability-impact matrix is relatively quick and easy to use, however, it will be necessary for the users to define or customise the probability and impact scales to suit their application (Merna & Al-Thani, 2005). The probability-impact matrix is particularly appropriate for situations where there is not enough information for detailed analysis or in situations that do not require the rigor, time and effort for quantitative analysis (ISO 31010, 2009).

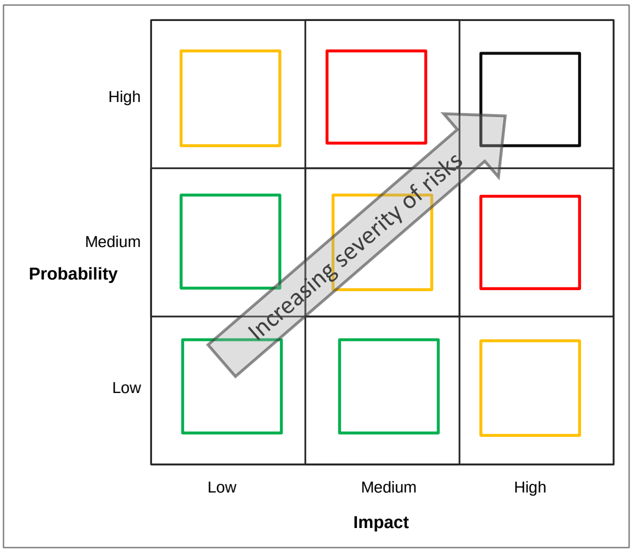


Figure 5.5 – Probability-impact matrix (adapted from Merna & Al-Thani, 2005)

TRL-risk assessment

Technology readiness levels (TRLs) were created by NASA and the US Department of Defence (DoD) in mid-1970s to assist with new technology development process. TRLs serve as part of the technology readiness assessment process, to evaluate the maturity or readiness of a technology or component to function in an integrated environment (Collins & Pincock, 2010; Nolte et al., 2003). There are nine TRLs as defined by the DoD (see Table 5.3).

Level 1	Basic principles observed and reported
Level 2	Technology concept and/or application formulated
Level 3	Analytical and experimental critical function and/or characteristic proof of concept
Level 4	Component validation in laboratory environment
Level 5	Component validation in relevant environment
Level 6	System/subsystem model or prototype demonstration in a relevant environment
Level 7	System prototype demonstration in an operational environment
Level 8	Actual system completed and qualified through test and demonstration
Level 9	Actual system proven through successful operations

Table 5.3 – Technology readiness levels (adapted from Nolte (2003))

TRLs provide an indication of the level of technology-related risk involved in development (or transitioning to the next stage of development) of a technology-based system (Nolte, 2003) (see Figure 5.6 and Figure 5.7). Figure 5.7, adapted from Collins & Pincock (2010), matches TRLs to risk levels with greater detail than Figure 5.6, albeit with an additional TRL (TRL 10: commercial production readiness). It must be noted however that there is a great degree of overlap across the risk levels matched to the TRLs due to the subjective nature of the risk scale (i.e. very high – very low). However, these can still provide useful insight to provide an indicator of technology risk level associated with pursuing a technology-based value proposition.

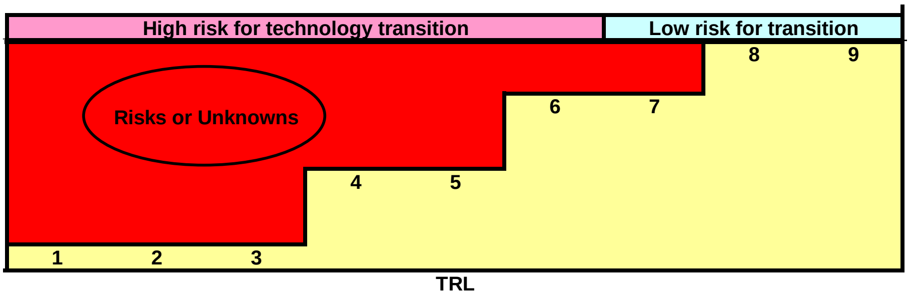


Figure 5.6 – TRLs and risk of technology transition (Nolte, 2004)

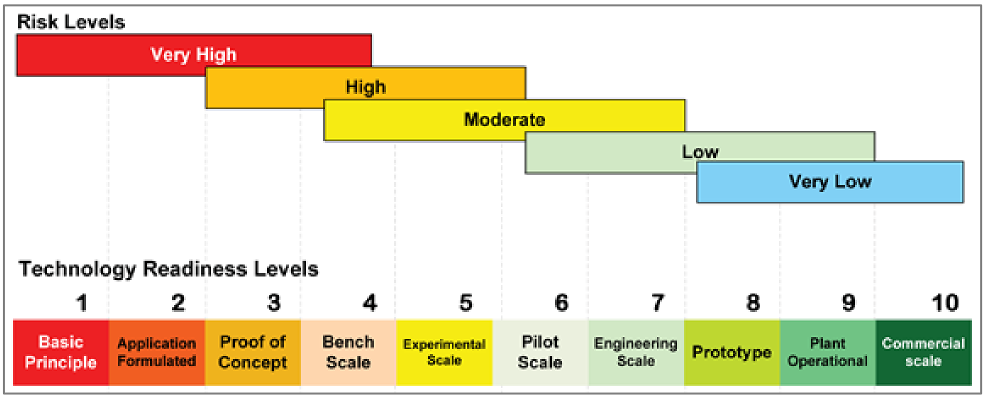


Figure 5.7 – Risk and technology readiness in parallel (adapted from Collins & Pincock (2010))

Risk-reward assessment

Risk-reward assessment is a risk assessment tool and also a portfolio management method. It assesses the risk associated with a proposed project (or value proposition) with the reward or benefit expected from it (e.g. in terms of market value or other measures such as NPV and IRR[31]). The assessment can be carried out quantitatively or qualitatively. One of its simple formats is the 2-dimensional risk-reward matrix (Figure 5.8), in which one of the axes represents risk (or probability of success in technical and/or commercial terms) and the other the expected reward (Cooper et al., 2001). The axes of the matrix may need to be defined in specific terms or values specific to suit the user's application. As indicated by Cooper et al. (2001), a number of other tools such as the cost-benefit assessment and ease-attractiveness assessment are similar in form to the risk-reward tool and are similarly applied.

[31] NPV - Net Present Value; IRR - Internal Rate of Return

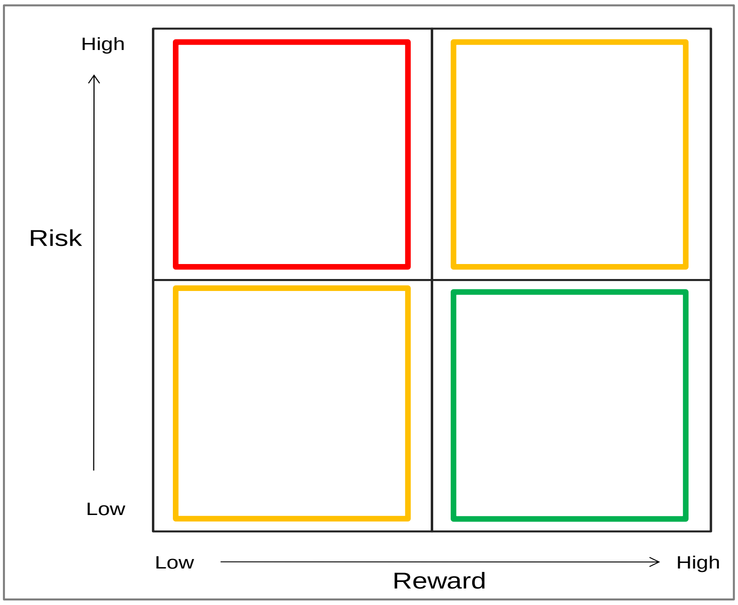


Figure 5.8 - Risk-reward matrix (adapted from Cooper et al. (2001))

<u>Standard risk treatment responses</u>

Risk treatment involves the selection among the various ways of modifying risks and the implementation of the selected options. Standard responses for risk treatment as recorded by ISO 31000 (2009) include:

- Risk avoidance by deciding not to start or continue the activity that gives rise to the risk
- Removing the risk source
- Changing the likelihood
- Changing the impact
- Sharing the risk with another party (e.g. insurance)
- Retaining the risk by informed decision

Treatment options can be applied individually or in combination. However, it must be pointed out that these are only suggestions and guidelines, and it is impossible to provide a detailed list of ways in which specific risks should be handled.

Real options thinking

Real options thinking (or options thinking/reasoning) gives insight on how decisions concerning strategic investments can be directed under uncertainty. It is an application of the real options theory, which in turn, is based on financial options theory.

In the financial sense, options give the right to buy or sell a stock or other asset at a predetermined price without being obliged to do so (Amram & Kulatilaka, 1999). So investors can spend a little in the present to buy the option, and that gives them the flexibility or choice on whether or not to buy the stock associated with that option in the future. Options therefore provide a way of managing risk introduced by the uncertainty over the fluctuations and viability of a stock investment. They enable investors to put off an investment decision until there is enough clarity or a clear opportunity to be gained from it. Real options theory extends the same principles to real investments (e.g. technology, new product development projects) to provide a background for strategic analysis of the investments based on assumption of managerial flexibility (Micalizzi & Trigeorgis, 1999).

It has been realised that the initial attempts (by several scholars) to apply the theory to [real] investment valuation are based on flawed assumptions and face severe limitations (Hunt et al., 2004). However, other ideas from the theory have found value in practice such as providing a way of *thinking* in strategic planning (Barnett, 2003; Micalizzi & Trigeorgis, 1999). Real options thinking, helps in setting up contingencies and designing flexibility into strategic decisions without undertaking the overly complex calculations that real option valuation models introduce (Faulkner, 1996). Table 5.4 describes the flexibility introduced by some of standard real options. Some of them are naturally occurring or inherent (and simply need to be recognised) while others might need to be created or built into strategic decisions.

- *Rolling-wave planning*

  The rolling-wave planning approach is a concept borrowed from project risk management. It "recognises that firm commitments cannot be sensibly made on incomplete knowledge [i.e. uncertainty]" (Pender, 2001, p 84), and therefore, concrete plans are extended into the future in relatively short bursts, only as far as available knowledge allows. This approach shares similarities with options thinking principles, in that it recognises that some uncertainties may resolve themselves over time and thus tries to retain the managerial flexibility to adapt to knowledge and information (which helps to clarify uncertainty) as it emerges.

Category	**Type of real option**	**Description of flexibility**
Inherent options	Option to wait/defer investment	Wait until more information is available to resolve uncertainty
	Option to shutdown/restart	Shutdown an unprofitable venture until it is profitable to restart it
	Option to abandon	Abandon venture permanently to truncate losses in severe cases of market decline
Created options	Option to alter operating scale (e.g. to expand, to contract)	Alter operating capacity depending on market conditions
	Option to switch (e.g. outputs or inputs)	Flexibility to change the nature of the input or output of operation
	Option to stage investments/ compound option/ sequence options	Option to break up investment into incremental [conditional] steps
	Growth (strategic)option	Flexibility for future expansion

Table 5.4 - Types of real options (adapted from Trigeorgis, 1995)

Decision trees

Decision trees facilitate the diagrammatic representation of a complex structure of decisions, which allows their understanding and communication (Wright & Goodwin, 2008). A typical decision tree shows the possible outcomes for a sequence of actions or decisions (Figure 5.9). The visual representation (and evaluation) helps in selecting an appropriate course of action when there is uncertainty on how to proceed based on the possible outcomes and their likelihood of occurrence (ISO 31010, 2009). However, to be useful in this way, it would be necessary to have an exhaustive view of all the different decision options and the different possible outcomes and an estimation of their occurrence. This may be particularly difficult in high-level strategic planning and especially at the front-end of innovation where an exhaustive view of outcomes and end-results would be impossible to determine. Nevertheless, decision trees remain useful as a visualisation tool to show a sequence of uncertain or complex decisions embedded in an action plan.

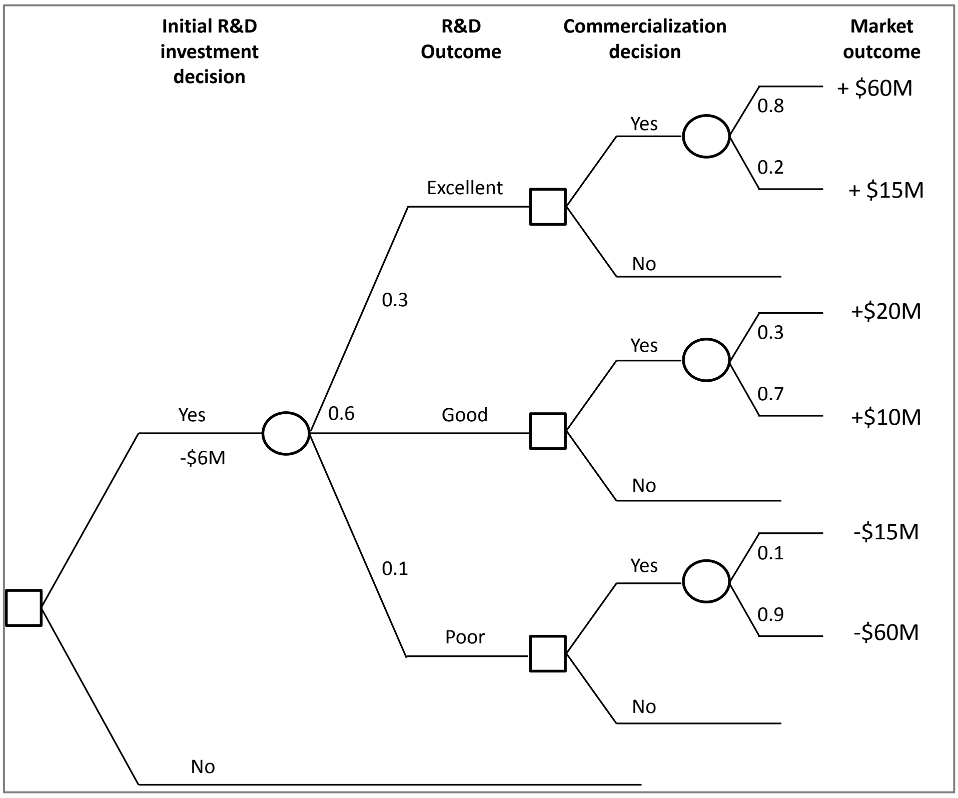


Figure 5.9 – Decision tree showing uncertainties and returns (adapted from Faulkner, 1996)

Multi-criteria decision analysis (MCDA)

Multi-criteria decision analysis is applied to reduce the difficulty of prioritising a set of alternatives by decomposing a decision situation into smaller problems that can be solved objectively (Wright & Goodwin, 2008). The goal is to apply a set of criteria that can be used equally across the set of alternatives (e.g. a set of value propositions) to transparently evaluate them and reach consensus on the most attractive one(s). First, the criteria are identified, and the importance of each criterion is determined relative to the others, by assigning numerical weights to them. The alternatives are then evaluated based on each criterion (and assigned a score) (see Table 5.5). By aggregating the scores for each alternative across the multiple criteria applied, and comparing the aggregate scores of the various alternatives against one another, a ranking of the alternatives would emerge and 'best' alternatives can be selected (ISO 31010, 2009). There are variants of MCDA including Weighted Scoring Model (WSM) and Analytical Hierarchy Process (AHP) (Gindy et al., 2006; Triantaphyllou & Mann, 1995). The WSM is the most commonly used and simplest approach. It is important that whatever approach is used in MCDA is understandable to all process participants, as mathematically sophisticated models that are cannot be understood by participants are of very little practical value (Stewart, 2005).

	Criteria (and weighting)				**Score (Weighted sum)**
Alternatives	**Criterion 1 (40)**	**Criterion 2 (25)**	**Criterion 3 (20)**	**Criterion 4 (15)**	
Alternative 1	***w***	***x***	***y***	***z***	= 40w + 25x + 20y + 15z
Alternative 2					
Alternative 3					
Alternative 4					
Alternative 5					
Alternative 6					

Table 5.5 – A depiction of the application of weighted scoring model (WSM) for MCDA

Blind voting techniques

The *blind voting techniques* described here are modified versions of the usual-practice dot-voting method (commonly used in workshop forums for choosing favourites or priorities from a list of alternatives[32]). The modifications are to improve the manner in which the uncertainty surrounding choice decisions within the process is addressed, and thereby improve the quality of the value proposition prioritisation and selection. Two forms of blind voting are suggested: semi-blind dot-voting and blind voting. In semi-blind dot-voting, the participants are presented with the set of alternatives individually (e.g. on a piece of paper) and encouraged to make up their minds independently on their preferred choice(s) (without consulting one another). Each participant then proceeds to the wall chart (on which the alternatives would be represented) to use the sticky dots to signify the choice(s) he/she had made. After the participants have identified their choices,

[32] See footnote in Section 4.3.2a and report by The Consulting Partnership (2012)

the votes are then collated openly. This attempts to keep the transparency of the dot-voting process while reducing in-group pressures and biases (and other influences such as the effect of prior votes and voting saturation (The Consulting Partnership, 2012)), which can negatively impact choice decision quality. In the case of blind voting, participants pass on their choice(s) directly to the facilitator who collates the results and feeds them back to the entire group. While this also removes groupthink in setting priorities, some of the transparency of the voting process is lost, and the participants would need to trust the facilitator to present accurate results.

TRIZ

TRIZ is an acronym for "**T**eorija **R**ezhenija **I**zobretatelskih **Z**adach", which is Russian for "theory of inventive problem solving" (Rantanen & Domb, 2008). TRIZ is perceived to be useful for addressing the uncertainty (or reducing the ambiguity), which can cloud the search or ideation process especially in the front-end innovation planning, and raise the risk of missing innovation ideas that otherwise could be profitable to the organisation. TRIZ was developed by Genrich Altshuller (a Russian scientist and engineer, 1926-1998) and it rests on the premise that the evolution of technical systems[33], through continuous innovation and invention over time, is not a random process, but is predictable and governed by certain laws (Eversheim, 2009). Thus, TRIZ explains innovation and inventive problem solving through analytical logic and systematic thinking (Savransky, 2000). This systematic approach gives TRIZ advantage over other methods (e.g. brainstorming, lateral thinking, morphological analysis, etc.), in idea generation for innovation. Through it, the most viable ideas and inventive solutions are considered for an innovation problem area or situation (Gadd, 2011), and this reduces the risk of missing valuable innovation ideas.

The TRIZ methodology consists of several concepts, tools and techniques. While there is no strict sequence to applying these (Eversheim, 2009), a framework by Pannenbacker (2001) that groups some of the tools according to application areas provides a view on how they may be applied coherently (see Table 5.6). This framework suggests tools within the ***goals*** application area are appropriate for identifying new innovation ideas.

[33] The portable music player system is an example of a technical system. Their development from cassette players, to compact disc players and now MP3 players is an example of how technical systems evolve.

However, ***understanding the current state*** may also point to the deficiencies in currently available products, which can stimulate innovation ideas.

Application area	TRIZ concept/ tool/technique
Understanding the current state: what is the current (or problem) situation?	Contradiction
	Function analysis
	Substance field analysis
	Patterns of evolution
Goals (for an intended state): which objectives are to be fulfilled (e.g. what value propositions to be pursued)?	Ideal final result
	Fitting
	Patterns of evolution
Transformation: how can the current state be transformed into achieve the goals in the intended state?	Inventive principles
	Contradiction matrix
	Separation principles
	Substance-field analysis
	Patterns of evolution
	Resource analysis
	Effects database
Resources: what is the best use of resources to achieve transformation?	Resource analysis

Table 5.6 - Classification of TRIZ tools according to application field (adapted from Pannenbacker (2001) through Moehrle (2005))

5.3.2 Process design considerations (and exclusions)

In integrating these methods into roadmapping, the overall process should remain simple and quick to carry out. This implies that the methods should be integrated in easy-to-apply formats. In addition, features of roadmapping such as visualisation, consensus generation and neutral facilitation[34] (Kerr et al., 2011) should be promoted as much as possible. Table 5.7 provides the mode of application of the methods (discussed in Section 5.3.1) in the RSRM process along these lines.

There is a notable exclusion in the design and description of the RSRM process that follows. The application of TRIZ in the process has been omitted even though it had been identified as a means to improve the idea generation procedure (over brainstorming) and

[34] The facilitator should be concerned with structuring and running the process and not contribute to the strategy content, so as not to skew the outcomes, as discussed in Section 4.5.1.

reduce the risk of missed opportunities. While the role and applicability of TRIZ to roadmapping was anticipated, the understanding of TRIZ methods and techniques, and their combination with S-Plan were found to be beyond the scope of the PhD research project[35]. The described RSRM process therefore reverts to using the brainstorming technique for ideation (in place of TRIZ).

Beyond the specific set of methods and techniques applied here, several other risk management methods exist which with appropriate modification perhaps can be integrated into roadmapping. These methods are identified (along with some of the ones highlighted above) and appraised in Appendix 5[36]. Appendix 5a shows the range of risk management methods drawn from risk management literature, while Appendix 5b classifies them into core, supporting and industry-specific methods. Core methods are those designed specifically for risk management and are generic enough to be applied in any industry. Industry-specific methods are the risk management methods likely to be used only in certain industries. Supporting methods are those that can be applied generally in risk management, but also for other issues other than addressing uncertainty and risk. Appendix 5c focuses on the core and supporting tools (since these will support the generic nature of roadmapping) and classifies them according to their applicability in a roadmapping workshop setting[37].

[35] The relationship between roadmapping and TRIZ has since been further explored by the researcher (Ilevbare et al., 2011; Ilevbare, et al., 2013).
[36] Appendix 5, 'Looking further afield (consideration of the applicability of other methods and techniques in roadmapping', explores a wider set of risk management methods drawn from risk management literature.
[37] This appraisal is based on the researcher's understanding of the various risk management methods.

Method/ technique	Objective(s) and conventional mode(s) of application	Adopted (simplified) mode of application for application in RSRM process
Scenario planning	Build up to 4 scenarios. Then use scenarios for: - sensitivity/risk assessment of a strategy - strategy evaluation - strategy development based on the 'most probable' scenario - strategy development using all scenarios	Use when faced with ambiguity. Build 2 scenarios to clarify the future view (build scenarios before roadmapping workshop). Develop roadmap (strategy) using all (both) scenarios: during workshop, develop 2 strategic landscapes, one for each scenario, identifying pertinent issues in each one (and comparing where there are overlaps and differences).
Brainstorming	Identification of risks by thinking of ways things might go wrong	Same. Structure brainstorming according to the focus of the roadmap. Risk identification can be facilitated using prompt lists drawn up according to the PESTLE framework. Introduce a 'risk layer' into the topic roadmap charts used to ensure that risk identification is not ignored *(visualisation)*
Prompt lists	To provide classes of risk relevant to the focus of planning to guide the identification of pertinent risks	Same. Prompts are drawn up in line with the PESTLE framework (and roadmap focus) to facilitate brainstorming of risks. Embed prompts into the background of the designated 'risk layers' in roadmap charts used *(visualisation)*
Assumptions analysis	To intuitively identify and assess assumptions implicit in a plan, to uncover risks.	Same. Facilitate assumptions analysis using SWIFT and Devil's advocacy techniques. Introduce an 'assumptions layer' on the roadmap charts used for the explicit assessment of assumptions (visualisation)
Devil's advocacy	To introduce formalised dissent into the planning process by choosing a member of the planning team as the devil's advocate, to critique assumptions underlying strategy	Same. Apply under assumptions analysis in conjunction with SWIFT
SWIFT (Structured What-if Technique)	To ask the questions "what if…?" in an attempt to identify underlying assumptions and risks in a plan. Usually the workshop's facilitator's responsibility to ask the "what if…?" questions	Same. Apply within assumptions analysis in conjunction with devil's advocacy. Facilitator should remove him/herself from the groups deliberations *(to maintain neutrality)* by delegating the role (of questioning) to the devil's advocate
Probability-impact assessment	To assess the severity of identified risks. Can be carried out qualitatively or semi-quantitatively to screen the identified risks and indicate which require further attention	Apply qualitatively. Introduce a probability-impact matrix as one of the charts used in the roadmapping workshop *(visualisation)*

Table 5.7 – Adopted modes of application of selected methods for developing the RSRM process (continued next page)

TRL-risk assessment	To assess the level of risk associated with a specific technology by virtue of its level of maturity.	Apply as a visual aid/scale (e.g. on a wall chart) to help in identifying the risk associated with a technology (that underpins a product or value proposition) identified for acquisition or development.
Risk-reward assessment	To assess a set of value propositions (prospective products, services, and projects) based on the benefit (or reward) they are expected to generate and the level of risk associated with the pursuance of the value proposition. Can be carried out quantitatively or qualitatively.	Apply qualitatively. Introduce a risk-reward matrix as one of the charts used in the roadmapping process *(visualisation).* Use during or after the roadmap workshop (depending on workshop time availability) to reappraise high-ranking value propositions identified on the strategic landscape roadmap.
Standard risk treatment responses	To draw up appropriate responses to risks assessed. Standard responses include: risk avoidance, removing the risk source (if possible), change likelihood, impact, sharing or retaining the risk.	Apply risk treatment responses as suggestions in the roadmapping process (include responses relating to options thinking in the responses). Include a risk treatment chart for drawing up responses to most critical risks.
Options thinking	To design flexibility and contingencies into action plans	Same. Apply along with the standard risk treatment responses (and rolling wave planning) to suggest ways for treating risks.
MCDA (multi-criteria decision analysis)	To help prioritise a set of alternatives, by applying appropriate criteria to objectively evaluate the alternatives and reach consensus on the most attractive ones.	Same. Apply MCDA using the weighted scoring model (WSM).
Semi-blind voting	To reduce the influence of groupthink in setting priorities.	Apply in identifying priorities during roadmapping workshop. May be applied alongside MCDA to score the alternatives
TRIZ (Theory of inventive problem solving)	A collection of concepts, methods and techniques for generating new product ideas and providing innovative solutions to problems based on structured thinking and analysis.	Techniques and concepts to apply from TRIZ (and mode of application) to roadmapping are not entirely clear at this point due to the extensive nature of TRIZ methodology. However, it is expected that the following TRIZ tools will be useful for ideation of value propositions in roadmapping *ideal final result, evolution analysis, function analysis and evolution analysis*
Decision trees	To facilitate decision-making under uncertainty through the diagrammatic representation of complex decisions, which also promotes communication	Apply decision trees only as a visualisation aid on the finished roadmap

Table 5.7 (contd.) – Adopted modes of application of selected methods for developing the RSRM process

5.4 Description of the proposed risk-aware [strategic] roadmapping (RSRM) process

5.4.1 Background, scope and assumptions of the RSRM process

The RSRM process described here has been developed in response to the observed lack of explicit guidance for managing uncertainty and risk in roadmapping (and wider strategic planning). The process proposed is based on the desirable features for risk-aware roadmapping identified through roadmapping expert practitioner discussions and case studies of roadmapping exercises discussed in Chapter 4 and summarised in Table 5.1.

While the RSRM process's intended application is focused on the front-end of innovation (according to the direct scope of this study), it is considered applicable to other strategic planning issues in the firm. The process is designed using S-Plan as a baseline roadmapping process, which assumes the time limitation of a one-day workshop process. However, it might be scaled-up to allow more time according to the scope and complexities of the strategic issue and (and time and resources available to the performing organisation). The process suggested is top-down oriented, i.e. it begins with the top layers of the roadmap by identifying external environment trends and drivers, and works its way downwards through the layers in a step-wise manner until the actions that need to be taken become clear.

The RSRM process relies on the most basic of resources: paper (for visualising the roadmap framework and other workshop charts and templates), sticky notes (for capturing and conveying knowledge and data to the charts and templates), and pens. The process relies on the involvement and collaboration of expert participants and is managed by a facilitator, who may be external or internal to the organisation for which the roadmap is created. The facilitator is different from the business owner or process sponsor[38] who is internal to the organisation and would own and apply the created roadmap.

[38] The process sponsor is regarded as the person who recognises the need for a roadmap within the organisation, and is ultimately responsible for providing the internal support needed to the roadmapping facilitator.

Following on from S-Plan, the main phases of the RSRM process are:

a. planning and pre-workshop preparation phase

The RSRM's planning phase incorporates procedures from the planning step of the standard risk management process (ISO 31000, 2009) into the planning required for S-Plan.

b. workshop phase

The major steps outlined for the workshop phase are based on the agenda of S-Plan.

i. Strategic landscaping and prioritisation: this plenary stage reviews the pre-workshop knowledge captured from the participants across the full scope of the roadmap. Market trends and drivers, value propositions, i.e. products (and services), and technology and resources (necessary for the value propositions) are reviewed, clustered and prioritised at this stage.

ii. Topic exploration: the most important topics (or value propositions) are explored in-depth in small groups. This stage points out the way forward for each of the selected priority topics in more detail.

iii. Review and way forward: the topics are presented for discussion and decisions are made on which to take forward.

c. post-workshop phase (reporting and review)

The data emerging from the strategic landscape and topic roadmaps are delivered to the process sponsor in form of a report. Ideas for visualisation pointed out in Section 4.4.2b (e.g. use of traffic colour schemes and decision trees) are used where applicable in the report. The RSRM process is reviewed in line with action research process followed in this phase of the research (see Section 3.3.2).

Table 5.8 presents a detailed outline of the RSRM process, giving a step-by-step description of the S-Plan and the interventions made at each stage to integrate risk management into it. Figures 5.10, 5.11 and 5.12 present flowcharts of the process.

Table 5.8 – Step-by-step description of the risk-aware strategic roadmapping (RSRM) process

Road-mapping stage	S-Plan steps (baseline process) (Phaal et al., 2010)	Proposed interventions (modifications and/or insertions)	Methods and techniques applied (for intervention)	Corresponding stage in generic risk management process (or purpose) (Figure 4.9)
Planning and pre-workshop data gathering	Define objectives and need for roadmap	Identify specific objectives (if any) for managing risk during the roadmapping process	None (Facilitator/process sponsor discussion)	Risk management planning
	Define scope of the roadmapping activity	Ensure there is an understanding of the extent of the risk management intervention	None (Facilitator/process sponsor discussion)	
	Agree on format of the roadmapping process	Agree on the risk techniques that will be applied	None (Facilitator/process sponsor discussion)	
	Customise the dimensions (layers and timescale of the roadmap).	None. Identified layers and sub-layers would indicate generic sources of uncertainty and risk	None (Facilitator/process sponsor discussion)	
	Identify participants in the roadmapping activity	Ensure that the participation is as diverse and reliable as possible. Assign any special responsibilities (e.g. devil's advocate) if there is a person clearly suited for the role.	None (Facilitator/process sponsor discussion)	
	Collect pre-workshop information/data	Participants should assign confidence ratings to market trends and drivers data they provide	None	To identify areas of ambiguity in market-related data

	Collect pre-workshop information/data (contd.)	Assess confidence ratings of market trends and drivers-related information. Determine from data if there are any key trends/drivers (particularly important to the business) around which there is a high level of uncertainty on how they will turn out. Decide if there is a need to develop multiple views of the future (using scenarios) and having two strategic landscapes.	None (Data inspection and discussion with process sponsor)	To identify ambiguity on any of the key drivers to warrant creation of alternative roadmaps.
		[If yes, develop two views of the future market, which would be presented and applied during the workshop]	Scenario building	To ease (or address) ambiguity by creating structured alternative views of the future. Each view of the future will be used to populate the market trends and drivers layer of the strategic landscape chart
		Identify the criteria (and their relative criteria weights) to be applied in WSM (MCDA) during the process.	None (Facilitator/process sponsor discussion)	To help in improving the selection process during the workshop.
Strategic landscaping activity (Plenary session)	Present and discuss data collected pre-workshop (including any scenarios created)	None (same as baseline) Split the workshop into two groups at this stage to apply the two scenarios in populating the market trends and drivers layer for each strategic landscape chart (and continue with the following steps).		
	Identify (and cluster) market trends and drivers	+ indicate level of confidence for each trend and driver information cluster.		To facilitate identification of uncertainties and risks

	Prioritise market trends and drivers using dot-voting	Apply semi-blind dot-voting (in place of dot-voting).	Semi-blind dot-voting	To reduce the influence on groupthink on the choice of key drivers and trends
	Identify technologies and resources	+ indicate level of confidence for each piece of technology/resource information	None.	
	Prioritise technologies and resources using dot-voting	Apply semi-blind dot-voting	Semi-blind dot-voting	To reduce the influence on groupthink on the choice of key technologies and resources
	Identify value propositions (products and services)	None (same as baseline)		
	Prioritise value propositions using dot-voting	Apply WSM (using criteria chosen during the planning stage). Assign scores to the value propositions (using dot voting).	MCDA (WSM)	To improve selection process (improve objectivity and reduce groupthink)
	Select priority value propositions	None (same as baseline)		
	[if multiple strategic landscapes have been created (to portray different scenarios)]	*Compare the priority value propositions from both strategic landscapes.* *Identify the value propositions that are scenario-dependent (i.e. differences across the strategic landscapes) and those that are scenario independent (similar across strategic landscapes)*	Discussion (use value proposition comparison chart)	To address ambiguity
	Identify linkages between the priority value propositions and market trends and drivers, and value propositions and technologies and resources.	None (same as baseline)		

	Additional step	Identify critical assumptions underlying the information on the strategic landscape, paying particular attention to the trends & drivers and technology & resources layer. Link the assumptions to the value propositions they affect, pointing out how they translate into risks.	Assumptions analysis Use devil's advocacy + SWIFT	To identify risks at strategic landscape level. (Risk identification)
	Visual templates and aids[39] Strategic landscape chart	+ *Assumptions layer* in strategic landscape chart + *Assumptions chart* to facilitate linking assumptions to value propositions. + marked out grids on sticky notes to encourage the indication of participants' confidence in the opinions and information supplied for the roadmap.		- To facilitate the identification of assumptions (and risks) - To point out where there may be uncertainties in information, and provide indicators risks. (Risk identification)
Topic exploration activity (Smaller groups in parallel sessions)	Summarise key drivers and assumptions	None (Same as baseline)		
	Clarify vision & objectives	None (Same as baseline)		
	Summarise current situation in products & services and technologies & capabilities	None (Same as baseline)		
	Map route forward	None (Same as baseline)		
	Highlight key risks, enablers, barriers, decision points and knowledge gaps	+ Identify market-related risks + Identify technology & resource-related risks	Brainstorming, Prompt lists	

[39] See Appendices 6 and 7 for the visual templates used

	Additional step(s)	Rate the risks using probability-impact matrix and identify key risks [Use the TRL-risk chart as an indicator of the level of risk surrounding the value proposition]	Probability-impact assessment TRL-risk chart	To indicate severity of risks (Risk assessment)
	Create business case: Identify rationale for pursuing topic. Specify required outcome and timing Point out current technology readiness/maturity – capability to develop & exploit Identify key gaps, enablers, barriers and actions	+ Identify risk mitigation measures in accordance with standard risk treatment responses and real options thinking.		
Review (Plenary session)	Give feedback of the outcomes of the parallel group discussions.	+ use risk-reward matrix to compare the top value propositions.	Risk-reward assessment	Comparison of the value propositions on the bases of foreseeable risks and expected reward.
Visual templates and aids[40]	Topic roadmap template Business case template	+ Distinct layers for identifying market risks and technology, capability & resource risk + Prompt-lists embedded in the background of the market risk and technology & resource risk layers to facilitate the brainstorming of risks	Prompt lists (generic list, developed around the PESTLE framework)	To facilitate the brainstorming and identification of risks
		+ Risk treatment template for critical risks.	Standard risk treatment responses + real options thinking.	Risk treatment.

[40] See Appendices 6 and 7 for the visual templates used

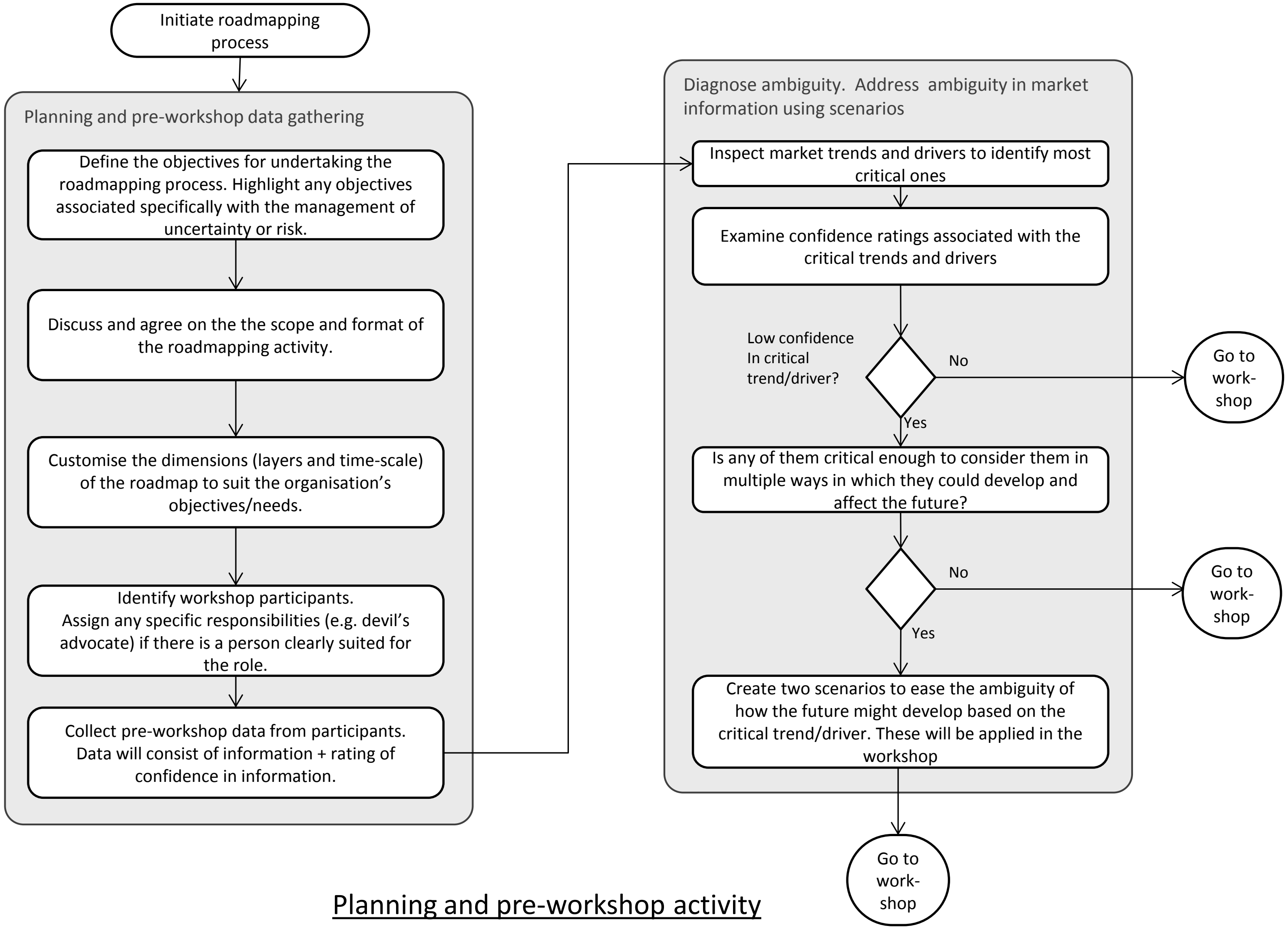


Figure 5.10 - Flowchart of RSRM process planning and pre-workshop

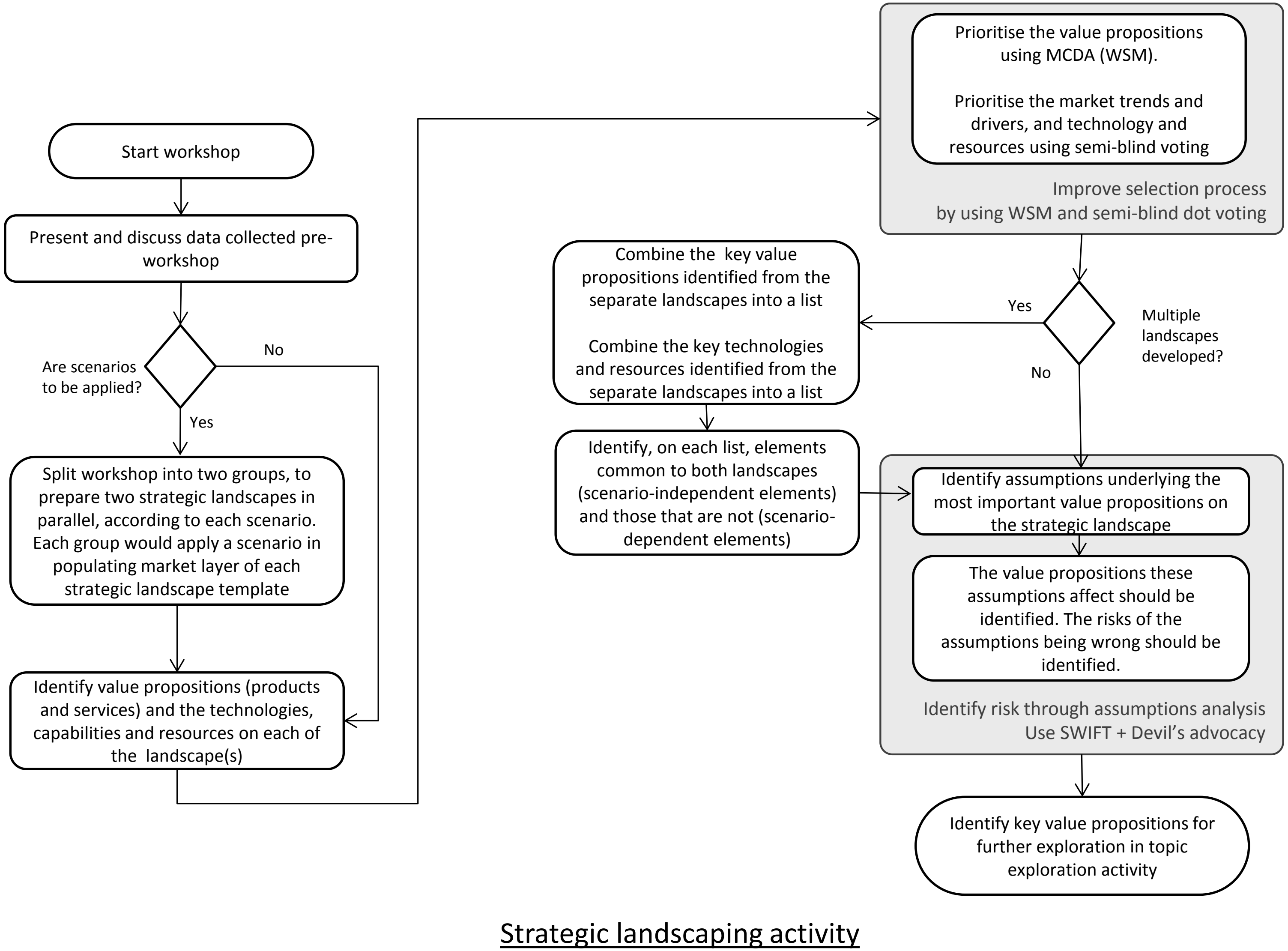


Figure 5.11 - Flowchart of RSRM process strategic landscaping activity (workshop stage)

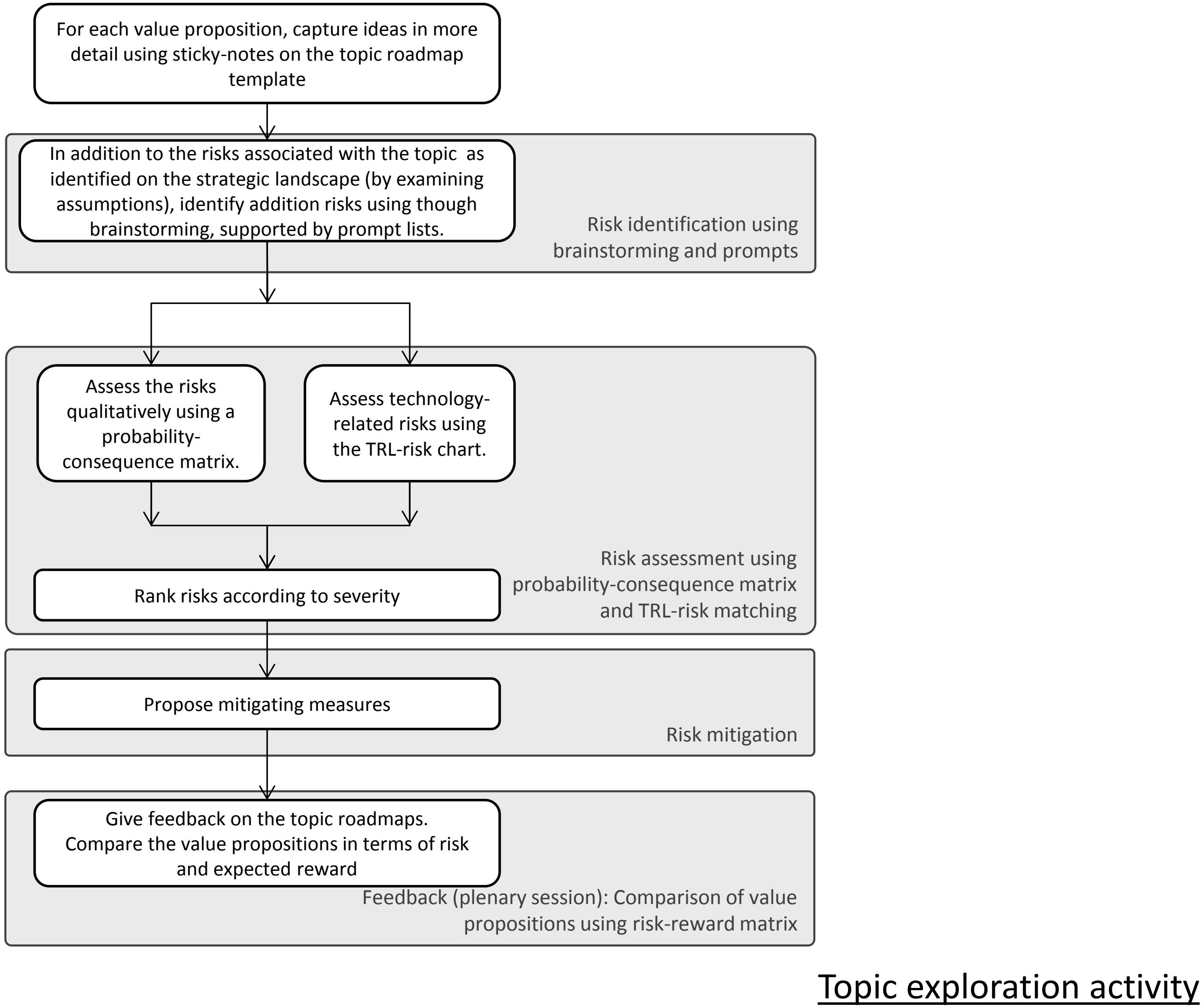


Figure 5.12 - Flowchart of RSRM process topic exploration activity (workshop stage)

5.5 Summary

This chapter presented the development of the risk-aware strategic roadmapping (RSRM) process based on findings from Chapter 4 as derived from theory and practice. The RSRM process is based on S-Plan, a fast-start workshop based roadmapping method, and it aims to ensure explicit attention is given to risk management in the roadmapping process. The RSRM process presented here should be regarded as the conceptual integration of S-Plan and selected methods and techniques.

Through subsequent research (to be presented in Chapters 6 and 7), the process was evaluated by strategic planners and roadmapping practitioners, and tested within companies under real-life conditions.

Chapter 6 – REFINING THE RISK-AWARE STRATEGIC ROADMAPPING PROCESS

Chapter 5 proposed the risk-aware strategic roadmapping (RSRM) process (summarised in Table 5.8) to operationalise the preliminary framework presented in Chapter 4. This chapter focuses on the assessment and refinement of the process (and preliminary framework). As described in Section 3.3.2b the three criteria suggested by Platts (1993) - feasibility, functionality (or utility) and usability - are used in assessing the process. Also, following from Platts (1993), a strategy process can be appraised at two levels:

- At a subjective level, by interviewing prospective users of the process using direct and indirect questions to establish their reactions to the process, and
- At a practical level, in terms of the application of the process in real life conditions (and its outputs, i.e. actions plans).

This chapter focuses on the subjective appraisal of the RSRM process. It is carried out as a preceding step to the practical assessment of the process through in-company case studies (which will be discussed in Chapter 7). The subjective appraisal stage was carried out by a focus group of strategic planning practitioners and a series of individual consultations with roadmapping practitioners familiar with S-Plan (the baseline process for the RSRM process).

Section 6.1 explains the appraisal process carried out through focus group discussions and consultations with practitioners, while Section 6.2 reflects on the output of the appraisal. Section 6.3 draws out the implications of the appraisal on the research. Section 6.4 discusses the significant adjustments made to the process and Section 6.5 summarises the chapter.

6.1 RSRM appraisal through focus group and roadmapping practitioner consultations

This section describes the subjective appraisal of the RSRM process through the focus group consultation and the individual consultations with roadmapping practitioners familiar with S-Plan, the roadmapping process on which the RSRM process based. The specific concerns and feedback obtained from the focus group and practitioner interviews are presented in Appendix 11I and Appendix 11J respectively. However, the most significant aspects of the feedback and their implications for the RSRM process are explained in Section 6.2.

6.1.1 Background to focus group (participant recruitment and conduct of meeting)

As explained in Section 3.3.2a, focus group participants were drawn from the Visual Strategy Network (VSN). The VSN is a community of interest in roadmapping and other related visual techniques to support strategy and innovation.

Recruitment of the focus group was facilitated by one of the co-founders of the VSN group. A briefing note explaining the objectives of the meeting was sent out along with the invitation. A total of 9 people responded to the invitation and participated (see Table 3.6 for participants' profiles). The focus group meeting was held on the 29th of November, 2011 from 10.30am to 2.30pm, at the Institute for Manufacturing, University of Cambridge. Table 6.1 outlines the meeting's agenda.

Agenda	**Time**
Arrival / coffee	10.00
Welcome and introductions	10.30
Presentations and discussion: - *Visual representations of uncertainty and risk in roadmaps* - *A framework and process for treating uncertainty and risk in roadmapping*	10.45
Group activity: - *Exploring the process for treating uncertainty and risk in roadmapping*	12.00
Lunch	13.00
Feedback & discussion	13.30
Review – VSN future directions	14.15
Meeting close & networking	14.30

Table 6.1 – Focus group agenda

The researcher facilitated the meeting (and was assisted by a co-facilitator). The proposed RSRM process described in detail through a presentation and thereafter, the group discussed and provided feedback. To ensure that process was discussed and commented upon as described, the process was laid out on A0 charts on the walls of the meeting room. The proposed modifications and interventions (to S-Plan) to create the RSRM process were clearly indicated. These charts are presented in Appendix 6.

The participants provided feedback by writing comments on sticky notes, and attaching the notes to the parts of the process (on the A0 charts) their comments were directed at. Additional feedback was gathered using a questionnaire, in which they were asked to score on the process' feasibility, functionality and usability. Details of the feedback are presented in Appendix 11I.

6.1.2 Consultations with practitioners familiar with S-Plan

Nine strategic planning practitioners familiar with S-Plan roadmapping process were consulted to discuss and comment on the proposed RSRM process. The consultations were carried out in the format of semi-structured interviews. Prior to the consultation sessions, the interviewees were sent a facilitation slide-set for the RSRM process to study. The slide-set described the process in detail (see Appendix 7).

At the start of each of the discussions, the process was summarised by the researcher, making reference the facilitation slide-set. The practitioners were then asked to comment freely on the feasibility, functionality and usability of the process and the embedded techniques. Parts of the process for which they had specific concerns were indicated. Suggestions were also given by some of the practitioners on how specific parts of the process could be improved. A summary of the feedback provided is presented in Appendix 11J.

6.2 Reflection on RSRM process appraisal

This section focuses on discussing the learning points from the appraisal of the process. First, specific concerns directed at particular stages of the process are presented, paying attention to feasibility, functionality and usability of the procedures suggested. This is followed by an overall assessment of the process with regard to these three criteria, reflected in the participants' views of the process and supported by the scores obtained from the focus group evaluation.

6.2.1 Feedback and learning on specific stages of the process

A. Preparation and pre-workshop data gathering stage

- Pre-workshop data collection and confidence ratings and determination of criteria for the MCDA step.
    - The planning and pre-workshop phase of the process was generally regarded as useful and necessary for the subsequent workshop steps. The focus group confirmed the importance of having a mix of appropriate expertise and personality in selecting process participants. However, it was indicated that the attempt to define who would take up specific responsibilities (such as the devil's advocate) before the workshop may complicate the process. In a related comment (under the assumptions analysis step) it is suggested that the responsibility for the devil's advocacy role should be shared amongst all participants as much as possible, to ensure the entire group is engaged in the discussion and group consensus is maintained.
    - The focus group indicated that the customisation of the roadmapping framework and process, selection of workshop participants and pre-workshop data gathering steps should ideally be treated as an iterative process. The level (in the organisation) of the roadmap vision, the level of uncertainty indicated in the pre-workshop data by the confidence levels should contribute to determining who attends the workshop.
    - To improve the efficiency of the process, Practitioner 1 suggested that in deciding which criteria to be used for the MCDA step, the process sponsor

should be presented with a 'standard' set of criteria, from which the most relevant to the organisation would be chosen. This would help reduce the time it would take to think-up criteria the criteria the organisation would employ. It was also suggested that the all workshop participants should be involved in determining the criteria.

- Creation and use of scenarios to ease ambiguity
  - The suggested creation and application of scenarios to be followed by parallel strategic landscaping sessions during the workshop raised concerns among practitioners 3, 6 and 13, who had experience in creating and applying scenarios. While the logic and functionality of the suggested use of the process was established, the usability, within the scope of the process (based on S-Plan), were challenged. It was pointed out that the benefit of having two alternative views (using scenarios) is usually minor compared to the complexity it introduces. Thus there is a trade-off between the functionality and usability of the proposed process. The practitioners made it clear that this would be the case especially for smaller organisations. Practitioner 6 also indicated that scenarios may not be relevant in most cases, in that the level of uncertainty of the future faced by the organisation is not usually high enough to necessitate the use of scenarios.

B. Workshop stage

Strategic landscaping activity

- Building multiple strategic landscapes following from the creation of multiple scenarios:
  - Usability concerns associated with this proposed stage of the process follow from those indicated with the creation of scenarios on which the strategic landscapes would be developed. Feasibility concerns were also raised by Practitioner 3 who pointed out that the logistics of running parallel strategic landscape sessions would be difficult. The process would also depend on the number of workshop participants. If there are only a

few people participating in the workshop, splitting them into two groups could result into producing strategic landscapes that are both poor in quality.

- Assumptions analysis (including the use of SWIFT and Devil's advocacy) to identify assumptions and resulting risks:
    - The addition of this step (including the addition on an assumption layer on the roadmap template) for capturing and assessing assumptions was recognised by the focus group as a useful idea that would help in uncovering assumptions that participants might have, but which are critical to the roadmap.
    - Practitioners 5 and 13 raised concerns on the complexity that analysis of assumptions at the strategic landscaping stage might introduce. Their suggestion to move this stage to the topic exploration stage was echoed by Practitioners 1 and 3.
- Use of MCDA's Weighted Scoring Model (WSM) for value proposition prioritisation:
    - The use of WSM to obtain a more objective and structured means of prioritizing and choosing among value propositions was seen as both feasible and useful. Practitioner 15 pointed out that it must be properly applied such that value proposition choices are not focused simply on risk avoidance at the expense of those that may appear to hold more risk (i.e. difficulty in realisation) but may have a lot of value potential. This suggests that this stage must include a form of balancing the portfolio of value propositions obtained from the strategic landscape.
    - It was suggested by Practitioners 1, 5 and 7 that two main criteria: 'value' and 'attainability' should be applied to improve the usability of the method. Practitioner 1 pointed out that other criteria can be grouped within these two broad groups and used to define what 'value' and 'attainability' mean to the group participating in the roadmapping workshop. Using these criteria in the form of matrix would facilitate an

appropriate balance of the portfolio of value propositions, therefore easing the concern raised by Practitioner 15 (in the previous point).

- Application of semi-blind dot voting:
  - Functionality and usability concerns were raised by Practitioners 3, 5, and 13 concerning the suggested use of semi-blind voting as a means of countering groupthink and in improving objectivity in prioritisation of trends and drivers and the technologies and resources.

    The suggested techniques rest on the supposition that value propositions identified on the strategic landscape would be compiled into a list during the workshop and made available to the participants, to facilitate individual voting. Practitioners 3 and 5 pointed out that compiling the list will constitute a logistical challenge. It was envisaged that the process will take too much time which would break the flow of the workshop. Practitioner 13 described the suggested process as being mechanical and faulted its functionality, pointing out that such a mechanical process will not allow debate and communication, which is a useful and important aspect of roadmapping.

Topic exploration activity

- Technology readiness level (TRL)-risk assessment
  - Regarding the functionality of this step, it was pointed out that using TRL as the sole indicator of riskiness associated with a value proposition was inadequate. The estimation of the risk level associated with a value proposition should not be based solely on the readiness level of the technology underpinning it. Other elements that would influence the innovation process should be considered to give a more robust assessment. This was also pointed out (although indirectly) by the focus group, who pointed out that technology obsolescence and the organisation’s capability to innovate should also considered as part of this stage.

6.2.2 Feedback and learning on overall process

The two sets of feedback (focus group and individual practitioner reviews) received from both stages of appraisal were consistent with each other. The focus group and practitioners indicated that the overall process was functional, and addressed an important gap of managing uncertainty and risk in roadmapping. The individual techniques introduced were generally regarded as functional. As detailed in Appendix 11J, modifications were suggested for some of them. Also, the process was generally regarded as feasible and logical for the workshop environment. The main concerns were directed at the usability of the process, especially when considered against the backdrop of the S-Plan fast-start process around which it was modelled. The process was regarded as too ‘complex’ or ‘heavy’ to fit into a day’s workshop schedule in the manner that had been proposed. This was reflected in the aggregate scores obtained from the focus group (shown in Appendix 11I), in which usability was scored low.

It was considered that the main constraint to the usability of the process was the set time-constraint of a one-day workshop. The foreseeable complexity of creating multiple strategic landscapes and any logistical challenges that may be associated with semi-blind voting may be eased by making more time available for the workshop. The logical response to improving usability would therefore be to extend the process over a two-day workshop schedule (at least).

However, it must be noted that limitation of the S-Plan to a one-day workshop process is a major incentive for organisations to take up the roadmapping process. Thus, it is important to find a means to streamline the process into a one-day workshop agenda. To achieve this, further modifications are proposed in Section 6.3.2.

6.3 Implications for the research

6.3.1 Reflection on the preliminary framework

Feedback received identified the issue of maturity (or experience) of the organisation in roadmapping. Part of the focus group feedback indicated that a prior experience with roadmapping can help participants complete the process more quickly. Practitioner 3 also highlighted the influence of prior understanding of the roadmapping process (amongst the participants) on the ability to run parallel strategic landscape activities (for addressing ambiguity). This brings to light the factor of the prior experience of roadmapping in the organisation, (or the organisation's roadmapping maturity (or spheres of influence according to Kappel (2001)) when considering how uncertainty and risk may be managed within the process. Thus, as indicated in the revised framework of Figure 6.1, the 'roadmapping maturity of the organisation' is indicated as one of the process factors on the framework and should be put into consideration. This factor is perhaps interrelated with the 'time and resource constraint' factor since the maturity of an organisation in applying roadmapping will suggest the level of recognition of the benefits of roadmapping and, in turn, how much time and effort it would allocate to it. However, these two factors which would affect the level of detail and complexity of risk management that can be tolerated in a given roadmapping exercise transcend risk management issues. The factors will affect any attempt to improve roadmapping from its basic forms, especially if this would involve integrating it with additional tools and techniques for achieving additional benefits.

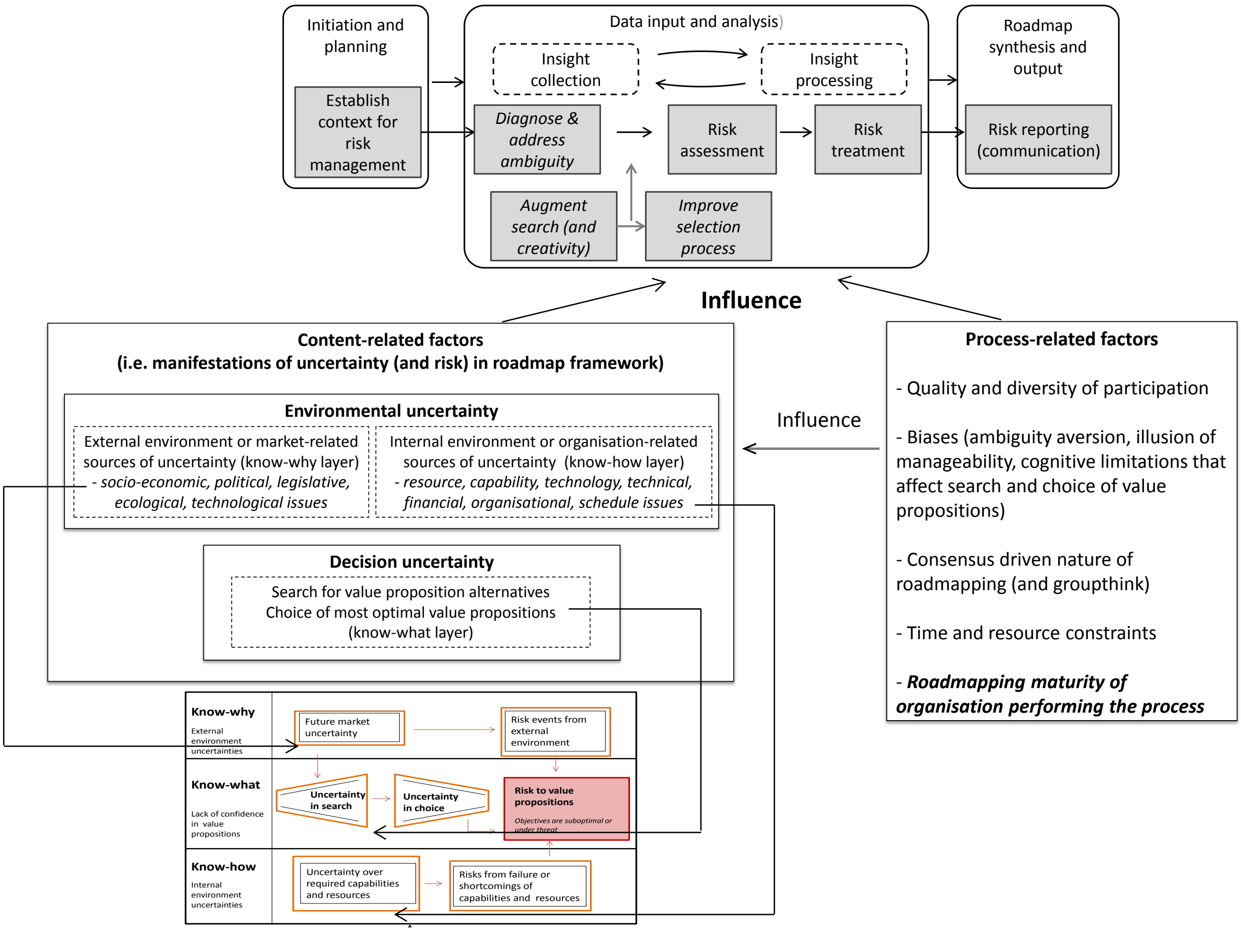


Figure 6.1 – Revised framework of factors influencing risk-aware roadmapping

6.3.2 Revision of the RSRM process

The learning points from the appraisal of the RSRM process and the feedback received led to its refinement. Since the feasibility and functionality of the original RSRM process was generally confirmed, the modifications made were predominantly to improve its usability by finding ways to reduce its complexity and the time it requires. The major changes leading to a revised version of the RSRM process include the modification of MCDA step for prioritisation and choice of key value propositions to take the form of a value-attainability appraisal so that it is simpler, and the modification of the TRL-risk assessment step into a more robust risk-profiling step. These are discussed in greater detail in Section 6.4.

6.4 Adjustments to methods within the process

6.4.1 Prioritisation and choice of key value propositions: identification of a standard set of sub-criteria for defining 'value' and 'attainability' criteria

The simplification of the initially proposed use of MCDA for prioritising value propositions requires the identification of a standard list of sub-criteria. This standard list of sub-criteria is meant to help the participants define (value and attainability) according to the organisation's needs and objectives of the roadmapping activity. The use of value and attainability as the two main criteria is supported by Phaal & Mitchell (2009) who explain that the attractiveness of a value proposition depends on opportunity and appropriability. It is also in line with Cooke & Slack (1991) who suggested three criteria: acceptability, feasibility and vulnerability.

The term 'value' adopted for this research, refers to 'opportunity' of Phaal & Mitchell (2009) and 'acceptability' of Cooke and Slack (1991), while 'attainability' refers to 'appropriability' of Phaal & Mitchell (2009), and combines 'feasibility' and 'vulnerability' of Cooke & Slack (1991). Following from the definition by Phaal & Mitchell (2009) and Cooke & Slack (1991), 'value' can be described as the foreseeable size of the benefit or level of positive return that will be made available to the organisation by successfully delivering the value proposition. Attainability can be described as the ease to the organisation of successfully delivering the value proposition into a final product.

To identify sub-criteria to be applied under the two main criteria adopted, detailed lists of criteria applied in organisations as identified Cooper et al (2001) and Goffin & Mitchell (2005) were examined. Each of these was then classified under either 'value' or 'attainability'. Details of this classification are presented in Appendix 8. The results from this are presented in Tables 6.2 and 6.3.

Value	Explanation
Strategic fit	Fit with the stated or implied strategy for the product line, business and or organisation
Synergies with other operation within the business	Ability to promotes success of other product/services, or functions or businesses within the organisation
Clear customer need	Whether a clear market need exists for the value proposition
Market size	The size of the market the value proposition would appeal to
Market growth potential	The potential of the market to keep growing
Profitability (margins in market) and cash flow	Financial returns (cash flow and profitability) to the organisation
Sustainability (or improvement) of competitive advantage	Attainment/sustenance/improvement of advantage edge over competitors, e.g. by providing strategic leverage over competitors as a result of proprietary position acquired through patents and trade secrets, etc.
Entry into new market	Provision of access into a new market
Industry/market readiness	State of the market in which the value proposition would break into (emerging, growing, mature (stabilised) or declining?
Differentiated product	Noticeability of value-adding differences in product when compared to similar ones in the market
Platform for growth	Potential to open up new technical and commercial fields
Cost reduction	Reduction of overhead costs of production
Business simplification[41]	*Reduce the complexity of the product chain/family or business*
Learning[41]	*Opportunity to enrich the organisation's knowledge base*

Table 6.2 – Identifying a list of sub-criteria for 'value'

Attainability	Explanation
Knowledge of market	Newness to the market – how well is the market known
Availability of manufacturing processes/ supply chain	Availability of the required parts of the value chain (that will help bring the value proposition to reality)
Availability of project champion (or top management backing)	Presence of a person within senior management committed (or who would commit) to the success of the proposition
Competitive intensity (and reaction) in the market	Toughness of competition in the industry
Technical uncertainty (or complexity)	Impact of success of product development by foreseeable complexity and newness of constituent technology(ies) (e.g. is it incremental or radical innovation for the organisation)
Technology maturity	Level of maturity of the primary technology in the strategic opportunity
Skill and labour requirements	Availability of people, resources and facilities to support the strategic opportunity (do we have the required skill base or is it completely new to us?)
Commercial uncertainty	How unstable or unpredictable is the market? – how potentially risky is it?
Regulatory impact	Potential impact of regulation on the success of the opportunity, if pursued
Fit with core competencies	Potential of the strategic opportunity to benefit from our core competencies
Routes to market (capability and cost)	Clarity of mode of reaching the customer with the product
Availability of funding (or grants)[41]	Potential of required level of funding being committed to strategic opportunity

Table 6.3 – Identifying a list of sub-criteria for 'attainability'

[41] The italicised criteria in Tables 6.2 and 6.3 were included based on consultation with practitioners 1 & 7 and are not based on literature.

6.4.2 Development of a risk-profiling step (to substitute the TRL-risk assessment) at the topic exploration stage

In the revised RSRM, more robust risk-profiling was introduced in place of using TRL as an indicator of overall riskiness of a value proposition. The risk-profiling step considers other risk-defining elements (in addition to TRL) to give a fuller assessment of risk surrounding a value proposition.

This expansion is in agreement with Valerdi & Kohl's (2004) proposition that TRL by itself does not provide an accurate assessment of the risk surrounding innovation and adopting a technology. It was pointed out that other factors such as *obsolescence* should be considered. These introduce the risk that a value proposition could become of little economic worth if it is dependent on technology that is on the verge of obsolescence or being leapfrogged by newer technology. In quantifying risk in technologies, Hartmann & Myers (2001) identified five contributors to risk in addition to technology readiness. These are:

- Availability of competencies and complementary technologies required
- Specification achievability
- Availability of value chain elements
- Product differentiation
- Market clarity (or acceptance)

The last three are market-related, while the first two, in addition to technology readiness, are technology-related.

The scoring system provided by Hartmann & Myers (2001) to capture these elements has been modified for use in the revised RSRM process, to include Valerdi & Kohl's (2004) scoring which combines TRL and obsolescence and is presented below in Tables 6.4, 6.5 and 6.6. This provides the opportunity to determine the level of technology risk and market risk separately. An aggregated score can also be obtained combining technology risk and market risk. The formulae suggested for these are taken from Hartmann & Myers (2001):

Technology risk = 1 - (P1. P2. P3. P4); *Market risk = 1 - (P4. P5. P6)*

Overall riskiness associated with value proposition = Technology risk ***X*** *Market risk.*

Technology-related risk element	Explanation
Technology readiness level	How ready is the primary technology?
Obsolescence	How quickly will the technology be outdated?
Availability of competencies and complementary technologies	Do we have or can we acquire the required competencies or complementary technologies to support primary technology?
Specification achievability	Can we deliver on time, within cost and according to quality and reliability specifications?
Market-related risk element	**Explanation**
Market clarity	Is there a market for the proposed product and what foothold does the organisation have in it?
Product differentiation	How different is the product when compared to similar ones in the market?
Availability of value chain elements	Are the required parts of value chain available, i.e. the organisations or units that will help bring the product to reality such as engineering, manufacturing, marketing, distribution and sales?

Table 6.4 – Explanation of risk elements in the risk-profiling step (adapted from Hartmann & Myers (2001) and Valerdi & Kohl (2004))

Technology-related elements				Probability of success for each element
Technical readiness level (TRL) (P1)	**Obsolescence (P2)**	**Availability of competencies and complementary technologies (P3)**	**Specification achievability (P4)**	
Incremental extension of existing in-house technology	(Obsolescence is not an issue)	Technology and advanced development competencies available, complementary technologies exist	Modest extension of existing specifications & performance requirements	**0.9**
Incremental extension of existing outside technology	(Obsolescence is not an issue)	Technology competency not available, advanced development competency and complementary technologies available	Major extension of specifications/ performance	**0.7**
New technology, feasibility demonstrated	Technology is state-of-the-practice; emerging technology could compete in future	Technology competency and complementary technologies available, advanced development competency not available	New specification in a new performance domain	**0.5**
New technology, feasibility not demonstrated	Technology is stale; new and better technology is on the horizon in the near-term	Technology or advanced development competencies available elsewhere, complementary technologies not available	Some specifications unknown or unknowable	**0.3**
New invention, not reduced to practice	Technology is outdated and use should be avoided in new systems; spare parts supply is scarce	Neither technology & advanced development competencies nor complementary technologies available	No specification known	**0.1**

Table 6.5 – Technology-related elements for the risk-profiling step (adapted from Hartmann & Myers (2001) and Valerdi & Kohl (2004))

Market-related elements			Probability of success for each element
Market clarity (P5)	**Product/service differentiation (P6)**	**Availability of value chain elements (P7)**	
Company is currently in the market	Product is best in class in all attributes	Value chain is available within the company	**0.9**
Company has contact with potential customers, but is not yet in the market	Product is best in some attributes, but not all	Major elements of company's value chain must be developed	**0.7**
Future market is clear and company is already active in a closely related market	Product offers advantages in one or two attributes	Company value chain is broken, many elements not available	**0.5**
Future market is quite clear but some uncertainties still exist	Product has same profile as competitors	No value chain elements exist within the company	**0.3**
Future market is unclear (there are fundamental uncertainties that can affect the form it will eventually take)	Product offers advantage in one or two attributes, but is worse in all others	Critical value chain elements do not exist anywhere	**0.1**

Table 6.6 - Market-related elements for the risk-profiling step (adapted from Hartmann & Myers (2001) and Valerdi & Kohl (2004))

6.5 Summary

The appraisals of the proposed RSRM process were carried out through a focus group discussion and interviews with roadmapping practitioners familiar with S-Plan, upon which the RSRM process is based. The feedback received from the appraisal demonstrated that the proposed RSRM process as ‘feasible’ and ‘useful’ (or functional). However, the usability of the process was questioned, especially considering the one-day time constraint imposed on the workshop stage of the process. Relevant comments and suggestions for improving the ‘usability’ of the process were captured through the appraisal process and applied in revising the process. In addition to refining the process, results of the appraisals suggested an additional factor to the preliminary framework. Thus, both the framework’s comprehensiveness and the RSRM process have been improved. The next chapter will discuss the results of testing the revised version of the RSRM process in five company case studies.

Chapter 7 – TESTING THE REVISED RSRM PROCESS

Chapter 6 discussed the first stage of assessment and refinement of the risk-aware strategic roadmapping (RSRM) process based on appraisal and feedback from strategic planning and roadmapping experts. This chapter presents the assessment of the RSRM process through five in-company case studies. The same criteria applied in Chapter 6 - feasibility, functionality and usability (Platts, 1993) - are used here. Further learning is generated from the feedback received from the in-company case study participants.

Section 7.1 presents a summary of the process followed and workshop templates. Section 7.2 presents a background to the company cases, Section 7.3 discusses the learning points from testing the process and Section 7.4 summarises the chapter.

7.1 Revised RSRM process overview

The RSRM process carried out in each of the in-company cases went through the stages of:

- Initiation - initial contact from company to researcher and commitment to the process (and the drawing up of confidentiality agreements to secure access),
- Process execution - workshop planning and pre-workshop data gathering (which would require input from the process sponsor and participants), the roadmapping workshop process and the delivery of workshop report to the process sponsor,
- Feedback – feedback on the feasibility, functionality and usability of the process from the participants and process sponsor (using post-workshop feedback questionnaires). The feedback provided a means of appraising the process and suggestions for further improvement.

The charts applied in the process execution stage (pre-workshop data gathering and workshop process) are presented in Section 7.1.1. Examples of how these charts were applied are shown in Appendix 9. The questionnaire used for collecting feedback is presented in Appendix 10.

7.1.1 Process execution summary: charts applied and workshop agenda

The process execution stage constitutes the RSRM process as detailed in Table 6.4. However, it is useful to point out the key stages once again, highlighting the templates applied in them. The process is made up of three stages:

- Planning and pre-workshop preparation: at this stage, the objectives, scope and format (including what techniques and methods would be applied) are discussed and agreed upon. Participants for the workshop process are identified by the process sponsor. Information that would be used to build the roadmap is collected from each participant (using the templates shown in Figures 7.1 and 7.2).

Name:		**Department:**	
Timeline	**Short** (1-3 years)	**Medium** (4-8 Years)	**Long** (8-18 Years)
Market trends & drivers	• XX (insert confidence level) • XX (insert confidence level) • XX (insert confidence level)	• XX (insert confidence level) • XX (insert confidence level) • XX (insert confidence level)	• XX (insert confidence level) • XX (insert confidence level) • XX (insert confidence level) *Example:* ***•Composition of global energy usage = 25% biofuel/renewable (3)***
Systems and applications (Products/services)	• XX • XX • XX	• XX • XX • XX	• XX • XX • XX
Technical Capabilities, resources and technologies	•XX •XX • XX	•XX • XX • XX	•XX •XX • XX

Assign a level of confidence to each piece of information you provide for the **market trends and drivers** section:
High confidence (3), Moderate confident (2), or Low confidence (1)

Beside each entry in the Trends & Drivers section assign a number to indicate how confident you are of the piece of information you are providing. As an example, see the entry: ***Legislative regulation sets the composition of energy usage to 25% Biofuel/renewable energy (3)***
This would indicate that you are very confident that there will be a regulation setting the composition of energy consumption to 25% renewable energy in 8-18 years.

Figure 7.1 – Pre-workshop data gathering template with confidence indicator for diagnosing level of uncertainty in information on the external environment

Value proposition (product/service) selection criteria

Value Criteria		Attainability Criteria	
Strategic fit		Knowledge of the market	
Synergies with other operations within the business		Availability of manufacturing processes/supply chain	
Clear customer need		Availability of project champion	
Size of market (available to us)		Competitive intensity (and reaction) in the market	
Market growth potential		Technical uncertainty (or complexity)	
Market profitability (margins in the market)		Technology maturity	
Sustainability (or improvement) of competitive advantage		Skills & labour requirements	
Entry into new market		Commercial uncertainty	
Industry maturity / readiness		Regulatory impact (e.g. environmental, legislation)	
Differentiated product		Fit with core competencies	
Platform for growth		Routes to market	
Cost reduction		Availability of funding (or grants)	
Business simplification			
Learning			

Figure 7.2 – Pre-workshop template for choosing sub-criteria under 'value' and 'attainability'

Figure 7.1 is used to gather information which would go directly onto the strategic landscape roadmap. Figure 7.2 is the template used to determine the sub-criteria that constitute the two main criteria of 'value' and 'attainability' (which would be used for ranking value propositions identified during the roadmapping process). Each participant chooses 5 sub-criteria to define 'value' and 5 sub-criteria to define 'attainability'. All the participants' choices are then aggregated to determine the 10 sub-criteria (5 for 'value' and 5 for 'attainability') most commonly identified across the participants, which would then be used during the roadmapping process. All the data collected before the workshop are presented, discussed and applied during the workshop. Examples of completed templates are shown in Appendix 9a and 9c.

- Workshop activity: this is a one-day process. Table 7.1 shows the agenda for the day, and indicates the two main parts:
    - Strategic landscaping activity and value proposition identification: first stage of the workshop, in which data collected pre-workshop is discussed and further brainstorming (of ideas) is carried out. The most important

know-why (market) and know-how (technologies and resources) information are identified. Value propositions are also identified and prioritised, with a set selected for further exploration.

- Topic exploration activity: priority value proposition(s) are further explored and risk management steps are followed to draw up an action plan to advance the development of the value proposition(s) explored.

Agenda	**Time**
Overview of aims and objectives of the roadmapping workshop	09.00 – 09.15
Agenda and roadmapping process description	09.15 – 09.30
Part 1: Strategic landscaping & value proposition identification (plenary session)	09.30 – 12.50
Strategic landscaping - Presentation from each participant (4 min each) (Share perspectives captured on strategic landscape) - Update trends & drivers, applications or innovation ideas (or value propositions), technologies and resources Value proposition identification and prioritisation - Prioritisation of market/business drivers and resources/technical capabilities *Tea break* - Brainstorm value propositions (based on priority market drivers and capabilities) - Prioritisation of value propositions	 09.30 – 10.30 10.30 – 11.00 11.00 – 11.20 11.20 – 11.55 11.55 – 12.50
LUNCH *(facilitation team collates results from Part 1 of workshop in readiness for Part 2)*	12.50 – 13.50
Part 2: Value proposition exploration (break-out groups)	13.50 – 17.05
Value proposition exploration - Articulate and detail-out future of value proposition - Identify risks and critical assumptions Tea break - Carry out risk assessment - Develop business case for value proposition explored Discussion (presentation of business cases) and next steps (plenary session)	 14.20 – 15.25 15.25 – 15.55 15.55 – 16.05 16.05 – 16.35 16.35 – 16.45 16.45 – 17.05
Feedback (for research purposes)	17.05 – 17.25
Closing	17.30

Table 7.1 – Agenda for the RSRM workshop activity

- Post-workshop reporting: the results from the workshop are presented in a report. Here, the traffic light colour scheme is used as a visual cue for risk-related data (in addition to the charts and templates translated from the workshop process) to capture and facilitate understanding of the information contained in the report.

Figures 7.3 – 7.7 show the charts (or templates) applied during the workshop process. These templates facilitate the application of the risk management techniques embedded in the RSRM process. Figure 7.8 shows the sequence of application of these templates

- The strategic landscape template captures the overall strategic direction, but no explicit risk management techniques are embedded in (or used with) it.
- The value proposition prioritisation matrix is a modified form of MCDA to improve the objectivity of the selection process, thereby reducing the risk of focussing on sub-optimal value propositions.
- On the topic roadmap template, which explores each selected value proposition in greater detail, participants are encouraged to apply brainstorming to identify market- and technology-related risks. What-if questioning (+ devil's advocacy) is applied to identify critical knowledge assumptions, also a means of identifying additional risk issues. Prompt-lists (drawn up in line with the PESTLE framework) are embedded into the background of the template in grey-scale to facilitate the identification of risks in the brainstorming and what-if questioning steps.
- The risk assessment chart facilitates the application of the probability-impact assessment of identified risks and also helps to create a risk profile for the overall topic to assess its riskiness. Through this the most critical risks can be identified.
- In the business case template, mitigating actions for most critical risks can be outlined. Prompts are embedded into the template suggesting ways risks can be mitigated, according to standard treatment responses and options thinking.

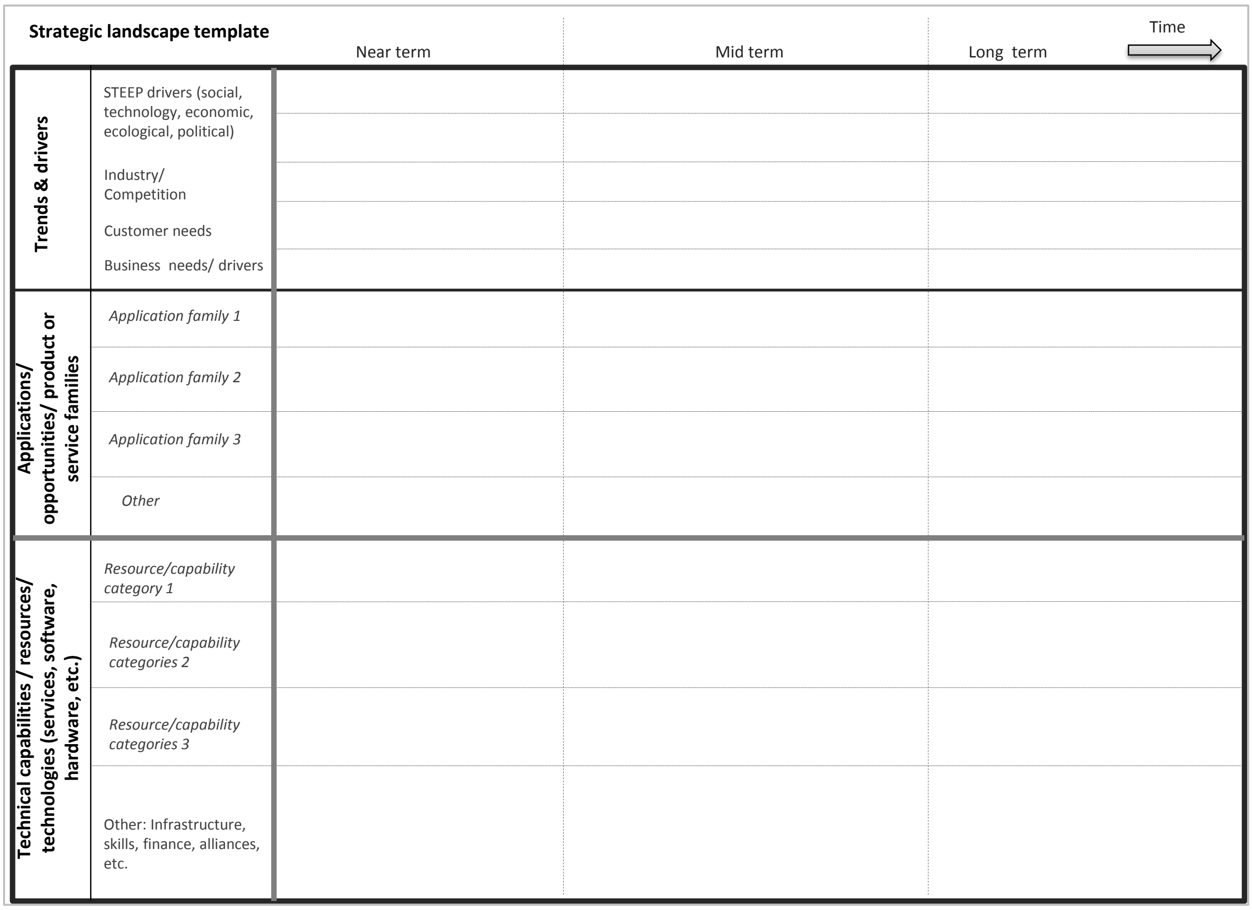


Figure 7.3 – Strategic landscape template

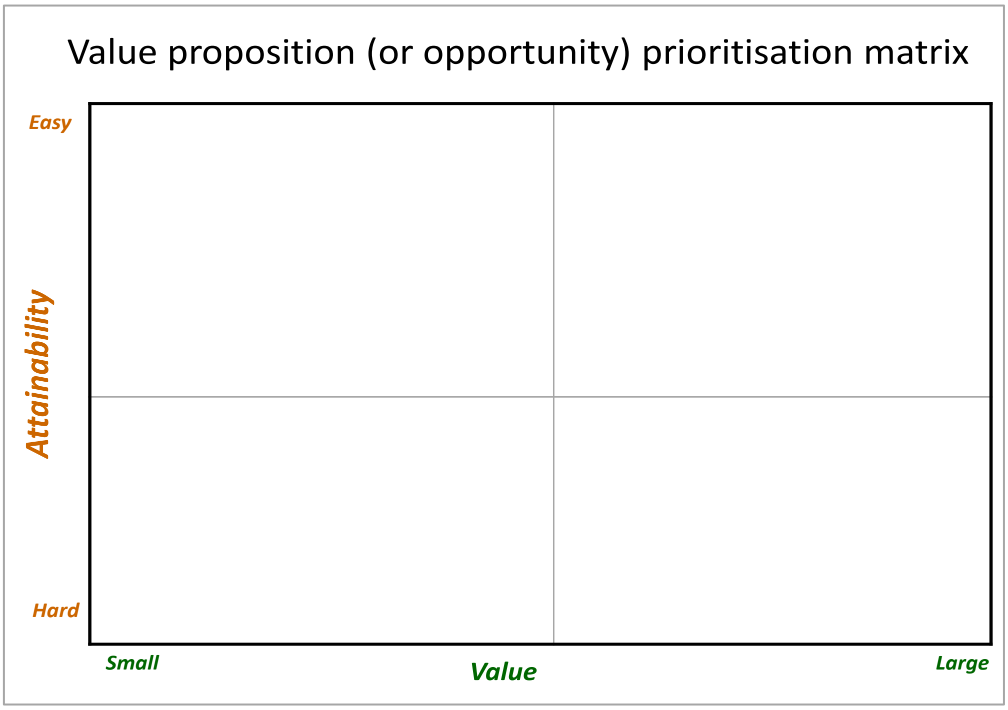


Figure 7.4 - Value proposition prioritisation template (value-attainability assessment)

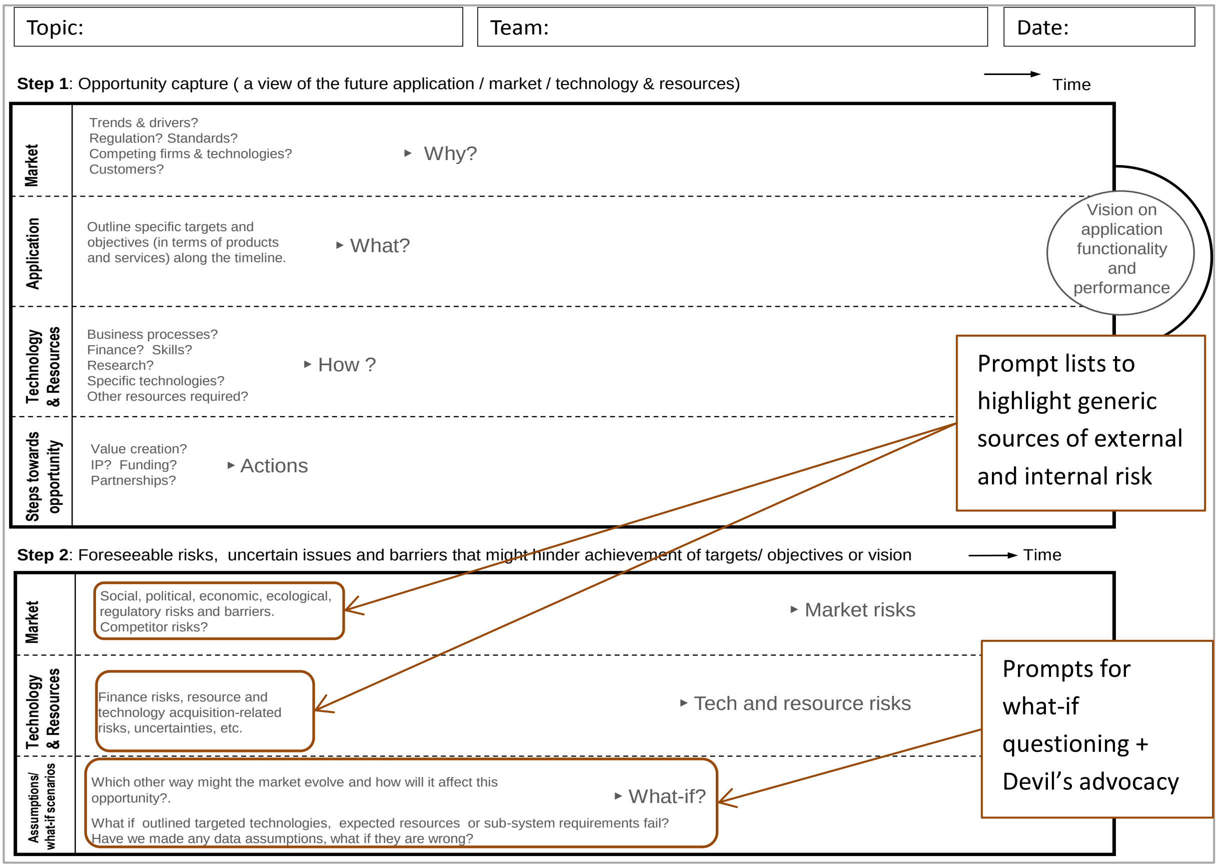


Figure 7.5 – Topic roadmap template (value proposition exploration including action plan and risk identification)

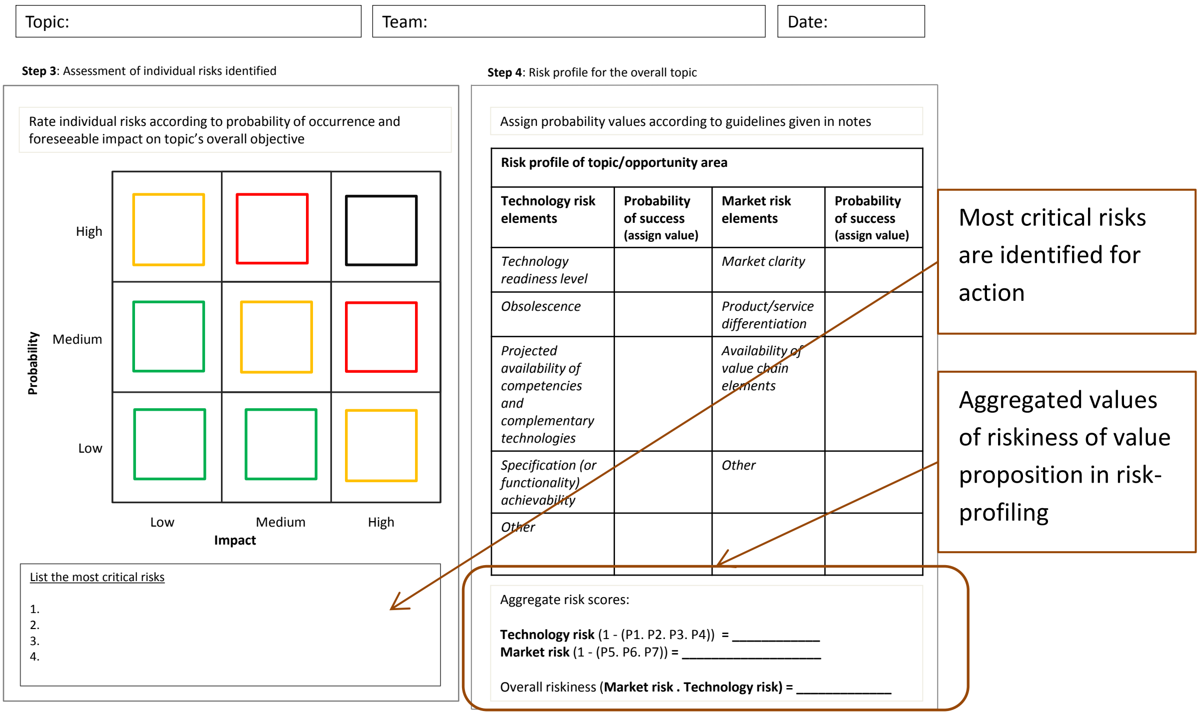


Figure 7.6 – Risk assessment template including the probability-impact assessment and risk-profiling

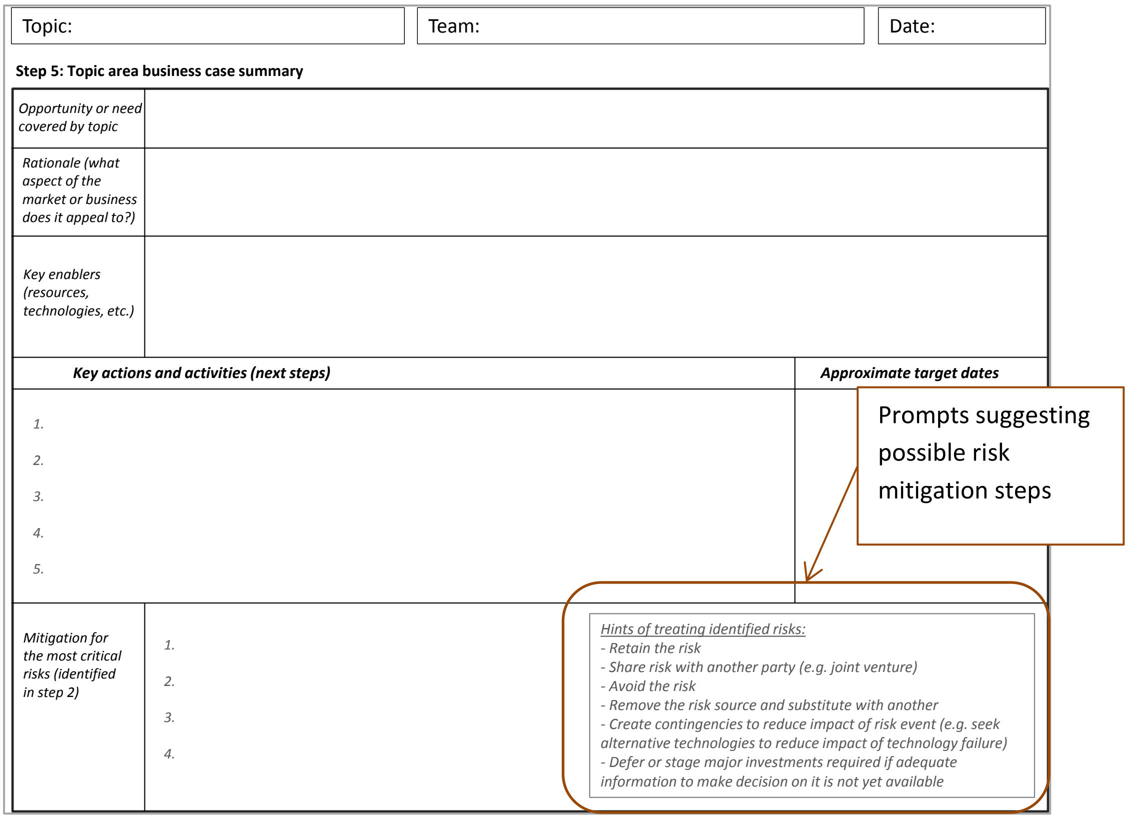


Figure 7.7 - Summary business case template including risk mitigation (Step 5, topic exploration stage)

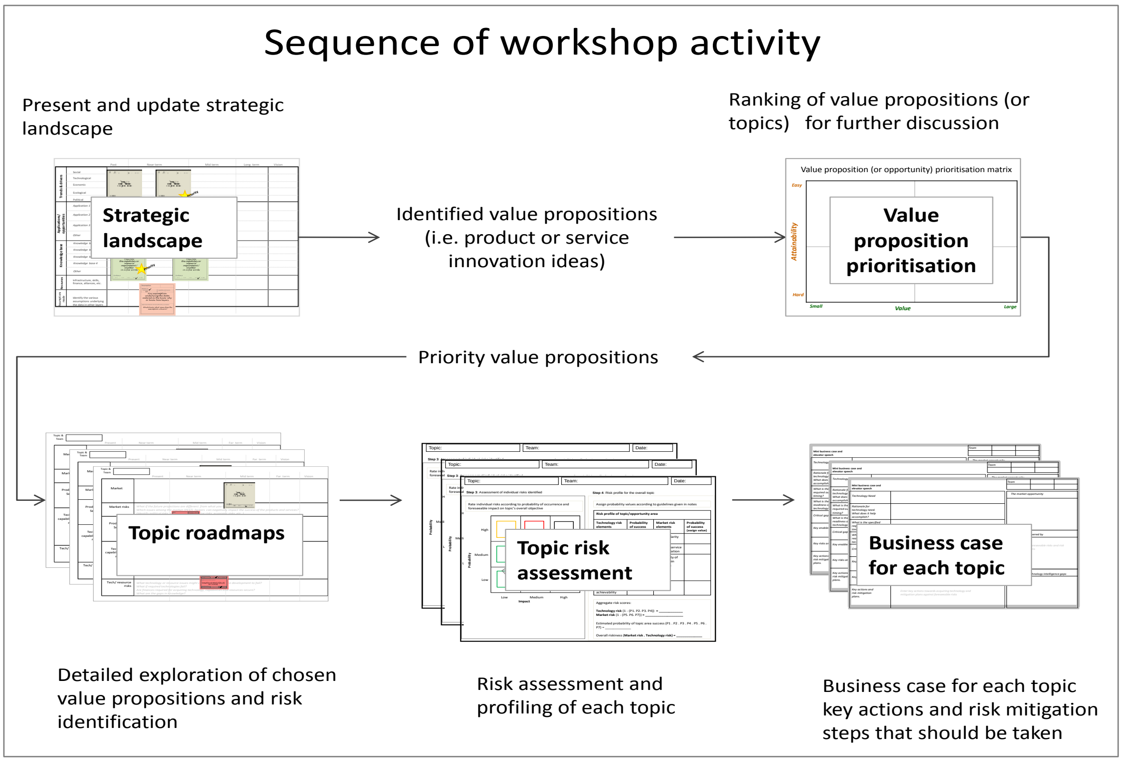


Figure 7.8 – Sequence of workshop activity

7.2 Background to in-company cases

While the workshop process was fitted into a day, pre-workshop planning and data gathering took a minimum of four weeks in each of the cases. As shown in Figure 7.9, the workshop exercises for the in-company cases were carried out one after another. This provided the opportunity to apply learning from earlier workshop exercises to subsequent ones. The total time it took to execute the cases (planning and workshop activity), ranged from 4 to 6 weeks.

Cases A and B were facilitated by roadmapping consultants, one for each case, in which they served as lead facilitators during the workshops, and acted in an advisory role to the researcher on improving the process. Cases C, D and E were fully carried out and facilitated by the researcher.

Table 7.2 provides details of the in-company cases, of how they were initiated, the reason each company undertook the process and a brief overview of each process.

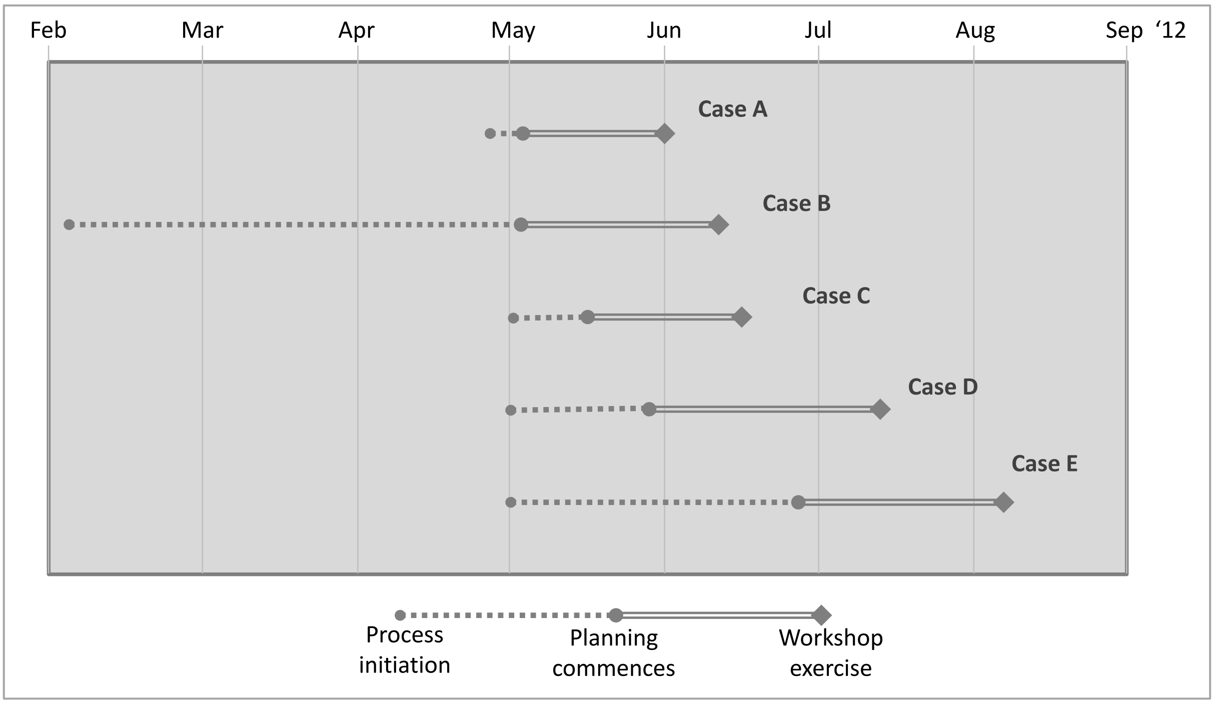


Figure 7.9 - Sequence and duration of in-company cases

Table 7.2 – Details of in-company case studies

	Case A (Company A)	**Case B (**Company B)	**Case C (**Company C)	**Case D (**Company D)	**Case E (**Company E)
Industry (corporate base)	Coatings (USA)	Defence (UK)	Wall and floor coverings (UK)	Healthcare (UK)	Power generation (UK)
Company background	Manufacturer and major global supplier of automobile and industrial coatings, employing 10,000 people	A defence, aerospace and security company, employing over 90,000 people globally	Manufacturer and supplier of wall and floor coverings, employing over 400 people	Start-up business of 4 people focused on healthcare solutions based on emerging research from a UK university	Manufacturer and supplier of power generating sets with over 3,000 employees
Process sponsor	Product management director	Head of innovation and growth	New product development manager	Company director	R&D engineering specialist
Process initiation and case access	The process sponsor became aware of the RSRM process through a roadmapping practitioner who attended one of the researcher's presentations of the RSRM process	The process sponsor expressed interest in collaborating on the in-company case research after participating in the focus group that appraised the first version of the RSRM process	The process sponsor responded to the advertisement of the RSRM process placed in the IfM's[1] roadmapping newsletter by the researcher, and identified Company C's need for innovation planning	The process sponsor responded to the advertisement of the RSRM process placed in the IfM's roadmapping newsletter by the researcher, in realisation of the start-up's need a coherent innovation strategy	The process sponsor responded to the advertisement of the RSRM process placed in the IfM's roadmapping newsletter by the researcher, recognising Company E's need for a product development plan
Reason for undertaking the RSRM process	Company A needed to define its product innovation strategy within an aspect of its business. It was interested in identifying the assumptions in the strategy and also where the uncertainties concerning disruptive developments	Company B required the process to explore and clarify innovation opportunities in a recently formed business unit set up to develop speciality defence and civilian products.	Company C was faced with uncertainty on what products ideas to explore and develop under one of its product lines. There was also the desire to identify specific risks that may adversely	Company D's flagship innovation proposition concerned glucose monitoring for diabetics. It was disruptive in nature and still in its early stages. Realisation of this highlighted the	Company E recognised the uncertain nature of the future power generation market especially concerning the drive for low carbon energy solutions and economic growth in developing

	associated with their key technologies. This highlighted the need for a planning methodology that had the additional capability to identify and address uncertainties and risks associated with the laid out plan	The process sponsor identified the need to consider uncertainties and risks pertaining to the market, relevant requirements in technology and resources in arriving at an innovation strategy	affect product innovation needs. Company C required a coherent process for developing this innovation strategy and therefore decided to apply the RSRM process	need for an innovation plan in which the risks most critical to the success of the proposition and its delivery to the market would be identified and addressed	nations. This created doubt over what solutions would be best suited for the market. Company E needed a coherent process to define and detail the solutions that would be pursued
Overview of process	A small group of three people (including the process sponsor) from Company A's leadership team participated in the process. The aim was to pilot the RSRM process first before full application at the organisation's headquarters. The process was carried out at IfM[1] on 31st May, 2012, after 4 weeks of planning. The roadmapping practitioner who had recommended the process facilitated the workshop	Workshop planning took 5 weeks. The workshop was carried out at Company B's premises on 12th June, 2012. There were 9 attendees, including the process sponsor. A roadmapping practitioner (different from the one in Case A) facilitated the workshop	Planning and pre-workshop preparation took 4 weeks. The workshop was carried out at Company C's premises on 15th June 2012. It was attended by 8 people, and facilitated by the researcher	Planning and pre-workshop preparation took 5 weeks. The workshop was carried out at the IfM. It was split over 2 half-day sessions (10th and 11th July, 2012), with strategic landscaping carried out the first half-day, and topic exploration carried out the second half-day. The 4 members of the start-up attended the workshop facilitated by the researcher	Planning and pre-workshop preparation took 6 weeks. The workshop was carried out at one of Company E's facilities in Northern Ireland on 8th August 2012. It was attended by 4 people, and was facilitated by the researcher

[1]IfM – Institute for Manufacturing, University of Cambridge

7.3 Case feedback and learning

This section focuses on discussing the feedback from the testing process. First, an overall assessment of the process regarding its feasibility, functionality and usability is presented. A more detailed discussion concerning the techniques applied in the process is then provided, focussing on the changes to the process as a result of carrying out the in-company cases. This discussion is based on feedback received from process participants and the researcher's observations.

7.3.1 Overall feedback

A summary of the evaluation of the RSRM process based on the feedback received through the post-workshop questionnaire (Appendix 10) is presented in Table 7.3 and 7.4. Questions were asked based on the three criteria: feasibility, functionality and utility. Each of the questions had a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The analysis of responses was carried out in accordance with James et al. (1984) and Caetano & Amaral (2011), who aggregated multiple-respondent feedback using the *mean* of the responses and *interrater agreement* among the respondents. These two measures were calculated for each item on the questionnaire. The *interrater agreement* (r_{wg})[42] indicates the level of agreement to the mean response between the respondents. These were calculated across the entire set of respondents across the five cases, and individually for each case as shown in Table 7.3.

The interrater agreement, $\boldsymbol{r_{wg}}$, is derived from the standard deviation ($\boldsymbol{S_x}$) and the variance index[43] ($\boldsymbol{\sigma_x^2}$) of the responses as shown in the following equations. ***A*** corresponds to the number of alternatives in the response scale (which was 5 in the questionnaires used).

$$r_{wg} = 1 - \left(\frac{S_x^2}{\sigma_x^2}\right), \quad \text{where } \sigma_x^2 = \frac{A^2-1}{12}$$

[42] The interrater agreement for a statement X in the questionnaire lies between 0 and 1, where 0 signifies perfect disagreement and 1 signifies perfect agreement among the respondents.

[43] The variance index is the expected variance due to purely random error.

Overall, the average score for the responses was between 4 and 5 across all questions in the questionnaire, which indicated high feasibility, functionality and usability of the process. The interrater agreement for these average scores showed a moderate to high degree of agreement between participants and across the cases (r_{wg} values ranged from 0.75 to 0.88). This indicates that the participants collectively felt that:

- the process was logical and that the workshop format was appropriate (feasible),
- the management of risk was well integrated into the overall roadmapping process and results were relevant to the objectives of the process and the organisation (functional), and
- the steps followed were clear, the visual charts and templates were easy to apply, the time allocated for the process (1-day workshop) was adequate and that the workshop was not overly arduous (usable).

Comments given as part of the feedback indicated that the structure and build-up of the process, from preparation through to the workshop stage was logical. The one-day format of the workshop was also seen to be appropriate. In terms of usefulness of process, the individual techniques applied were generally seen as appropriate for the risk assessment steps, as indicated by Table 7.4 (further explained in Section 7.3.2). Feedback also indicated that the process, in addition to helping to identify (and better define) new market opportunities, helped the participants to think through the possible risks and improve their action plans. The value-attainability-based prioritisation and selection of value propositions was also seen as an improvement over the use of simple dot-voting. The risk-profiling step was particularly useful in all the cases for exposing risk-laden issues in the value propositions. However, modifications were made to it after Case B (according to suggestions to improve its functionality). Also, slight modifications were made to the value-attainability matrix and the probability-impact matrix to improve their functionality. These modifications will be discussed in Section 7.3.3. On usability, comments indicated the process was simple and understandable as a whole, and the methodology followed was clear. However, in the course of the process, certain terms required clarification by the facilitator (or researcher). For example, the sub-criteria used in the prioritisation of value propositions sometimes needed further explanation to the workshop participants. Overall, compared to the feedback received on the initial version of the process (Section 6.1), the feedback here suggests that the process has been improved, especially in terms of its usability.

Nevertheless, examination of the scores showed that most of the lower scores were registered under 'usability', indicative that is still room for improving the ease of applying the process. One way to achieve this might be to apply the process in a two half-day format, as was carried out in Case D. This appears to be supported by Case D participants' responses to the statement about how reasonable the physical and mental demands of the process were (question C4 in Appendix 10). For this question, Case D registered the highest mean and interrater agreement scores, suggesting an improvement in usability could be achieved by splitting the process into two sessions. However, this might introduce logistical challenges (and possibly additional costs) especially if participants are not co-located.

Feedback indicated there was adequate time within the 1-day workshop session (and in Case D, two half-day sessions) to carry out the process. This is thought to have been influenced by the choice of methods, especially considering the non-application of scenarios (and the resulting need to develop multiple strategic landscapes) within the workshop process.

7.3.2 Feedback on choice and usefulness of techniques

As part of the planning process, it was required that the researcher and process sponsor reached an agreement on what techniques to apply. The same set of techniques was presented to the process sponsors across the five cases. Notably, in all the cases, the process sponsors decided they would not want to build scenarios, when they realised that it would lead to a process requiring more time in preparation and possibly during the workshop.

However, the researcher proceeded to assess the level of certainty in the pre-workshop information relating to the external environment of the organisation (i.e. market trends and drivers) to see if ambiguity could be diagnosed in the collected data. This was carried out as part of the pre-workshop data collection process by asking the participants to assign levels of certainty (based on three levels of confidence) to the information they supplied (see Figure 7.1 for template used for this purpose, and Appendix 9a for an example of a filled template)[44]. Across the cases, it was identified that very few of the most critical of the data was regarded as highly uncertain by the participants. Participants were moderately or highly certain on most of the information they provided, suggesting that it would have been unnecessary to apply scenario techniques even if they had been allowed by the process sponsors. Pieces of information around which there was moderate-to-high uncertainty were used to indicate risks in the risk identification and assessment step during topic exploration (as shown in Figure 7.10). The other techniques/methods applied during the process are as follows:

- Brainstorming (for risk identification)
- What-if questioning + devil's advocacy (for identifying and questioning assumptions)
- Prompt lists (to facilitate brainstorming and what-if questioning for risk identification)
- Probability consequence assessment of risks
- Risk-profiling (assessment of the riskiness of value proposition)
- Value-attainability assessment of value propositions[45]
- Risk mitigation hints
- Charts applied in the process for visualisation and communication

The participants were asked to specifically indicate which of these they found useful in the process. As shown in Table 7.4, all the techniques were considered particularly useful by at least two-thirds of all the participants (14 out of 21) involved in the process testing. In communicating the outcomes of the workshop, the traffic light colour scheme was used to indicate levels of criticality of risks and uncertainties as assessed during the roadmapping process. Post-workshop report feedback from the process sponsors indicated that the reports were easy to read and understand.

[44] Where participants assigned different levels of certainty to similar information, an aggregate level of certainty was determined. For example, if three different ratings, e.g. 'high', 'high', 'medium', were received for the same piece of information, a 'high' rating is adopted. If there are two ratings of 'medium' and 'low', then the rating assigned to the piece of data or information is 'medium/low'. Interestingly, where different ratings were assigned to the same information, the participants' perceptions were quite consistent with one another. For example, the two extreme ratings 'high' and 'low' were not seen to have been assigned to the same piece of information in any of the cases.

[45] Risk-reward matrix was also suggested for use, but was dropped since it was clearly a variant of the attainability-value matrix.

Process evaluation summary													
		Overall		**Case A**		**Case B**		**Case C**		**Case D**		**Case E**	
Criteria	**Statement (sub-criteria)**	$\boldsymbol{\mu}$	r_{wg}	$\boldsymbol{\mu_1}$	r_{wg1}	$\boldsymbol{\mu_2}$	r_{wg2}	$\boldsymbol{\mu_3}$	r_{wg3}	$\boldsymbol{\mu_4}$	r_{wg4}	$\boldsymbol{\mu_5}$	r_{wg5}
	The identification of risk issues as well as the assessment of their severity and identification of mitigating actions were achievable **(Logical flow)**	**4.55**	0.83	**4.67**	0.89	**4.40**	0.68	**4.57**	0.88	**4.75**	0.91	**4.33**	0.89
Feasibility	Overall workshop format was appropriate **(format)**	**4.55**	0.88	**5.00**	1.00	**4.40**	0.88	**4.57**	0.88	**4.50**	0.88	**4.33**	0.89
	The process (techniques) supported the identification, assessment and mitigation of (uncertainty and) risk well **(Integration)**	**4.55**	0.88	**4.67**	0.89	**4.60**	0.88	**4.43**	0.88	**4.75**	0.91	**4.33**	0.89
	The risk issues identified and mitigating actions drawn up were relevant to the objectives of carrying out the process [and the organisation] **(Relevance)**	**4.27**	0.81	**4.00**	0.67	**4.60**	0.88	**4.00**	0.86	**4.50**	0.88	**4.33**	0.89
Functionality	I will be willing to apply the process again in the future **(Usefulness/ willingness to repeat)**	**4.73**	0.86	**5.00**	1.00	**4.40**	0.88	**4.86**	0.94	**5.00**	1.00	**4.33**	0.56
	The steps to be followed were clearly understood (Clarity)	**4.32**	0.80	**4.67**	0.89	**4.60**	0.88	**4.14**	0.80	**4.00**	0.75	**4.33**	0.89
	The visual templates and were straightforward and easy to apply **(Ease of application – visual charts)**	**4.36**	0.75	**4.33**	0.89	**4.80**	0.92	**4.14**	0.65	**4.50**	0.88	**4.00**	0.67
	There was sufficient time to discuss *the important issues* as well as the risks **(Time sufficiency)**	**4.36**	0.75	**4.67**	0.89	**4.60**	0.88	**4.14**	0.65	**4.50**	0.88	**4.00**	0.67
Usability	Demands of the process on you as a participant were reasonable **(Ease of application - analysis)**	**4.45**	0.79	**4.33**	0.89	**4.20**	0.72	**4.43**	0.73	**4.75**	0.91	**4.67**	0.89

Table 7.3 – Process evaluation feedback

Functionality of process design elements (tick the elements you found useful)		Case A			Case B						Case C					Case D				Case E			**Total**
		CH	ES	AC	CT	NF	RP	DD	PJ	AS	GS	GB	AH	RC	NM	SK	NL	ML	MM	SM	MJ	GM	
Identify uncertainty and risk	Brainstorming risks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	19
	What-if questioning + devils advocacy		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		17
	Prompt lists	✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓				✓	✓	14
Assess risks	Probability-consequence matrix	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	20
	Risk/Maturity profiling		✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓			✓	✓	✓	14
	Feasibilibility - Opportunity matrix	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓		✓	✓	✓		16
Mitigate risks	Hints (prompts) for risk mitigation	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓	✓		15
Communicate risks	Charts used	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓		15

Table 7.4 – Feedback on the functionality of techniques

KEY Market / Industry Drivers				
Rank	**Market / Industry Drivers**	**Timescale**	**Votes**	**Confidence**
1	Healthcare costs in high income countries unsustainable	S	6	High
2	Increasing healthcare costs in medium income countries	L	4	Low
3	Growing diabetic population in high/med income countries	S/M/L	4	HIgh
4	No practical cure for diabetes achieved (Stem cell replacement pancreas)	L	3	Medium/ Low
5	Use of ****** **** in med apps	M	3	Medium
	Sales, marketing and distribution partners looking for ****	M	2	High
6	No overwhelming competitor product	L	2	Low
7	Improved user experience (Patient compliance)	S	2	High
8	Agreement on reimbursement level	M	1	Low
9	Regulators update their **** position	M	1	Low
10	Technology savy patients (Continued growth in smart phone use)	M	1	Medium/ High
11	E-health regulation	L	1	HIgh
12	********* ********* market growing & Move from ***** to******	S/M/L	1	HIgh
13	Explosion of type II diabetes globally	L	1	HIgh
14	Closed loop control (artificial pancreas)	L	0	Low

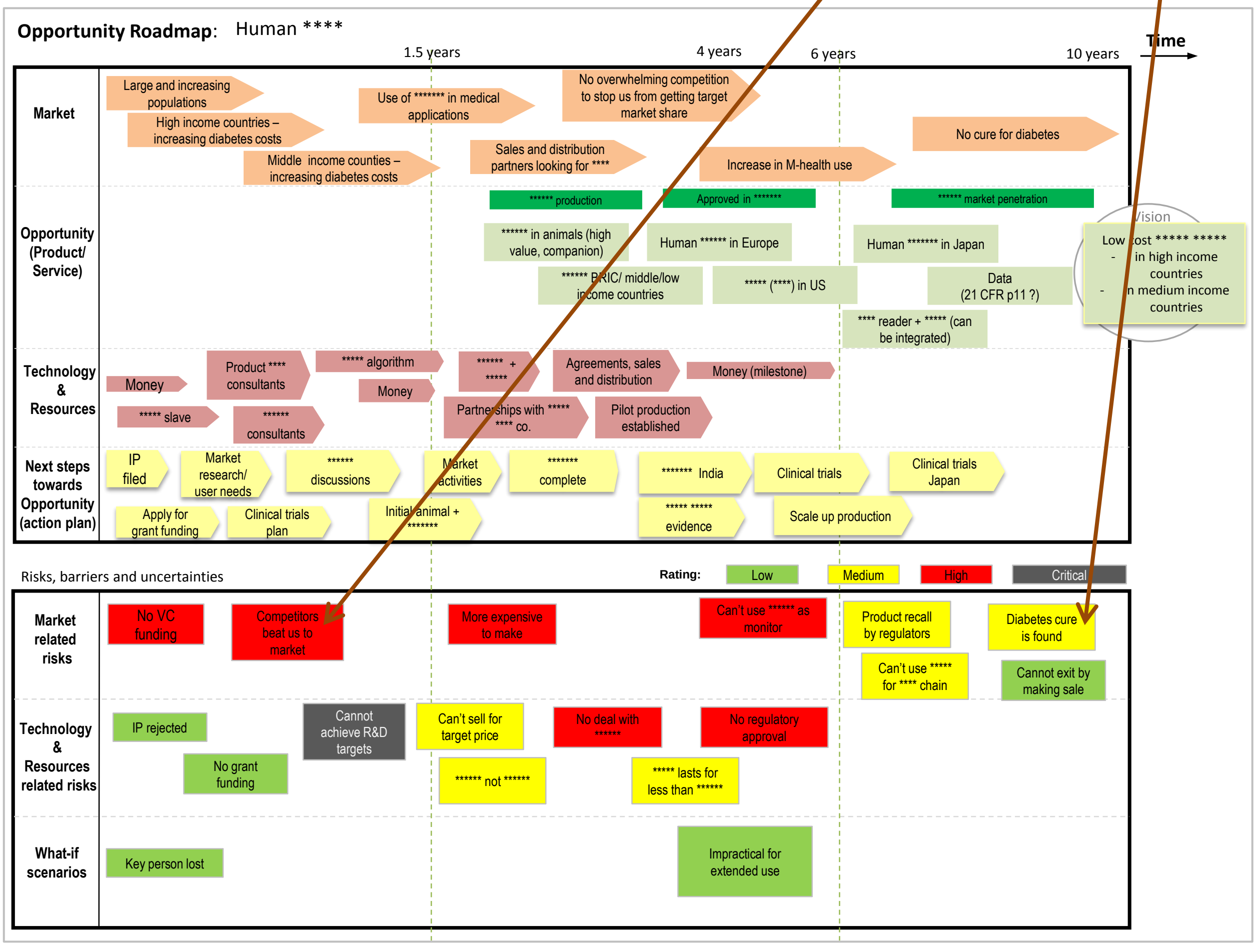


Figure 7.10 - In addition to the use of brainstorming, market information with low-rated certainty levels were applied as indicators of risk areas (Case D)

7.3.3 The changes to methods and techniques as process testing progressed

Based on some of the feedback and discussion with process sponsors, modifications were made to some of the techniques within the RSRM process. These changes were applied to subsequent cases.

a. Modifications resulting from Case A

The application of the process in Case A prompted the following:

- Modifications to the value proposition prioritisation step:

  It was suggested that in choosing value propositions, the timeframes in which they are expected to be actualised (i.e. short term, mid-term or long term) should be considered in addition to their 'value' and 'attainability' (Figure 7.11). Thus, time was used as a third dimension (in addition to value and attainability), to improve the strategic balance (across time) of the value proposition choices made.

  It was also noted that it would be necessary to follow-up the initial positioning of value proposition on the value-attainability chart (through scoring) with a discussion among workshop participants as a means of sense-checking the results. This approach promotes consensus among the group in addition to the objectivity achieved as a result of prioritising the value propositions based on the criteria. It might however lead to a re-ordering of some of the value propositions on the chart (Figure 7.13).

- Modification to the probability-impact assessment step:

  In the assessment of identified risks (under topic exploration), it was pointed out that it would be necessary to clarify what the 'low', 'medium' and 'high' levels of 'impact' mean in specific terms for the organisation and the vision for the value proposition (Figure 7.12). Also, similar to the introduction of the time dimension in the value-attainability matrix, it was suggested that an introduction of the third dimension of time on the probability-impact matrix would further help in identifying the relative criticality of identified risks.

- Addition of cross-business risk chart

  The inclusion of a cross-business risk chart (Figure 7.14) in the post-workshop report was suggested. This was to communicate risks (that were identified during the topic exploration process) that recurred across multiple value propositions. Its application would involve comparing risks identified from the various topic exploration activities (for the different value propositions), to see if there are any commonalities. This will point to risks that may be business-wide, for which coordinated mitigation action may be useful.

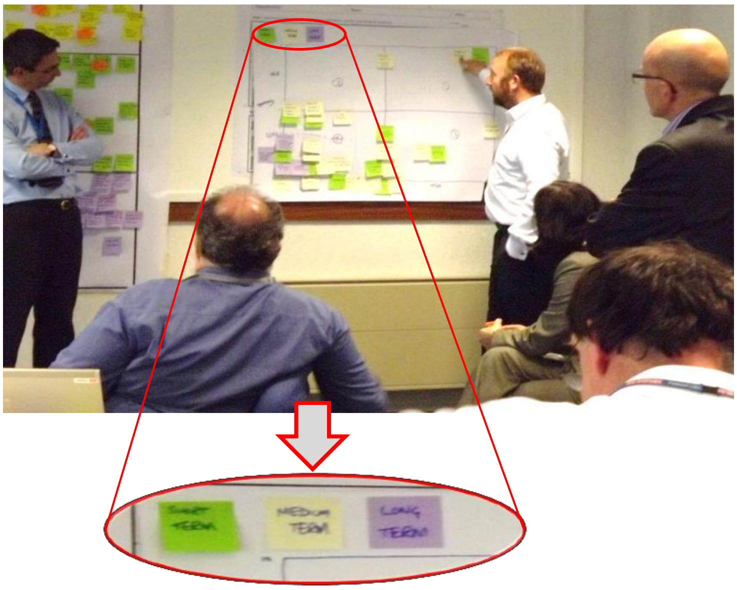


Figure 7.11 - Discussing initial results from the value-attainability matrix (i.e. performing a sense-check) in Case B. The picture also shows time being considered in prioritising the value propositions

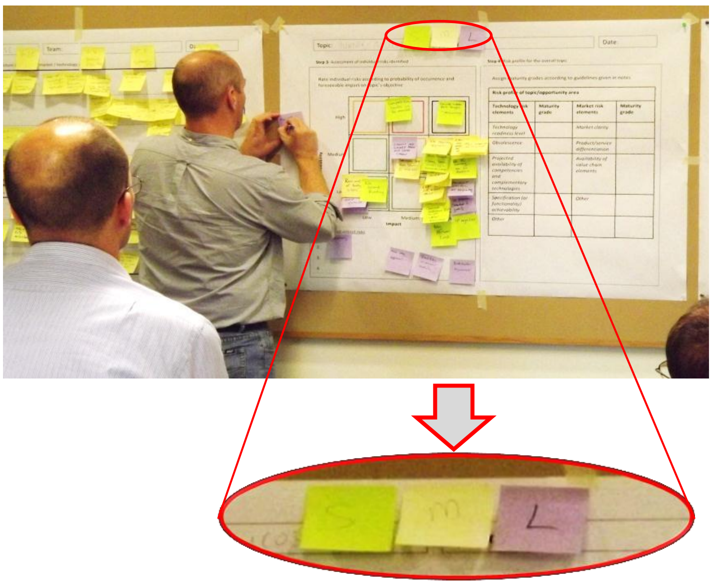


Figure 7.12 - Using the probability impact-matrix in Case D to rank identified risks with the consideration of time

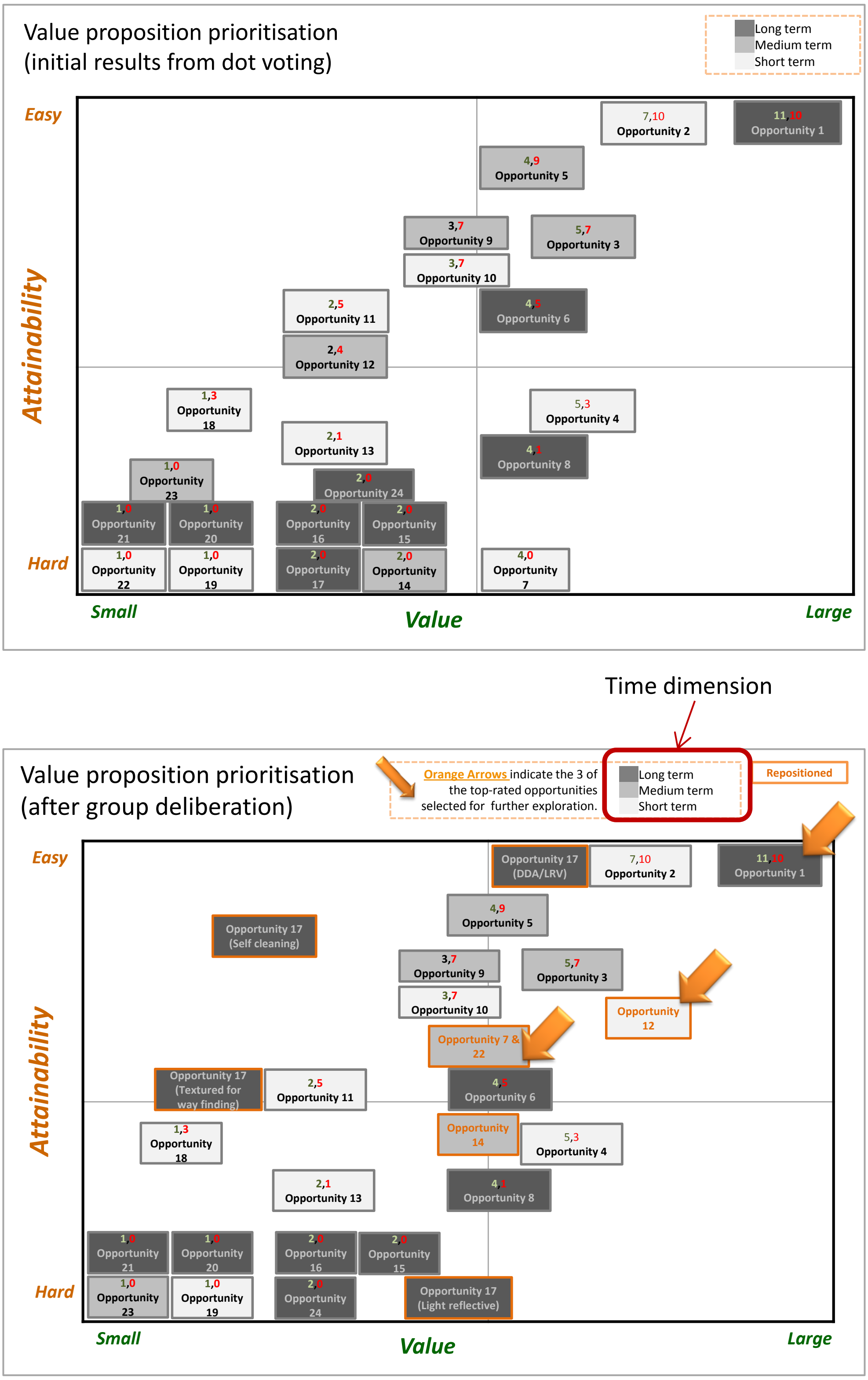


Figure 7.13 - Charts showing value propositions on the value-attainability matrix before and after the sanity check (through group discussion) from Case B

The orange arrows show the top-three value propositions chosen for further exploration. The time dimension was put into consideration in selecting them (targeted actualisation times are spread over the short, medium and long term) for strategic balance. Appendix 9h shows the list of value propositions (and results of voting), which was used to generate the top chart.

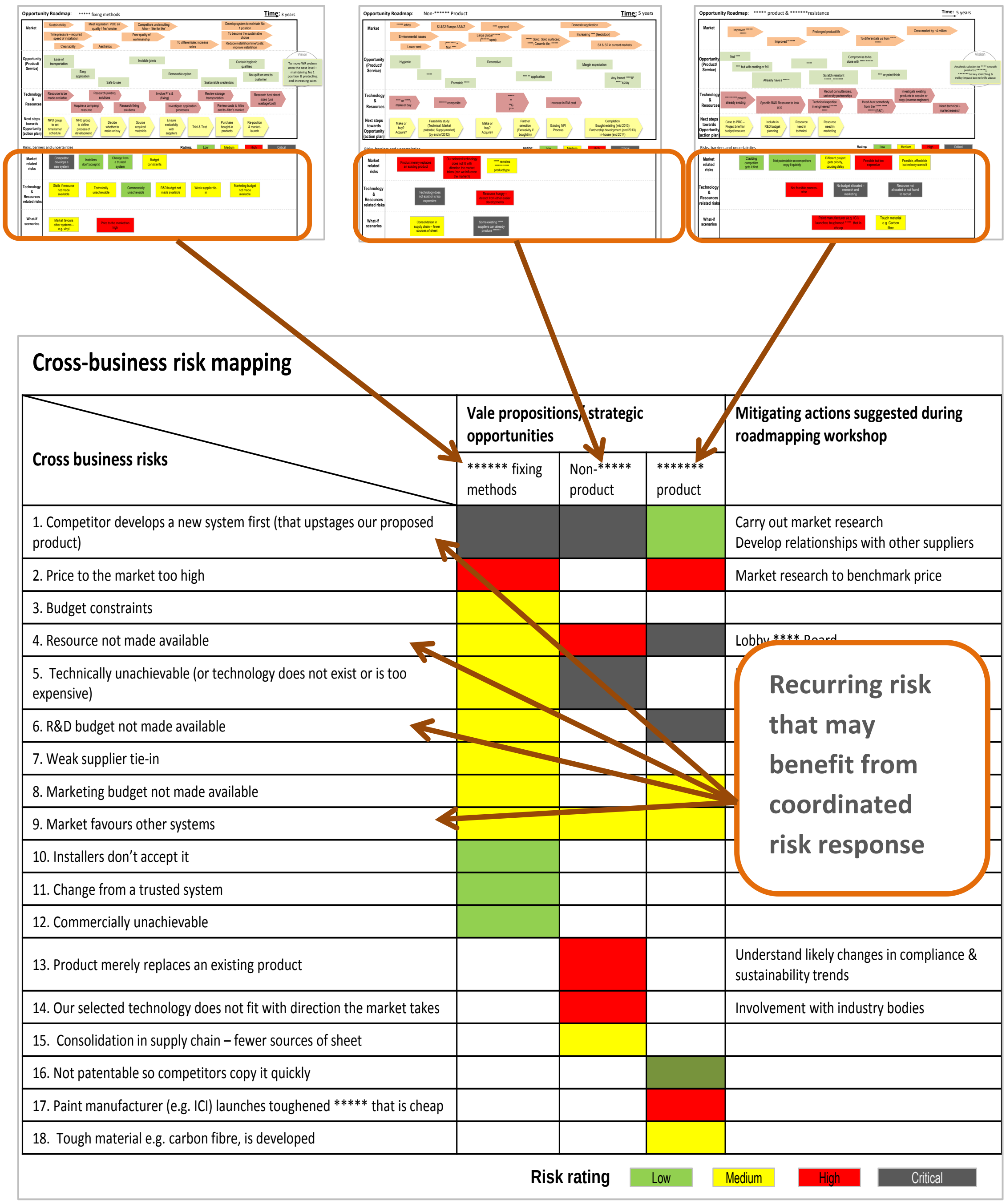


Figure 7.14 - Cross-business risk map generated showing commonalities among the risks identified from the three value propositions explored during the roadmapping exercise in Case C

b. Modification resulting from Case B

The application of the process to Case B prompted the following:

- Modification to the risk-profiling step during topic exploration activity.

  As intended, the risk-profiling step served to calculate the level of market and technology (and overall) riskiness associated with the value proposition. However, the computation of riskiness (using formulae given in Section 6.5.2) led to disagreements among the group about the merits of pursuing the value proposition[46]. This posed a significant drawback to group consensus, which had the potential to damage its collective ability to take forward the value propositions through product development. As a result, it was considered that the risk-profiling step may be better applied as a means of identifying gaps (or weaknesses) in the organisation's market understanding and capabilities (technology and resources), which would expose the value proposition under consideration to risk of failure. To this end, the values assigned to 'probability of success' were simply used to indicate the organisation's maturity (or generate a *risk maturity profile*) in terms of market understanding and technology capabilities. Thus, the values assigned to the individual market and technology risk elements were retained, but their aggregation using the formulae was discontinued for subsequent cases. This mode of applying the risk-profiling step as a means of gauging the 'risk maturity' was preferred since it brought to light areas of organisational weaknesses, which in turn indicated additional risk issues, and therefore prompted necessary mitigation actions. The risk-profiling step (now called 'risk maturity profiling') was applied in this revised format in subsequent cases.

c. Modifications resulting from Cases C, D and E

No further modifications were made to the RSRM process as a result of carrying out Cases C, D and E. Figure 7.15 indicates the number of modifications made to the RSRM process at each stage of appraisal since it was first described in Chapter 5 of the thesis.

[46] The values computed for riskiness were quite high (understandably so, when one considers that the value propositions were all still early-stage). However, it was seen that these high values generated disagreement among the participants on the relative merit of the value propositions vs. the riskiness and tended to weaken the resolve to advance the value propositions.

The ‘levelling out’ of the graph (over cases C, D and E) indicates a stabilisation of the process (Platts, 2010; Maslen & Lewis, 1994).

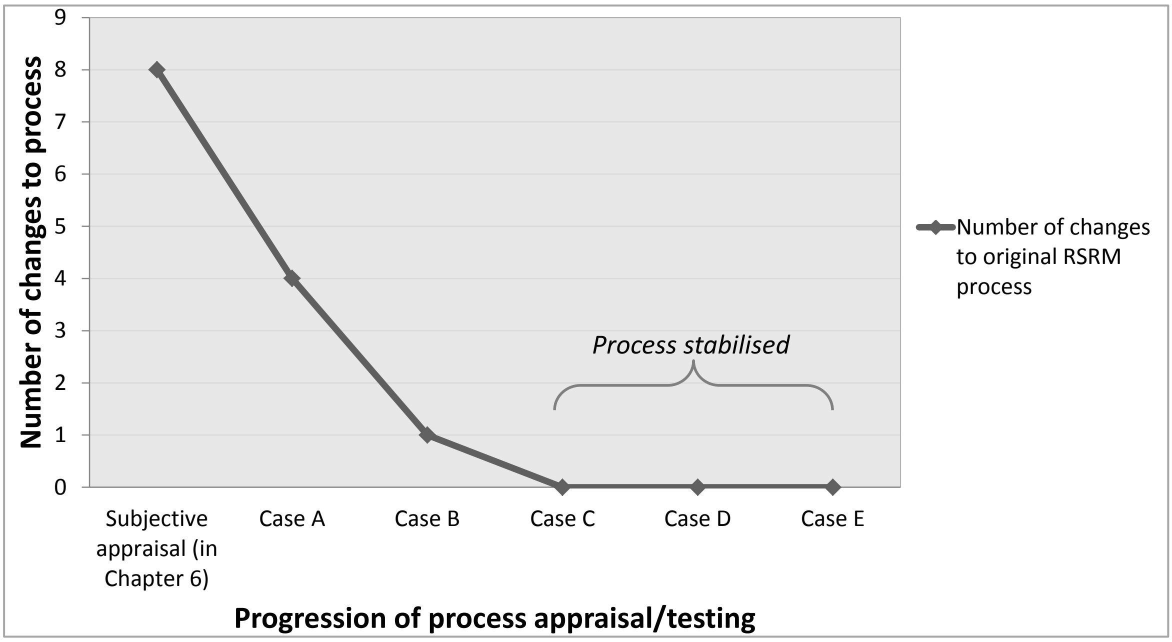


Figure 7.15 – Number of changes to RSRM process as appraisal progressed

7.3.4 Further reflection and learning

Further learning was generated based on observations and reflection of the researcher and the feedback comments received from the participants across the process.

The organisations that took part in the RSRM process testing process belonged to different industries (chemical, defence, building/decoration, medical devices and power generation). The positive feedback received from all of them indicated that the process is generic enough to be applied across industries.

Also, these organisations had no previous practical experience in roadmapping. However, prior knowledge and experience in risk management techniques appeared to contribute to the ease with which the RSRM process was completed. For example, the participants in Case B had prior understanding of some of the risk management steps applied, and required less guidance from the facilitator when compared to other cases.

The devil's advocate technique works particularly well if there is a 'sceptic' among the group. This was the situation in Case B (Figure 7.16), in which one of the participants led the entire group in identifying risks, assessing and supplying mitigation actions to them (steps 2, 3, 4 and 5) across the three value propositions explored. If such a personality is noticed, he/she should be nominated by the facilitator/process sponsor to drive the aspects that concern risk management within the process. If not, as was done in the other cases, the role of devil's advocate can be shared amongst the members of each topic exploration group, facilitated by the prompts on the roadmap template.

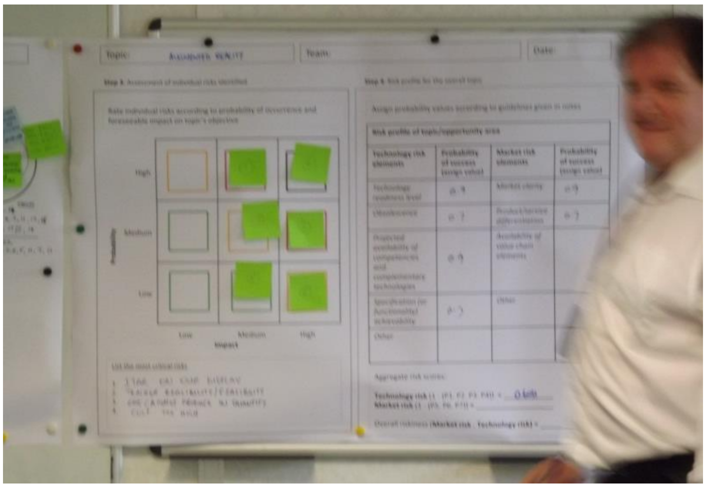


Figure 7.16 - Devil's advocate role taken up by one of the participants in Case B

The determination to have the RSRM workshop process completed within a day's schedule made it necessary to apply most of the techniques in their basic formats. It should be recalled that the one-day programme was designed as a fast-start to encourage organisations to employ the roadmapping and also to explicitly consider uncertainty and risk in a structured format within it. However, if the performing organisation can devote more time and resources to the process, it is possible to apply the steps and techniques described here in more sophisticated formats. For example, in prioritising value propositions, the application of the value-attainability matrix could be modified to allow individual weighting, scoring (and aggregation) of the sub-criteria that have been used to define the 'value' and 'attainability' criteria here. In addition, the elements (or factors) considered in the risk/maturity profiling step may be expanded (i.e. added to) to give a more comprehensive risk profile.

The addition of the time dimension to the value-attainability and probability-impact matrices (used to prioritise value propositions, and assess risks, respectively), is significant since the time dimension is fundamental to roadmapping. The relative priorities of (otherwise closely rated) issues can be made more distinctive by considering how soon they are expected to be delivered (for value propositions) or how imminent they are (for the risks). It should be noted that the consideration of time in applying these techniques during the RSRM process was intuitive. However, it is envisaged that more rigorous analysis may be applicable in a more sophisticated process of *time discounting* (Frederick et al., 2002) in identifying priorities among alternatives that span across time.

The mitigation actions drawn up as a result of following this process provided additional action steps that would otherwise have been unidentified in S-Plan (i.e. the original roadmapping process upon which the RSRM is based). Compared to S-Plan, RSRM provides the additional advantage of a structured and logical procedure for identifying risks and critical gaps in knowledge for value propositions in their early stages of development.

The RSRM process (by virtue of the integration of roadmapping and risk management) reinforces the expectation that roadmaps should not be created as a one-off but consistently revisited and updated. It is necessary to revisit the roadmap, and make sure the identified risks are being monitored and proposed action plans and risk mitigating steps are followed up and acted upon. The risk maturity profile should be monitored and updated to ensure that steps are being taken to strengthen the organisation's position in areas the risk profile showed as being weak.

7.3.5 Reflection on the framework

The application of the RSRM process in this testing phase revealed no additional factors to be considered in dealing with uncertainty and risk in roadmapping. This indicated that the framework is comprehensive and robust.

7.4 Summary

This chapter presented the testing of the RSRM process using five in-company case studies, through action research. The process was taken through some modifications during the first two cases, and was seen to be stable over the last three cases. Feedback from the process participants indicated the process was feasible, functional and useful. Cases A and B were facilitated by roadmapping practitioners, while Cases C, D and E were facilitated by the researcher. The involvement of the roadmapping practitioners in facilitating the first two in-company cases provided an independent and external (and more objective) view of the process, to ensure reliability of research process and results (Gummesson, 1991).

Chapter 8 – DISCUSSION

The previous chapters have presented findings from research carried out to investigate the treatment of uncertainty and risk in roadmapping, spread over two phases: 1. the exploration of roadmapping practice to understand the mechanisms of uncertainty and risk within roadmapping, and 2. creation of a roadmapping process which recognizes these mechanisms and addresses them. This chapter discusses the practical and theoretical contributions of this research work. It builds on earlier reflections and discussions in this thesis across both phases of research (as presented in Sections 4.3.2, 6.4 and 7.3).

Section 8.1 provides a summary of the research problem and research methods applied. Section 8.2 presents a summary of research findings. Section 8.3 discusses these findings and draws out practical and theoretical contributions from them, and Section 8.4 summarises the chapter.

8.1 Summary of research problem and approach to research

8.1.1 Research problem

Roadmapping is an increasingly dominant approach used for strategic innovation planning, especially for planning at the early-stages of innovation. Uncertainty and risk are fundamental and important issues in strategy and innovation, and they directly affect a firm's objective of value creation. However, it has been noted that very limited attention has been given to how these issues are addressed in roadmapping, strategic planning and the early-stages (or front-end) of innovation activities. The mechanisms of risk management and how to respond to different kinds of uncertainty are not fully understood. Also, despite the awareness that roadmapping should deliver, as part of its benefits, the identification, resolution and communication of uncertainty and risk surrounding the strategic issue it addresses, there is no practical guidance within roadmapping on how these can be achieved. It is these gaps that research conducted here aimed to bridge through the provision of a framework that explains the factors that influence the explicit treatment of uncertainty and risk in roadmapping, and the development of a roadmapping process that is aware of these factors and considers them deliberately in addressing uncertainties and risks pertinent to the strategic focus of the roadmap.

The specific questions the research sought to answer, with respect to these gaps and objectives were:

- How is uncertainty and risk manifested in roadmapping, within the context of its application to early-stage innovation strategy, and what are the implications for roadmapping practice?
- How might roadmapping (in the context of its application for early-stage innovation strategy) be carried out to so that uncertainty and risk are explicitly considered and managed within it?

8.1.2 Research approach

The entire research was split into two phases, each phase corresponding to each of the research questions outlined above. The first phase of research relied on the insight from existing literature and roadmapping practice. The literature explored was that linking roadmapping and uncertainty, risk and risk management (through strategic planning and innovation literature). Insight from roadmapping practice was obtained through interviews of roadmapping practitioners, case studies of roadmapping exercises, and an analysis of a corpus of published roadmaps. All the interviews were recorded and fully transcribed, and a thematic analysis of the transcriptions was carried out. An analysis of the content of the corpus of roadmaps was also done.

The second phase of this study was carried out using procedural action research (PAR) methodology to build a risk-aware strategic roadmapping (RSRM) process, which integrates appropriate risk management steps and methods into roadmapping. The PAR methodology comprised the creation of a conceptual RSRM process, and subsequently testing and improving it through a combination of appraisals by roadmapping and strategic planning professionals (series of interviews and focus group meeting), and its application in five in-company case studies.

8.2 Summary of research findings

This summary of research findings is presented in two parts. The first part corresponds to the first phase of research, which attends to the first research question, while the second part corresponds to the second phase of the research, which attends to the second research question.

8.2.1 Phase one findings

The findings in the first phase of research were derived from a combination of literature exploring the treatment of uncertainty and risk in strategic planning, consultation of roadmapping practitioners (through interviews) carried out in two stages (Practitioners 1-6, and then Practitioners 7-11), the examination of five case studies of roadmapping exercises, and the exploration of a corpus of published roadmaps available in the public domain. It is necessary to point out that the practitioners interviewed explicitly expressed the practical need for a better understanding of how to address uncertainty and risk in roadmapping. In addition, while the five roadmapping cases explored were those to which the researcher was able to obtain access to certain conditions set out in the search and choice of cases. The most important of these were that each case concerned roadmapping at the early-stage of innovation, and that the roadmap created was strategic in its purpose and outlook (i.e. of a long-term time horizon). The corpus of roadmapping documents explored were strategic early-stage innovation roadmaps that had been compiled by Phaal (2011).

In summarising the findings, first general findings are presented, which draw together commonalities from the various sources of data consulted in the research (i.e. practitioner interviews, case studies, and corpus analysis). This is then followed by a presentation of the differences amongst some the data collected thought to carry significant implications for the findings, particularly amongst the case studies examined, and the roadmaps retrieved from the corpus.

A. General findings

These general findings are captured by the framework developed in the course of the research (as presented in Figure 8.1). These findings, drawn from interviews with roadmapping practitioners, case studies of roadmapping exercises and a review of the roadmapping corpus are grouped under two broad topics:

- Factors influencing the treatment of uncertainty and risk in roadmapping
    - Content-related factors
    - Process-related factors
- Risk-aware roadmapping
    - The risk-aware roadmapping process
    - The methods applied in the process

i. Factors influencing the treatment of uncertainty and risk in roadmapping

The factors identified are those that must be taken into consideration in addressing uncertainty and risk in roadmapping. These factors are in two groups, namely the roadmap content-related factors, and roadmapping process-related factors.

1. Roadmap content-related factors

The roadmap content-related factors are the manifestations of uncertainty and risk within the roadmap framework (Figure 2.10). Primarily, these factors are the sources of uncertainty (and risk) for the focus of the roadmap, (i.e. the focus of the strategic innovation plan). It was identified that up to three types of uncertainty may be manifested in roadmapping and that these three correspond in terms of relevance and importance to the three layers of the roadmap framework (as was captured in Figure 4.6):

- External environment uncertainty: know-why layer (which holds the information on the trends and drivers leading up to the future market),
- Internal environment uncertainty: know-how layer (which holds the information on the resources, capabilities and technologies that would be mustered by the organisation to innovate), and
- Decision uncertainty: know-what layer (which holds the value propositions, i.e. the innovation ideas, which will be developed into products and services along the more mature stages of innovation).

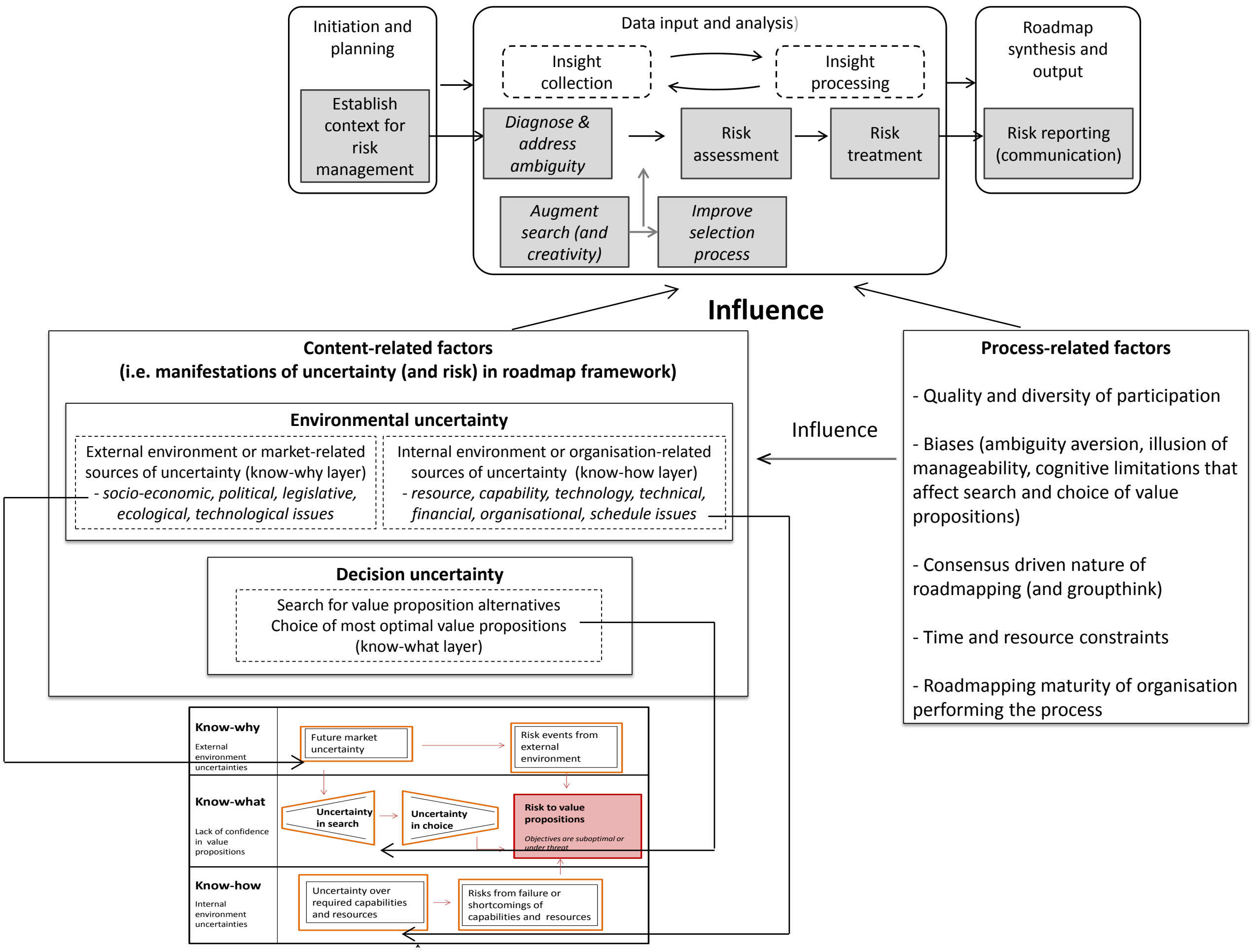


Figure 8.1 - Framework of factors influencing risk-aware roadmapping

The external environment [or market-related sources of] uncertainty factor concerns uncertainty surrounding the data or knowledge relating to the external environment of the organisation, or the direction and needs of the future market. This external environment factor might include uncertainties surrounding specifics like the socio-economic , political, legislative, ecological and competitive trends and drivers that combine to ultimately shape the future market. The significance of this is that without a clear view of the future external environment, the innovation focus of the roadmap may be wrongly formulated for a target market, or at extreme, targeted at a non-existent market. Thus there is a risk that a product, even if created successfully, will fail because the market would have been misunderstood.

The internal environment [or organisation-related sources of] uncertainty factor concerns uncertainty surrounding the availability of the necessary resources, capabilities and technologies for delivering value propositions identified on the roadmap. It also concerns the perceived ability of the organisation to combine these resources, capabilities and technologies in such a way that the value propositions are delivered successfully. In finer detail, issues captured under this group of factors may include technical, financial and schedule uncertainties. The significance of internal environment uncertainty factor is that it indicates the risk to the successful delivery of innovation by the organisation.

The two previous factors concern uncertainty surrounding knowledge of the direction of the external organisational environment (or future market), and the capabilities in the internal organisation used in building the roadmap. However, the decision uncertainty factor relates to two important decision routines carried out within the roadmapping process. These are the search routine and choice routine, i.e. the search for value propositions alternatives (innovative ideas and concepts), and the choice from those alternatives of the one(s) that appear most promising to carry forward for development. The significance of decision uncertainty is that a lack of clarity surrounds the identification of innovative ideas and the choice of the most beneficial of those ideas, to create and capture maximum value both for the customers and organisation.

2. <u>Roadmap process-related factors</u>

These are factors related to the running of the roadmapping process and the context or setting within which it is carried out. The significance of these factors is that they can affect the perception of uncertainty (and risk) and/or influence how it is addressed. Factors identified are:

- Quality of participants in the roadmapping process,
- Diversity of the participants,
- The cognitive biases of the participants such as ambiguity aversion, illusion of manageability and the focus on limited alternatives,
- The consensus-driven nature of roadmapping,
- Time and resource constraints usually associated with roadmapping exercises, and
- The roadmapping maturity (or experience) of the organisation carrying out the process.

The strategic information contained in roadmaps (in the three layers of the roadmap) relies heavily on the knowledge and expertise of the process participants. Their depth of knowledge and experience translates into the accuracy and completeness (and therefore, certainty) associated with the roadmap's data, on the external and internal environments and what the value propositions and critical objectives are. The less the diversity of participants, in terms of expertise or knowledge area, the more likely it is to have a narrow range of views and data, that might have neglected certain pertinent issues, which can be crucial to the success of the objectives. This can affect the type, range and importance of the uncertainties and risks perceived by the roadmapping process participants. For example, the Case 3 Facilitator explained that the only market-related risks were identified during the roadmapping process because the participants were technically biased in their knowledge and so did not identify any technology-related risks. The reason for this was attributed to the control the participants believed they had over technical issues included in the roadmap (i.e. the illusion of manageability), and therefore did not see how technical aspects could pose risks.

The consensus-driven nature of roadmapping promotes groupthink, which in turn may enhance the biases (such as ambiguity aversion) or help them spread to the rest of the group from one individual. Importantly, roadmapping exercises are often carried out under limited and budgetary constraints[47], and under such conditions, explicit and conscious risk management is easily relegated to the background or not attended to, especially if it is not regarded as being central to decision-making process. However, higher organisation maturity (and experience) in roadmapping is associated with recognition of the benefits of roadmapping and therefore an allocation of greater time and resources to the exercises, and possibly, as a result, more attention to addressing uncertainty and risk.

ii. Risk-aware roadmapping

1. The generic process

A generic conceptualisation of risk-aware roadmapping (i.e. a roadmapping process in which uncertainty and risk are explicitly addressed) is included in the findings of this research. A combination of views from practitioners interviewed and some of the case studies examined showed that in roadmapping (especially for planning at the early-stages of innovation), risk management[48] should go beyond generic risk management steps (of risk assessment, risk treatment and risk reporting). One reason for this is that uncertainty in roadmapping extends beyond environmental uncertainty (i.e. focusing on risk events arising from the external and internal environments of the organisation, which is the usual focus of risk management literature) to include uncertainty associated with decision routines in roadmapping as earlier pointed out. The findings show that two decisions, which are integral to rational planning, are particularly important to roadmapping and are affected by uncertainty. They concern *the search (or generation) of strategic alternatives to meet objectives* and *the selection from a set of alternatives*

[47] This is probably more of the case with organisations for whom roadmapping is still new approach (and have not yet developed a roadmapping system)

[48] Recall that risk management primarily concerns managing uncertainty (Fowler, 2006)

(through screening and evaluation[49]). This lack of clarity on strategic alternatives (or value propositions) constitutes a form of risk, – the risk of missing innovation opportunities – that corresponds to the decision uncertainty factor earlier described in this chapter. This is important especially when one considers that potential value could be lost by an organisation's inability to identify and focus on 'optimal' or market winning opportunities. The steps of *augment search* (to generate strategic ideas in greater quality and quantity through creativity) and *improve selection* (from a group of alternatives) have therefore been included in the generic risk-aware roadmapping process (as shown in Figure 4.9), to address decision uncertainty in roadmapping through more objective and better-structured means.

The step of *diagnose and address ambiguity* was also introduced into the generic risk-aware roadmapping process, given the understanding that with long-term planning (which is usually the case for strategic innovation roadmaps), there may be a highly uncertain and ambiguous perception of the future external and market environment. This can paralyse the roadmapping process because in such a situation, there is an ambiguous vision or direction for the roadmap and it is unclear how the activity should proceed. Where this is the case (as described by Practitioner 4, and as seen in some of the corpus documents (Roadmaps A1 – A11, as later explained)), it is necessary to undergo, as an initial procedure in risk-aware roadmapping, steps that will help in reducing the ambiguity faced, by providing a structured perception of the future, and creating clear visions for the roadmap.

Thus the generic risk-aware roadmapping process contains the well-known risk management process (i.e. risk identification, assessment and mitigation). However, this risk management process should be preceded by the diagnosis and reduction of ambiguity (if it exists) and accompanied by steps that structure and enhance ideation, and structure and improve selection from a group of innovation ideas.

[49] These are phases of roadmapping (and the rational model). However, in line with Simon (1977), these have been seen to be decision processes in their own right.

2. The risk management methods applied

Risk management methods and techniques applied (or applicable) in roadmapping were identified across the practitioner interviews, the case studies and the corpus analysis. The list of these provided in Table 4.5 (which was compiled across interviews and case studies) includes scenario planning techniques, brainstorming, SWOT analysis, assumptions analysis, SWIFT, devils advocacy, probability-impact assessment, risk-reward analysis, technology readiness level assessment, real options thinking, and TRIZ. However, the list contained in Table 4.5 is by no means exhaustive, as other methods may be applied according to specific customisations and configurations of the generic risk-aware roadmapping process.

B. Differences (and similarities) within data units (i.e. within the case studies of roadmapping exercises, and the corpus of roadmaps)

i. Case studies

1. Similarities amongst the five roadmapping case studies examined

The five case studies examined in Phase 1 of research were similar in that they all concerned roadmapping exercises carried out to provide strategic direction for innovative endeavours. All the cases were similar in structure and execution, leading with a planning phase followed by roadmapping workshops, which relied on expert knowledge. The results of these roadmapping exercises were also similar across the cases in that they all identified their innovation targets and defined the research and other actions needed to reach those targets.

A common and key step in each of the cases was the identification of top priorities among a set of potential innovation ideas or targets, to appropriately focus subsequent innovation efforts. This step was regarded as a means of managing uncertainty. For example, in Case 4 the act of addressing uncertainty by “down-selection” of technology options was pointed out. Similarly, Case 1 explained that prioritisation was used to focus and “reduce uncertainty”. This process of down-selection was executed in varying ways, for example, Case 3 and Case 5 relied on participants’ voting and simple consensus, Case

1 and Case 4 used MCDA techniques, while Case 2 used a combination of voting and MCDA techniques. This step (and manner of managing uncertainty) appears to be crucial for roadmapping as can be seen in one of the descriptions of the roadmapping process as stated for Case 1: "… helping stakeholders to prioritize R&D and assisting DND [Department of National Defence] to bring *certainty* to future requirements" (Soldier Systems Roadmap 2011-2025: Capstone report, 2011, p. 29).

2. Differences amongst the five roadmapping case studies examined

The cases were different in certain respects. These have been captured in Appendix 13B and are outlined below. The most significant differences noticed were those that set Case 4 apart from the other cases as described below.

- Attitude to addressing uncertainty and risk in the roadmapping process

  Case 4 was the only case in which uncertainty and risk were expressly mentioned and explicitly addressed as issues important to roadmapping. Steps for identifying risks, assessing them and mitigating them are clearly outlined items in the process followed, and methods and techniques used include brainstorming, probability-consequence matrix, and TRL-risk assessment.

  While the other Cases also dealt with uncertainty and risk, the steps taken were more implied or hidden. In Cases 1, 2, 3 and 5, no direct mention was made of risk and it appeared no deliberate risk management efforts were taken. However, within these cases, some procedures, which might be regarded as risk management procedures were applied. Examples include the brainstorming of 'bottlenecks' (i.e. risks) in Case 3 (even though the term 'risk' was not mentioned within the roadmapping exercise), and the application of real-options thinking for risk mitigation in Case 1 (even though the term 'real-options thinking' or 'risk mitigation' was not mentioned within the roadmapping exercise).

- The role of roadmapping

  Following on from the preceding point, while Cases 1, 2, 3 and 5 appeared to have used roadmapping more as a planning tool with little or no explicit attention given to risk management, in Case 4 the roadmapping was regarded as primarily providing a means to systematically perform risk-informed decision-making and risk reduction in innovation. Thus, in Case 4, roadmapping was seen both as an innovation planning process and an innovation risk management process. The other cases, Case 1, 2, 3 and 5, it appears roadmapping was applied primarily as a means of planning innovation and any risk management steps applied considered an add-on.

- Nature of Case 4 in terms of its relative position in the early-stage of innovation

  First, it should be recalled that roadmapping for innovation usually has a combination of market pull (or market need) and technology push (as indicated in Figure 2.10). This combination was clearly visible in Cases 1, 2, 3 and 5, in which both the market need and technology perspectives appeared to have been considered for the first time in creating the innovation plan. However, Case 4 appeared to focus only on the technology aspects. The roadmapping process in Case 4 appeared to have been predicated on a market need fully pre-determined prior to the roadmapping activity. The purpose of the roadmap was then only focused on the identification and development of technologies needed to achieve the strategic objectives of the roadmap. In comparison, the other Cases included steps to clarify the market need as well as identify technologies and capabilities needed to accomplish their innovation objectives. Therefore, even though all these cases have to do with the early-stages of innovation, it appears that Case 4 was further advanced down the innovation funnel than the others, given that the market need had been previously clarified, innovation targets had been specified, and the roadmapping process was focused on the development of the technologies required to meet those targets.

- Nature and role of participants

  Another difference between Case 4 and the other cases is found in the role of the participants. In Cases 1, 2, 3, and 5 the creation of the roadmap (i.e. the gathering and analysis of data) relied on workshop participants. However, in Case 4, a core team of 4 persons, who were subject area specialists, created the roadmap. The application of workshops in Case 4 was limited to choice of criteria (through voting) used in the 'down-selection' of innovation targets, and ratifying the roadmap produced by the core team.

- Other differences amongst the cases

  Other differences noted amongst the cases include the differences in:

  - Industry and time horizon of roadmaps: The roadmaps were created for different purposes regarding different industries (Case 1: Defence, Case 2: Energy, Case 3: ICT (and Environmental Sustainability), Case 4: Energy, Case 5: Environmental Sustainability). The time horizon of the roadmaps in each of the cases are considered commensurate with what may be regarded as strategic (or long-term) for their respective industries (Case 1: 15 years (Defence), Case 2: 20 years (Energy), Case 3: 5 years (ICT), Case 4: 14 years (Energy), Case 5: 20 years (Sustainability)). These differences in industry and time horizon are not considered to have introduced significant discrepancies among the roadmapping processes.
  - Resource and time available for roadmapping activity: Case 1 and Case 4 appeared to have spent the longest periods of time on their roadmapping processes, covering 4 years and 2½ years respectively. Cases 2, 3, and 5 created their roadmaps in 6, 8 and 8 months respectively. In addition, compared to the other cases, the roadmapping process in Case 1 appeared to have had ample resources at its disposal, given that an online-based *wiki* was created for the purpose of the roadmap, and over 1500 people were involved. As may be expected, the data showed that greater resource and time afforded carrying out extra data analysis (which include carrying out additional risk management activities) within the roadmapping

process. This finding concerning the effect of resource and time availability on risk-aware roadmapping has already been captured in the framework as discussed under Section 8.2.1A.

ii. Roadmap corpus

Of 650 roadmaps that made up the corpus, only 22 were found to have addressed uncertainty and risk explicitly. 11 of these 22 (i.e. 50%) applied scenario techniques, while the other 11 used other methods. These 2 groups of roadmaps, referred to as 'Roadmaps applying scenarios' and 'Roadmaps not applying scenarios' are discussed separately below, explaining similarities and differences within the groups.

1. Roadmaps applying scenarios

The 11 roadmaps in which scenarios were applied are presented in Appendix 13A.1, to point out some of their features, e.g. the type of scenarios used (whether exploratory or normative) and the purpose of scenario application. Appendix 13A.1 also shows what other risk management steps were taken along with the use of scenarios. Similarities and differences across these 11 roadmaps may be drawn within and across the lines of the type of scenarios and the manner of their application to roadmapping. Of the 11 roadmaps, 6 applied exploratory scenarios (roadmaps A1-A6) while 5 applied normative scenarios (roadmaps A7-A11).

Exploratory scenarios are scenarios created based on projections of past and present trends into the future and they explore situations which are considered future possibilities. Normative scenarios are goal-directed scenarios, which are built on the basis of desired or feared visions of the future. The scenarios draw up how that future may be achieved or avoided (Godet & Roubelat, 1996; Borjeson, et al., 2006). The manner of their application in the roadmap corpus is further described in the corpus below.

- Roadmaps applying exploratory scenarios

  In Roadmaps A1-A6, multiple exploratory scenarios were applied. Across the roadmaps, the aim of using these scenarios was to manage the uncertainty perceived of the future, by understanding different future possibilities, and ***facilitating*** the creation of a future vision for the roadmap. Regardless of the number of exploratory scenarios developed (ranging from 2 – 8 in these cases), a single roadmap emerged from the process. The application of multiple scenarios varied from one case to the other. The following are examples of how the multiple scenarios were used:

- All the scenarios were applied equally in the creation of a single roadmap: Roadmaps A1, A2, A5, A6
- The roadmap is based on the most likely or 'most realistic' scenario, and uses the others to test the robustness of the roadmap or to include contingency plans in the roadmap: Roadmaps A3 and A4.

As identified in Roadmaps A5 and A6, the application of scenarios was followed by the use of other risk management methods. Gap analysis (or backcasting) was commonly used across the roadmaps to translate the roadmap visions (created through the application of scenarios) into actual roadmaps.

- <u>Roadmaps applying normative scenarios</u>

As with the six roadmaps that applied exploratory scenarios (Roadmaps A1-A6), Roadmaps A7-A11 that applied normative scenarios did so to manage uncertainty perceived. However, while exploratory scenarios *facilitated* the creation of visions for their respective roadmaps by clarifying the future, normative scenarios were used to *dictate* the visions for their respective roadmaps. They defined the specific goals and targets for the roadmap, thus fully predicating the framework for creating the roadmap.

In each of Roadmaps A1-A6, multiple exploratory scenarios were used to create a single roadmap. However, in Roadmaps A7-A11, every normative scenario introduced into the roadmapping process was translated into a roadmap. Where multiple normative scenarios were introduced into a roadmapping process e.g. in A10 and A11, each of the scenarios was translated into a roadmap, so that there were multiple roadmaps created within these roadmapping activities. Roadmap A10 is peculiar in that the purpose of the normative scenarios was to define and segment the future market. Each of the four scenarios described a type of future customer (and their specific needs and wants) regarding the innovation the roadmap was planning out. The purpose of these normative scenarios in these roadmaps was 'to remove the highly uncertain and vague nature' (Bridging the gap from earth markets into new space markets (2006)) of roadmap visions and goals, as expressed in Roadmap A11. Roadmaps were then built around each of these storylines to show the technologically feasible route to the goal.

It is noted that the 11 roadmaps applying scenarios were predominantly ICT industry and Energy industry affiliated. The specific reason attributed to this is not ascertained, but reasons speculated include the fast pace of change in the ICT industry and the huge capital expenditure required in the Energy industry, which may increase the perceived business environment variability (and thus uncertainty) and perceived impact of uncertainty (and thus risk) respectively. Both conditions may direct increased attention to uncertainty and a need to address it through the application of scenarios.

<u>2. Roadmaps not applying scenarios (but applying other risk management methods)</u>

11 roadmaps explicitly acknowledged uncertainty and risk, and took steps other than scenario planning techniques to address it. These roadmaps are identified as Roadmaps B1 – B11. These roadmaps were developed for organisations across various industries (e.g. military aviation, ICT, energy, building, Water, and transport). These 11 roadmaps are divided along the lines of how they specifically address uncertainty and risk, as described in the following:

- <u>Roadmaps including explicit risk management steps</u>

  In creating Roadmaps B1 – B6 various types (or sources) of uncertainty were identified and steps were taken to address them. The steps included the application of the risk management process (and corresponding methods and techniques). The types of uncertainty identified across these roadmaps were varied, with examples including economic, commercial, technology, and funding uncertainties, thus covering issues external to the firm (e.g. the economy and market) and those internal to the firm (e.g. resources and capabilities). The specific risk management steps, methods or techniques applied include risk identification, risk assessment, involving risk-benefit (or risk-contribution) appraisals of proposed research activities or technical solutions, risk mitigation, including identifying contingency plans and activities (such as "developing partnerships across the industry to manage technology risks" in Roadmap B3). The variability in the specific steps taken or the methods used in addressing uncertainty across the cases cannot be specifically linked to the differences in topic or industry for which the roadmap was created, and are thought to have been due to the preferences of the process owners or facilitators.

- <u>Roadmaps whose topics focused on risk mitigation</u>

  The purpose of Roadmaps B7 – B9 was to create plans and draw up innovation paths to mitigate potential societal risks (such as the cyber security risks to control systems in the water sector, and ICT vulnerabilities to power systems). The provision of these plans and R&D paths served as a means of identifying mitigation actions. In these roadmaps, specific risk management methods were not applied, but the roadmapping efforts (whether entirely, like in Roadmaps B7 and B8, or partially in Roadmaps B9), were directed at identifying innovation to address the societal risks they were focused on mitigating or avoiding.

- <u>Roadmaps from roadmapping processes applied as risk management tools</u>

  Roadmaps B10 and B11, both created by Idaho National Laboratory (INL) (same as in Case 4) were created based on the application of roadmapping as a risk management tool or process. The roadmaps were created to reduce uncertainty and risk surrounding their targeted technological developments. Within the roadmapping process, uncertainties (or gaps in technical knowledge) surrounding the technology development were identified, the most critical ones selected (i.e. those with greatest impact on the roadmap vision), which were then resolved by outlining developmental plans (to close the knowledge gaps). Risk management steps such as risk identification (by brainstorming), and assessment (by ranking the impact of uncertainties) were identifiable in these processes. However, these risk management steps formed the very fabric of the roadmapping process followed, not as add-ons to the roadmapping process. This is similar to the application of roadmapping in Case 4.

8.2.2 Phase 2 findings

A. The risk-aware strategic roadmapping (RSRM) process

The RSRM process was developed in response to the need for a practical process. In achieving this, it considered the implications of the framework developed as previously discussed in Section 5.1. The RSRM process was taken through a series of appraisals based on the view of roadmapping practitioners (in interviews and focus group meetings) and five in-company case studies (labelled Cases A-E).

The RSRM process is based on S-Plan, a fast-start workshop-based approach to strategic innovation roadmapping. The fast-start model requires minimal time and resource commitments. Its application as a foundation for the RSRM process, helped in easing the tension between having explicit steps of risk management in the roadmapping process and the general unwillingness of organisations to commit extensive time and effort to such a process. In line with S-Plan, the RSRM process was developed as a one-day workshop-driven exercise[50], requiring only basic resources (of pen, paper and participants). The workshop aspect of the process is however preceded by a planning (and pre-workshop) phase.

The planning stage integrates roadmapping planning and risk management planning. To increase the time efficiency of the RSRM process, the planning stage is also used to collect and do some pre-analysis of the data, which would otherwise have been carried out during the workshop. These pre-workshop activities involve the collection of data from participants, determining the level of uncertainty surrounding the data (to decide if

[50] Confining the RSRM workshop activity to one day also facilitated access to in-company cases, as it was envisaged that companies would be less likely to give more to a pilot. Planning activity, which includes gathering some of the data to be used in the workshop, precedes the workshop process.

there is a high level of uncertainty), and what criteria to use in the MCDA step (i.e. value-attainability matrix) contained in the process.

An important planning step is the choice of participants who will constitute a good mix of expertise and diversity for the process, especially considering the importance of having good quality and diverse participants as highlighted by the framework. However, as an external facilitator to the case-study companies, the researcher's ability to influence the participant selection process was limited. While the researcher was able to advise on who should be present to have an 'appropriate' mix, the determination of participants rested mostly with the process sponsor. Moreover, the decision of who will attend was sometimes overridden by practical matters, such as availability of the expert participants and size of the organisation. For example in Case D, the entire workforce of 4 people was present at the RSRM exercise, while in Case E, participants that had committed to attending were prevented from doing so by work demands. Even if it were the case that the range of participants could be fully decided by the researcher, there was no objective means of deciding how 'good' or 'appropriate' the mix of participants are for a roadmapping process at hand.

In practical terms, addressing uncertainty and risk in roadmapping involves the application of appropriate tools and techniques that would address the different factors identified on the framework. Identification of relevant tools (and techniques) relied on the experience of roadmapping practitioners and findings from case studies of roadmapping exercises and published roadmaps. The following were identified and integrated into S-Plan:

- scenario planning techniques (to reduce ambiguity),
- brainstorming (with prompt lists) and assumption analysis (with devil's advocacy and SWIFT) for risk identification,
- probability-impact matrix, TRL-risk chart and risk-reward matrix for risk assessment,
- standard risk treatment responses and options thinking for risk treatment,

- TRIZ[51] and MCDA (and blind-voting techniques) to be applied as improvements (that better address search and choice decision uncertainty) over existing techniques of brainstorming and dot-voting techniques in identifying and choosing strategic opportunities (or value propositions) respectively,
- visualisation techniques (particularly the traffic-light colour scheme) to communicate risks and uncertainties on the roadmap visual.

Some of these tools (and techniques) are used for conventional risk management and were also found applicable for use in the RSRM process e.g. assumptions analysis, brainstorming and probability-impact matrix. However, these (and the other tools) were modified (from their standard formats) during process development, to improve their usability, feasibility and functionality. Most of the modifications concerned improving usability as this appeared to be a critical concern to the practitioners and strategic planners. It was particularly important that the overall roadmapping process was simple enough and required minimal time commitment. Notable modifications include:

- The MCDA technique: this was modified from its initial form of the weighted scoring model (WSM) to a time-based value-attainability matrix, which provided the desired functionality of objective prioritisation (for selection) of strategic alternatives identified on the roadmap. With the value-attainability matrix, it is possible to streamline a wide array of criteria (which would have been considered within the WSM) into two main criteria of 'value' and 'attainability'. Inclusion of the time dimension is in line with an important roadmapping feature, and importantly, it facilitates focussing on opportunities that are strategically balanced over time. The value-attainability matrix facilitates an objective and structured prioritisation of strategic alternatives (or value propositions) over a two-step process of initial scoring and group deliberation and debate (for sanity check). The two steps balance the achievement of objectivity with maintaining group consensus (which is important for roadmapping).

[51] TRIZ was not actually applied in the RSRM process. Its nature and combination with roadmapping has been explored outside the scope of this thesis (Ilevbare et al., 2011; Ilevbare et al., 2013)

- The TRL-risk assessment: this was modified from its initial form as a chart that provided an indication of the riskiness of a strategic alternative (or value proposition) based on the readiness of the technology underpinning that strategic alternative. This was expanded into a risk-profiling step, to provide a more robust risk assessment based on the inclusion of six other contributors (in addition to TRL) to risk and uncertainty. The risk profile generated exposes knowledge gaps and indicates areas of weakness in the firm's technological capability and market understanding, to which the firm can respond by drawing up appropriate mitigating action.
- Visualisation: it was important that uncertainty and risk were appropriately communicated during the process and in the final roadmap report. Apart from additional charts of probability-impact matrix and value-attainability matrix, this involved making modifications to charts originally used in S-Plan by including sections that clearly communicated identified risks and their severities. An important inclusion for risk communication was the cross-business risk chart visual which indicated risks that appeared to be business-wide, and which would benefit from coordinated mitigation action by the organisation.

B. Case-specific findings from testing the RSRM process (Cases A-E)

The 5 companies were selected because they offered the researcher the opportunity to test the RSRM process, and met the condition that the focus of the roadmap should be the planning of innovation at its early-stages. 7 companies had shown interest in the process testing, but 5, which best met this condition, were selected.

i. Similarities among the case studies

All the Companies involved were concerned with planning for the introduction of new products to market. The five cases were also similar in that they had no prior practical roadmapping experience, and they had not applied explicit risk management in any of their previous innovation planning endeavours.

ii. Differences among the cases

The main differences in Cases A-E are found in the industries to which the different companies who took part belong, and the sizes (and operating experience) of the companies. Companies in Cases A, B, C, D, and E, belonged to the Coatings, Defence, Wall & Floor Coverings, Biotech, and Energy industries respectively. In terms of sizes, Cases A, B and E had 1000s of employees, Case C had 400, while Case D had 4 employees. However, these differences are considered to have had little impact on the roadmapping process itself. The variability in industry to which the Companies belonged is irrelevant because the RSRM process being tested had been designed to be generic, allowing successful application across industries. The sizes of the companies also become irrelevant considering that the process was carried out with a small number of participants in each of the cases: 3 in Case A, 10 in Case B, 9 in Case C, 4 in Case D, and 4 in Case E.

However, specific differences related to the specific RSRM cases were found in:

- The number of days over which the RSRM workshop was spread
- The participant-mix in the RSRM process
- The criteria used for MCDA step (i.e. for prioritising (or down-selecting) among innovation alternatives)
- Intentions after RSRM process

Cases A, B, C, and E were carried out as one-day workshop sessions while Case D was carried out as 2 half-day workshops. The effect of this was that in appraising the process, Case D scored higher in usability than the other cases. Case D participants found the RSRM process easier when spread over two days, than in the other cases where participants described the 1-day RSRM process as intense.

There was some variability in the participant-mix in the RSRM processes. All the cases except Case C (which had a market-biased participation-mix) had technically-biased participants. The relevance of this difference becomes significant if the following notion established in earlier parts of the thesis is revisited. The notion that participants in a roadmapping process are more likely to identify risks and uncertainties outside their domains of expertise as reported by the Case 3 facilitator (and explained as the *illusion of manageability* in Section 8.2.1A). The nature of risks identified in these cases disagrees with this notion, given that market-biased participants appeared to identify more market-related risks, while technical-biased group appeared to identify more technology-related risks, as shown in Appendix 13D.

In the five cases, the participants were presented with the same set of criteria for the MCDA step. However, there were differences in the specific criteria chosen across the cases as presented in Appendix 13E. While these differences in choice may not be fully explicable, the similarities in the choices provide certain insight as to how innovation projects are chosen at the front-end as will be discussed later in Section 8.3.1B.

The companies had various intentions of what to do with the outputs from the roadmapping process. Some of these are due to practicalities such as in Case A and E, where the RSRM process was carried out as a test-run of a process to be repeated at headquarters, and the participant attendance was poor due to last minute cancellations, respectively. In both cases, the process owners intended to repeat the RSRM process. In Cases B, C, and D the intentions were similar: to start implementing the roadmap. However, in Case C, considerable gaps in technical knowledge were identified in the course of the RSRM activity, leading to the realisation as the process carried on and the direction of the roadmap emerged that the participants were not diverse enough to provide some of the crucial knowledge needed. Therefore, in addition to implementing the roadmap, the intention was to repeat the process with more technically oriented staff.

8.3 Discussion of findings and contributions (according to SaP research)

The findings summarised in the previous section are discussed here in the context of Strategy as Practice perspective of strategic management, which was shown in Section 2.2.2C to provide a compelling and strong basis for examining roadmapping. The discussions are presented in two parts. The first part looks directly at the findings and discusses their contributions to knowledge according to the overarching conceptual framework of SaP research (i.e. the *practices – practice – practitioners* framework). This part focuses more on the practical contributions of this study. The second part discusses the findings in the light of *organisation sensemaking*, which is one of the theories underpinning SaP research. This part identifies the theoretical contributions of this study.

8.3.1 Discussion and contributions according to the overarching conceptual framework of SaP research

As identified by Jarzabkowski (2005), each of the aspects of the praxis-practice-practitioners framework provides a mode of entry into the study of Strategy as Practice. The aspects focused upon here (and discussed in the following sub-sections) are the ***practices*** *in roadmapping regarding the treatment of uncertainty and risk within it,* and the ***praxis*** *of innovation regarding planning at the early stages innovation (through roadmapping)*. Both aspects of the framework help to draw out practical contributions for roadmapping in particular and SaP in general. Discussions of the ***practitioners*** dimension of the framework are embedded in the sub-sections devoted to *practices* and *praxis*, and is not examined separately. The apparently pivotal role of scenario planning techniques in roadmapping as seen from the findings is also discussed. Implications for practice are drawn out as part of these discussions.

A. Practices: Practices in roadmapping regarding the treatment of risk and uncertainty within it

Practical issues concerning the central objective of this study, i.e., an examination of the treatment of uncertainty and risk in roadmapping, are discussed here. The first point discussed highlights the views of roadmapping concerning the treatment of uncertainty and risk-aware roadmapping. Secondly, further implications of the risk-aware roadmapping process, are discussed. Following these, practicalities surrounding the development of the RSRM process are discussed, highlighting the differences (and difficulties) between conceptualisation of strategy processes and realities of turning such concepts into practice, both of which are carried out in this research.

i. Views of roadmapping regarding risk management

There are at least three ways in which one might view the relationship between roadmapping and risk management that:

- Basic roadmapping addresses uncertainty and risk

  One should not ignore the notion that by simply carrying out roadmapping in its basic format, an organisation is able to reduce some of the uncertainty it faces, especially in its application at the early-stage of innovation. The prioritisation step commonly carried out in roadmapping process is a key step for the process, as pointed out in Section 8.2.1B. Various innovation options that may be at the disposal of an organisation at the early-stage of innovation, and this may leave the organisation uncertain as to what direction to face or focus on. The prioritisation step, regardless of the specific techniques used to carry it out, addresses this uncertainty by focussing the range of innovation directions to a few that the organisation can better manage and advance through the innovation funnel. Given the definition for risk management given in Section 2.3.4, this act of addressing uncertainty, even if it is done subconsciously, is risk management. The argument here is not whether this focus is right or wrong, optimal or sub-optimal (i.e. whether the best choices were made), but that a set of choices has been made (and legitimised by the roadmapping process), to give the organisation the clarity of direction and the confidence to advance its innovation efforts. However, this argument may indeed be made for any form of strategic planning that aims to clarify an organisation's vision for the future (which is inherently uncertain), and specify action steps to follow (from a range of various alternative routes that are available) in a bid to attain that vision, as roadmapping does. Any deliberate act of planning, which focuses the efforts of an organisation, can be regarded as addressing future uncertainty, and thus, risk management.

- Risk management steps included into basic roadmapping to improve the quality of the roadmapping outputs

  Beyond the consideration that roadmapping (in its basic form) is a form of risk management, there is a clear appetite in practice for explicitly addressing risk in roadmapping (and planning in general) and for an increased understanding of how this may be carried out. Risk management steps, even if not explicitly stated or even understood as such, improve the quality and clarity of plans produced through roadmapping. That is, embedding additional risk management steps in roadmapping can provide an improvement in the structure of established steps (for example the use of the MCDA techniques over voting in identifying innovation priorities, and the structured identification of gaps in knowledge using the risk-maturity profiling procedure). An aspect of including explicit risk management step involves identifying the negatively impacting issues that may affect the goal, especially those arising from the organisational environment and addressing them. Steps taken, such as clarifying the vision of the roadmap through the application of scenarios, and creating contingency plans, are all means of managing uncertainty. Overall, these steps are important to organisations, to maximise and protect the potential value they may accrue from their innovation efforts.

- Roadmapping is in itself an explicit risk management tool

  There is also the view that roadmapping is a risk management tool, and should be explicitly used as such. This notion appears not to be a commonly held view, as all the Cases and Roadmaps in which this was observed were created by the same organisation (Idaho National Laboratory), and therefore may be seen as the roadmapping system adopted by the INL (Case 4, Roadmaps B10 and B11). The INL uses roadmapping to draw up innovation plans in such as a manner as to actively reduce the uncertainty and risk associated with a specific innovation. This involves identifying the most critical uncertainties in pursuing an innovation, and outlining steps (such as the necessary research to be carried out) to reduce those uncertainties. The overall goal is to reduce the risk of innovation failure. Risk management methods and techniques are embedded within what may be regarded as a basic roadmapping process to accomplish this. However, where this view is different from the previous view is that the entire roadmapping process is seen as a risk management process.

The three views of roadmapping expressed above are quite similar in that they all involve planning. Perhaps what actually sets them apart is the view of what roadmapping involves and the emphasis placed on risk management as opposed to planning. The variability in this emphasis may not be measurable especially if one agrees to the notion that any form of planning in itself may be regarded as risk management because it provides a way of dealing with uncertainty. However, while planning or any form of roadmapping may not be devoid of risk management, the amount of risk management and the effort devoted to it in the overall roadmapping process can be increased, ranging from *underlying* as in the first view, to *moderate* as in the second view, and then *overwhelmingly* (perhaps) as expressed within the third view.

This third view, of roadmapping being an explicit risk management tool in itself, is only acknowledged and not pursued in the thesis. This is because this view appears to be peculiar only to one organisation, and not generic or fully representative of the cases and roadmaps explored. Rather, the second view, that roadmapping is first a planning tool whose quality may be improved by embedding it with appropriate risk management steps, appears to be the more commonly held view and is what is focused upon, in discussing *risk-aware roadmapping* in the next sub-section.

ii. The generic (and ideal) risk-aware roadmapping process, and its implications for practice

The concept of risk-aware roadmapping as presented in the findings (and Figure 4.9) may be regarded as an ideal process for ensuring uncertainty (and risk) is explicitly considered and managed in roadmapping. Even though it is considered as embedding risk management steps in roadmapping, risk-aware roadmapping, for purposes of strategic innovation planning goes beyond the widely accepted risk management process of risk identification, estimation and mitigation in two ways.

Firstly, risk-aware roadmapping includes three additional risk managing steps to what may be regarded the standard risk management process. These are: diagnose and address ambiguity (to reduce high environmental uncertainty and provide a focus or vision for the roadmap, if necessary), augment creativity and improve selection to reduce the risk of missing valuable innovation value propositions. The implication of this summation of the three additional steps and the standard risk management process is that both environmental uncertainty and decision uncertainty are explicitly considered and addressed within the same process (i.e. *diagnose and address ambiguity, risk identification, risk estimation* and *risk mitigation* are focused on the external environment, while *augment creativity* and *improve selection* concern decision uncertainty). Previously, these two aspects of uncertainty have largely been discussed separately across the evolution of strategic management (as shown in Figure 8.2). Figure 8.2 shows the evolution (or progression) of studies on uncertainty and risk in strategic management literature, starting from the emergence of the risk management field up until the recent calls for explicit risk management in formal planning.

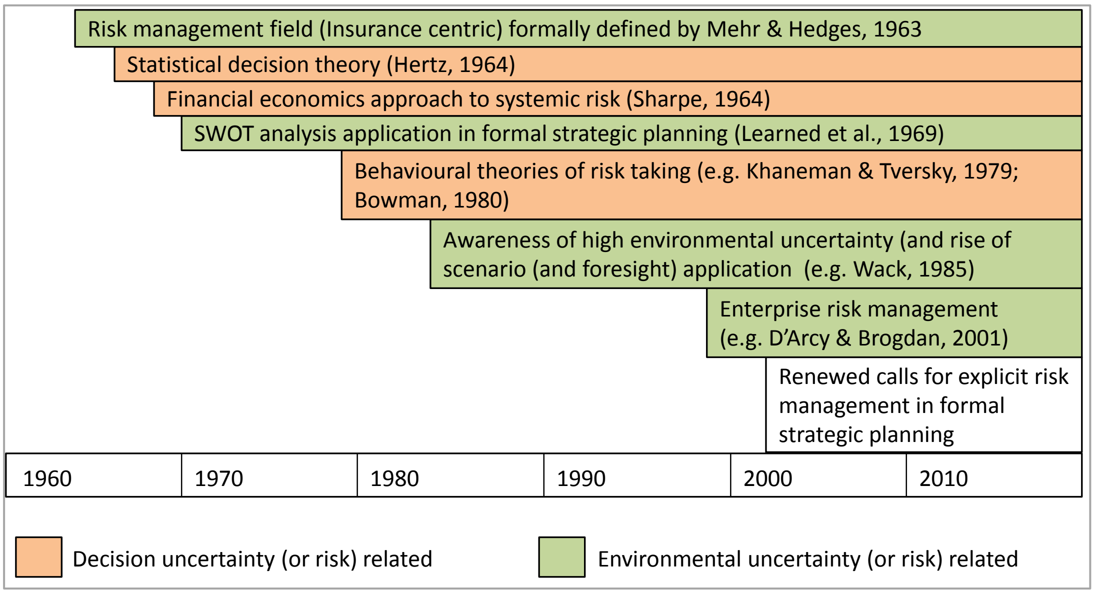


Figure 8.2 - General progression of risk (and uncertainty) studies in strategic management (own diagram)

Therefore, this study demonstrates the case for combining these separate discussions and also highlights an important aspect in decision uncertainty that has been overlooked: the uncertainty that surrounds the search routine within the planning process, to which the *augment creativity* step (to identify innovation ideas of greater quality and in higher quantities) responds. However, augmenting creativity as part of risk management appears counter-intuitive especially if one considers that encouraging creativity may lead to radically innovative ideas (Liefer et al, 2000), which in turn carry greater risks of failure. Thus the inclusion of creativity enhancement as a part of risk management can lead to increased risk, which presents a creativity-risk paradox. The wider question this raises for the front-end of innovation is "how can a balance be struck between pushing for creativity to reduce the risk of missing valuable opportunities and the increased risk of failure that arises from pursuing highly creative ideas?" This thesis does not propose an answer to this now, but sees this as issue that should be further examined.

Furthermore, the inclusion of explicit risk management into roadmapping overcomes some of its flaws. Kappel (2001) explained that roadmapping is weak in encouraging creativity and dealing with uncertainty. By setting out to accomplish the expectations of roadmapping regarding its treatment of uncertainty and risk as expressed by EIRMA (1997), the risk-aware roadmapping process provides a means of dealing with these weaknesses.

Secondly, risk-aware roadmapping requires an active management of data sources (e.g. finding the right mix of participants to promote diversity and expertise) and finding ways for them to contribute and analyse information with minimal influence of their subjectivities and biases. Without these the treatment of risk would be inadequate or inaccurate. However, some of the measures require interventions that cause tensions within traditional views of roadmapping. The suggested active involvement of the facilitator in participants' discussions of the roadmap content, to force the group to identify uncertain and risky issues when the participants appear to ignore them, is against the norm of neutral facilitation (de Laat & McKibbin, 2002). Neutral facilitation is meant to prevent the skewing of roadmap outputs towards the views of the facilitator, which is quite an easy trap to fall into given the important and powerful role the facilitator fills in the process. Another is the introduction of dissent through devil's advocacy, to help the group see through assumptions and identify risks, which has a potential to upset the consensus of the group towards collective action (Brunsson, 1982), one of the core attributes of roadmapping as earlier indicated in the paper. Also, embedding risk will require greater need of time and resources as it is bound to increase the amount (and possibly the complexity) of analysis carried out in roadmapping. Organisations may be unwilling to commit this time and effort, but it must be recognised that a major requirement of managing risk is the willingness to commit the necessary time and effort to it (Steele, 1989). There is a need to appropriately balance the effort towards risk analysis against the abilities of the participants, so that the planning process does not become overly complex and stifle innovation altogether.

iii. Practicalities of the RSRM process: translating the idealised (or generic) into the practical

It should be noted that the RSRM process itself is a practical contribution to knowledge by this thesis. The conceptualisation and development of the process has been extensively discussed in Chapters 5, 6 and 7. This will not be repeated here. However, what this subsection does is that it provides an opportunity to discuss some supplementary findings identified from development and testing of the RSRM process. These point out some of the practicalities of translating an idealised (and generic) process (as described above) into a practical one to be applied in real-life.

First, it should be pointed out that the type of industry the companies that applied the process belonged to, and the size or maturity of these companies did not have any significant consequence on the structure and flow of the process (i.e. its usability, functionality and feasibility), which were of main concern in the research. However, what this indicates is that the RSRM process, as presented in Chapter 7, is generic and flexible enough to be applied across industry types and company sizes, which is positive feature of the process. The differences in industry and subject matter as well as the fact that modifications were made to the RSRM process as the cases progressed, makes it inappropriate to have a strict cross-case comparison. However, because the process was tested under real-life conditions and applied to real problems, it is possible to identify certain significant occurrences among the cases to bring to light some of the practicalities of translating idealised research models and process into practice. Three issues are concentrated upon here:

- the choice and modification of methods and procedures for the RSRM process
- the selection of participants for the RSRM process
- the role of structure and intuition in risk management

These relate mainly to the makeup of the RSRM process and provide an insight into some issues surrounding the application of processes or tools designed for use in early-stage innovation planning or management. In discussing these, some of the assumptions or preconceptions held by the researcher in designing the idealised risk-aware roadmapping process and framework are challenged.

- <u>Behaviours in choice and modification of tools or processes</u>

  It is important to note that all the Cases were presented with the same RSRM process and a standard set of steps, tools and techniques that made it up. The behaviours of participants concerning two of the tools applied are discussed here.

  One of the key tools within the process is scenarios, which is meant to help address ambiguity that surrounds the future of the organisation's external environment (or market). All the process owners rejected the application of scenarios even before it was ascertained whether they scenario techniques would be required or not within their respective roadmapping activities (there is a step of *diagnosing ambiguity* to ascertain this). This rejection is attributed mainly to the additional time and effort the process owners realised the application of scenarios will require. The other notable issue concerns the application of the *risk-profiling step,* which originally included assigning probabilities to specific elements of technology risk and market risk associated with a value proposition, and aggregating these probabilities to determine an overall level of riskiness associated with that value proposition. In Case B, participants decided that the steps that calculated riskiness should be removed because the values of riskiness generated were too high, and would dissuade investment in the selected value propositions, even though those value propositions had been determined to be the most promising of the available alternatives.

These two instances contrast in that they appear to demonstrate two different reasons why processes and tools may be applied differently from the intentions of the process or tool developer. In the first example, a key aspect of the process is omitted because it is expected that it would require too much time and effort regardless of whether or not it is necessary. In the second example, an aspect of a step in the process is modified because it did not yield desirable results, even though the results are accurate based on the information given by participants. The *risk-profiling* step was modified to produce the kinds of results that the users were more comfortable with, and what will help in the advancement of their intentions.

- Selection of participants

  One of the steps in the planning phase of the RSRM process is the selection of participants so that there is adequate diversity and experience between them to provide the data necessary to generate roadmaps of good quality. The post-process intentions of the Company in Case C of repeating the RSRM process with a different set of participants illustrates why this is difficult, particularly for processes related to early-stage innovation. In planning for early-stage innovation, as carried out using the RSRM, directions the plan takes only becomes clear as the process is carried out and sense is being made out of an unclear situation. In Case C, even though a deliberate selection of participants to involve was undertaken before the process, it was by going through the process that there was a better realisation of who should have been involved, because the directions the roadmap would take, and the nature of the knowledge that would be required in such directions could not be fully determined until the process had been carried out. Thus, the choice of participants as defined for the RSRM process is only a best guess and it may require going through the process to know if the right group had been convened. Of course this becomes less of a problem when the roadmap is created for a very small company, all of whose members take part in the process as there is then no question of whom to include (e.g. the Company in Case D is a very small company only 4 members, and all of them took part in the process).

Comparisons across the two sets of case studies i.e. Cases 1-5 and Cases A-E, which were carried out in government-owned organisations and private companies respectively, showed significant differences between both groups in the numbers that took part in the roadmapping processes. Public owned organisations have greater freedom in deciding who should participate in roadmapping activities and have the opportunity to cherry-pick participants so that there is adequate diversity and experience amongst them (as required by the RSRM process). Private companies are always wary of competition and limit participation to internal staff. The numbers that can be convened by an internal organisation may be further limited by the focus of the roadmapping activity, leaving just a handful of relevant people. Thus, the concept of having participants that are both diverse and experienced to take part in roadmapping process appears to apply better to public organisations than privately-owned companies. In privately companies one might only be able to hope to have the 'best available' participating in the process.

The data retrieved from Cases A-E, which shows how participation mix contrasts with the type of risks identified, gives opportunity to challenge the notion of the *illusion of manageability* bias attributed as one of the factors that prevents balanced identification of uncertainty and risk in roadmapping (and strategy in general (as put forward by Das & Teng (1999)). This was presented in the first phase of this thesis as one of the underpinnings for the requirement of including participants of diverse expertise. The *illusion of manageability* suggests that generally participants will not identify risks belonging to their areas of expertise (which was supported by Case 3 (first phase of research) because they believe they can control results favourably. However, results from second phase (Case A-E) suggest otherwise, as they show that participant-mix in the cases (i.e. whether market- or technology-oriented) aligns with the majority of the risks identified (i.e., a market-biased group of participants appeared to identify more market-related risks than technology related risks, and vice versa) (see Appendix 13D for this). The reason for this may be that with greater knowledge in an area, it is possible to better understand the uncertainties and see how things might go wrong. This is not to throw out the possibility or significance of the influence of the *illusion of manageability* bias, but to point out that it does not necessarily have to be the overriding concern in trying to make sure participants are adequately diverse.

- <u>The role of structure vs. intuition (objectivity vs. subjectivity) in dealing with uncertainty</u>
  Certain risk management steps within the RSRM process are actually improvements on steps pre-existing in roadmapping and not completely new steps, as can be deduced from the names they are given: "augment search (and creativity)" and "improve selection process". Steps of creativity and selection pre-existed in roadmapping before the RSRM process, albeit executed using somewhat basic techniques such as *brainstorming* and *voting* respectively. Phase 1 of the research identified that improving these steps for the RSRM process involved replacing these subjective techniques with better structured and objective ones so as to remove/reduce the influence of human bias and limited cognition, which can very easily lead to distorted and sub-optimal results. It was because of this TRIZ and MCDA techniques were included in the RSRM process.

  The MCDA procedure was modified for application in the RSRM process and eventually carried out using the value-attainability matrix. In application, it was realised that it was necessary for the participants to discuss and debate the prioritisation results generated by the matrix. This fostered consensual acceptance and ownership of the results. However, across the Cases, the debate led to some re-ordering of the priorities. While the reordering was not drastic in any of the Cases (i.e. an innovation idea of lowest priority did not suddenly become top priority), the changes were significant in that they eventually determined what the organisation would address as its first innovation priority. Overall, this combination of objectivity using the matrix and subjective judgement that was reintroduced through debate and discussion was seen as a more appropriate way of carrying out this step given the context of its application to early-stage innovation. The point being demonstrated here is that in situations clouded by uncertainty, such as at the early-stages of innovation, there is a need for objectivity (to reflect reality as much as possible). However, it appears there is also a need for *measured* subjectivity. Issues in the early-stages of innovation are usually too uncertain or formless (as a result of lack of any real data) for a fully objective procedure. Highly structured processes will deliver results that are (at best) *approximately* correct, but ultimately, specific choices will usually remain subjective (to be inspired by experience and gut feel of key players or decision makers). The application of the value-attainability matrix introduces the required objectivity *and* provides a setting for controlled subjectivity. This measured balance of objectivity and subjectivity appears to be an acceptable approach, especially for early-stage innovation procedures, and the provision of an appropriate setting for such an approach appears to be an important issue.

<u>B. Praxis: Early-stage innovation planning and the significance of *constraints* on innovation ideas</u>

The discussion on the contribution to the praxis of innovation by this thesis is built on Mumford et al.'s (2008) paper: 'Constraints on innovation: planning as a context for creativity'. There Mumford et al. (2008) introduce an issue of 'constraints' which is of significance to the routines of identification and selection of innovation ideas in roadmapping in particular and the concept of risk-aware roadmapping in general.

Constraints are issues such as the organisation environment, competition and available technology that impose boundaries within which innovators and decision makers work and make plans. Constraints such as '*what fundamentals to focus on and which ones to ignore',* are implicit in planning and ultimately have a significant effect on the quality of ideas that emerge from an innovation planning process. Available expertise or knowledge is also a constraint as plans are made within a body of existing knowledge (Weisberg, 1999). However, the authors also indicated that certain constraints are not implied as those indicated above, but need to be chosen and appropriately imposed in planning for innovation. Mumford et al (2008) specifically identified as constraints the criteria used for evaluating innovation ideas, which are particularly key to the type of ideas that emerge from an innovation plan.

Mumford et al (2008) indicated that adequate research indicating precisely which constraints should be imposed at the stages of innovation is lacking and "this lack of information on relevant constraints and the optimal timing of their implementation represents one of the important directions for future research on organisational innovation" (p. 194). In the context of roadmapping for innovation, the issue of choosing constraints is similar to the notion of imposing appropriate ***structure*** on the roadmapping process as part of the increased awareness to uncertainty and risk as discussed in the preceding sub-section on objectivity vs. subjectivity). Aspects of the risk-aware roadmapping process, especially the steps of 'augment search' and 'improve selection', provide an opportunity to address the issues identified by Mumford et al (2008). Two aspects are briefly discussed here:

- Firstly, an indication of the type of constraints chosen for evaluating ideas specifically at the early stages of innovation is provided. This is derived from an examination of the criteria most commonly applied within the value-attainability matrix in the RSRM process across the five in-company test cases.
- Secondly, Mumford et al (2008) mentioned the importance of selecting appropriate constraints for the generation and evaluation of innovation ideas. However, their discussion focused only on the criteria for idea evaluation as constraints and there is no clarity in their account on how constraints apply to

generation of ideas. The notion of constraints for idea generation is explored here in the context of risk-aware roadmapping as conceptualised in this thesis.

An examination of the Table in Appendix 13E provides the set of criteria that were used in defining the Value-Attainability matrix used in the selection of innovation ideas in Cases A-E. The criteria applied are listed in descending order starting from the most commonly applied ones. Those used in at least three cases are listed below, and identified here as particularly pertinent constraints for the early-stages of innovation:

- Clear customer need
- Market growth potential
- Size of market
- Platform for growth
- Market profitability
- Differentiated product
- Routes to market

These criteria (or constraints) are mostly ‘value’ criteria, rather than attainability criteria. They help the organisation to focus on the value of the innovation idea to itself first, rather than the technicalities (and level of difficulty) of transforming the idea into a real product. Thus it appears that at the early stages innovation, constraints that emphasize value and the positive aspects of innovation ideas are favoured by organisations over those that highlight the difficulties associated with converting those ideas to reality. Not only are these the constraints that are favoured, it appears it is these types that are most helpful to organisation to advance ideas at the early stages of innovation. It is constraints that emphasize the positives, e.g. in terms of a clear market need, market profitability and market growth potential, are those that would help to overcome inertia that could prevent the advancement and development of innovation ideas. This agrees with Kitchell (1995) who explained that evaluation criteria that stress growth promote innovation. Constraints that emphasize the technicalities (and difficulties) will not be quite as helpful at the early-stages, and stifle the innovation process if fixated upon.

Perhaps, Mumford et al (2008) did not discuss the selection of constraints for generation of innovation ideas because such constraints are thought only to be implied, relying on expertise and experience of innovators and planners. Risk-aware roadmapping recognises that uncertainty obscures idea generation. From the perspective of risk-aware roadmapping, applying [implied] constraints such as expertise and experience only for idea generation may not be adequate in overcoming this uncertainty. Risk-aware roadmapping's response to this is to systematise and structure ideation using TRIZ. Application of TRIZ helps in generation of ideas in greater quality and quantity, and it does this by breaking through cognitive limitations imposed by expertise and experience (Ilevbare et al., 2013). TRIZ allows one to reach beyond the constraints of immediate (and apparently relevant) expertise and experience into more widely available knowledge in developing new ideas. Thus, rather than imposing constraints as in idea evaluation, the appropriate attitude to constraints surrounding idea generation may be to lift or break them down (and redefine them). That these existing [implied] constraints are broken down using a systematic method like TRIZ also suggests that existing constraints are not altogether broken down, but expanded by imposing appropriate new structures.

C. A discussion on the role of scenarios in roadmapping

Of the 22 roadmaps identified from the corpus to have taken steps to address uncertainty and risk, 11 of these (50%) applied scenarios. It is important to explore issues contributing to and surrounding this significant proportion especially since no other technique was used as often or as consistently in roadmapping on the matter of uncertainty or risk. This gives an opportunity to provide additional explanation for scenario planning practices, which Wilkinson (2009) pointed to as under-researched and under-theorised. The only known attempt to theorise scenarios is by Chermack (2005), who developed a set of hypotheses by linking up 5 units of scenario theory (scenario stories, learning, mental models, decision making, and performance). While the scenario-related aspects of this thesis may not be sufficient for an outright testing of Chermack's hypothesis, they provide some additional insight and clarification to one of them. Three issues are explored here in relation to the findings along the following topics:

- The ambiguity reduction role of scenarios in roadmapping
- Challenging established traditions of scenario application
- What makes scenarios compatible with roadmapping?

i. The ambiguity-reduction role of scenarios in roadmapping (Diagnosing ambiguity, a necessary precursor to the application of scenarios)

In the 11 roadmaps scenarios were used to determine the vision of their respective roadmaps, to give the roadmap a clear view of the future (external organisation environment). Where the future is highly uncertain or ambiguous, there is the potential that the roadmapping effort will be paralysed or at best, yield unreliable results. This is the rationale for the *reduce ambiguity* step that leads the risk-aware roadmapping process. However, before any effort is dedicated to the reduction of ambiguity using scenario techniques, there is a need to *diagnose* ambiguity. Generally, scenario planning literature appears to suggest that firms perpetually operate in high-uncertainty (or ambiguous) environments, thus justifying the need for scenarios (Varum & Melo, 2010). However, the application of scenarios is not always necessary, as seen in Cases A-E, where the uncertainty faced was not high enough to require the use of scenarios. It is important to consider this, given the realisation that an inclusion of scenarios in strategy processes can lead to a complex process which might become difficult to manage (scenario planning literature has generally failed to point out this complexity of the method). As such, the step – diagnose ambiguity - of ensuring the application of scenarios is considered here to be a crucial one.

ii. Challenging established traditions and a theory of scenario application

Scenario planning literature outlines certain norms and ideals for creation and application of scenarios. This thesis is able to identify practices that have not been captured in literature, that appear to go beyond the codified norms. These are then used to challenge a theory of scenario planning presented by Chermack (2005).

The intuitive logics technique (described in Section 5.3.1), created by Pierre Wack in the 1970s and popularized by Schwartz (1991), both of Royal Dutch Shell, which combines two scenario logics to produce multiple scenarios, is the gold standard for scenario building (Millet, 2003). Wilson (2000) identified four ways in which a set of scenarios may be applied to strategy (listed in Section 5.3.1) and explained that the ideal application is to give all of them an equal level of importance and likelihood, to create a strategy that is resilient across all of them (Wilson, 2000).

Scenario planning literature acknowledges two types of scenarios (exploratory and normative scenarios) (van Notten et al, 2003; Borjeson et al, 2006). However, on closer inspection, these ideals for scenario development and application identified above apply only on the exploratory scenarios. In fact, apart from acknowledging the existence or possibility of normative scenarios, there is no visible explanation of normative scenario practices across literature. Of the 11 roadmaps from the corpus in which scenarios were applied, 6 applied exploratory scenarios, while 5 applied normative scenarios. The manner of application of exploratory scenarios to the roadmaps corresponds with Wilson's outline of scenario application in strategy, and so there is not much to add in that. It is the instances of normative scenario application that are discussed here to draw out new insight on scenario application.

1. Creation and application of normative scenarios (challenging established traditions of scenario creation and application)

From the findings, scenarios are generally created singly to define a vision and a coherent set of goals and targets leading to that vision. This makes the intuitive logics method an unlikely and in fact illogical route for the development of normative scenarios. At first glance, the 4 scenarios created in Roadmap A10 appear to have been created using intuitive logics (See Figure 8.3). However, the two axes used to define the scenarios were chosen not because they were uncertain and critical external trends and drivers (which is key to intuitive logics), but because they provided a means of appropriately defining a future market (by segmenting it). Normative scenarios do not rely on trends and drivers for their creation because they are inward looking, focusing on the company vision and targets. However, these visions should be sensible and generally align with the evolution of the external business environment

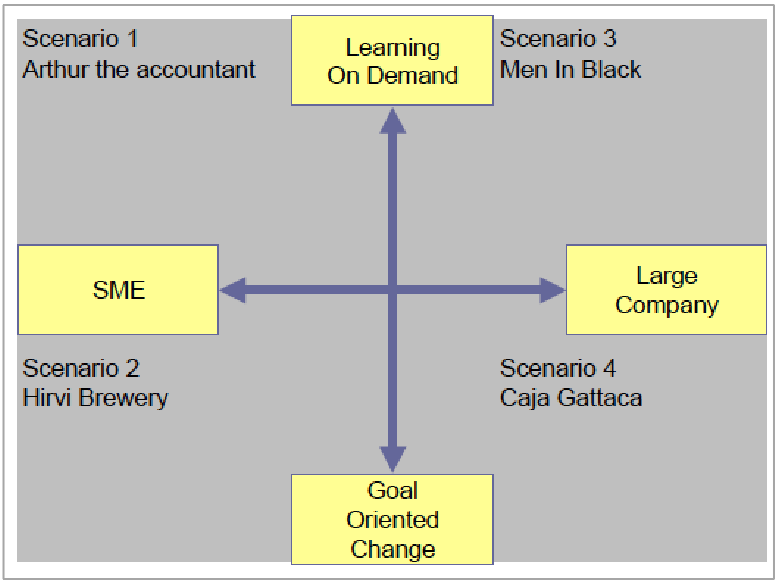


Figure 8.3 – Use of normative scenarios for future market segmentation (from Roadmap A10: European roadmap for Professional eTraining (2004))

While exploratory scenarios facilitate the creation of a vision by providing a wide understanding of ways the future external environment might evolve, normative scenarios are much more narrowed, defining desired future states, in terms of a specific market focus, and/or technology targets to achieve in meeting those needs. This narrowed focus appears to be particularly useful in setting targets when the creation of the roadmap is primarily driven or inspired by technologies (or capabilities) that have potential but are underdeveloped (i.e. technology-push), rather than being driven by pressing market needs (i.e. market-pull). For such technologies, further development would require the creation of a picture of a future in which the technology would be found useful (i.e. a rationale or a need towards which that technology can be targeted). Normative scenarios readily provide this picture as in the case of Roadmaps A8 and A9. Roadmap A11 appears to take a more extreme form of this, in which it appears the roadmap's subject matter, economic exploration of the moon, is one that (at this present time) may be regarded as only remotely possible at best. The use of scenarios helps to transcend the scepticism and ambiguity of this pursuit, and provides the roadmap with clear goals and technologically logical routes to achieve those goals.

The findings and foregoing discussion appear to suggest that this role of defining or shaping the future using normative scenarios is pertinent to technology-push roadmaps, where technology development is feasible, but the market need for such technology is not clear. This notion appears to be supported by Phaal et al.'s (2012) use of "opportunity scenarios" in creating *emergence roadmaps*, which chart out potential commercial exploitation paths for an emerging technology. Phaal et al.'s (2012) description of the use of these scenarios is as "articulating the target-opportunity scenario in terms of market, application and technology … to qualify and quantify the goals as much as possible in terms of target market and scale, application functionality and technical performance" (p 38) closely follows that of a normative scenario.

In these types of situations, normative scenarios (and the roadmaps created from them) appear to take up a role that is more of shaping the future, i.e. picturing a future market that does not yet exist and accomplishing/creating that future market, than the understanding of likely futures (through exploratory scenarios), and the adaptive and/or flexible strategies they facilitate in the roadmaps created. The terms 'shaping' and 'adapting' are intentionally applied here to align with Courtney et al's (1997) usage of the terms to describe *strategic postures* or behaviours taken by organisations when faced with uncertainty. *Shapers* drive the industry into a new structure by controlling the direction of the market, while *adapters* take the future evolution of the market as givens and react to the opportunities the market offers. Here, it is the view that in formulation of strategy and the usage of scenarios, normative scenarios are more applicable to shaping strategies while exploratory scenarios are more applicable to adaptive strategies.

Courtney et al (1997) explained that a shaping posture is more suitable in situations of high uncertainty and ambiguity, while an adaptive posture is suitable for lower levels of uncertainty. This suggests that situations in which normative scenarios are used are of higher ambiguity than those of exploratory scenarios. Both types of scenarios are used to make sense of an ambiguous future. However, under the highest levels of ambiguity (e.g. the situation described as 'true ambiguity' by Courtney et al (1997), where present external trends and drivers are not traceable to a coherent future view for the sake of adapting to it as in exploratory scenario building), a practical thing to do would be to define visions, targets and goals for the future using normative scenarios, to give form to an otherwise formless future and facilitate strategic planning. This will give the organisation a sense of progress despite ambiguity that otherwise would have been debilitative to strategic planning.

<u>2. Examining an aspect of Chermack's theory on scenarios</u>

The foregoing discussion on scenarios is summed up by examining Chermack's (2005) hypothesis linking *scenario stories* and *decision making* in his theory of scenario planning. Chermack (2005) hypothesised that ***there will be a positive relationship between the application of scenarios and improved decision making***.

The question this raises is "how is improvement in decision making measured?" If this is to be answered appropriately, one must first understand how scenarios are applied in decision making. This is because one cannot determine the effectiveness or evaluate the relationship between scenarios and strategic decision making if the relationships are not identified, and the purposes set out for applying scenarios are not acknowledged. The examination, in this thesis, of scenarios application to roadmapping has provided additional understanding on these relationships. Two types of scenarios have been discussed here, and conditions relating to their application to strategy (through roadmapping), such as the level of uncertainty faced have been pointed out. The ideal formats for using these scenarios are also different. Chermack's hypothesis fails to capture these issues and perhaps should be revisited and reformulated.

Also, in characterizing improved decision making, is one looking at the improvement of decision making for its own sake, or for the sake of effective action? If it is for improved decision making process how does one know that decision making has been improved? One way of looking at this is that decision making is improved when it is structured better, supported by the assumption that a better-structured decision process implies better decisions. The foregoing discussion demonstrates the application of scenarios provides some structure or form to decision processes that are faced with ambiguity and therefore Chermack's hypothesis would hold.

However, even though the application of scenarios imposes a better structure to decision making processes, it also usually leads to more complex strategies or action plans as demonstrated in the point on selection of methods in Section 8.3.1A(iii). Do more complex strategies or action plans then equate to better decision making? One must acknowledge that decision making does not stand alone and it is meant to spur action, and those that do not are a waste of time (Brunsson, 1982). If strategies become too complex to understand or execute, has decision-making been improved?

To avoid this improvement-complexity confusion surrounding scenarios, fuelled by the realisation that there are different types of scenarios (used in different ways, under different conditions of uncertainty), perhaps, Chermack's hypothesis would be better stated as: ***"there will be a positive relationship between the application of scenarios and better-structured decision making processes"***. This appears more acceptable as there is little doubt that scenarios, whether exploratory or normative, provide better structure or form for decision making faced with uncertainty. The question of whether the improved structure introduced by scenarios eventually leads to improved decisions and effective actions can be the subject a separate debate.

iii. What makes scenarios compatible with roadmapping?

The fact that scenarios were used in a significant proportion 50% of roadmaps addressing uncertainty and risk in the corpus should not be overlooked. The question this raises, especially since no other risk management method was used as extensively as scenarios, is 'what draws roadmapping to the use of scenarios'? Functional and structural interdependencies (between scenarios and roadmaps) are attributed to this. They are described briefly below.

1. Functional interdependencies

Roadmapping is predominantly a *market needs-driven* process, in which innovation efforts are inspired by clear market needs (Garcia & Bray, 1995). However, at the early stages of innovation, where the product is still far from market delivery, roadmapping is usually technology-push, driven more by available technology and capability and research than market needs, as identified by Phaal et al (2003). Especially in such cases of technology-push, it remains necessary to identify a market need for the roadmap to serve as a guide for the development of technologies and capabilities. The application of scenarios provides a vision and focus for a roadmap, usually by defining a set of market need-aligned objectives. As seen in Roadmap A8 and A11, scenarios can help such roadmaps define those market needs and ensuring the innovation is directed towards them even during the early stages.

2. Structural interdependencies

On the other hand, the creation of roadmaps following the application of scenarios completes the scenario planning cycle, and this ensures that the important step of translating scenarios into real action plans is undertaken (Wilson, 2000; Inyatullah, 2009). The four ways described by Wilson (2000) by which scenarios may be translated or used in developing strategy are clearly identifiable in Roadmaps A1-A11. The translation of scenarios into strategy is facilitated by the roadmapping framework (Figure 2.10). Scenarios can be mapped out in the top-layer (know-why layer) of the roadmap visual framework, and their implications and action plan can be mapped into the lower layers (know-what, know-how and action plan layers).

3. Other reasons

Flippant as it may sound, the significant proportion of scenario application to roadmapping may be due in part to the 'bandwagon effect', where it is trendy or appears 'necessary' to apply scenarios as a result of preferences of planners, and not as a result of any real internal need for clarifying an ambiguous future. The influence of a multinational like Shell promoting the use of scenarios and scenario planning through various published papers and books should not be underestimated. Also, Martelli (2001) identified that the use of scenarios comes and goes in waves, coinciding with periods of general uncertainty in the business environment. Wilkinson (2009) explained that scenario work increases after a the time of crises pointing to periods following the 1973 oil crises and 9/11 attacks in 2001 as times that saw significant scenario activity. It is worthy of mention that of the roadmaps examined, 2 were pre-2001, while the others were post-2001. While this does not definitively confirm Wilkinson (2009) view, it does not disagree with it, and the influence of such should not be ruled out in the results obtained from the examination of the corpus of roadmaps.

D. The role of the other risk management tools in knowledge creation in roadmapping

The inclusion of risk management into roadmapping (through the methods used) has a contributory impact in terms of knowledge creation and learning. This can be demonstrated in the light of knowledge conversion and explained using Drew's (1999) knowledge portfolio, which depicts four classes of knowledge: 'what we know we know', 'what we know we don't know', 'what we don't know we know', and 'what we don't know we know' (as shown in Figure 2.16).

The tools and techniques employed in the RSRM process may be said to be of particular impact in two of the knowledge classes by:

- Making explicit 'what we don't know we know': the use of tools (and techniques), especially those for identification, and assessment of risks, such as brainstorming, assumptions analysis and probability-impact assessment, help in bringing to the fore-front and clarifying risk issues that are usually neglected and would remained hidden or tacit (considering how roadmapping processes have been carried out in the past). In the RSRM process, the application of these tools facilitated collective deliberation over risk issues relying on the combination of the individual knowledge, experience and awareness of the participants on issues associated with the failure (or success) of set out objective(s).
- Exploring 'what we don't know we don't know': the application of the risk-profiling tool created awareness of knowledge gaps and issues that required better understanding by the organisation in pursuing the laid out value propositions. These gaps may not have been identified without the tool. Similarly, integrating a tool such as TRIZ in roadmapping, to improve creativity and augment the search for strategic alternatives or value propositions, may help in identifying completely new and valuable alternatives.

As shown in Figure 8.3, these knowledge transformations facilitated by the embedded tools may be seen in terms of tacit knowledge to explicit knowledge, when the roadmapping group and organisation become conscious (through the use of the tools) of knowledge that they may already have but have neglected. This brings to light the role of tools in tacit-to-explicit knowledge transformation, which had earlier been pointed out simply as being the result of a process of externalisation, through the use of metaphors and descriptors (Nonaka, 1994), and achieved in the roadmapping process by capturing shared knowledge on the roadmap visual (Phaal, 2005)[52]. This role of the risk management tools and techniques in knowledge conversion and creation alongside the participants in a roadmapping process is in line with the view of Moisander & Stenfors (2009) that strategy tools are objects of knowledge actively involved in organisational knowledge production.

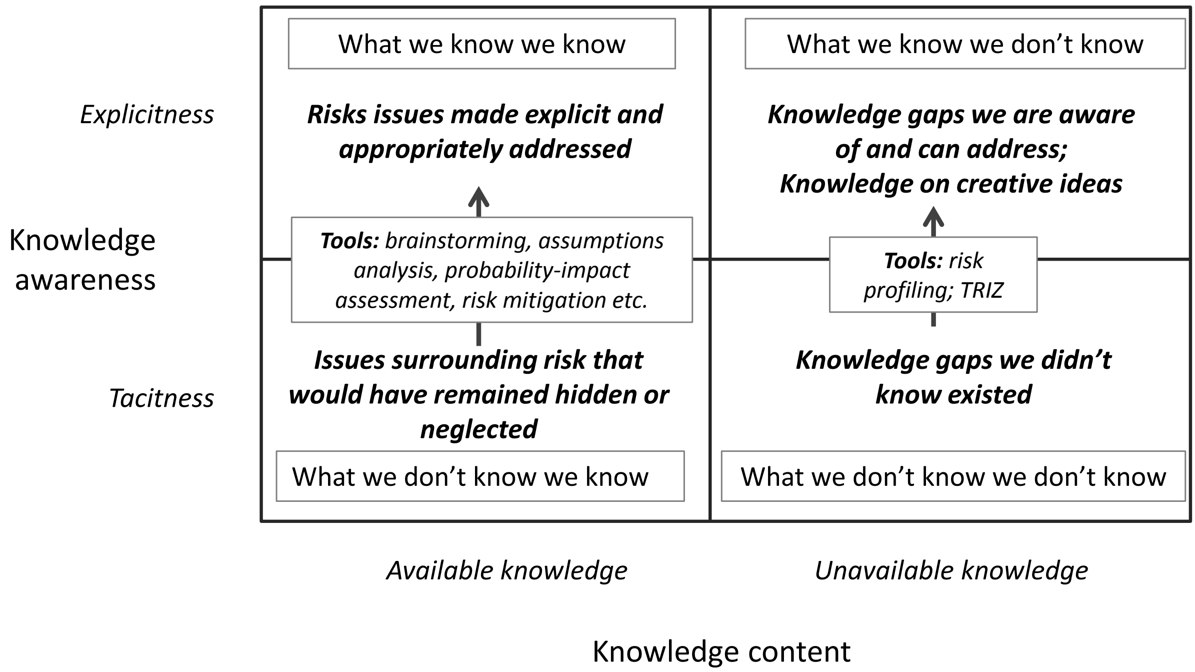


Figure 8.4 - Tacit-explicit knowledge transformation facilitated by risk management tools

[52] Roadmapping might be regarded as a tool in itself, which facilitates this knowledge conversions, but it remains important to point out some of the conversions can be attributed directly to other tools and techniques used within the roadmapping process.

8.3.2 Contributions to Weick's (1995) theory of organisational sensemaking

Weick's theory of organisational sensemaking was summarised in Section 2.2.2C, and its relevance to this thesis was explained. Seven properties of sensemaking were pointed out and of these, four were identified as being most directly relevant for the research carried out here. These, already explained in greater detail in Section 2.2.2C, are:

- sensemaking is retrospective
- sensemaking is grounded in identity construction
- sensemaking is enactive of sensible environments
- sensemaking is driven by plausibility rather than accuracy

These four are examined in the context of the findings from this research. In addition, Weick (1995) explained that sensemaking is triggered by occasions of ambiguity and uncertainty. This is also examined within the context of the risk-aware roadmapping process. Weick (1995) had admitted his views were generalised over various organisational processes and settings, and that it would be important to examine them in more specific sensemaking situations, to know where his theory holds and where it does not. The research described in this thesis provides an opportunity to explore the aspects of Weick's theory highlighted above in specific situations of planning and innovation. The discussion that follows examines some of the research findings and foregoing discussion.

Considering the focus of this thesis, there is a basic and perhaps central question to Weick's notion that sensemaking is retrospective in nature, i.e. that it is a process of giving attention to what has already occurred. Weick had identified ambiguity and uncertainty as two occasions for sensemaking. These are the issues that face planners and futurists when they think about the future. The act of planning (and roadmapping) itself is a process of making sense of the uncertainty that clouds the future, and as explained earlier in Section 8.3.1A(i), roadmapping itself can be regarded a risk management tool, since it provides a means of uncertainty, and therefore is a sensemaking activity. The act of roadmapping for innovation further establishes this notion since innovation itself is a sensemaking activity as indicated by Weick. Given that roadmapping (and all forms of strategic planning) is forward looking, it is clear that sensemaking can be prospective, concerning things of the future, and not only things that have already occurred as Weick explained. In terms of strategy, Weick's notion of retrospective sensemaking is not entirely wrong, and in fact may be linked to Mintzberg's (1978) view of emergent strategy, which is discovered retrospectively, as opposed to intended strategy, which is futuristic and is what roadmapping is about.

Weick explained that the establishment and maintenance of an identity is core to sensemaking and that sensemaking may in fact be triggered by the inability to confirm one's identity. Weick explained that an organisation confirms its identity by projecting it onto the environment and observing the consequences (i.e. by using the environment as a mirror to observe itself). It is obvious, using the mirror metaphor, that an unclear environment would produce an unclear image and therefore hinder sensemaking. Roadmapping (and planning) helps an organisation create a futuristic identity for itself and to do this it needs to have a clear view of the future environment context, before projecting itself unto that environment. The application of scenarios clarifies the environment if required, and the ways of achieving this clarity is what the application of scenarios discussed in Section 8.3.1C(ii) attends to. As earlier discussed, through the use of exploratory and normative scenarios the future can either be understood or created. Thus, as part of sensemaking, before an organisation can confirm its identity by projecting it onto the environment, it may have to clarify that future environment first, either by understanding it as much as possible (through exploratory scenarios), or by constructing a desired future environment (through normative scenarios). This act of creating or clarifying the environment before projecting one's self onto it is a critical step for sensemaking.

Weick also explained that sensemaking is enactive of sensible environments, i.e. it creates a reality in an environment by applying constraints and rules so that action can be taken in that environment confidently. Constraints can be implied or selected as demonstrated in Section 8.3.1B (i.e. Mumford et al., 2008) and they help in making sense of uncertain or ambiguous situations. As demonstrated in Section 8.3.1B, risk-aware roadmapping involves the selection and application of appropriate and objective constraints, as carried out for the selection of ideas. This is in agreement with the views of Weick. Beyond this, however, is the appropriate breakdown or lifting of certain constraints, especially implied ones in the ideation process, which are heavily influenced by cognitive limitations. These can then be replaced by new structures or constraints (e.g. using a method like TRIZ, and MCDA techniques) that promote production of ideas of greater quality and viability, which in turn reduce the potential loss of valuable ideas. Thus sensemaking involves the enactment of constraints and rules. Improved sensemaking, which pays extra attention to uncertainty, will also seek to remove or lift unhelpful constraints such as cognitive limitations that adversely affect results. The selection of appropriate constraints for a given sensemaking situation is of importance and mentioned by Mumford et al (2008). As demonstrated by this thesis, constraints that emphasize a clear market need, market profitability and market growth potential are appropriate for early-stages of innovation. In general, including explicit risk management in planning may be seen as a case of testing constraints, breaking them down and renewing them. This is necessary to accommodate a more objective view of reality, and acknowledge the limits of our knowledge and the impact it may have. This comes first with the realisation that constraints we set up knowingly or unknowingly may be faulty and then to proceed to examine, test and adjust them accordingly. This process is akin to one of learning, or knowledge creation, and it has been demonstrated in Section 8.3.1D and Figure 8.4, that generally risk management methods embedded in roadmapping help in achieving this.

Sensemaking is driven by plausibility rather than accuracy. According to Weick sensemaking is subjective. It is not about objective perception, but about expediency, plausibility, coherence, and “a good story” (p 61, Weick, 1995), taking a relative approach to the truth. Improving roadmapping (or planning) by paying better attention to uncertainty and risk (and thus improved sensemaking) involves making attempts to introduce more objectivity into the planning process. The imposition of appropriate structures and constraints in the risk-aware roadmapping process as carried out in this thesis is a means of achieving such improvement, instilling greater confidence in the results generated from the process. As explained by Weick (1995), accurate perceptions may not be necessary, and, an attempt to be accurate may lead to elaboration that hinders action (Brunsson, 1982). However, to fail to aspire to accuracy and try to be more accurate is considered unhelpful particularly to planning at the front-end of innovation, where resource and financial commitments are strategic in nature and there is the potential for huge waste if faulty plans are acted upon. Also, Weick explained that coherence is more important than accuracy, but how is coherence established in the absence of appropriate rules, constraints and objective structures that help to establish and instill good judgment? On the other hand, as earlier pointed out under the discussion of "structure vs. intuition: in Section 8.3.1A (iii), the early stages of innovation are too formless or uncertain for a fully objective process that promotes accuracy, and there needs to be room for measured or controlled subjectivity, to make better sense of the planning or roadmapping situation. Thus, sensemaking in the context of planning especially for the early phases of innovation should strive for accuracy but balance it with subjectivity (or plausibility). Doing one without the other will either hinder action or create the potential for incurring huge losses.

Weick's description and discussion of the occasions for sensemaking (i.e. ambiguity and uncertainty) suggest that these are occasions that are separately encountered in sensemaking activities. The nature of the risk-aware roadmapping process suggests otherwise, that both ambiguity and uncertainty can be encountered within the same sensemaking activity especially in the context of strategic episodes such as roadmapping. One of the first steps in risk-aware roadmapping is the reduction of ambiguity, which can be described as a severe form of uncertainty (according to Courtney et al's (1997) levels of uncertainty). The application of scenarios helps in achieving this purpose by clarifying the future market, the organisation's vision and goals for the subject of the roadmapping activity (as observable in Roadmaps A1-A11), thus reducing ambiguity to levels of uncertainty that standard risk management steps can subsequently cope with as the roadmapping process proceeds. However, ambiguity and uncertainty may not always exist sequentially as described, especially since there are steps within the roadmapping process where ambiguity might again set in even after it might have been previously addressed using scenarios. These, following McCaskey (1982) who described characteristics of ambiguous situations, would include situations where there is a lack of objective criteria, where people have to rely only on personal or professional values to make sense of a situation. This description fits the conditions surrounding *generation of ideas* and *selection of ideas*, which are critical steps to roadmapping but are clouded by uncertainty (as discussed in Section 8.3.1A (ii). Risk-aware roadmapping takes steps to improve the structure and objectivity of these steps using appropriate methods, thus reducing the level of uncertainty that surrounds them from a state of ambiguity to a level of uncertainty more easily dealt with. It can be said therefore that ambiguity and uncertainty coexist in planning and strategic episodes such as roadmapping. It may in fact be said, on closer look at the risk-aware roadmapping framework (Figure 8.1) and foregoing discussion, that the entire roadmapping process is ambiguous, given other characteristics of ambiguous situations provided by McCaskey (1982) listed as follows:

- Information amount and reliability is problematical (Section 8.2.1, Figure 8.1)
- Time, money and attention are lacking (Section 8.2.1, Figure 8.1)
- Contradictions and paradoxes appear (Section 8.3.1A (ii): tensions between traditional roadmapping practices and demands of risk-awareness)
- Roles are vague, responsibilities are unclear (Section 8.3.1A(iii): discussion on selection of participants).

The impact of the risk-aware roadmapping is then to appropriately address the situations such as to reduce the ambiguity faced to levels of uncertainty that can be coped with more easily. It should be noted that this notion of reducing ambiguity to lower levels of uncertainty is in agreement with the view that ambiguity is a more severe form of uncertainty (Courtney et al., 1997; Knight, 1965).

Overall, it is the view here that having a risk-aware attitude to roadmapping and planning provides the opportunity for improved sensemaking. Also, and importantly, an increased awareness and attention to uncertainty and risk in roadmapping for early-stage innovation as carried out in this thesis inspires confirmation and modifications to some of Weick's theories. First, there is the basic understanding that sensemaking can be both retrospective and prospective. Secondly, constraints are enacted in sensemaking for the sake of planning in agreement with Weick, but to improve planning (by better addressing uncertainty (and risk) within it), it may be necessary to breakdown unhelpful constraints and impose new appropriate ones. Thirdly, the improvement of sensemaking (through improved risk- and uncertainty-awareness) would require a drive for accuracy, but balanced with subjectivity (or plausibility). Weick had suggested only plausibility was required and accuracy was unnecessary. Finally, sensemaking in strategic episodes such as roadmapping can involve addressing ambiguity and uncertainty within the same sensemaking process, and in such cases may even involve the transformation of ambiguity into uncertainty. Weick had suggested uncertainty and ambiguity as separate occasions for sensemaking.

8.4 Summary

This chapter presented a summary of findings from the research carried out in this thesis and discussed them, drawing out contributions both to practice and theory roadmapping and strategy. Relying predominantly on the Strategy as Practice framework, further insight into strategy practices of managers in the context of roadmapping have been uncovered. Specifically these include the understanding of how uncertainty and risk may be addressed in strategy, what factors influence the process, and what implications hold for roadmapping practice.

Importantly, issues such as the relationship between roadmapping and risk management were highlighted, pointing out that roadmapping might be regarded as a risk management method or process in itself since its basic process help in making sense of uncertain and ambiguous situations. However, an inclusion of explicit risk management effort in roadmapping improves the process and the ‘accuracy’ and acceptability of its outputs.

Some practicalities of converting a conceptual strategy process (in the form of risk-aware roadmapping process) into a practical process (RSRM process) were drawn out. These practical realities experienced inspired the researcher to challenge some aspects of the framework upon which the conceptual process was built.

Theoretical contributions of this research ranged from the conceptualisation of scenarios and their effect on decision making to the influence of risk management on sensemaking. Established properties and concepts of organisational sensemaking (which embody the theory of organisational sensemaking) were examined and challenged within the context of this research.

Chapter 9 - CONCLUSIONS

This chapter provides a summary of the foregoing chapters of this thesis. It reiterates the findings and the contributions of the research to practice and theory. It explains the limitations of the research and draws conclusions from the research, both in the context of the academic work presented in this thesis and personal experience of the researcher in carrying out the work. Finally, it suggests additional work that can be carried out to advance the research and further clarify some of its findings.

Section 9.1 provides the background to the research, while the research approach is explained in Section 9.2. Next, the outcomes of the research are presented: Section 9.3 presents outlines the findings and Section 9.4 presents the practical and theoretical contributions from these findings. In Section 9.5, the difficulties faced by the researcher are explained and the limitations of the research and findings are recognised. Conclusions drawn from the research are presented in Section 9.6 and followed by suggestions for further work in Section 9.7.

9.1 Research background and context

This thesis explained and established the application of roadmapping as an approach to strategy at the early stage of innovation. It also showed the lack of explicit attention to the treatment of uncertainty and risk within the approach. This lack of attention was observed both in roadmapping literature and practice, despite the awareness that roadmapping is meant to identify, resolve and communicate uncertainties and risks as part of its benefits. Similarly, strategic planning, especially planning at the early stages of innovation has been found generally to be lacking in its treatment of uncertainty and risk. It is in response to this that the research reported by this thesis was carried out. This thesis has been focused on providing an understanding of uncertainty and risk in roadmapping and how they may be addressed with respect to roadmapping's application to strategic planning early-stage innovation planning. It has also provided practical guidance on how roadmapping that explicitly addresses uncertainty and risk may be carried out. These objectives of the research were captured in the research questions:

- How is uncertainty and risk manifested in roadmapping within the context of strategic early-stage innovation planning, and what are their implications for roadmapping practice?
- How might roadmapping be carried out to incorporate explicit consideration of uncertainty and risk?

9.2 Research approach

The research was carried out in two phases of qualitative research. Each phase was designed to answer one research question. The first phase combined research methods, which facilitated the exploration of multiple data sources. Archival analysis was used to explore a corpus of 650 roadmap documents and found 22 of these documents to have addressed uncertainty and risk explicitly. Findings from these were combined with those from experience surveys, in which the experiences of 11 roadmapping practitioners were drawn upon through interviews and the 5 case studies of roadmapping exercises explored. In combination, these provided an understanding of treatment of uncertainty and risk in roadmapping and the issues and factors surrounding them, as well as the interrelationships between these factors. The second phase of the research was carried out using procedural action research, which included the use of interviews, focus groups, and case studies in the creation and testing of the roadmapping process created to explicitly address uncertainty and risk.

9.3 Research findings

Overall the research findings are in two parts. Results from the experience surveys, archival analysis and case studies first phase are captured in the framework. This framework has two parts: factors that may affect the treatment of uncertainty and risk in roadmapping and a conceptual risk-aware roadmapping process (i.e. a roadmapping process which recognises the various types and sources of uncertainty and risk and explicitly addresses them). Two groups of factors were identified:

- those that explained the manifestations (or the sources and types) of uncertainty and risk within the data content of a roadmap (called the roadmap-content-related factors). These include:
    - external environmental uncertainty
    - internal environmental uncertainty
    - decision uncertainty (including uncertainty about the search and choice decisions in the roadmapping activity), and
- the factors that influenced how those uncertainties and risks may (or may not) be addressed (called the roadmap process-related factors). These are:
    - type and quality of participants in the roadmapping process
    - cognitive biases of the participants of the participants
    - the consensus-driven nature of roadmapping
    - time and resource constraints usually associated with roadmapping exercises
    - the roadmapping maturity (or experience) of the organisation carrying out the process.

The conceptual risk-aware roadmapping process developed explains that dealing with risk and uncertainty in roadmapping requires a combination of the generic risk management steps (of risk identification, estimation and treatment), the diagnosis and reduction of ambiguity, and the improvement of structure of search and choice routines in the roadmapping activity. Also, methods used in practice to address these steps (including scenarios) were identified and examined.

The second phase of findings focused on creating a risk-aware strategic roadmapping (RSRM) process. This process was developed based on the framework created within the general findings, operationalizing the generic risk-aware roadmapping process and paying attention to both the content-related and process-related factors surrounding it. The process was taken through a series of appraisals by roadmapping and strategic planning experts as well as real-life in-company tests to ensure its feasibility, usability and functionality. Similarities and differences between the cases were identified, which included an examination of the criteria used in the choice routines within the process and the effect of the participant-mix on the types of risk addressed in the roadmapping process.

9.4 Research contributions

In its study of roadmapping, this thesis contributes both to knowledge both in practice and theory through the Strategy as Practice (SaP) perspective of strategic management. Practical contributions are found in the identified practices in roadmapping for addressing uncertainty and risk, and its implication for the praxis of innovation, focusing especially on early stage innovation. It should be recalled that it is these issues of roadmapping, uncertainty and risk, and early stage innovation that are the focus of this thesis. Theoretical contributions are made to Weick's (1995) organisational sensemaking, which is a theory associated with SaP. Also there are contributions to Chermack's (2005) theory on scenarios.

It became clear from the findings that there are no set approaches or the appearance of general consensus on the treatment of uncertainty and risk in roadmapping (i.e. on risk management in roadmapping). However, this thesis shows three standpoints of roadmapping on risk management. That:

- roadmapping in its basic form addresses uncertainty and risk: roadmapping in its basic format contains steps that help to address some of the uncertainty that is inherent in planning especially for the early stages of innovation
- additional (or explicit) risk management steps can be included into basic roadmapping to improve the quality of its outputs: there is an appetite in practice to consciously and further address uncertainty and risk beyond what roadmapping does in its basic format, and
- roadmapping itself is a risk management tool: in some instances, roadmapping itself may be regarded as an approach to risk management. The explicit goal of this view is that roadmapping is a tool for reducing the risk of innovation failure,

and risk management methods are embedded in roadmapping for this sole purpose.

The difference between these three views lies in the emphasis on risk management over planning in the roadmapping activity, with the emphasis increasing down the list above.

Further exploration of the second standpoint led to an understanding of risk management steps necessary for addressing uncertainty in roadmapping as well as methods that can be used in those steps within roadmapping.

- In addition to the standard risk management steps, in dealing with uncertainty and risk, roadmapping requires additional steps of diagnosis and reduction of ambiguity, augmenting creativity and structuring the selection process. By including all these steps for risk management in roadmapping, two types of uncertainty – environmental uncertainty and decision uncertainty – that have been discussed separately in strategic management literature are combined in one coherent process. Augmenting creativity is an important step for risk-aware roadmapping. However, its inclusion presents a risk-creativity paradox, which raises the question of how to achieve a balance between pushing for creativity to reduce the risk of missing valuable innovation opportunities and the increased risk of failure that arises from pursuing highly creative ideas. Also, there are factors that surround the explicit treatment of uncertainty and risk in roadmapping, which indicate that risk-aware roadmapping requires some activities that conflict with traditional views of roadmapping.
- Embedding the appropriate risk management method in roadmapping facilitates knowledge creation and learning. The methods used can be seen to help in knowledge transformation across tacit and explicit boundaries, both in available and unavailable knowledge. They create clarity on important issues to the roadmap that were unclear or would have otherwise remained unknown. Of these methods, scenarios planning takes up an important role, especially in dealing

with high levels of external environmental uncertainty in roadmapping and two forms in which they are applied are:

- exploratory scenarios, which addressed ambiguity by seeking an understanding of the future external environment and adapting the roadmap development to it, and
- normative scenarios, which addressed ambiguity by adopting a desired view of the future external environment and building the roadmap to shape the future into that view.

These two forms address uncertainty relating to the future external environment of a firm carrying out roadmapping differently. There is also the indication that normative scenarios are better suited to technology-oriented (or technology push) strategies (rather than market-oriented (or market-pull) strategies), and they can address higher levels of uncertainty than exploratory scenarios.

The risk-aware strategic roadmapping (RSRM) process created within this thesis is a translation of the conceptual risk-aware roadmapping process developed within this thesis to practice. This process, created by the integration of appropriate risk management methods into S-Plan (a pre-existing version of roadmapping), provides a feasible, useful and usable roadmapping process that identifies, estimates and communicates uncertainty and risk explicitly. In the course of applying the process, some aspects of the conceptual risk-aware roadmapping process that underpinned the RSRM process were challenged. These are that:

- The actual application of the risk management methods embedded in the RSRM process appears to be influenced first by the time and effort it is perceived the application of that method will take, rather than the actual utility of the method.
- The set of participants selected for the process (to satisfy the need for a diverse and experienced set of participants in risk-aware roadmapping) can only be treated as a best guess. This is because the nature of the planning problem is not always completely clear until the first iteration of roadmap is completed.

Therefore, the best combination of participants to suite the planning problem cannot be known upfront, as had been suggested in the conceptual process.

- Whereas the conceptual process promoted objectivity of roadmapping steps as a means oaf addressing some of the uncertainty faced, the RSRM process found that it was more appropriate to have a balance of objectivity and subjectivity.

On issues surrounding early-stage innovation itself, an aspect RSRM process provided some clarity on what *constraints* or criteria are appropriate for selecting innovation ideas at the early stages of innovation. These criteria, which literature had previously indicated as unclear, include *clarity of customer need*, *potential for market growth* and *market profitability*. These criteria appear to be those that are highlight the positives and possibilities of the ideas rather than their technicalities or the difficulties associated with translating them into reality. Thus they give an indication of how innovation ideas may be chosen at the early-stages of innovation as opposed to the latter stages.

The contribution to theory relates to four general properties of organisational sensemaking as presented by Weick (1995). Uncertainty and ambiguity are occasions for sensemaking and the findings from this thesis provide opportunity to challenge Weick's notions that sensemaking is retrospective, grounded in identity construction, enactive of sensible environments and is driven by plausibility rather than accuracy. The consideration of uncertainty and ambiguity as discrete occasions for sensemaking as suggested by Weick are also challenged, as it is evident that the boundaries between uncertainty and ambiguity are blurry especially for roadmapping. It is clear that having an explicit attitude to the treatment of uncertainty and risk in roadmapping (and strategic planning in general) provides an opportunity for improved sensemaking (and decision making). Another contribution concerns Chermack's theory on scenarios. Chermack proposed that there is positive relationship between the application of scenarios and improved decision-making. Upon examination, Chermack's hypothesis may be better presented as that there is a positive relationship between the application of scenarios and a better structure of the decision-making process.

9.5 Research considerations, challenges and limitations

9.5.1 Research considerations

Although the overall research direction and methods used are in agreement with the requirements of the research focus and research paradigm (of interpretive research) followed as demonstrated in Chapter 3, certain choices were made regarding the research steps. Some of these choices were intentional to improve quality of the research while others were the result of pragmatic considerations, or personal preferences of the researcher. These are highlighted below and implications are presented, especially where they are thought to have had significant effects on the nature of results produced.

- Use of mix methods: research methods were mixed in both the first and second phases of the research to overcome weaknesses of individual research methods. In Phase 1, where retrospective studies were carried out, a combination of practitioner interviews (experience surveys), archival analysis and case studies were applied to explore the research problem. The number of case studies was limited to 5 due to the difficulty in gaining access to appropriate cases. Potential problems with generalizability of results from these cases were alleviated by the corpus analysis carried out in which 650 roadmap documents were examined and the experiences of 11 roadmapping practitioners. The procedural action research methodology followed in Phase 2 of the research focuses on in-company testing, and does not necessitate the use of subjective appraisals as was carried out in this research. However, subjective appraisals have been applied in other forms of action research. Carrying out the subjective appraisals before in-company testing enabled sense-checking and improvement of the RSRM process under 'friendly' conditions. It was expected that the access to cases for in-company testing would be difficult (as it was), and it was considered expedient to use whatever case access was available to test a much more improved process with fewer errors, and closer to stability. While 5 in-company cases were adequate to bring the RSRM process to stability, the accessibility to cases was constrained. Only 7 companies provided access, of which 2 did not meet conditions for inclusion. The differences among the 5 companies made no difference to the manner in which RSRM process was carried out.

- The use of real-life case studies to test the RSRM process: Given the time pressures of doctoral research, the application of real-life test cases was not compulsory. The researcher had the choice of simulating the testing of the RSRM process (i.e. following an experimental approach), by setting up a company scenario, assigning roles to individuals that had been sourced and using constructed data to run the process. The use of simulations was not followed for two reasons: First, the research objective was for a practical usable process. The use of such experiments would have made issues central to roadmapping (such as reaching consensus in the midst of uncertainty) artificial. Secondly, it would have prevented the examination into issues surrounding innovation in real life and prevented any substantial contribution there. However it would have been significantly easier for the researcher to run these experiments, especially since there would not have been the need (and difficulty faced) to gain company access.
- Modification of the RSRM process as testing progressed: the in-company testing of the RSRM process could have progressed in two ways: a. testing the same version of the process in successive in-company case studies and improving the process when all the tests have been completed based on the aggregation of feedback received through the cases, or b. improving the process as the testing progressed based on feedback received on a case-by-case basis. The first option gives the opportunity to carry out cross-case comparison since exactly the same process would have been tested in all the cases. The ability to do this is reduced if the second option is followed, since different processes (as a result of the progressive modifications) would have been applied. However, this second option was adopted in this research because it enabled the progressive improvement of the RSRM process in accordance with the research objectives.

9.5.2 Research challenges

The researcher faced both theoretical and practical challenges in carrying out the research reported in this thesis. The theoretical difficulties had to do with the breadth of the fields of strategic management combined in the research problem. Practical challenges were of the nature of the difficulties faced especially in gaining access to case studies and the study of diverse forms of roadmaps.

Uncertainty, risk and strategic planning are subjects that are quite vast in breadth and this study on roadmapping for early-stage innovation planning combines them. Issues on uncertainty, risk and planning permeate almost every aspect of human endeavour and can therefore be examined from several angles. In this study, they were examined from a strategic management perspective. Even so, the various views of strategic management scholars and practitioners on these issues make it difficult to explain them in definite terms. This notion and the complexity it brought to the study is captured in the statement "all [strategic] management is risk management" by Crockford, (1982), as boundaries between strategic management, uncertainty and risk are fuzzy but interrelated. However, the researcher was able to identify definitions for each of these and link them within the context of strategic management for the purpose of early-stage innovation roadmapping.

In addition, the field of roadmapping itself is quite broad and this is evident from the descriptions of roadmapping typology as provided in Section 2.1.2 and Figure 2.6. These typologies are not strictly followed in practice, and it this contributes to the difficulty associated with studying roadmapping, especially when the study's focus is on a specific type of roadmap (e.g. strategic innovation roadmaps, as in this research), and it is necessary that it is only this type of roadmap included in the study. The flexibility of roadmapping and the roadmapping framework, which is a strength in that it makes the approach easy to customise and apply, contributes to this practical challenge. It has led to a proliferation of structure, language and presentation of the roadmap content in practice. Therefore, there is bound to be lack of uniformity across roadmaps examined in a study, except where all have been created by a single organization and share the same format. Where the roadmaps are different, as was the case in the research reported in this thesis, it becomes the duty of the researcher to look beneath these formats for relevant data or information.

As already indicated in the preceding section, the researcher found access to case studies for both phases of the research difficult. This is attributed to the nature of research's focus on innovation planning, for which organisations appear generally unwilling to share information. This constrained the researcher to a few cases. The 5 cases examined in the first phase of the research were not from typical privately-owned (and run-for-profit) organisations, but from research organisations owned by the government, for whom competition and IP protection were not strict issues. To gain access to cases in the second phase of the study, the researcher was required to sign agreements of non-disclosure of the content of the roadmaps developed using the RSRM process. It is also worth highlighting that companies that tested the RSRM process rejected the use of scenarios (that fulfilled an important step in the process). This was because of the additional time and effort it would require to apply them. Even though the data from the company eventually showed that the step would have been unnecessary for the specific RSRM processes, the companies gave no opportunity to test it.

9.5.3 Research limitations

The scope of the research and the generalisability of its results are limited by the following:

- As reported in the thesis, the RSRM process developed in the second part of the research was based on S-Plan, a pre-existing fast-start model of strategic roadmapping. The context of the usage of this roadmapping method is the same as the focus of this study – strategic innovation planning at the early-stages of innovation. Therefore, the application of the RSRM process is limited to the same context, and may not be used for other roadmapping purposes like program planning and integration planning. In addition, the process was developed and tested with product innovation in mind, and therefore, may not be directly (or fully) applicable to service innovation. However, it is expected that the same principles and generic steps of risk-aware roadmapping will be applicable to other models of strategic roadmapping (i.e. different from S-Plan) that wish to embed explicit risk management steps, and to the use of the RSRM process in service innovation. Still, this cannot be fully ascertained until it is tested in practice.

- Care was taken by the researcher to build the RSRM process to be generic and flexible for early-stage innovation planning by ensuring that the risk management methods introduced into S-Plan were not industry-specific. This objective was achieved, attested to by the generally positive feedback received in all five companies (from five different industries), where RSRM testing was carried out. It can therefore be expected that the process would be applicable across organisations regardless of industry affiliation. This notion is reasonably since S-Plan, the roadmapping process on which the RSRM process is based, has been successfully applied across industries. However, this generalisation is not made outrightly here since the study did not formally investigate *the wider applicability of the process,* the final step of the procedural action research methodology that was used in developing the RSRM process. Investigating the wider applicability involves seeking feedback from a wide range (and large sample) of managers who have applied the process, and this was not carried out for practical reasons as discussed in Section 3.3.2a.
- Addressing the uncertainty surrounding the search for strategic alternatives (or value propositions) by enhancing and bringing structure to the creativity of participants in the roadmapping process is an important step in risk-aware roadmapping. However, TRIZ, the tool earmarked in this study to introduce this structured creativity into roadmapping, was not included in the development process. This is due to its extensive nature (thus creating the need felt by the researcher to properly understand it before integrating it). The RSRM process reverted to using *brainstorming* in place of TRIZ and therefore the application of TRIZ within the RSRM process was not tested within this thesis. Nevertheless, TRIZ and its potential to improve creativity in roadmapping were (and are still being) explored outside the scope of this doctoral thesis by the researcher (see Ilevbare et al, 2011 and Ilevbare et al., 2013). Similarly, even the test cases did not give

opportunity to test scenario techniques within the RSRM process, practitioner accounts and the corpus documents reviewed show that they can be applied in roadmapping to reduce ambiguity. What remains to be seen is how it actually works when applied in the 'fast-start' format as described in the RSRM process.

9.6 Conclusions

This research has examined how uncertainty and risk are addressed in roadmapping, specifically in its application for strategic innovation planning at the early stages of innovation. Personal motivation for the study was borne out of a combination of the researcher's interest to understand the application of roadmapping as an approach to planning under conditions where uncertainty and risk abound (as found in the early-stages of innovation) and the research agenda of the Centre for Technology Management, University of Cambridge to further understand the theory and practice of roadmapping. However, and importantly, this study was underpinned by the identified lack of explicit risk management in roadmapping. This absence of explicit risk management is also generally found in strategic planning (and planning at the early stages of innovation) as seen from literature, which are common applications of the approach. This focus to understand the treatment of uncertainty and risk in roadmapping is, in particular, motivated by the assertions made of roadmapping in a seminal paper by the European Industrial Research Management Association on roadmapping (EIRMA, 1997), which identified that roadmapping should deliver the identification, resolution and communication of uncertainties and risks surrounding the strategic issues as part of its benefits. However, there is little evidence from literature to confirm roadmapping's ability in terms of this assertion even though it has since been echoed by other roadmapping publications: Bruce & Fine (2004) and Petrick & Provance (2005). A very small percentage of roadmaps from practice were found to acknowledge uncertainty and risk, let alone address it.

Given these assertions, and the results from the study, a question that should be asked is whether the study was worth undertaking. The results of this study have shown that roadmapping, in its basic format, addresses some of uncertainty surrounding strategic planning and in some cases, has even been considered a risk management tool. Does this then mean that roadmapping already addresses uncertainty and risk as required based on the assertions of EIRMA (1997) and the other roadmapping publications? In a way, yes. However, as a result of the detailed examination of roadmapping by this study, it is clear that roadmapping, by itself, addresses only one type of uncertainty (choice decision uncertainty) and even at that, it does not address it optimally without additional explicit or conscious measures taken. Treatment of uncertainty and risk requires a conscious consideration of both environmental uncertainties and decision uncertainties as both types of uncertainties revolve around roadmapping (and strategic planning in general). If done properly, risk management in roadmapping will address both. Importantly, risk management also involves the active management of knowledge sources (especially the participants) involved in roadmapping. It requires the awareness of the cognitive limits of those involved in the process and how their behaviours might adversely affect results and taking steps to deal with this. This, in part, leads to the realisation that an aspect of a risk-aware roadmapping is the enhancement of creativity and ideation routines within the planning process so that they are more structured and objective. This is considered important reduce the risk of missing innovation opportunities. Thus, the treatment of uncertainty and risk involves giving attention both to the content of the roadmap and the activities involved in the process that creates the roadmap. This is so because it is considered here that both the content and process of roadmapping are intertwined and to get roadmaps of de-risked content, the process itself needs to be de-risked in some manner.

Overall, the explicit treatment of uncertainty and risk in roadmapping leads to roadmaps of much better quality, and it appears that this is the ultimate advantage of paying better attention to uncertainty and risk. Issues that can derail or limit innovation can be more confidently addressed early on so that the chances of success and accruement of value to the organisation through innovation are maximised. However, one must recognise that there should be a limit to what is done in terms of risk management within roadmapping sessions so that the process is not overburdened to a point where it becomes impossible to manage. There must be a careful balance of risk management aspects with the main innovation-planning objective of the process so that innovation is not stifled. The RSRM process is testament to this. Even after much simplification, it was still considered intense by those who applied. Perhaps at such early stages of innovation, dealing with uncertainty and risk is not a question of how much is done in terms of the depth of risk management analysis but how well it is done. It is important that all the main manifestations of uncertainty in roadmapping are recognised and addressed as much as possible. Care must be taken so that whatever analysis is included fits the ability, time and resource of the organisation undertaking the process. Still, to address uncertainty and risk, it is important that organisations commit enough time and resource to the approach. Unfortunately, it appears many are unwilling to do so.

Overall, this study has achieved the two objectives questions it set out to resolve (stated in the early parts of this chapter): to provide an understanding of the treatment of uncertainty and risk in roadmapping and the various factors surrounding it, and to develop a risk-aware roadmapping process that can be applied in practice. The study has been conducted from the perspective of practice to contribute learning and knowledge to practice and also theory. To maintain a view of what is generally feasible and useful in practice, the risk management analysis included in this roadmapping study does not involve any quantitative risk analysis. Based on the findings of this study, it is considered that quantitatively detailed risk analysis in roadmapping would be inappropriate at the early-stages of innovation. At the early stages reliable data appears generally difficult to find and the content of the roadmap relies heavily on intuition, experience and foresight in ways that are not quantifiable. Quantitative risk analysis might be appropriate further into the innovation funnel, when innovation ideas would have advanced and in more concrete forms, and more tangible data can be sourced or made available. Still, it appears the nature of the roadmapping approach does not particularly endear itself to this sort of quantitative analysis within the average organisation. Roadmapping, by nature, should be carried out using diverse knowledge from a diverse mix of individuals from the organisation, owned by them (because they built it and have bought into it) and presented in such a way that it remains accessible to them after it is created. In other words, in most cases, it should be simple enough for the average employee understand and apply. This does not particularly give leeway for very complicated analysis.

The practice-oriented findings from this study have theoretical implications, when examined in the light of organisational sensemaking. They provide an opportunity to challenge (and extend) Weick's (1995) theories on organisational sensemaking, which explain how organisations 'make sense' of uncertain or ambiguous situations. Based on this study, it has been proposed that sensemaking can be prospective (and not just retrospective as Weick identified), and that it is driven by accuracy as well as plausibility (Weick had explained that sensemaking is driven rather by plausibility than accuracy). The relationship between uncertainty and ambiguity within roadmapping also shows that both can be present in the same sensemaking situation rather than being regarded only as separate occasions for sensemaking (as presented by Weick). Additionally, this study on roadmapping provided opportunity to challenge Chermack's (2005) theory on scenarios, which have become an important method for addressing uncertainty and risk. The theory postulates that there is a positive relationship between the application scenarios and improved decision-making. Upon examination, an updated and more accurate version of the theory is proposed here, that the application of scenarios contributes to better-structured decision-making. The question of whether better structure equates to an improvement in decision making is down to another argument of what constitutes better decision-making.

9.7 Research recommendations

The following are linked to issues identified earlier on in the thesis either as questions raised within the discussion or as the challenges and limitations of the research. It is the opinion of the researcher that these issues would benefit from further work, either to clarify some of the findings or extend the generalisability of the results. They are presented as follows:

- *How do scenarios contribute to better decision-making?* This question was raised in looking at how scenarios are used in roadmapping. What is clear is that scenarios (either exploratory or normative) provide better structure and thus clarity to aspects of decision-making. But the question of what makes for better decision making is raised if Brunsson's (1982) view that the usefulness of decision making is found in its ability to spur action is considered. It may be useful to strengthen linkage between application of scenarios and the improvement of decisions in the light of Brunsson's perspective and understand how scenarios lead to action that provides positive results.

- *Establishing the significance of constraints for the creative aspect of ideation.* The role of constraints, in the form of criteria used in choosing innovation ideas is clear from this thesis and the work of Mumford et al (2008). However, this thesis has identified that constraints (perhaps in another form) have a role in the identification of innovation ideas (i.e. ideation). However, the forms they take and the manner in which they apply are not completely clear. That is, the question of what constraints to apply and how they can be applied in improving creativity within planning should be asked.
- *Balancing the risk of creativity vs. the risk of non-creativity.* The risk of missing potentially valuable innovation ideas is an important manifestation of uncertainty in innovation planning. Addressing this uncertainty would involve improving the ideation process by using methods that introduce structure into it. It is envisaged that this would result in more innovative ideas that potentially carry greater risk of failure in development or in the market. The question this raises is one of how to balance the initial risk of missing an innovation opportunity with the risk of the innovative idea failing.
- *On the modification of management tools.* In the course of testing the RSRM process, this research provided a glimpse into how management tools change from their intended forms of application to how they are eventually used in practice. From this study, one of the reasons managers appear to change tools (especially after they first encounter them) is so that the tools provide them with results they are comfortable with, or that advance their personal agenda. This type of behaviour appears to align itself with aspects of agency theory of strategic management, and it might be worth examining more closely how this theory

relates to application of management tools. It might explain how certain management tools have become widely used in practice, and perhaps contribute to the understanding of how management tools might be developed from research to have greater uptake among practitioners.

- *Participant profiling for roadmapping processes.* Making sure roadmapping is carried out by a diverse and qualified mix of knowledgeable participants is one of the important factors affecting risk management in roadmapping. However, such decisions on the choice of participants are subjective and on occasions (especially in early-stage innovation), it is not until the roadmapping process has been completed that there is a realisation that the participant selection could have been better. It would be useful to have a more objective means of deciding how appropriate the quality and mix of participants are prior to a roadmapping process.
- *Integration of relevant TRIZ techniques into the RSRM process.* To reduce the risk of missing innovation opportunities, preliminary work has already been carried out (Ilevbare et al., 2011) and a workshop-based integration of roadmapping and TRIZ has been piloted with some positive feedback[53]. However, further testing and modification is necessary, the results of which might indicate what aspects of TRIZ (and in what forms) would be most useful for integration into the RSRM process.
- *Integrating scenario planning techniques into roadmapping under fast-start conditions.* The use of scenarios in the RSRM exercise (or a similar fast-start process), to ease future ambiguity needs testing under real-life conditions. It will be useful to assess how the benefits of applying it compares with the added complexity it introduces to the roadmapping process.
- *Replicating or extending this study's findings, by focussing on private companies.* Further retrospective studies should be carried out in private companies since they were not directly investigated in Phase 1 of the research. Such research would be useful especially if the investigated companies have their own internal roadmapping systems, built and customised to suit their own strategic planning

[53] A process integrating roadmapping and TRIZ has been piloted in two companies by external innovation consultants.

and innovation needs. Such research will be useful to further identify factors that may influence the treatment of uncertainty and risk other than those already identified in this research.

- *Investigation of the wider applicability of the RSRM process.* Wider applicability of the RSRM process should be examined by disseminating the method to various managers and roadmapping practitioners and seeking feedback on it. It will be useful to see how the RSRM process will perform if applied to service innovation, to identify what modifications would be necessary.

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APPENDICES

Appendix 1 - Evolution of the strategic management field and strategic planning as reported by different scholars

Author	1920 1950 1960 1970 1980 1990 2000 2010
Rumelt et al. (1994) (Development of strategic management (SM))	Precursors → Birth of strategic management field → Transition toward research orientation → Use of industrial organisation economics to relate strategy to performance
Hammer (1996) (Eras of strategic planning (SP))	Era of portfolio management → Era of competitive strategy → Era of core competencies
Bonn & Christodoulou (1996) (History of strategic management (SM))	Mid 1950s – Inception of strategic management (SM) → SM as a budgeting exercise → SM as strategic planning → SM as competitive advantage → 'Reformalisation' of strategic planning processes
Carter (1999) (Evolution of SP)	1920s - Harvard Policy Model for SP developed by HBS → Focus of planning moves from policy to promotion of growth and market share → Rise in prominence of strategic planning → Focus shifts from strategic planning to a customer focused approach to management → Strategic planning returns to the firm
Hoskisson et al. (1999) (Evolution of SM)	Early theories: emphasizing the normative aspect of business knowledge, development of administrative structures and strategy formulation → Early intermediate theories: industrial economics: SCP framework, strategic groups, competitive dynamics → Intermediate theories :transaction costs economics & agency theory) → Current theories: Resource based view, strategic leadership and strategic decision theory, & knowledge based view
O'Regan & Ghobadian (2002) (evolution of SP)	Focus on corporate planning → Focus shifts to organisational positioning and competitive advantage → Integration of the deployment of business process initiatives with formal strategic planning
Volberda (2004) (evolution of SM perspectives)	Classical perspectives: strategy as an integrated plan; a deliberate planning process initiated by top management → Modern perspectives: strategy as a messy, disorderly and disjointed process → Post modern perspectives: creating and maintaining systems to enable the firm to create or adapt to competitive change
Herrman (2005) (evolution of SM)	1960s - Emergence of strategic management → Strategy defined as planning and executing company growth → Separation of SM into process and content research → Content research as dominant form of (SM) research → Rise of knowledge based view of the firm
Furrer et al. (2008) (evolution of SM)	1960s- Birth of strategic management → Emphasis on prescriptive studies of strategy showing how strategy should be carried out → Dichotomy of studies: i. Descriptive studies of how strategy is formed, ii. Studies to understand the relationship between strategy and performance; competitive advantage → Focus on organisational economics: TCE, agency theory → Resource based theory (along with theory of invisible assets and competence based theories of corporate diversification)

Appendix 2 - Guide for consultation interviews with roadmapping experts

Consultation summary sheet

Contact type: Phone _____ In Person _______	Time ________ Date_________
Participant: ___________________________	Organisation: _________________________

Background information of roadmapping organisation	
a. Nature of business and industry	
b. Organisation structure (presence of a planning department if any)	
c. History of application of roadmapping i. Nature of typical application of roadmapping ii. Approximate number of times and length of roadmapping experience	
d. General framework followed for roadmapping (if any)	

Practical illustration ***(****To understand (through one or two examples that you think are appropriate) the process you follow in roadmapping, especially those in which you consider that you were faced with uncertainty and/or risk****)***	
a. Name of project and/or client	
b. Rationale	
c. Duration of roadmap activity (Approx dates)	
d. Mode of roadmapping activity (meetings, workshops, desk research)	
e. Variety and number of participants	
f. RM process detail (Highlight major phases of roadmapping process e.g. i. Planning ii. Insight collection iii. Insight processing iv. Roadmap/ report creation)	Planning meetings Workshop processes Post-workshop processing/desk research Other activities/meetings
g. Methods and techniques applied	Planning meetings Workshop processes Post-workshop processing/desk research Other activities/meetings
h. Sources of uncertainty and risks	
i. Influence of RM timeframe	

j. Specific ways in which they were handled (if any)	
k. Influence of people involved on the way risk and uncertainty was addressed. *How were they able to work together?*	
l. Supporting documentation	Reports (Interim or final), papers written, roadmap visuals
Challenges in dealing with uncertainty and risk in roadmapping activities	
What are they?	
Any steps/ progress made in dealing with them	
Any other special methods applied other than already highlighted in the examples given How are they applied during the RM process	
Other things (factors) that should be taken into consideration to make uncertainty and risk management explicitly addressed in roadmapping	

Summary

Appendix 3 - Case study protocol for case study interviews with the facilitators of studied exercises

1. Background information of organisation (that carried out roadmapping or for whom roadmapping was carried out)
    a. Nature of business and industry (e.g. manufacturing, research, consultancy services, nature of products and services)
    b. Management and organisation structure (e.g. presence of planning department responsible for roadmapping)
    c. History of application of roadmapping
        i. Nature of typical application points (or issues to which roadmapping has been applied)
        ii. Approximate number of times of roadmapping and length of roadmapping experience in time.
    d. General nature of roadmapping exercises, i.e. what is the usual purpose of roadmapping (e.g. Motivation (exploratory, normative), time frame (long term, mid-term, short term), purpose (innovation, information, consensus generating), etc.)

2. Practical illustration(s) of roadmapping process
    a. Could you give a major (and recent) roadmapping exercise carried out, (preferably one in which you were faced with considerable uncertainty) as an illustration of your roadmapping process?
    b. Any documentation produced during process (or as output of the process) that I can look at?

    c. Are there challenges you face in trying to deal with uncertainty and risk while roadmapping?
        i. What are they?
        ii. How do you think/expect that they should be resolved?
    d. Are there other methods or techniques that you know that have been applied for addressing uncertainty other than those you highlighted in the roadmapping example you just gave?
    e. What factors would you say would influence (or enabling conditions within the roadmapping process for) the explicit and effective treatment of uncertainty and risk?

3. Closing
   Could you point us to other people who might be willing to share their experience on roadmapping (especially on the issue of uncertainty and risk in roadmapping)?

Appendix 4A - Excerpt from results in the examination of roadmap documents

SN	Roadmap document	Year	Roadmap organisation/publisher	Roadmap purpose	Text extraction concerning 'uncertainty'	Text extraction on "risk"	Remarks (visual?)	Methods
1	Virtual organisations A roadmap for strategic research on virtual organizations	2003	Camarinha-Matos & Afsarmanesh	The roadmapping project was designed to identify and characterize the key research challenges needed to fulfill the vision, required consistency and implementaiton model for… virtual organisations	"The elaboration and characterisation of plausible future scenarios… were carefully taken into account" p 36	None	Yes visual	Scenarios
2	A roadmap for developing Accelerator Transmutation of waste technology	1999	US DoE	Addresses the potential application of ATW to civilian spent nuclear fuel	"Stochastic models where used to address the inherent uncertainty in predicting performance for 10,000 or more years" p5-2. It also appears that an uncertainty analysis was carried out "based on the various components of the total cost and the estimated uncertainty in each" P 7-3	"Development schedule risks were pointed out ATW technology R&D and demonstration development schedule risks have been addressed and minimized during this roadmapping effort by using related information from other more mature programs" P A-23 (look out for more risk reduction features)	Yes visual	Stochastic models to address uncertainty
3	Strategic program plan for space radiation health research Space radiation health	1998	NASA	Not identified	Uncertainties of certain parameters e.g. space radiation can be estimated using well defined theories	None	Uncertainty is more centred on the estimation of the degree of risk of radiation	
4	Sodium bearing waste	2000?	INEEL (Idaho National Engineering and Environmental Laboratory)	To capture what development work must occur to resolve the key uncertainties in SWB disposition	"Roadmap schedule was developed based ona prioritisation of uncertainties and development activites they require for resolution" P i	"Overall reduction in uncertainty for the various alternatives is captured in the risk waterfall, which can be used to predict important milestones… " P i	Yes visual	
5	Smart adaptive systems: state-of-the-art and challenging new applications and resaerch areas	2004	EUNITE	to describe the state-of-the art and the vision, on the development of technologies, markets, education, research	"One important issue here is the representation and handling of the uncertainty that is conveyed in all the classification actions of user profiling and updating" p5 Use of decision points and a "triple path solution"	Expression of the presence of risk in SAS in terms of economical risk and technological risk; p29 time risks and resources risks are also identified	No roadmap visual is present	
6	ROADiBROM-D2 vision development Roadmapping Digital Broadcasting/mobile convergence. Future scenarios and vision development report	2007	European Community under the IST	"...Joint EU-China roadmapping project addressing digital broadcasting and mobile convergence towards 2015"... "…inteded to be exploited as a guideline and instrument to set up a joint Europe and China think-tank in this area"	It is recognised within the roadmap document that risk and uncertainty surrounding the development of these new Mobile multimedia and mobile TV technologies is increasing Treatment of uncertainty was done mainly through the application of roadmaps	This documents reports the building of scenarios which are then applied later in developing roadmaps. The development of roadmaps are covered in another document	This appears to be WP2 (Working paper 2?), and roadmapping was not directly mentioned or treated here. WP 4 is expected to deal with Roadmapping p52 This document (or report) was concerned with developing Future scenarios and vision.	Scenarios Expert interviews Brainstorming Desk research analysis

Appendix 4B - Excerpt from results in developed from the examination of roadmap visuals

S/N	Roadmap name/description	Year published	Theme	Roadmap class	Uncertainty/risk indicators	Explicit?	Addressed?	Publisher	URL	Visuals database
31	Air Force Space Command strategic master plan FY06 and beyond	2003	Space	1d	NN (none noticed)			US Air Force	http://ddaybarcelona.com/DOCUMENTS/masterplan.pdf	40
32	Alumina technology roadmap	2006	Metals/Energy	1c	Overall economic/technical risk level of [topic] roadmap pointed out as either low, moderate or high	Y	Y	International Aluminium Institute	http://www.world-aluminium.org/cache/fl0000224.pdf	361
33	Aluminum industry technology roadmap	2003	Metals/Energy	1a	Level and source of technical risk indicated	Y	Y	The Aluminum Association	http://www1.eere.energy.gov/manufacturing/industries_technologies/aluminum/pdfs/al_roadmap.pdf	362
34	An independent report of the future of the automotive industry in the UK	2009	Transport	1e	Barriers identified	N		New Automotive Innovation and Growth Team (NAIGT)	http://www.bis.gov.uk/files/file51139.pdf	412
35	An independent report of the future of the automotive industry in the UK	2009	Transport	1d	NN			New Automotive Innovation and Growth Team (NAIGT)	http://www.bis.gov.uk/files/file51139.pdf	415
36	An independent report of the future of the automotive industry in the UK	2009	Transport	1d	Use of question marks	N		New Automotive Innovation and Growth Team (NAIGT)	http://www.bis.gov.uk/files/file51139.pdf	414

Appendix 5: Looking further afield (consideration of other methods and techniques and their applicability in roadmapping

A - Common methods and techniques for addressing uncertainty and risk gathered from risk management manuals and texts

S/N	Method/ technique	Sources					
		ISO 31010 (2009)	APM (1997)	IRM (2002)	Chapman (2006)	Schoemaker (2002)	Courtney (2001)
1	**Scenario analysis**	✓		✓	✓	✓	✓
2	**Decision tree**	✓	✓			✓	✓
3	**Monte Carlo simulation**	✓	✓		✓	✓	
4	**Brainstorming**	✓	✓	✓			
5	**Checklists**	✓	✓		✓		
6	**Decision analysis**				✓	✓	✓
7	**Sensitivity analysis**		✓		✓	✓	
8	**Real options**			✓		✓	✓
9	**Interviews**	✓	✓				
10	**Delphi**	✓	✓				
11	**FMEA**	✓		✓			
12	**Fault tree**	✓		✓			
13	**Prompt lists**		✓		✓		
14	**Questionnaires**			✓	✓		
15	**Industry benchmarking**			✓		✓	
16	**SWOT**			✓	✓		
17	**System dynamics**					✓	✓
18	**HAZOP**	✓		✓			
19	**Consequence-probability matrix**	✓	✓				
20	**Business impact analysis**	✓		✓			
21	**Event tree analysis**	✓		✓			
22	**Markov analysis**	✓			✓		
23	**Bayesian statistics**	✓		✓			
24	**Risk register**		✓		✓		
25	**PESTLEanalysis**			✓	✓		
26	**Investment appraisal**				✓	✓	
27	**Game theory**					✓	✓
28	**Cause and effect analysis**	✓					
29	**Root cause analysis**	✓					
30	**Assumption analysis**		✓				
31	**Influence diagrams**		✓				
32	**Risk breakdown structure**				✓		
33	**Primary hazard analysis**	✓					
34	**HACCP**	✓					
35	**Environmental risk assessment**	✓					
36	**SWIFT**	✓					
37	**Reliability centred maintenance**	✓					
38	**Human reliability analysis**	✓					
39	**Layer protection analysis**	✓					
40	**FN curves**	✓					
41	**Risk indices**	✓					
42	**Cost/benefit analysis**	✓					
43	**MCDA**	✓					
44	**Bow tie analysis**	✓					
45	**PERT**		✓				
46	**CIM**		✓				
47	**Incident investigation**			✓			
48	**Auditing and inspection**			✓			
49	**Dependency modelling**			✓			
50	**Business continuity planning**			✓			

51	**Pareto analysis**				✓		
52	**CAPM**				✓		
53	**Probability trees**				✓		

References

APM. (1997). *Project Risk Analysis and Management (PRAM) Guide*: Association for Project Management (APM).

Chapman, R. J. (2006). *Simple Tools and Techniques for Enterprise Risk Management*: John Wiley & Sons.

Courtney, H. (2001). *20/20 foresight: crafting strategy in an uncertain world*: Harvard Business Press.

IRM. (2002). A risk management standard: The Institute of Risk Management.

ISO. (2009). ISO 31010: Risk management - risk assessment techniques: IEC (International Electrotechnical Commission)/FDIS.

Schoemaker, P. J. H. (2002). *Profiting from Uncertainty - Strategies for Succeeding No matter What the Future Brings*: The Free Press.

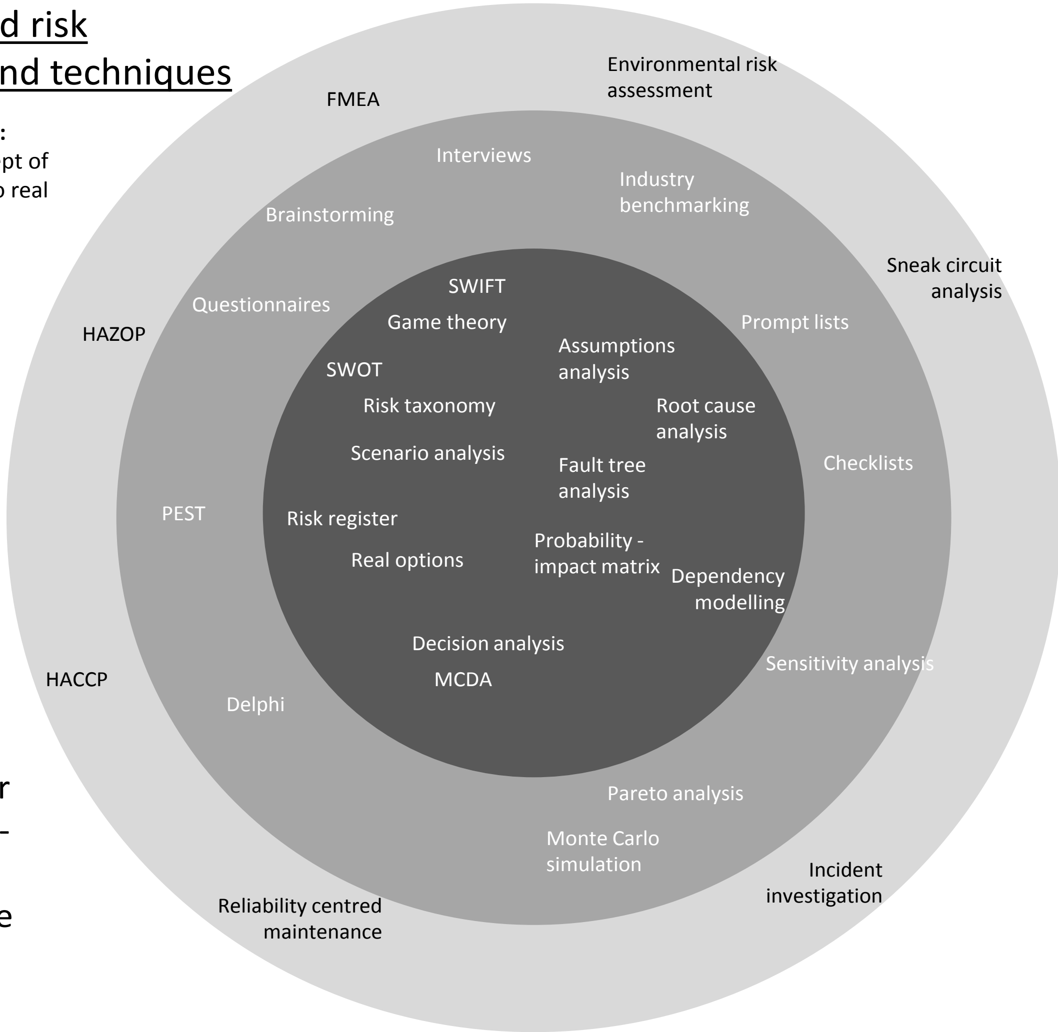
Classification of identified risk management methods and techniques

Core risk/uncertainty tools: operate solely on the concept of risk and uncertainty with no real industry affiliation

Supporting tools: Applied to risk management but can be applied for other non risk-centric processes as well. Can support of core and specialised and other supporting tools.

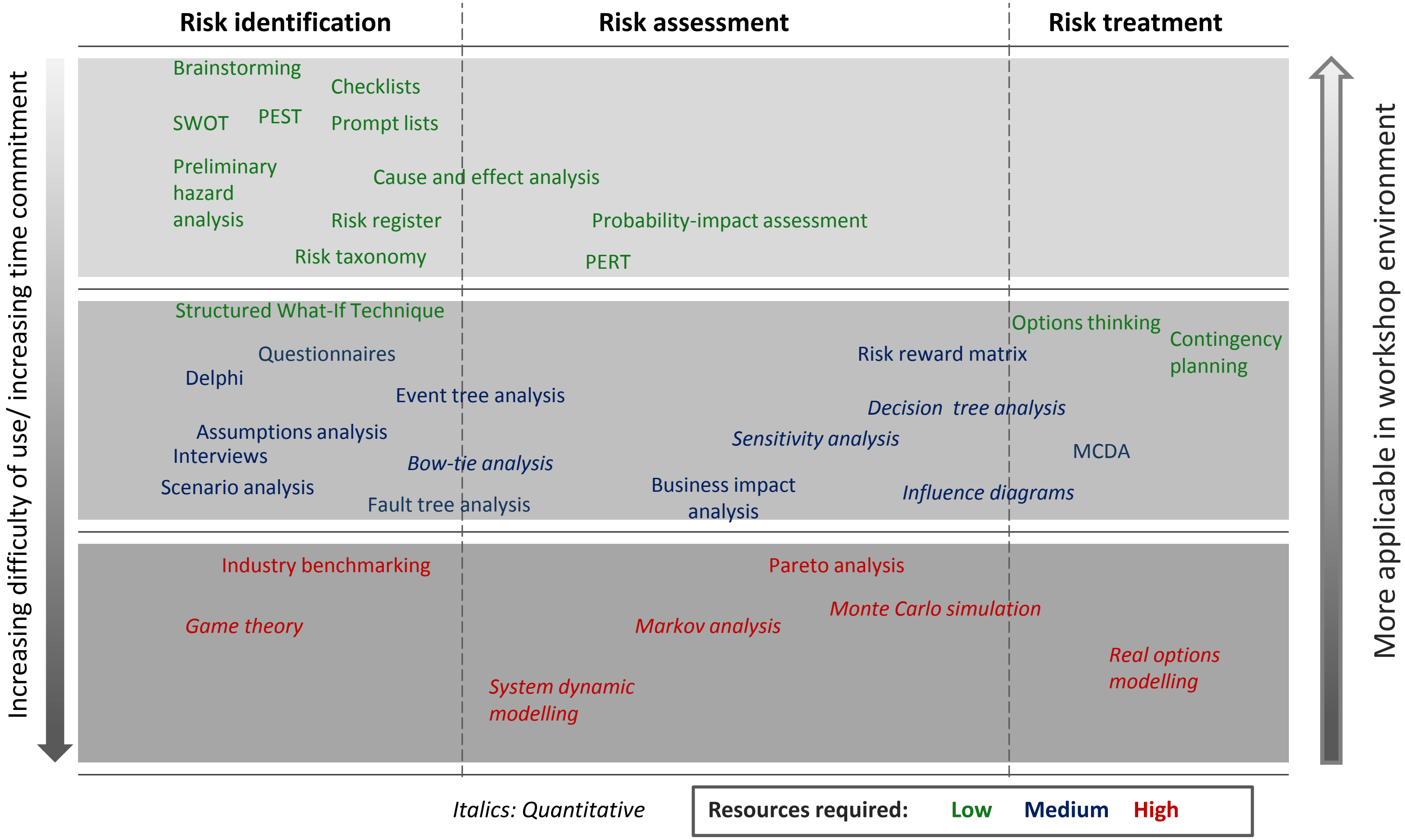
Industry specific tools: Used for risk management but are more likely to be used in certain industries

Core and supporting tools will be particularly useful for creating generic risk-aware roadmapping processes that can be applied across industries



B – Classification of methods according to their applicability for generic purposes

Mapping core and supporting tools and techniques according to resource and time requirement and difficulty of application



C – Mapping generic risk methods according to their time and resource requirements (and applicability to workshop-based roadmapping)

Appendix 6 – Charts used in focus group meeting for appraisal of RSRM process

Risk-aware strategic roadmapping process description and charts - focus group meeting

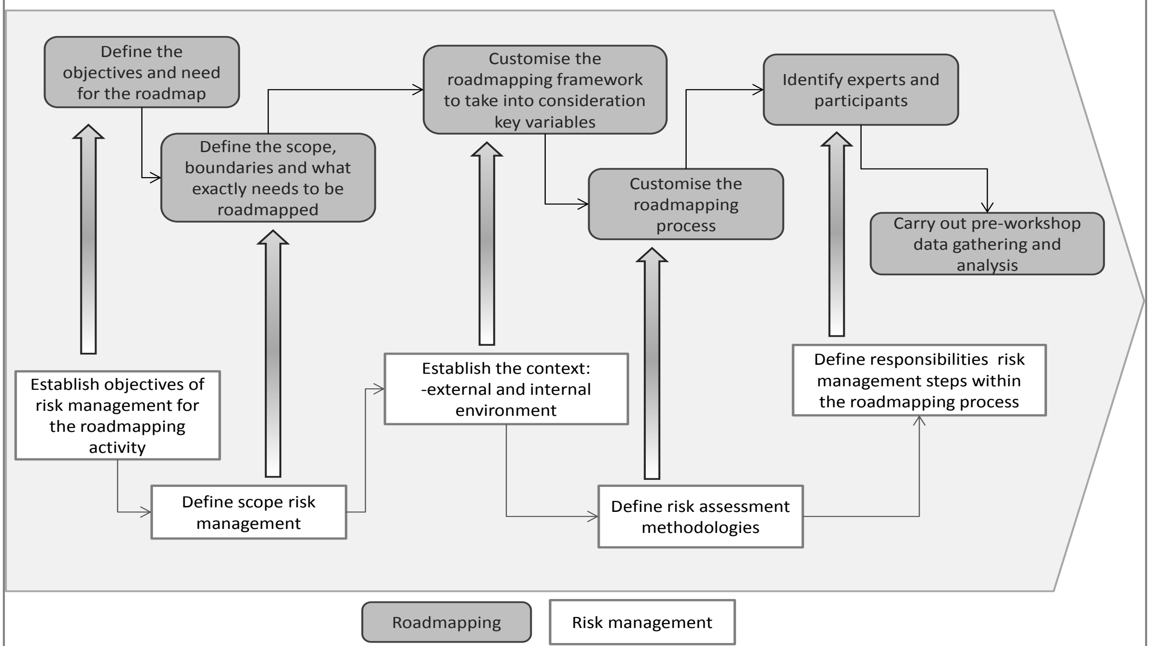
Institute for Manufacturing, University of Cambridge
29/11/2011

Imoh Ilevbare, CTM. VSN meeting 29/11/11

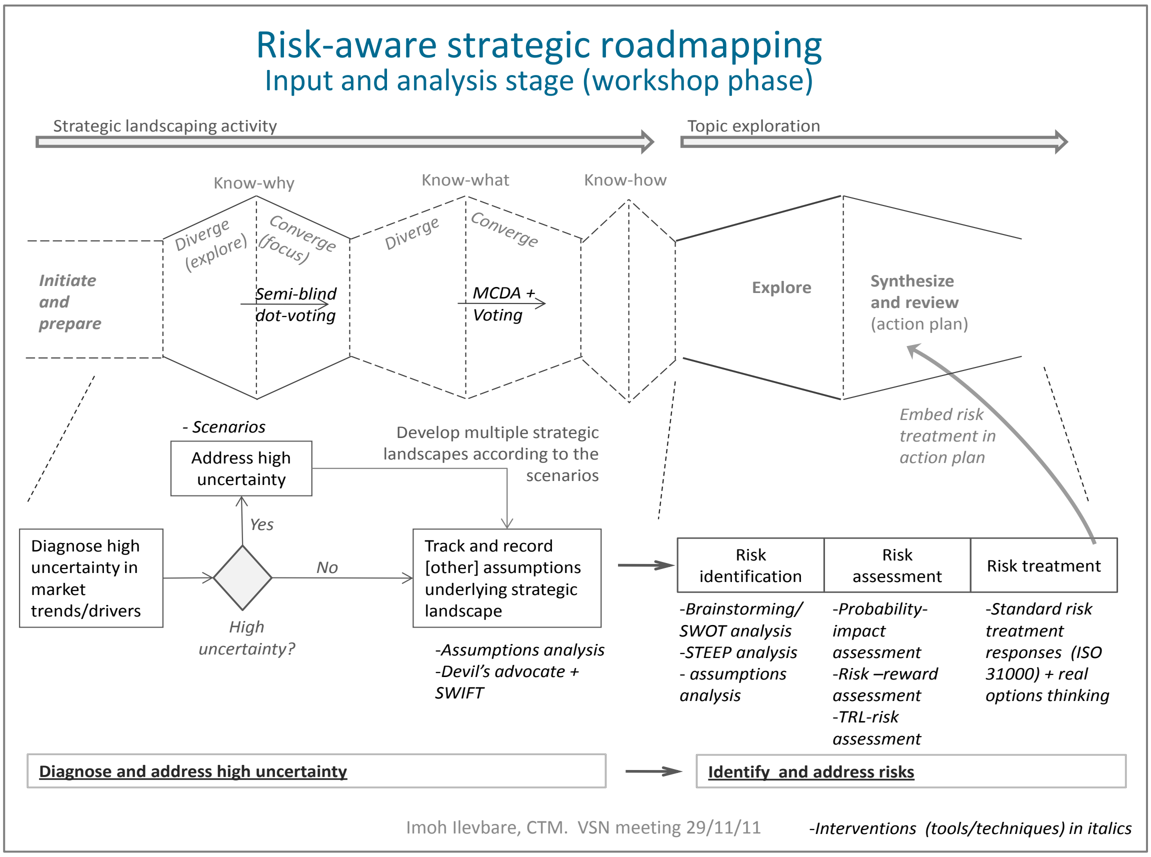
1

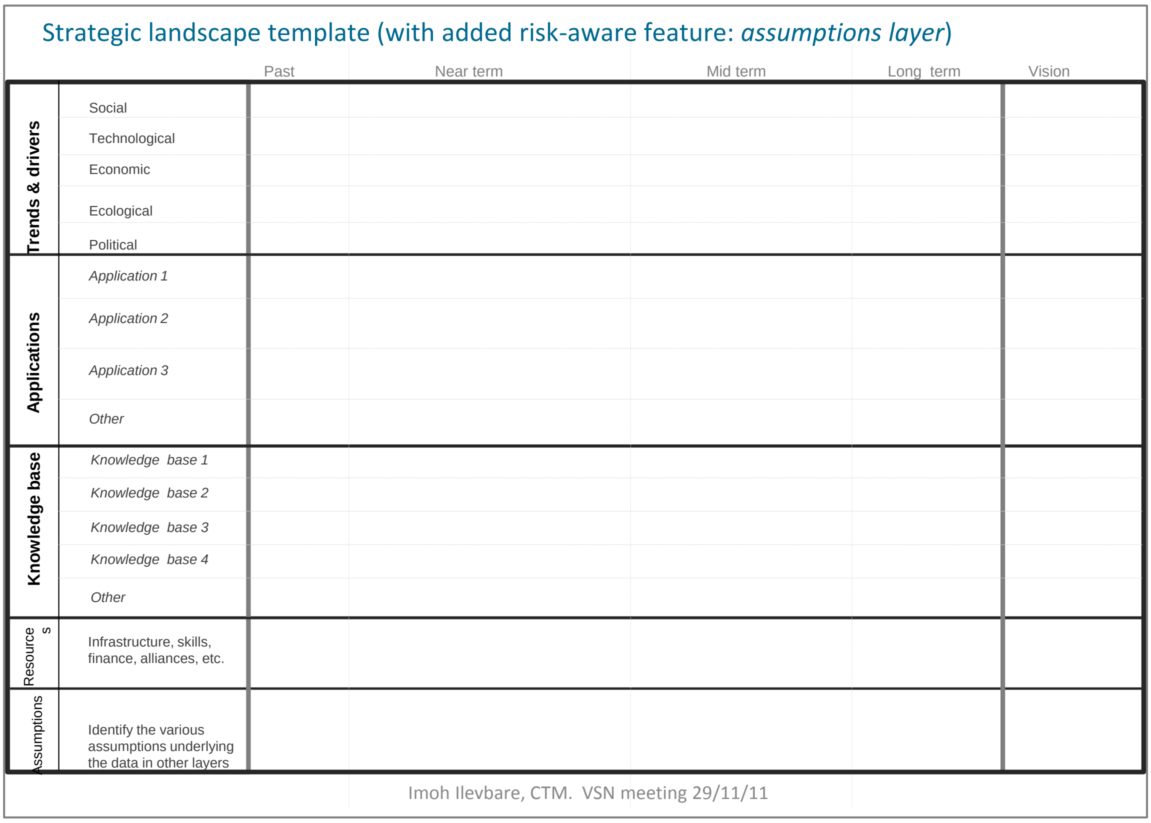
Risk-aware strategic roadmapping

Planning and pre-workshop data gathering



Imoh Ilevbare, CTM. VSN meeting 29/11/11


Risk-aware strategic roadmapping
Input and analysis stage (workshop phase)
Strategic landscaping activity
Topic exploration
Know-why
Know-what
Know-how
Diverge (explore)
Converge (focus)
Diverge
Converge
Initiate and prepare
Semi-blind dot-voting
MCDA + Voting
Explore
Synthesize and review (action plan)
Embed risk treatment in action plan
- Scenarios
Address high uncertainty
Develop multiple strategic landscapes according to the scenarios
Yes
No
Diagnose high uncertainty in market trends/drivers
High uncertainty?
Track and record [other] assumptions underlying strategic landscape
-Assumptions analysis
-Devil's advocate + SWIFT
Risk identification
Risk assessment
Risk treatment
-Brainstorming/ SWOT analysis
-STEEP analysis
- assumptions analysis
-Probability-impact assessment
-Risk –reward assessment
-TRL-risk assessment
-Standard risk treatment responses (ISO 31000) + real options thinking
Diagnose and address high uncertainty
Identify and address risks
Imoh Ilevbare, CTM. VSN meeting 29/11/11
-Interventions (tools/techniques) in italics


Strategic landscape template (with added risk-aware feature: assumptions layer)
Past
Near term
Mid term
Long term
Vision
Trends & drivers
Social
Technological
Economic
Ecological
Political
Applications
Application 1
Application 2
Application 3
Other
Knowledge base
Knowledge base 1
Knowledge base 2
Knowledge base 3
Knowledge base 4
Other
Resources
Infrastructure, skills, finance, alliances, etc.
Assumptions
Identify the various assumptions underlying the data in other layers
Imoh Ilevbare, CTM. VSN meeting 29/11/11

Assumptions chart template

Assumption	***Link*** *(Trend/driver or Capability/ resource*	***Objective under threat***	***Resulting risk***	***Critical? (Yes/No)***

Imoh Ilevbare, CTM. VSN meeting 29/11/11

Topic roadmap template (with added risk-aware feature: distinctive market risk and technology risk layer with embedded prompts)

Topic & Team

	Present	Near term	Mid term	Far term	Vision
Market					
Market risks	*What if the future projections are different from what you have identified?* *Which issues among the market (PEST) factors can negatively impact the success of the products and services? (Identify political risks, societal risks, legislative risks, economic risks, etc.)*				
Products & Services	*What if the proposed schedule for achieving the objectives and deliverables is not met?* *What issues might lead to missing the schedule?*				
Technology , capabilities and resources					
Tech/ resource risks	*What technology or resource issues might cause product/ service development to fail?* *What if required technologies fail?* *Are finances required for acquiring technology, capabilities and resources secure?* *What are the gaps in knowledge?*				

Imoh Ilevbare, CTM. VSN meeting 29/11/11

Business case template (with added risk-aware feature)

Team		

Mini business case and elevator speech

Technology Need			
Rationale for technology need. What does it help accomplish?			
What is the specified required outcome and timing?			
What is the current readiness of the technology (TRL)?		***What is the corresponding level of technology failure risk?***	
Critical gaps			
Key enablers			
Key risks and barriers			
Key actions and risk mitigation plans.	*Enter key actions towards acquiring technology and mitigation plans against foreseeable risks*		

The market opportunity

This will be delivered by
Key actions, foreseeable risks and risk mitigation plans

Market and technology intelligence gaps

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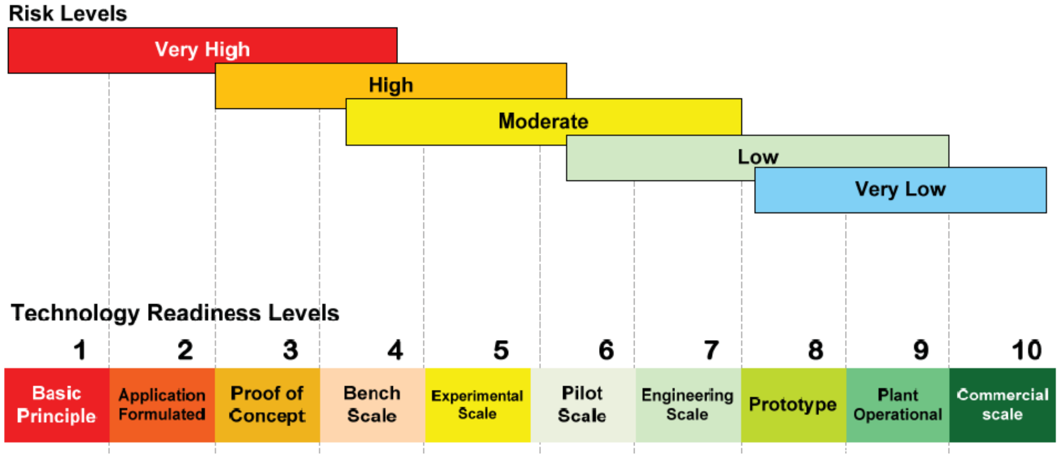
Technology readiness levels – Risk Level comparison chart



Adapted from Collins, J. W., and Pincock, L. (2010). *Technology Development Roadmaps - A systematic approach to maturing needed technologies*.

Imoh Ilevbare, CTM. VSN meeting 29/11/11

Focus group session

Appendix 7 - RSRM facilitation slide set sent to roadmapping professionals for appraisal

Risk-aware roadmapping

Facilitation guide and notes

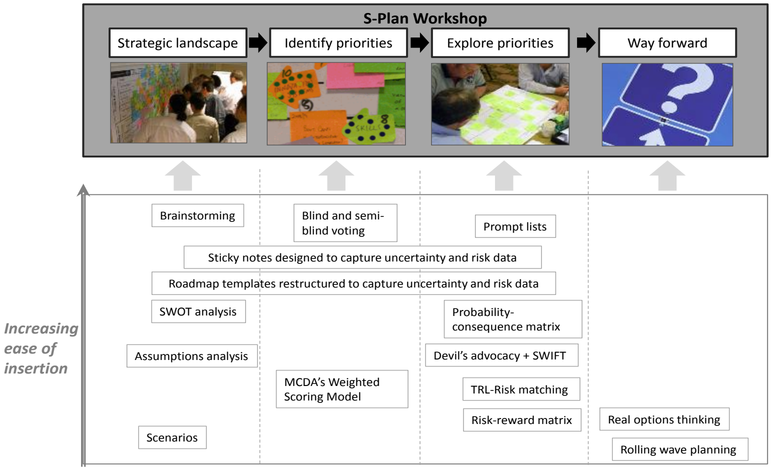
Imoh ILEVBARE

Presentation is best viewed as a slideshow to allow functionality of included hyperlinks

Purpose

- This set of slides serve as facilitation guide for risk-aware roadmapping, and have been developed with the S-Plan in mind.
- It has been prepared for the sake of appraising the usefulness, functionality and usability of risk-aware roadmapping.

Summary: Risk techniques that can be embedded in the S-Plan



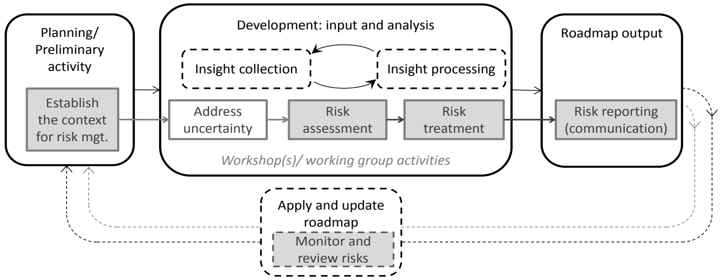
MCDA: Multi-criteria decision making *TRL: Technology readiness levels* *SWIFT: Structured What-If Technique*

Go to Content

Content (click on the content headings to view topics)

A. BACKGROUND AND OVERVIEW: Introduction

- Risk-aware roadmapping embeds risk (and uncertainty) management steps into the roadmapping process

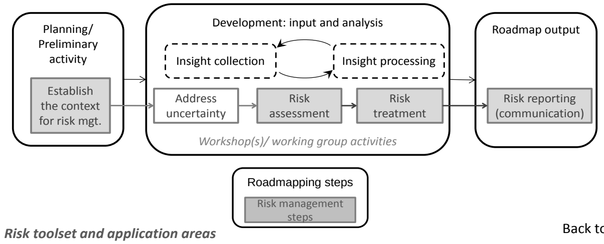


Next slide: *Process framework*   Back to Content

Process framework

The roadmapping process follows these general steps:

- Planning & preliminary/ pre-workshop data gathering
- Roadmap development workshop
  - Strategic landscaping
  - Topic exploration
- Post-workshop
  - Visualisation to produce the roadmap output



Next slide: *Risk toolset and application areas*   Back to Content

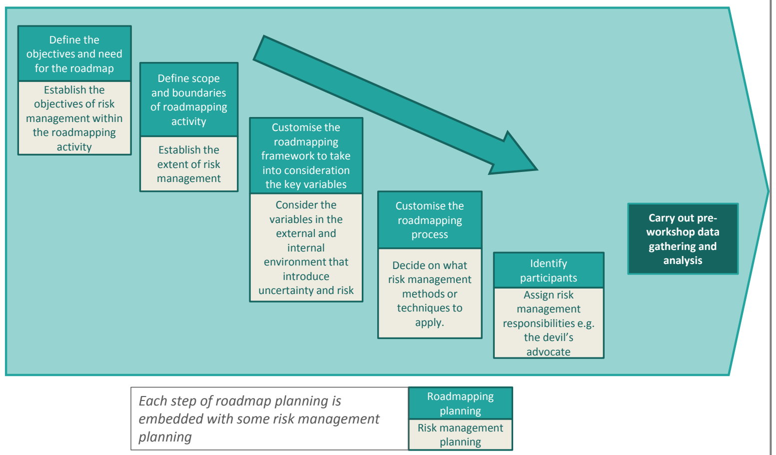
Recommended risk toolset and application areas

Addressing high uncertainty	Risk identification	Risk assessment	Risk treatment
Scenarios	Scenarios	Probability-consequence matrix	Real options thinking
	Assumptions analysis	Risk-reward matrix	Rolling wave planning
	Brainstorming	TRL-Risk matching	*Decision trees*
	SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis	Multi-criteria decision making (MCDA)	*Revised voting methods (to counter groupthink)*
	Prompt lists		*MCDA (to counter groupthink)*
	Structured What-If Technique (SWIFT)		
	Devil's advocacy		

Press 'Escape' button to read "Description of methods" under Notes section of this slide

Next slide: *PLANNING ACTIVITY: Planning process*   Back to Content

B. PLANNING ACTIVITY: Planning process for risk-aware roadmapping



Next slide: *Pre-workshop data gathering*   Back to Content

Pre-workshop data gathering

- Data, especially on trends and drivers can be gathered through:
  - Interviews of key stakeholders (top management) within the organisation
  - Gathering data from workshop participants using templates. Use either the
    - Roadmap framework as a template, or
    - Data capture template that also allows respondents to signify the level of confidence (or uncertainty) on the data they provide.

Next slide: *Example of roadmap framework template* **Back to** Content

Example of roadmap framework template

		Past	2011 Short term 2014	2014 Medium term 2018	2018 Long term 2030	Vision
Trends and drivers	Social					
	Technological					
	Environmental					
	Economic					
	Political & Legal					
Targets and applications	Objectives & Deliverables					
	Product 1					
	Product 2					
	Service 1					
	Service 2					
Resources & capabilities	Technology					
	Research & Development					
	Funding & Resources					
	People & Skills					
	Facilities & Infrastructure					

Next slide: *Pre-workshop data capture template* **Back to** Content

Pre-workshop data capture template (for Trends and drivers)

	Trend/driver (include estimated values if applicable)	Timeframe	Confidence (rate 1, 2, or 3)	Importance (rate 1, 2, or 3)
Social				
Technology				
Ecological				
Economic				
Political/ Legislative				

Similar templates can be used for the know-what and know-how layers of the roadmap

Next slide: *When there is high uncertainty over a critical trend/driver (building scenarios)* **Back to** Content

When there is high uncertainty over a critical trend/driver (building scenarios)

- The decision on which trend or driver is regarded as most critical and uncertain should be based on the results of the pre-workshop data collected but ultimately rests with the ‘business owner’ and ‘process facilitator’.
  - The business owner and process facilitator would decide if the uncertainty over the trend/driver is ‘worth’ the creation of scenarios.
  - Ready-made scenarios (from trustworthy sources) that are applicable to the strategic issue can also be used instead of building scenarios from scratch.
- The scenarios built at this stage are best applied for top-down scenario integration into roadmapping (not testing resilience of a finished roadmap)

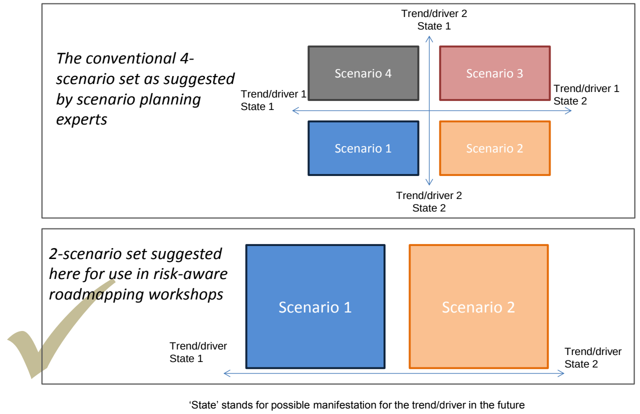
Next slide: *Building scenarios* **Back to** Content

Building scenarios

- Identify the trends/drivers influencing the strategic issue which is the focus of the roadmapping activity
- Rank the trends/drivers by criticality (importance) and uncertainty
- Identify the trend/driver that is most critical and most uncertain
- Build scenario logics (consistent and plausible plots) based on two[most] likely states of the future for the critical trend/driver.
  - In the scenario logics, trends and drivers should interact to give a plausible story. It must also be recognised that the alternative possible states of the future might have different counter-effects on the other trends and drivers.

Next slide: *Building scenarios (contd.)* **Back to** Content

Building scenarios (contd.)



'State' stands for possible manifestation for the trend/driver in the future

Next slide: *WORKSHOP PROCESS: Workshop format and agenda* **Back to** Content

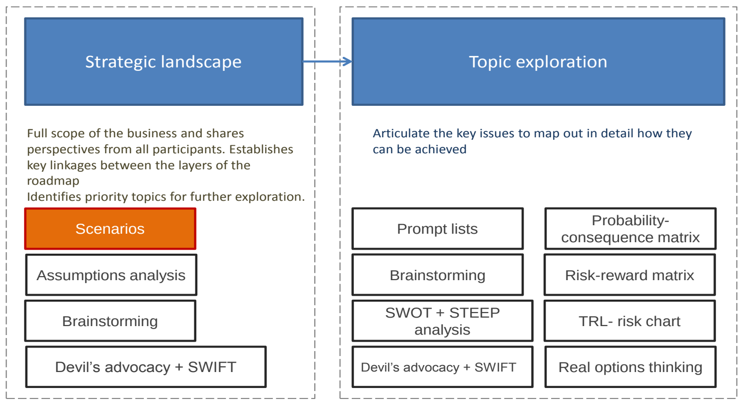
C. WORKSHOP PROCESS: Workshop format and agenda

- Generally follows the outline of the University of Cambridge S-Plan for roadmapping.
- It has one day agenda similar to that of the S-Plan.
  - However, it can be expanded and carried out over a longer period of time to allow for deeper analysis and reflection on results.
- It is a simple, easy to follow process with minimum resource requirements

- Key people
  - Facilitator (and roadmap development team)
  - Participants

Next slide: *Process flowchart and risk techniques applicable* **Back to** Content

Process flowchart and risk techniques applicable



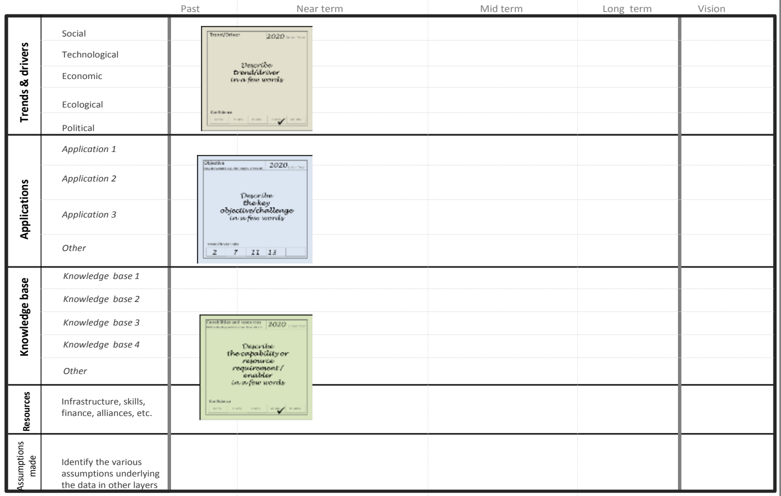
Next slide: *Strategic landscaping process* **Back to** Content

Strategic landscaping process

- It is expected that the strategic landscape template used would have been pre-filled based on the data gathered from the participants before the workshop.
- Updates and additions will be made to it during the workshop.

Next slide: *Strategic landscape template (and sticky notes used to collect data)* **Back to** Content

Strategic landscape template (and sticky notes used to collect data)



Next slide: *If scenarios were applied to address high uncertainty…* **Back to** Content

If scenarios were applied to address high uncertainty…

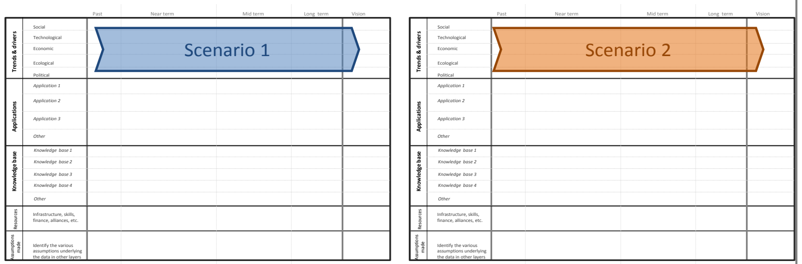
- Split the group into two (or the number of scenarios created)
- Each group should be directed to handle the strategic landscape for a designated scenario.

If scenarios were NOT applied…

- One strategic landscaping chart should be used by everyone.

Next slide: *Applying scenarios* **Back to** Content

Applying scenarios:



Roadmap 1 Roadmap 2

Translate each of the scenarios into the know-why layer of a strategic landscape roadmap. This step should be carried out prior to the commencement of the workshop (when the strategic landscape is being pre-populated).

The remainder of each roadmap will then be built based on the respective trends and drivers.

Next slide: *Filling data and identifying priorities on the roadmap* **Back to** Content

Filling data and identifying priorities on the strategic landscape roadmap

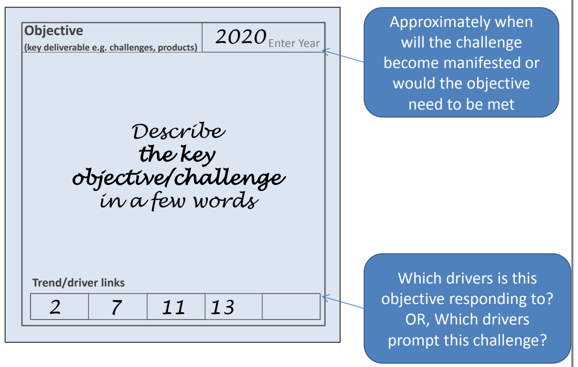
- Ask participants to examine the trends/drivers, objectives/application and resource/capability layers already filled into the strategic landscape template(s) and suggest additional ones that are important for the strategic issue being considered.
  - The sticky notes redesigned to capture uncertainty and risk information should be used.
- For each layer, priority issues can be identified using
  - Blind voting or semi-blind dot-voting
  - Use the Weighted Sum Model of MCDA
    - The criteria against which the data entries would be examined to identify which ones are most critical to the strategic objective must have been decided in advance.

Next slide: *Using the sticky notes – Trends and drivers layer* **Back to** Content

Using the sticky notes – Trends and drivers layer

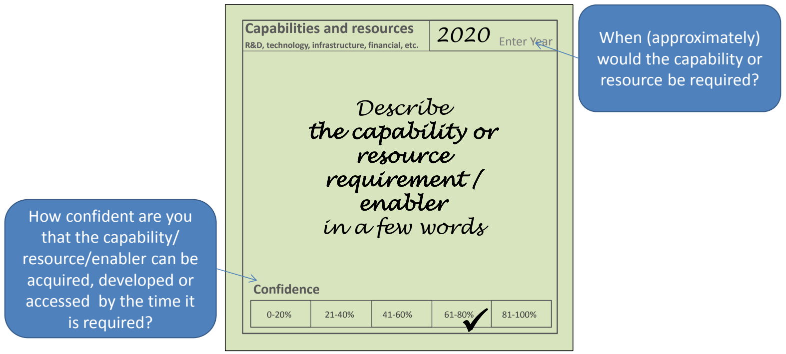
Next slide: *Using the sticky notes – applications (objectives, challenges, products, services, etc.) layer* **Back to** Content

Using the sticky notes – applications (objectives, challenges, products, services etc.) layer



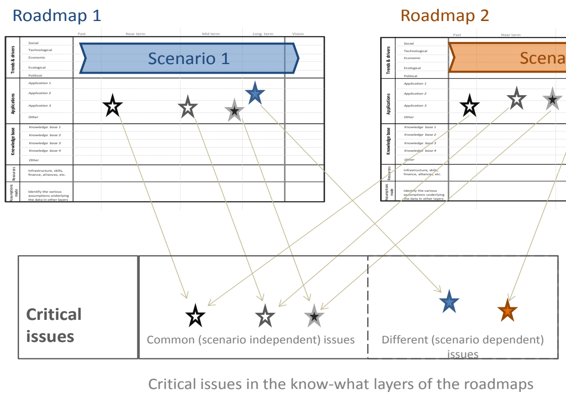
Next slide: *Using the sticky notes – Capabilities and resources layer* **Back to** Content

Using the sticky notes – Capabilities and resources layer



Next slide: *Comparing the roadmaps (if multiple strategic landscapes are developed for different scenarios)* **Back to** Content

Comparing the roadmaps (if multiple strategic landscapes are developed for scenarios)



Most critical issues will be further addressed at the topic exploration stage. However, take note which ones are scenario-dependent

Next slide: *Chart for comparing multiple strategic landscape roadmaps* **Back to** Content

Chart for comparing targets and applications across multiple strategic landscape roadmaps

	Roadmap 1	Roadmap 2	Common targets/ applications	Different targets/ application
Key targets/ deliverables/ applications across roadmaps				

The results of the strategic landscaping should be brought side by side to identify which targets and deliverables are common to both roadmaps and which ones are peculiar to either one.

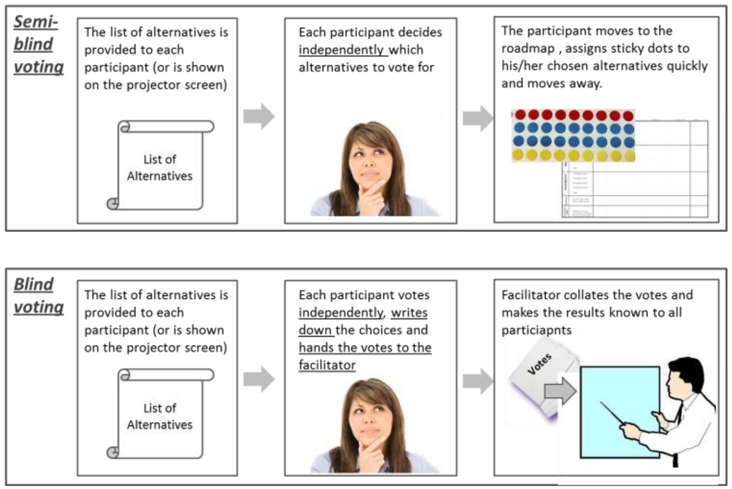
Identify and list the key elements of the know-what layer for both roadmaps and compare them to identify common elements and scenario specific (or dependent) ones.

Key topics which would be further explored would be a combination of these common targets and applications.

This chart can be filled by the workshop facilitation team while the other participants are on lunch break.

Next slide: *Explaining the blind and semi-blind voting techniques* **Back to** Content

Explaining the blind and semi-blind voting techniques



Next slide: *Applying MCDA's Weighted Sum Model* **Back to** Content

Applying MCDA's Weighted Sum Model

- The weighted sum model (WSM) is suggested for the workshop process for identifying priorities as an improved substitute to simple majority voting.
- To apply the weighted scoring model, the criteria to be used in identifying most critical issues from a group of alternatives must have been decided in advance.
- Importance of the each criterion is reflected by the weight assigned to it.
- The higher the score accrued by the alternative, the more critical it is to the strategic issue it is.
- Scores can be assigned through dot voting.

	Criteria (and weighting)				**Score (Weighted sum)**
Alternatives	**Criterion 1 (40)**	**Criterion 2 (25)**	**Criterion 3 (20)**	**Criterion 4 (15)**	
Alternative 1	*w*	*x*	*y*	*z*	= 40w + 25x + 20y + 15z
Alternative 2					
Alternative 3					
Alternative 4					
Alternative 5					
Alternative 6					

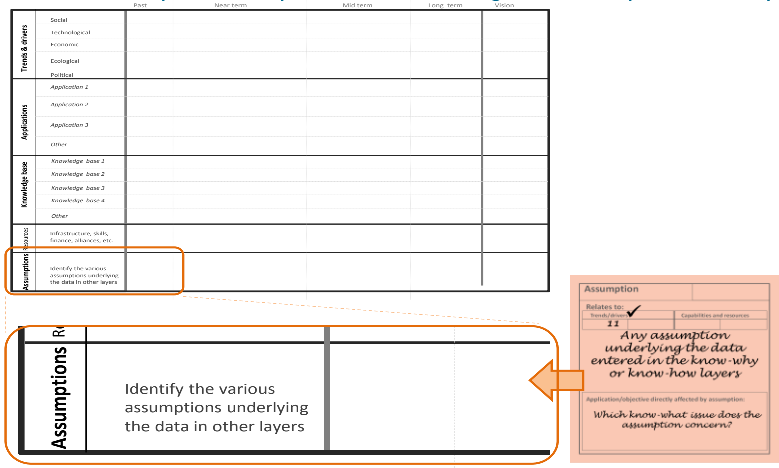
Next slide: *Identifying assumptions underlying the data contained in the roadmap (assumptions analysis)* **Back to** Content

Identifying assumptions underlying the data contained in the roadmap (assumptions analysis)

- The strategic landscape roadmap template has been modified to contain an 'Assumptions' layer
- As part of the landscaping process, ask participants to identify the assumptions underlying the trend/drivers or resource/capabilities included in the roadmap.
  - The identified trend/driver or resource/capability is a risk source for the target/application identified on the post it.
- Identify key assumptions
  - Use blind voting or semi-blind dot-voting

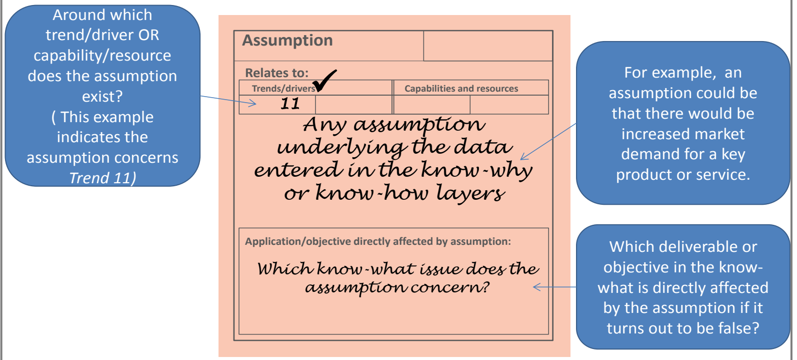
Next slide: *The 'Assumptions' layer on the strategic landscape roadmap* **Back to** Content

The 'Assumptions' layer on the strategic landscape roadmap



Next slide: *Using the sticky notes – identifying underlying assumptions* **Back to** Content

Using the sticky notes – identifying underlying assumptions



Next slide: *Assumptions chart template* **Back to** Content

Assumptions chart template

- All the key assumptions can be transferred onto this chart and the resulting risks from them can then be inferred.

Assumption	*Link (Trend/driver or Capability/ resource*	*Objective under threat*	*Resulting risk*	*Critical? (Yes/No)*

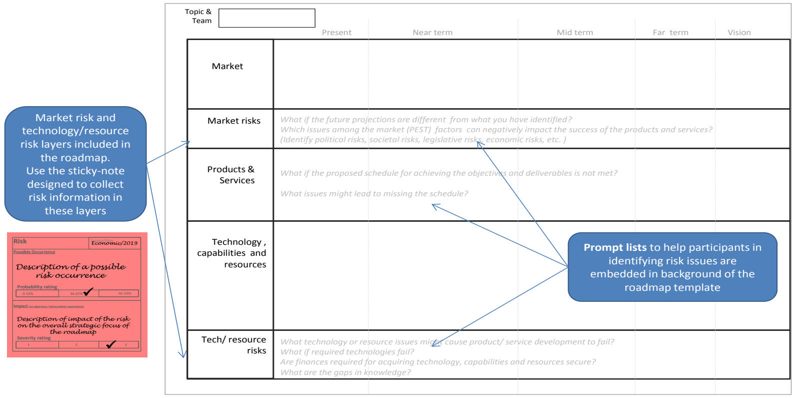
Next slide: *Topic exploration process* **Back to** Content

Topic exploration process

- The entire group of participants is split into smaller groups.
- Each group is assigned one of the key topics identified during strategic roadmapping and asked to explore it in greater detail.
- A topic roadmap is created, and a business case is made for the topic.
  - Risks are also identified and examined more thoroughly. Prompt lists are embedded into the topic roadmap to help in identifying risks. They are estimated and ways to reduce or remove them can be suggested.

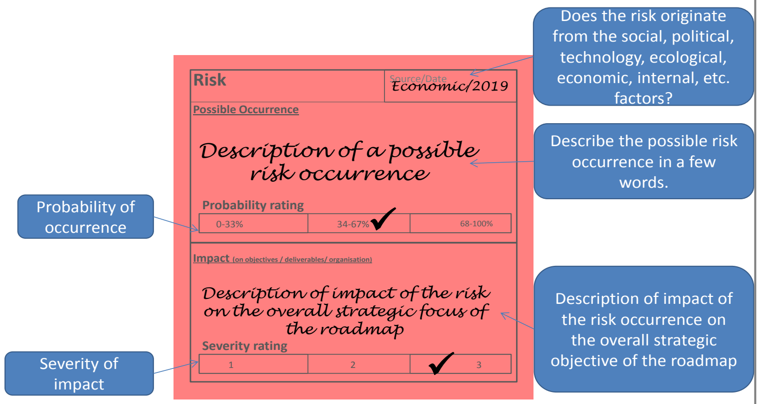
Next slide: *Topic roadmap template containing risk layers* **Back to** Content

Topic roadmap template containing risk layers (embedded with prompt lists to help identify risks)



Next slide: *Using the sticky notes – identifying and estimating risks* **Back to** Content

Using the sticky notes – identifying and estimating risks

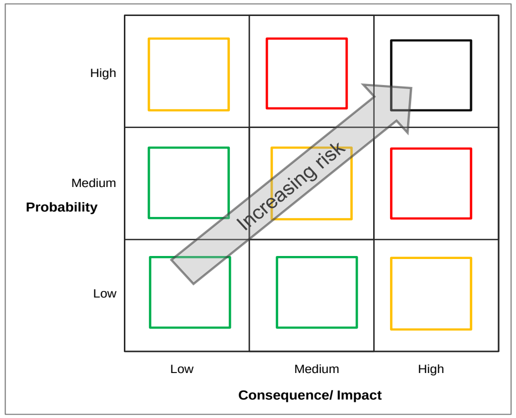


Next slide: *Probability-consequence matrix for rating risks* **Back to** Content

The probability-consequence matrix for rating risks

Transfer the risks identified on the topic roadmap to the probability-consequence matrix.

This will indicate which risks are most critical and therefore should be given priority treatment.



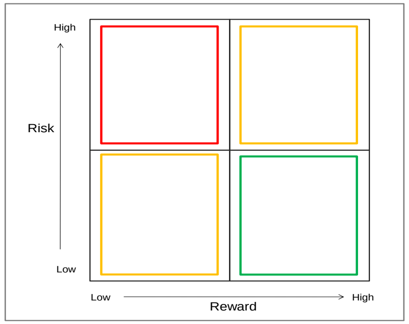
Next slide: *Risk reward matrix to visualise risk levels associated with planned investments* **Back to** Content

Risk-reward matrix to visualise the risk levels of investments (e.g. products, services and technologies) and expected rewards.

All identified technologies and investments (and products) can be represented on this chart.

If the topic of the roadmap is a product or service it should also be rated on the chart.
A judgment on the level of risk associated with the topic can be given based on a rough aggregate of all the risks identified and estimated within that topic roadmap (as represented on the probability-consequence matrix).

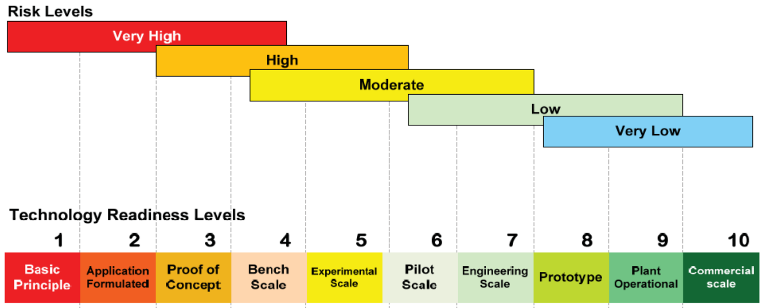
The [aggregate] risk level associated with the investment is juxtaposed with the rewards expected from it.



Next slide: *Technology readiness level – Risk level comparison chart* **Back to** Content

Technology readiness levels – Risk level comparison chart

adapted from Collins, J. W., and Pincock, L. (2010). Technology development roadmaps – A systematic approach to maturing needed technologies.



This chart is most useful for determining the risk level (risk of failure) associated with a technology earmarked for acquisition or development as part of the suggested outcomes of the roadmapping exercise.

Next slide: *Treating risks and uncertainties* **Back to** Content

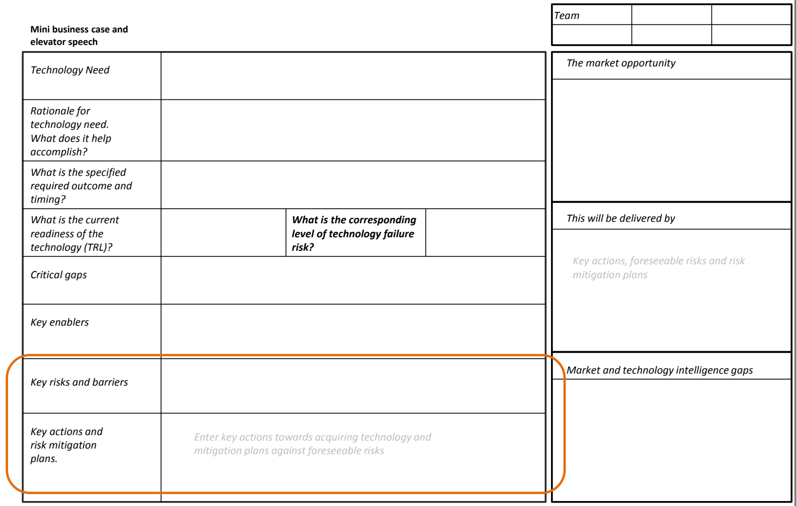
Treating the risks and uncertainties

	Risks/ uncertainties	Response (treating the risks/ uncertainties)		Timeframe
		Code	Response description	
Market/ external environment of organisation				
Resources/ technology/ Internal environment of organisation				

Code	What it stands for
A	Avoid the risk by deciding not to start or continue the risk producing activity
Ret	Retain risk
Rem	Remove risk source (or substitute it with one that carries less risk if possible)
Sh	Share risk with another party (insurance/joint venture)
C	Create contingencies to reduce impact of risk
D	Defer investment (wait for more information to be available to reduce uncertainty before making the decision)
St	Stage investment (break up investment into incremental (and conditional) steps)
Gr	Growth option (create infrastructure and opportunity for future expansion to seize a potential opportunity for growth)

Next slide: *Business case template embedded with risk section* **Back to** Content

Business case template embedded with risk section



Next slide: *Suggestions for visualisation* **Back to** Content

D. Suggestions for visualisation

- Use bars with tapered or faded edges to represent elements whose start/end dates are not certain.
- Use the traffic light colour scheme to represent the level of risk [of failure] or uncertainty associated with objectives, technologies and resources.
- Use decision points indicate where start/wait/discontinue decisions need to be made
- Draw a separate risk roadmap to communicate all the risks associated with the strategic issue, their sources, severity of their impact and time they are expected to occur.

Next slide: ***END***

Back to Content

END

Back to Content

Appendix 8 – Identification and classification of weighted scoring model criteria under ‘value’ and ‘attainability’

Author		Factor	Value	Attainability	Generic term adopted
DuPont (Cooper et al., 2001)	1	Strategy alignment	✓		Strategic fit
	2	Value	✓		Profitability (margins in market) and cash flow
	3	Competitive advantage	✓		Sustainability or improvement of competitive advantage
	4	Market attractiveness	✓		Size of market /market growth potential / margins in market
	5	Fit to existing supply chain		✓	Availability of manufacturing processes/supply chain
	6	Time to breakeven	✓		Profitability (margins in market) and cash flow
	7	NPV	✓		Profitability (margins in market) and cash flow
Composite (Cooper et al., 2001)	1	Strategic congruence	✓		Strategic fit
	2	Strategic impact	✓		Synergies with other operations within the business
	3	Customer benefits	✓		Clear customer needs (or provides benefits)
	4	Meets customer needs	✓		Clear customer needs (or provides benefits)
	5	Customer value for money	✓		Clear customer needs (or provides benefits)
	6	Market size	✓		Market size
	7	Market growth	✓		Market growth potential
	8	Margins in this market	✓		Profitability (margins in market) and cash flow
	9	Competitive situation		✓	Competitive intensity (and reaction)
	10	Marketing synergies	✓		Synergies with other operations within the business
	11	Technological synergies	✓		Synergies with other operations within the business
	12	Production synergies	✓		Synergies with other operations within the business
	13	Size of technical gap		✓	Technical uncertainty (or complexity)
	14	Technical complexity		✓	Technical uncertainty (or complexity)
	15	Technical uncertainty		✓	Technical uncertainty (or complexity
	16	Demonstrated technical feasibility		✓	Technology maturity
	17	Expected profitability	✓		Profitability (margins in market) and cash flow
	18	Return IRR	✓		Profitability (margins in market) and cash flow
	19	Payback period	✓		Profitability (margins in market) and cash flow
	20	Certainty of return		✓	Knowledge of market
	21	Time to commercial start-up	✓		Profitability (margins in market) and cash flow
Celanese (Cooper et al, (2001)	1	Strategic congruence	✓		Strategic fit
	2	Strategic impact	✓		Synergies with other operations within the business

	3	Proprietary position	✓		Proprietary position
	4	Platform for growth	✓		Platform for growth (commercial or technological)
	5	Durability	✓		Or longevity (opposite of obsolescence) – related to profitability? *May not be relevant for front end*
	6	Synergy with other operations	✓		Synergies with other operations within the business
	7	Technical gap		✓	Technical uncertainty (or complexity)
	8	Program complexity		✓	Technical uncertainty (or complexity)
	9	Technology skill base		✓	Skill and labour requirements
	10	Availability of people and facilities		✓	Skill and labour requirement
	11	Market need	✓		Clear customer need/meets customer needs
	12	Market maturity	✓		Industry (or market) readiness
	13	Competitive intensity		✓	Competitive intensity (and reaction) in the market
	14	Commercial applications development skills		✓	Skills & labour requirements
	15	Commercial assumptions		✓	Commercial uncertainty
	16	Regulatory, Social, Political impact		✓	Regulatory impact
	17	Contribution to profitability	✓		Profitability (margins in market) and cash flow
	18	Technology payback	✓		Profitability (margins in market) and cash flow
	19	Time to commercial start-up	✓		Profitability (margins in market) and cash flow
Speciality minerals (Cooper et al., 2001)	1	Management interest		✓	Availability of project champion (or top management backing)
	2	Customer interest	✓		Meets customer needs (or provides benefits)
	3	Sustainability of competitive advantage	✓		Sustainability or improvement of competitive advantage
	4	Technical feasibility		✓	Technical uncertainty (or complexity)
	5	Business case strength	✓		Profitability (margins in market) + market growth potential/entry into new market
	6	Fit with core competencies		✓	Fit with core competencies
	7	Profitability and impact	✓		Profitability (margins in market) and cash flow
Reckitt-Benckiser Cooper et al., 2001	1	Advantage over what's available	✓`		Differentiated product
	2	Competitive position improvement	✓		Sustainability (or improvement) of competitive advantage
	3	Sustainability of competitive advantage	✓		Sustainability (or improvement) of competitive advantage
	4	Geographic scope	✓		Geographic scope
	5	Technical competitive strength		✓	Fit with core competencies
	6	Technical maturity		✓	Technology maturity
	7	Manufacture		✓	Availability of manufacturing processes/ supply chain
	8	Sales and distribution		✓	Availability of manufacturing

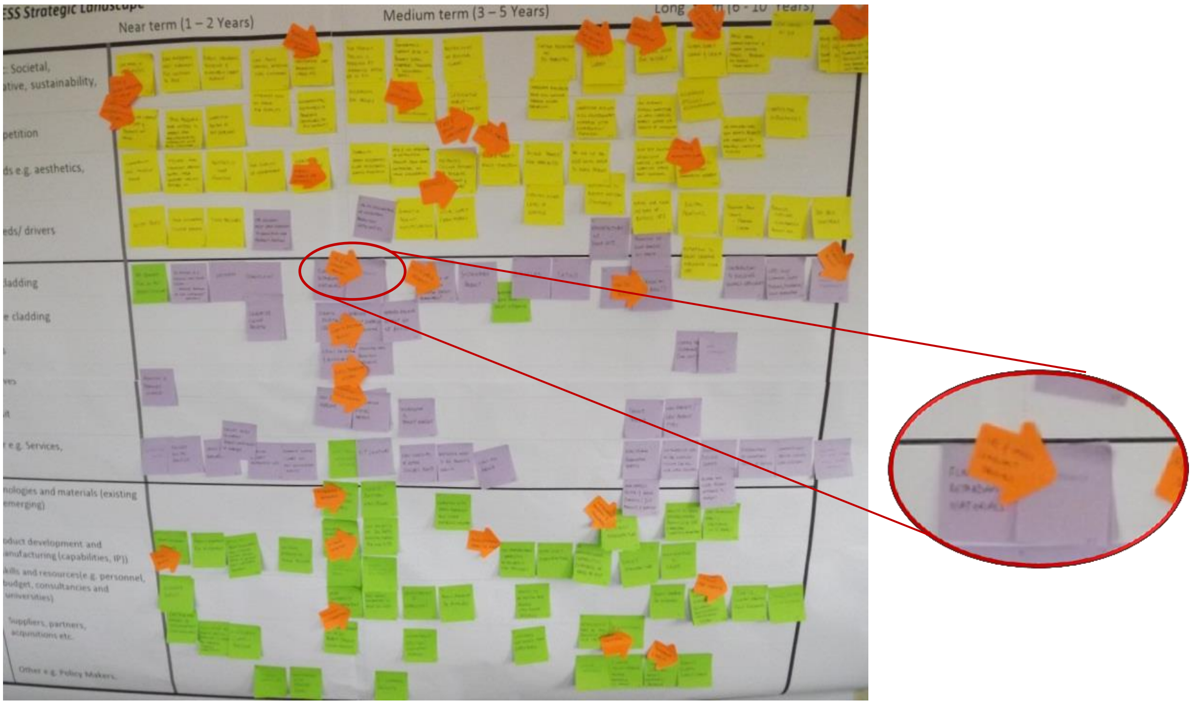
					processes/ supply chain
Laserco (Goffin and Mitchell, 2005)	1	Increased sales	✓		Profitability (margins in market) and cash flow
	2	Cost reduction	✓		Cost reduction
	3	Gross margin in target market	✓		Profitability (margins in market)
	4	Channel cost		✓	Routes to market (cost and capability)
	5	Customer impact	✓		Meets customer needs (or provides benefits)
	6	Technology as a platform for growth	✓		Platform for growth (commercial and technological)
	7	Size of technical change		✓	Technical uncertainty
	8	Technical uncertainty		✓	Technical uncertainty
	9	Demonstrated feasibility		✓	Technology readiness or maturity
	10	Knowledge of the market		✓	Knowledge of market
	11	Market readiness		✓	Market (or industry) readiness/maturity
	12	Channel capability		✓	Routes to market (cost and capability)

Appendix 9 - Examples of how the charts presented in Section 7.1.1 were applied

Name: ****** ******	**Department: Technology**

Timeline	**Short (1-3 years)**	**Medium (4-8 Years)**	**Long (8-18 Years)**
Market trends & drivers	• Increasing fuel costs (3) • Increased connectivity (3) • Infrastructure decision need made (1)	• Low carbon technology maturity (2) • Markets become more standby (3) • Increasing energy demand (3)	• Commercialisation of low carbon tech. (2) • GHG impact (2) • Rural electrification (2)
Systems and applications (Products/services)	• System ***** • Basic ***** • **** efficiency	• Active system *** ***** • Integration of *** *** *** • Process *** ****	• Interact with *** **** • *** **** systems • **** from ****
Technical Capabilities, resources and technologies	• **** electronics • Controls - software • Component development	• ****** capabilities • System ******	• ***** protocols • System integration • *** partners

A. A filled pre-workshop data collection template (input from a participant). Numbers assigned beside the market trends and driers information denote levels of certainty (1- lowest, 3 highest)



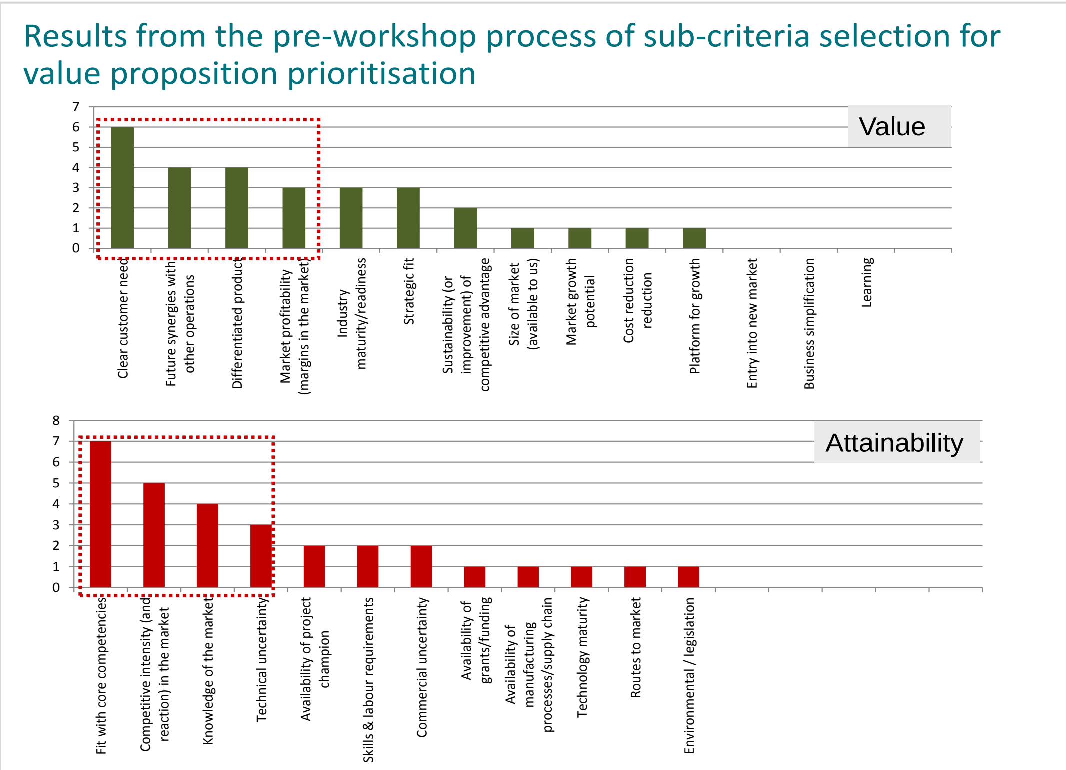
B. Strategic landscape populated with data collected from several participants. The data is transferred to the strategic landscape template using post-it notes. Orange arrows denote clusters of similar information provided by different participants.

Value proposition (product/service) selection criteria

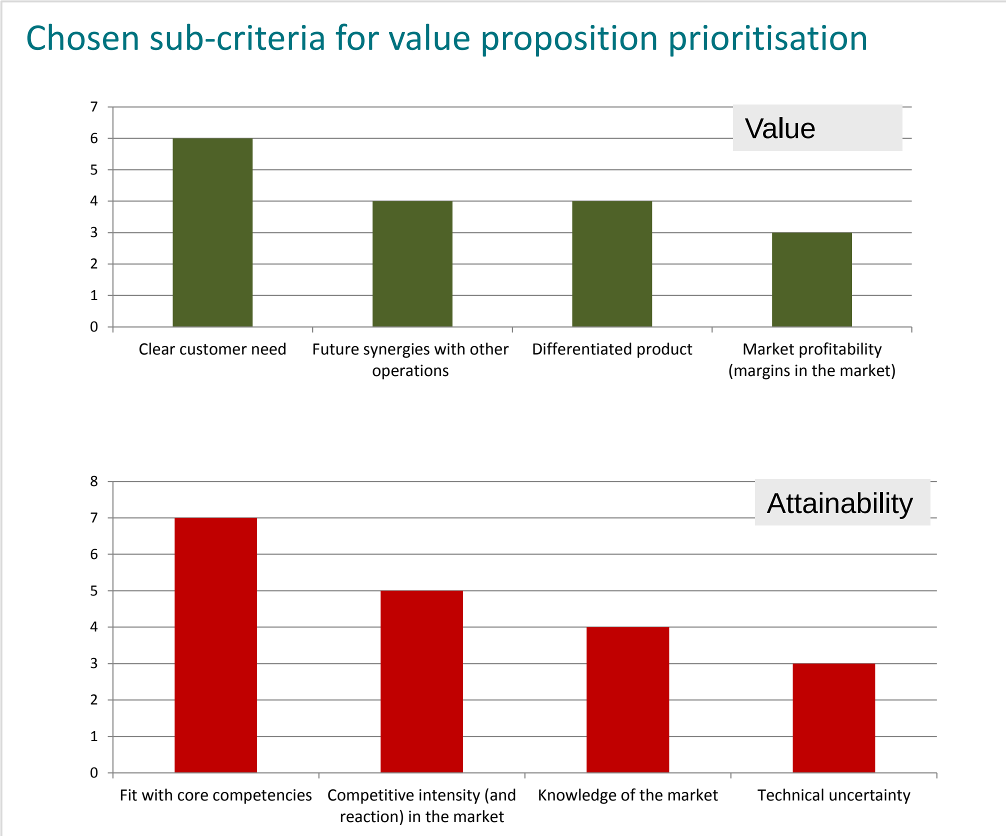
Value Criteria		Attainability Criteria	
Strategic fit		Knowledge of the market	
Synergies with other operations within the business		Availability of manufacturing processes/supply chain	
Clear customer need	✓	Availability of project champion	✓
Size of market (available to us)	✓	Competitive intensity (and reaction) in the market	✓
Market growth potential	✓	Technical uncertainty (or complexity)	✓
Market profitability (margins in the market)	✓	Technology maturity	
Sustainability (or improvement) of competitive advantage		Skills & labour requirements	
Entry into new market		Commercial uncertainty	✓
Industry maturity / readiness		Regulatory impact (e.g. environmental, legislation)	
Differentiated product	✓	Fit with core competencies	✓
Platform for growth		Routes to market	
Cost reduction		Availability of funding (or grants)	
Business simplification			
Learning			

Tick (✓) to indicate your choice of 5 most critical criteria under each column

C. A filled pre-workshop template for deciding the sub-criteria under value and attainability (input from a participant)

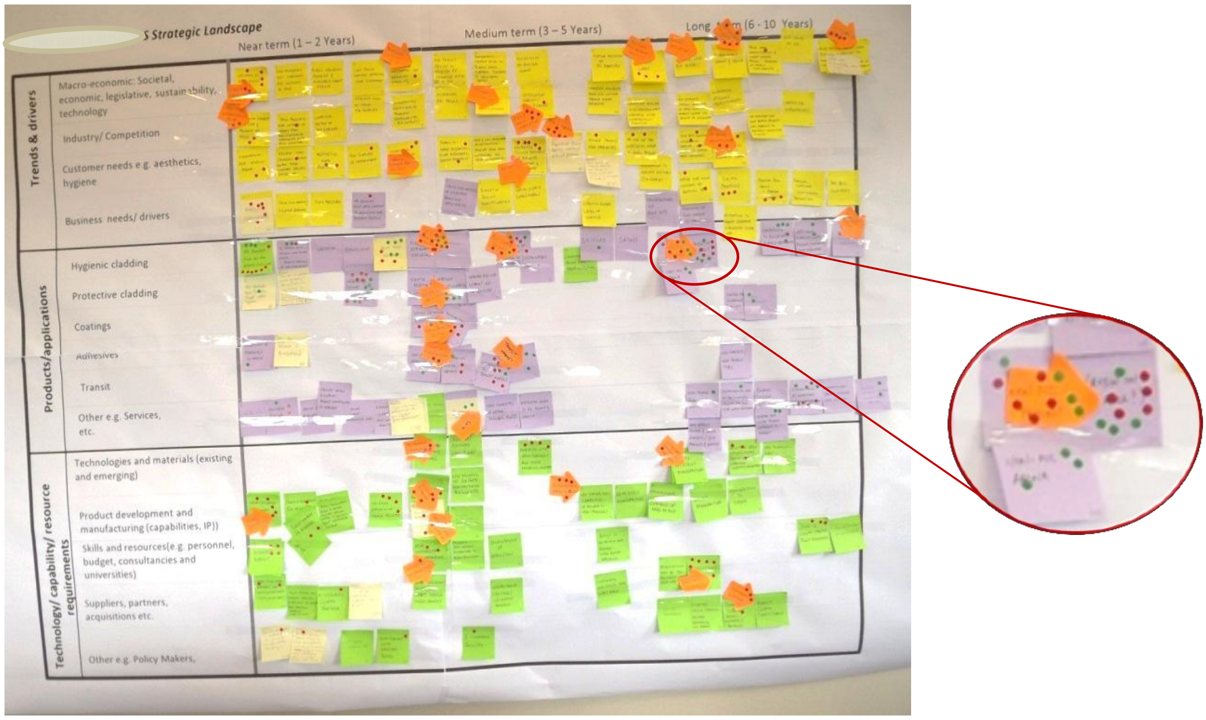


D. Aggregation of sub-criteria choices from the participants to show the most highly ranked ones



E. Top 4 sub-criteria for 'value' and 'attainability' used to guide value proposition prioritisation and selection

F. Dot voting on the value propositions on the strategic landscape based on value and attainability (participants are guided by the top sub-criteria (visible in the background))

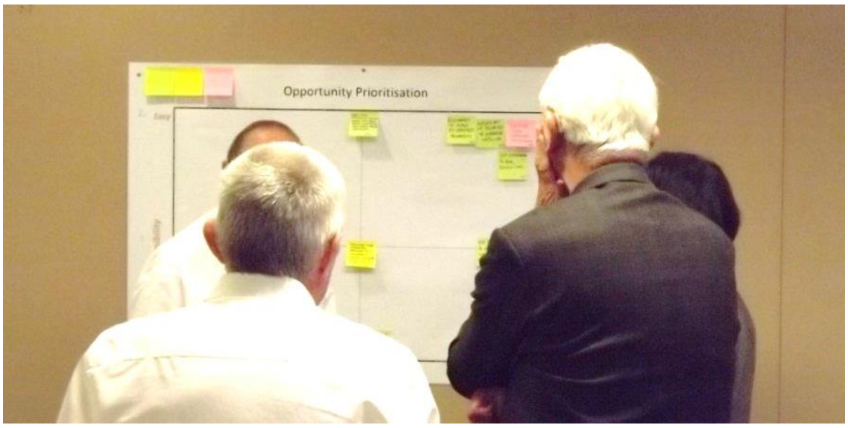


G. Example of result of dot voting showing 11 green dots and 10 red dots (i.e. a score of 11 for value and 10 for attainability) on a certain value proposition

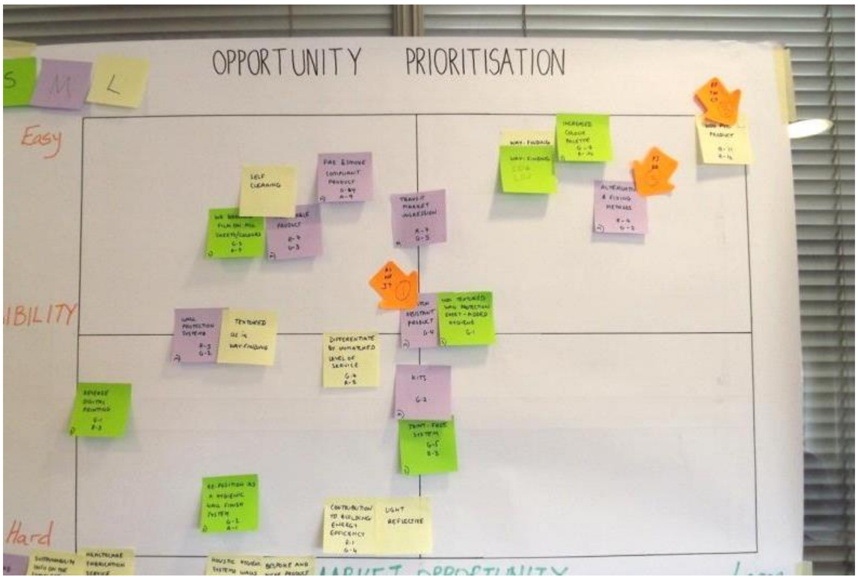
Key value propositions		Suggested Timeframe	Green Votes	Red Votes	Total Votes
1	Non-***** product	L	11	10	21
2	Increased **** ******	S	7	10	17
3	***** ******* ingression	M	5	7	12
4	****-free system	S	5	3	8
5	******* compliant product	M/S	4	9	13
6	Differentiate ****** service	L	4	5	9
7	****** product	S/M	4	0	4
8	Contribution to *******efficiency	S	4	1	5
9	**** product	M	3	7	10
10	****** on all sheets/colours	S	3	7	10
11	******** system	S	2	5	7
12	****** fixing methods	M	2	4	6
13	**** system portfolio	S	2	1	3
14	***** solutions	M	2	0	2
15	Wall coatings (***** platforms)	L	2	0	2
16	****** ******* systems walls floor ceiling	L	2	0	2
17	NPD – *****/ *****/ ******	L	2	0	2
18	******* ****** printing	S	1	3	4
19	******* adhesives	S	1	0	1
20	******** fabrication service	L	1	0	1
21	******** **** on the complete system for all our wall finishes	L	1	0	1
22	****** wall protection sheet - added ******	S	1	0	1
23	******	M	1	0	1
24	******* product offering to market	L	2	0	2

H. List of value propositions and the voting results (example shown in G. is number 1 on the list)

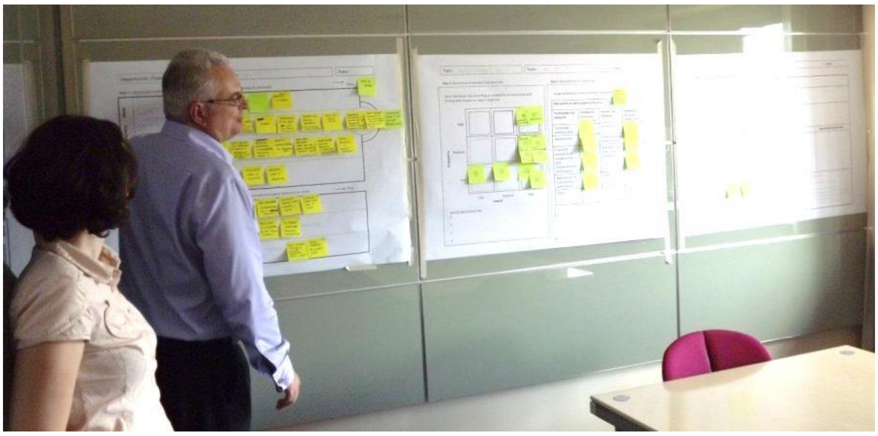
I. Mapping the results from dot voting (list in H.) onto the value-attainability template (also showing the different timeframes for the value propositions, denoted using the differently coloured sticky notes).



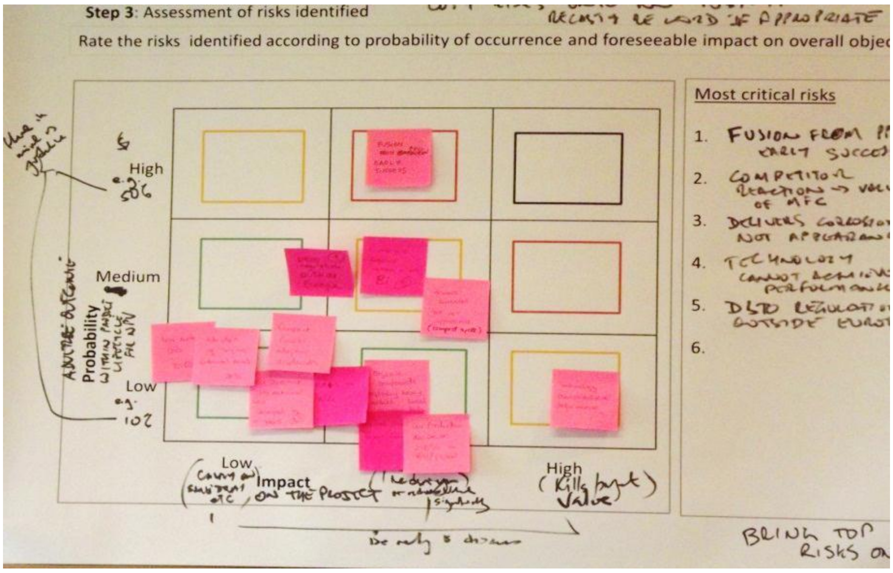
J. Sense-checking the initial mapping of results on the value-attainability template.



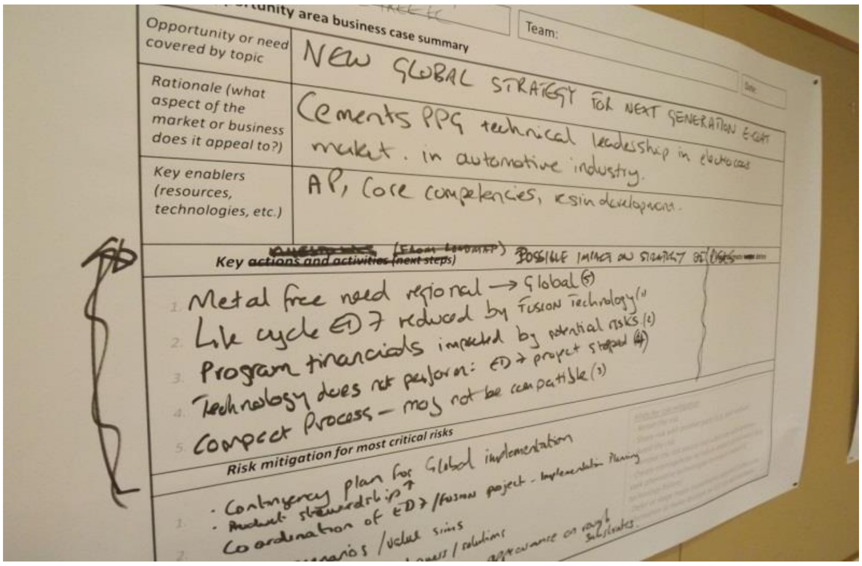
K. Post sense-checking and value-attainability template. Orange arrows show top rated value propositions chosen for further exploration through topic roadmapping.



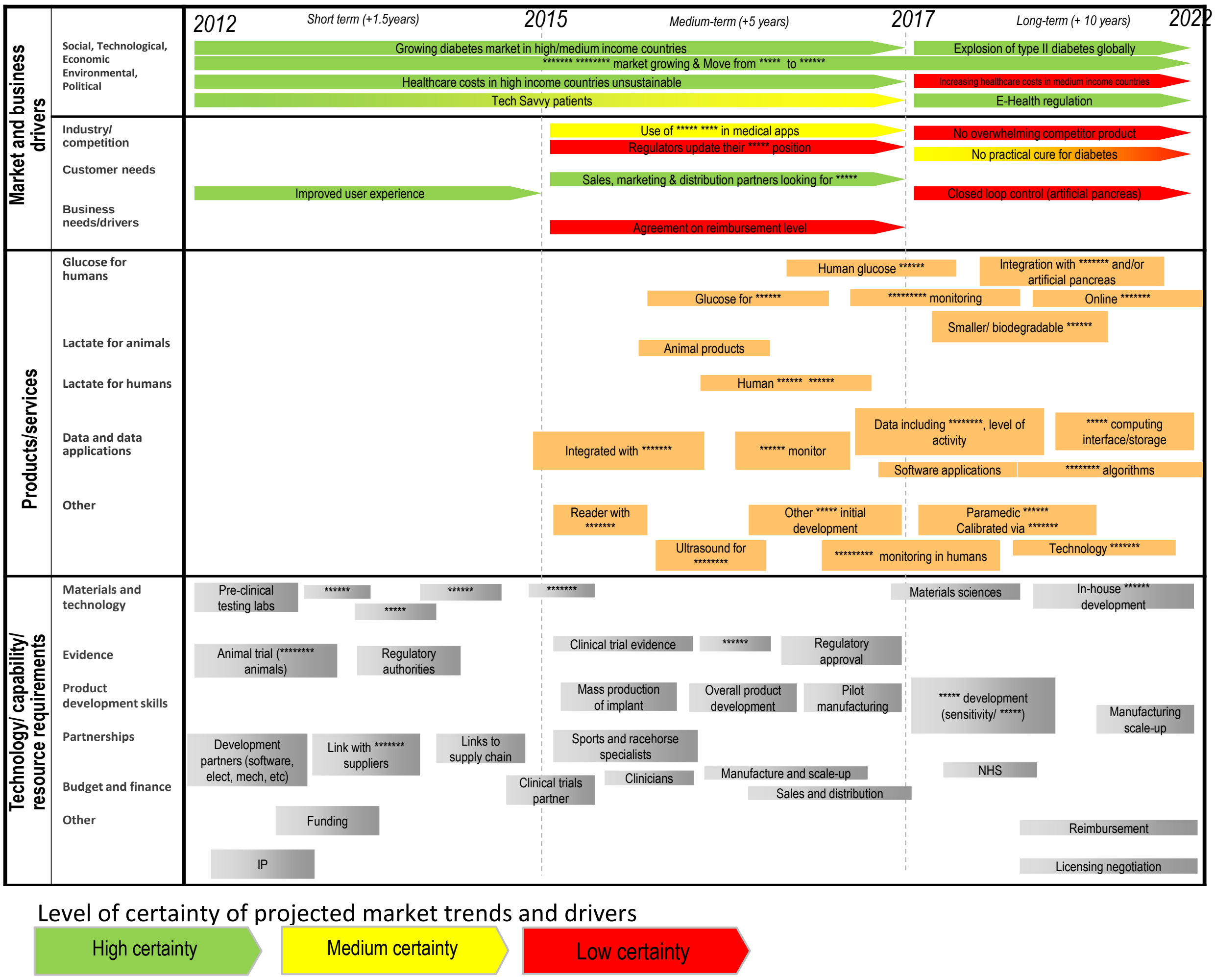
L. Topic exploration stage (showing the three templates used)



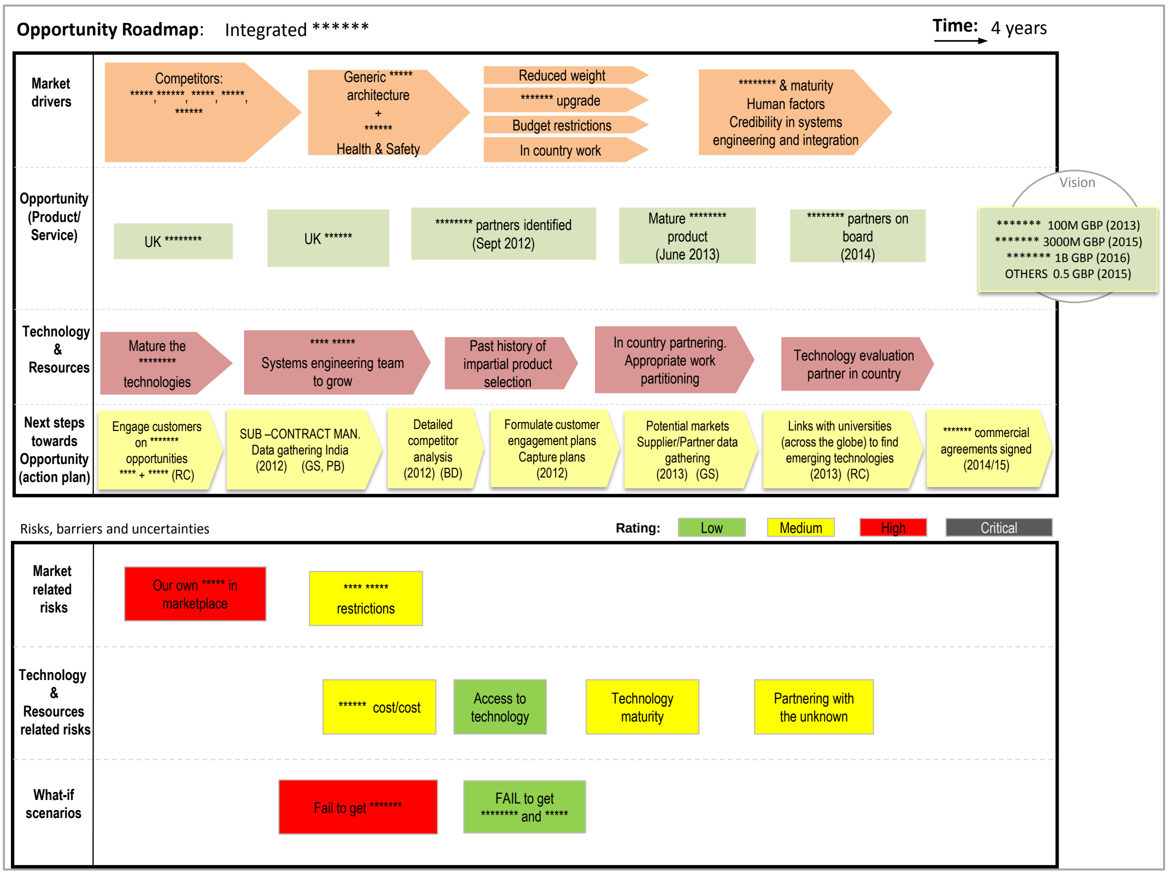
M. Risks identified mapped onto the probability-impact matrix (significance of 'low', 'medium', 'high' impact ratings are defined specifically for the value proposition under consideration)



N. Completed business case template showing risk mitigation actions for critical risks



O. An example of a reported strategic landscape roadmap



Risk maturity profile of Opportunity Roadmap: Integrated *****

Technology related maturity profile				
Technology element	*Technology readiness level*	*Obsolescence*	*Availability of competencies and complementary technologies*	*Specification (or functionality) achievability*
Maturity grade	0.5	0.5	0.9	0.7

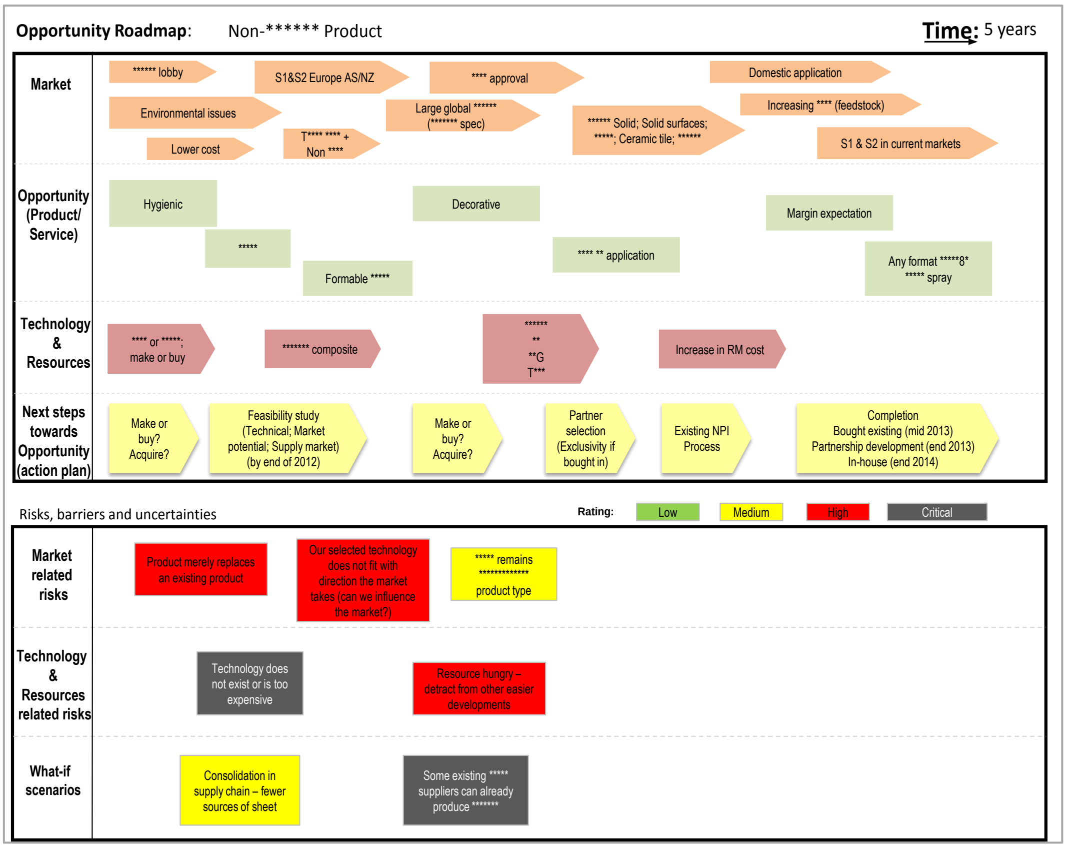
Market related maturity profile			
Market element	*Market clarity*	*Product/service differentiation*	*Availability of value chain elements*
Maturity grade	0.7	0.5	0.7

Low risk — High risk

Mitigation actions for most critical maturity issues:

	Critical maturity issues	Mitigating actions
1	Low rated TRL	Do environmental testing of technology
2	Low rated obsolescence	Analyse and monitor system for obsolescence

P. A topic roadmap (for a value proposition) showing the action plan, identified risks and their ratings, the risk maturity profile and mitigation actions. Here mitigation actions are drawn up in response to the most critical issues identified from the risk maturity profiling step.



Risk profile of Opportunity Roadmap: Non-******* Product

Technology related risk profile				
Technology element	*Technology readiness level*	*Obsolescence*	*Projected availability of competencies and complementary technologies*	*Specification (or functionality) achievability*
Grade	0.5	0.5	0.3	0.5

Market related risk profile			
Market element	*Market clarity*	*Product/service differentiation*	*Availability of value chain elements*
Grade	0.6	0.6	0.5

Low risk — High risk

Most critical risks and proposed mitigating actions: Non-***** Product

	Critical risks	Mitigating actions
1	Technology is too expensive or does not exist	Realistic assessment of cost. Kill project if required
2	Some existing suppliers may already have this technology	Develop relationships with other suppliers
3	Selected technology does not fit with market direction (we cannot influence this	Involvement with industry bodies (& find out what they are?)
4	This product merely replaces existing product	Understand likely changes in compliance & sustainability trends

Q. A topic roadmap (for a value proposition) showing the action plan, identified risks and their ratings, the risk maturity profile and mitigation actions. Here mitigation actions are drawn up in response to the most risks identified directly on the roadmap.

Appendix 10 – RSRM process feedback questionnaire

RISK-AWARE STRATEGIC ROADMAPPING (FEEDBACK FORM)

Background

This questionnaire is designed to assess the risk-aware strategic roadmapping process in order to capture learning and improve it in preparation for practical application.

Completed by: Name: …………………………………………………………………..

Organisation: ………………………………………..………………….

Date: ……………………………………………………………………..

A. This process was designed with the intention of facilitating the following in addition to articulating strategy:

1. Identification of risks,
2. Assessment of the risks,
3. Drawing up mitigation measures, and
4. Communication/discussion of risks issues

A.1 The process followed supported these.

Strongly disagree	1		2		3		4		5		Strongly agree

Comments (on areas of particular strength and weakness):

____

____

____

____

A2. The objectives of the process were clear (or clarified) and the risk issues identified were relevant to them

Strongly disagree	1		2		3		4		5		Strongly agree

Comments: ____

____

A3. I will be willing to apply the process again in the future

Strongly disagree	1		2		3		4		5		Strongly agree

Comments: ____

____

A4. The aims of designing the process in the way it was presented are given below. Please place a tick (✓) beside the design elements if you think they helped in meeting these objectives.

Objectives and explanation	**Identify uncertainty and risk**		**Assess risks**		**Mitigate risks**		**Communicate risks**	
	To draw up a list of risk issues to the strategic opportunities on the roadmap		To rate the risks according to criticality. To have a view of the riskiness of a strategic opportunity		To help in outlining specific measures that can be taken to counter risks		To visually show where risks are present and facilitate discussion within the process	
Design elements	**Brainstorming risks**		**Probability-consequence matrix**		**Risk mitigation prompts on topic summary template**		**Charts used** (did they support the discussion?)	
	Prompts lists on the roadmap template		**Risk profiling of the value proposition**					
	***What-if* questioning of assumptions**		**Value-attainability matrix to compare strategic opportunities**					

Comments:

____

____

____

Indicate the level of your agreement with the following statements.

Please include any comments you may have that relate to the statements.

B1. Within the group you worked with, identification of risk issues as well as the estimation of their severity and identification of mitigation steps were achievable

Strongly disagree	**1**		**2**		**3**		**4**		**5**		**Strongly agree**

Comments: ____

____

B2. Overall workshop format was appropriate

Strongly disagree	**1**		**2**		**3**		**4**		**5**		**Strongly agree**

Comments: ____

____

C1. The steps followed were clearly understood

Strongly disagree	**1**		**2**		**3**		**4**		**5**		**Strongly agree**

Comments: ____

____

C2. The visual charts were straightforward and easy to apply

Strongly disagree	**1**		**2**		**3**		**4**		**5**		**Strongly agree**

Comments: ____

____

C3. There was sufficient time to discuss important issues as well as the risks

Strongly disagree	1		2		3		4		5		Strongly agree

Comments: ____

____

C4. Demands of the process (in terms of the amount of analysis necessary) on you as a participant were reasonable

Strongly disagree	1		2		3		4		5		Strongly agree

Comments: ____

____

Main problems encountered: Please give your view of the main problems encountered in:

- **Selection/prioritisation of strategic opportunities**

Comments: ____

____

- **Identifying risks and uncertainties**

Comments: ____

____

- **Assessing the risks/uncertainties**

Comments: ____

____

- **Deciding how to mitigate or respond to the risks (or uncertainties)**

Comments: ____

____

Other comments

- What parts of the process do you think were particularly useful?
- What parts should be improved?

<u>**Appendix 11**</u>

A. Examination of 22 roadmaps from Corpus that address uncertainty and risk

A.1. Roadmaps applying scenarios

S/N	Roadmap name	Date	Organisation	Indus-try	Roadmap purpose	Use of scenarios within roadmap				
						Number of scenarios; names of scenarios	**Origin of scenarios**	**Type of scenarios: exploratory/ normative**	**Purpose and application of scenarios**	**Other steps taken alongside scenarios**
1	Roadmapping eGovernment Research: Visions and measure towards Innovative Governments in 2020	2004	eGovRTD2020 Project Consortium - EC-funded Project eGovRTD2020	ICT	To plan the integration of multidisciplinary views into a holistic vision for eGovernment research and technology development	8; Orchestrating government; Ambient government; Empowering state; Social state; Individualised society; Incident politics; Transition period; Government keeps on trying	Scenarios developed as part of the roadmapping process	Exploratory; Expert-driven (workshop based)	To develop visions for the roadmap and define future needs. The scenarios and the gap storylines (developed through gap analysis) were used as the main input to the roadmapping activity.	**Gap analysis** to develop 'gap storylines' to link the vision to the present
2	ROADiBROM: Roadmapping Digital Broadcasting / Mobile Convergence	2007	ROADiBROM Consortium - EC funded Project under the Information Societies Technologies	ICT	The roadmap proposes research themes and actions in order to advance mobile and digital broadcasting convergence research in the near future.	4; Creative destruction; Controlled innovation; Orchestrate improvement; Collective innovation.	Scenarios developed as part of the roadmapping process	Exploratory	Scenarios were reportedly built for a 'disruptive environment'. They were used to develop the vision of the roadmap. Used to understand the different perspectives or images of the future, on which roadmaps will then be based.	Gap analysis to link the vision to the present
3	Roadmaps for the Integration of Distributed Generation and the Development of Sustainable Electricity Networks	2004	Energy Research Centre of the Netherlands	Energy	Roadmap stipulates regulatory strategies and actions that are necessary to reach a desired future state and indicates the timing of the actions	4; DG opportunities in a fully harmonised EU market; Difficult times for DG in a fully harmonised EU market; DG opportunities in national markets; Difficult times for DG in national markets	Scenarios had been developed outside the roadmapping process. They were imported into roadmapping for application	Exploratory	One of the scenarios is identified as the best-case scenario is applied as the preferred scenario (scenario 1: DG opportunities in a fully harmonised EU market). *That scenario is applied in a normative manner.* A background story line is constructed for the roadmap based on the preferred scenario, on which critical points and path dependencies are identified for achieving the medium and long term targets. The other scenarios are used to test the robustness of the roadmap.	Backcasting to assign timings to the roadmap
4	Parabolic-Trough Technology Roadmap	1999	US Department of Energy (US DoE)	Energy	To evaluate the market potential of for trough power projects , develop a better understanding of the current state of the technology, and to develop a conceptual plan for advancing the state of parabolic-trough technology	3; Low cost competitive power market; Global Climate Change; Fossil Fuel Price Escalation	Scenarios developed as part of the roadmapping process	Exploratory	Scenarios served as a means of understanding the emerging market and identifying opportunities within it. The roadmap was built to reflect the scenario which is thought to be the more realistic picture of the future (Low cost competitive power market). Activities addressing the other two scenarios were used in the roadmap as "insurance policy" for the future.	None identified

5	BioVision: Roadmap for Biometrics in Europe to 2010	2003	The BioVision Consortium. National Research Institute for Mathematics and Computer Science, Netherlands.	ICT	To determine the best opportunities for the application of biometrics in key in sectors of the European community. The roadmap examines a selection of major application areas.	2; Names not given.	Scenarios developed as part of the roadmapping process	Exploratory	Scenarios were used to develop visions of the future. A storyline was created for each of the scenarios together with a realistic description of how the world would have evolved towards this situation. Roadmaps were then built based on these storylines.	Identification of risks and measures proposed to minimise them.
6	Strategic Roadmap: Next-Generation Knowledge Management Thematic Network	2003	The VISION Project, IST Programme	ICT	To provide a strategic roadmap for future developments towards next generation organisational knowledge management.	4; Enterprise knowledge portals in action; Mobile knowledge access and usage; Gathering knowledge from the web; Knowledge sharing in smart organisations	Scenarios developed as part of the roadmapping process	Exploratory	Scenarios were used to create clear pictures of the future. Four scenarios for possible future applications concerning knowledge management are developed. 4 roadmaps are then developed, one for each scenario. The intention is to generate one integrated roadmap from the four roadmaps. As part of the scenario analysis, SWOT analysis carried out for each scenario before roadmapping, to examine the predefined enabling technologies and identify key research areas. The key technologies involved in each scenario are identified. The key research areas under each enabling technology are mapped out on a roadmap for each scenario The consolidated roadmap is created by extracting and sorting all key research areas from each of the four roadmaps, and combining them under their enabling technologies	SWOT analysis used in transforming scenarios into roadmaps
7	Technology roadmap - Carbon capture and storage	2009	International Energy Agency	Energy	The roadmap identifies a vision for the growth of carbon capture and storage. The roadmap provides a set of near term actions to achieve the roadmap's vision.	1; BLUE Map scenario	Scenarios had been developed outside the roadmapping process. They were imported into roadmapping for application	Normative	To provide a vision and targets for the roadmap. The roadmap starts with the IEA BLUE Map scenario. The roadmap then outlines a set of quantitative measures and qualitative actions that define a pathway for the attainment of the results of the BLUE Map scenario. The application of the roadmap allows the identification of technology gaps along the growth pathway, for which specific action items are then identified.	None identified
8	A roadmap for developing Accelerator Transmutation of waste technology	1999	US DoE	Energy	To provide an R&D plan to address the potential application of Accelerator Transmutation of Waste to civilian spent nuclear fuel	1; Rapid implementation scenario	Scenarios developed as part of the roadmapping process	Normative	The scenario provided a clear definition of scope and timeframe for the roadmap. The specified scenario provided a framework within which the roadmap could be created.	None identified
9	A roadmap for recycling end-of-life vehicles of the future	2001	US DoE	Energy	To identify the R&D needed to recycle automotive materials and components that will reach end-of-life status in 2020	1; End of Life Recycling scenario	Scenarios developed as part of the roadmapping process	Normative	To define the goals and targets for end-of-life vehicle recycling, by providing a picture of what ELV in 2020 will look like. A strawman scenario was developed to investigate the recovery requirements associated with establishing the specific goal and targets for material and component recovery along the recycling continuum	Risk identification and assessment

10	TIME2LEARN Network: European Roadmap for Professional eTraining	2004	TIME2LEARN Network	ICT	The roadmap defines the priority areas for future research to respond to the needs of emerging European Professional eLearning solutions)	4; Arthur the accountant; Hirvi Brewery; Men in Black; Caja Gattaca	Scenarios developed as part of the roadmapping process	Normative	The scenarios describe the desired future states of technology-enhanced training in 2010. Each scenario represents a specific category of potential customers (and therefore, the scenarios were used to segment the future market). All scenarios are equally applied. The eTraining solutions described in each of the four scenarios were broken down into components (critical capabilities) that would enable the gap analysis between the future and current state. A roadmap is then developed for each scenario (i.e. each future market)	Gap analysis to link prescribed future market states to the present
11	Bridging the gap from earth markets to new space markets	2006	Industry roundtable (including Boeing, Lockheed Martin, Honeywell, Mitsubishi Corp)	Astro-nomy	To carry out broad and rigorous evaluation of particular pace commerce opportunities.	5; Names not given (One scenario is developed each of the set of roadmaps developed)	Scenarios developed as part of the roadmapping process	Normative	**The scenarios describe realistic and technologically possible accounts of how to achieve the goal of economic exploration of the moon, to remove the highly uncertain and vague nature of the true potential for economic exploration of the moon.** Roadmaps are built around the scenarios to provide a technologically feasible route to the goal	Risk assessment and risk reduction carried out for each roadmap.

A.2. Roadmaps not applying scenarios (but applying other risk management methods)

S/N	Roadmap name	Date	Organisation	Industry	Roadmap purpose	Type of uncertainties (and risks) identified	Notes	Risk management steps taken
1	Why and Whither Hypersonics research in the US Air force	2000	US Air Force Scientific Advisory Board	Military/ aviation	To identify R&D and ground test infrastructure needs.	Technology (and technical/design) uncertainties	Identify various technical solutions and compare them based on their pros and cons and inherent technical uncertainties and risks.	Risk-benefit appraisal of technical solutions.
2	Vision and roadmap for integrating national research activities	2006	ALIPRO Consortium	ICT	To foster national research on mobility, and opening up research programs supporting research on mobile communications.	Funding uncertainty Organisational uncertainty	The roadmap identifies the related risks towards the desired vision, estimates their probability and relevance, and outlines contingency actions against them	Risk identification Risk assessment (probability-impact) Contingency planning
3	Roadmap for process heating technology	2001	Industrial Heating Equipment Association and US DOE, office of industrial technologies	Energy	To provide a comprehensive plan, which sets forth priority goals and direction for meeting end users' process and equipment needs over the next 20 years	Economic uncertainty Technology uncertainty	Uncertainty and inconsistency of environmental regulations identified as key barriers to consistent and rational plans. Economic risk (to budget) seen as a key barrier to the use of advanced process heating technology.	Developing partnerships across the industry suggested as a means of addressing technology risks.
4	Window industry technology roadmap. A 20 year industry plan for window technology	2000	Office of Building Technology, State and Community Programs Energy Efficiency and Renewable Energy. US DoE	Building/ equipment	To identify key goals and strategies for different areas of the building and equipment industry.	Investment uncertainty (and risk): relating to the level of investment and chance of success of the investment in the research area. Identified that important trends leading to the vision remain uncertain.	Risk assessment of how much risk each research area carries. (Uncertainty level associated with research was scored in determining the level of risk. The higher the uncertainty, the higher its effect on the risk profile of the research activity.) Use of risk-contribution charts to appraise research areas.	Risk assessment: Risk-contribution (Qualitative measures) (i.e. risk-reward) charts are used to prioritise research activities according to how they contribute to the vision and how much risk the activity entails.
5	Energy-efficiency Petroleum-refinery Energy Efficiency Roadmap for Petroleum Refineries in California	2004	California Energy Commission (by Energetics Incorporated)	Energy	To define the R&D needed to improve energy efficiency and help refineries meet future energy demand	Technology uncertainty Commercial uncertainty	The risks to each priority research area were juxtaposed with the expected benefits to industry using 6 metrics (Energy, Potential to reduce electric demand, potential to reduce natural gas demand, production costs benefits, productivity/yield improvements and environment/regulatory)	There is an assessment of technology risk and commercial risk for each priority issue on the roadmap. There is no indication of how to reduce the risks. Risk benefit appraisals were also carried out
6	An integrated roadmap for the programmatic resolution of gas generation issues	2001	INEEL (Idaho National Engineering and Environmental Laboratory)	Energy	To foster technology development and deployment efforts to transuranic waste, nuclear materials and spent nuclear fuels programs' needs and requirements.	Uncertainty concerning decisions external to the actual roadmap.	The roadmap shows pathways that have significant risk, which may indicate more emphasis, should be placed on contingency planning. The roadmap focuses technical support to the baselines where there is high uncertainty (i.e. probability of success is low) and the consequences of failure are relatively high.	Risk identification Risk assessment. Contingency planning. Risk communication: There is a use of colours to indicate levels of risk associated with roadmap data.
7	Roadmap to secure control systems in the water sector	2008	Water Sector Coordinating Council for Cyber Security (report prepared by Energetics)	Water	To provide a plan to address the full range of needs for mitigating cyber security risk to ICS across the water sector	Market and regulatory uncertainty Environmental uncertainty	The roadmap is specifically meant to reduce the risk exposure of ICS across the water sector. Risk mitigation is central to the theme of the roadmap and so risk receives a lot of attention in creating the roadmap.	No specific steps or methods. Risks identified, assessed and mitigation measures drawn up in line with the focus of the roadmap.
8	ICT vulnerabilities of power systems: a roadmap for future research	2007	Grid Consortium	ICT	To identify key issues for research in power system vulnerabilities in the view of the challenges driven by the transformation of European power infrastructure and ICT integration.	Technology uncertainty	This roadmap topic focuses on reducing the risks to security of electric power systems. One of the priorities for research is the "Risk and vulnerability assessment of tools and methods" applicable to the energy industry.	There is a roadmap specifically for risk reduction/ management

9	Future Transport Service	2008	VTT	Transport	To provide perspectives into the development of transport system technology services, presenting tools and forms of cooperation needed based on set out visions	Technology uncertainty	Risk assessment for information security is one of the strategic issues focused on in the roadmapping process. The treatment of risk in this roadmap is not ingrained in the roadmapping process but in the content of the roadmap.	None specific steps or methods
10	Sodium bearing waste roadmap	2000	INL (Idaho National Laboratory)	Energy	To capture what development work must occur to resolve the key uncertainties in SWB disposition. The roadmap details the development activities for three alternatives that have performed well The roadmap plans a long-term detail for the development of the technology alternatives.	Technology uncertainty (and risk)	The entire roadmap is used as an uncertainty/risk reduction tool. The roadmap identifies the uncertainties, termed gaps in technical knowledge required to fulfil the vision of the roadmap, and is focused on reducing the most critical ones (i.e. the ones that would have the highest impact on the vision of the roadmap). The propositions made on the roadmap (with regards developmental activities) are meant to reduce the uncertainty surrounding the topic of the roadmap.	Uncertainty identification by brainstorming failure modes, safety issues and engineering needs. Uncertainty (risk) assessment based on consequence (whether their failure could impact the viability of the process [leading to the vision], resulting in high cost impacts). Resolution of uncertainties (risk) by specifying developmental activities.
11	The DOE Complex-wide vadose zone science and technology roadmap	2000	INL (Idaho National Laboratory)	Energy	To identify important paths that will lead to the tools and fundamental scientific understanding of the ***vadose*** zone	Technology uncertainty	The entire roadmap is considered an uncertainty/risk reduction tool. The roadmap considers the research that will improve predictions of fate and transport of contaminants in the vadose zone, and thus reduce uncertainty in decision-making across the DOE complex.	No specific steps or methods. The uncertainty in question here is external to the roadmapping activity. It is the uncertainty in certain decision making within the organisation.

B. **Comparisons of Cases 1-5 showing the format of the roadmapping processes and the nature of risk management activities carried out within them**

	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
Facilitating organisation	Industry Canada, Canada	Bonneville Power Administration, USA	VTT Technical Research Centre, Finland	Idaho National Laboratory, USA	Institute for Manufacturing, and Natural Environment Research Council
Industry	Defence	Energy	ICT	Energy	Environmental protection
Roadmapping objective	To identify potential technology solutions that will enhance the operational effectiveness of soldiers	To develop R&D plans to meet strategic goals in regard to improving energy efficiency.	To create plan on how ICT may be used optimally for sustainability	To provide structure to R&D and engineering efforts concerning the technologies required for next generation nuclear plants	To optimise the coherence and effectiveness of environmental research, identifying the necessary capabilities and resources
Roadmapping process duration	4 years	6 months	8 months	2 years, 6 months	8 months
No. of people involved	~ 1500	35	30	Core team of 4. Several other participants (exact number unknown)	25-40 per workshop
Process format	- Planning - Workshops: a series of two-day workshops – one for each of the 6 strategic areas of explored under the roadmapping activity, - Post-workshop online discussions among the participants, facilitated by a web-based wiki specially designed for the roadmapping process)	- Planning - Workshop processes (4 one-day workshops)	- Planning - Workshops (2 one-day workshops)	- Workshops: 2 one-day workshops for each of the 15 strategic areas explored within the roadmapping activity. - Desk research carried out between the two workshops under each strategic area.	- Planning - Workshops: a series of one-day workshops. One for each of the 6 strategic areas explored within the roadmapping activity.
Explicit risk mgt?	No	No	No	Yes	No
Practices highlighting how uncertainty/risk was addressed	- Decisions (to invest or not) in technologies incorporated real options thinking.	- Fact checking post roadmap creation to ensure accuracy of data included in roadmap.	- Facilitators (who also were experts in Green ICT) helped in steering the discussions based on their own knowledge whenever participants were faced with uncertainty	- Selection of innovative technologies based on a set of objective criteria.	- Participants were asked to indicate their level of confidence regarding some of the data they provided. - Selection of innovation ideas using semi-blind dot voting

Methods and techniques applied (and suggested)	- Brainstorming - MCDA (to focus and prioritise technologies) - SWOT analysis - Options thinking to make decisions (on what position to take on investing in technologies in the face of uncertainty)	- Brainstorming - Blind- voting used in combination with MCDA	- Brainstorming to identify risks (called bottlenecks)	- Brainstorming - MCDA techniques used in selecting technologies (voting used to decide criteria used in MCDA) - TRL (for characterising technology risk.) - Probability-consequence matrix for assessing risks associated with technologies	- Prioritisation of innovation ideas using semi-blind dot voting - Scenario techniques to stress-test roadmaps (post-roadmap development).
Visualisation of uncertainty and risk on finished roadmap	None	None	- Layer dedicated to 'bottlenecks' associated with the trends and drivers in the final roadmap	- Decision points are shown on the roadmap visual - Use of TRLs as surrogates for uncertainty (and risk) levels associated with success of technologies	None
Factors that influenced how uncertainty/risk issues were addressed	- Ample resources and time (e.g. development of web-based software for roadmapping exercise) allowed a more comprehensive application of [risk management] techniques	- Quality of participation (ensure that expertise involved is right for the requirements of the roadmapping activity)	- Resources (budget) constraints limited the use of specialised methods.	- Groupthink. - Ability to increase objectivity of decisions by using a set of criteria to select key technologies. - Availability of resources - Experience of participants in using risk management methods	- Groupthink observed to have played a part in the non-questioning of data applied in roadmapping process.

C. Comparison of Cases A – E, showing previous roadmapping experience, planning capability and risk management experience

Case	Industry	Focus of roadmapping process undertaken	Purpose	Prior roadmapping experience	Previous planning capability	Prior risk management experience
A	Automotive coatings	To define product innovation strategy within an aspect of its business. Interested in identifying the assumptions in the strategy and also where the uncertainties concerning disruptive developments are associated with key technologies.	Redefinition of innovation strategy for existing business	None	Yes, but not in strategic innovation planning. First time using roadmapping	Risk management for HSE. Risk management not applied to strategic/innovation planning
B	Defence	To explore and clarify innovation opportunities in a recently formed business unit set up to develop speciality defence and civilian products. The process sponsor identified the need to consider uncertainties and risks pertaining to the market, required technology and resources in arriving at an innovation strategy	Definition of strategy for new business in an established company (putting existing knowledge and technology to use in delivering new products)	None (process sponsor had attended roadmapping process training)	Yes, but not in strategic innovation planning.	Yes, in project management. Significant but not applied to strategic planning
C	Wall & Floor coverings	To clarify what product ideas to explore and develop under one of its product lines. There was the desire to identify specific risks that may adversely affect product innovation needs	Redefinition of innovation strategy for existing business, with a strong desire to deliver new products to the market	None (process sponsor attended roadmapping process training)	Yes, but not in strategic innovation planning.	Yes, in project management. Significant but not applied to strategic planning
D	Biotech	To clarify its flagship innovation proposition (glucose monitoring for diabetics). It was disruptive in nature but still in its early stages. Realisation of this highlighted the need for an innovation strategy in which the risks most critical to the success of the proposition and its delivery to the market can start being identified and addressed.	Definition of strategy for new business in a newly forming company	None	None	None

E	Energy	Recognised the uncertain nature of the future power generation market especially concerning the drive for low carbon energy solutions and economic growth in developing nations. This created doubt over what solutions would be best suited for the market, and therefore the company needed a coherent process to define and detail the solutions to be pursued	Redefinition of innovation strategy for existing business	None	Yes, but not in strategic innovation planning	Yes, but fragmented

D. Participant mix versus risk identification and treatment in Cases A-E

Case		**A**	**B**	**C**	**D**	**E**
Participation mix	Market bias	1	4	5	1	1
	Technical bias	2	6	4	3	3
Risk identification mix (number of risk issues identified)	Market-related risk	10	9	18	8	3
	Technical (or resource) related risk	3	12	11	10	10
Risk mitigation mix (number of risk issues mitigated)	Market-related risk	2	1	7	1	2
	Technical(or resource)-related risk	3	3	4	2	1

Case	**A**	**B**	**C**	**D**	**E**
Participation mix	Slight technical bias	Technical bias	Slight market bias	Technical bias	Technical bias
Criticality on risk issues	More critical on the market side	Slightly more critical on the technical side	More critical on the market side	Slightly more critical on the technical side	More critical on the technical side

E. Nature of criteria used in the value-attainability matrix for structured selection of innovation ideas in Cases A-E (i.e. nature of constraints used at the early-stages of innovation)

Criteria	**Criterion type**	**A**	**B**	**C**	**D**	**E**	**TOTAL**
Clear customer need	Value	✓	✓	✓	✓	✓	**5**
Market growth potential	Value	✓	✓	✓	✓		**4**
Size of market (available to us)	Value	✓	✓	✓	✓		**4**
Platform for growth	Value	✓	✓	✓	✓		**4**
Market profitability	Value			✓	✓	✓	**3**
Differentiated product	Value	✓		✓		✓	**3**
Routes to market	Attainability		✓	✓	✓		**3**
Opportunity to enter new market	Value	✓	✓				**2**
Industry maturity/readiness	Value				✓	✓	**2**
Sustainability of competitive advantage	Value	✓		✓			**2**
Strategic fit	Attainability		✓	✓			**2**
Fit with core competences	Attainability	✓				✓	**2**
Availability of grants/funding	Attainability		✓		✓		**2**
Knowledge of the market	Attainability		✓			✓	**2**
Technical risks	Attainability				✓	✓	**2**
Synergies with other operations	Value					✓	**1**
Regulatory impact	Attainability			✓			**1**
Skills & labour requirements	Attainability				✓		**1**
Competitive intensity (and reaction)	Attainability					✓	**1**

F. Post-roadmapping intentions of Companies in Cases A-E

Case	Intentions after roadmapping activity
A	To carry out roadmapping process at company headquarters (initial process was only a test-run
B	To start implementing roadmap
C	To start implementing roadmap, and to repeat process with more technical staff who will be able to fill technical knowledge gaps. There was a realisation at the end of the process that the initial participant mix was not adequate.
D	To start implementing roadmap
E	To repeat process at a better opportuned time as a result of poor attendance in initial process. Participant mix was also inadequate (like Case C), but this was more as a result of the attendees not turning up

G. Summary of findings from first stage of practitioner consultation interviews

	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6
Relevance of study	- Addressing uncertainty and risk is quite central to roadmapping and it will be useful to have a framework for this.	- It is important to make sure uncertainty and risk is addressed in roadmapping.	- The study should help in providing a way of forcing people to deal with risk and uncertainty.	- Roadmapping should illustrate gaps, uncertainties and risks, but in terms of how to deal with it, the present roadmapping technique cannot do that.	- Roadmapping could be improved if more detailed risk and uncertainty analysis is accommodated within it.	- Methods that can be used in roadmapping to assess risk at strategic levels will be extremely useful
Sources of uncertainty (and risk)	- Market (developing something the market does not want) - Every layer of the roadmap holds uncertainty and therefore, is a source of risk.	- External environment and internal environment - Specifics will depend on the roadmap topic and organisation context	- External environment: competitive, economic and political uncertainty Internal environment: technical uncertainty - The exact sources of uncertainty and risk will depend on the issue addressed by the roadmap.	- External environment - Financial risks - Technology risks	- External environment: political, economic, social, technology, legislation; internal environment: technology risk, resource risk - Specific sources will depend on the focus of the roadmap.	- External environment: political, economic, social, technology, legislative, ecological uncertainty - Schedule uncertainty
Factors that would influence how uncertainty/risk is addressed in roadmapping	- Subjectivity among the group - Prior knowledge: experience	- Experience: it is important to have the right group of people in the room	- Experience and knowledge of the group	- People are the biggest aspect to think about (their knowledge and perception) - The external environment is crucial.	- Incomplete information - Groupthink (and consensus)	- Time horizon of roadmap - Participants' risk tolerance and level of control
Methods (or techniques) suggested by practitioners for addressing uncertainty and risk	- Checklists - Market intelligence gathering	- Checklist - Brainstorming - Portfolio analysis - SWOT assessment	- Probability-impact appraisal - Risk-reward assessment	- Probability-impact appraisal - Scenario planning techniques	- Scenario planning techniques - Real options thinking	- Scenario planning techniques - Risk-reward appraisal - Probability-impact appraisal

H. Summary of findings from second stage of practitioner consultation interviews

	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11
Sources of uncertainty (and risk)	- Market uncertainty - Technology/ technical - Missing out value opportunities	- Limitations in participants' mental abilities	- External environment - Technology development	- Technical - Financial - Organisational - Commercial or market	- Market - Technical - Schedule - Economic - Resource/ organisational
Factors that influence and should be considered in addressing uncertainty and risk in roadmapping	- Quality of participation	- Quality of participation (reliability of data sources) - Quality of facilitation - Complexity of process (choice of techniques used)	- Quality of participation (experience and familiarity of participants with applied techniques) - Quality of facilitation.	- Process constraints (time and resource available to spend on process) - Complexity of process	- Quality of facilitation - Time constraint - Integrity of the roadmapping process
Methods and techniques applied (or suggested) for addressing uncertainty and risk	- Scenario planning - MCDA for prioritisation and selection decisions - TRIZ	- Scenario techniques (and mathematical modelling) - What-if? questioning to identify assumptions and underlying uncertainties. - Making the entire process more systematic and analytical.	- Scenario planning - Rolling wave planning - Assumptions analysis (what-if questioning) - Devil's advocacy	- Scenario planning - SWOT analysis - MCDA for prioritisation decisions	- Scenario techniques - Devil's advocacy - Assumption analysis (what-if questioning)
Other practices to address uncertainty and risk (based on past personal roadmapping experience and understanding of good-practice)	- Further market research to update roadmap (and fill gaps in market knowledge). - Contingency planning: lining up alternative technologies on the roadmap that can serve the same purpose.	- Assessing the roadmapping readiness of the organisation (during planning) to ensure information required to build roadmap is available/ accessible. - Developing an alternative back-up roadmap (contingency planning) - Further desk research post-roadmapping activity to fill knowledge gaps identified during the process.	- Addition of a *know-what-if* layer to make explicit the identification and questioning of any data assumptions. - Regular revision of created roadmap.	- Provision of a visual structure for the brainstorming of risks (e.g. through mind mapping)	- A risk roadmap is dedicated to visualise the risks that threaten the roadmap. - Use of decision points on roadmaps visual to indicate uncertainty

I. Summary of feedback on RSRM process appraisal from focus group

<table>
<tr><td colspan="4">Focus group feedback</td></tr>
<tr><td>Process stage</td><td>Step/ Technique</td><td colspan="2">Concerns/comments</td></tr>
<tr><td rowspan="3">Planning and pre-workshop data collection</td><td>Preparation steps</td><td colspan="2">No concerns indicated.

Comments:
The group confirmed that the process requires the right mix of people. Their expertise and personality should be considered in selection.

However, it was suggested that an attempt to strictly define responsibilities of workshop participants (e.g. for the devil's advocate) before the workshop may complicate the process.</td></tr>
<tr><td>Pre-workshop data gathering (and confidence rating of collected information on market trends)</td><td colspan="2">No concerns indicated.

Comments:
Customisation of the roadmapping framework and process, selection of workshop participants and pre-workshop data gathering stages should be treated as an iterative process. The level [in the organisation] of the roadmap vision, the level of uncertainty identified in the pre-workshop data collection should influence who attends the workshop.</td></tr>
<tr><td>[Mini]-scenarios building</td><td colspan="2">No concerns indicated</td></tr>
<tr><td rowspan="4">Strategic landscape activity</td><td>Parallel strategic roadmapping sessions in response to alternative scenarios</td><td colspan="2">No concerns indicated

Comments:
When two scenarios are applied during the workshop, the mapping should include the bifurcation point, at which the future starts playing out differently.</td></tr>
<tr><td>Assumptions analysis (with Devil's advocacy and SWIFT)</td><td colspan="2">No concerns indicated

Comments:
The addition of the assumption layer on the roadmapping template and analysis of assumptions was recognised as 'a very useful and insightful idea' that would encourage the discussion of assumptions that people might have coming into the process.</td></tr>
<tr><td>Semi-blind dot voting</td><td colspan="2">No concerns indicated</td></tr>
<tr><td>MCDA (Weighted scoring model)</td><td colspan="2">No concerns indicated</td></tr>
<tr><td rowspan="2">Topic exploration activity</td><td>Brainstorming</td><td>No concerns indicated</td><td rowspan="2">Comment (concerning risk identification):
The identification of risk may hamper consensus and the ability of the roadmap to convince business stakeholders</td></tr>
<tr><td>Prompt lists</td><td>No concerns indicated</td></tr>
</table>

<table>
<tr><td rowspan="4"></td><td>Probability-impact assessment</td><td>No concerns indicated</td><td rowspan="2">Comments:
It would be useful to define what the different levels of risk indicate for the organisation applying the probability-impact matrix and the TRL-risk assessment

The technology readiness level chart should be expanded to include other elements such as technology obsolescence and others that characterise the capability of the organisation.</td></tr>
<tr><td>TRL-risk assessment</td><td>No concerns indicated</td></tr>
<tr><td>Risk mitigation</td><td colspan="2">No concerns indicated</td></tr>
<tr><td>Risk-reward assessment</td><td colspan="2">No concerns indicated</td></tr>
<tr><td>Comments on overall process</td><td colspan="3">Feasibility: No concerns indicated.

Functionality: No concerns indicated.
Feedback received from the group indicated that the techniques described are suitable for the functions to which they had been assigned. It was also recognised that the process is addressing an important gap.

Usability concerns:
Across the participants, concerns were raised on the apparent complexity of the process (and the time it would take to run the workshop process). This is highlighted by some of the comments from the questionnaire and the ratings of the criteria:

“My main concern is the complexity of the additional steps and how well a group will engage with the process”
“The potential for the process is excellent but I worry about the execution in the real environment”
“If people coming to the process do not have any prior background with roadmapping and such ideas, it will not be easy to get them going on it as it is presented now. So it may be helpful to modify based on audience that you are setting the workshop for”
“I am not confident enough to try it with a critical group. However, I would be keen to see it trialled with a friendly group”</td></tr>
</table>

Criteria	**Statement in questionnaire**	**Average score**
Feasibility	Process can be followed	4
Functionality	Process supports the management of uncertainty and risk in roadmapping	4
Usability	Demands of the process on facilitator and participant are within reasonable limits	3.3
	The management of uncertainty and risk is well integrated into roadmapping	3.3
	I am confident to apply the process on a real case	2.3

Likert scale
5: Strongly agree – 1: Strongly disagree

J. Summary of feedback from practitioners familiar with the S-Plan

Stage	Step/ Technique	Feedback (concerns and suggestions)
Planning and pre-workshop data collection	Preparation steps	No concerns indicated. **Suggestion to improve usability** (Practitioner 1): It will be useful to present a standard set of criteria, from which the most relevant for the organisation (undertaking the roadmapping activity) can be chosen for the MCDA process.
	Confidence rating of market information	**Usability concerns** (Practitioner 13): Rating the confidence the participants have in the information they provide might lead to a complicated process.
	[Mini]-scenarios building	**Usability concerns** (Practitioner 3): The seriousness of the uncertainty must be balanced with the complexity of running scenarios. **Usability concerns** (Practitioner 6): Scenarios are useful but may be too complex, especially for the smaller organisations. Also, the application of scenarios may not be relevant to most cases. **Functionality and usability concerns** (Practitioner 13): The benefit of having alternative views is usually minor compared to the complexity it introduces.
Strategic landscape activity	Parallel strategic roadmapping sessions in response to alternative scenarios	**Feasibility and usability concerns** (Practitioner 3): Running parallel strategic landscaping sessions (at the same time) will be complex. Feasibility of the process will depend on the number of workshop participants and the prior knowledge of roadmapping (or the S-Plan). **Functionality and usability concerns** (Practitioner 6, 13): Concerns follow from those associated with the application of scenarios to develop alternative views of the future
	Assumptions analysis (with Devil's advocacy and SWIFT)	**Suggestion to improve usability** (Practitioner 1, 3, 5, 13**):** Looking at assumptions underlying the entire strategic landscape could lead to a complicated process. It would be better to identify assumptions at the topic exploration stage so that it concentrates on the key topics, which can be dealt with one at a time. **Suggestions to improve functionality** (Practitioner 7): - The assumptions analysis should focus more on the market trends and drivers. - A way should be found to spread the role of the devil's advocate among the participants to maintain group consensus.
	Semi-blind dot-voting	**Usability concerns** (Practitioner 3): The process will take too much time and would disturb the rhythm of the workshop. **Usability concerns** (Practitioner 5): Logistical problems foreseen, in that there will be a need for each participant to have a complete list of all the options that are being considered in the voting process. **Functionality concerns** (Practitioner 13): Process appears too mechanical. It will be difficult to track what people have voted for and it is always important to support voting results with debate (which this step will not allow)

	MCDA (Weighted scoring model)	**Functionality concerns** (Practitioner 15) Care must be taken that people do not focus only on value propositions that appear to be low-risk to the detriment of value propositions that have high value potential but appear to be high-risk. **Suggestion to improve functionality** (Practitioner 13): It will be necessary to be very clear on the criteria being used at the workshop and what they stand for. **Suggestion to improve usability** (Practitioner 1, 5, 7): Value and attainability can be used as the two main criteria in this step. Modify the step by classifying all other criteria (that would have been used in the scoring model) under 'value' or 'attainability'. Value should be scored first, and attainability should be scored second.
Topic exploration activity	Brainstorming	No concerns indicated
	Prompt lists	No concerns indicated
	Probability-impact assessment	No concerns indicated
	TRL-risk assessment	No concerns indicated **Suggestion to improve functionality** (Practitioner 3): Other elements that help characterise the value chain should be included. This is so that this step is more about the assessment of innovation readiness and not just technology readiness.
	Risk mitigation	No concerns indicated
	Risk-reward assessment	No concerns indicated
Comments on overall process	**Practitioner 1**: It is a sensible process. But it appears it would take too long. It is too busy for a day's schedule. **Practitioner 3**: The process provides a nice provocation so that people are sure they are aligning what they are thinking about with risks. **Practitioner 5**: Process will not fit into a day schedule as proposed. **Practitioner 6**: I think it is a good pack. Cutting the process down to a few tools and techniques would be valuable. **Practitioner 7**: The overall process can be followed and it is functional, but looks quite complicated. I am not sure how willing people will be to spend a lot of time on the process. The workshop should provide only a quick analysis. **Practitioner 13**: Overall process is feasible for the workshop environment. The process should be kept simple so that it is transparent and participants have confidence in it. **Practitioner 14**: I think it is very comprehensive and progresses well through the risk management steps. The process is feasible, but there is a limit to what can be done in the workshop. **Practitioner 15**: The process is feasible and it adds value to the traditional [S-Plan] process. The topic exploration stage would be a good stage for thinking about risks. It is a lot more controllable since there are fewer people in the group. One day would be enough only if you have a very controlled group.	