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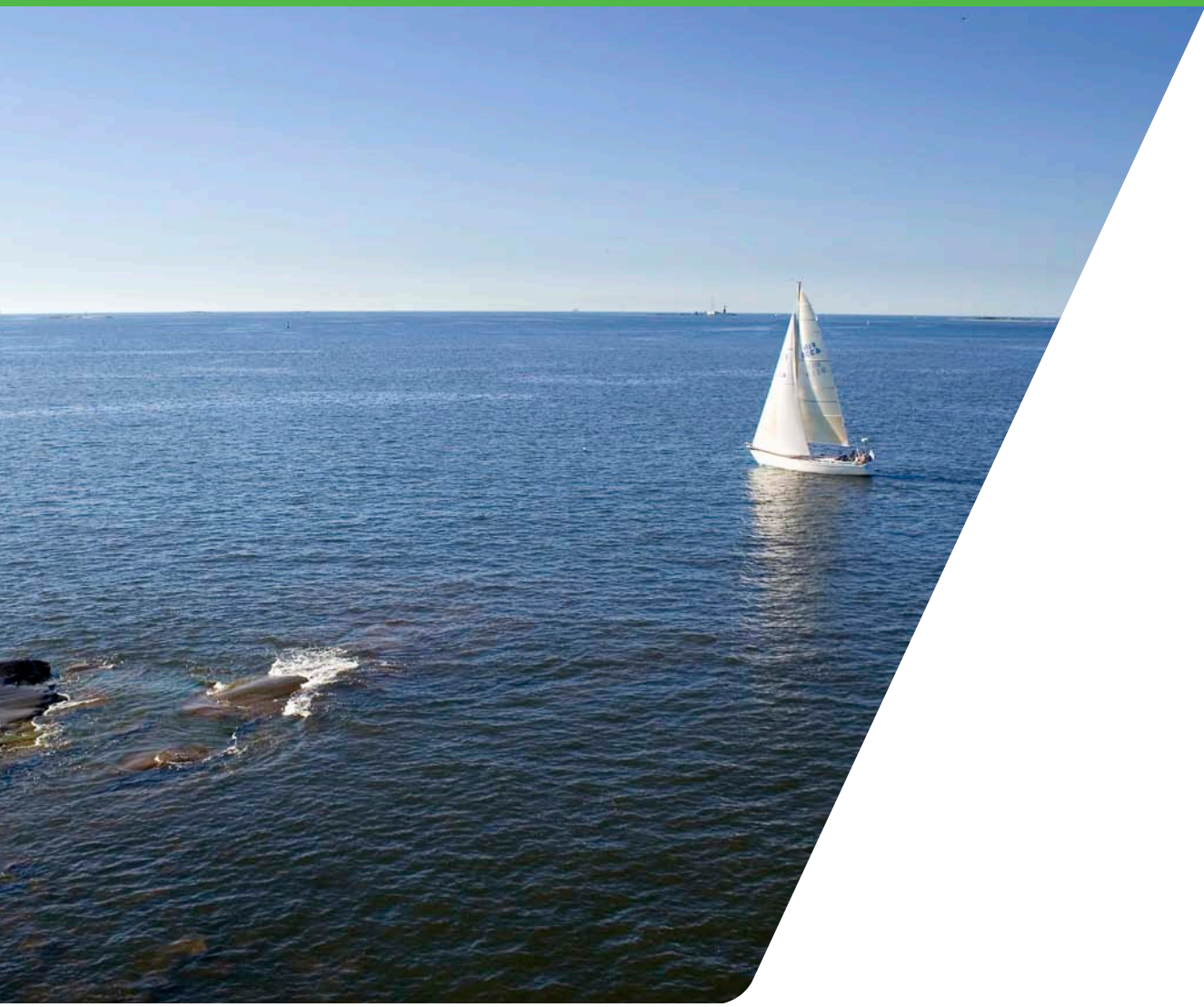

Jaakko Paasi & Pasi Valkokari (eds.)

Elucidating the fuzzy front end

Experiences from the INNORISK project

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VTT, Bergsmansvägen 5, PB 1000, 02044 VTT
tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 5, P.O. Box 1000, FI-02044 VTT, Finland
phone internat. +358 20 722 111, fax + 358 20 722 4374

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Keywords innovation, innovation management, uncertainty management, opportunity recognition, risk management, fuzzy front end, radical innovation, new business development

Abstract

Companies in the process creating new business – or innovations – are also moving towards an unknown future, which includes several uncertainties. The management of uncertainty in the development of technological innovations was studied with a focus in the fuzzy front end stage of the innovation development process. The guiding principle behind the study and the development work involved the application of the generic methodology of risk management to the challenges associated with new business creation, with the intention of raising open discussion about the aim of the risk management. The target is not only to identify and assess risks, and select risk reducing measures, but also to consider how best to quickly and effectively respond to realised opportunities and risks as they arise.

A study of extant literature was supplemented by further analysis of the previous large interview study of innovation management practices (in which 43 managers were interviewed from 12 major companies and public organisations). The main research question of the work could subsequently be defined as "*How should future uncertainty be managed in new innovation and business development?*"

Based on the results of the literature study, a generic model, which describes the main phases and the influencing factors of the innovation process, could also be defined. Emphasis was placed on the modelling the front end, especially the conceptualisation phase. Integration DEFinition (IDEF) methods were applied in this work. The overall goal was to support strategic decision making at critical points of the innovation process by helping companies to identify phases and elements in their innovation process where specific managerial or development actions are needed. Subsequently, the front end was no longer as "fuzzy"; it should now be elucidated.

The main effort during this study was directed at the real innovation development cases at three companies. Although different approaches were used in each of the cases; they all started from an idea associated with a new business opportunity, but the operative development of the new innovation involved was very different. The cases were named accordingly:

1. **Case conceptualisation** which followed the traditional approach; where concept development was succeeded by new product development.
2. **Case strategic co-ordination** where the technology of innovation was already available in-house, but the new business creation required a new kind of strategic offering planning for the company.
3. **Case acquisition** where new technology necessary for the new business was taken over by an acquisition.

Tools and methods were applied and further developed within these cases, such as roadmapping, portfolio management and scorecards for specific phases in innovation management. Discussion was initiated on not only how best to consider the commercialisation phase during the early stages of the innovation process, but also on what the challenges while creating new service business actually are.

The feedback led to a conclusion that a systematic approach to decision making that could be applied throughout the innovation life cycle was still needed. As a final result of this endeavour, a systematic innovation management framework focused on providing support for strategic decision making under conditions of high uncertainty about the future, was developed. The work was conducted in cooperation with the experts of the service science and technology foresight from the IBM Almaden Research (USA).

This publication combines the main results of the work done at VTT within the INNORISK project. INNORISK was a 3-year joint research project between the Corporate Foresight Group (CoFi) of Åbo Akademi and VTT Technical Research Centre of Finland as a part of the LIITO technology programme of Tekes.

The main research finding of the work can be presented as a proposition: It is less important as to which particular tool is used in supporting the decision making related to new innovation and business development under a high level of future uncertainty. What is the most important is that this analysis is done in a systematic way that considers multiple viewpoints.

The project provided a good overview of the demands of innovation process management. Since INNORISK had a broad scope, some of the developed

methods need to be further enhanced and refined in order to provide practical tools for practitioners (companies and organisations). The work of INNORISK is therefore being continued at VTT. Case-specific projects are being investigated in order to gain practical results for the needs of practitioners interested in improving their capabilities for business renewal.

Jaakko Paasi & Pasi Valkokari (toim.). Elucidating the fuzzy front end – Experiences from the INNORISK project [Innovaatioprosessin alkuvaiheiden hahmottaminen – Kokemuksia INNORISK-projektista]. Espoo 2010. VTT Publications 743. 160 s.

Avainsanat innovation, innovation management, uncertainty management, opportunity recognition, risk management, fuzzy front end, radical innovation, new business development

Tiivistelmä

Kun yritykset luovat uutta liiketoimintaa – eli innovaatioita – ne ovat samalla matkalla kohti tuntematonta tulevaisuutta, joka sisältää useita liiketoimintaan liittyviä epävarmuuksia. Siksi tutkimme epävarmuuden hallintaa teknologisten innovaatioiden kehitystyössä. Tutkimuksessa keskityimme innovaatioprosessin sumeaksi kutsuttuun alkuvaiheeseen. Perusperiaatteena tutkimus- ja kehitystyössä oli riskienhallinnan yleisten menetelmien soveltaminen niihin haasteisiin, jotka liittyvät uuden liiketoiminnan luomiseen. Tämän toivomme herättävän avointa keskustelua riskienhallinnan tavoitteista. Riskienhallinnassa kyse ei ole vain riskien tunnistamisesta, arvioinnista ja riskiä vähentävien toimenpiteiden vallinnasta vaan myös kyvystä havaita uusia liiketoimintamahdollisuuksia sekä vastata niihin nopeasti ja tehokkaasti.

Tutkimustyö aloitettiin kirjallisuuskatsauksella ja analysoimalla uudelleen suuren haastattelututkimuksen tulokset. Haastattelututkimuksessa oli selvitetty innovaatioiden hallinnan käytäntöjä 12 suuressa yrityksessä ja julkisessa organisaatiossa. Haastatteluihin osallistui 43 johtajaa näistä organisaatioista. Tämän vaiheen tuloksena pystyimme määrittelemään hankkeemme varsinaisen tutkimuskysymyksen: *Miten tulevaisuuden epävarmuutta pitäisi hallita kehitettäessä uusia innovaatioita ja uutta liiketoimintaa?*

Vaiheen toisena tuloksena syntyi ehdotus innovaatioprosessin yleiseksi malliksi. Mallissa kuvataan innovaatioprosessin keskeiset vaiheet ja siihen vaikuttavat tekijät. Mallintamisessa olemme korostaneet konseptointivaiheen kuvausta. Työssä sovellettiin Integration Definition (IDEF) -menetelmiä. Konseptointivaiheen kuvauksen tavoitteena on tukea strategista päätöksentekoa innovaatioprosessin kriittisissä kohdissa. Kun toimija kykenee tunnistamaan innovaatioprosessin vaiheet ja siihen vaikuttavat kriittiset tekijät, on hänellä paremmat mahdollisuudet tehdä uuden liiketoiminnan kehittämisen johtamiseen liittyviä kriittisiä

päätöksiä. Kun konseptointivaihe pystytään kuvaamaan, innovaatioprosessin alkuvaihe ei ole enää niin epäselvä vaan se on saanut rakenteen.

Tutkimuksen päähuomio kohdistui kuitenkin kolmen yrityksen todellisiin innovaatioiden kehittämiseen liittyviin caseihin. Nämä caset sisälsivät kaikki erilaisen lähestymistavan. Kaikki alkoivat uuden liiketoimintamahdollisuuden tunnistamisesta, mutta niiden operatiivinen johtamisessa sekä uusien innovaatioiden kehittämisessä sovellettiin täysin erilaisia lähestymistapoja. Caset olivat seuraavat:

1. **Case konseptoinnissa** oli varsin perinteinen lähestymistapa. Menestyksellisestä konseptivaiheesta oli tavoitteena siirtyä uusien tuotteiden kehittämiseen.
2. **Case strateginen koordinoinnin** yrityksellä oli varsin uusi teknologia, mutta tässä tapauksessa uuden liiketoiminnan kehittäminen vaati uudenlaista strategista suunnittelua.
3. **Case hankinnassa** yritys hankki uudelle liiketoiminnalle välttämättömän teknologian ostamalla teknologian kehittäjäyrityksen.

Näissä case-tutkimuksissa sovelsimme ja kehitimme työkaluja ja menetelmiä, kuten roadmappaus, portfolion hallinta ja pisteytyskortit (*score card*), kriittisiin innovaatioprosessin vaiheisiin liittyvän päätöksenteon epävarmuuden hallitsemiseksi. Aloitimme myös keskustelun siitä, miten olisi mahdollista huomioida kaupallistamisvaiheen vaatimukset jo innovaatioprosessin alussa ja mitä erityisiä haasteita uuden palveluliiketoiminnan kehittämiseen liittyy.

Tutkimustuloksista teimme johtopäätökset, että emme olleet vielä löytäneet järjestelmällistä lähestymistapaa, jota voitaisiin soveltaa päätöksentekoon koko innovaation elinkaaren aikana. Tämän tutkimuksen lopullisena tuloksena kehitimme järjestelmällisen innovaatioiden hallinnan viitekehyksen, joka fokusoituu tukemaan strategista päätöksentekoa olosuhteissa, joissa vallitsee suuri epävarmuus tulevaisuudesta. Tämä työ tehtiin yhteistyössä IBM Almaden Researchin (USA) palvelutieteen ja teknologian ennakoinnin asiantuntijoiden kanssa.

Tämä julkaisu kokoaa VTT:n tärkeimmät havainnot ja tulokset INNORISK-hankkeessa. INNORISK oli kolmivuotinen yhteishanke Åbo Akademin Corporate Foresight Groupin (CoFi) ja VTT:n välillä. Hanke rahoitettiin Tekesin LIITO-teknologiaohjelmasta.

Hankkeen päähavainto on, että kehitettäessä uusia innovaatioita ja uutta liiketoimintaa epävarmuuden vallitessa ei ole niinkään olennaista se, mitä epävarmuuden hallinnan työkalua päätöksenteossa käytetään, kuin se, että päätöksente-

kijät itse tarkastelevat tilannetta useammasta näkökulmasta ja tekevät sen systemaattisesti.

Hankkeen tuloksena muodostui varsin kattava näkemys innovaatioprosessin johtamisen vaatimuksista. Koska INNORISKin tutkimuskohde oli laaja, on osaa kehitetyistä menetelmistä edelleen kehitettävä, jotta käytännön työkaluja voitaisiin tarjota eri toimijoille (yritykset ja organisaatiot). Siksi INNORISK-työ jatkuu VTT:ssä hankkeissa, joissa on asetettu case-kohdennetut tavoitteet. Näin kehitetään yhä käytännöllisempiä menetelmiä päätöksenteon tueksi toimijoille, jotka ovat kiinnostuneita kehittämään valmiuksiaan liiketoimintansa uudistamisessa.

Foreword

The importance of innovations and innovation management is recognised in companies, research institutes, and the whole of society. The European Commission has placed the development of innovation processes and innovation policy in a central position in the Lisbon strategy (launched in 2000), which is being aimed at turning the EU into the foremost competitive and dynamic economy by 2010. According to the European Commission (2003):

"*It takes creativity or innovation to enter and compete in an existing market, to change or even to create a new market. To turn a business idea into success requires the ability to blend creativity or innovation with sound management and to adapt a business to optimise its development during all phases of its life cycle.*"

We also know that most innovations will not achieve commercial success, as a matter of fact, most innovations fail. On the other hand, companies that do not innovate will, sooner or later, face an economic crisis and die. This contradiction describes more or less the basic dilemma that initiated the INNORISK project – a 3 year (2006–2009) joint research project (http://www.vtt.fi/innorisk/) between the Corporate Foresight Group (CoFi) of Åbo Akademi and VTT Technical Research Centre of Finland as part of the LIITO technology programme of Tekes. A component of VTT's INNORISK work was done in conjunction with IBM Almaden Research Center (CA, USA). The full name of the INNORISK project "Exploring and managing future uncertainties in the business driven innovation process with the focus in the implementation of new technology" tells much about the targets and challenges of the project.

This report aims to summarise the results achieved at VTT within the INNORISK project. It consists of a selection of original publications that the INNORISK research group at VTT issued during the project. An introductory

part (i.e. an introduction and descriptions of the methodology, theory, summary of publications, and conclusion) is included prior to the mentioned set of publications. The introductory part, and in fact also the original publications, were written with an aim to support practitioners when they are developing and improving their processes for innovation and new business development. Through this work we hope to initiate open discussion about the management and coordination of opportunities, threats and uncertainties in new business creation.

The INNORISK project covered a broad range of issues about the management of future uncertainties of new business development. Based on the research work done during INNORISK, we are now able to suggest models that support the executives of organisations in their efforts to better understand the challenges related to their own innovation processes. The developed models should also be effective when the company specific conceptualisation phases are being defined. Therefore, these models should be especially helpful for when elucidation of the fuzzy front end is required.

The project provided a good overview on the topic. However, even with all the newly developed results, mainly due to the broad scope of the INNORISK, well-defined tools for practitioners (companies) are still not specifically available. Therefore, the INNORISK work continues at VTT through the application of case-specific projects in order to gain practical results for the needs of companies interested in improving their capabilities for business renewal. Follow-up projects are already proceeding, but we are also still keen to pursue new initiatives.

Tampere, April 2010

Jaakko Paasi & Pasi Valkokari

VTT Technical Research Centre of Finland

Contents

Glossary

Business operations – Operations, the objective of which are to produce products and services onto selected markets in a manner that produces added value for selected customer segments and profit for invested capital.

Challenge management – Management and control of an innovation process in order to create business operations in a manner that takes changes in the operational environment into account (threats or opportunities).

Conceptualisation – Seeing the solution model of a product or service as a whole, but in broad outline before the final product or service solution.

Co-ordination of commercialisation – Activities that aim to control the uncertainty of commercialisation-related information through the innovation process.

Foresight – Multi-science mapping of future alternatives and timing from the actor's point of view.

Future research – Multi-science research that studies the present from an interest in knowing the future and combines ideological with documented information.

INNORISK model – An operational model that combines future research, technological forecasts, business concepts and risk management into one package, which supports the flexible operational methods of companies in the changing world.

Innovation – A new concept that can be commercialised and is significantly better than an earlier solution. The innovation can relate to products, services, technologies, business and organisational models, operational processes or operational methods.

Innovation process – A managed systematic operational method with which innovations are produced.

Market research – Analysis of the market at a micro- and macro-level, and mapping the operator's competitive position in relation to other operators and customers.

New technology – Technology that is based on new ground research or applies previously unused information to the application target in question.

Offering planning – Process in which the company creates a strategic plan for future products and technologies that are responsive to the company's business strategy.

Portfolio management – Activities which aim to ensure that an on-going set of new product development projects are likely to provide the anticipated returns, are responsive to the company's business strategy, and reflect the best possible utilisation of resources.

Risk – Combination of frequency or probability of a defined event and its consequences. The defined event may be recognised or imaginable. The consequences may be positive (opportunities) or negative (threats).

Risk Management – Utilisation of management principles, procedures and practices in order to analyse risks, assess significances and actively control.

Signpost – A potential future event that is both recognisable and actionable.

Strategic focus – Selection of the product, service, technology or business model from all alternatives in a manner that corresponds to the requirements of the future operational environment and strategic guidelines.

Technology – Utilisation of people's skills and knowledge in order to reach the desired goals (tekhne + logos).

1. Introduction

In the INNORISK project, the essential focus was on the opportunity recognition and management of future uncertainties and risks in companies that are giving rise to a new business. New business creation obviously involves stepping towards an unknown future, and there are many kinds of uncertainties associated to the associated decision making. Renewal of the business, however, is the key to the long term success of companies. Companies rarely die solely due to the making occasional wrong movements. It is more likely, however, that companies will not be successful in the future if they continue too long with a strategy that only fits the needs of today.

Innovations are often classified as incremental or radical according to changes in business environment resulting from the innovation (e.g. Morone, 1993; Utterback, 1994; Leiter *et al.*, 2000). Innovations are typically incremental, since they incorporate gradual enhancements or feature upgrades to existing products, services, processes or business models. As a matter of fact, it is often hard to say when the question is actually about 'new innovation' as opposed to a 'product upgrade'. Quite often incremental innovations allow an organisation to maintain its current approach to target markets, i.e. they do not create new lines of business, nor do they seek completely new markets for an existing product or service. In this case, the objective of a company is to strengthen its competitive edge in the current markets by with slightly improving the product's features.

Radical innovations, by contrast, correspond to disruptive change. The disruptive change can be related to technology, markets, society, or any combination of these. An innovation can be said to be radical when it has the potential to produce one or more of the following: (a) an entirely new set of performance features, (b) improvements in the known performance features of five times or greater, or (c) a significant (30% or greater) reduction of cost (Leifer *et al.*, 2000). A radical innovation significantly changes supply and demand conditions in a market. We claim that if an organisation could turn their radical innovations into commercial success, it really is capable to create new lines of business. The introduction of consumer digital photography is a good example of a radical innovation that caused major disruptive technological and social changes. Such major

disruptive changes are rare; but smaller scale disruptive changes, affecting primarily the business of a single company, occur more frequently.

The creation of completely new, perhaps radical, business is not easy and the situation becomes even more challenging when it is a question of business renewal of mature company. The recognition of radical opportunities, required for the business renewal, rarely fit with companies' current business strategies and may, therefore, be neglected or even rejected. Uncertainties related to new markets or new technology further increases the difficulty in decision making, where one also must consider the time span in which markets operate in the short term whereas technology R&D could last for years. All these aspects call for a practical approach which helps to improve the long-term abilities of companies to renew their business. All the above mentioned aspects associated to the renewal of mature companies are also applicable to entrepreneurs creating a new business. Entrepreneurship begins from an opportunity of a new business and calls for tools and methods in order to manage risks related to future uncertainties.

As the importance of the service sector in new business creation rises, more attention has to be also focussed on the problems associated with managing these service provider organisations properly. Not only do a vast range of organisations offer predominantly a ‘service product’, but those that offer ‘tangible’ products also additionally provide related after-sales services, distribution services etc. At the same time, service providers must constantly look for new approaches to service design and delivery (Smith *et al.*, 2007).

This report presents the results of the work done at VTT within the INNORISK project. The objective of the INNORISK project has been to develop tools and methods for companies in order to support the decision making related to the taking of existing technologies into new markets, the development of new technologies for existing markets, or the creation of new technologies in new markets. The word 'new' can here mean either new-to-the-company or new-to-the-world. In short, the INNORISK tools are supporting companies in stepping out of the box of current business.

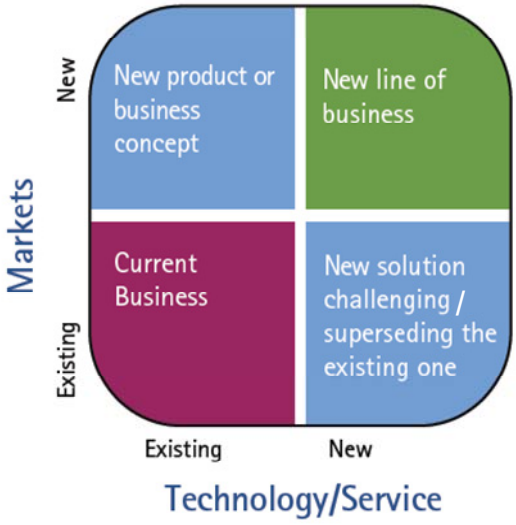

Figure 1. Focus of the INNORISK project, the management of new business opportunities, risks and uncertainties.

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2. Methodology

Research institutes and companies in Finland have been very skilful in creating and developing new technology with a business potential – i.e. innovations according to the definition used in the project. However, very few of them ever have become a commercial success story. One reason for this is that the new business development in Finland has been traditionally directed by technology, without paying detailed attention to real market needs and market driven business opportunities. The actual situation, however, is not really that simplistic.

In 2003–2005 a group of researchers at VTT initiated a preparatory study about why the commercialisation of many advanced technological innovations fails. In addition to insufficient market perspective, the new innovation and business development also often suffered from some sort of failures in the implementation of new technology. These findings were in line with those reported in literature (Leifer *et al.*, 2000; Kim & Mauborgne, 2005). Both these market and technology issues could be said to arise from insufficient management of future uncertainty in the new innovation and business development. The **main research question for the INNORISK work** therefore became:

How should future uncertainty be managed in new innovation and business development?

The focus was on new business development where new technology plays a central role. By the new business development we mean, as in accordance with Figure 1, a new product or business concept, a new solution superseding the existing one, or totally a new line of business.

In parallel with the preparatory study for INNORISK, VTT performed in 2005 a large interview study of innovation management practices in which 43 managers were interviewed from 12 major companies and public organisations in Finland (Kettunen *et al.*, 2007). The goal of the interview study was to gain an understanding of the current practices, potential problem areas and development needs. The participating organisations were: ABB, Consolis, FMI, Metso, M-Real, Nokia, Schering, Tekes, Vaisala, VTI Tech-

nologies, VTT and Wärtsilä. The study revealed the following generalisations about the innovation process:

a) new product development is typically well-structured and controlled, but
b) early concept and design (i.e. front end of innovation process) is unstructured and uncontrolled.

According to the findings of the interview study, the management of future uncertainty was identified as one of the main challenges for corporate executives. This challenge was reported to be great throughout the innovation process, but greatest at the fuzzy front end (Kettunen *et al.*, 2007). This finding had an important impact for the work plan of INNORISK, in which more emphasis is directed at the front end activities. A primary objective therefore was to create a model which elucidates the fuzzy front end and makes it more understandable for practitioners.

The approach of the INNORISK-project towards finding answers to the research question was based on a constructivist case methodology (Schwandt, 1994) that focused on different viewpoints and the direct experience of the organisational members. The core INNORISK-research group at VTT have extensive experience in research and development, both in industry and research organisations, in various fields of technology and risk management. It was that joint experience which enabled us to assimilate different viewpoints and experience, at first to specify the research problem in more detail, and then to develop tools and methods in order to overcome the weak points, from the perspective of uncertainty management, in the new innovation development identified in the interview study. The process subsequently raised several related sub-questions (to the main research question of INNORISK) and led to the series of separate publications which form the core part of this report. The sub-questions related to specific publications are outlined in Section 4 together with descriptions of how the constructivist methodology was applied in the particular case.

The INNORISK work started with a re-analysis of the interview study and extant literature (from the viewpoint of the main INNORISK research question). The work then progressed through real innovation development cases at three companies. The three cases each represented different approaches. While they all originated from an idea for a new business opportunity, totally different approaches were applied for the operative development of the new innovation (business). The cases were accordingly formulated as:

1. **Case conceptualisation** – follows the traditional approach in which the concept development was succeeded by new product development
2. **Case strategic co-ordination** – where the technology of innovation was already available in-house but the new business creation required new kind of strategic offering planning for the company
3. **Case acquisition** – where new technology necessary for the new business was taken over by an acquisition.

Brief descriptions of the cases are given in **Publication I**.

The research progressed through active interaction between the industrial cases and the theoretical development work.

The cases focused on specific phases of new innovation and business development. While applying and further developing existing tools and methods for each phase, such as roadmapping, portfolio management, scorecards, etc. (Koen *et al.*, 2002; Dunham, 2002; Cooper *et al.*, 2005; Paasi *et al.* in **Publication II**, 2007; Luoma & Paasi in **Publication III**, 2007; Luoma *et al.* in **Publication IV**, 2008), it was deemed that a systematic approach to decision making that could be applied throughout the innovation life cycle was still lacking. This conclusion gave rise to the final stage of the research: the development of a *systematic innovation management framework* focused on providing support for strategic decision making under conditions of high uncertainty about the future. At this stage, service science and technology foresight experts of IBM Almaden Research (USA) brought their experience to the research group. However, due to time constraints the results of this final stage (**Publications V–VII**) in practice in new business development cases was not tested during the INNORISK project.

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3. Theory

The interview study (Kettunen *et al.*, 2007) revealed that the new product development (NPD) phase of the innovation life cycle is well structured and controlled in the vast majority of organisations, but the front end of innovation process is typically unstructured and uncontrolled. The reason for the well structured and controlled NPD may related to the well-developed theory of new product development (Ullrich & Eppinger, 2004; Cooper & Edgett, 2005). For the beginning of the process (the front end), there is no similar well-established theory. In some proposals the front end process is linear like the product development process (Ullrich & Eppinger, 2004; Cooper & Edgett, 2005; Kettunen *et al.*, 2007), while other models emphasise the complex and iterative nature of the front end (Orihata & Watanabe, 2000; Koen *et al.*, 2002; Dorval & Lauer, 2004).

Our early hypothesis was that the major challenges of corporate executives related to new business development and uncertainty management are, in part, due to the unstructured and uncontrolled front end of innovation process in their organisations.

In order to manage uncertainty, the front end process should be modelled. This means that front end phases, elements and decision points should be identified, inputs and outputs to and from each phase should be defined, and information used at decision points should be identified, etc.

Experience from the three INNORISK cases supports the hypothesis. By assigning some structure to the process, future uncertainty became more identifiable and therefore better manageable. This does not mean that the future will be predictable, but rather the organisation becomes better prepared for future eventualities. When elements and critical decision points in the front end have been identified, and information, as well as the necessary decision criteria, have been defined, the front end becomes more controllable and actions for new business creation can be managed.

At the beginning of the project, factors influencing the innovation process were defined. The innovation process is commonly regarded as being rather a creative and un-

structured process. This is something, which is usually hard for people having a technical background to understand. For the modelling work, therefore, the Integration DEFinition (IDEF) family of methods were applied. These modelling methods were originally developed in a U.S. Airforce program in order to graphically capture the characteristics of manufacturing. The final aim in this development work was the increased productivity in complex manufacturing processes (Le Clair, 1982). Visualisation of an upper level innovation process model includes, as shown in Figure 2:

- weak signals, megatrends, market research, business intelligence as examples of valuable inputs for the innovation process
- strategy, laws, permission, regulations, standards and trends as examples of controlling factors for the process
- employees, customers, end-users, research institutes partners, foresight and market research methods, risk management methods as examples of enabling mechanisms and resources for the innovation process.

In the next phase of the modelling work, the main steps of the innovation process were defined. Most often the innovation process is divided into four areas: foresight and concept development (which together form the fuzzy front end), the new product development, and commercialisation. Naturally, the target was to deepen the understanding of the front end activities.

For the modelling of front end, and especially the concept development, various evolution versions were created. The final one, made at the end of the project using the direct experience from the INNORISK cases, is presented in Figure 3. It includes the front end elements of

- idea generation
- opportunity identification
- opportunity analysis
- idea enrichment
- concept definition,

already identified and described in a large front end study of Koen *et al.* (2002). These elements can always be identified when designing innovations that are new-to-the-company or new-to-the-world. In the case of incremental improvements of products, services, processes of running lines of business, the situation may different, but the INNORISK work focused on innovations new-to-the-company or new-to-the-world.

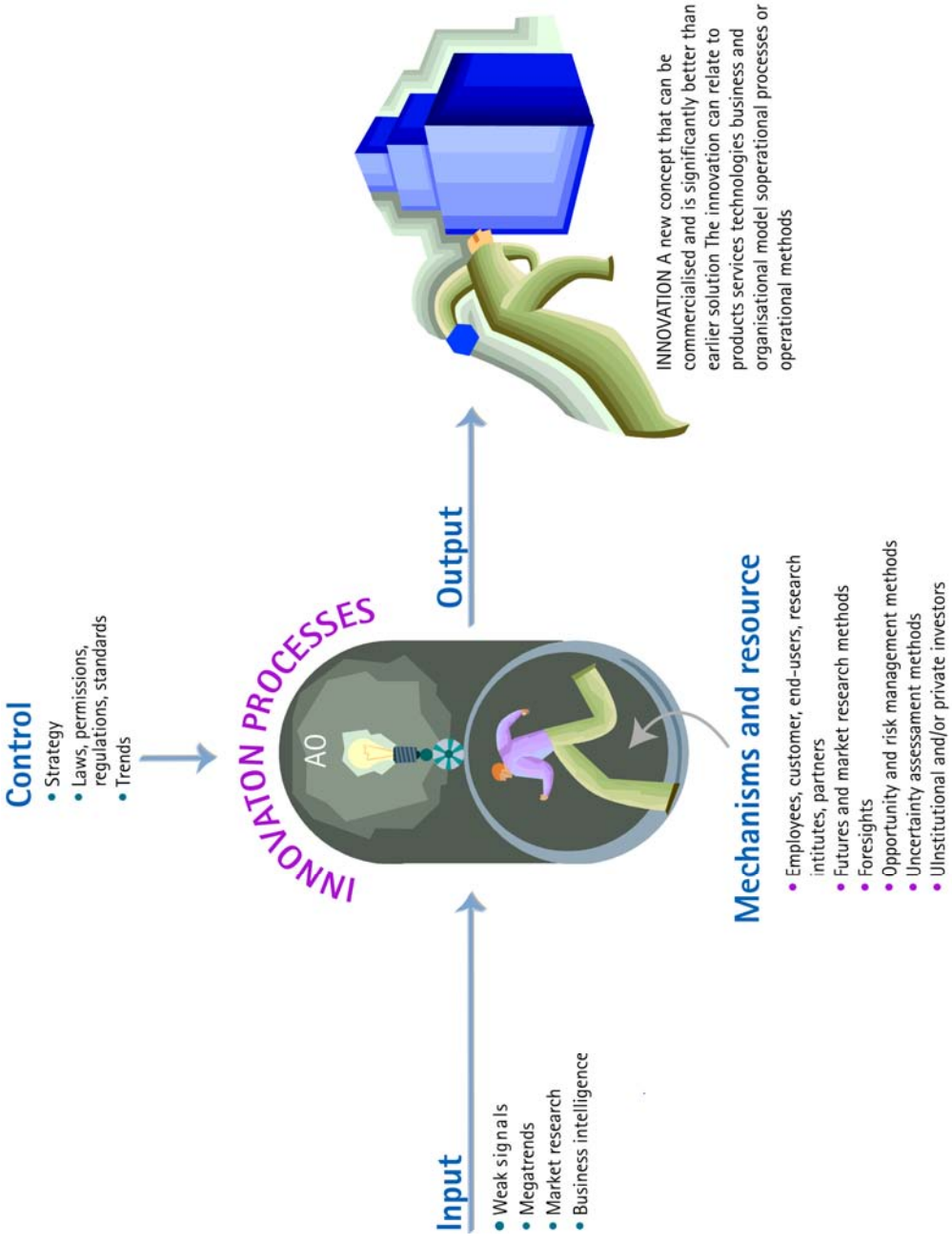

Figure 2. Factors influencing innovation and new business development process.

In the developed model, the process starts either at an idea (or preferably many ideas) of the new business or at an identification of new business opportunity. The difference is that we understood an idea to be a describable new product, service or process, and we understood an opportunity to be an identified market need without a clear idea yet of the actual product or the service that could fulfil that need. New knowledge in the form of foresight, market information, and R&D provides input information for the front end elements. After the idea generation (or opportunity identification) the process accordingly continues to the idea enrichment or opportunity analysis stage. The elements of idea enrichment, opportunity analysis and concept definition form a three element group in where the actual new concept development work takes place. The idea journeys around these three elements until the new business concept is sufficiently well developed and a strategic decision can be made in regards to whether it can pass the gate to the NPD phase, whether the work should be placed on hold, whether the work should be returned to the front end process for elaboration, or whether it should be stopped. The spirit of open innovation is also illustrated in this model. An option to sell the results of the front end work is available as well as an option to buy or integrate technology from other actors by agreement. The process, its elements, and the uncertainty management actions related to each element are described in more detail in the separate Publications of the report.

The feedback from the INNORISK cases clearly indicated that the modelling of the front end activities provided structure and control to the front end work in the companies. It forced them to work systematically and consider issues related to uncertain future from multiple viewpoints. In this way they could improve their management of future uncertainty. It was less important as to which particular tool was used in gaining the viewpoints – more important was the fact that the decision making systematically took into account multiple perspectives in the very early phases of new business development. Both Ullrich & Eppinger (2004) and Cooper & Edgett (2005) have reported similar findings for the new product development stage of innovation process (i.e. it is more important just to consider multiple viewpoints to support the decision making than to use some specific tool to support the decision making). The INNORISK findings suggest that the same is valid also for the very early phases of the innovation process. In fact, this is believed to be the main research finding of the project.

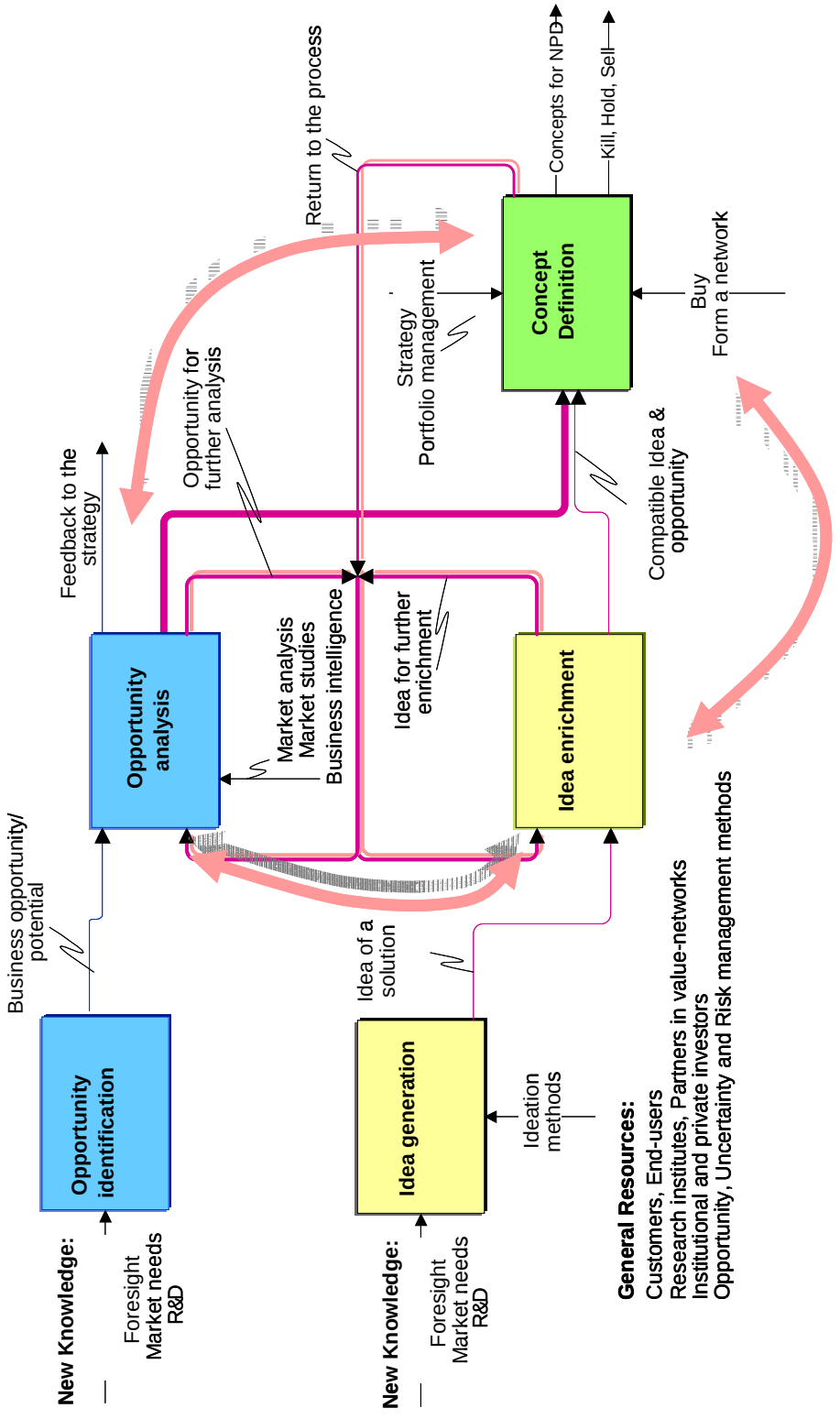

Figure 3. Process model for the front end activities of innovation development.

Figure 4 shows another INNORISK model for the innovation development with an emphasis on the front end activities. It is similar to that of Figure 3, but while Figure 3 highlights the front end process, Figure 4 presents a broader framework for the innovation development. The process begins from the identification of a new business opportunity. Before the opportunity can be evolved into an innovation, one needs a strong ability to make important strategic decisions, a capability to conceptualise the opportunity and to transform it into a final product, and, importantly, to manage risks related to commercialisation. In practice the elements contained within Figure 4 are more or less interlinked. A major challenge concerns the question of timing – markets operate in the short term, while technology R&D activities could take several years. It is an immense challenge to manage the timing so that the market needs will be met at the moment of the innovation launch.

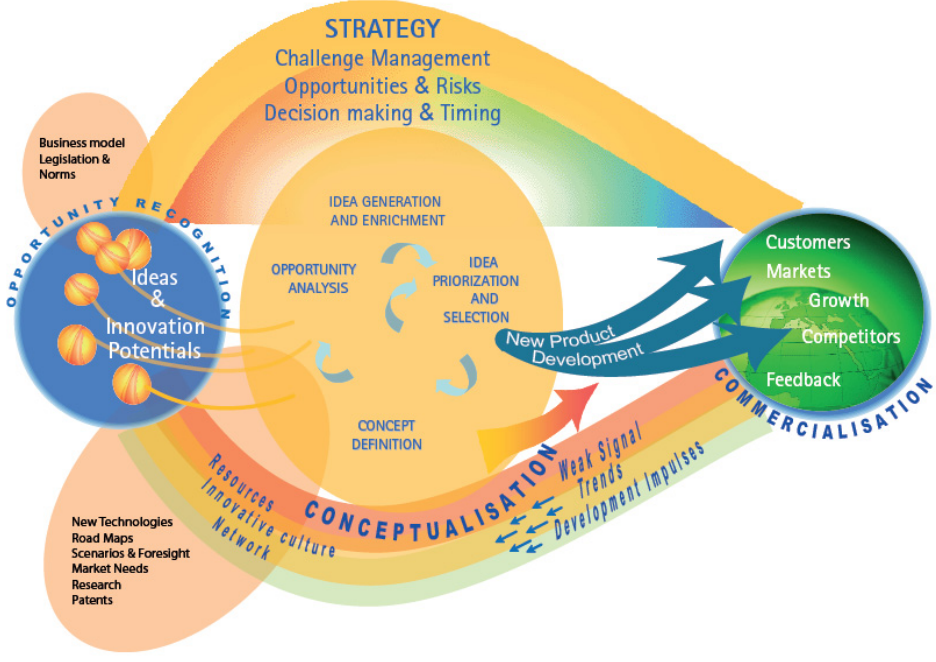

Figure 4. An INNORISK innovation process model.

The rest of the models, methods and tools to be presented in this publication cover perspectives from the early stages of the innovation process. The exception is for the tools specifically for the NPD stage, because there are already a wide range of tools available.

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4. Summary of publications

This chapter provides a brief overview of the original **Publications I–VII** where central results of VTT's INNORISK work are presented in more detail. The introduction indicates which perspective is being considered with regards to the main research question of the project "How should future uncertainty be managed in new innovation and business development?", discusses the methodology, and presents the main findings of the publication.

Publication I – *Uncertainty management in the front end of innovation development* is a summary paper of VTT's INNORISK results, written for the INNORISK final report (Meristö & Laitinen, 2009). The real new business development cases, where the INNORISK research work was mainly done, are also described.

Publication II – *Managing uncertainty in the front end of radical innovation development* was the first INNORISK paper. The main research question was not specified for the paper. It has a constructivist approach which integrates the lessons learned from the literature and the earlier experience of the authors into the INNORISK cases running in parallel with the research. The paper focuses on the modelling of front end activities – central elements and critical decision points – and how uncertainty management could be implemented into the front end work and decision making during the front end phase of innovation development. It also suggests specific tools and procedures for uncertainty management supporting the decision making in the identified critical decision points of front end. The driving principle was to move the common decision making in the case of incremental innovation development into earlier stages of the front end phase, where the uncertainty of information is small when compared to radical innovation cases, and where initial decisions may only occur at the gate preceding new product development. In this way, more effective guidance can be provided for the remaining front end work and more effective use made of resources throughout the innovation process.

Publication III – *Commercialisation success in innovation development* is a practice-oriented paper that considers the commercialisation-related perspectives of the main INNORISK research question using the constructivist research methodology. The paper applies a risk management approach to the commercialisation management of innova-

tions, with a special emphasis being on innovations where one aims to deliver a product, process or service with unprecedented performance features. A guiding principle of the work was to expand the consideration of commercialisation questions and risks from the late phase of new product development and product launch to the very beginning of the innovation process, where important decisions related to the market attractiveness of the new product are made.

Publication IV – *Managing commercialisation risks in innovation development: linking front end and commercialisation* forms together with Publication III an ensemble: while Publication III provides tools for practitioners, Publication IV emphasises the importance of linking front end and commercialisation activities from the academic perspective with a specific research question of "How are the front end and commercialisation phases of the innovation process linked and how can those linkages be managed?" It was found that the front end and commercialisation phases of the innovation process are strongly linked through questions critical to both phases and through personnel involved with both processes. The questions are related to seven categories: market need, market environment, technology, idea/value proposition, business environment, and management and collaboration network.

Publication V – *Systematic strategic decision support for innovation development* is the first paper in the trilogy consisting of Publications V–VII. The early INNORISK work as well as the work in the three INNORISK cases focused on developing tools and procedures for specific phases of the innovation process (Publications I–IV). The importance of good linkage between the phases was recognised in the publications as well as in the cases, but systematic support for strategic decision making in new business development was still lacking. The final phase of INNORISK was thus started and focussed on the development of a framework (concept model) for systematic decision support of innovation development. It was constructed to make use of a small number of reusable modular process building blocks and qualitative evaluation techniques, based on the risk management methodology. Thus, this paper is strongly based on the early INNORISK work. Publication V provides an overview for the framework (concept model) and addresses the specific research question of “How should future uncertainty be managed during the entire innovation process?” The approach towards finding answers to the question was, again, based on constructivist methodology. The paper presents a framework model which was considered in more detail in Publications VI and VII.

Publication VI – *Uncertainty management in service innovation* is the second paper of the trilogy. It goes into more practical details than Publication V, which remained focussed on the framework. The focus of the paper is in new service business development with the specific research question of “How could uncertainties related to service innovation be bet-

ter managed?" Service design is quite similar to product design since it uses design methods to develop new offerings. Nonetheless, unlike goods, services are dominated by intangible elements which make a service system unusually complex and its behaviour difficult to predict. Publication VI suggests practical tools and procedures that an innovative service enterprise can use for an ongoing screening process – for moving from a relatively large number of perceived opportunities to a relatively small number of new service offerings.

Publication VII – *Systematic risk management for the innovative enterprise* is the final paper of the trilogy involving the framework model for systematic strategic decision support for innovation development (Publication V), examples of practical tools for new service business development within the framework model (Publication VI), and a description of risk taxonomy forming the core tool of the framework model (Publication VII). The risk taxonomy is dynamically evolving a taxonomy of factors, characteristic of the business in question, that may influence the success potential of an innovation. The factors can be mapped to either qualitative or quantitative decision processes. In this framework, risk is defined as the combination of the probability of an event and its consequences. This concept of risk covers both positive and negative consequences, i.e. both opportunities and threats. The paper addresses the research question of "How should future uncertainty be managed during the entire innovation life cycle?" Accordingly, it extends the front end focused studies of the earlier papers to cover the entire innovation life cycle. Using the constructivist methodology, the authors consider the subject in a more theoretical than practical perspective. The main contribution of the paper can be summarised as a working hypothesis: "The potential and actual lines of business of an innovative enterprise can be effectively and usefully managed by means of decision support based on a dynamic risk taxonomy."

5. Publication I: Uncertainty management in the front end of innovation development

Jaakko Paasi, Pasi Valkokari, Pekka Maijala, Tuija Luoma & Sirra Toivonen

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland.
E-mail: firstname.lastname@vtt.fi.

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Abstract: *When companies are creating new business – or innovations – they are also stepping towards an unknown future, which includes several uncertainties. Therefore, the management of uncertainty in the development of technological innovations has been studied with a focus in the fuzzy front end stage of innovation development process. The development of innovations, which will be new to the company or even new to the world, is always very challenging and risky because of uncertainty in many aspects of the development and commercialisation processes. Tools and procedures used for the management of incremental innovation development, exploiting current lines of business, may not give much help in the case where one aims to deliver a product, process or service with unprecedented performance features.*

The new business development cases presented in this paper represents all different approaches. All cases started from an idea of new business opportunity, but the operative development of new innovation (business) applied totally different approach for uncertainty management: one case followed the traditional approach in where concept development was succeeded by new product development, in one case the technology of innovation was already available in-house but the new business creation required new kind of strategic offering planning for the company and in one case new technology necessary for the new business was taken over by an acquisition.

This paper also describes a risk management based practical approach in supporting the decision-making of commercialisation related issues in the front end. The linkage of the front end and commercialisation phases of the innovation process is important in order assure that the opportunities and uncertainties related to commercialisation are taken into consideration during the first steps of the new business creation.

Keywords**:** *uncertainty management, fuzzy front end, radical innovation, innovation management, new business development.*

1. Introduction

The importance of innovations and innovation management as a source of economic growth, competitiveness and wellbeing is almost universally recognised today. Also recognised is the fact that most innovations will not achieve commercial success, as a matter of fact, most innovations fail. New business creation obviously involves stepping towards an unknown future, involving a plethora of uncertainties. Renewal of the business, however, is the key for the long term success of companies. Companies rarely die for the making of wrong movements occasionally. It is more likely that companies will not be successful in the future if they go on too long with the strategy fitting for the needs of today.

The starting point for the creation of a new line of business – or an innovation – is the recognition of new business opportunity. The opportunity can be, for instance, a new product or service, a new material, a new market or a new method of production. The recognition of new business opportunities, in itself, is not easy and the situation becomes even more difficult when it is a question of business renewal of mature company. Radical ideas, required for the business renewal, rarely fit with companies' current business strategies and may, therefore, be neglected or even rejected. Uncertainties related to new markets or new technology further increases the difficulty in decision making, where one has to take into account also the time span in which markets operate in the short term whereas technology R&D could last for years. All these call for a practical approach which helps to improve the long-term abilities of companies to renew their business. What is said above for the renewal of mature companies applies as well for entrepreneurs creating a new business. Entrepreneurship starts from an opportunity of a new business and calls for tools and methods in order to manage risks related to future uncertainties.

In 2005 VTT performed a large interview study of innovation management practice in which 43 managers were interviewed from 12 major companies and public organisations in Finland (Kettunen *et al.*, 2007). The study revealed the following generalisations about the innovation process:

- new product development is well structured and controlled, but
- early concept and design (i.e. front end of innovation process) is unstructured and uncontrolled.

The reason for (a) may be the well developed theory of new product development (Ullrich & Eppinger, 2004; Cooper & Edgett, 2005). For the beginning of the process (the front end), there is no similar well established theory. In some proposals the front end process is linear like the product development process (Ullrich & Eppinger, 2004; Cooper & Edgett, 2005; Kettunen *et al.*, 2007), other models emphasise the complex and iterative nature of the front end (Orihata & Watanabe, 2000; Koen *et al.*, 2002; Dorval & Lauer, 2004). Authors' proposal for the innovation development model, with an emphasis on the front end activities, is given in Figure 5 (Paasi *et al.*, 2008a). The development of new innovation usually starts from an idea of a new business opportunity but, what follows, is more or less fuzzy until the idea has been elaborated so much that the actual product development work can start. However, the fact that it is fuzzy does not make it unmanageable. In the front end, the operational work is strongly connected to strategic decision making (Paasi *et al.*, 2008b). Furthermore, both operational and strategic activities are surrounded by information from markets, technology development, legislation etc.

The need of companies for practical methods for opportunity, risk and uncertainty management in innovation (new business) development triggered the INNORISK project (Meristö *et al.*, 2006). The objective of the INNORISK project was to develop methods for companies in order to support the decision making related to the taking of existing technologies into new markets, development of new technologies for existing markets, or creating new technologies to new markets. This paper focuses to results achieved at VTT within the INNORISK project.

The objective has been in activities which take place in the (fuzzy) front end of innovation process, i.e. before new product development and commercialisation stages of innovation development. Decisions done in the fuzzy front end are of primary importance: studies have shown that most of the important factors affecting the success of the potential innovation are fixed before the business idea or concept goes to the new product development phase (Cooper & Edgett, 2005; Kettunen *et al.*, 2007).

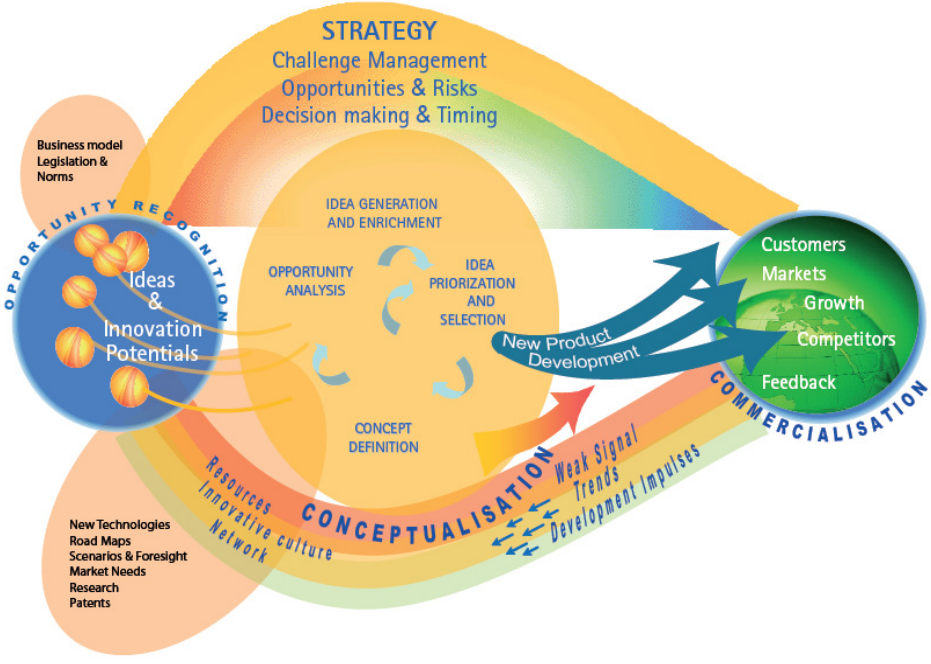

Figure 5. VTT's INNORISK model for the innovation process (Paasi *et al.*, 2008a).

2. Research Methodology

VTT's interview study identified management of future uncertainty as one of the main challenges to corporate executives (Kettunen *et al.*, 2007). This challenge was reported to be great throughout the innovation process, but the greatest at the fuzzy front end. That initiated the research question of the work:

How should future uncertainty be managed in new innovation and business development?

Answers to the research questions were searched by applying generic risk management methodology (Suokas & Kakko, 1993; SME Risk Management Toolkit, 2002) to real new business development cases in different kinds of companies. Learning experiences from the cases were then analysed by applying constructivist collective case methodology (Schwandt, 1994; Hatch, 1997). Risk management aims, in general, to protect the property, income and different activities of a company while aiming to keep the overall costs

at as low a level as possible. Risk management is not only about identifying and assessing risks and selecting risk reducing measures, but also about being able to respond quickly and effectively to realised opportunities and risks as they arise.

3. Cases

The new business development cases presented in this paper represent all different approaches. All cases started from an idea of new business opportunity, but the operative development of new innovation (business) applied totally different approach: one case followed the traditional approach in where concept development was succeeded by new product development (case conseptualisation), in one case the technology of innovation was already available in-house but the new business creation required new kind of strategic offering planning for the company (strategic co-ordination), in one case new technology necessary for the new business was taken over by an acquisition (case acquisition). Brief descriptions of the cases are given in Tables 1–3.

The research for finding answers to the research question was done largely in these cases. The INNORISK research project provided a framework for developing practical methods and tools for the management of opportunities, risks and uncertainties in the front end of innovation (new business) development, while the real cases at the companies offered a test bench for the methods and tools. Developed methods to manage uncertainty related to conceptualisation, strategic co-ordination and commercialisations aspects are given in short in the following chapters. Most of the tools used are not novel and correspond to current best practices in innovation development. What was novel is the systematic way how these tools were applied to manage uncertainty in new business development.

Table 1. New innovation and business development cases of the study: Case Conseptualisation.

Case Conseptualisation

Company and goals: A medium size company, manufacturing different kinds of products to keep manufacturing environment of high-tech companies in order, was looking for new business. The opportunity they saw was to create value to their products by adding new technology into them.

Type of innovation and new business: With new technology they looked for new solutions (a product or product family) challenging the existing one: at first to existing markets, later on maybe also on new markets.

Steps of the work and examples of tools used: The work started with scanning of potential technologies as well as market needs in a future. The survey produced lots of material and a few business opportunities for more detailed analysis. The material was analysed with the help of various tools, including roadmapping and opportunity balance matrix. Some early ideas of product concepts were generated while still analysing the opportunities. Three alternative futures were created for the opportunities in order to evaluate their business potential after 5–10 years (it was estimated that it may take 5 years to commercialise the ideas). Finally one opportunity was selected for more thorough concept development including iterative steps of idea generation and enrichment, concept elaboration and business potential analysis. Concept elaboration was guided by transparent criteria of idea and concept evaluation. The criteria also forced to take into account various kinds of uncertainties and make actions in order to manage them.

Role of decision makers: Top management of the company was strongly involved with the process. That was very important because lots of important strategic decision will be done during the fuzzy front end stage of innovation and new business development. Active involvement with the process made it possible for the decision makers to have a good vision of opportunities and risks related to the new (potential) business and managerial actions required in order to manage them.

Table 2. New innovation and business development cases of the study: Case Strategic co-ordination.

Case Strategic co-ordination

Company and goals: A medium size technology company wanted to renew their business so that, instead of project deliveries, they would offer products and by this way to improve their value capturing. The product development of the company was strongly guided by requirements of individual customers. Therefore, new products that were launched into markets were likely applicable for very limited amount of customers. Investments made into the new product development did not give maximal growth for the business. Individual customer driven new product development had also caused that personnel resources were spread too thinly between several ongoing projects resulting in elongation of the lead-times of these projects, and accordingly, increased risk for economic losses.

Type of innovation and new business: At first the expectations of company's representatives were that they should concentrate only on management of the product performance issues. During the process, the development of the life cycle services and delivery channel unveiled more and more attractive opportunities for new business creation.

Steps of the work and examples of tools used: It was decided to develop offering planning and portfolio management processes in the company so that they could minimise the economic risk related to new product development investments and to enhance the resource management in these operations. The offering planning process started by the definition of current product offering in one business line. It helped in unifying the viewpoints between company's representatives involved in the process. The next task was the recognition of future targets. Thereafter, steps and actions filling the gap between state-of-the-art and future vision were defined. What was actually done was a roadmap for the offering of the company in the future.

Role of decision makers: The work was initiated by the top management of the company. They were also active in the process, for example, by making the recognition of future targets and especially in the definition of the most important decision-making criteria. The hard work in creation of the offering planning was executed by business leadership team. This team was comprised of directors and managers from product business, sales and R&D.

Table 3. New innovation and business development cases of the study: Case Acquisition.

Case Acquisition

Company and goals: A large technology company had identified a new market need and a related opportunity of new business in global markets. The need was arisen from an increased threat of terrorism in logistics and resulting changes in security legislation. Fast transformation of the market need into a real business offering with product characteristics fulfilling the market need would mean significant benefit in global markets.

Type of innovation and new business: With new technology, the company looked for a new product concept to meet the new requirements: at first to U.S. markets, later on also on new global markets. The need to develop life cycle services based on the new product concept created a totally new opportunity for new business.

Steps of the work and examples of tools used: The work started by a detailed analysis of the identified market need and the business opportunity related to need. Check-lists were used to consider uncertainties related to the new business opportunity. The analysis was supplemented by surveys of security-technologies, patents and competitors. Roadmapping techniques were used in linking market need, technological possibilities and business drivers with time. Commercialisation viewpoints play a high role in the analysis. Development of product concept was straightforward after the analysis. The next step was a preliminary business case analysis in where the maturity of technology as well networking required in the product concept were evaluated. The analysis resulted in a decision to take over the technology required by an acquisition. Acquisition is always accompanied by risks but it was evaluated that costs and risks of acquisition were smaller than those related to the development of the technology in-house. Benefit of shortening the time-to-markets was also in favour for acquisition.

Role of decision makers: Analyses were done in expert groups consisting of top managers (i.e. the decision makers), marketing and product managers, external new technology, security and risk management experts. Active involvement of the decision makers in the analysis allowed them to have a broad and realistic image about opportunities and risks related to the new (potential) business.

4. Conceptualisation

Conceptualisation is an expression used for describing the fuzzy front end of innovation process. The development of new lines of business starts from the recognition of an opportunity. What follows is more or less fuzzy, and therefore the front end of innovation process is often called as the fuzzy front end. On the other hand, the front end is not uncontrollable. Managing (or co-ordinating) the front end is the key for successful innovation. Many important factors affecting the success potential of a radical innovation creating new business are already fixed before the innovation project enters the new product development stage. In order to manage the front end, it must be modelled. This means that phases, elements, and decision points should be identified, inputs and outputs to and from each phase should be defined, and information used at decision points should be identified, etc. A practical proactive risk management procedure for the uncertainty management in the front end should guide the creativity in the front end by using a handful of simple rules and tools which allow simultaneous and systematic analysis of the opportunities and threats. At the same time, it should enhance the conceptualisation process and minimize the risk of submitting false projects (i.e. projects for products or services that are not likely to obtain commercial success) into the new product development and commercialisation stages.

The New Concept Development (NCD) presented in Figure 6 provides a good and generic starting point for the management of conceptualisation / fuzzy front end stage. The NCD consists of five elements: 1) opportunity recognition, 2) opportunity analysis, 3) idea generation and enrichment, 4) idea selection, and 5) concept definition (Koen *et al.*, 2002). Foresight and market studies supplies input into the NCD engine. R&D is an interactive link to research which may cover a large network of players. The NCD engine starts with an idea for a new business opportunity, but it thereafter does not have to proceed in the given order. The idea remains in the engine until the concept is ready – both in technological and business aspects. A concept is in our work understood to be a well-defined form: including its primary features and customer benefits, an understanding of the technology needed, and the defined business idea (case) about how the company will profit by the foreseen product or service defined by the concept. Sometimes it may be necessary to rotate several cycles, and even revisit the foresight and market information or Networks and R&D, before the concept is ready for the gate decision preceding New Product Development (NPD) or other action (kill, recycle, hold, sell).

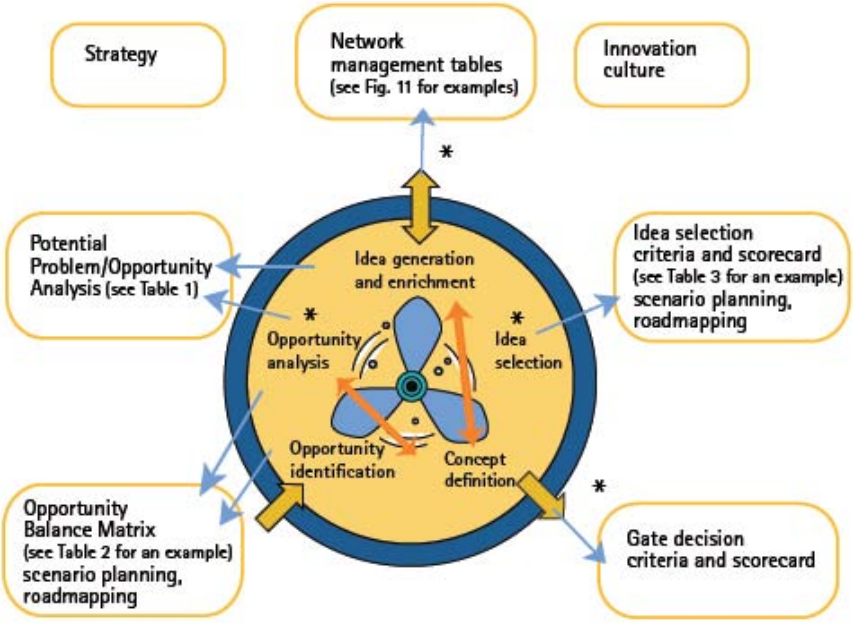

Figure 6. Overview of key elements, tools and procedures in the uncertainty management model for the front end stage of radical innovation development (Paasi et al., 2007). Critical decision points are indicated by an asterisk. In the core of the model there are the five elements of New Concept Development model of Koen et al. (2002).

We have applied tools and procedures for the management of uncertainty into the elements of NCD in order to gain a proactive uncertainty management model (Paasi *et al.*, 2007). Critical decision points at the front end are indicated by an asterisk. Typically, most of the decision making occurs only at the gate preceding new product development. In our model, part of the crucial decision making has been brought forward into earlier phases of the front end. The driving idea of our uncertainty management model has been to develop tools, procedures and criteria for the uncertainty management at these important decision points and, by this way, increase the possibility of successful product launch in the future. Early decision making also supports the effective use of resources throughout the innovation process. The elements of the NCD model, and how the uncertainty management can be conducted are described in more detail elsewhere (Paasi *et al.*, 2008a).

5. Strategic co-ordination

Strategic guidance or co-ordination is very important when companies are creating new lines of business. In the INNORISK project, we have proceeded to the strategic viewpoint by applying the approach of portfolio management. Portfolio management is about project prioritisation and resource allocation to achieve new product objectives for the company. It is a dynamic decision process wherein the list of active new products (offerings) and R&D projects (utilisation of capital and human resources) is constantly revised. It is also about finding and maintaining the right balance between short-term offerings and projects supporting current lines of business, and long-term offerings and projects that create new business. The target of the strategic co-ordination by portfolio management is simply: Do the right projects!

In the INNORISK project we have sought ways to implement strategic co-ordination by portfolio management in a light, practical way and keeping the emphasis on the process of offering planning and portfolio management. The framework used in the INNORISK approach of strategic co-ordination is given in Figure 7.

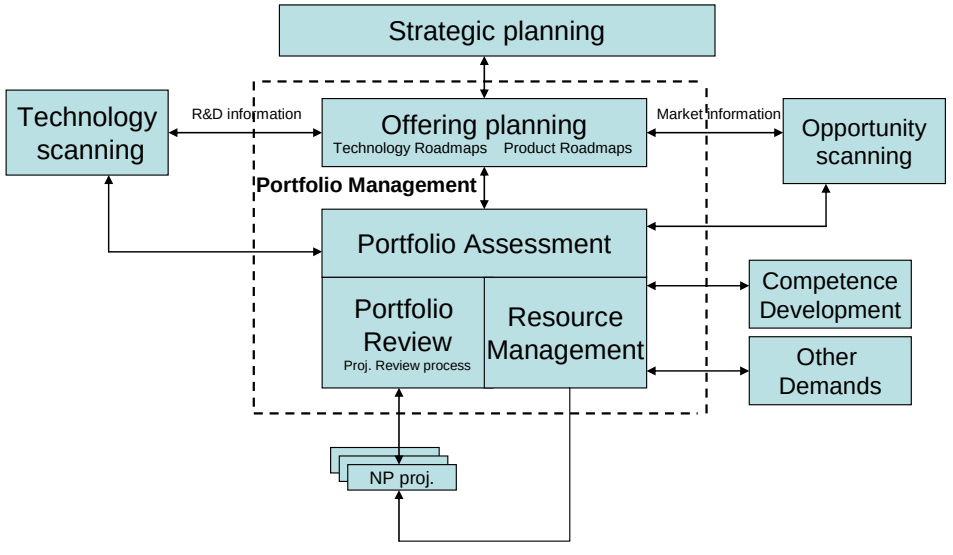

Figure 7. Offering planning and portfolio management activities (adapted from Patterson, 2005).

The offering planning process starts by the definition of current product offering in one (or more) business line. The next task involves the recognition of future targets, and is done by the members of the business leadership team. Thereafter, steps and actions for filling the gap between the state-of-the-art and future vision are defined. What is actually done is a roadmap for the offering of the company in the future. By applying the steps given above, a company will be able to create a strategic plan for new products (including services) and technologies that respond to the company strategy. The offering plan will be used as a guiding input for conseptualisation, because it sets a desired framework for the future product and technology investments. The results of the opportunity planning include

- roadmaps of future products and services
- roadmaps for future technology targets
- recognized business opportunities, i.e. proposals of new products or technology objectives for the current project portfolio.

The development of portfolio management processes needs to be done alongside the offering planning process, and includes methods and tools for portfolio assessment, resource management and portfolio review as well as criteria for decision making covering all critical decision making points of the entire innovation process. For more details, see (Paasi *et al.*, 2008a).

6. Co-ordination of commercialisation

Commercialisation is often understood to be the final stage of innovation process: 1) fuzzy front end, 2) new product development, and 3) commercialisation. Commercialisation-related data is typically only brought to the fore in the later phases of a new product development process, by which time most of the important factors affecting the success of the potential innovation are already fixed. This is often due to the fact that the commercialisation data of a new innovation is of a very uncertain and variable nature, and especially the revenue expectations are unpredictable in the chaotic fuzzy front end where the performance features, etc. affecting the attractiveness of the innovation are fixed. The commercialisation aspect should, therefore, be considered more strongly already at the fuzzy front end stage of innovation development. The INNORISK focus on the commercialisation success in the development of innovations is the management of the uncertainty of commercialisation-related information through the innovation process, but particularly in the front end. Practical risk management

tools and procedures for the commercialisation management of innovations were developed, in particular for the development of innovations where one aims to deliver a product, process or service with unprecedented performance features, see (Luoma, 2007 and 2008) for details.

An example of tool developed in the project is given in Figure 8. It is a risk map of commercialisation covering factors that should be consider in the front end of innovation process (Luoma *et al.*, 2008). It provides a basis for considering commercialisation risks and thereby offers important information for decision making. A risk map provides the company a clear general overview of the risks that threaten its operation (SME Risk Management Toolkit, 2002) and, on the other hand, of the opportunities that the company may face. Companies applying the risk map should carefully consider which factors in the sample risk map are critical to them, or whether any important factors are missing. According to Ulleberg (1993) the categorisation and evaluation of vulnerability risk factors is best done by a multidisciplinary team where different experts provide valuable approaches to the opportunities and threats.

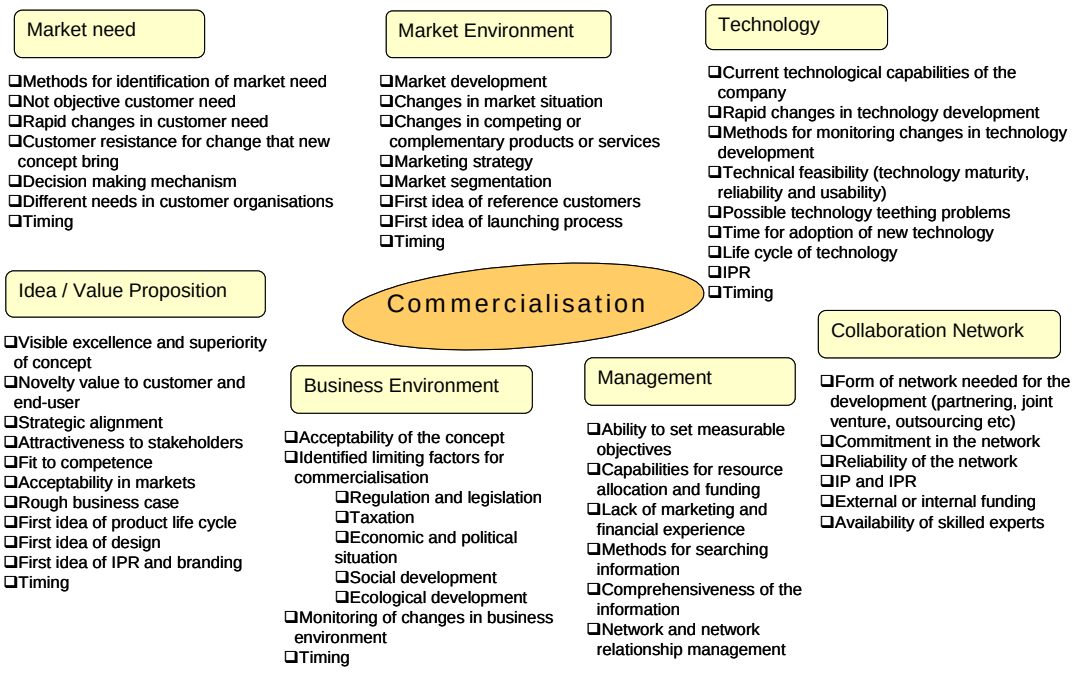

Figure 8. Commercialisation risk map supporting decision making in the front end of innovation development (Luoma et al., 2008).

7. Conclusions

This paper is a summary of the work done at VTT within the INNORISK project. The focus has been in the development of practical methods and tools for the management of opportunities, risks and uncertainties in new business creation. In order to ensure the functionality of the methods and tools, the work has been done in close collaboration with companies (both SMEs and large corporations). The guiding principle behind the work has been to apply the generic methodology of risk management to challenges related to new business creation.

New business creation starts from the recognition of a new business opportunity. Before the opportunity could be evolved into an innovation, we need a strong ability to make important strategic decisions, a capability to conceptualise the opportunity and to transform it into the final product, process or service, and to manage risks related to commercialisation. A major challenge related to all this is the question of timing. The INNORISK approach aims to support decision making in companies at critical points of the innovation process. The methods help companies to identify phases and elements in their innovation process where specific managerial or development actions are needed. As a result, the fuzzy front end of the innovation process is no longer so fuzzy. When elements and critical decision points in the front end have been identified, and information as well as decision criteria needed have been defined, the front end becomes controllable and actions for new business creation can be managed.

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6. Publication II: Managing uncertainty in the front end of radical innovation development

Jaakko Paasi, Pasi Valkokari, Pekka Maijala, Tuija Luoma & Sirra Toivonen

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland. E-mail: firstname.lastname@vtt.fi.

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Abstract: *The management of uncertainty in the development of radical technological innovations has been studied with a focus in the fuzzy front end stage of innovation development process. The development of innovations, which will be new to the company or even new to the world, is always very challenging and risky because of uncertainty in many aspects of the development and commercialisation processes. Tools and procedures used for the management of incremental innovation development, exploiting current lines of business, may not give much help in the case where one aims to deliver a product, process or service with unprecedented performance features.*

In this paper an opportunity and risk management based assessment model is proposed for the management of uncertainty in the front end of radical technological innovation. The core for the uncertainty management is the modelling of front end activities where five elements were identified: opportunity identification, opportunity analysis, idea generation and enrichment, idea selection, and concept definition. Other elements important in the uncertainty management include strategy, corporate culture, and networking. Important decision points were identified at opportunity analysis, idea selection, networking and at the

gate preceding product development stage. Special attention was paid to the development of tools and procedures for the uncertainty management at these important decision points. For examples, the tools include a new tool called Opportunity Balance Matrix and a new application of a known method called Potential Problem Analysis. The developed tools and procedures support decision making already at early phases of the front end work. Early decision making and upper management support can give effective guidance for the remaining front end work and make effective use of resources possible throughout the innovation process. All the uncertainty management actions will increase the possibility of successful product launch in the future.

The model for the uncertainty management has been applied in a few conceptualization cases at different companies and industries. In this paper examples of uncertainty management at the front end work of the Center for Printed Intelligence at VTT are given.

Keywords: *uncertainty management, fuzzy front end, conceptualization, new concept development, radical innovation, open innovation.*

1. Introduction

Exploring possibilities for new lines of business is vital for mature companies in order to sustain or increase the profitability of company in times of changes and crises taking place in the business environment. G. Hamel has said that the most important business issue of our time is finding a way to build companies where innovation is both radical and systemic (Hamel, 2002). The development of radical breakthrough innovations, which make new lines of business possible, is always very challenging and risky because of uncertainty in many aspects of the development and commercialization processes. Tools and procedures successfully used for the management of incremental innovation development exploiting current lines of business (e.g. Cooper, 1993; Cooper & Kleinschmidt, 1995; Ullrich & Eppinger, 2004) may not give much help in the case where one aims to deliver a product, process or service with unprecedented performance features because development projects for radical innovations are surrounded by multiple uncertainty. Leifer *et al.* have defined four major dimensions of uncertainty that are characteristics for all radical innovation development projects: technological, market, organizational, and resource uncertainties (Leifer *et al.*, 2000). The management challenge of multiple dimensions of uncertainty is complicated by the fact that the uncertainties interact with one another. Very few companies

have systems to overcome these management challenges and effectively commercialize radical innovations repeatedly (O'Connor *et al.*, 2004).

We have studied the management of uncertainty in the development of radical technological innovations (i.e. innovations new-to-the-company or new-to-the-world), with a focus in the fuzzy front end stage of innovation development process. We propose an opportunity and risk based assessment model for the management of uncertainty in order to overcome common problems faced by many companies at their fuzzy front end activities. The paper is arranged as follows. At first, we introduce the research approach and framework for our model. Then the model for the uncertainty management is described, and brief examples on the application of the model in practice are presented. Finally, conclusions are given.

2. Research aproach

The authors have long experience in technology R&D at research institutes, technical university, large corporations as well as in small and medium size enterprises which made the authors ask, *why large amounts of good R&D work resulting in advanced new technology are producing so little successful innovations?* The question initiates a research on the uncertainty management in radical technological innovation development. A large interview study was done about the innovation management practices in Finnish companies (in which most are operating in global markets). Important input came also from findings reported in textbooks (e.g. Chesbrough, 2003; Cooper & Edgett, 2005; Kim & Mauborgne, 2005; Koen *et al.*, 2002; Leifer *et al.*, 2000; von Hippel, 2005).

In Figure 1 we present the innovation management framework for radical innovation development used as a basis of the work (Meristö *et al.*, 2006). The innovation process is divided into four areas: foresight and concept development (which together form the fuzzy front end), the new product development, and commercialization. The framework includes also strategy (business, marketing, technology, innovation strategies) and resources (financial and intangible resources) elements. In the case of radical technological innovations it is important to take into account also the time span: markets operate in the short term, whereas technology R&D could last for years. The used framework is a novel way of thinking the innovation process as a loop, instead of classical 1-dimensional new product development process. In the framework, the market and business environment provide input for different stages of the innovation

process, particularly to the very beginning of the innovation process where the search for opportunities for new businesses and products is enhanced by the means of futures research and foresight studies.

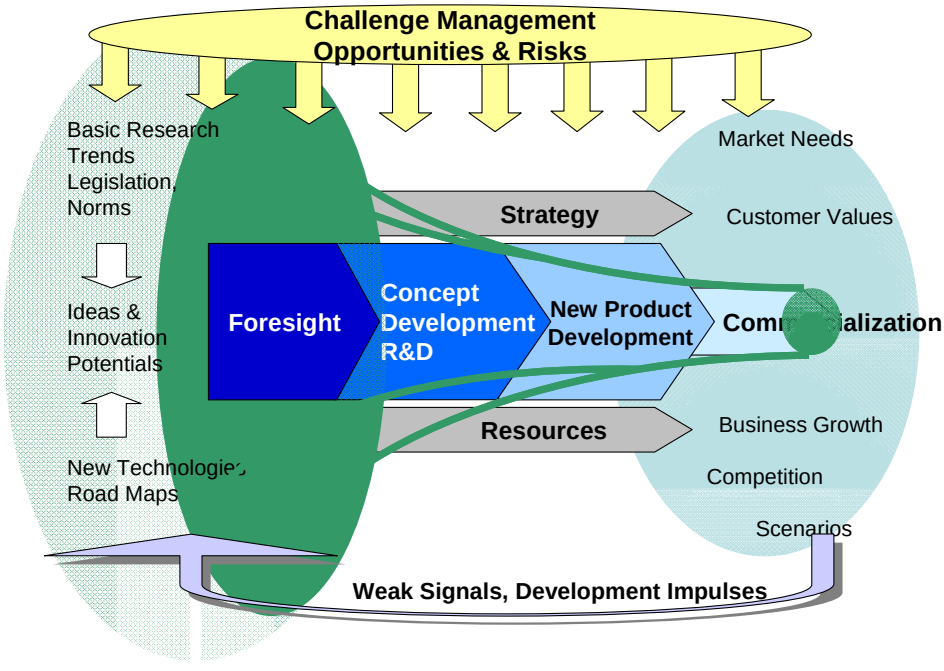

Figure 9. Framework of development process for radical innovations, including the management of opportunities and risks related to the development of new lines of business (Meristö et al., 2006).

The markets and foresight knowledge is linked with risk management throughout the process with the aim to optimise the innovation process in the new business creation. Figure 9 describes the entire process, but in this paper we will focus on the front end.

Based on how the fuzzy front end stage activities are organized at different companies and on authors' experience about technology R&D, new tools and procedures for the uncertainty management were developed. As a result, we are proposing a generic opportunity and risk based assessment model for the management of uncertainty in the front end of breakthrough innovation development. The main goal has been to develop an easy-to-use, proactive risk-management model for uncertainty management in order to overcome common problems faced by many companies at their front end activities. The major challenge of

companies is in the development of new lines of business, but the results are equally important to cases where existing technology (or technology based service) is applied for new markets or new technology (or technology based service) is applied to existing markets, Figure 10. The model is not so relevant for incremental innovation development supporting current lines of business where the uncertainty of information is small if compared to the other three cases.

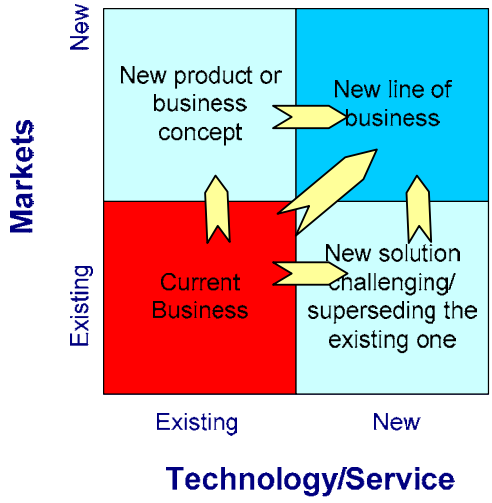

Figure 10. Uncertainty of information is high in those boxes of technology/service vs markets table where new technology and/or new markets are involved. In these cases systematic risk management actions should be taken (instead of an ad hoc approach) in order to make right decisions at different stages of innovation process.

The model has been field-tested in a few conceptualization cases at different companies and industries with good response from the companies. However, it will take several years until statistically reliable results will be available about the true success of the model in minimizing the submission of false projects (i.e. projects for products which will have no or minor commercial success in the future) into the new product development and commercialization, because the time from concept to product launch is often long for radical technological innovations. In this paper, brief examples on the application of the model in the front end work at the Center for Printed Intelligence of VTT are given.

3. Front end of innovation development process

Managing the front end is the key for successful innovation. Many important factors affecting the success potential of a radical innovation are already fixed before the innovation project enters the new product development stage. In order to manage the front end, it must be modelled. This means that phases, elements, and decision points should be identified, inputs and outputs to and from each phase should be defined, information used at decision points should be identified, etc.

The New Concept Development (NCD) model by Koen at al (Koen *at al*, 2002) provides a good and generic starting point for the management of the fuzzy front end / concept development stage[1]. The NCD consists of five elements: opportunity identification, opportunity analysis, idea generation and enrichment, idea selection, and concept definition, Figure 11. We have extended the original NCD model and strengthened the open innovation -philosophy in the model. Open innovation means different ways of leveraging external sources of technology and innovation to drive internal growth and the spin-off and outsourcing of unused intellectual property (Chesbrough, 2003). The open innovation is included in the model so that user-centred innovation (von Hippel, 2005) as well as basic and applied research done in companies, universities and research institutes are interactively linked to the NCD stage (see "Networks, R&D" in Figure 3): on one hand it provides input for different process elements as well as direct participation in the elements and, on the other, the NCD elements define the possible research and networking need. Foresight and market need information provides another input for the NCP engine. The NCD engine starts either at opportunity identification or at idea generation, but it does not have to proceed in the given order. Sometimes it may be necessary to rotate several cycles, and even come back to foresight and market information or Networks and R&D, before the concept is ready for gate decision preceding New Product Development (NPD) or other action (kill, recycle, hold, sell). See the original work for more details (Koen *et al.*, 2002).

[1] A concept is in our work understood as a well-defined form, including its primary features and customer benefits combined with an understanding of the technology needed, together with defined business idea (case) about how the company will make profit by the foreseen product defined by the concept. The definition is wider than what is traditionally understood as a concept (Ullrich & Eppinger, 2004) because both technological and business aspects are included.

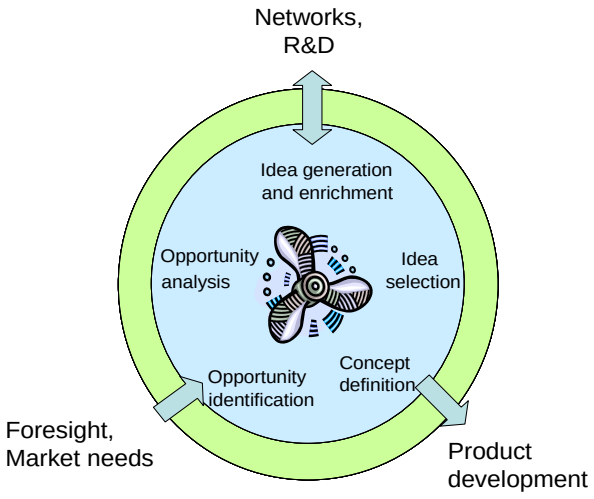

Figure 11. New Concept Development (NCD) model (engine) with its five core elements.

The figure is a simplified re-drawing of the original NCD engine of Koen *et al.* (2002) with an emphasis on uncertainty management aspects in an open innovation environment. The elements inside the engine can proceed in any order making the stage fuzzy. The engine could rotate several rounds before the concept is ready for the gate decision preceding the new product development or other management action.

In the used framework, the NCD stage includes both the development of technological (or service) concept and the business case related to the concept. It is no matter whether an idea of a new product or business concept is discovered first. The idea roams in the engine as long as the concept is ready both in technological and business aspects.

4. Model for the uncertainty management

A practical proactive risk management procedure for the uncertainty management should guide the creativity in the front end through the complexity of the modern business environment by using a handful of simple rules and tools which allow simultaneous and systematic analysis of opportunities and threats. At the same time, it should enhance the conceptualization (NCD) process and minimize the risk of submitting false projects (i.e. projects for products or services with unlikely commercial success) into the new product development and commercialization stages.

We have applied the NCD model and implied the uncertainty management into the elements of NCD in order to have a proactive uncertainty management model. An overview of the developed model is presented over the NCD engine in Figure 12The elements of the NCD model and how the uncertainty management can be done at the elements are described in more detail in the following subsections. We have aimed to a generic model. The necessary depth of analysis using the model, however, depends on the field and nature of business, company's size, company's role in its value network, etc. Therefore, some customizing is usually necessary when applying the uncertainty management model in practice.

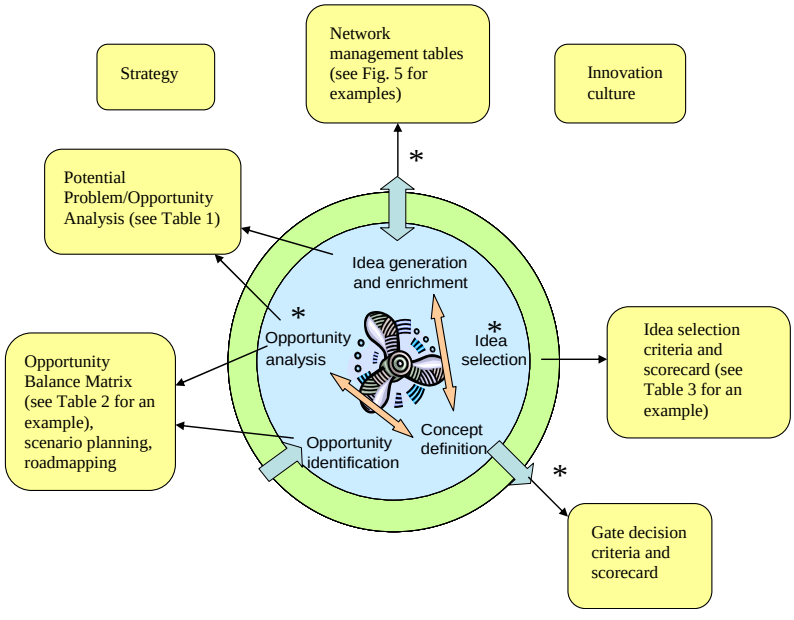

Figure 12Overview of key elements, tools and procedures in the uncertainty management model for the front end stage of radical innovation development. Critical decision points are indicated by an asterisk. Part of crucial decision making has been advanced in the model from the gate at the end of the front end stage to earlier phases of the front end and, by this way, the management of uncertainty has been improved and the future success potential of innovation has been increased.

5. Opportunity identification and analysis

Opportunity identification defines the market or technology arena the company may want to participate in. It brings input for the conceptualization work. A company may have a formal opportunity identification process or it may be informal, including ad hoc sessions or individual insights. Opportunity identification may precede idea generation or, if an idea already exists, idea enrichment. Methods commonly used in the opportunity identification include market need analysis, market research, technology trend analysis, roadmapping, scenario generating techniques. In the case of radical innovation development, the major challenges of companies in the opportunity identification are to broaden the standpoint sufficiently out of the current lines of business and to include the long time frame into the consideration with sufficiently alternative scenarios for the future, confronting the prevailing mind-set.

Opportunity analysis translates the opportunity identification into specific business and technology opportunities. It has a strong link to strategy and strategy work by translating strategic goals into conceptualization and vice versa. The methods used in the opportunity identification apply also in the opportunity analysis, but the effort would be considerably expanded. The opportunity analysis includes also making early technology and market assessments. The level of detail in these assessments is directly related to the uncertainty of conclusions of the opportunity analysis.

In the search of radical innovations, a challenge is to broaden the standpoint sufficiently out of the current lines of business. In this aspect, Potential Problem/Opportunity Analysis, (PPA) (Kepner & Tregoe, 1981; Reunanen, 1993) can be used as an effective method in the opportunity identification and analysis. PPA is quite commonly used expertise group method to identify potential safety hazards in process industry, but the method directly applies to obtaining general view of attractive opportunities from the mass of potential business and technology opportunities. The phases of PPA when applied to opportunity identification and analysis are given in Table 4 The core of PPA is silent brainstorming sessions of an expert group having sufficiently different expertises. One advantage of PPA is based in the belief that one can glimpse into the future, see what it may hold and then return to the present to take the action when it can do the most good (Kepner & Tregoe, 1981). The wide perspective applied to analyzed opportunities restricts the profoundness of the analysis results. Therefore, further evaluation of the analyzed opportunities is required. On the other hand, PPA

could combine opportunity analysis and idea generation and enrichments phases of the NCD model.

A major challenge in the decision making of opportunity analysis is to manage the large amount of uncertain information produced at the opportunity identification and analysis. The time span tension between short term market operations and long term technology R&D bring additional challenges to the decision making. In Table 5 we present a new tool, Opportunity Balance Matrix (OBM), which we have developed for the management of uncertainty at the opportunity analysis. The matrix includes potentially important market need and foresight factors. PPA steps A and B (Table 4 could produce a lot of input to the Opportunity Balance Matrix. The factors and necessary depth of an analysis will vary from business to business, depending also whether it is a question of a SME or a large corporation with global operations. The standpoint in the different factors of OBM is focused to the new concept opportunity (including business and technological aspects). The uncertainty of foresight and market need information is managed by generating three (or more) possible futures: optimistic, pessimistic and likely. Usually, a company develops product concepts only for the most likely future. However, the company could also prepare itself and create readiness, competences and agility by developing alternative concepts for other probable futures and by this means minimize the influence of future uncertainty (Kivistö-Rahnasto *et al.*, 2000; Vuori *et al.*, 2001; Peltola *et al.*, 2003). Preparation for alternative futures is the more important the longer is the time span of study. Finally, opportunities and risks related to specific factors in each possible future are ranked.

Table 4. Steps and phases of Potential Problem / Opportunity Analysis (PPA) when applied to the fuzzy front end stage of innovation process.

A. Identification of opportunities

Phase 1
- Ideas of opportunities are sought by silent brainstorming

Phase 2
- Ideas are sought by silent brainstorming
- Keywords are applied to stimulate the search for ideas
- Special attentation is paid to major opportunities

B. Evaluation of opportunities identified

Phase 1
- Identification of true opportunities and selection of them for evaluation

Phase 2
- Identification of the contributors for the selected opportunities
- Ranking of key contributors and opportunities

C. Idea generation and enrichment based on the results of Step B.

Phase 1
- Ideas of are sought by silent brainstorming

Phase 2
- Ideas are enriched by silent brainstorming
- Keywords are applied to stimulate the idea enrichment

Phase 3
- Most promising ideas are selected for further evaluation

The example OBM shown in Table 5 is for a case where uncertainties related to the technology were not high and main interests of uncertainty management were elsewhere. When uncertainties related to technology are high, there should be more technology related factors in the Opportunity Balance Matrix.

The OBM is useful in the management of uncertainty of information used for the decision making, but the decision making may need also other tools to manage the large amount of information. Roadmapping is a good example of powerful tool in linking market needs and drivers with available, feasible and possible technology into specific and desired business opportunities (Phaal *et al.*, 2004).

Table 5. Example of an Opportunity Balance Matrix (OBM) used for the opportunity analysis. The number of sub-factors under each main category typically varies from 3 to 10. Opportunities and risks related to each sub-factor are ranked from 1–5 (1 = low opportunity/risk … 5 = high opportunity/risk) for three possible futures.

	FUTURE			OPPORTUNITY (1 - 5)				RISK (1 - 5)		
FACTOR	**Optimistic**	**Pessimistic**	**Likely**	**Weighting**	**Optimistic future**	**Pessimistic future**	**Likely future**	**Optimistic future**	**Pessimistic future**	**Likely future**
Technological environment										
Manufacturing technology					5	1	4	2	5	3
Information technology					5	3	5	2	5	2
etc.										
Special technology assessments										
Maturity					5	2	4	1	4	3
Substitute technologies					5	1	4	1	5	2
etc.										
Market environment										
General market trend										
Market segment 1										
etc.										
Market needs										
Future potential 1										
Future potential 2										
etc.										
Competition environment										
Competitors										
Potential entrants										
etc.										
Interest groups										
Owners										
Financiers										
etc.										
Political environment										
Legislation										
Financial support										
etc.										
Social environment										
Health and safety										
Security										
etc.										
Ecological environment										
Global warming										
Waste										
etc.										

Example

VTT Technical Research Centre of Finland is an impartial expert organization with 2 700 employees. Its objective is to develop new technologies, create new innovations and value added thus increasing the competitiveness of its customers. VTT has made successful small-scale basic research on printed intelligence for a few years. According to a Frost & Sullivan market study, the market for organic and printable electronics is expected to be a $35 billion industry by 2015 and reach over $300 billion in 2025. The European market share is assumed to be one-third of the global market and production is expected to keep near the markets. Based on this and a few other foresight studies, VTT made a strategic decision to the scale-up its activities in the field of printed intelligence. A detailed opportunity analysis, with a special emphasis on anticipated future markets needs, own technological strengths and competition environment analysis (an OBM study), resulted in a decision to focus on the generic technology of

roll-to-roll manufacturing and start to look for concepts for potential innovations based on roll-to-roll manufacturing techniques. Three strategic fields were chosen for concept development: bioactive paper and fiber products, multi-technological smart products, and ICT/electronic products. Roadmapping was used as the final tool in the decision making.

6. Network

Innovation processes of companies are becoming more and more open so that partners of value network (existing or potential) do have active role in different elements of fuzzy front end, new product development and commercialization stages. In the front end stage, lead user-centred innovation has in many cases resulted in greater commercial attractiveness of the innovation than the classical way where the lead users only gave input to the conceptualization work but did not take part in the actual work (von Hippel, 2005). Furthermore, universities, research institutes, R&D companies, start-ups, etc. can supplement in-house R&D in many aspects by bringing input to the conceptualization, taking actively part in the different elements of conceptualization work, and carrying out R&D work defined by the conceptualization.

The open innovation philosophy and networking bring additional challenges into the uncertainty management related to radical technological innovation development. By networking (open innovation) it is possible to share and lower the risk of false innovations and resource usage. On the other hand, networking increases complexity and organizations have a risk of being engulfed in the complexity of relationships, ideas, projects that need to be managed. It is highly important to have right key people in the network with inspired leadership and aligned incentives. Perhaps the most challenging and difficult issues relate to intellectual property rights (IPR), particularly in the case of radical innovations aiming to new markets (which do not exist yet). Key questions are how to define the value of IPR and how to share IPR between different players in the network? For the IPR share there are several possibilities: fully protected IPR, partially protected (open to partners but not for everyone), or fully open source approach. In the open source approach there will be no IPR incomes, but there are lots of examples how it have proved to be a powerful way in creating new markets to radical innovations (for example, open source or free softwares and services subject to a charge built above that). Overall, practices related to open innovation are new and there is little long-term experience available. Therefore, all

important challenges related to the uncertainty management in the Network element of front end stage may not have been identified, and further research is needed for that.

An example of tables that can be used in managing uncertainties and risks related to networking at the front end stage of radical technological innovation development are given in Figure 12. There could be an own table for each critical issue, such as technology, competence, resources, people, IPR, etc. The idea of the tables is to find out critical subjects in the network which may need specific risk management actions. They may also serve for the selection of partners for a specific conceptualization and innovation work.

COMPETENCE	Network partner									
	In-house R&D	University 1	University 2	Raw material supplier 1	Raw material supllier 2	Manufacturer 1	Manufacturer 2	Lead-user 1	Lead-user 2	
Conductive ink	1		3	4						
Customer packaging solutions						3	2	4	4	
Machine vision	5	5								
etc.										
	Level of competence									

RESOURCES	Network partner									
	In-house R&D	University 1	University 2	Raw material supplier 1	Raw material supllier 2	Manufacturer 1	Manufacturer 2	Lead-user 1	Lead-user 2	
Human resources	1	1	3	4	3			5	3	
Financial resources				4	3	4	2	4	4	
Equipment	5	5				5	2			
etc.										
	Level of resources									

Figure 12. Examples of tables used for the management of uncertainties related to networking. There can be own tables for each critical issue under consideration, such as technology, competence, resources, people, IPR, etc.. Factors are ranked from 1 to 5 for each potential network partner, and remarks related to specific benefits and risks can be done.

Example

The VTT vision in the field of printed intelligence is to be globally the leading innovation centre in roll-to-roll printed intelligence. Accordingly, activities will happen in an open innovation environment where profits will be gained by contract research and other cooperation models for R&D services, licensing, start-ups and joint ventures. IPR strategy was defined and building of networks for chosen fields of interest was started. In some cases network building started before any detailed idea of concept, in other cases a network was built around an existing idea or concept. In former cases there were stronger multidisciplinary involvement in different elements of conceptualization, while the latter cases allowed more freedom to partner selection based on competence and resource suitability. Different kinds of tables have been used to find out critical subjects where risk management actions may be needed.

7. Idea generation and enrichment

Idea generation and enrichment is the most creative part of the front end stage. It is an evolutionary process. An idea may go through many iterations and changes while interacting with other elements of the NCD model. Idea generation is seldom the weakest link in companies' innovation process, but most ideas are typically supporting current lines of business. Special actions may be needed to promote idea generation for innovations new-to-the-company or new-to-the-world.

The role of uncertainty management in the idea generation and enrichment is to guide the creativity to desired direction. Opportunity identification and analysis give a good guidance for that. The step C of PPA (Table 1) belongs to the idea generation and enrichment phase, based on the selected opportunity. A useful practice is to identify drivers related to opportunities and to use that information as input for idea generation and enrichment. Another useful practice is to have customers and other players from company's value network actively involved in the idea generation and enrichment (user-centred innovation), as already described in the beginning of sub-section Network.

8. Idea selection

Once ideas have been generated, the challenge is in selecting right ideas from the mass. Management of uncertainty related to the idea selection is very much of having defined selection criteria and process, which are transparent to all at

the organization. Transparent selection criteria and process are important because most businesses tend naturally to reject disruptive innovation ideas which do not provide value to company's current customers but addresses to potential new customers (Bower & Christensen, 1995).

At idea selection it is important to understand that, in the case of potential radical or breakthrough innovation, uncertainties are high and many aspects of potential innovation may be open – it is just a question of an idea, not a defined concept. It is neither possible nor relevant to go into such details as it will be done in gate decision point preceding the new product development stage. Selection decisions are done using incomplete and uncertain information, and that should be taken into account when making tools which help the selection of ideas.

An example of simple scorecard that we have developed for idea selection is given in Table 6. The scorecard is two phased. Phase 1 is based on qualitative analysis (due to the lack of reliable quantitative figures) about product advantage, market attractiveness and financial reward vs. risks. Minimum hurdles must be passed in all three aspects for an idea to go into Phase 2. In Phase 2, the idea is qualitatively assessed for strategic alignment, fit to competence, human resource and technical feasibility points of view. For these aspects there are no minimum hurdles, but weak rating in several aspects would lead to the rejection of idea. The main intention in Phase 2 is to give guidance and suggest risk management actions in order to reduce uncertainty factors for a promising idea of innovation. Such actions may include addressing the technical gap, suggestions for network build-up, input to strategy work, etc.

The scorecard in Table 6 is an example. Some customizing may be required when applied into a specific company or business. For example, technical feasibility may reserve more attention if there are high uncertainties related to technical questions.

Table 6. Example of a simple scorecard used for the selection of ideas for radical technological innovations.

Phase 1					
	Rating scale				
Criteria	1	5	10	Minimum hurdles	Rating
Product advantage	Marginal customer benefit	Moderate customer benefit	Unique customer benefit	Yes	
Market attractiveness	Extensive market development required	Clear relationship between product and need	Product immediately responsive to large customer need	Yes	
Financial reward vs. risk	Limited opportunity	High opportunity but also high risks	High opportunity and low risks	Yes	
Phase 2					
	Rating scale				
Criteria	1	5	10	Following actions	
Strategic alignment	Only weak fit with current strategy	Good fit with key elements of strategy	Strong fit with several elements of strategy		
Fit to competence	Weak fit with existing competence	Missing competence available by networking	Perfect fit to competence		
Human resources	Only reduced resources available	Missing resources available by networking	Well available		
Technical feasibility	Big gap	Some gap or questions, but attainable	Enabling technology available		

Uncertainty related to the process can be reduced by having a special radical innovation hub operating under upper management, which executes the idea selection and coordinates consequent conceptualization actions, including financial resources for the conceptualization work (Leifer *et al.*, 2000; Koen *et al.*, 2002).

Example

Ideas of innovative technology solutions, applications and business concepts are evaluated by the management group of VTT's Center for Printed Intelligence by using a simple scorecard, similar to that of Table 6. Uncertainty of information is typically very high at this stage, many details may be missing, and the idea seldom consists of both technological and business cases. Special attention is typically paid on qualitative information on anticipated user benefit, market attractiveness and rough financial reward vs. risk analyses where minimum hurdles must be passed.

9. Concept definition

Concept definition is the final element of the NCD model. In the case of radical technological innovation development, both technical and business aspects of the concept become seldom ready at once, and the work requires going back to other elements of the NCD engine. The philosophy of the proposed model for the uncertainty management is to consider and proactively minimize uncertainty factors as soon as they appear in the NCD engine and, therefore, many uncertainty factors are minimised already before the concept definition work. Some uncertainty management actions still remain for the concept definition element. The different time spans between market operations and technology R&D lay uncertainty over the whole conceptualization work. Risks due to the time factors could be managed at concept definition by pursuing alternative approaches and concepts for possible futures defined at opportunity identification and analysis. Alternative concepts may increase the possibility for future success. Lead-user involvement in the concept definition work (whenever possible) has been found to give good end results (von Hippel, 2005; Koen *et al.*, 2002). Finally, the concept evaluation criteria used at the gate preceding the New Product Development stage can effectively guide the concept definition work. Experience has shown that transparent and properly chosen gate decision criteria pull the concept definition work to a right direction which increases the possibility of successful product launch in the future.

10. Gate decision to NPD

Management of uncertainty plays an important role when making a decision what to do with the defined concept: shall we let it go to the New Product Development stage, hold it, return back to NCD for enrichment, try to sell it, or simply kill it? In the case of incremental innovations economical figures play an important role in making the decision. Uncertainties related to figures could be small when the innovation is aiming to existing, known markets. In the case of radical innovations, however, economical figures contain high uncertainties because the target markets may not exist yet. Therefore, criteria for radical innovations must be different, more qualitative than for incremental innovations. The criteria should cover similar aspects than at idea selection – product advantage, market attractiveness, financial reward vs. risk, strategic alignment, fit to compe-

tence, human resources, technical feasibility – but now in much more detail. There could be minimum hurdles that have to be passed at all seven aspects.

A good experience has been to implement the criteria into a scorecard and have multicriteria decision making in order to minimize the risk of poor decisions (naturally the criteria and their scoring as well as weighting should be properly done). Good examples of gate decision lists and scorecards that have been successfully used in industry for the evaluation of concepts of radical technological innovations can be found in literature (e.g. Cooper *et al.*, 2001; Dunham, 2002; Koen *et al.*, 2002).

11. Strategy

Strategy is highly important factor in innovation development. In the case of innovations supporting current lines of business, strategies (including business, market, technology, innovation strategies) set-up the frames for the entire innovation work from the fuzzy front end, through NPD to commercialization. In the case of potential innovations which are new-to-the-company (or even new-to-the-world), the situation becomes more complicated. Opportunities, ideas, or concepts of breakthrough innovations are giving input to the strategy work. Therefore, the link between strategy and conceptualization works should be strong and interactive when aiming to innovations new-to-the-company (or new-to-the-world).

Uncertainty related to future is typically taken into account in the strategy work by generating alternative long term scenarios of future and by adding actor's perspective to the future scenarios. If the strategic approach is focused towards renewal, changes in the business environment do not come as surprises and would not lead to crises. Instead, companies are prepared to implement radical changes in their business models and to renew product portfolios. Therefore, there should be a strong and interactive link between strategy and fuzzy front end works in order to manage the uncertainty of future in business-driven innovation processes (Meristö *et al.*, 2006). So far uncertainties related to strategy are, in the proposed uncertainty management model for the front end work, taken into account only indirectly at decision points related to opportunity analysis and idea selection by giving alternative futures and by the possibility to send well-founded input to the strategy work. That may be insufficient. Enlargement of the proposed uncertainty management model to cover aspects of strategic focus and renewal in more detail is in progress.

12. Corporate and innovation cultures

Corporate culture, in general, and the innovation culture of company are also very important factors affecting on uncertainties related to the radical innovation development (Figure 4). In the information and process focused uncertainty management model, uncertainty related to individuals can be taken into account only weakly at network, idea selection and gate decision criteria. That may be insufficient because personalities of people involved in the front end stage of radical innovation development and how these people are organized have high impact on the overall success of the innovation (Simon *et al.*, 2003; Stevens *et al.*, 2003). The support of upper management from the very beginning is important for the success of breakthrough innovations and plays a key role in the management of uncertainties due to the culture of the company (Leifer *et al.*, 2000; Swink, 2005).

13. Conclusions

We have proposed an opportunity and risk management based assessment model for the management of uncertainty in the front end of radical technological innovation development. The uncertainty can deal with the reliability of foresight and market need information, technological aspects, ranking of ideas and concepts, open innovation and networking issues, organizational and resource uncertainties, etc.

The core for the uncertainty management is the modelling of the front end activities for radical innovations. The following front end elements have been identified: opportunity identification, opportunity analysis, idea generation and enrichment, idea selection and concept definition. The front end activities will start either at opportunity identification or idea generation, but after that the conceptualization may proceed in any order making the stage fuzzy. Other elements important in the uncertainty management include strategy, corporate culture, and networking together with R&D. Important decision points were identified at opportunity analysis, idea selection, networking, and at the gate preceding the new product development. Special attention was paid to develop tools and procedures for the uncertainty management at these important decision points. The aim was to move the most crucial decision making into earlier phases of the front end stage with respect to common decision making in the case of incremental innovation development, where the uncertainty of information is small if

compared to radical innovation cases and where first decisions may happen only at the gate preceding new product development. An early support for decision making can effectively guide the conceptualization work at the different elements of front end to a direction which increases the possibility of successful product launch in the future. Early decision making also supports effective use of resources throughout the innovation process.

We have applied the uncertainty management model in a few very different conceptualization cases in different companies and industries with good response from the companies. However, it will take several years until statistically reliable results will be available about the true success of the model in minimizing the submission of false projects (i.e. projects for products which will have no or minor commercial success in the future) into the new product development and commercialization stages, because the time from concept to product launch is often long for radical technological innovations. One should also keep in mind that concept development is only one stage in the renewal of companies business. Management of future uncertainty should include the whole innovation process when aiming to technological breakthrough innovations: a full uncertainty management model should cover, in addition to the conceptualization work, also future and foresight studies, strategy work, product development, commercialization, networking and open innovation aspects. Work towards the enlargement of the proposed model is in progress.

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7. Publication III: Commercialisation success in innovation development

Tuija Luoma* & Jaakko Paasi

* Corresponding author

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland. E-mail: tuija.luoma@vtt.fi, jaakko.paasi@vtt.fi.

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Abstract: *A risk management methodology has been applied to the commercialisation management of innovations, with a special emphasis on innovations where one aims to deliver a product, process or service with unprecedented performance features. New tools and procedures have been developed in order to increase the probability of successful commercialisation of technological innovations. A guiding principle has been to expand the consideration of commercialisation questions and risks from the late phase of new product development and product launch to the very beginning of the innovation process, where important decisions related to the market attractiveness of the new product are made. The goal of the work has been to develop simple tools and procedures to support the commercialisation decision making particularly at SMEs where resources for in-depth analysis are often very limited.*

Keywords: *commercialisation, uncertainty management, radical innovation, commercialisation risk.*

1. Introduction

Successful commercialisation of an innovation can be very challenging, particularly if the innovation involves a new technology and can be considered as radical containing an entirely new set of performance features [1]. It is often asked that is it possible to manage the commercialisation so that success is followed, and, if yes, how it should be done? Cooper emphasises that strong market orientation in new product development is critical to success, and that it is missing in the majority of companies' new product development projects [2]. Rogers says that innovation is a change in market or society and entrepreneurship always needs to be market-focused, indeed, market-driven [3]. Market viewpoint is very important and should be taken into consideration as early as possible in new product development process. According to Kotler and Keller the development of a high-tech product contains high technological and market uncertainty, high competitive volatility, high investment costs, low variable costs and short life [4]. Leifer *et al.* emphasises the high uncertainty (organisation, resource, technical and market) of breakthrough/radical innovations. Incremental innovations have lower uncertainty level [1].

We have studied the commercialisation success in the development of innovations by focusing to the management of uncertainty of commercialisation related information through the innovation process. The goal has been to develop simple risk management tools and procedures for the commercialisation management of innovations at small and medium sized enterprises (SMEs), with a special emphasis of innovations where one aims to deliver a product, process or service with unprecedented performance features.

2. Research approach

The research is based on interviews of innovation commercialisation practices at companies of various sizes and from different business areas as well as findings reported in literature [see e.g. 1, 2 and 4–7]. The results of the interview and literature studies were discussed in workshops with wide range of experts with an aim to find out weakness in the commercialisation practices of companies in the case of radical innovations new-to-the-company or new-to-the-world and to find out ways to increase the probability for commercialisation success. Finally, new risk management based tools and procedures were developed in order to overcome commercialisation problems commonly faced by companies. The developed tools and procedures consider the commercialisation from the new

innovation (product) standpoint. Other standpoints may need other tools and procedures.

As the goal was to develop simple tools for the use at commercialisation decision making at SMEs, we focused on tools and procedures which give at a glance an overall picture of uncertainties and opportunities (and attendant success factors) concerning commercialisation, helping agile decision making at different stages of innovation development process. We paid less attention to the statistical reliability of data used in decision making and other factors often used in in-depth business risk evaluation [8] (they are important but SMEs typically have very limited resources to pay attention to such questions). We have aimed to generic risk management tools and procedures for the commercialisation success management, underlining the fact that some customising may be required the generic tools into a specific company and business. The tools and procedures have been field-tested in a SME with a successful product launch.

3. Risk management tools and procedures for commercialisation success management

Commercialisation is often understood as the final stage of innovation process: 1. fuzzy front end, 2. new product development process, and 3. commercialisation. The commercialisation data is usually brought into discussion not until at the late phases of new product development process, in where most of the important factors affecting to the success of the potential innovation are already fixed. That is often because commercialisation data of new innovation is very uncertain and variable and revenue expectations are unpredictable in the chaotic fuzzy front end where the performance features, etc. affecting the attractiveness of the innovation are fixed. Therefore, commercialisation aspect should be strongly present already at the fuzzy front end stage of innovation development. The high level of uncertainty related to commercialisation information should be managed by scenario generating techniques and risk management methods [9, 10].

In Figure 13 we present the commercialisation management framework used as a basis of this work. The commercialisation process is modelled as a funnel with many layers, instead of the final stage in classical 1-dimensional new product development process. In the chosen framework, market information is fed to the very beginning of innovation process where the search for opportunities for new businesses and products is enhanced by the means of future research and foresight studies. In this framework, risks related to commercialisation are taken

into consideration already at the early stages of innovation process. Commercialisation procedures and marketing strategies shape up little by little when the process progress, and they do not come up unexpectedly when the product is ready. During the process the commercialisation risks become more concrete and focused for example from the common level of market situation risks to more concrete levels of launching and after-sales risks (timing, marketing material, etc.).

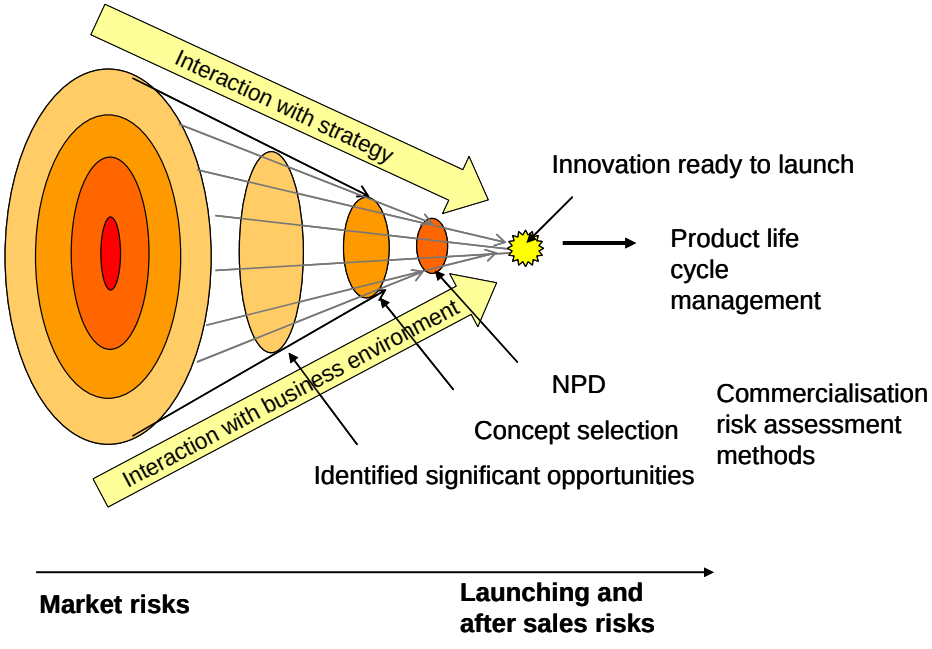

Figure 13. Framework of commercialisation process in innovation development.

Risk management, in general, aims to protect the property, income and different activities of company and yet keeping the total cost as low level as possible. Risk management is a systematic approach which supports the search for the optimum risk/cost level. Risk management is a managerial approach. Risk analysis is a tool used for hazard identification and assessment and it gives a basis for evaluating tolerability of risks and for deciding on necessary risk reducing/controlling measures [11].

We have exploited risk management methods into commercialisation management. In this work we understand risk management as the management of both uncertainties and opportunities so that the risk management is naturally

built-in the processes of company, such as strategy work, product development and marketing. The main steps of risk management are shown in Figure 14, which gives also an overview of the commercialisation success and uncertainty management model. The steps and methods of the model are described in more detail in the following subsections. The presented model gives a simplified example on how commercialisation risk management can be integrated into the innovation process. Companies should make it more focused and detailed to their own business fields.

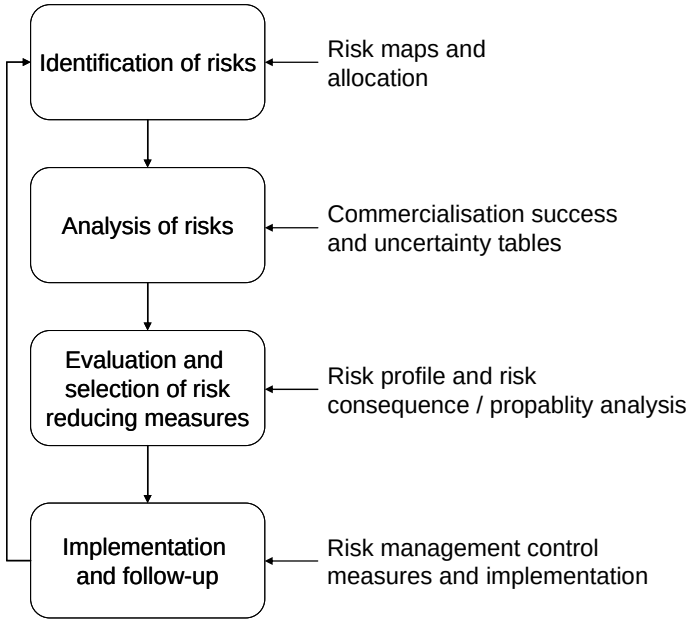

Figure 14. The main steps in risk management [simplified from 11] and overview of key elements, tools and procedures in the commercialisation success and uncertainty management model.

Identification of risks

The first step in the management of commercialisation risks (and attendant commercialisation success) is based on the use of risk maps. A risk map provides a basis to consider commercialisation risks and thereby offers important information for decision making. A risk map is part of a vulnerability analysis. The term “vulnerability” describes the uncertainty related to risk management

that threatens a company's operation. The risk map provides a company with a clear general picture of risks that threaten its operation [12].

The commercialisation risk map is divided into different risk groups – market/marketing, product/concept, technology, business, environment, commitment and launching process, see Figure 15.

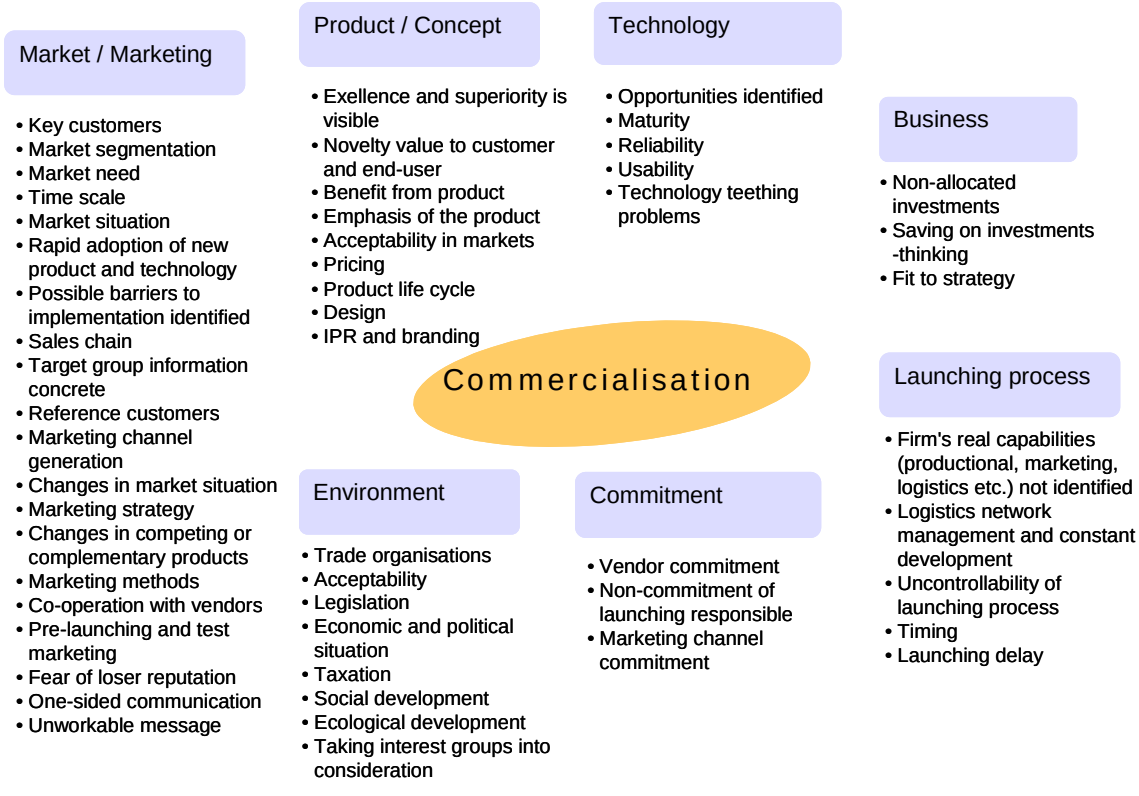

Figure 15. Commercialisation risk map.

The commercialisation risk map includes also product and environment viewpoints. The understanding of the product itself is very important in the commercialisation process. The benefit to customers and the customers' customers, the level of used technology and target markets have an effect on risks which the commercialisation process of an innovation contains. The commercialisation decisions calls output from company's present environment and future trends.

Different analyses, for example, company, environment, competitor and market analyses, give important information for the commercialisation decision

making but it is important also to pay attention to the relevancy and accuracy of that information. For instance, misunderstanding of the environment analysis could lead to serious troubles within the commercialisation process. Rapid giant steps in technology may cause that the new potential innovation based on old technology is no more desired by the markets. If the company could foresee those rapid changes beforehand, it would have competitive advantage and make correct decisions for the innovation development. However, it is difficult to evaluate all these factors so that an overall picture of all influencing factors is seen at a glance.

The risk map provides an excellent overview of factors affecting the commercialisation. In the following, the commercialisation risk map will be applied to the four different phases of innovation process: 1. opportunity identification, 2. concept selection, 3. new product development (NPD), and 4. launch decision. In Figure 16, we have brought the risk map to preceding phases as main categories as an example. Companies applying the model should consider carefully which factors in the example risk map are critical to them, or are there any factors important for them missing.

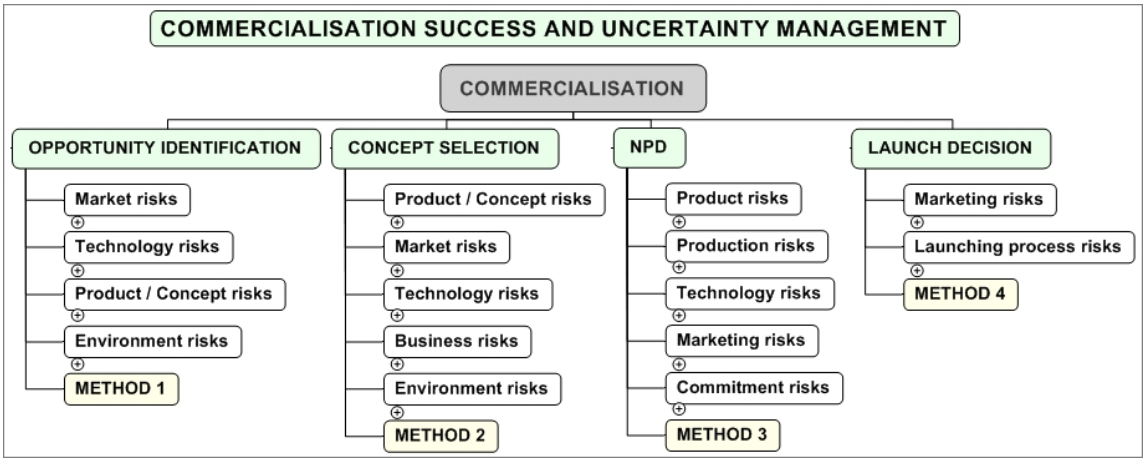

Figure 16. Commercialisation success and uncertainty management in the innovation development.

Analysis of risks

The necessary information for the commercialisation decision making is brought together in a success and uncertainty management table. The success and uncertainty management tables are meant to use in a SME's expert group where each expert gives their assessment of the factors. In Tables 7–10 there are presented success and uncertainty management tables for phases 1–4: opportunity identification, concept selection, NPD and launch decision. There are statements for every main category and these statements are ranked as follow:

1 = I strongly disagree with this statement.
2 = I disagree somewhat with this statement.
3 = I neither agree nor disagree with this statement.
4 = I agree somewhat with this statement.
5 = I strongly agree with this statement.

If statements have same high value all along the line, experts are unanimous in the estimated level of agreement and possibility of success can be realistic. If the standard deviation is high there is a risk of uncertainty and confusion.

In the phase one, opportunity identification, it is important to see the general view of factors affecting commercialisation – what could be the major risks and barriers to commercialise the new opportunity. Is there market need for the opportunity and are the markets attractive? Is there some kind of knowledge of technical feasibility and availability of this technology needed? Is the superiority of the new opportunity to competitive and substitute products visible? How does the environment (society, legislation, taxation) react to this new opportunity?

Table 7. Example of simplified success and uncertainty management table of commercialisation – Phase 1, opportunity identification, where SD is the standard deviation, A1 is assessment 1, A2 is assessment 2, and so on.

Success and Uncertainty Management of Commercialisation (1=I strongly disagree…I strongly agree=5)					
Phase 1 Opportunity Identification	*A 1*	*A 2*	*A n*	*Average*	*SD*
Market risks					
Identification and integration of potential key customers to innovation process is in progress.	4	3	5	4,0	1,0
Market need is known and potential.	2	3	3	2,7	0,6
Market situation – common future prospects, trace recession, market size, etc. is clear and attractive.					
etc.					
Technology risks					
Technology opportunities are identified.	2	4	5	3,7	1,5
Technology is acceptable in markets.					
Maturity and availability of technology are identified.					
etc.					
Product/Concept risk					
Excellence and superiority of the identified opportunity are visible.	1	5	1	2,3	2,3
etc.					
Environment risks					
Economic and political situation doesn't prevent commercialising the opportunity.					
Taxation is not an obstacle for commercialisation.					
etc.					

In phase two, “concept selection”, the main goal is to see the commercialisation viewpoints in selection of concepts (Table 8). Are the pricing, benefits, features and novelty value of the new concept (or product) attractive and acceptable among customers? Are early adopters and target groups identified? Is the technology needed available and usable? Are the strategy and financial issues taken care of? Supports the environment this new concept or is it against it?

Table 8. Example of simplified success and uncertainty management table of commercialisation – Phase 2 concept selection, where SD is the standard deviation, A1 is assessment 1, A2 is assessment 2, and so on.

Success and Uncertainty Management of Commercialisation (1=I strongly disagree…I strongly agree=5)					
Phase 2 Concept Selection	*A 1*	*A 2*	*A n*	*Average*	*SD*
Product/Concept risk					
Product offers positive, unique benefits and features.					
The concept is clearly superior to competitors in meeting customer need.					
A price scale compared to competitive and substitute products is identified.					
etc.					
Market risks					
Innovators and early adopters of new concept and technology are identified.					
Possible barriers to implementation are identified.					
Target group information (who, what, how much willing to pay) is concrete.					
etc.					
Technology risks					
Usability of technology is identified.					
etc.					
Business risks					
Investments are allocated correctly to new innovation development.					
Strategy viewpoints (fit to current strategy, changes in strategy) are clear.					
etc.					
Environment risks					
The concept is acceptable.					
Legislation limitations are clarified.					
Possible barrier quarters (e.g. trade organisations) are identified.					
etc.					

In the phase three, NPD, the main goal is get a general view about whether the product is ready for launching (Table 9). Is the product functional, protected, producible and right-priced? Is it profitable to produce? Is it possible to respond to an unexpected strong demand? Are there expected changes in market situation

and is the market situation in continuous control? Are salespersons committed for selling the product?

Table 9. Example of simplified success and uncertainty management table of commercialisation – Phase 3 NPD, where SD is the standard deviation, A1 is assessment 1, A2 is assessment 2, and so on.

Success and Uncertainty Management of Commercialisation (1=I strongly disagree…I strongly agree=5)					
Phase 3 NPD	*A 1*	*A 2*	*A n*	*Average*	*SD*
Product risks					
Product life cycle is clear.					
The design is attractive from marketing viewpoint.					
Pricing is realistic, acceptable among customers and profitable.					
IPR and branding issues are clear.					
etc.					
Production risks					
Dependence risks of subcontractors are clarified.					
Changes in costs of production or/and raw materials are notified.					
etc.					
Technology risks					
Possible technology teething problems are clear.					
etc.					
Marketing risks					
Reference customers are chosen considering marketing viewpoints.					
Changes in market situation are under continuous control and foreseeable.					
Changes in competing or complementary products are under continuous control and foreseeable.					
etc.					
Commitment risks					
Vendors are committed to sell the product.					
Launching responsible is committed.					
Marketing channels are committed to market and sell the product.					
etc.					

In the phase four, launch decision, the main goal is to check that all critical issues concerning commercialisation are noticed and the launching process is controlled (Table 10). In this phase marketing risks are more concrete than at earlier phases. Issues under interest include, for example, workable marketing material and message from the product among customers.

Table 10. Example of simplified success and uncertainty management table of commercialisation – Phase 4 launch decision, where SD is the standard deviation, A1 is assessment 1, A2 is assessment 2, and so on.

Success and Uncertainty Management of Commercialisation (1=I strongly disagree…I strongly agree=5)					
Phase 4 Launch Decision	*A 1*	*A 2*	*A n*	*Average*	*SD*
Marketing risks					
Marketing strategy is clear for the new product.					
Fearing of loser reputation is not a risk.					
Communication is not one-sided.					
etc.					
Launching process risks					
Company's real capabilities (production, marketing, logistics, etc.) are identified.					
Launching process is controlled.					
Timing (market entry strategy and time schedule reaching that) issues are clear.					
etc.					

Evaluation and selection of risk reducing measures

Evaluation and selection of risk reducing measures should be done shortly after each phase. The model gives tools for risk level evaluation. In Figure 17 there is an example of a risk profile from ranked statements (simplified to main categories) with their average values. The profile gives a fast preview for the success and uncertainty level of commercialisation at each phase. If the value is near the inner shell of the risk profile, then these factors should be taken into more comprehensive consideration.

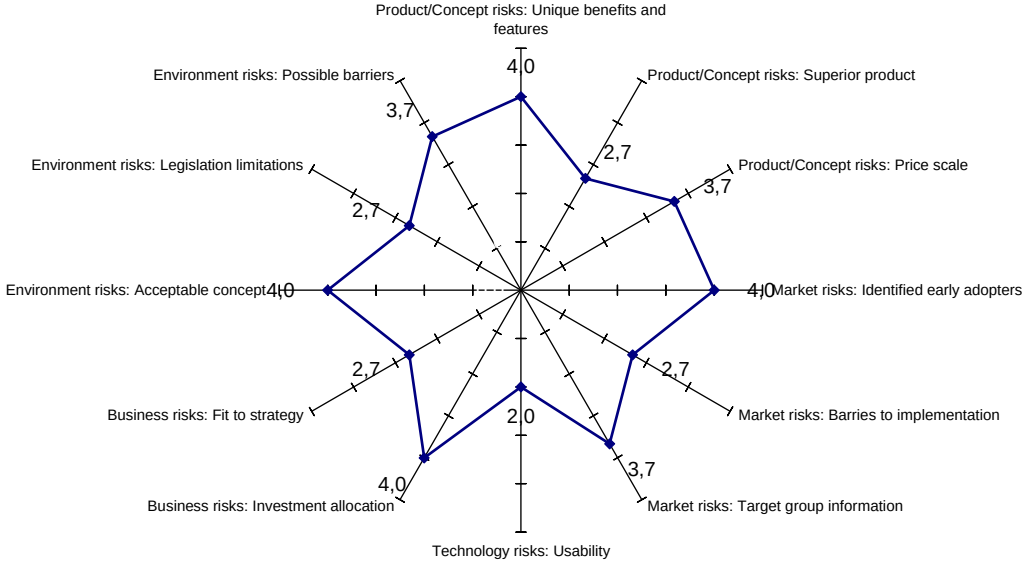

Figure 17. Uncertainty management of commercialisation – an example of a risk profile. The inner circle means value 1 and the outer circle value 5.

Main risks and strengths can be seen at a glance from the risk profile but the criticalness of the risk must still be assessed. The urgency of risk management control measures is primarily decided according to the magnitude of the risk involved. The magnitude of the risk depends of two factors: probability and consequences. Risks can be assessed according to many different scales. Table 11 provides a reference framework to determination whether the risk is large or small. The magnitude of risk can be expressed in words, such s trivial or intolerable, or in number, for example from 1–25. The assessment of the magnitude of risk does not make the risk larger or smaller but only helps to direct risk management control measures correctly.

Table 11. Example of simple risk level estimator [modified from 13].

RISK FACTOR		CONSEQUENCES		
		Slightly harmful (1)	**Harmful (3)**	**Extremely harmful (5)**
PROBABILITY	**Highly unlikely (1)**	Trivial Risk (1), no actions	Tolerable Risk (3), control	Moderate Risk (5), actions needed
	Unlikely (3)	Tolerable Risk (3), control	Moderate Risk (5), actions needed	Substantial Risk (15), actions essential
	Likely (5)	Moderate Risk (5), actions needed	Substantial Risk (15), actions essential	Intolerable Risk (25), immediate actions needed

Implementation and follow-up

After determining the possible risks and their probabilities and severities, the risk management control measures should be decided and implemented. Not all commercialisation risks can be eliminated in reality, so the implementation of the control measures must be prioritised according to the level of risk, with the highest commercialisation risks being tackled at first. When planning risk management control measures and their schedules, it is worth of thinking that how to integrate them into the other activities of company, e.g. market surveys, training events, employee arrangements.

4. Conclusions

We have applied risk management methodology for the commercialisation management of innovations, with a special emphasis on innovations where one aims to deliver a product, process or service with unprecedented performance features. Our goal has been to develop simple tools for the use at commercialisation decision making at SMEs. The tools and procedures include commercialisation risk map for the identification of risks, success and uncertainty management tables of commercialisation for the analysis of risks, and risk profiles and tables for the evaluation and selection of risk reducing measures.

A guiding principle of the work has been to expand the consideration of commercialisation questions and, accordingly, commercialisation risks from the product launch stage, through the new product development stage, to the very beginning of innovation process, to the fuzzy front end, where most of the im-

portant decisions related to the performance features and market attractiveness of the new product are done and fixed. At the fuzzy front end there are lots of uncertainties but, when commercialisation questions and risks are taken into account from the very beginning of the innovation process, commercialisation procedures and marketing strategies shape up little by little, and they do not come up unexpectedly when the product is ready. All that will increase the probability for a successful commercialisation of an innovation.

Acknowledgements

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8. Publication IV: Managing commercialisation risks in innovation development: linking front end and commercialisation

Tuija Luoma*, Jaakko Paasi

* Corresponding author

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere.
E-mail: firstname.lastname@vtt.fi.

Hanna Nordlund

Innovation Management Institute, Helsinki University of Technology, P.O. Box 5500, FI-02015 TKK, Finland. E-mail: firstname.lastname@hut.fi.

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Abstract: *Although front end and commercialisation phases of new innovation development process are usually presented in separate and sequential phases, the phases are linked in practical new innovation development work. This paper describes a risk management based practical approach in supporting the linking of commercialisation related issues in the front end work and decision making of innovation development. By linking the front end and commercialisation opportunities, uncertainties and risks related to commercialisation are taken into consideration already at the early stages of innovation development where most of the important decisions related to the performance features, market attractiveness and costs of the new innovation are done and fixed. The work is based on a large interview study of innovation management practices in companies and an*

analysis of the empirical material using the constructivist collective case study methodology.

Keywords: *commercialisation, innovation development, front end, risk, uncertainty.*

1. Introduction

Commercialisation of an innovation is encompassed by multiple uncertainties, particularly if one aims to deliver a product, process or service with unprecedented performance features. Uncertainties related to markets, technology and business model are high. Accordingly, the commercialisation of innovation includes many risks. Taking that into account, it is not surprising that most innovations will not achieve commercial success; as a matter of fact, most innovations fail.

Commercialisation is often understood to be the final phase of the innovation process: fuzzy front end, the new product development process, and commercialisation [1, 2, 3]. Fuzzy front end refers to the period of time between when an opportunity is first considered and when it is considered to be ready for development [4]. Front end is characterised by uncertainty, unpredictability and the nature of work during front end is experimental and chaotic. Thus, it is very different from the structured, well-defined, disciplined and formal development phase [2, 3, 4]. The emphasis on front end is in discovering and decision making while the development phase concentrates relatively straightforward and fast development of the concept. The final phase, commercialisation, determines how well the potential of the ideas developed during the earlier phases can be utilised [6, 7]. In the extant literature, innovation process is presented as sequential and the different phases are clearly separated. It is also a common practice in companies.

The front end sets the direction for the entire innovation process [8] because it is at that stage that crucial decisions regarding the target markets and customers, strategic alignment and resources are made [4]. Of the total costs of a product development project, 70 % is determined by the decisions made during the front end, but only around 10% is realised at this stage [9, 10]. The commercialisation is the most costly part of the new product development [11]. The economic benefits of a new innovation are never fully realised until the innovation is actually introduced to market [12]. In spite of this, commercialisation is often a poorly managed phase. Cooper *et al.* (2005) states that a strong market orienta-

tion in new product development is critical to success, and that it is missing in the majority of companies' new product development projects [13].

The fact that most of the new product development costs are determined by the decisions made at the front end phase, but they are realised at the commercialisation phase, would suggest a strong link between the front end and commercialisation phases. However, the area is largely unexplored in the literature. Some authors have also studied the linkage between R&D and marketing as functions [see e.g. 14, 15, 16, 17] but none of these researchers have provided specific details for actually integrating the two functions [17].

In this paper we have studied the link between the front end and commercialisation phases of new innovation development. Because both phases are encompassed by a high level of uncertainty, we have applied a new approach for the subject – the generic methodology of risk management – in order to support the decision making within the front end regarding issues influencing the commercialisation of innovation under development. The paper is arranged as follows. At first, in Chapter 2 we define the research question and present the research methodology used in the work. Then in Chapters 3 and 4, we take a brief look at the extant literature on the subject area of the work. Finally, we present the actual results of the work in Chapters 5 "Linkages between the front end and commercialisation phases" and Chapter 6 "Managing the commercialisation: A risk management approach".

2. Research question and methodology

The purpose of this paper is to understand and describe the dynamics between the front end and commercialisation phases of an innovation process. Our objective, for one, is to provide a rich description and create new knowledge about how the front end and commercialisation phases are linked. Secondly, our objective is to develop a practical tool for organisations in order to improve the linkages between the two phases. Thus, in this paper we pose the following research question:

How are the front end and commercialisation phases of the innovation process linked and how can those linkages be managed?

We answer the research question by applying a constructivist [see e.g. 18, 19, 20] collective case study [see e.g. 21, 22] method to empirical material where the innovation management practices of 12 organisations were studied. Accord-

ing to the spirit of constructivist inquiry, the study focused on a variety of different practices of innovation management in the studied companies.

The empirical material was collected by a group of 21 researchers (including one author of this paper) who interviewed 43 managers in 12 organisations. The organisations were established, globally operating Finnish companies with innovation processes and systematic practices in use and explicitly described. This again was expected to create a common ground on which to build the interviews. Both private and public organisations were included and represented different fields of industry; bringing diversity to the empirical material and maximising the learning and variety in the data (see Table 12 for more details). The interviewees were people occupying senior corporate, R&D and business unit or marketing management positions. Semi-structured theme interviews were chosen as the main source of empirical material because the study was partly explorative in nature and the meanings of concepts needed to be negotiated with the interviewees. The interview material was complemented by process descriptions, strategy documents and product presentations.

Table 12. Case studies.

Organisation	*Industry / products / services*	*Personnel (2007)*
ABB Finland	Power and automation technologies	6 650
Consolis / Parma	Building elements	968
Metso Automation	Control and automation systems	3 600
M-Real	Pulp and paper	9 500
Nokia	Telecommunications	68 483
Schering	Pharmaceuticals	400
Vaisala	Environmental measurement	1 113
VTI Technologies	Motion and pressure sensors	704
Wärtsilä	Ship power and power plants systems	3 000
FMI	Meteorology	599
Tekes	Research and development funding	290
VTT	Research and development services	2 740

Analysis of the empirical material proceeded in two phases. First, the material was analysed by a large group of researchers from five viewpoints: “fuzzy front end”, “commercialisation and market entry”, “networking”, “steering and financing” and “innovation management challenges”. The chosen viewpoints were

not defined beforehand but emerged during the analysis of the interview material. The main results and conclusions of the first phase analysis have been published elsewhere by Kettunen *et al.* (2007) so in this paper we will focus only the second phase of the analysis [23].

The first phase identified a few problem areas and development needs in the new innovation development work at the organisations at large and triggered the initiation of several lines of research, including the one which this paper reports. In the second phase of the analysis that relates to this paper we delve into one specific aspect of innovation management challenges, the "linkages between front end and commercialisation phases". This appeared to be a challenge that concerned several companies and which appeared interesting and little understood in the existing literature. According to the collective case study approach [21, 22] we were first and foremost interested in the phenomenon – linkages between the front end and commercialisation – we want to understand and describe. Thus, we had little intrinsic interest in the practices and challenges of individual companies. The individual companies are studied because they are expected to improve our understanding of the phenomenon of interest. In the analysis we first looked for categories that according to our interpretation seemed to link the front end and commercialisation phases together. The categories we found were market need, market environment, technology, idea/value proposition, business environment, management and collaboration network. This way we found that the dynamics and challenges in linking the front end and commercialisation resembled management challenges of safety critical systems, where the risk management methodology has been successfully applied. In regard to our second objective this led us to apply the methodology in this context as well.

3. Front end phase of the innovation process

Front end refers to the early stages of the innovation process [24] between when an opportunity is identified and when an idea is considered ready for development [4]. During the front end a product concept is formulated and an organisation determines whether or not the organisation will invest in the concrete development of the idea from concept to product [14]. Creating new knowledge, learning and being creative are at the core of front end activities. The information available for decision making in the front end is often qualitative, informal and approximate. Thus, in the front end it is necessary to accept solutions that

are approximate rather than exact facts [4]. Furthermore, the nature of the work during the front end is experimental and chaotic. The focus should be on finding failures and making mistakes, thus the failure rate is high [5].

Uncertainty is a central characteristic of the front end [2, 5]. Gupta and Wilemon (1990) argued that uncertainties related to the front end include increased local and global scale competition, continuous development of new technologies, which lead to compensating old technologies at an increasingly rapid pace, and changing customer needs and requirements. It also shortens the product life cycles and increases the need for external involvement in innovation processes [25]. Thus, activities of the front end aim at reducing uncertainty and ambiguity [4, 5].

During the front end the direction for the entire innovation process is set [8] because crucial decisions regarding the target market and customers, strategic alignments, and resources are made [4]. Of the total costs of a product development project, 70 % is determined by the decisions made during the front end, but only around 10 % is realised at this stage. The costs of developing a new product increase significantly as a function of elapsed time [9, 10]. During the front end it is easy to develop and test ideas, however, after the front end the costs start to rise drastically. As Reid and de Brentani (2004) state, the costs of developing several ideas are marginal compared to implementing any one idea [8].

4. Commercialisation phase of the innovation process

Commercialisation is often considered as the process of introducing a new product into the market. The actual launch of a new product or service is the final stage of new product or service development. It is at this stage where substantial amount of money needs to be directed towards advertising, sales promotion, and other marketing efforts [11, 26]. Commercialisation needs also pre-commercial activities, such as marketing strategy development and business analysis, to achieve success. All these prior activities of commercialisation comprise a "commercialisation process".

In the final commercialisation phase it may be difficult or impossible to make the most appropriate tactical launch decisions because earlier made strategic decisions dictate the final decisions. Some commercialisation related decisions take place already early in the innovation development cycle and these strategic decisions strongly influence the commercialisation and launching, while other decisions occur after conceptual and physical development of a new product

[27]. It is subsequently important to understand all the factors that influence the commercialisation already at the beginning of the innovation process.

Commercialisation is a critical phase of the innovation process. Without delicate commercialisation preparations during the innovation process, also good new products or services may fail. Another important aspect at this stage is the accumulation of cost [6, 11, 12]. It is actually the most costly part of the new product development [11].

5. Linkages between the front end and commercialisation phases

Our interpretation of the empirical material implies that the front end and commercialisation phases of the innovation process are strongly linked. Although the innovation processes were described as sequential in the interviewed organisations (in accordance with the extant literature) our interpretation of the practices perceived overlapping of phases in time so that the commercialisation phase runs in parallel with the concept development, new product development and market entry [see 23 for earlier analysis of the data].

Interactions between various interest groups and persons (such as R&D, product and marketing personnel) are an integral part of true innovation development practice in many organisations. The interaction can be very strong and happen already at the very beginning of the innovation process when new business opportunities are identified. It is particularly true when developing new services or physical products enhanced with a service component. Ideas associated to service related innovations often arise from the customer interface. Thus the suggestion that the R&D department takes care of the front end and new product development and marketing takes care of commercialisation is no longer so clear in companies. Front end and commercialisation practices are linked in companies, not only through people taking part in both phases but also through the information used in the phases. The empirical material showed that the link between the phases may sometimes be weak in the sense of information exchange but, nevertheless, it is present.

We found several different categories that link the phases together: market need, market environment, technology, idea / value proposition, business environment, management and collaboration network. Due to the space constraints we discuss in more detail here only two categories: technology and market need. Other categories are briefly touched upon in the next chapter.

Technology is an important category, critical both from the front end and commercialisation viewpoints. The company should analyse its own technological capabilities versus the technology needed for the new innovation. What is the technology needed? Are we able to apply the technology? The company ought to also discuss whether the technology for the concept is available. If not, how long until the technology is feasible – is it in the near future, intermediate future or in the deep future. Also changes in technology development and also in the time for adoption of new technology should be monitored. Rapid technological development may mean that a new potential innovation based on old technology is no longer desirable to the markets. Changes in technology adoption can mean that the time for commercialisation may be longer than expected. Obviously, if a company could foresee those developments, it would have a competitive advantage and subsequently would take appropriate actions with regards to any corresponding innovation development.

Attention should be paid also to the market need in the front end phase of innovation development. For example, customer needs are neither objective nor are they stable and that may affect the commercialisation. In the front end phase we should ask, for example: Do we fully understand the customer need and not just assume to understand? Interpretations of concept developers may differ significantly from those of the customers'. Furthermore, the needs and requirements of customers are dynamic – they evolve over time. Thus, even if the interpretations of the concept developers' correspond to those of the customers' customers own understanding of their needs may change before the commercialisation phase. It is also important to understand that customers may be unable to articulate their needs. A large part of their knowledge is embedded in the regular routines and practices in which they participate and customers do not notice them or they may consider them so self-evident that they do not understand their significance from the viewpoint of the innovation process. Misunderstandings in the interpretations of the customer need may lead to a situation where the company develops a totally "wrong", unsuitable product or service for the customers. The ability of customers to accept and apply new products and services is limited and that also has a significant effect on commercialisation. Thus, even if a product would be useful to customers they may be unable to receive it. Also, customers may resist a new concept because they cause changes that again require learning, abandoning existing practices and routines, and sometimes change social aspects and hierarchies at work.

6. Managing the commercialisation: A risk management approach

The second objective for this paper involves creating a practical tool for organisations in order to improve the linking of the front end and commercialisation. In the development of the tool, the following specifications arose from the second analysis of the empirical material:

1. The tool should focus on information critical for both the front end and commercialisation phases.
2. As most of the costs of new innovation development are realised in the commercialisation phase, the viewpoint of the tool should be in supporting decision making in commercialisation related questions.
3. The tool should be generic and reusable so that most organisations could use it (after minor customisation, if necessary).
4. As the new innovation development is encompassed by multiple uncertainties, a risk management methodology should be applied in the tool in order to make the uncertainty management systematic and practical.

The development work started by defining a framework model for the linkage between the front end and commercialisation. We applied the framework model of commercialisation by Luoma and Paasi (2007), Figure 1 [28]. In the model, the commercialisation activities begin already at the identification of new business opportunities (that is, in the beginning of the front end). The entire commercialisation process is modelled as a funnel with many layers, instead of only being the final stage in the classical 1-dimensional new product development process; the converging funnel representing decreasing uncertainty of information in commercialisation related questions. The front end phase of the innovation development is depicted in the left half of Figure 17. In the model, market information is provided as an input already at the very beginning of the innovation process whereby the search for new business and product opportunities is enhanced by means of future research and foresight studies. By applying this framework, risks related to commercialisation are taken into consideration already at the early stages of the innovation process.

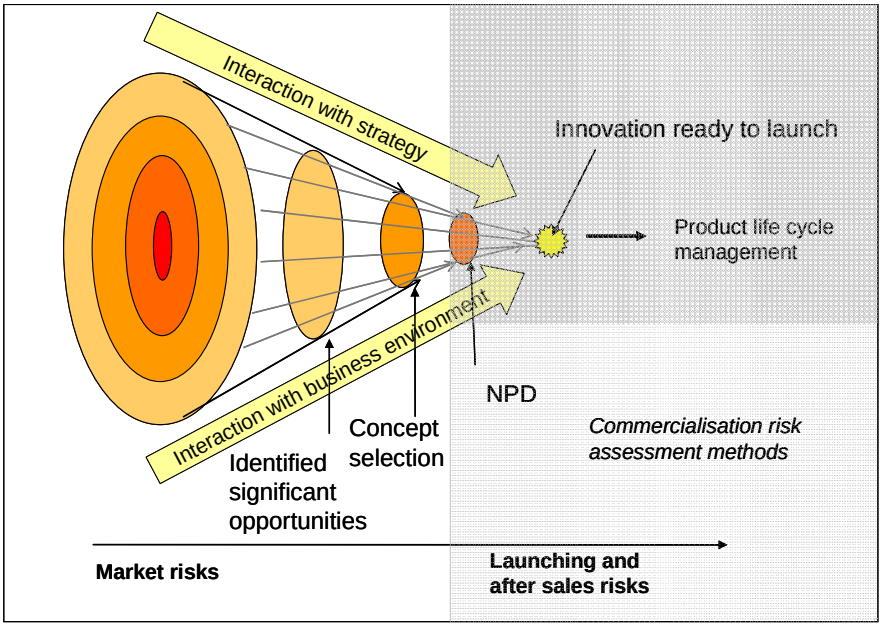

Figure 17. Framework of commercialisation process in innovation development [28].

The empirical material highlighted multiple challenges in the decision making at early phases of the innovation process due to the high level of future uncertainty in technological, market and business model related issues [23]. Critical strategic decisions must be made, typically without solid facts as a basis. In that sense we found much analogy in the management challenges between the fuzzy front end and safety critical systems, where risk management methodology has been successfully used for years in hazard identification and assessment. In both cases critical decisions must be made in the presence of high uncertainty. That allows us to formulate a working hypothesis on our research question: "How can the front end and commercialisation phases of innovation process be linked and managed?"

Working hypothesis: Front end and commercialisation phases of innovation development are encompassed by multiple uncertainties. In order to manage that, the phases should be strongly linked by applying the generic methodology of risk management.

In general, risk management aims to protect the property, income and different activities of a company while aiming to keep the overall costs at as low a level as possible. Risk management is not only about identifying and assessing risks and selecting risk reducing measures, but also about being able to respond quickly and effectively to realised threats as they arise [29]. Risk analysis provides a basis for evaluating the tolerability of risks and for deciding necessary risk reducing/controlling measures [30]. The generic main steps in risk management are shown in Figure 18. We have applied risk management methods to commercialisation risk management in the front end phase. In this work we understand risk management to entail the management of both uncertainties and opportunities.

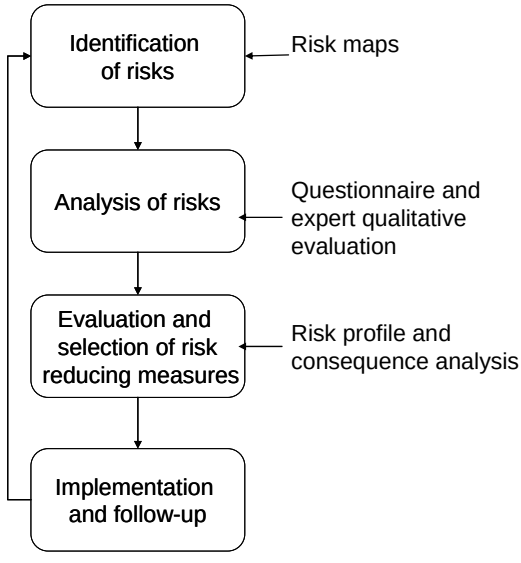

Figure 18. The main steps in risk management (simplified from [30]).

In the front end it is important to get a clear overview of the commercialisation risks because many important decisions that influence the commercialisation are already made during the front end phase. The first step in the management of commercialisation risks in the front end involves the use of risk maps. Risk maps are typically used when conducting vulnerability analyses. For conducting a vulnerability analysis, the first step involves the categorisation of vulnerability factors (i.e. undesired conditions) and this is followed by the rating of risk levels [31]. Categorisation of vulnerability factors – a risk map – is a practical tool

which provides the company with a clear general overview of the risks that threaten its operation or goals. A risk map provides an excellent overview of the factors affecting the commercialisation. When all the important factors that can affect the commercialisation success are included in the map, the commercialisation risk map provides valuable support for the decision making. The risk map can be used like a checklist during the front end phase. In such a case, the critical factors affecting commercialisation are taken into consideration already in the front end.

The risk map presented in this paper (Figure 19) is based on the empirical material of the interview study, supplemented by findings reported in the literature, and finally, synthesised with our own empirical experience in new innovation development. It is a result of a longer development work, and the methodology and earlier versions of commercialisation risk maps [28] were field-tested in a few companies. Companies applying the model should carefully consider which factors in the sample risk map are critical to them, or whether any important factors are missing. According to Ulleberg (1993) the categorisation of vulnerability or risk factors is best done by a multidisciplinary team where different experts provide valuable approaches to the threats [31].

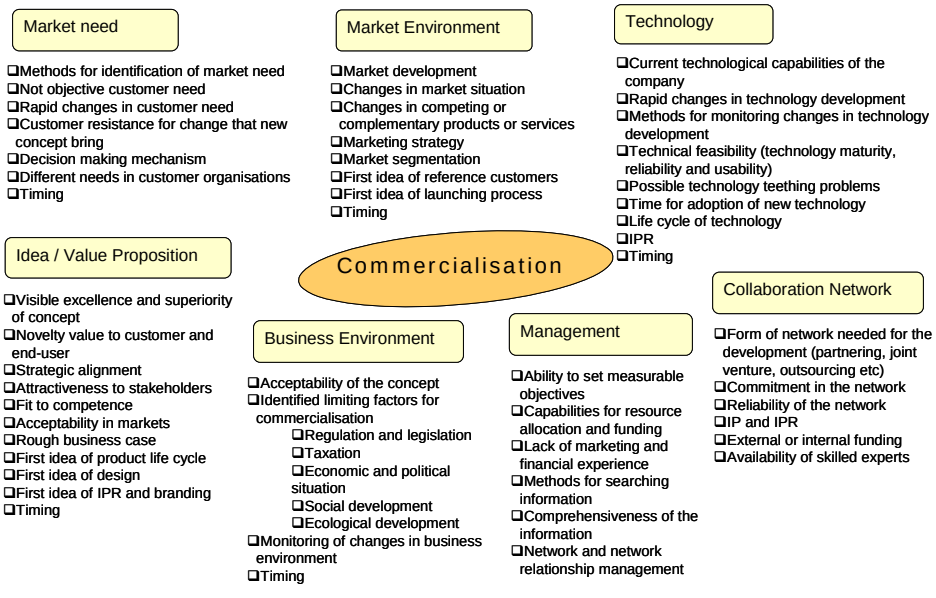

Figure 19. Commercialisation risk map supporting decision making in the front end of innovation development.

Analysis of risks can largely be done by experts using a Delphi procedure fulfilling four key features of the Delphi procedure: anonymity, iteration, controlled feedback, and the statistical aggregation of group response [32]. When assessing the risks and selecting and prioritising risk reducing measures, one should consider both the likelihood and consequences of the event [28]. For example, standard BS 8800 (1996) provides a reference framework to aid in the determination of whether the risk is large or small. The magnitude of risk can be expressed in words, such as trivial or intolerable, or by a number, for example, from 1–25 [33]. The assessment of the magnitude of risk itself does not make the risk larger or smaller but it helps to direct risk management measures correctly and, in this way, to cost effectively increase the success potential of the new innovation under development. Estimating uncertainty and the associated magnitude and tolerability of risk is one part of our decision support process. Equally important is estimating the magnitude of business potential. When both aspects are evaluated, the process can be linked to standard portfolio management practices [34] used in companies. The risk management procedure is described in more detail in Luoma and Paasi (2007) [28].

7. Conclusions

In our study we have found that the front end and commercialisation phases of innovation process are strongly linked through questions critical to both phases and through personnel involved with both processes. The questions are related to seven categories: market need, market environment, technology, idea / value proposition, business environment, management and collaboration network.

In order to improve the linkage between the phases in practice, we have proposed a new tool – a commercialisation risk map – to support the decision making at the front end of innovation development in issues influencing the successful commercialisation of the innovation. The proposed tool applies a generic risk management methodology. It offers a practical way for fast qualitative evaluation of potential vulnerability factors for the commercialisation of the innovation under development. The development work for the risk map was initiated by the analysis of the empirical study on innovation development practices in 12 major Finnish organisations, which revealed the need to link the front end and commercialisation phases of innovation development. Also the content of the risk map was strongly influenced by the empirical study.

The driving principle in the risk map has been to link the commercialisation and front end phases of innovation development in a way that commercialisation related questions, uncertainties, risks and opportunities are taken into account systematically from the very beginning of the innovation process through the concept design and product development phases to the launch. The risk map presented in this paper is for the front end, but similar risk maps could be created also for the later phases of innovation life cycle. We believe that the method promotes efficient use of resources in the innovation development and increases the success potential of the innovation.

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9. Publication V: Systematic strategic decision support for innovation development

Jaakko Paasi & Tuija Luoma

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland. E-mail: jaakko.paasi@vtt.fi, tuija.luoma@vtt.fi.

Ray Strong & Ruoyi Zhou

IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120, USA. E-mail: hrstrong@us.ibm.com, ruoyi@us.ibm.com.

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Abstract: *Development projects for radical innovations are typically long in duration and, therefore, surrounded by a high level of technological, market, organizational and resource uncertainties. Various techniques have been developed in order to manage the uncertainties due to unpredictable future and to support managers in their strategic decision making during the innovation development process. Typically such techniques give support for decision making only in a particular phase or element of the innovation process. Systematic strategic support throughout the innovation process under high level of future uncertainty, from the first evaluation of ideas of new business opportunities through design and development stages to commercialization and launch, is usually highly insufficient or missing.*

This paper describes a systematic framework to support strategic decision making in innovation development that attempts to put appropriate amounts of planning resource into the process at different stages. It is constructed to make

use of qualitative evaluation techniques, based on risk management methodology, early in the process when faster, less expensive methods are preferred to more accurate quantitative techniques. It is also constructed to make use of a small number of reusable process building blocks, including a simple process for approximating expert consensus without requiring face-to-face meetings of experts. It makes use of modern contingency planning techniques in order reduce wasteful investment in ideas that will eventually be discarded during the innovation process.

The starting point of the paper was a large interview study about innovation management practices in major Finnish organizations. The study identified management of future uncertainty as one of the main challenges of corporate executives, which initiated the present research for the development of practical techniques to support strategic decision making at multiple critical decision points of innovation development under high level of uncertain information. The work is a joint study involving IBM Research and VTT Technical Research Centre of Finland. As a result, separately developed techniques were integrated to produce a more systematic, more comprehensive, but highly efficient innovation management framework.

Keywords*: *innovation development, uncertainty management, risk management, decision support, contingency planning, signpost.

1. Introduction

The importance of innovations and innovation management is recognised in companies, research institutes, and in the whole of society. Most innovations will not achieve commercial success, as a matter of fact, most innovations fail. On the other hand, companies that do not innovate will, sooner or later, face an economic crisis and die.

Innovations can be classified as incremental and radical (disruptive) according to changes resulting from the innovation (e.g. Morone, 1993; Utterback, 1994; Leifer *et al.*, 2000). Most innovations are incremental being gradual enhancements or feature replacements to existing products, services, processes, business models. Actually, it is often difficult to say when the question is about 'new innovation' and when about 'product enhancement'. Incremental innovations have a sustaining nature and allow an organization to maintain its current approach to

target markets. That is, they do not create new lines of business, nor do they completely new markets for an existing product or service.

Radical innovations, by contrast, correspond to disruptive change. The disruptive change can be related to technology, markets, society, or all of them. An innovation can be said to be radical when it has the potential to produce one or more of the following: (a) an entirely new set of performance features, (b) improvements in known performance features of five times or greater, or (c) a significant (30 percent or greater) reduction of cost (Leifer *et al.*, 2000). A radical innovation significantly changes supply and demand conditions in a market. Radical innovations create new lines of business. The introduction of consumer digital photography is a good example of a radical innovation that caused major disruptive technological and social changes. Such major disruptive changes are rare; but smaller scale disruptive changes, affecting primarily the business of a single company, happen frequently.

Development projects for radical innovation are typically long in duration. It often takes several years from the discovery of a new business opportunity through the incubation (i.e. evolving the opportunity into a business proposition) to acceleration or ramping up of the business to stand on its own (O'Connor, 2006). Ten years is not a long time for this process. Partially because of the long duration, development projects for radical innovations are surrounded by multiple uncertainties (Utterback, 1994; Leifer *et al.*, 2000). Leifer *et al.* (2000) have defined four major dimensions of uncertainty that are relevant for all radical innovation development projects: technological, market, organizational, and resource uncertainties. The management challenge of multiple dimensions of uncertainty is complicated by the fact that the uncertainties interact with each other, in the sense that there are complex correlations. Further complexity is brought by the long time span of the process during which major disruptive changes may happen in technology, markets and competition having major influence (either positive or negative) to the business potential of the innovation.

In this paper we propose a relatively inexpensive, systematic approach to managing future uncertainty related to radical innovation. The starting point of the paper is a large interview study about innovation management practices in major Finnish organizations (Kettunen *et al.*, 2007). The study revealed that management of future uncertainty is one of the main challenges of corporate executives. That initiated the present research for the development of practical methods and tools to support strategic decision making at multiple critical decision points in the innovation process.

2. Research methodology

In 2005 VTT performed a large interview study of innovation management practice in which 43 managers were interviewed from 12 major companies and public organizations in Finland. The goals of the study were to understand and describe innovation management practices in the organizations, to chart generic success factors, and to identify potential problem areas and development needs. The interviews also covered strategies and business models. The list of interviewed organizations includes ABB, Consolis, FMI, Metso, M-Real, Nokia, Schering, Tekes, Vaisala, VTI Technologies, VTT, and Wärtsilä. These are well established, globally recognized enterprises possessing process descriptions for their innovation processes. They represent diverse branches of industry and are intended to provide some level of comprehensiveness. The interviews were semi-structured with a special focus on obtaining a wide range of differing opinions. Interviewed managers included people occupying senior corporate, R&D and business unit or marketing management positions. The interviews were supplemented by written material including process descriptions, strategies, and product presentations of the organizations.

A group of scientists from VTT (including one author of this paper) applied a constructivist collective case methodology to material from the interviews. This methodology focuses on different viewpoints and lived experience of organizational members (Schwandt, 1994, Hatch, 1997) and is committed to bringing up multiple voices and viewpoints. The group has extensive experience in technology R&D and management at various companies and research organizations. The analysis was done from four major perspectives of innovation management: fuzzy front end, commercialization and market entry, networking, steering and financing. The main results and conclusions of the study were published by Kettunen *et al.* (2007), the detailed case analyses, however, remaining confidential.

The potential problem areas and development needs identified by the study triggered the initiation of several lines of research, including the one which this paper reports. The original study identified management of future uncertainty as one of the main challenges to corporate executives. This challenge was reported to be great throughout the innovation process, but greatest at the fuzzy front end, which is much less structured than new product development and commercialization processes at each of the case organizations of the study.

In this paper we suggest an answer to the question, How should future uncertainty be managed during the entire innovation process?

The approach of the work towards finding answers to the research question was, again, based on constructivist methodology. The authors have wide experience in research and development for various fields, in the development of new services, and in consultancy work in the fields of technology foresight and risk management. This experience allows us to assimilate different viewpoints and experience, at first, in order to specify the research problem in a more detail, and then, to develop tools and methods in order to overcome the weak points, from the viewpoint of uncertainty management, in the new innovation development processes identified in the interview study.

Initially we focussed on specific phases of new innovation and business development. As we developed and tested the tools for each phase, we found that we still lacked a systematic approach to decision making that could be applied throughout the innovation process. This discovery initiated the final stage of our research: the development of a systematic, comprehensive, and efficient innovation management framework focused on providing support for strategic decision making under conditions of high uncertainty about the future. Our framework includes techniques, originally developed for the separate phases, integrated by means of generic risk management methodology (Suokas & Kakko, 1993).

This paper focuses to the research and results of the final stage. The resulting framework is supplemented by working hypotheses which are strongly influenced by the experience of the authors and reflect our interpretation of development needs in innovation management practice.

3. Management of unpredictable futures

The future will always be unpredictable, but with the right techniques the opportunities and threats of the future can be managed. The right choice of techniques depends on the scope of study: short term studies can be largely done by extrapolating current trends and exploring the likelihood of meeting current challenges, while long term future studies require different approaches in order to better prepare for unexpected. Time series and other history data can not predict disruptive changes. In the case of radical technological innovation development, long time span is very important (but challenging), because technology R&D

will take place over several years (typically 5–10 years) while markets operate with a much shorter time horizon.

The technology roadmap approach (Phaal, 2004) has been widely used in technology foresight studies as well as in business planning and project planning for innovation development (Kettunen *et al.*, 2007). In practice, according to our experience and the results of the interview study, this road mapping methodology is predominately restricted to the extrapolation of current trends. Thus, road mapping is suitable for business and innovation development planning for a three to five year horizon, within which the plans are based on the expected course of technology progress and business environment (Strong *et al.*, 2007a). Accordingly, the technique is very suitable for incremental innovation development projects.

To accommodate a time horizon longer than 3–5 years or to better prepare for the unexpected, scenario planning techniques are widely used to support strategic decision making for business development (Wack, 1985; Godet, 2000). Scenario planning explores multiple potential futures rather than a single "most likely" future. These explorations are framed in narratives (called scenarios) designed to influence key decision makers. By working with scenarios of quite different futures, the analytical focus is shifted from trying to estimating what is most likely to occur towards contingency planning to determine the consequences and most appropriate responses under different circumstances (Duinker & Greig, 2007).

The scenario process as well as the application of scenarios in strategic decision making include also pitfalls: One must ask the right questions, formulate the right hypotheses clearly, and ascertain the coherence and probability of possible combinations. Without these, one risks leaving out most possible futures (Godet, 2000). Furthermore, it is not straightforward to tie scenarios to the advancing current state of reality, facilitating the development of a flexible, contingency strategy (Schoemaker, 1998; Strong *et al.*, 2007a). At the level of operative new business development, while scenarios may give some support for the ideation of new innovations and business opportunities, they give little support for the corresponding daily decision making. This is particularly true in the fuzzy front end of the innovation development process where the critical decisions affecting the success potential of the innovation are made (Koen *at al*, 2002; Paasi, 2007). All these call for other, perhaps complementary, methods to link the management of unpredictable future to the daily strategic decision making of innovation or new business development.

Strong *et al.* (2007a, 2007b) proposed a novel methodology, called the signpost method, for adaptive contingency planning at the strategic initiative level, complementing normal business planning that uses a schedule based on predictions tied to dates in the future. A signpost is a recognizable potential future event that signals a change of such importance to an enterprise that it is actionable. The methodology includes ideation, information mining, scenario envisioning, and the selection of signpost events upon which to base a set of contingent strategic initiatives. The signpost method has been successfully field tested in several cases related to enterprise strategy (Strong *et al.*, 2007a, 2007b), but not for direct support of the entire innovation process.

4. Managing new innovation development

Recall that the VTT interview study revealed the following generalizations about the innovation process:

1) *new product development is well structured and controlled, but*
2) *early concept and design is unstructured and uncontrolled.*

(Kettunen *et al.*, 2007). The reason for (1) may be the well developed theory of new product development (Ullrich & Eppinger, 2004; Cooper & Edgett, 2005). For the beginning of the process (the front end), there is no similar well established theory. The development of new innovation usually starts from an idea of a new business opportunity but, what follows, is more or less fuzzy until the idea has been elaborated so much that the actual product development work can start. Therefore, the front end of the innovation process is often known as the fuzzy front end. However, the fact that it is fuzzy does not make it unmanageable.

The front end of the process has been modelled in companies: in some models the process is linear like the product development process (e.g. Ullrich & Eppinger, 2004; Cooper & Edgett, 2005; Kettunen *et al.*, 2007), other models emphasize the complex and iterative nature of the front end (Orihata & Watanabe, 2000; Koen *et al.*, 2002; Dorval & Lauer, 2004). In a study of front end practices, Koen *et al.* (2002) identified five clearly distinguishable elements: opportunity identification, opportunity analysis, idea generation and enrichment, idea selection, and concept definition. The process starts with an idea for new business opportunity but after that it may proceed through the different elements in variable orders until the idea has been developed into a vision or concept that is

ready in both technological and business aspects. Each of the elements incorporates important decision points.

Innovation processes include lots of different kinds of decision points. In the context of innovation uncertainty management, we must ask two questions:

1) Are all decision points critical and equally important?
2) What are the critical decision points of innovation development process in which foresight plays an important role?

To (1) we suggest that not all decision points are critical and equally important. Paasi *et al.* (2007) identified four critical decision points in the front end of radical innovation development: selection of new business opportunity for further elaboration, selection of elaborated business idea for concept definition, selection of external partners for networking, and selection of concepts of new innovations for product development. Each of these decision points includes strategic aspects to which foresight is relevant. Subsequent critical decision points in the innovation development process could be the gates of new product development and commercialization process suggested by Dunham (2002) and by Schmidt (2005).

5. Our framework for systematic decision support

We developed our framework model for systematic strategic decision support in innovation development from the following specifications, which are based on the constructivist analysis of the interview material by the authors:

1. The model should be flexible in order to adapt company specific innovation processes, which are often stage-gate like processes, and it should be made of reusable process building blocks which would progressively evolve along the use of the model, creating a reusable innovation management asset.
2. It should optimise the amounts of planning resources into the process at different stages. This can be achieved by a three-part approach: (a) fast reduction in the number of ideas and projects in the innovation development process, (b) qualitative evaluation techniques early in the process when faster, less expensive methods are preferred to more accurate quantitative techniques (work demanding more accurate quantitative studies can be valuable at later stages of the process for topics identified in qualitative studies), and (c) a simple process for approximating expert consensus without requiring face-to-face meetings of experts.

3. The foresight aspect should promote enterprise strategic preparation for the unexpected, and should be so practical that it ties important scenarios to the advancing current state of reality in way which guides right-timed actions at the strategic initiative level of new innovation and business development throughout the process.
4. Risk management methodology should be built into the model in order to make uncertainty management systematic and straightforward in identifying potential opportunities and threats where specific management actions or deeper studies and analysis could be necessary.

The resulting framework model is presented in Figure 20. The framework starts with (preferably many) ideas of new business opportunities and ends with one or more lines of business (or analogous innovation results for non-profit organizations).

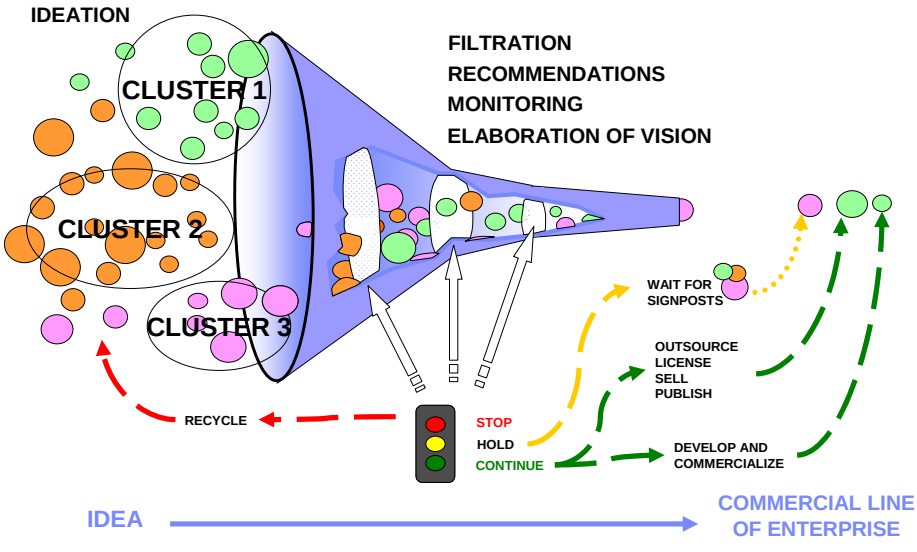

Figure 20. Framework of strategic decision making in the development of new innovations and new lines of business.

At the beginning there is an ideation stage which includes phases of preparatory background information studies, idea generation and idea clustering. Idea clustering means that compatible and related ideas are collected together to be treated as one object of analysis having a common vision of future. A particular challenge in ideation is to create ideas and visions for which realization will likely occur beyond the typical business planning horizon of three to five years.

Being generally unexpected such ideas are more likely to be associated with radical disruptions. Reasoning about such ideas can also lead to unexpected ideas that could likely be realized in the near future and could lead eventually to the deeper future ideas. Such unexpected ideas can be generated by asking subject matter experts for deep future ideas "one hundred years out" and then backcasting into the near future. See Strong *et al.* (2007a, 2007b) and references therein for more details about the ideation stage.

After ideation there is the first filtering of ideas (visions) in order to reduce the number of ideas, visions, and projects in subsequent stages. We accelerate the narrowing of the funnel depicted by increasing the bias toward stopping an idea at an early filtration step. Filtration is followed by recommendations for further actions, which may simply be 'stop', 'hold' or 'continue'. A 'stop'recommendation could mean either discarding or recycling the idea. A 'Hold' recommendation could mean creating one or more signposts and active monitoring these signposts for future conditions under which the idea would be returned to the active innovation process. A 'continue' may include alternatives of product development, commercialization, collaborating, outsourcing, patenting, licensing, selling, publishing. All these are strategic decisions.

Filtration, recommendations, monitoring and elaboration of vision (i.e. the actual innovation development work) form a five-phased iterative process which will be repeated at each stage of innovation process and, depending on the company, may even be repeated inside a single stage such as product development, Figure 21. The filtration and recommendations phases are current business practices at the gates of the stage-gate process. Active monitoring of ideas or projects on hold, however, is a novel enhancement to observed innovation practices reported in (Kettunen *et al.*, 2007).

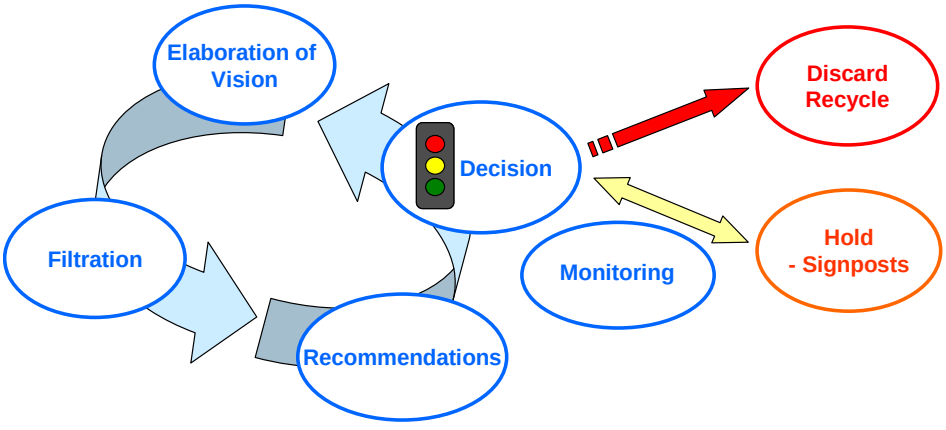

Figure 21. A five-phased iterative process of innovation development consisting of strategic decision making elements of filtration, recommendations and decision, active monitoring supporting the decision making, and the elaboration of vision, which contains the actual innovation development work.

Idea generation, filtration of ideas, recommendations for further actions, elaboration of ideas, and accelerated early reduction of development projects (so that, for example, from 100 ideas only 10 will be conceptualized and only one will be commercialized) correspond to current best innovation practices. What is novel is the linkage between the strategic initiative level and decision making by means of active monitoring of signposts (easily recognizable potential future events that signal changes of importance to the enterprise and call for a strategic action in the innovation development process). Furthermore, what is novel is the systematic way this is done throughout the innovation process from idea evaluation through conceptualization and new product development stages until the launching decision. The model can even be used to facilitate decisions about when to terminate a line of business. The idea to terminate can be sent through the entire innovation process with appropriate analogs for design and development phases. For example, the anticipated cost savings in terminating the line of business at the right time, can be viewed as the impact or reward.

Uncertainty management has been built in the model by the means of risk management. Risk management is systematic process where organizations methodologically address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities (A Risk Management Standard, 2002). In general, risk management aims to protect the property, income and different activities of a company while minimizing costs.

The generic main steps of risk management are shown in Figure 22 (adapted from: Suokas & Kakko, 1993). Risk management steps are included in our decision support model with specialization for each innovation stage.

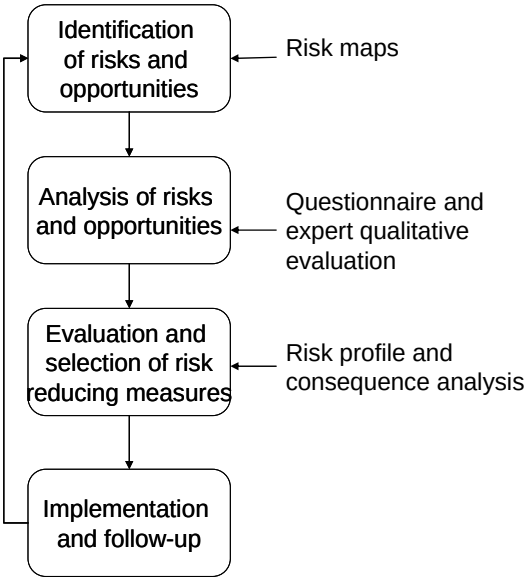

Figure 22. The main steps in risk management (adapted from: Suokas & Kakko, 1993).

In our ideation stage risk management is incorporated by going beyond the extrapolation of current trends to prepare for the unexpected. In the stages of innovation development, we supply risk management for the five-phased iterative process shown in Figure 21 in three different ways:

1. Strategic decision making is supported by qualitative risk evaluation maps covering check lists of potential issues for conceptualization/design, development or commercialization aspects of new innovation development (e.g. Luoma & Paasi, 2007).
2. Analysis of risks is largely done by experts using an approximate Delphi procedure fulfilling four key features of the Delphi procedure: anonymity, iteration, controlled feedback, and the statistical aggregation of group response (Rowe & Wright, 1999). The procedure is based on the use of simple, reusable, electronic questionnaires covering those aspects of future uncertainty critical from the viewpoint of

strategic decision making. The number of aspects as well as the level of details increases as the project is progressing in the innovation development process.

3. Risks related to timing issues are managed by generating appropriate signposts and by active monitoring of the signposts.

The framework model will be described in more detail elsewhere together with examples of qualitative risk evaluation maps and questionnaires used at the filtration, examples of graphs supplementing the recommendations, and examples of signpost generation for the active monitoring.

Our framework model for innovation development has been generated in accordance with a set of working hypotheses, which will be validated or modified based on continuing experience. These hypotheses are synthesized from our interpretation of the interview study results, related findings reported in the literature, and response from separate field tests of tools and techniques used in the framework model.

Working hypothesis 1: Qualitative decision support techniques can be less expensive than quantitative techniques. They may be also less accurate, but they are sufficiently accurate to be appropriate in early stages of innovation development process. In particular an approximate Delphi process using self-rating of expertise for weight in a weighted average is an inexpensive but powerful tool for providing qualitative decision support, especially for prioritizing and filtering ideas in the early stages of the innovation process.

There is always the risk that an important idea is discarded early in the innovation process. This might lead one to spend a great deal of effort at the beginning of the process attempting to predict which ideas will be successful; but we believe that this effort would be misplaced and would encounter a diminishing return in which more and more effort is required to save fewer and fewer *innovations*. We expect such effort would produce a heavy front end with costs that would discourage innovation. Instead, we propose to mitigate the risk of discarding a good idea by conserving and reusing discarded ideas. Our ability to reuse discarded ideas and to monitor for signposts that would indicate a better time to develop an idea can make us freer to generate and discard ideas easily. Such freedom would likely lead to an enhanced flow of increasingly creative ideas during the early stages of innovation.

Systematic application of increasingly comprehensive qualitative risk management techniques, such as lists of potential risk factors and questions derived from the risk factors directed to subject matter experts who respond according to the approximate Delphi, can, according to our experience, provide the appropriate level of decision support at each stage of the innovation process. Relatively expensive quantitative techniques may be valuable at later stages of the innovation process for studying specific questions arising from the qualitative analyses. Quantitative techniques to be considered may include: light weight information mining techniques useful in generating and monitoring signposts and in estimating general levels of R&D investment in given topics, heavier information mining techniques to determine buzz about a topic such as a technology, and massive and expensive polling techniques for determining market readiness.

Working hypothesis 2: The intellectual capital represented by innovative ideas in various stages of design and development can and should be conserved, even when it is appropriate to stop or hold (pause) the innovation process.

Signposts have been suggested as a link between scenario based strategic initiatives and the advancing state of the world (Schoemaker 1998, Strong 2007a) We suggest that signposts could link strategic initiatives to decision points in an expanded innovation process that includes a hold state. This could dramatically improve right timing of innovations. Ideas can be placed on hold to be returned to the same stage of the innovation process when conditions are more appropriate. This process can conserve much of the intellectual capital of even relatively developed ideas, if the return can be associated with the realization of a recognizable signpost event. Active monitoring of signposts can insure that ideas are brought to market at the right time rather than at the first time they are ready.

Working hypothesis 3: High uncertainty in risk factors is tolerable in the design stage of innovation but must be reduced before launch (unless negative potential consequences are mitigated).

Radical innovation development projects are surrounded by multiple dimensions of uncertainty, as described already in the Introduction. Such projects may be attractive when high risks are accompanied by high opportunities for rewarding new business. Our framework provides a way to engage risk management from the beginning of innovation development in order to manage and reduce the

uncertainties. Working hypothesis 3 can be phrased as an operating principle for innovation development: start the development phase with high uncertainty in many high level factors but launch with low uncertainty in all. Ideally the development phase should be started with low uncertainty; but, according to our experience, this desire is unrealistic for radical innovation development projects. An accompanying principle is that, for factors over which there is little or no direct control, interpret high uncertainty (without mitigation of potential negative consequences) as an indication that "it is not the right time for this project". A "not right time" result suggests either stopping development or putting development on hold and actively monitoring one or more signposts. For factors over which there is significant direct control, uncertainty management actions should be executed. If uncertainty is not reduced by the actions, development work should stop.

6. Conclusions

We have presented a framework for decision support for the innovation process, especially for radical innovation development projects surrounded by high level of multiple dimensions of uncertainty. In the framework, we have integrated fast risk-reward estimation foresight techniques with high level risk management techniques to produce inexpensive qualitative filters for the design and development phases, and suggested the addition of increasingly expensive quantitative techniques toward the end of the development phase, especially for exploring competition and market issues. Furthermore, we have proposed the novel idea of putting plans on hold and actively monitoring signposts with consequent improvement in right timing of market launch.

We believe that our systematic strategic decision support framework will assist managers in their decision making, by supplying systematic answers to the following questions throughout the radical innovation development process:

- How do we conserve the intellectual capital represented by partially developed ideas and visions?
- How do we avoid launching a new innovation either too early or too late?
- How much time and effort should be invested in early idea filtration and how much time in decision support for ideas that are progressing through development toward commercialization?
- How do we manage uncertainty during development?
- How do we maintain a steady pipeline of innovation?

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10. Publication VI: Uncertainty management in service innovation

Tuija Luoma*, Jaakko Paasi

* Corresponding author

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland. E-mail: firstname.lastname@vtt.fi.

Ray Strong, Ruoyi Zhou

IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120, USA. E-mail: hrstrong@us.ibm.com, ruoyi@us.ibm.com.

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Abstract: *A systematic framework to support uncertainty management and decision making in service innovation design, development and offering (business) phases is presented. At the core of the system is a dynamically evolving risk taxonomy that is mapped to either qualitative or quantitative decision process. The work was triggered by the results of large interview study about innovation management practice in 12 major Finnish organizations and an attendant research question "How could uncertainties related to service innovation be better managed?" The approach towards finding answers to the question was based on constructivist collective case methodology: at first, in identifying weak points in uncertainty management and decision making at different stages of service innovation life cycle, and, then, in suggesting the systematic framework and risk taxonomy to support the uncertainty management in decision making related to service innovation.*

Keywords: *innovation development, service innovation, risk, uncertainty.*

1. Introduction

The importance of innovation management is almost universally recognized today. Also recognized is the fact that most innovations fail. New business creation obviously involves stepping towards an unknown future, involving a plethora of uncertainties. With the increasing importance of the service sector, attention has focussed on the problems of managing service provider organisations. Not only do a vast range of organisations offer predominantly a 'service product', but those that offer 'tangible' products also add to these after-sales services, distribution services etc. At the same time, service providers must constantly look for new approaches to service design and delivery. [1] Renewal of the business, however, is the key to the long term enterprise success. Companies will not be successful in the long run if they continue too long with a strategy that only fits the needs of today.

Service design is quite similar to product design since it uses design methods to develop new offerings. Nonetheless, unlike goods, services are dominated by intangible elements. Therefore, service design focuses on bringing many intangible elements together into a cohesive client experience [2]. Services have both "front stage" and "back stage" components. The front stage is about provider-client interactions and the back stage is about operational efficiency and beating the competition. These components lead to a question: "How can the 'voice of client' and the 'voice of process' be matched for the best overall performance?" A service system is usually a complex system where resources interact in non-linear ways. That is why the behaviour of service systems is difficult to predict [3]. An innovative service enterprise must have an ongoing process for moving from a relatively large number of perceived opportunities to a relatively small number of new service offerings. It must also have a process for reviewing and updating its current repertoire. With the co-production of value that often involves prolonged interactions over significant periods of time, services generate more time related risks and require more responsiveness to the changing needs of clients than do products.

Methods currently used for the management of early innovation development are largely based on those of manufacturing enterprises [4, 5, and 6]. Service innovations, however, are inherently much more multidisciplinary than manufacturing innovations and, therefore, call for a graceful change of methods and procedures used for innovation management at different stages of the innovation life cycle. Service innovation typically needs four aspects of innovation to be successful: technological, business, social-organizational and demand innovation

[7]. In the case of manufacturing enterprise innovations each the four are present but a breakthrough in one is typically sufficient. Therefore, service innovation is hard for enterprises focussed primarily on high tech [7].

This work is a result of a joint study involving VTT Technical Research Centre of Finland and IBM Research. This paper reports one part of the joint study: decision support at multiple critical decision points of early service innovation development. In this joint work we have integrated separately developed techniques to produce a more systematic, more comprehensive, but highly efficient innovation management process for the new service development.

2. Research question and methodology

A large interview study was done by VTT in 2005 about innovation management practices in companies and public organizations in which 43 managers were interviewed from 12 major companies and public organizations in Finland (see [6] for more details). The organisations were established, globally operating Finnish companies with innovation processes and systematic practices in use and explicitly described. The original study identified management of future uncertainty as one of the main challenges to corporate executives. That resulted in the big research question of the joint work:

How should future uncertainty be managed during the entire innovation process?

The joint work describes a systematic framework to support strategic decision making in innovation development that attempts to put appropriate amounts of planning resource into the process at different stages. It is constructed to make use of qualitative evaluation techniques, based on risk management methodology, early in the process when faster, less expensive methods are preferred to more accurate quantitative techniques [8]. See chapter 3 for more details and also other publications [9, 10 and 11].

This paper reports the part of the joint work focusing on service innovation development. The research question of this part is the following:

How could uncertainties related to service innovation be better managed?

The approach of the work towards finding answers to the research question was based on constructivist case methodology which focuses on different viewpoints

and lived experience of organizational members [12, 13] and is committed to bringing up multiple voices and viewpoints. The authors have wide experience in the development of new technology and services. This experience was complemented by several discussions with other colleagues having long history in the field of service business development, viewpoints based on their experience as well as findings reported in literature. As a result, we could identify several weak points, from the viewpoint of uncertainty management, in the new service innovation life cycle. Many of them were related to decision making and to the question of right timing. Finally, the research resulted in a framework in order to overcome the weak points. The framework includes tools that have originally been developed for some separate phase or phases of innovation development but which we integrated into an uncertainty management system of service innovation by the means of generic risk management methodology [8].

3. Definitions

According to ISO/IEC Guide 73 **risk** is defined as the "combination of the probability of an event and its consequences" [14]. This concept of risk covers both positive and negative consequences, both opportunities and threats.

Risk management is systematic process where organizations methodologically "address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities" [15]. **A risk factor** is a factor that may potentially affect the organization. And **a risk taxonomy** is a hierarchical organization of (possibly overlapping) risk factors by set inclusion. An important part of our risk management methodology is the prioritizing of risk factors at an assessment point. To enable that prioritization, we have defined a quantity called **risk priority** for the estimation of risk level on a five point scale.

We also use the terms, idea, idea cluster and vision. Following [16] we define an **idea** as a description of some aspects of a potential future state of reality. A **vision** is an **idea cluster** where a consistent set of ideas are gathered together and treated as a one object of analysis. For purposes of analysis and assessment, we will often equate a risk factor with the set of enterprise related visions that would be classified as belonging to the factor.

Finally, we define term **signpost** as a potential future event that is both recognizable and actionable [17].

4. Framework for uncertainty management in innovation development

Our work is based on a framework of strategic decision making in innovation development which has been described in more detail elsewhere [9, 10 and 11]. The framework model is presented in Figure 23. The framework starts with (preferably many) ideas of new business opportunities and ends with one or more lines of business with unpredictable lifetime.

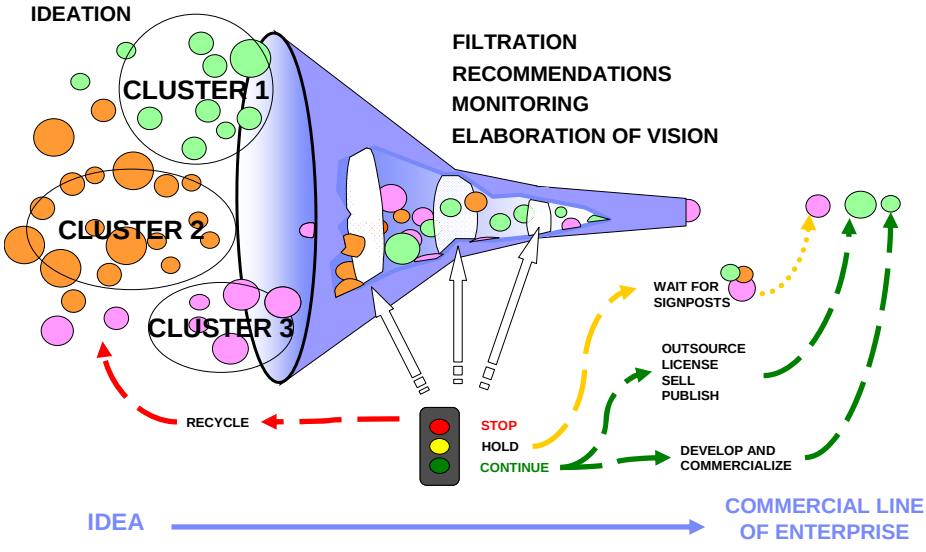

Figure 23. Framework of strategic decision making in the development of new innovations and new lines of business.

The framework illustrates how a large number of ideas can be reduced into a small number of ideas, quickly and with rather low cost. At the beginning there is an ideation stage which includes phases of preparatory background information studies, idea generation and idea clustering. In the ideation stage small single ideas are clustered into an idea cluster. Idea clustering means that ideas containing similar words or words close enough are collected together to be treated as a one object of analysis. These idea clusters have a common vision of the future and contain only a short descriptive name with a couple of sentences, a succinct statement, to summarize the idea cluster into a vision. The idea clustering is best performed by one generalist. A particular challenge in ideation is to create ideas and visions for which realization will likely occur beyond the typi-

cal business planning horizon of three to five years. See Strong *et al.* [16 and 17] and references therein for more details about the ideation stage.

After ideation there is the first filtering of idea clusters (visions) in order to reduce the number of visions in subsequent stages. The first filtration is important in narrowing the funnel more rapidly and keeping the costs low (when the number of visions can be clearly reduced in the first filtration step the lower are the costs at the later stages of the process). Filtration is followed by recommendations for further actions, which may simply be 'stop', 'hold' or 'continue'. A 'stop' recommendation could mean either discarding or recycling the idea. A 'hold' recommendation could mean creating one or more signposts and active monitoring these signposts for future conditions under which the idea would be returned to the active innovation process. A 'continue' may include alternatives of product development, commercialization, collaborating, outsourcing, patenting, licensing, selling, publishing. All these are strategic decisions.

Filtration, recommendations, monitoring and elaboration of vision form a five-phased iterative process which will be repeated at each stage of innovation process. The filtration and recommendations phases are current business practices at the gates of any stage-gate process. Active monitoring of ideas or projects on hold, however, is a novel enhancement to observed innovation practices reported in ref. [6]

The framework model follows the generic methodology of risk management, including the steps of identification of risks, analysis of risks, evaluation and selection of risk reducing measures, and implementation and follow up [8]. Risk management is a tool used for hazard identification and assessment. In general, risk management aims to protect the property, income and different activities of a company while minimizing costs. Risk analysis provides a basis for evaluating the tolerability of risks and for deciding necessary risk reducing/controlling measures.

5. Risk taxonomy and vision filtration in service innovation

This chapter describes an uncertainty management process designed for the design and development of service visions (cohesive collections of ideas and plans for a service offering) to markets and running business until the termination of a service line of business. Our method is built around the concept of a risk taxonomy, a combination of a prioritized taxonomy of service innovation risk factors with a corresponding decision tree. The risk taxonomy is a hierarchical organization of (possibly overlapping) risk factors. Relevant risk factors will depend on the

stage of the service life cycle. Potential risk factors at the early, design stage of new innovation (service design) may different to those of development project (service development) and definitely different to those of running line of business (service offering). An example of top level risk taxonomy for service innovation and life cycle management is given in Figure 24. The top level service design, service development and service offering trees contain groups of risk factors, such as market environment, idea/value proposition etc. Several potential risk factors could be identified under each group. An example of risk taxonomy for the service design context is given in Figure 25. It comprises several risk factors.

Risk taxonomies are typically used when conducting vulnerability analyses [18] and can be used as a checklist at decision points in the innovation life cycle [19 and 20]. Enterprises applying the model should carefully consider which factors in the sample risk taxonomy are critical to them, or whether any important factors are missing since a risk taxonomy may be comprehensive for one enterprise but not for another. In our opinion good risk taxonomies are reusable resources and adapting a ready generic risk taxonomy is likely much faster and less expensive than developing a new risk taxonomy for each enterprise. Furthermore, the taxonomy can be evolved along with its use, following its own constructivist methodology.

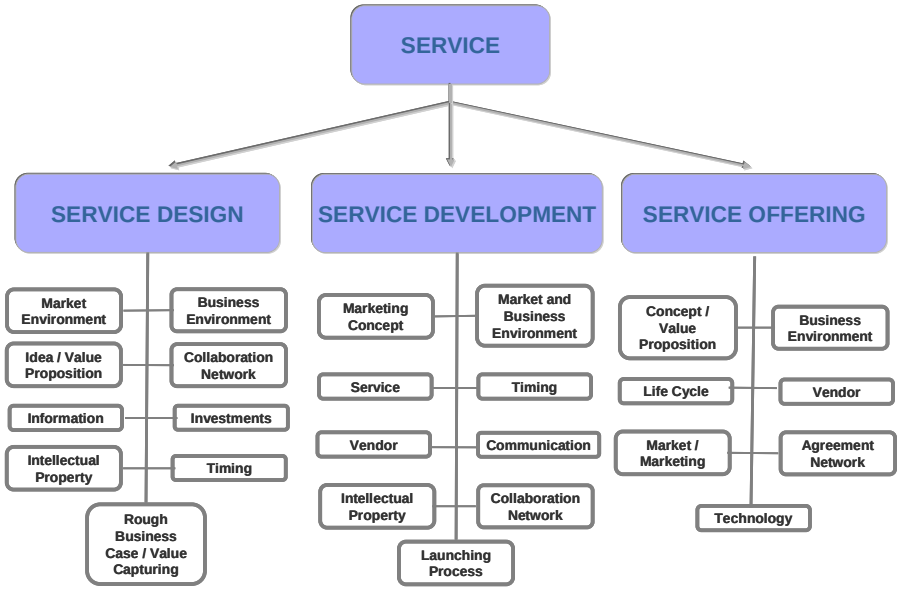

Figure 24. An example of top level of risk taxonomy of service innovation.

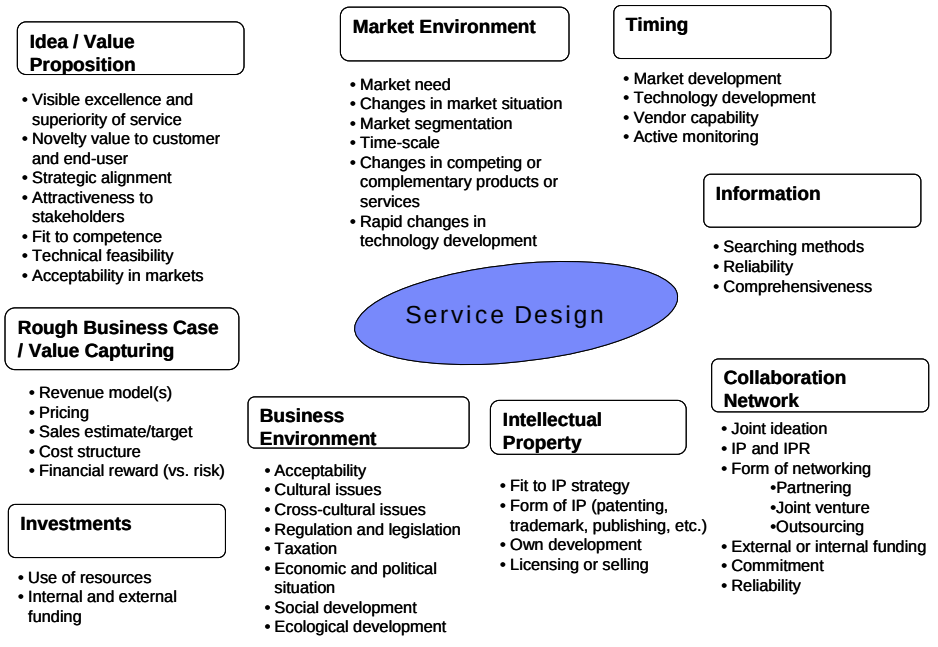

Figure 25. An example of risk taxonomy for service design.

Risk factors are turned into questions used for obtaining qualitative expert estimates, Figure 26. A question is here defined as a request for an estimate that can be answered with any rational number on a five point scale (from 1 to 5). At this level of taxonomy, differences between service enterprise and manufacturing enterprise innovations are obvious. The results of the expert estimates are used for risk prioritizing and input for strategic decision making. Throughout the process, our focus is on performing the minimum amount of work required to support service innovation life cycle decisions.

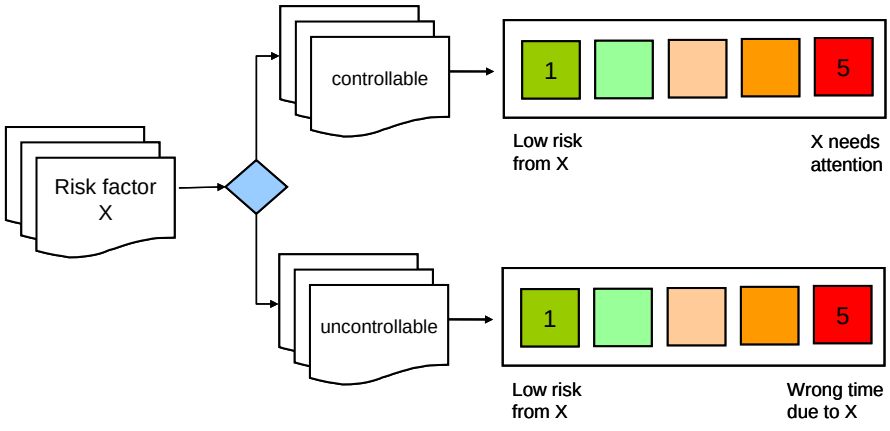

Figure 26. Map from risk factors to questions used in expert analysis of potential risks.

In the context of creating new service concepts, controllable risk factors cover (for example) issues like the actual concept and the business plan. What is the value of this new service concept for the client? What kind of technical features does it exhibit? What kind of marketing methods will be used? Some enterprise ecosystem issues are also controllable risk factors. What kind of collaboration network does the enterprise have? What kind of resources in terms of supplies, technology and people does the enterprise have? And how are the intellectual property (IP) issues handled in the enterprise? Uncontrollable risk factors are (for example) market environment and external ecosystem issues. What is the competitive situation? What is the general economic situation? What kind of vendors are there? What kind of IP do the competitors have?

From the services point of view, understanding clients and their requirements are essential issues. Clients play a larger role with a typically longer duration in services. Their needs are neither objective nor are they stable. They use the service and experience the benefit. It is often hard to predict how they will interpret that experience. The client experience may also lead to a word-of-mouth epidemic of unforgettable importance [21]. In the beginning of the innovation process we should ask: “Do we fully understand the client need?” Nearly all service offerings involve close interaction with clients. Client interaction has a positive effect on new service performance and may be a success factor for a new service [22 and 23]. All the factors related to service innovation may be difficult to see because services are intangible and complex. For example collaboration networks associated with services are more complex than those associated with

products, since service offerings usually involve several partners (including the client!) who provide the service jointly. Moreover, intellectual property and contract issues may be difficult to formulate because of the intangibility of the service.

We give two examples of expert questionnaires used in the analysis of risks at the beginning of the innovation process: the first is used for the initial evaluation of clustered ideas (visions), and the second is at the second filtering of ideas of new business opportunities after the visions have passed the first screening and have been elaborated to the next step.

The first filtering (Step 0) is done using Table 13, in which the impacts and uncertainties are briefly ranked by experts. The first filtering (Step 0) gives a good first overview of visions. The filter can evaluate aspects such as:

- How much profit or savings could we make from the vision? That is, what is the impact – net positive benefit – to the company? If measured in $, one should think log scale because at this stage of innovation process uncertainties related to profit or savings estimations are high. *(1 = potential profit or savings from this idea would be very low, 5 = potential profit or savings from the idea could be very high.)*
- How much uncertainty is there? That is, how much time, knowledge and development do we need before the idea has been grown into a business? According to what we know now, will the service offering take place in the near future, intermediate future or deep future? *(1 = low uncertainty or near future, 3 = medium uncertainty or intermediate future, and 5 = high uncertainty or deep future.)*

The ideas (visions) at this early stage of innovation process are very rough and contain only a little information, for example:

A) Name: New way to fund research
   a. description: host market for trading options on potential license value of results of proposed research
   b. constituent ideas:
      i. prediction markets associated with patents
      ii. markets in (options on) licenses associated with patent applications
      iii. research proposal goes public: analogy with IPO
      iv. role of underwriter in funding and remarketing research proposals.

Experts are asked to submit both a response to the question and a self-evaluation of their own expertise with respect to the question. Responses are weighted by self reported expertise and averaged to provide the expert qualitative evaluation. The results (weighted averages and recommendations) are provided as a support for decision making (Figure 23) together with additional viewpoints from the strategy. We do not suggest these weighted average responses be compared without thought against some fixed thresholds.

The result of Step 0 is a two-dimensional plot of these ideas from which one can decide which ideas to carry on to the next phase, Figure 27. The graphical representation of the results of Step 0 facilitates selection of ideas to continue in the process. Presumably, one would not keep an idea that was below and to the right of an idea that was discarded. The choice of which specific ideas to keep depends on the orientation of the enterprise toward the future.

Table 13. Example of filter used for the first screening of ideas or visions.

VISION FILTRATION - STEP 0	Evaluation of factor (1=low and 5=high)	
Vision	Impact	Uncertainty
New way to fund research		
Evaluator	Level of expertise (1-5)	
Battery change service		
Evaluator	Level of expertise (1-5)	
Financial anomaly reporting		
Evaluator	Level of expertise (1-5)	
New recruiting service		
Evaluator	Level of expertise (1-5)	
Self-service optimization		
Evaluator	Level of expertise (1-5)	

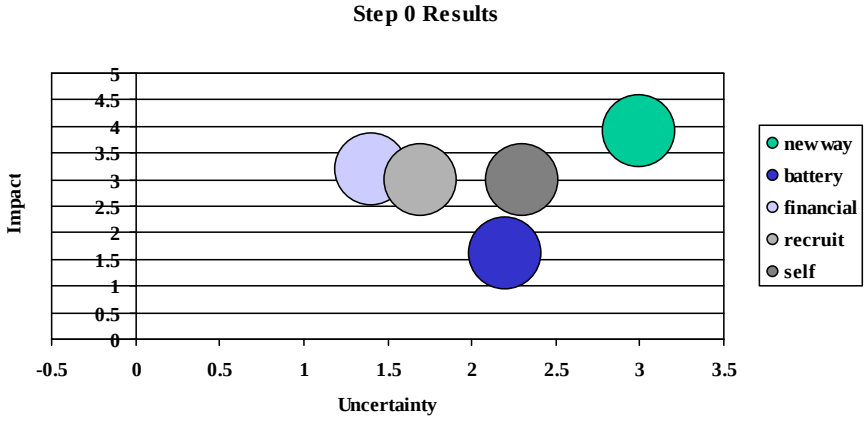

Figure 27. Visualization example of the results of Step 0 (expert evaluation of visions) from which one can decide which ideas to carry on to the next phase.

Note that we can consider concurrently visions that will very likely be realized at very different times, separated by years or even decades. Our methods provide the flexibility to allow concurrent development projects with arbitrarily different expected durations.

After the decisions related to Step 0, the visions which passed the gate will be elaborated in activities related to new innovation development [0, 0 and 0]. After elaboration, the visions will go to the second filtering (Step 1). The second filtering is done like Step 0, but now the expert questionnaire goes into more details, Table 14. The filter can evaluate aspects such as:

- What are the impacts of the vision? (*1 = lowest impact – the potential profit or savings from the idea are very low and also the potential change is very low, 5 = highest impact – the potential profit or savings from the idea are very high.*)
- Is the vision (value proposition) novel and exciting? (*1 = idea is novel, clear, exciting; benefits are easy to understand, 5 = idea is old, vague, boring; no obvious benefits.*)
- Will the business plan be straightforward and easy to create? (*1 = plan will be straightforward and easy to create, 5 = plan will be almost impossible to create.*)
- Do we have everything we need in terms of
    - technology and skilled resources
    - regulatory climate, patents, licenses, trade or service marks
    - market demand, lack of competition, business culture?

- Or is the time not right for this idea yet? (*1 = we have everything we need in terms of technical / regulatory / market feasibility, 5 = the time isn't right for this idea.*)

Table 14. Example of filter (expert questionnaire) used for the second screening of elaborated ideas or visions.

VISION FILTRATION - STEP 1	**Uncertainty / Impact Related to Factor Group** *(1=low uncertainty/expertise/impact and 5=high uncertainty/expertise/impact)*					
	Uncertainty					**Impact**
Vision	**Value Proposition**	**Business Plan**	**Technical Feasibility**	**Regulatory Feasibility**	**Market Feasibility**	**Net positive benefit**
A: New way to fund research						
A: Evaluator – Level of Expertise (1-5)						
C: Financial anomaly reporting						
C: Evaluator – Level of Expertise (1-5)						
D: New recruiting service						
D: Evaluator – Level of Expertise (1-5)						

A risk taxonomy for the design stage is used in order to support the uncertainty evaluation of ideas/visions by experts. Each decision in Step 1 (and in the following steps) has the additional 'hold' alternative, which means a decision to create a signpost and wait for the right time.

Note that we have dropped the battery service and the self-service optimization after the first filter. This doesn't mean that we have forever decided against offering such services. When the vision is stopped, its constituent ideas are returned to the pool of initial ideas for possible incorporation in other visions. What kind of visions are filtered depend also on the ability of the client to tolerate risk and how far-reaching is the client.

After each filter remaining idea clusters, visions, are elaborated into more detailed description about the vision and finally into the business plan. As the idea goes forward in the innovation process, the content of the questionnaires at filtering could become the same as the evaluation scorecards at the gates [24, 25

and 26]. Depending on the innovation development process of company, the same filter could be used at multiple gates.

Filtration and consequent recommendations give valuable input for the decision making at different stages of service innovation. Although the recommendations are accompanied by the results of expert evaluation (figures), we do not suggest to use some fixed thresholds when making the decisions about the next steps with the vision (stop, hold, continue). Instead, one could use the expert evaluation of impacts and uncertainties in linking the process to standard portfolio management practices [25]. What will then follow in the decision making depends on the strategy and risk taking profile of the company.

6. Conclusions

To be flexible in responding to changing markets, economies, etc., a service provider must maintain a large pipeline of early stage ideas and visions corresponding to potential service offerings. By example, we have elaborated on the application of our innovation management framework to early (design phase) innovation management for potential service offerings. We have illustrated how our innovation process is designed for continual innovation and for innovation development projects with vastly disparate life cycles. We have provided somewhat realistic potential service offerings and followed them through the first two filtrations steps. These early steps are designed to reduce dramatically the number of visions into which significant resources will be invested without requiring proportionally high resource costs for execution of the filters. We illustrated the role of risk taxonomy and how to convert risk factors into questions that experts can answer quickly and thus relatively inexpensively. Decisions at later stages of the innovation life cycle incorporate both the qualitative methods described here and more expensive quantitative methods, but these later filter steps are performed on much smaller numbers of potential service offerings because of the early filtration.

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11. Publication VII: Systematic risk management for the innovative enterprise

Jaakko Paasi* & Tuija Luoma

* Corresponding author

VTT Technical Research Centre of Finland, P.O. Box 1300, FI-33101 Tampere, Finland. E-mail: jaakko.paasi@vtt.fi, tuija.luoma@vtt.fi.

Ray Strong, Ruoyi Zhou

IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120, USA, E-mail: hrstrong@us.ibm.com, ruoyi@us.ibm.com

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Abstract: *We present systematic decision support for innovation management. At the core of our system is a dynamically evolving risk taxonomy that can be mapped to either qualitative or quantitative decision processes. The work is based on a large interview study about innovation management practices in companies which initiated the research question of the work: How should future uncertainty be managed during the entire innovation life cycle? The approach towards finding answers to the question was based on constructivist collective case methodology. Some of the individual building blocks described in this paper are well known, but our concept for their integration into a risk management based decision support system is novel. In the context of a portfolio of potential and actual business offerings, we discuss how to spread, hedge, or mitigate risk, and how these activities constitute enterprise innovation management.*

Keywords: *innovation; innovation management; risk; uncertainty; risk management; strategic management; decision making; innovative enterprise.*

1. Introduction

The modern enterprise that bases its business models on innovation requires a management system that provides both encouragement for risk taking and agility at navigating disruptive changes in the ecosystem. Yesterday's innovative products and services are today's commodities. In order to maintain a high profit margin and characterization as a growth company, the enterprise must generate new ideas that lead eventually to new lines of business and new business models. It is not enough to simply improve productivity within a fixed line or model.

Disruptive changes in an enterprise ecosystem are accompanied by multiple uncertainties. Leifer *et al.* have defined four major dimensions of uncertainty that are relevant for all innovation development projects targeting to new lines of business: technological, market, organizational, and resource uncertainties [1]. The management challenge of multiple dimensions of uncertainty is complicated by the fact that the uncertainties interact with each other, in the sense that there are complex correlations. Additional management challenges come when the innovation idea is not perfectly in line with company's current strategy, which is a frequent case when the innovation would mean a new line of business for the company [1, 2, 3]. Many of these challenges can be met with the aid of a systematic support system for decision making in order to manage the innovative enterprise throughout the innovation life cycle from idea to the termination of line of business.

While the support of operative management is well developed in the majority of enterprises, much less attention has been paid to the support of strategic management. There are tools and techniques available to support strategic decision, such as various kind of foresight techniques [4, 5, and 6], business insight tools [7], SWOT [8] and Delphi technique [9], etc. However, while these tools and techniques may give valuable support for decision making at some specific phases of new innovation development, systematic support for strategic decision making related to new innovation and business development from an idea through development and offering phases until the termination of a line of business is lacking.

We present a system that provides decision support for innovation management, focusing on an innovation life cycle from idea to line of business. Our system is based on a set of operating principles including

1. encouraging innovation
2. efficient decision making
3. minimizing waste of intellectual capital

4. an open-ended and dynamic risk taxonomy
5. the treatment of risk via either mitigation or insurance.

While the focus of (1), (2), and (3) is in the front end activities of the innovation life cycle, (4) and (5) cover the entire life cycle, including the termination of lines of business. Principles (1), (2), and (3) have been presented elsewhere [10,11]. Here we just summarize extensive discussion of the first three principles: (1) we suggest encouraging innovation by soliciting undeveloped, ambiguous ideas (to be combined into project visions) rather than well developed proposals with business cases; (2) we suggest that qualitative techniques for decision support are less expensive and more appropriate than quantitative techniques early in the innovation life cycle; (3) we suggest conserving intellectual capital by recycling ideas that have previously been constituents of the vision of a terminated project.

In this paper we will focus on principles (4) and (5). We illustrate the development and application of an open-ended hierarchy of risk factors to the stages of innovation life cycle. We show how to map this risk taxonomy onto sets of questions appropriate for different stages of development, and how to use sets of responses to these questions both to support decision making and to support the evolution of the risk taxonomy itself. Throughout the paper we discuss how to spread, hedge, or mitigate risk, and how these activities constitute enterprise innovation management.

2. Methodology

The work is based on a large interview study done by VTT in 2005 about innovation management practices in companies and public organizations (see [2] for more details). The study identified management of future uncertainty as one of the main challenges to corporate executives. That initiated the research question of the work:

How should future uncertainty be managed during the entire innovation life cycle?

Our approach is based on constructivist methodology, focusing on different viewpoints and lived experience of organizational members and is committed to bringing up multiple voices and viewpoints [12,13]. The authors have wide experience in research, development and consultancy work in the fields of technology foresight and risk management as well as in the development of new technology and services. We draw on this experience in order to specify the research

problem in a more detail, and then, to develop tools and methods for the management of the uncertainty. The tools (process building blocks) have been integrated by applying the generic methodology of risk management [14, 15, 16] in order to produce the primary novel contribution of the work: a dynamically evolving risk taxonomy to provide systematic support for decision making in the innovative enterprise. The risk taxonomy itself follows the constructivist methodology: the taxonomy evolves in response to different viewpoints and lived experience of organizational members. Risk management has been widely used in financial sector as well as in safety engineering but rarely applied in business management in general.

Some of the individual building blocks described in this paper are well known and widely used. However, our concept for their integration into a decision support system is novel and presented as a working hypothesis:

Working Hypothesis: The potential and actual lines of business of an innovative enterprise can be efficiently and usefully managed by means of decision support based on a dynamic risk taxonomy.

Validation of the hypothesis could be done in two ways: (1) by developing the concepts presented in this paper into a practical tool and by testing it in real innovation (new business) development cases in several enterprises, or (2) by defining and performing specific explicit experiments that advance the science supporting the working hypothesis. While actions towards the validation through way 1 are in progress, it will take several years from an idea to a running business so that the validation process will be long. Therefore, this conceptual paper enumerates four explicit experiments that could be done in a short term. We invite scientific society to perform and report the results of these experiments.

3. Definitions

At the conceptual level, (enterprise) risk is defined in a standard way as the "combination of the probability of an event and its consequences" [14, 15]. This concept of risk covers both positive and negative consequences, both opportunities and threats.

An enterprise is a value delivery system with relatively well-defined boundaries, a portfolio of lines of business (each with a business model), a dominant culture, and motivation to achieve profit. Note that events (changes in the state of reality) may lead to or realize risks; but events are not risks, themselves. Risk management is systematic process where organizations methodologically "ad-

dress the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities" [17]. A Risk factor is a factor that may potentially affect the organization. And a risk taxonomy is an organization of (possibly overlapping) risk factors by set inclusion.

We call any specific stage in the innovation life cycle of a potential or actual line of business an assessment point. Much of the methodology of this paper is devoted to assessing risk associated with a risk factor at an assessment point. An important part of our risk management methodology is the prioritizing of risk factors at an assessment point. Related to that we have defined a quantity called risk priority for the estimation of risk level on a five point scale.

We also use terms idea and vision. Following [18] we define an idea as a description of some aspects of a potential future state of reality. A vision is a consistent set of ideas. For purposes of analysis and assessment, we will often equate a risk factor with the set of enterprise related visions that would be classified as belonging to the factor.

4. Decision support

Decision points

The innovation life cycle contains several stages which can be sequential or overlapping. Each stage contains at least one strategic decision point, assessment point at which decisions will be made that affect the innovation life cycle, Figure 28.

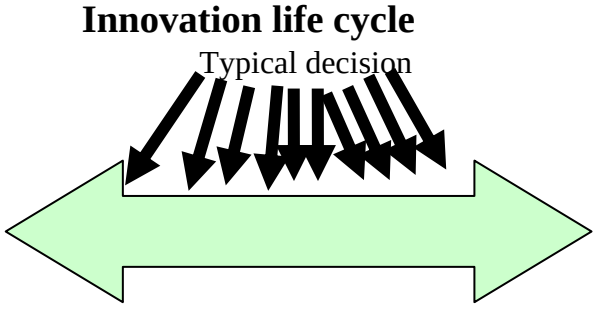

Figure 28. Life cycle decision points of innovation.

The basic decision: stop, hold, or go

At each decision point the basic decision is whether to GO on in the potential or actual line of business or to STOP and terminate the process. A third alternative is to put the potential or actual line of business into a temporary HOLD state to wait for a better time to continue the process, Figure 29. The choice to stop or hold an initiative under development cannot be made lightly. If we stop, then we may recycle the basic ideas; but we have definitely expended some research and development effort without any return to show for it. If we put an initiative on hold, we have the ability to resume the initiative when conditions are more auspicious. But there is always a cost in stopping a productive team in the middle and redirecting or even breaking up that team.

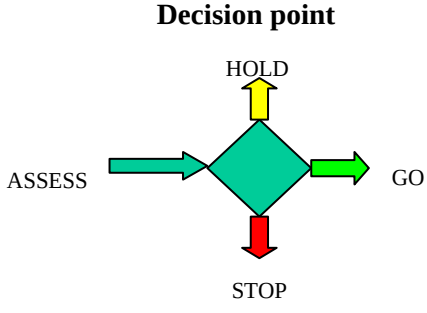

Figure 29. Stop, hold, or go.

We have discussed elsewhere [10] the utility of the signpost method in returning a potential or actual line of business from a temporary HOLD state. The signpost method is a way to systematically explore possible futures, setting up networks of visions punctuated by signposts [18]. A signpost is a potential future event that is both recognizable and actionable. Part of the cost of entering a HOLD state is the cost of defining the signpost that will be used to signal its recommended return. If no such signpost can be found, then it is likely better to end (STOP) the project or offering, since we can't define explicit conditions under which we believe we should restart it.

Expert evaluation as decision support

When using any measure or estimate in support of a decision, one of the two processes can be used: (1) direct measurement, observation, or report of an authoritative data source, or (2) estimates made by various subject matter experts. The latter process could be based on the standard Delphi method with the key features of anonymity, iteration, controlled feedback, and the statistical aggregation of group response [9], or some kind of approximation of the standard Delphi. The standard Delphi is a slow (and expensive) process as it calls for a consensus with all experts participating simultaneously in a meeting. Therefore, good alternatives would be welcomed by the industry.

We are suggesting an approximation of Delphi in where the experts give quantitative evaluations on a five-point scale by using simple, reusable, electronic questionnaires without the need of simultaneous meeting. Weights used in the weighted average of the process are self assessed measures of expertise relevant to the specific estimate (see [11] for more details). In order to distinguish with the standard Delphi, we call the approximation as qualitative expert evaluation process.

Below, we will discuss mapping risk factors into questions. These questions are directed to multiple subject matter experts who respond according to the qualitative expert evaluation process. Later, some of these questions are answered by means of quantitative studies.

Here we mention the first of several experiments to be performed in order to improve our system. We welcome any independent reports of results of experiments of this type.

Experiment 1. With the same set of subject matter experts, perform concurrently approximate Delphi and a standard Delphi process to measure the accuracy of approximate Delphi and to determine any systematic bias it may introduce.

5. Risk management for systematic innovation management

In this paper we treat risks associated with potential or actual enterprise lines of business that are products of innovation. We follow the generic methodology of risk management, including the steps of identification of risks, analysis of risks, evaluation and selection of risk reducing measures, and implementation and follow up [16] with some refinement based on the controllability of risk factors. In general, risk management aims to protect the property, income and different

activities of a company while minimizing costs. Note that, according to the definition in section 3, risks may be associated with events having either positive (opportunity) or negative (threat) impact to the enterprise.

The framework of risk management developed in this work is shown in Figure 30. The process starts from a taxonomy based risk identification where check lists are used for potential risk factors. Identified risks are qualitatively analyzed and evaluated by experts with the help of questionnaires. After ranking and prioritizing the risks (risk profile and consequence analysis), negative risk reducing measures are selected. If necessary, qualitative risk analysis is supplemented by a quantitative study. The result is a complete package of support for a specific decision point. Once the decision is made, any negative risk reduction measures can be implemented and tracked for consideration at the next decision point.

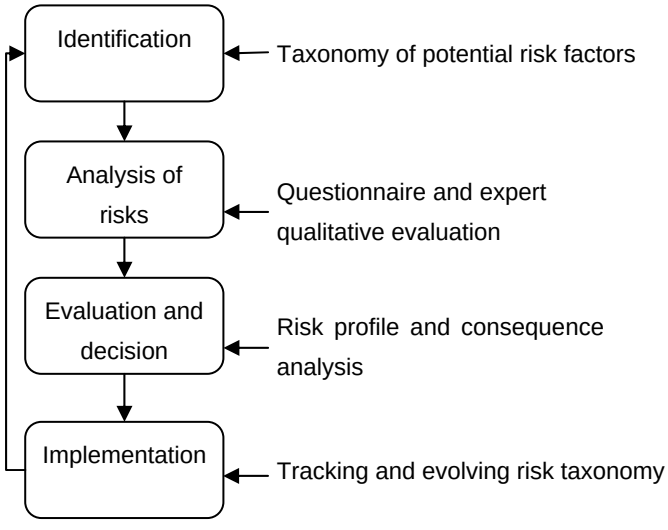

Figure 30. Framework of risk management steps for systematic innovation management (adapted from [16]).

It is important to point out that in our framework the risk assessment (in the first level) is based on qualitative estimation of likelihood and consequences. Qualitative estimates of likelihood should not treated as probabilities, and they should not be used to estimate expected costs.

We use the qualitative expert evaluation process described in section 4 as a qualitative technique for prioritizing risk factors at an assessment point. A quan-

tity called risk priority is estimated on our standard five point scale. A high risk priority means that the risk factor needs attention. Estimated risk priority may not be proportional in size to negative impact on some specific key performance indicator like profit [19]. Instead, this kind of impact is estimated as a product of a likelihood of realization of a vision associated with the risk factor and an estimate for the impact of the vision. Note that this approach to risk is very different from the approach that treats risk as volatility in a time series [20]. We use brainstorming among a team of subject matter experts to enumerate visions relevant to a given risk factor. We reorganize the separate visions to be as independent as possible. Then we sum the products of estimated probabilities and impacts in order to estimate the risk.

Experiment 2. With the same set of subject matter experts and with respect to the same assessment point and risk factor, enumerate the visions associated with the risk factor. Use the qualitative expert evaluation process to estimate (a) the risk priority, (b) the likelihood of each of the visions, (c) the negative impact of each of the visions. Repeat this operation for several different assessment points and risk factors. Test for the degree of correlation between (a) and the inner product of (b) and (c).

If there is good correlation between risk priority and the product of likelihood and impact, then we can skip estimations (b) and (c) in favor of (a). In any case, we believe we can use (a) to decide when estimations (b) and (c) are necessary.

6. Dynamic risk taxonomy

Risk taxonomy

A risk taxonomy is a hierarchical organization of (possibly overlapping) risk factors, the hierarchy representing set inclusion of the associated ideas. It is helpful to bifurcate the hierarchy (at the top) with a classification of risk factors that are controllable and those that are not, Figure 31. By controllable, we mean that the enterprise has either the ability to mitigate the risk or to compensate for the risk. Note that it is easy to construct risk factors that are partially controllable and partially not. Moreover, there are risk factors and enterprises for which the classification is unknown. However, where possible, we attempt to deal only with risk factors that are known to be exclusively controllable or exclusively not controllable by the enterprise.

- **Controllable**
  - Concept
    - Idea
      - *Value Proposition*
    - Plan
      - *Technical*
      - *Marketing*
      - *Delivery*
  - Enterprise ecosystem
    - Collaboration network
    - Resources
      - *Supplies*
      - *Technology*
      - *People*
    - Intellectual Property
- **Uncontrollable**
  - Market environment
    - Client preferences
    - Competition
    - Economy
  - Other environment
  - External ecosystem
    - Collaborators
    - Vendors
    - Intellectual Property

Figure 31. An example of high level portion of a services risk taxonomy.

Another desirable quality for a risk taxonomy is comprehensiveness. It would be nice if the set of risk factors covered every imaginable risk related to the enterprise and its portfolio of potential and actual lines of business. However, the nature of human knowledge makes this type of comprehensiveness impossible. Instead, we choose to define our taxonomy as comprehensive if it is a dynamic structure that is open-ended and the union of risk factors covered by its nodes is intended to represent all known risk factors relevant to the enterprise.

A risk taxonomy can be used as a checklist at decision points in the innovation life cycle [19]. Note that a risk taxonomy may be comprehensive for one enter-

prise but not for another. Nevertheless, we believe that good risk taxonomies are reusable resources and that the exercise of adapting a risk taxonomy from one enterprise to another is likely much faster and less expensive than developing a new risk taxonomy for each enterprise.

Map from risk factors to questions

In order to provide a single standard type of expert estimate, we define a question as a request for an estimate that can be answered with any rational number on a five point scale (from 1 to 5). For qualitative estimates, the end points of the scale are given meanings and the middle point of the scale (value 3) is considered neutral between values 1 and 5. Thus the generic map from risk factors to questions produces a scale with 1 defined as “low risk”, 3 defined as “medium risk”, and 5 defined as “high risk”. This is the question used to measure the priority of a risk factor.

Often a more specific and more appropriate question can be generated for a given risk factor. Our preferred systematic approach is to map controllable risk factors to questions where the scale has 1 defined as “low risk priority” and 5 defined as “needs attention”; and to map uncontrollable risk factors to questions where the scale has 1 defined as “low risk” but 5 is defined as “not the right time for this line of business due to this risk factor” or “wrong time” (short label), Figure 32. The implication of the “wrong time” rating is that the project to develop the potential line of business should be placed on hold but not terminated. If the line of business is already offered, then the implication is that the enterprise should temporarily (not permanently) cease offering it.

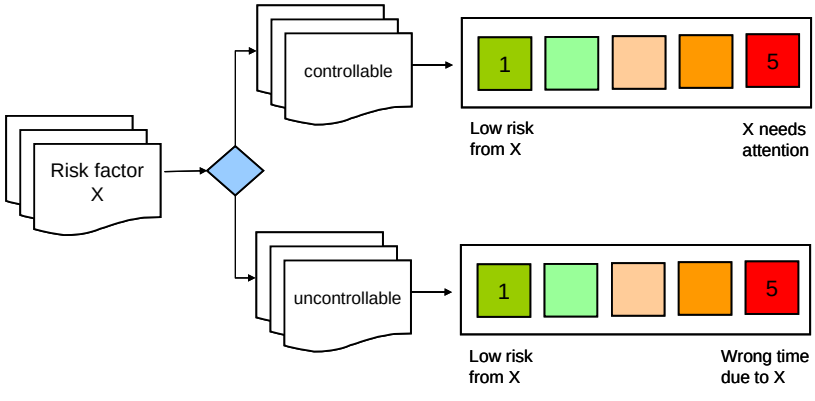

Figure 32. Map from risk factors to questions.

Note that controllability is a dynamic attribute of risk factors. Controllability may be affected by changes in offerings of other enterprises in the relevant ecosystem. For example, some enterprise may initiate an offering of a type of financial option, swap, or other derivative that would allow a purchaser to hedge against a particular risk factor. Consider a planned line of business within a jurisdiction where the relevant transactions are not currently taxed. The risk of a new tax or tax increase might not be controllable by the enterprise until some other enterprise offered tax increase insurance.

Generally, lack of knowledge about a market is a controllable risk factor; but market preferences and competition are not. However, the introduction of prediction markets [21, 22] with appropriate derivative options could make all three risk factors at least somewhat controllable.

Whether the question asks about “needs attention” or about “wrong time” the decision supported by the question has all three possible outcomes (from section 4). The “wrong time” rating suggests a decision of HOLD rather than STOP and the “needs attention” rating suggests STOP rather than HOLD; but these are simply systematic decision support recommendations, not rigid rules.

Tolerable risk

In general innovation management decisions are made by analyzing both risk and reward potential. While many of the techniques we discuss can also be used to analyze rewards, a general system for reward management is beyond the scope of this paper. Instead we emphasize how much can be done while operating strictly on the risk assessment side and treating the reward analysis (business case analysis) as a risk factor.

A partial reason for standardizing our risk assessment with questions on a uniform five point scale is the possibility of adopting a uniform threshold for tolerable risk priority. When risks are assessed below a tolerability threshold, no further analysis work would be necessary. Only when risk factors were evaluated above such a threshold would they require further analysis, e.g. analysis about right timing and analysis about ability to mitigate or control risk in the future. Such a threshold would be computed separately for controllable and uncontrollable risk, with the controllable risk threshold shrinking to some minimum at the assessment point corresponding to a launch decision. Note that such thresholds could be used as throttles to control the rate of development of potential new lines of business.

Initially, such thresholds could be set via the qualitative expert evaluation process, but we would expect to use machine learning techniques to adjust them over time. This envisioned process suggests experiments that could be performed on a small set of real assessment points for potential lines of business.

Experiment 3. Break a large group of subject matter experts into two groups, controlling for as many group differentiating factors as possible. The two groups perform the following two assessments in opposite order: (1) estimate a uniform tolerability threshold for controllable risk factors, and (2) estimate risk priority for a set of controllable risk factors. Compare the results of the two groups for systematic bias.

Experiment 4. Compare controllable risk priority assessments over the course of several subsequent assessment points. Can we predict later assessments from early assessments? Is there a threshold such that assessments above the threshold remain above the threshold and tend to increase while assessments below the threshold remain below the threshold and tend to decrease?

Dynamical evolving of risk taxonomy

Our risk taxonomy is dynamic with respect to total content, and organization. The content is dynamic in order to meet our comprehensiveness requirement. Whenever we discover a new risk factor that is not covered by the current taxonomy, we must add it to the taxonomy in order to maintain comprehensiveness (coverage of known risk factors). When we use subject matter experts to evaluate risk factors, we also ask our experts for any suggestions of risk factors we may have missed.

The organization determines order of application in life cycle (high level for early, more detailed for later). At each assessment point, we select a comprehensive frontier of the risk taxonomy for analysis. Figure 33 illustrates the difference between the frontier selected for an early assessment point and that selected for a later assessment point. The process of moving the frontier to a more detailed level is motivated by our principle of efficient decisions: we wish to save more detailed and thus more expensive analysis for later in the life cycle. This is the same reason we prefer qualitative to quantitative analysis early in the life cycle. For simplicity, we attempt to keep the frontier selected at a uniform level in the hierarchy. Note that in Figure 6, the early frontier is at level 2 and the late frontier is at level 5 except where the hierarchy does not extend to level 5.

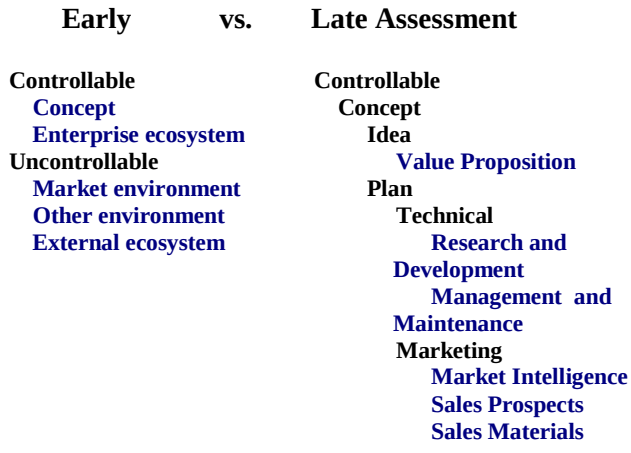

Figure 33. Portion of risk factors analyzed for early versus late assessment points.

Both assessment points in Figure 33 are assumed to occur before delivery. Launching a line of business eliminates branches of the hierarchy that apply only to design or development stages, but also brings up new factors relevant only to the offering stage of business.

Subject matter experts are shown the entire risk taxonomy; but asked to respond to questions that have been mapped from the chosen level of the hierarchy. In free form comments they can also suggest whether a given factor is relevant.

When a risk factor is assessed by subject matter experts, we expect the weights corresponding to self evaluated expertise to be low if the experts don't feel comfortable evaluating the factor at the particular assessment point. So, when we receive an aggregate low rating in expertise, we can return to the experts to determine whether we are simply missing appropriate expertise or there is some reason why they believe the question cannot be answered. If the answer is that the assessment point is too early, then we effectively demote the risk factor by one or more levels in the hierarchy, replacing it with placeholders not intended for evaluation when necessary. Likewise, the submitted estimates may be widely distributed. When the expertise weight is widely distributed we may suspect that the risk factor has separate aspects with different estimates. Having ascertained this information from the subject matter experts, either by asking directly, or from their free form comments, we may promote the risk factor higher in the hierarchy, so that it is evaluated earlier and its constituents are evaluated for the current assessment point, Figure 34.

We envision each potential or actual line of business having an associated official risk taxonomy, mapped at an active frontier of the hierarchy into a list of questions with the latest qualitative or quantitative estimates, visualized for easy presentation, as part of a governance (decision making) package.

Figure 34. Risk taxonomy organization before and after feedback induced promotion of one factor.

Portfolio management and control of negative risk

Decisions about whether to continue developing or offering a particular line of business should be made in the context of the whole enterprise portfolio of potential and actual lines of business. This management principle is justified by the need to optimize investment but also by the potential for compensating risks. The influence of future uncertainty with respect to some risk factors to the portfolio of businesses or projects (potential businesses) could be simulated by the help of uncertainty and sensitivity analysis (for example, by using Monte Carlo technique [23]). Such an uncertainty and sensitivity analysis would give additional support for the decision makers for their stop, hold, or go -decisions related to a single project or business in a portfolio.

Controllable negative risks should be tolerably controlled before we proceed to launch or resume offering a line of business. This is a special case of a broader principle that suggests making larger investments in order to mitigate larger risks corresponding to larger investments associated with later stages in the innovation life cycle: “Like any activity in project management, the efforts

spent in risk management must commensurate with the risks involved, the scale of the projects, the costs of managing such risks and how it will affect the objectives of the project" [24].

7. Conclusions

In this paper we have introduced the concept of a dynamic risk taxonomy. We describe risk assessment by the qualitative technique of subject matter expert evaluation. We have shown how to use increasingly deeper levels in a risk taxonomy over the course of the complete innovation life cycle. We have suggested applying modern portfolio management theory to the enterprise portfolio of potential and actual lines of business. Finally, we have illustrated how the dynamic risk taxonomy can evolve as a byproduct of our qualitative and quantitative assessments.

Some of the individual building blocks described in this paper are well known and widely used. However, our concept for their integration into a decision support system is novel. Accordingly, the main contribution of the paper could be summarized as a detailed presentation of the working hypothesis "The potential and actual lines of business of an innovative enterprise can be efficiently and usefully managed by means of decision support based on a dynamic risk taxonomy".

If the working hypothesis will be validated (even if only partially), the framework of the risk management presented in the paper would offer a systematic way for innovative enterprises to manage uncertainties related to technology, markets, organizations and resources throughout the innovation life cycle from an idea to the termination of line of business. Before practical applications, the conceptual model presented in the paper has to be developed into a practical real working tool. Work towards that is in progress.

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12. Conclusion

This is the final report of the work done at VTT within INNORISK project, a 3-year (1/2006–2/2009) joint research project between the Corporate Foresight Group (CoFi) of Åbo Akademi and VTT Technical Research Centre of Finland as a part of the LIITO technology programme of Tekes. The focus of VTT's work in the project was on the development of practical methods and tools for the management of opportunities, risks and uncertainties in new business creation. In order to ensure the functionality of the methods and tools, the work was done in close collaboration with companies (both SMEs and large corporations) and experts from Finland, the Netherlands and the USA. The work was restricted to methods and tools for supporting the decision making related to the implementation of existing technologies into new markets, the development of new technologies for existing markets, or the creation of new technologies in new markets. Decision making related to incremental improvements of existing technologies to existing markests was not within the scope of the project.

The guiding principle behind the work has been to apply the generic methodology of risk management to challenges related to new business creation. New business creation starts from the recognition of new business opportunities. Before an opportunity could be evolved into an innovation, we need a strong ability to make important strategic decisions, a capability to conceptualise the opportunity and to transform it into the final product, process or service, and to manage risks related to the commercialisation. A major challenge related to all this is the question of timing. When it is a question of new technology, the time needed from the original idea to the product launch can be several years. The long duration itself brings challenges to all decision making during the new business creation because of the associated uncertainties of the technology, markets, organisation and resource aspects. There is a clear need in companies for the management of future uncertainties, and this is what INNORISK is all about.

Some of the methods and tools presented in this report are well established and present current best practices in the innovation (new business) development process. Also, some methods and tools were specifically designed within the INNORISK project and, thus, are more or less only at a conceptual level and further development work is needed before they could be implemented into the innovation processes of companies.

The INNORISK methods and tools aim to support decision making in companies at critical points of the innovation process when companies are creating new business. The methods help companies to identify phases and elements in their innovation process where specific managerial or development actions are needed. As a result, the fuzzy front-end of the innovation process is no longer so fuzzy – it has been elucidated. When elements and critical decision points in the front-end have been identified, and both the information and the necessary decision criteria have been defined, the front-end becomes controllable and actions for new business creation can be co-ordinated.

The main research finding of the work can be presented as: It is less important as to which particular tool is used in supporting the decision making under high level of future uncertainty. What is the most important is that this analysis is done in a systematic way that considers multiple viewpoints.

The use of supporting tools is important and highly recommended. Such tools bring strong supporting elements to a process where the decision makers should systematically consider alternative future possibilities related to their new innovation and business development. In this way practitioners become better prepared for the future.

The research was based on a constructivist case methodology and the validity of the project results needs to be approved through real new innovation and new business development cases where the results have been applied. The methods developed in the INNORISK project were tested in just a few cases, and the associated companies were all from the technology industry sector. Comprehensive validity testing of the INNORISK tools and methods would require substantially more industrial cases. Even so, the evaluation of the benefit impact for the associated companies would still need to be investigated. The models presented in Section 3 of the report have a solid foundation in the extant literature and will not need as broad testing for the validation as the validation of the specific tools presented in Publications I–VII of the report, with many of the tools still being on a conceptual level and requiring further development before they could be implemented in real cases.

Although the INNORISK project has been concluded, the work itself continues at VTT through follow-up projects focused on specific issues of new business development. Experiences from the INNORISK has been the inspiration for at least three of VTT's recent research projects on the topics of management of the M&A process (http://www.vtt.fi/sites/manmap), management of the intellectual property in open business models (http://www.vtt.fi/proj/ipob) and defining and describing the value of corporate security services in order to create new security business (http://www.vtt.fi/sites/valuesse/).

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Jaakko Paasi & Pasi Valkokari (eds.)

Title

Elucidating the fuzzy front end

Experiences from the INNORISK project

Abstract

Companies in the process creating new business – or innovations – are also moving towards an unknown future, which includes several uncertainties. The management of uncertainty in the development of technological innovations was studied with a focus in the fuzzy front end stage of the innovation development process. The guiding principle behind the study and the development work involved the application of the generic methodology of risk management to the challenges associated with new business creation, with the intention of raising open discussion about the aim of the risk management. The target is not only to identify and assess risks, and select risk reducing measures, but also to consider how best to quickly and effectively respond to realised opportunities and risks as they arise.

The main effort during this study was directed at the real innovation development cases at three companies. Although different approaches were used in each of the cases; they all started from an idea associated with a new business opportunity, but the operative development of the new innovation involved was very different. The cases were named accordingly: 1. Case conceptualisation which followed the traditional approach; where concept development was succeeded by new product development, 2. Case strategic co-ordination where the technology of innovation was already available in-house, but the new business creation required a new kind of strategic offering planning for the company, 3. Case acquisition where new technology necessary for the new business was taken over by an acquisition.

The feedback led to a conclusion that a systematic approach to decision making that could be applied throughout the innovation life cycle was still needed. As a final result of this endeavour, a systematic innovation management framework focused on providing support for strategic decision making under conditions of high uncertainty about the future, was developed. The work was conducted in cooperation with the experts of the service science and technology foresight from the IBM Almaden Research (USA).

This publication combines the main results of the work done at VTT within the INNORISK project. INNORISK was a 3-year joint research project between the Corporate Foresight Group (CoFi) of Åbo Akademi and VTT Technical Research Centre of Finland as a part of the LIITO technology programme of Tekes.

The main research finding of the work can be presented as a proposition: It is less important as to which particular tool is used in supporting the decision making related to new innovation and business development under a high level of future uncertainty. What is the most important is that this analysis is done in a systematic way that considers multiple viewpoints. The project provided a good overview of the demands of innovation process management. Since INNORISK had a broad scope, some of the developed methods need to be further enhanced and refined in order to provide practical tools for practitioners (companies and organisations). The work of INNORISK is therefore being continued at VTT. Case-specific projects are being investigated in order to gain practical results for the needs of practitioners interested in improving their capabilities for business renewal.

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Jaakko Paasi & Pasi Valkokari (toim.)

Nimeke

Innovaatioprosessin alkuvaiheiden hahmottaminen

Kokemuksia INNORISK-projektista

Tiivistelmä

Kun yritykset luovat uutta liiketoimintaa – eli innovaatioita – ne ovat samalla matkalla kohti tuntematonta tulevaisuutta, joka sisältää useita liiketoimintaan liittyviä epävarmuuksia. Siksi tutkimme epävarmuuden hallintaa teknologisten innovaatioiden kehitystyössä. Tutkimuksessa keskityimme innovaatioprosessin sumeaksi kutsuttuun alkuvaiheeseen. Perusperiaatteena tutkimus- ja kehitystyössä oli riskienhallinnan yleisten menetelmien soveltaminen haasteisiin, jotka liittyvät uuden liiketoiminnan luomiseen. Tämän toivomme herättävän avointa keskustelua riskienhallinnan tavoitteista. Riskienhallinnassa kyse ei ole vain riskien tunnistamisesta, arvioinnista ja riskiä vähentävien toimenpiteiden vallinnasta vaan myös kyvystä havaita uusia liiketoimintamahdollisuuksia sekä vastata niihin nopeasti ja tehokkaasti.

Tutkimuksen päähuomio kohdistui kolmen yrityksen todellisiin innovaatioiden kehittämiseen liittyviin caseihin. Kaikki caset alkoivat uuden liiketoimintamahdollisuuden tunnistamisesta, mutta niiden operatiivisessa johtamisessa sekä uusien innovaatioiden kehittämisessä sovellettiin täysin erilaisia lähestymistapoja. Case konseptoinnissa oli varsin perinteinen lähestymistapa. Menestyksellisestä konseptivaiheesta oli tavoitteena siirtyä uusien tuotteiden kehittämiseen. Case strateginen koordinoinnin yrityksellä oli varsin uusi teknologia, mutta uuden liiketoiminnan kehittäminen vaati uudenlaista strategista suunnittelua. Case hankinnassa yritys hankki uudelle liiketoiminnalle välttämättömän teknologian ostamalla teknologian kehittäjäyrityksen. Näissä case-tutkimuksissa sovelsimme ja kehitimme työkaluja ja menetelmiä, kuten roadmappaus, portfolion hallinta ja pisteytyskortit (*score card*), kriittisiin innovaatioprosessin vaiheisiin liittyvän päätöksenteon epävarmuuden hallitsemiseksi.

Tutkimustuloksista teimme johtopäätökset, että emme olleet vielä löytäneet järjestelmällistä lähestymistapaa, jota voitaisiin soveltaa päätöksentekoon koko innovaation elinkaaren aikana. Tämän tutkimuksen lopullisena tuloksena kehitimme järjestelmällisen innovaatioiden hallinnan viitekehyksen, joka fokusoituu tukemaan strategista päätöksentekoa olosuhteissa, joissa vallitsee suuri epävarmuus tulevaisuudesta. Tämä työ tehtiin yhteistyössä IBM Almaden Researchin (USA) palvelutieteen ja teknologian ennakoinnin asiantuntijoiden kanssa.

Tämä julkaisu kokoaa VTT:n tärkeimmät havainnot ja tulokset INNORISK-hankkeessa. INNORISK oli kolmivuotinen yhteishanke Åbo Akademin Corporate Foresight Groupin (CoFi) ja VTT:n välillä. Hanke rahoitettiin Tekesin LIITO-teknologiaohjelmasta.

Hankkeen päähavainto on, että kehitettäessä uusia innovaatioita ja uutta liiketoimintaa epävarmuuden vallitessa ei ole niinkään olennaista se, mitä epävarmuuden hallinnan työkalua päätöksenteossa käytetään, kuin se, että päätöksentekijät itse tarkastelevat tilannetta useammasta näkökulmasta ja tekevät sen systemaattisesti. Hankkeen tuloksena muodostui varsin kattava näkemys innovaatioprosessin johtamisen vaatimuksista. Koska INNORISKin tutkimuskohde oli laaja, on osaa kehitetyistä menetelmistä edelleen kehitettävä, jotta käytännön työkaluja voitaisiin tarjota eri toimijoille (yritykset ja organisaatiot). Siksi INNORISK-työ jatkuu VTT:ssä hankkeissa, joissa on asetettu case-kohdennetut tavoitteet. Näin kehitetään yhä käytännöllisempiä menetelmiä päätöksenteon tueksi toimijoille, jotka ovat kiinnostuneita kehittämään valmiuksiaan liiketoimintansa uudistamisessa.

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