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OPEN INNOVATION IN HIGH-TECHNOLOGY COMPANIES

Case study of biotechnology and pharmaceutical companies

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AHP	Analytical hierarchy process
B2B	Business-to-business
B2C	Business-to-consumer
BCFI	Balanced critical factor index
CC1	Case company 1
CC2	Case company 2
CC3	Case company 3
CC4	Case company 4
CFI	Critical factor index
CRA	Constructive research approach
CRO	Contract research organization
CV-%	Coefficient of variation
DI	Disruptive innovation
EEA	European Economic Area
FEI	Front-end innovation
FMCG	Fast-moving consumer goods
ICR	Inconsistency ratio
ICT	Information and communication technology
IP	Intellectual property
IPR	Intellectual property right
ISI	Innovation strategy index
ISI_O	Amplitude of outside-in innovation strategy index
ISI_I	Amplitude of inside-out innovation strategy index
ISI_C	Amplitude of closed innovation strategy index
IVD	*In vitro* diagnostics
LE	Large enterprise
M&A	Mergers & acquisitions
MAD	Maximum absolute deviation
MAPE	Mean absolute percentage error
MNE	Multinational enterprise
NGO	Non-profit organization
NIH	Not-Invented-Here

NPD	New product development
NSCFI	Normalized scaled critical factor index
NSH	Not-Sold-Here
OECD	Organization for Economic Co-operation and Development
OI	Open innovation
RAI	Resource allocation index
RAI_O	Amplitude of outside-in resource allocation index
RAI_I	Amplitude of inside-out resource allocation index
RAI_C	Amplitude of closed innovation resource allocation index
RAL	Responsiveness, agility, and leanness
RI	Radical innovation
RQ	Research questions
RBV	Resource-based view
R&D	Research and development
RMSE	Root mean squared error
SCA	Sustainable competitive advantage
SCFI	Scaled critical factor index
SD	Standard deviation
SME	Small and medium-sized company
SMT	Strong market test
S-SMT	Semi-strong market test
S&R	Sense and respond
TH	Triple Helix
UI	User innovation
VRIN	Valuable, rare, inimitable, and non-substitutable resources
WMT	Weak market test

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ABSTRACT:

Companies innovation process is an important way to both achieve and sustain competitive advantage in today's business world. The innovation happens in companies within a process consisting from three processes: the front-end innovation process, the new product development process, and commercialization process. The innovation strategy of companies is comprised from different attributes that the company's emphasis and values in their decision-making process.

The theoretical framework of this thesis is built on the principles on open innovation, aggressiveness strategy of the companies, and holistic analytical model developed to evaluate companies' strategic priorities. The open innovation is scoped by selected strategic attributes in the companies, from which the overall innovation strategy of the company is formed.

This study tries to analytically model the open innovation strategy of the case companies within biotechnology and pharmaceutical industries. This study uses several critical factors index-based methods to evaluate the past experiences and future expectations of the companies' top management personnel around the open innovation. In addition, an analytical hierarchy process method is used to specify and evaluate the case companies' overall innovation strategy around open innovation parameters. This study evaluates the different innovation strategy types used in high technology companies. This study was able to quantitatively determine the innovation strategy types of the case companies using the innovation strategy index method, which was originally derived from manufacturing strategy index method. However, no correlation around the resource allocation index and innovation strategy index was not found.

KEYWORDS: innovation, open innovation, front-end innovation process, analytical hierarchy process, resource allocation, performance measurement

1. INTRODUCTION

The key success factor for companies in competitive settings is a flexibility to answer to the customer's needs and an ability to launch new products, which the market needs in given time (Skinner 1986: 55-59). This happens through an innovation process that can be divided into three segments: The front-end innovation (FEI), the new product development (NPD) process, and commercialization (Koen, Bertels & Kleinschmidt 2014: 34-43). The FEI refers to the first and most important phase of innovation before the development and the commercialization process takes place, and in which the start and resource commitments are decided (Cegarra-Navarro, Reverte, Gómez-Melero & Wensley 2016: 530-539; Mohan, Voss & Jiménez 2017: 193-201). Accordingly, the NPD process is the where the actual development of the innovation happens. For successful NPD process, two types of knowledge are required: component knowledge and architectural knowledge. The component knowledge is about the core design concepts and how they are implemented in a specific component. The architectural knowledge instead, is about the knowledge of design by which the specific components are linked to other components in a coherent way (Henderson & Clark 1990: 9-30).

The company has sustainable competitive advantage (SCA) when it is implementing a value creating strategy that is simultaneously not implemented by any other of its current or potential competitors, because they are unable to reproduce the same strategy for their benefit. In the resource-based view (RBV) in order to achieve the full potential of SCA, the resources of the company must meet the following four attributes: it must be valuable when exploiting opportunities, it must be rare among the company's current and potential competition, it must be inimitable, and the resources needs to be non-substitutable for other non-rare resources (Barney 1991: 99-120). Furthermore, the resources can be categorized into tangible and intangible resources (Caves 1980: 64). Tangible resources are exhaustible physical objects, such as land or properties (Wernerfelt 1989: 4-12). These resources are protected by normal property rights and therefore easy to replicate by current or potential competitors. However, intangible resources are inexhaustible where the use by one does not prevent others from using the same resource. These resources consist from patents, copyrights, and trademarks, and they are protected by intellectual property rights (IPR), because without protection those who have made efforts for producing the resource cannot prevent others from using the information.

Because the intangible resources are protected by IPR especially in knowledge-intensive industries, they are usually categorized into the valuable, rare, inimitable, and non-substitutable (VRIN) resources based on the RBV. Because of the VRIN-nature, these resources are also target of insourcing and out-licensing in forms of spin-off companies, joint ventures, and mergers and acquisitions (M&A), which are corporate level strategic issues (figure 1). In this case, the use of external knowledge needs to be embedded in the overall strategy of the company, although it is mainly used in business level strategic issues (Brem, Nylund & Hitchen 2017: 1285-1306). Nevertheless, the technologically motivated M&As have shown to increase the innovation inputs and outputs in general, there are still high number of variables included. The innovation efficiency is mostly increased in the cases where the technologies are complementary between the merged entities and decreases when the technologies are substitutive (Colombo & Garrone 2006: 104-133). The use of open innovation (OI) can help the technology integration process after M&As in acquiring companies in way that the company will be able to be more efficient on its overall innovation process.

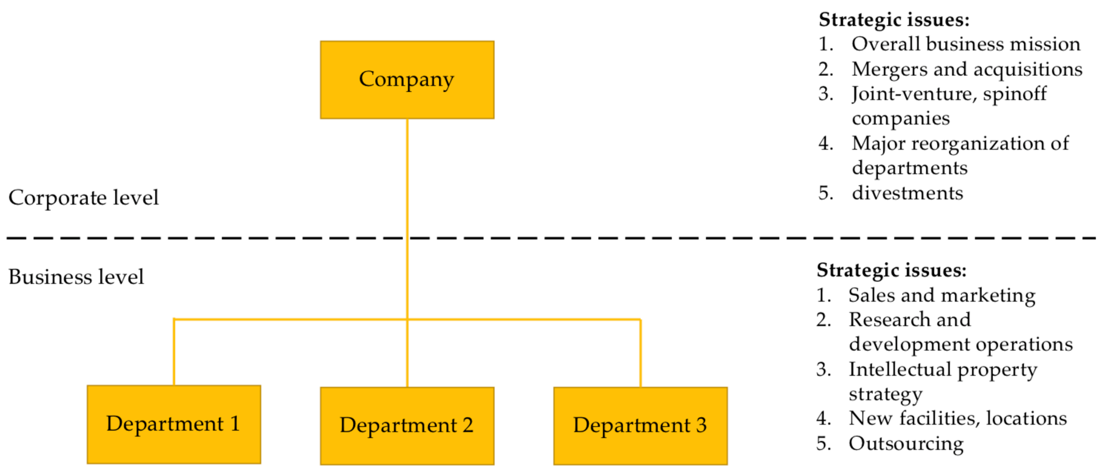

Figure 1. Corporate and business level strategy hierarchy in companies (Adapted from b. Takala, Muhos, Tilabi, TAS & Yan 2013: 55-64).

1.1. Objective of the thesis

Earlier research indicates that OI strategies have had a positive effect related to firm's innovation performance because of their tendency to lower the barriers of innovations which results from the size of the company (Brem et al 2017). The recent studies of OI have extended to variety of areas, such as small and medium-sized enterprises (SMEs), non-profit organizations (NGOs), new units of analysis, and different companies in high-technology and low-technology industries (Bogers, Chesbrough & Moedas 2018: 5-16). However, there is a lack of research how quantitatively evaluate the state of the OI strategies in companies. Therefore, this thesis is conducted to observe the performance of innovation and attempts to find answers to following research questions (RQ):

RQ1: Is there a correlation between innovation strategy and resource allocation profiles?
RQ2: Can innovation strategy be defined and evaluated in terms of SCA?
RQ3: Can innovation strategy be analytically modelled based on strategic priorities of technology, knowledge, development, and co-operation?

In order to answer to the RQs presented above, this thesis examines the general characteristics of innovation by defining variant types of innovation. After the theoretical foundation and qualitative characteristics are identified, the RQ1 and RQ2 are answered with the quantitative methods applied to empirical data gathered for this study. The answer to the RQ3 is gathered, verified, validated through interviews of the case companies.

1.2. Structure of the thesis

The structure of this study is organized as follows: it consists of ten main chapters which start with an introduction and framework, and continues to review the relevant literature, context, overview of the case companies, and methodology in order to provide necessary background for the case studies.

In the introduction, general background for the thesis is described with objectives and research questions. The framework for the study is described in the second chapter and sufficient literature review about the issues connected to the research are described in the third chapter. In chapter four and chapter five the environment of the case companies and the case companies itself are described in order to provide background where the study subjects operate.

In chapters six, seven, and eight the methodology, relevant results, and analysis of the study are described and analyzed. In chapter nine there are discussion about how the results and analysis of the result should be interpreted, and in the final chapter ten there are conclusion about the study results with recommendations for the future research.

2. CONCEPTUAL FRAMEWORK

The main theoretical framework is based on the theories presented by Henry Chesbrough on open innovation, Raymond Miles and Charles Snow on aggressiveness strategy, and Josu Takala on holistic analytical model using four main criteria: quality, cost, time, and flexibility. The main research areas of this thesis are "innovation strategy", "high-technology companies", and "business model" (figure 2). The literature is chosen according to the research topics and is focused on the concept of OI particularly in life science, biotechnology, and pharmaceutical industries.

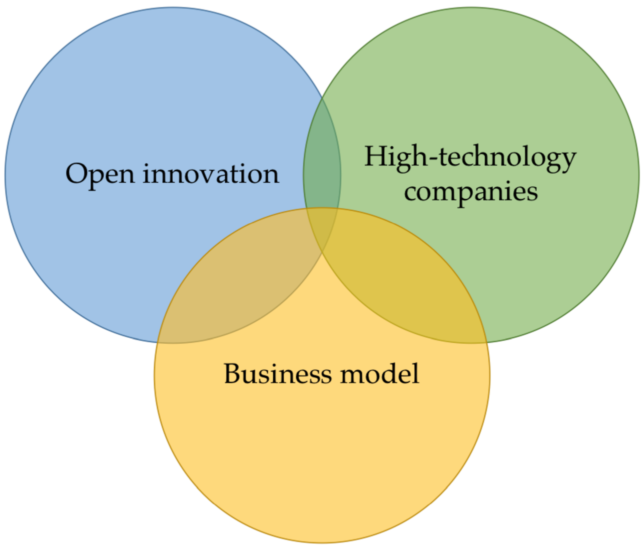

Figure 2. The main research areas of the thesis.

The research focus on the different business models of OI in high-technology and medium-high-technology companies based on the technology intensity definition of the Organization for Economic Co-operation and Development (OECD). The study tries to take into account all forms of OI described by Chesbrough. However, the study is limited only to manufacturing companies focusing on business-to-business (B2B) commerce and companies focusing on business-to-consumers (B2C) or providing solely consultation and other types of services is left out of the scope of this study.

3. LITERATURE REVIEW

The definition of innovation varies greatly in existing scientific literature (Dziallas & Blind 2018: 3-29). The objective of innovations is to create tangible value by implementing commercially viable solutions to customers' needs, problems, and business opportunities (Racheria 2016: 25-52). Innovations can be considered as one of the key factors for the SCA of a company in the competitive global environment. The patterns of innovations can be categorized into product innovations and process innovations (Freeman & Soete 1997: 242-264). Companies that innovate are more capable of responding to the surrounding challenges faster compared to the companies that are not able to innovate (Cegarra-Navarro et al 2016). The SCA is obtained by offering greater value compared to competitors, either by more affordable prices or by providing more innovative products, which enable higher sales prices. It may also include enhanced access to resources, such as tacit knowledge in form of highly skilled labour, or access to the leading-edge technology.

To achieve the SCA, companies should have efficient operational strategy that helps them to allocate their resources properly. Initially four different strategy types have been categorized based on the strategy aggressiveness: prospector, analyser, defender, reactor (table 1). In the prospector strategy the company drives to be a market leader through innovations. In the defender strategy the company seeks profit from core customers with low cost-structure in order to establish a stable market position. In contrast, the analyser strategy is a combination of the prospector and the defender strategy. The reactor strategy is usually not classified as a strategy, but it is targeted for situations that need rapid responding (Miles, Snow, Meyer & Coleman 1978: 546-562).

Table 1. Definition of strategy aggressiveness typologies (Adapted from Miles et al 1978).

Strategy type	**Definition**
Prospector	Innovatively oriented and looks constantly for new market opportunities.
Analyser	Prefers the status quo of current market position and has moderate orientation towards innovations.
Defender	Prefers to protect the position in current market and maintain stable growth.
Reactor	Does not have a specific strategy. The mode of operation is to react to the needs of the market.

The literature review of this study categorizes innovation by the newness of technology and business model (figure 3). The innovation categories used in this study includes incremental innovation, radical innovation (RI), and disruptive innovation (DI). In addition, the literature part reviews user innovation (UI), and closed innovation and open innovation (OI) paradigms as well.

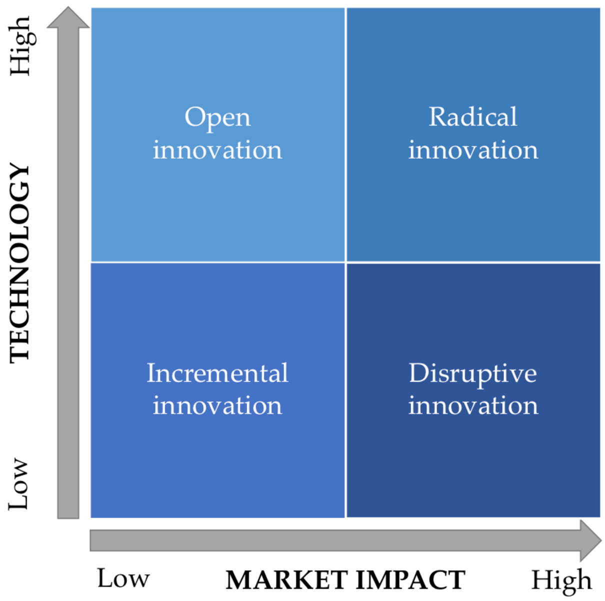

Figure 3. Innovation matrix.

Despite that the impact to the market in OI is not high in general, does not mean that the impact to the market in a case of specific company would not be high.

The OI offers wider possibilities to companies to exploit their own technology or technology of others.

3.1. Closed innovation paradigm

Companies that are mostly internally focused are considered to follow the closed innovation approach (a. Chesbrough 2003: 35-41). Closed innovation follows the traditional vertical integration in which the internal innovation activities of a company leads to internally developed outcome by a company's own research and development (R&D) operations. The innovations are later also commercialized and distributed by the company itself. In the closed innovation model, the R&D projects are started from the internal technology and science base of the company (figure 4). The NPD process progresses through the NPD funnel or are terminated during the process (Chesbrough 2012: 20-27).

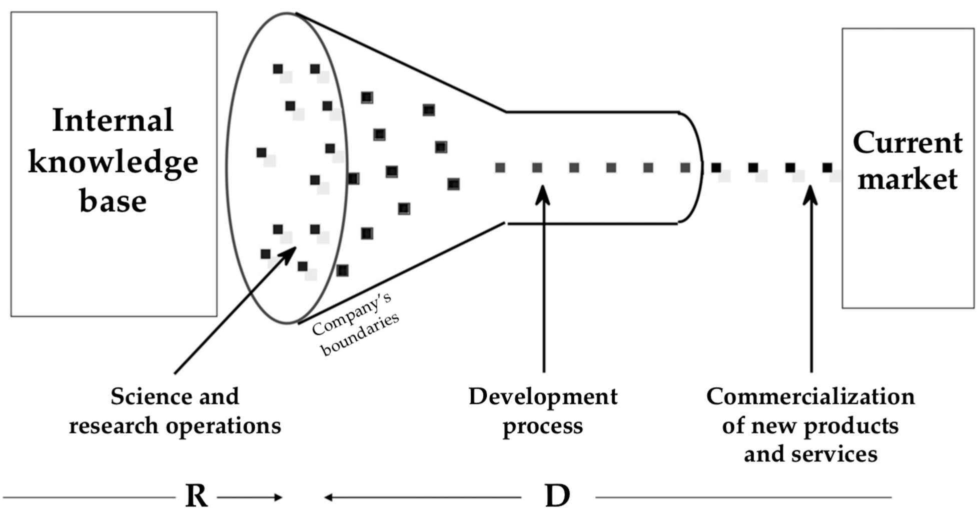

Figure 4. Closed innovation funnel. The *R* represents research and *D* represents development (Adapted from Chesbrough 2012).

In closed innovation the company's boundaries are solid and allows no interaction with external R&D activities (b. Chesbrough 2003: 30-53). In the closed innovation projects can enter to the NPD funnel only from one end and exit to the market from another end. Another characteristic of closed innovation model is the accumulation of IPR, which secures the freedom to operate to internal R&D

personnel of a company (Chesbrough 2012: 20-27). The closed innovation model also has similarities to competitive advantage, where key strategic assets are either low cost, differentiation, or niche market (Chesbrough 2012).

3.2. Open innovation paradigms

OI paradigm was coined by Henry Chesbrough in 2003. It integrates internal and external knowledge to create new systems and architectures, and to construct more complex combinations of knowledge. The foundation of OI model is the need of companies for technologies that are not internally developed their own R&D. The NPD funnel in OI is not linear as in closed innovation model (figure 5). In the OI model the ideas can enter to the funnel from both internal and external knowledge base of the company (b. Chesbrough 2003).

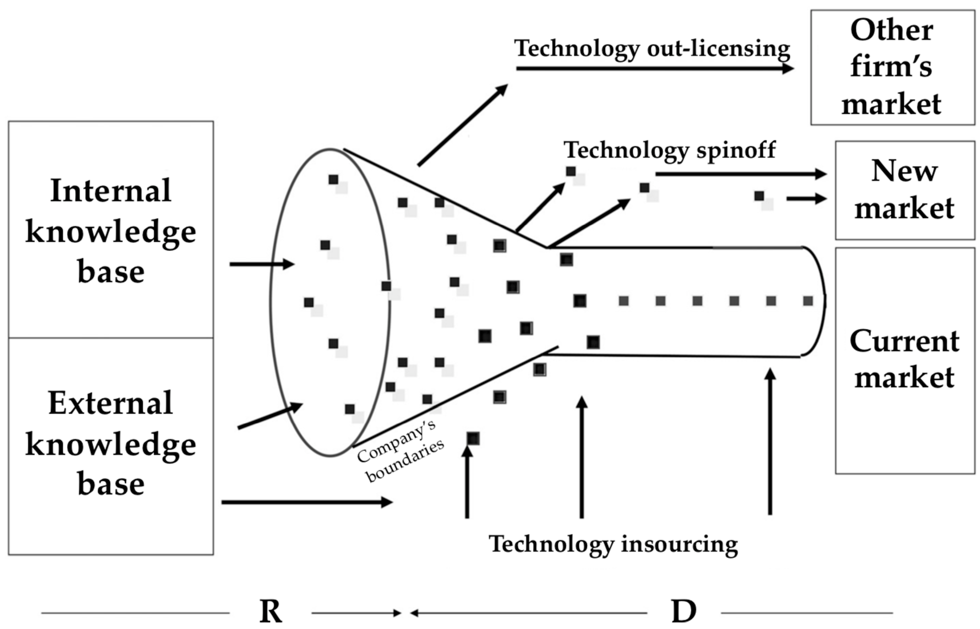

Figure 5. Open innovation funnel. The *R* represents research and *D* represents development (Adapted from Chesbrough 2012).

In the OI model the rationale for internal R&D has changed. The innovation funnel is permeable, so that there are inflows and outflows of innovations also during the development phase which provides innovations alternative ways to market (b. Chesbrough 2003). These alternative ways include two major strategy types of OI: outside-in strategy and inside-out strategy. These are also referred to as inbound and outbound OI strategies, respectively (Bogers et al 2018). These two strategies can be further categorized in to pecuniary and non-pecuniary segments (table 2) based on the type of financial compensation they possess (Busarovs 2013: 103-119). In the abundant knowledge landscape, companies must organize their internal R&D functions to identify, to understand, to select, and to connect to the profusion of available external knowledge. Internal R&D is also needed to fulfil the components of externally developed knowledge needed for the company's own processes. Nevertheless, the strategies of companies change nowadays faster than the basic research. Therefore, companies should not wait for the technologies they need to arrive. Instead, they should gain access to the technology as soon as possible: either from internal sources or from external sources. Companies can also generate additional incomes by selling their internal R&D outputs to other companies to be used in their systems and platforms (b. Chesbrough 2003).

Table 2. Subtypes of open innovation based on financial compensation (Adapted from Chesbrough & Brunswicker 2014: 16-25).

	Pecuniary	**Non-pecuniary**
Outside-in	In-licensing technologies Contract R&D services University research grants Start-up competitions	Co-creation with customers Crowdsourcing Publicly funded R&D consortiums Informal networking
Inside-out	Spinoff technologies Market-ready products Out-licensing technologies	Joint ventures Public standardization Donations to NGOs

In most cases the non-pecuniary outside-in and inside-out OI strategies can be categorized as coupled OI strategy because of its aim for joined innovation and exploitation with mutual benefit (Gassman & Enkel 2004: 1-18). In practice the coupled OI strategy is a combination of the outside-in and inside-out OI strategies (figure 6), which happens through the inflows and outflows of knowledge (Lameras 2015: 1-51).

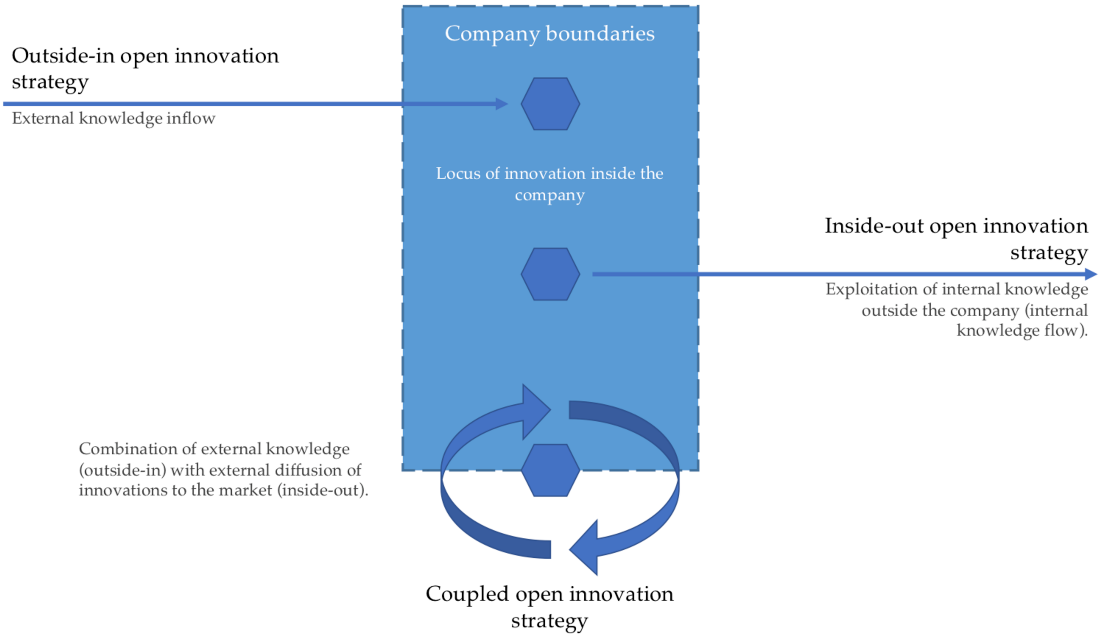

Figure 6. The relation between open innovation strategies (Adapted from Lameras 2015).

In general, OI activities can be considered as one type of enhancement to dynamic innovation capabilities, which enables companies to achieve breakthrough innovations (Cheng & Chen 2013: 444-454). To make these innovations happen, a combination of ideas, that arise from combining deep expertise and knowledge from closely related fields of industry, are usually needed (Satell 2017: 48). In addition, IPR management is tightly connected to the company's innovation strategy and effective insourcing and outsourcing strategy as well. In the chapters below, these different OI strategies are described more thoroughly. Although all of the OI types described represents a different kind of OI, from which not all of them are equally important to every company (Gassman & Enkel 2004). Connection between different types of OI are described more thoroughly in Appendix 1.

The OI model is also defined by innovation process and transaction process, where the innovation process can have an inside-out or outside-in strategy nature and the transactions includes economic or financial processes. Furthermore, the outside-in strategies are characterized by cost and additions, and inside-out strategies by revenues and disposals. Additionally, the economic transactions are characterized by cost, revenue and financial transactions by additions and disposals (figure 7). In outside-in strategy the cost arises from collaborative development, outsourcing research services with contract research organizations (CRO), and in-licensing. Accordingly, in inside-out process the revenues comes from collaborative development, and outsourced CRO services as well, but also from R&D awards, and out-licensing. Furthermore, the additions and disposals consist of licenses, patents, trademarks, and technologies in both inside-out and outside-in OI strategies (Michelino, Lamberti, Cammarano & Caputo 2015: 4-28).

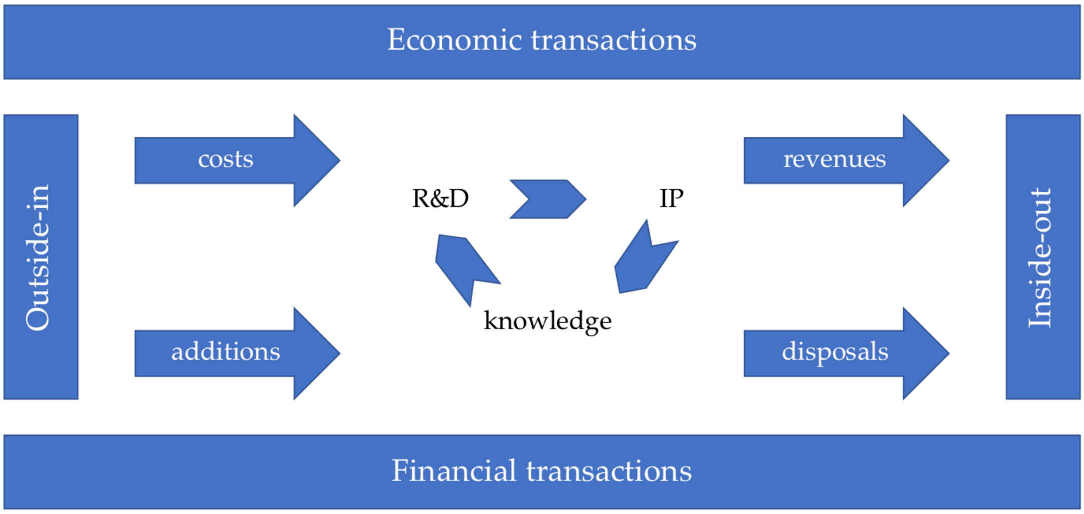

Figure 7. Framework for open innovation measurements (Adapted from Michelino et al 2015).

According to Michelino et al (2015) the four basic ratios of OI can be determined using the costs, revenues, additions, and disposals as described above. These ratios can be calculated with equations described in table 3.

Table 3. The economic ratios of open innovation. *CR* represents cost-ratio, *RR* represents revenue-ratio, *AR* represents additions-ratio, and *DR* represents disposals-ratio (Adapted from Michelino et al 2015).

	Economic transactions	**Financial transactions**
Outside-in strategy	$CR = \frac{costs\ from\ OI}{total\ R\&D\ and\ IP\ costs}$	$AR = \frac{additions\ from\ OI}{total\ intangibles}$
Inside-out strategy	$RR = \frac{revenue\ from\ OI}{total\ revenues}$	$DR = \frac{disposals\ from\ OI}{total\ intangibles}$

3.2.1. Outside-in open innovation strategy

In the outside-in OI strategy, company choose to integrate external knowledge in to its internal innovation process. This can be achieved through customer and supplier integration, investing in global knowledge creation, buying or licensing external IPR. The in-licensing has proven to be a fast, relatively low risk, and inexpensive alternative to gain access to new external technologies. Companies take part of outside-in OI operations usually because their need for knowledge or technology are not met with internal capacities. Gassman & Enkel (2004) state that outside-in OI strategy is primarily used in low-technology industries for similar technology acquisition from high-technology industries in form of "spillovers". However, outside-in OI strategy is also widely used in high-knowledge intensity industries such as biotechnology and pharmaceutical industries (Gassman & Enkel 2004).

From the OI strategies described in chapter 3.2, the outside-in OI strategy is the most common type of OI (Chesbrough & Brunswicker 2014). This aspect has also received the greatest attention in both academic research and in industry practice (Bogers et al 2018). As the outside-in OI strategy consist of opening the companies' internal R&D processes to external inputs, it has been suggested that outside-in strategy could bring value in at least three following cases (Bogers et al 2018; Gassman & Enkel 2004):
1) lack of internal resources,
2) better external technology position, and
3) easier transferability of external technology or knowledge and low-barrier market-entry.

Main reason for underutilization of outside-in OI strategy is the "Not-Invented-Here" (NIH) syndrome, in which the companies are unwilling to use external knowledge only because it is not invented in-house. This happens especially at the early stage of companies' OI programs, but it tends remain important reason over the time as well (Chesbrough & Brunswicker 2014). In order for companies to use outside-in OI strategy, they need to invest in their internal innovation activities as well, because at the end it is the internal competence which enables companies to access to external ideas, knowledge, and technologies (Hung & Chou 2013: 368-380; Christensen, Olesen & Kjær 2005: 1533-1549). This also explains why some companies are more capable of using outside-in OI strategy than others (Pihlajamaa 2018: 37).

3.2.2. Inside-out open innovation strategy

Compared to the outside-in OI strategy, the inside-out OI strategy is far less explored in both industry practices and academic research. The inside-out OI requires companies to have a process to allow untapped and underutilized ideas and technologies to flow outside the company for the use of others in their business stragegy and core operations (Bogers et al 2018). In the inside-out OI strategy companies focus on externalising their own knowledge and innovation in order to commercialize them faster compared to their internal NPD funnel (Gassmann & Enkel 2004).

Inside-out operations happens in three major ways: out-licensing, technology spinoffs, and divestments. From these the out-licensing of technology or other knowledge is the most common in the inside-out OI strategy. Most of the companies are unable to fully capitalize their own technological knowledge internally, and therefore the technology out-licensing allows them to capture additional value from this knowledge (Lichtenthaler 2010: 429-435). However, strong patent protection has no direct connections to the performance of inside-out OI strategy. The higher the patent protection is, the higher the transaction rate for the technology in the markets is as well (Lichtenthaler 2009: 38-54). The other forms of inside-out OI strategies include technology spinoffs, where usually former employees establish their own companies around the technology that is not needed in the company that originally developed it. Supporting this through direct investments can generate strategic benefits to the parent company of the technology. Additionally, the divestments use the same method as the technology spinoff model with the exception that the outsourced technology is either sold as a whole (pecuniary method) or leaves the parent company without any transactions (non-pecuniary method) usually because the technology has been neglected in the parent company.

The relationship between IPR and OI is controversial because the IPR prevents and promotes OI at the same time, even though in overall the goal of the IPR is to insure and encourage companies to invest in innovations. Nevertheless, the IPR offers opportunities through OI to scale the R&D activities, which would not be otherwise feasible without these protection options (Brem et al 2017). On the other hand, "Not-Sold-Here" (NSH) syndrome includes a negative attitude, which are very similar compared to the transfer of companies' internal technologies in NIH. The fear in NSH towards the inside-out OI strategy arise from a fear of strengthening competitors by selling technologies and innovations of the company to its competitors. The NSH syndrome becomes stronger along with lack of experience in inside-out technology transfer and ineffective markets for technological knowledge. Focusing only on internally developed technologies may also result for a limited exploitation of companies' own technology base (Lichtenthaler, Hoegl & Muethel 2011: 45-48).

By changing the locus of exploitation of innovations to outside the company, enables companies to generate revenue and profits by licensing or selling their IPR and multiplying their technologies to other companies. The use of the inside-out OI strategy also offers opportunities for alternative markets to companies using this strategy. Other benefits of using the inside-out strategy includes complementary knowledge, when gaining access to other markets, reducing time-to-market of internal ideas, when they do not have to be hold on reserve, and the possibility to concentrate on core competencies of the company, while sharing the cost via out-licensing (Gassmann & Enkel 2004).

3.2.3. Coupled open innovation strategy

In the coupled OI strategy the creation, exploitation, and commercialization of new knowledge is conducted in co-operation with one or several external collaborators (Cheng & Huizingh 2014: 1235-1253). The coupled OI strategy integrates outside-in and inside-out operations by working in collaboration in different alliances with complementary partners that are crucial for the success of participating companies. The collaboration happens in strategic networks. To succeed in co-operation, it is in it necessary to both give and receive knowledge. The co-operation happens usually by in joint development of knowledge in relationship with specific collaborators like consortia of customers, competitors, suppliers, joint ventures, and universities and research institutes. In most cases the co-operation can be characterised by a fundamental interaction between participating parties over a long period of time (Gassmann & Enkel 2004). In established core collaboration process of innovation, companies can obtain external knowledge through the outside-in OI process and have their internal ideas migrate to the market through the inside-out OI process simultaneously (figure 6) (Lichtenthaler & Ernst 2007: 383-397).

Global biotechnology and pharmaceutical companies have formed numerous new alliances as the biotechnology have been seen as a significant input in pharmaceutical R&D process. The most important success factor for these companies using the coupled OI strategy is an ability to re-evaluate and learn. Another important factor is the optimal balance of outside-in and inside-out operations within the coupled OI strategy. The companies must have imperative quality to integrate external knowledge into their own technology and knowledge base and at the same time outsource them for the benefit of the collaborators. Accordingly, the collaborators must be able to provide competencies that are needed to achieve competitive advantage in their own market (Gassmann & Enkel 2004).

Compared to the linear model of innovation, where the invention follows the innovation and diffusion to market, a more collaborative model between academia, industry, and government called Triple Helix (TH) have been theorized as well (Etzkowitz & Leydesdorff 1995: 14-19). The main idea around the concept of TH model is that academia is in a key role of innovation working together with industrial and governmental agencies. The academia engages in basic research and prepares the core for the future innovations. The role of the government as a policy maker is to act as an enabler and regulator for the other participants in the model. These governmental organizations may consist of technology transfer offices or industry associations. The industry is seen as producers of commercial goods that diffuse the innovative products to the market. However, in addition to these traditional tasks in TH model, each participant adopts new roles and performs roles of other segments described above as well (Sotarauta & Heinonen 2016: 1-20). The strength of the interactions between academia, industry, and government depends on which of these segments is the driving force in the framework (Etzkowitz 2002: 1-16). These different interactions can also form negative and positive overlaps in the subsystems they form (figure 8). Nevertheless, the TH innovation model has obscured the traditional roles of the parties in innovation schemes (Etzkowitz 2003: 293-337).

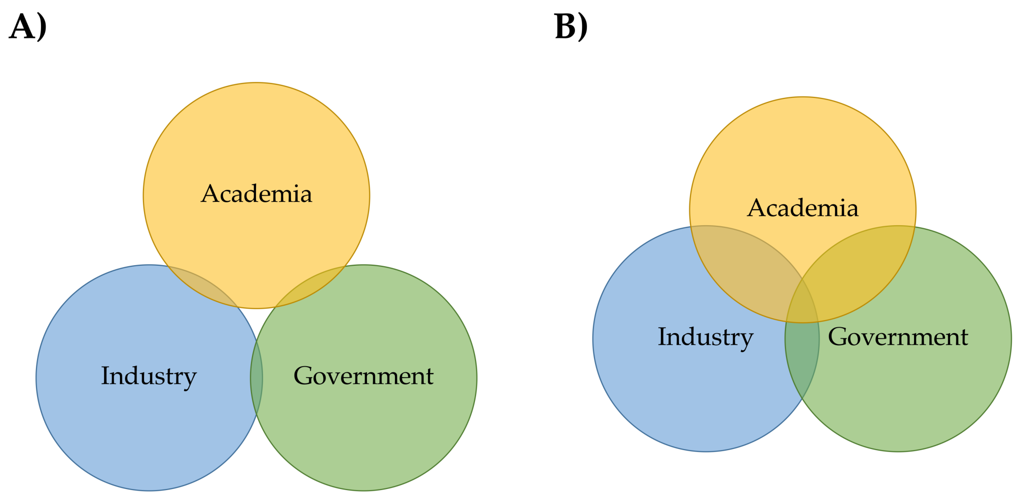

Figure 8. Triple Helix -model. Configurations with A) negative and B) positive overlaps with the subsystems of academia, industry, and government segments (Adapted from Smith & Leydesdorff 2012: 1-13).

The TH model has also become more open in time as it has gone through several development phases. Currently, the universities and academic research affect to innovation systems in four ways: education, generation of new knowledge, enhancing problem solving capacity, and by providing interpretative statistics for future exploration. The transfer of knowledge generated in academic research into companies has also a pivotal role in OI (Torkkeli, Hilmola, Salmi, Viskari, Käki, Ahonen & Inkinen 2007: 33-34).

3.3. User innovation

The term UI was originally coined by Eric von Hippel (1986). In the UI the innovation is done by lead-users who are creating solution to fulfil an unmet need that does not have a commercially available solution. The user refers to intermediate users such as user firms, user communities, or individual end-users (Gambardella, Raasch & von Hippel 2017: 1450-1468). The innovations developed by users can be industrial innovations, consumer product innovations, or process innovations (Churchill, von Hippel & Sonnack 2009: 6-26). In contrast to the traditional innovation, in the UI model the diffusion of innovations happens from peer-to-peer and never proceeds to commercial market as such. Therefore, the IPR does not apply to the user derived innovations. The benefit of the UI is only a solution to a known problem of individual.

The UI model interacts with the traditional vertical innovation model by providing information of the design adopted from the lead-users. In addition, the traditional vertical innovation model provides innovation supports to the lead-users to make better UI derived products (figure 9). This interaction connects the UI to the external knowledge base of the OI model (figure 5). The UI brings value to the innovation value chain by collaboration with the lead-users, but also through coupled OI strategy when the proposition of innovating users is at least on moderate level. However, when the proportion of innovating users are at low level, the innovation happens mostly through the closed innovation model (Gambardella et al 2017). Furthermore, the diffusion of physical UI derived products to the market through manufacturers' is still more common than information-based lead-user innovation derived products (von Hippel 2005).

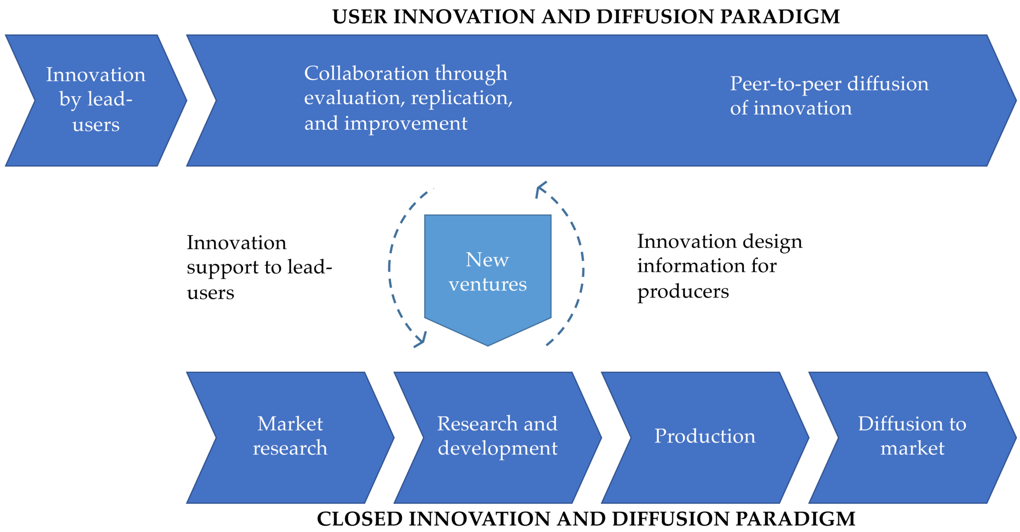

Figure 9. User and closed innovation diffusion paradigms (Adapted from Gambardella et al 2017).

Transferring UIs into mass production effectively gives companies a competitive advantage (von Hippel 2005). This will happen especially if capabilities to innovate expands in many industries, as it will shift the innovation tasks to the demand side (Gambardella et al 2017). Lead-users are innovators that are experiencing a specific need at the beginning of the innovation lifecycle before the market trend. Lead-user derived innovations can be identified by observing the crowd adoptions of new UI, and by exploring the innovation activity of a known trend at the so-called "leading-edge" (figure 10). The adoption is driven by the evolvement of market over time and underlying important trends in the market (von Hippel 2005: 133-146). The potential of UI rises from the mass. The innovating users includes millions of people collectively investing billions of dollars and hours annually of their own money and time in NPD (Garbardella et al 2017). Based on the innovation intensity, the lead-users are not the same as "Innovators" or "Early adopters", who can be categorized as the first users of commercially available products or services. Because lead-users have new product and service needs that are ahead of the market situation, companies should harness them in their own innovation process (Churchill et al 2009).

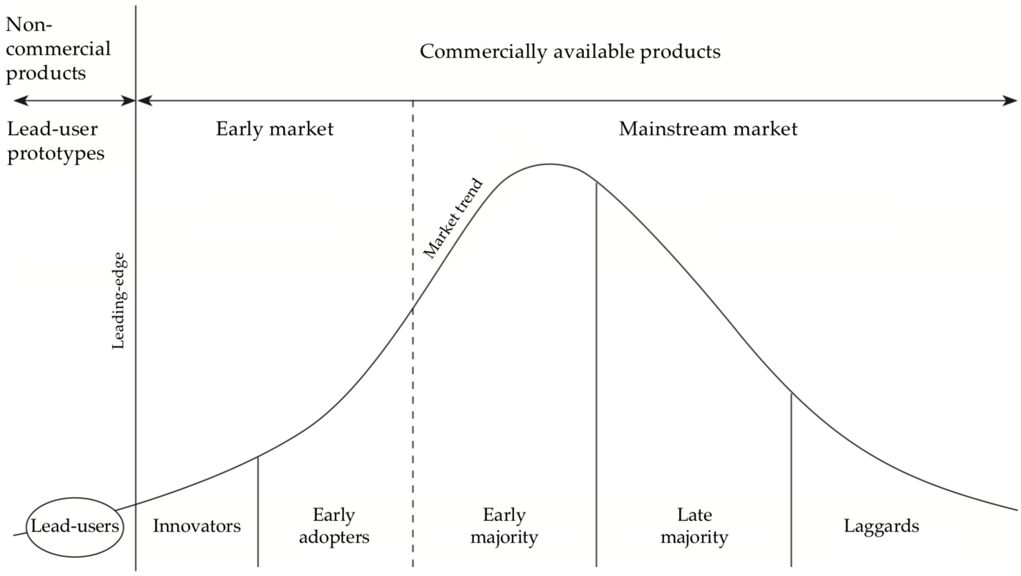

Figure 10. Lead-user concept on innovation lifecycle (Adapted from von Hippel 2005).

Lead-user developed innovations are often commercially more attractive, have a higher degree of novelty, and address more of current customer needs (Lilien, Morrison, Searls, Sonnack & von Hippel 2002: 1042-1059). The greater the benefit the lead-user is expecting to achieve, the greater will be the investment for obtaining the solution. In the UI research three different types of lead-users have been identified: 1) lead-users specific to the target innovation and market, 2) lead-users in similar innovation targets and analogue markets, and 3) lead-users facing other important problems in the target market (Churchill et al 2009). By analysing all the three types of lead-users, companies will be able to gain better and more explicit conception about the future market needs than using conventional market research methods. This will also increase the possibility to identify RI for their target market (Churchill et al 2009; Lilien et al 2002).

3.4. Incremental innovation

Incremental innovations are described as series of small improvements to the existing products with a purpose to maintain or improve competitive position of the company over a time of period. Most of the innovation are incremental because they tend to focus on current customers and their needs. It has been estimated that 85 to 95 percent of companies R&D portfolios are consisting of incremental innovation projects. These types of innovations exploit the existing technologies and shapes the existing technology to be used in some other purposes as well. By this definition, the incremental innovations are innovations at the margin (Luecke 2009: 2-7). The incremental innovations have a tendency to reinforce the competitive advantage of established companies by impacting on their core competencies (Henderson & Clark 1990). Incremental innovations can be further categorized into modular innovations and architectural innovations. A modular innovation involves changing a module of the design in a business model, process, or design of the product in order to create improvements. Architectural innovations include improvement changes on how the modules are used in situations mentioned earlier, and how they work together bringing substantial improvements to the business model process or products (Pham-Gia 2011: 1-28).

Incremental innovations are continuous form of innovation, which are represented in companies through continuous innovation process, idea, and innovation management. Many companies concentrate on incremental innovations because it has significantly lower risk of failure and it allows companies to introduce changes through a longer period of time making the adoption of innovations more likely. The management of incremental innovation is described by transparent and static innovation process from an innovative idea to the implementation of the idea. Incremental innovations are designed to follow well defined processes and responsibilities (Pham-Gia 2011). Incremental innovation strategy helps companies to maintain and improve their competitive advantage over time compared to their competitors. Conversely, companies that fail to introduce incremental and sustaining innovations at regular basis will lose their competitive advantage. Therefore, incremental innovations are more common in high-technology companies, and for example consumer technology developers are constantly introducing new features to existing products. Accordingly, from the high-technology consumer market-side, people are waiting for updated product features as well (Oja 2010: 75-77).

3.5. Radical innovation

RI causes drastic changes on how things are done. They establish new functionalities and processes in companies (White & Bruton 2007: 40). RIs have a tendency to destroy or displace an existing business model with an entirely new business model by changing the components and their interactions with each other in new ways. RIs have elements from both incremental innovations and DIs, although incremental innovations and RIs can be seen as the ends of a continuum. They require fully novel competencies, which can displace the old competencies in companies. They can also be considered as breakthrough innovations that transform the market essentially (Green, Gavin & Aiman-Smith 1995: 203-214).

RIs can result in high level of compensation, but they include a high degree risk as well when compared to incremental innovations. In addition, RI includes an eminent resistance and slow adoption rate. Nevertheless, RIs are strategic options for companies and therefore intentional and promoted. They enable companies to differentiate from their competitors by creating potential high return on their investment. RIs tend to create dramatic change in the companies' processes, their products, and services by transforming existing markets or industries, or even creating new ones.

In different industries the incremental and RIs often go together with each other. The development of innovations is characterized by long periods of incremental innovations paced by random actions of RIs (figure 11). RIs take place between small incremental innovations which are abrupt by a technological leap forward in performance per cost. The incremental innovations resume after the RIs (Luecke 2009). RIs usually happen in complex uncertainty. To evolve RI with external knowledge, idea base, and technologies; companies must have capabilities and processes to identify and to utilize them with their existing internal knowledge base and company culture (Pihlajamaa 2018: 122).

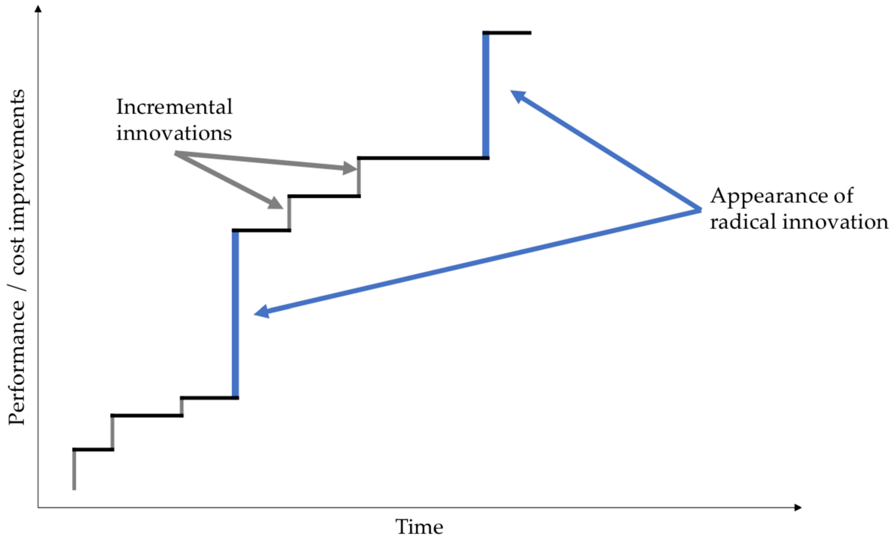

Figure 11. Timeline of radical and incremental innovations (Adapted from Luecke 2009).

Although there are several advantages in RI, it presents several major challenges for companies as well. Projects involving RIs are expensive, usually takes many years to produce potential tangible results, which increases their risks (Luecke 2009). The transformation to RI can be extremely challenging for companies which have focused on the incremental and closed innovation processes (Pihlajamaa 2018). RIs create obvious challenges for established companies, because they have a capability to annihilate the utility of their existing capacities (Henderson & Clark 1990). Although RI are defined by the degree of their novelty, the general problem between incremental and RIs is that they are poorly defined and difficult to determine exactly when an innovation shifts from incremental to radical (Trauffler & Tschirky 2007: 35; Rehn 2018: 42). That can change the competitive advantage for the favour of the innovator (Luecke 2009).

3.6. Disruptive innovation

The DI paradigm was first coined by Harvard professors Clayton M. Christensen in 1997. The DI can be categorized as technology, product or process, that evolved from below of established companies with an agenda to displace them. Technically the disrupter offers technologies with lower performance and less functionalities with lower price than the technology offered by the established companies.

However, the technology, product, or process offered by the new companies is sufficient for some of the customers, who are usually operating in different business or industries than the customers using the technology offered by the established companies. Additionally, the new technology, product, or process evolves in time to the point where it replaces the incumbent technology (Christensen 1997: 1-96). This happens because the properties offered by the mainstream innovation is usually higher than the need of the customers. At the same time, the properties of the DI have become sufficient enough for the customers of the established companies, which will move using the upcoming innovation (figure 12). Both of the innovation trajectories evolve through incremental innovations. The disruption happens when the DI reached the performance demand of the low-end market.

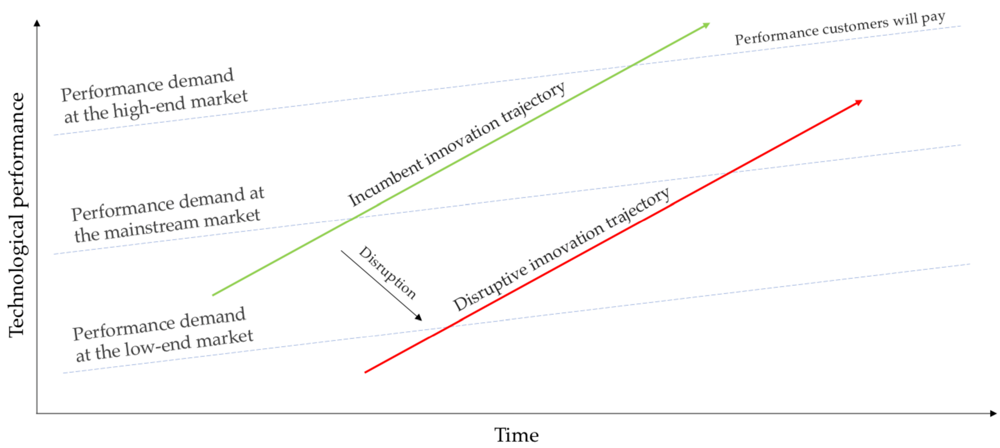

Figure 12. The model of disruptive innovation. Green arrow represents incumbent innovation trajectory and red arrow represents disruptive innovation trajectory (Adapted from Christensen, Raynor & McDonald 2015: 44-53).

In many industries the pace of technological development overcomes the demand of customers in higher-performing technologies. This leads to overserved markets in the incumbent innovation trajectory as it will eventually produce more advanced, property-rich innovations above the customer needs. Eventually this will result to a gap at the bottom of the market between the customers' needs and the performance of the innovations provided by the companies (Christensen, McDonald, Altman & Palmer 2018: 1043-1078). Nevertheless, incremental innovations are what companies acknowledge are useful and therefore they are applied to the NPD process. At the same time, the knowledge obtained from the

NPD process in not only useful but may harm the companies (Henderson & Clark 1990). This is because the incremental innovations diffuse along the mainstream market, where as DI commence from the low-end encroachment and diffuse upward from below of the mainstream market (Schimdt & Druehl 2008: 347-369). Although DIs are inferior to products developed by incumbent innovations based on the performance, they offer a set of attributes that will benefit customers at the bottom of the market because they are often cheaper, smaller, more accessible and more convenient. Additionally, companies utilizing incumbent innovations are typically unmotivated to develop DIs that target to smaller markets, because the Dis provide lower margins for their current customers and services which they are unable to use (Christensen et al 2018).

The DI can be characterized into two categories: new-market and low-end disruptions. New-market disruption begins from the niche-markets where the overall customer needs are gradually changed or from detached-markets, where customer needs are thoroughly diverse (Schimdt & Druehl 2008). In majority of the cases the new-market DIs are targeted to the customers who does not have resources to obtain the mainstream market innovations (Christensen & Raynor 2003: 102). Correspondingly, the low-end DIs happens in the mainstream markets and are more immediate compared to the new-market DIs (Schmidt & Druehl 2008). The difference between RI and DI is that RI impacts the industry of interest by replacing existing technology with better technology, which have a focus and priority on a long-term objective. The Dis however happens when companies start from a small market and focus to achieve short-term objectives, thriving on low-end market penetration.

4. CASE STUDY CONTEXT

In this chapter the high-technology, biotechnology, and pharmaceutical industries are defined. In addition, the operations of companies functioning in those industries are described.

4.1. Definition of high-technology companies

The classification of technology is relative and many manufacturing operations in companies can be considered as high-technology operations. In addition, many of these companies produce variety of products that can be considered either low-technology or high-technology products. However, when the companies are evaluated by their direct R&D intensities, they can be assessed by their relative R&D performance. For service industries other indicators, for example skill intensity, indirect R&D measures, and technology developed in investments can be used. The OECD industry technology intensity classification methodology uses three indicators in aspect of technology producers and technology users (International Standard Industrial Classification Revision 3 Technology Intensity Definition 2011: 1-6):

1) R&D expenditure per value added,
2) R&D expenditure per production value,
3) R&D expenditure added with technology developed in intermediate and investment goods per production value.

The OECD's categorization of manufacturing industries into high-technology, medium-high-technology, medium-low-technology, and low-technology segments is made after ranking the industries according to their average R&D intensities (table 4). Industries, which are categorized into higher technology groups, have higher average technology intensities in the indicators compared to the industries in the lower technology groups. The lower technology groups include industries from relatively low aggregate sectors (International Standard Industrial Classification Revision 3 Technology Intensity Definition 2011).

Table 4. Technology intensity classification of manufacturing industries (Adapted from International Standard Industrial Classification Revision 3 Technology Intensity Definition 2011)

High-technology industries	**Medium-high-technology industries**
Aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, TV, and information and communication technology (ICT); medical precision, and optical instruments and materials.	Electrical machinery and apparatus; motor vehicles, trailers and semi-trailers; chemicals excluding pharmaceuticals; railroad and transport equipment; machinery and equipment.
Medium-low-technology industries	**Low-technology industries**
Shipbuilding and boat building and repairing; rubber and plastics-based products; coke, refined petroleum products and nuclear fuel; basic metals and fabricated metal products; other non-metallic mineral products.	Manufacturing; recycling; wood, pulp, paper, paper derived products, printing and publishing; fast-moving consumer goods (FMCG) and tobacco; textiles, textile and other clothing products.

4.2. Definition of biotechnology industry

OECD has defined biotechnology by a single definition as:

> *"the application of science and technology to organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."*

This definition covers both modern biotechnology and the traditional activities in the industry. Therefore, a list-based definition of biotechnology is included with the single definition for more operational description (table 5). The list-based definition is only indicative, and it is expected to change over time as the biotechnology industry evolves, but the single definition is expected to remain the same for a longer period of time (van Beuzekom & Arundel 2009: 9-11).

Table 5. The list-based definition of biotechnology (adapted from van Beuzekom & Arundel 2009).

Category	**Definition**
DNA/RNA	Genomics, pharmacogenomics, DNA probes, genetic engineering, DNA/RNA sequencing, synthesis, and amplification, gene expression profiling, and use of antisense technology.
Proteins and other molecules	Sequencing, synthesis, and engineering of proteins and peptides, including large molecule hormones; improved large molecule drug delivery methods; proteomics, protein isolation and purification, identification of cell receptors and signalling.
Cell and tissue culture engineering	Cell and tissue culture, tissue engineering including tissue scaffold and biomedical engineering, cellular fusion, vaccine and immune stimulants, embryo manipulation.
Process biotechnology techniques	Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, biomediation, biofiltration and phytoremediation.
Gene and RNA vectors	Gene therapy, viral vectors.
Bioinformatics	Construction of databases on genomes, protein sequences; modelling complex biological processes including systems biology.
Nanobiotechnology	Applies the tools and processes of nano- and microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics etc.

The companies are defined by the engagement in biotechnology operations described in the list-based definition by using one or more biotechnology methods to produce goods or services, or to perform R&D in biotechnology. In the context of all companies the biotechnology companies can be categorized into two groups: dedicated biotechnology firms and biotechnology R&D firms (figure 13). The dedicated biotechnology firm's predominant activity involves the application of biotechnology to produce goods. The biotechnology R&D firms are defined as firms that conduct biotechnology R&D. A subset of this group are dedicated biotechnology R&D firms, which include companies that devote more than 75 % of their total R&D to biotechnology R&D (van Beuzekom & Arundel 2009).

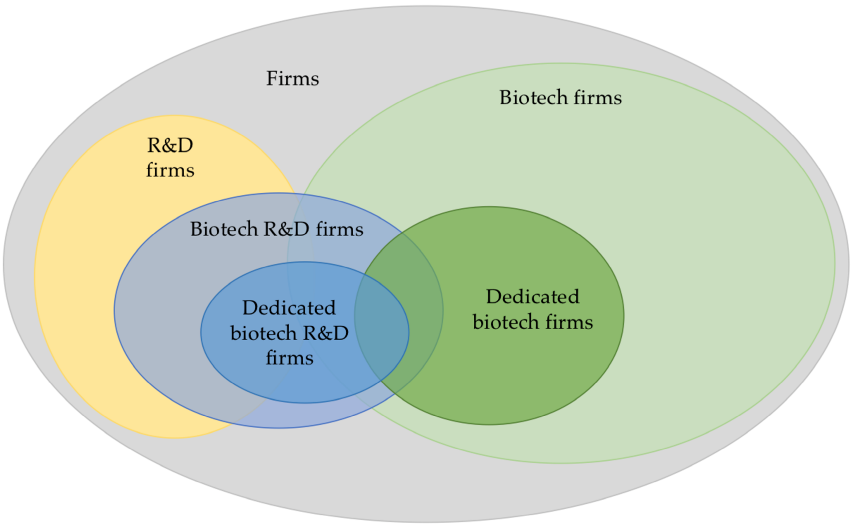

Figure 13. The segmentation of biotechnology companies (adapted form van Beuzekom & Arundel 2009).

4.3. Definition of pharmaceutical industry

The pharmaceutical industry is globally one of the most research-intensive industries and it operates globally in terms of sales, production and R&D, with the vast majority of these activities occurring within the markets represented by the OECD countries. The global pharmaceutical industry consists of several small and medium-sized companies (SME) from all over the world. However, the industry is dominated by research-based multinational enterprises (MNE), when analysed by the share of total pharmaceutical sales. The top ten pharmaceutical companies account for 46 % of the global pharmaceutical sales. Accordingly, in pharmaceutical manufacturing the unit production costs are very low compared to the unit prices. This results to a very high reliance on IPR in order to protect the high R&D investments from competitors (Pharmaceutical Pricing Policies in a Global Market 2008: 51-205).

Pharmaceutical industry reinvests on average 15.9 % of their sales revenue back to R&D. However, the R&D investments are very concentrated as the top 15 largest companies accounted for 72 % of global pharmaceutical R&D investments. From all of the global top 1,250 firms, the pharmaceutical companies accounted for 19.4 % of spending on R&D. From this group two different major types of innovation have been discovered: incremental innovation and RI. Incremental innovations offer minor improvements to therapeutic benefit of the existing products. These includes the "me-too" pharmaceuticals, which molecule structures are novel, but the treatment for the specific disease already exists. These innovations comprise a major share of the R&D expenditure in the pharmaceutical industry (Pharmaceutical Pricing Policies in a Global Market 2008). The RIs are more valuable than incremental innovations (Sorescu, Chandy & Prabhu 2003: 82-102). These include non-chemical entity biotherapeutics drugs and genome-based medicines for example (Schmid & Smith 2005: 50-57).

There are total of six distinguishable phases in the pharmaceutical NPD process (table 6). Approximately five of every 10,000 compounds tested moves forward from the Phase I and II. Furthermore, one of five compounds that moves to clinical trials can successfully complete the Phase III trials. The first two phases of the NPD process typically last about six years. The timeline for potential drug to successfully pass the clinical trial phases I to III takes an average of five years, which makes the total timeline of the new drug development for more than 10 years (Pharmaceutical Pricing Policies in a Global Market 2008).

Table 6. Phases of the new pharmaceutical product development (Adapted from Pharmaceutical Pricing Policies in a Global Market 2008).

Phase	**Description**
Drug discovery	Researchers in private companies, government and academic research institutions are searching promising compounds that are potential for treating diseases. The best compounds are moved further to preclinical testing phase.
Preclinical testing	The compounds found in drug discovery phase are further tested *in vitro* and *in vivo* in animal models. If the specific compounds show promising results, the developer can apply a permission from the national marketing authorisation agency to begin human clinical trials. The specifications for approval vary in different areas (e.g. United, States and European Union).
Phase I	The first phase of human clinical trials is conducted with relatively small number of healthy volunteers to determine the range of safe dosing and toxicity of the drug compound.
Phase II	In the second phase, the drug compound is tested with a larger group of volunteers, who have been diagnosed with the medical condition that the drug is intended to treat.
Phase III	The third phase of the clinical trials includes a larger sample of volunteers, who have been diagnosed with the medical condition of interest. The main objective is to demonstrate the efficacy of the drug compound and to finalize the dosing. The most likely safety issues are detected in Phase III clinical trials, but the subject sample sizes are still too small to detect rare adverse side-effects.
Marketing authorisation application	After the drug compound have successfully passed the clinical trials, an authorisation to market the drug is applied from the authorisation agency. The average time from the application to the approval has been 13 to 25 months in the recent years.

5. OVERVIEW OF THE CASE COMPANIES

The selected case companies were raw material suppliers for *in vitro* diagnostics (IVD) companies, an IVD company and a pharmaceutical company. All of the case companies participate in R&D activities. The group of the case companies presents a very homogenous group as they all operate either directly or indirectly in very regulated business environment. The size of the companies varied from SMEs to large enterprises (LE) based on the European Commission's definition on enterprise size of employees and revenue or balance sheet total (European Union recommendation 2003/361).

All the case companies described in this study belongs to the OECD's "high-technology industry" category of "pharmaceuticals" and "medical precision, and optical instruments and materials". In addition, all of the companies are applicable either to the "synthesis, and engineering of proteins and peptides" in the proteins and other molecules category and "applications in drug delivery and diagnostics" in the nanobiotechnology category of the list-based biotechnology definition. The companies, results, validation, and conclusions are described as confidential information, and therefore acronyms are used instead of the official company names. Additionally, the source of information concerning the case companies the will not be disclosed in the list of reference. However, for the accuracy and reliability, only information from case companies' personnel, official documents, and website are used.

5.1. Case company 1

The case company 1 (CC1) is a raw material supplier for the IVD companies. The company is a multinational SME with an annual revenue of approximately 25 million euros. They have approximately 100 employees and operations in three different countries. The company operates on B2B market and the products of their customers are also sold in B2B market

The questionnaires were sent to four executive level personnel out of whom three provided answers. In addition, the results were validated with one of the four executives in the CC1.

5.2. Case company 2

The case company 2 (CC2) is also a raw material supplier for the IVD companies. The company is also a multinational SME with an annual revenue of approximately 20 million euros. They have total of about 90 employees and operations in two countries. The company's main operations are in B2B market and the products of their customer are also sold in B2B market. The CC1 and CC2 operates in the same business, so the companies can be considered as competitors.

The questionnaires were sent to five executive level personnel out of whom all provided answers. In addition, the results were validated with one of the five executives in CC2.

5.3. Case company 3

The case company 3 (CC3) develops, manufactures, and distributes IVD test analysers and test intended for clinical diagnostics, life science research, food, environmental, and industrial testing. The CC3 is a Finnish subsidiary of a multinational LE, which consolidated annual revenue is approximately 2.26 billion USD and the consolidated annual revenue of the diagnostics division is about 680 million USD. The Finnish subsidiary has a key role in the research and NPD of the company group and their annual revenue is about 270 million euros. The CC3 has more than 11,200 employees globally and they have operations in more than 150 countries. CC1 and CC2 are potential raw material suppliers for CC3. The company operates in B2B market and the products of their customer are also sold in B2B market as well.

The questionnaires were sent to three executive level personnel in Finnish subsidiary from which all of the respondents were able to provide answers. In addition, the results were validated with one of the three executives in the Finnish subsidiary of CC3.

5.4. Case company 4

The case company 4 (CC4) is a life science and pharmaceutical company that develops, manufactures, and distributes pharmaceuticals for diseases that for example CC3 provides clinical IVD tests for. The CC4 is a Finnish subsidiary of a multinational LE, which consolidated annual revenue is approximately 35 billion euros. The annual revenue of the Finnish subsidiary is approximately 900 million euros and they have a significant role in some of the pharmaceutical development and manufacturing in the company group. The CC4 has more than 120,000 employees globally and they have operations in more than 80 different countries. The company operates in B2B market, but the products are supplied to both B2B and B2C markets.

The questionnaires were sent to four top-level executives in Finnish subsidiary from which three were able to provide answers. In addition, the results were validated with one of the three executives in Finnish subsidiary.

6. METHODOLOGY

In this study two questionnaires were used to evaluate the resource allocation for innovation and innovation strategy of the case companies: sense and respond (S&R) questionnaire and analytical hierarchy process (AHP) questionnaire. The S&R-questionnaire was used to analyse how the resource allocations adapts with changing business environment and AHP-questionnaire was used to evaluate the innovation strategy of the case companies respectively. For both methods four main criteria, that were considered to reflect the open and closed innovation strategies best, were defined and selected: technology, knowledge, development, co-operation criteria. In addition, in the S&R-questionnaire five subattributes was used to reflect the four main criteria and quality, cost, time, and flexibility criteria respectively (Takala 2002: 345-350).

6.1. Definition of the main attributes

6.1.1. Technology

The definition of technology is wide. It can be described as products, tools or processes integrated directly into the company's operations. Technology is used to increase productivity and efficiency and to develop better products. In this study, the technology criterion included leading-edge technology, external technology, external product development ideas, external intellectual property, and high-quality contract research. The technology criterion and its subattributes were corresponding to the quality criterion described by Takala (2002).

Leading-edge technology means the latest technology available for the company. External technology means the use of technology developed outside of the company but integrated into its core processes. External product development ideas mean the exploitation of product development ideas arising outside of the company but developed in-house. External intellectual property means licensing external IPR to be used in the company's products and/or processes. High-quality contract research means the use of high technology and high-quality contract research as a part of the company's processes. The technology main attribute addresses the priorities of these external resources for the company in the past and the future timeframe to leverage them as inputs as a part of the company's innovation strategy.

6.1.2. Knowledge

Knowledge is an intangible value of organization which is considered as an asset and can be referred as an intellectual capital. Knowledge is based on skills rather than physical objects. Knowledge tends to provide a company a competitive advantage against its competitors. In this study, the knowledge attribute included core competence, cost of publications, cost of IP, cost for attending to alternative markets, and value of own IP. The knowledge criterion and its subattributes were corresponding to the cost criterion described by Takala (2002).

Cost of core competence means the expenses that are caused from the core knowledge. Cost of publications means the expenses arising from publishing information that supports the business. Cost if IP means the explicit expenses of the IPR that the company uses in its business. Cost for attending to alternative markets means expenses ensuing from attending to markets other than the company's main market. Value of own IP means the material and immaterial valuation of the company's own IP. The knowledge main criterion addresses the priorities of these resources for the company in the past and the future timeframe to leverage these knowledge-related inputs as a part of the company's innovation strategy.

6.1.3. Development

Development can be considered as actions of companies to introduce and improve products and procedures from which they seek growth. In this study, the development criterion included time used for basic research, control of the company's own IP, internal new product development ideas, timing in current market and own R&D. The development criterion and its subattributes were corresponding to the time criterion described by Takala (2002).

Time used for basic research means the effort that is allocated for the basic research that aims to deeper understanding of concepts in the company. Control of own IP means how actively the company controls the use of its own IP by other companies and how much time the company uses for this control. The timing in current market means the company's timing in general in its main market compared to the global trends. The own R&D means how much time and effort the company puts on its own R&D in general. The development main criterion addresses the priorities of these resources for the company in the past and the future timeframe to leverage these internal inputs as a part of the company's innovation strategy.

6.1.4. Co-operation

Co-operation is a process where two entities or more are working together towards mutual economic benefit. In this study, the co-operation criterion included business model management, venture management, outsourcing management, involvement in other markets, and collaboration management. The co-operation criterion and its subattributes were corresponding to the flexibility criterion described by Takala (2002).

Business model management means the responses of core aspects of business to the corporate strategy and competitive advantage. Venture management means the activity of which the company pursuits different ventures, e.g. M&As, joint ventures, or strategic alliances. Outsourcing management means the activity of the company towards outsourcing its projects and processes. Involvement in other markets means the activity of the company in other markets than its main market. Collaboration management means the activity of the company to pursuit collaboration with other parties, e.g. academic, institutional, or industrial partners. The co-operation main criterion addresses the priorities of these resources for the company in the past and the future timeframe to leverage these collaboration inputs as a part of the company's innovation strategy.

6.2. Sense and respond

S&R method is an instrument that can be utilised for recognition, expectation, adaption, and responding to constantly changing business environments and situations in order to maintain the SCA. The objective of this method is to evaluate the resource allocation in companies and to recognize the impaired, balanced, and over resourced assets.

The S&R-questionnaire used in this study contained questions regarding the attributes that was considered as critical factors and has an influence on the resource allocation of the innovation strategy in the case companies. The questionnaire form included quantitative estimations of each attribute in scale 1-10, where the 1 represented low and 10 represented high values respectively. Total of 3-5 management executives were asked to fill the S&R-questionnaire, after which the results were analysed in order to determine the critical factors in the case companies' innovation strategy.

The S&R questionnaire were comprised of questions concerning the main attributes and total of 20 subattribute questions derived from the main attributes. The main and subattribute questions were evaluated based on empirical experience of the respondent in terms of whether the performance of an attribute has improved, stayed the same, or declined in the past 3-5 years. Additionally, the same evaluation was done based on the expectations of the respondents that do they believe that the performance of an attribute will improve, stay the same, or decline in the next 3-5 years. Each of the attributes was also evaluated against the case company's competitors based on subjective estimation of the respondents, whether the case company's performance was better, same, or worse compared to its competitors. The S&R-questionnaire used in this study is described in Appendix 2.

The relative performance of a case company compared to its competitors was determined a relative weight of the worse, same, and better answers based on the answers of the respondents (equation 1). The best fitting subjective performance was chosen based on the highest value

$$Relative\ performance = \frac{\sum Performance_i}{\sum Performance_W + \sum Performance_S + \sum Perfomance_B} \quad (1)$$

In the equation the $Performance_i$ represents the sum of worse, same, or better answers of the respondents, $Performance_W$ represents the sum of the "worse" answers of the respondents, $Performance_S$ represents the sum of the "same" answers of the respondents, and $Performance_B$ represents the sum of the "better" answers of the respondents.

6.2.1. Resource allocation index

Critical factor index (CFI) is a strategy instrument that supports strategy decisions that are based on empirical expectations and experiences. The combination of standard deviation (SD) of experiences and expectations leads to measurement of CFI. Compared to CFI, the balanced critical factor index (BCFI) provides more reliable indication of critical factors and therefore offers an extensive analysis tool as well (Nadler & Takala 2009: 1333-1339). In the BCFI the critical and non-critical attributes are more easily recognized, in order to better define the strategy and adjust different resources according to it.

An enhanced model called scaled critical factor index (SCFI) has also been developed to better reflect the core theory of S&R (Liu, Wu, Zhao & Takala 2011: 1010-1015). The even more improved model of SCFI is called normalized scaled critical factor index (NSCFI). The difference between SCFI and NSCFI models is the gap index and development index, which are formulated into the NSCFI model with an exponential function to keep the range of data in moderate level. In the CFI, BCFI, and SCFI models, the gap index may cause huge variation in small sample volumes and lead to exaggerated interpretation because of the multiplication by 0.1 or 10 (Liu & Liang 2015: 1019-1037). For the CFI, BCFI, SCFI, and NSCFI, the Performance index, Importance index, Gap index or Gap index', Development index or Development index', and SD indexes for expectation and experience (equations 2-9) are calculated before the final analysis (Liu & Liang 2015; Liu et al 2011):

$$Performance\ index = \frac{Average(experience)}{10} \tag{2}$$

$$Importance\ index = \frac{Average(expectation)}{10} \tag{3}$$

$$Gap\ index = \left|\frac{Average(experience) - Average(expectation)}{10} - 1\right| \tag{4}$$

$$Gap\ index' = 2^{\frac{Average(expectation) - Average(experience)}{10}} \tag{5}$$

$$Development\ index = |(better\% - worse\%)\ \times\ 0.9 - 1| \tag{6}$$

$$Development\ index' = 2^{(worse\% - better\%)} \tag{7}$$

$$SD_{expectation}\ index = \frac{SD_{expectation}}{10} + 1 \tag{8}$$

$$SD_{experience}\ index = \frac{SD_{experience}}{10} + 1 \tag{9}$$

The Gap indexes distinguish the gap between experiences and expectations of a particular attribute and helps to understand whether the expectations are corresponding to the reality. The Development indexes indicates the direction of the attributes' performance. Importance index evaluates the importance of specific attribute among other attributes, as it reflects the expectations of respondent concerning the attribute. Performance index on the other hand, evaluates the actual performance concerning specific attribute based on the empirical experience of the respondents. SD indexes for expectation and experience measures the respondent's similarity or controversy of an attribute based on the expectation and experience they might have. Using these indexes, the CFI, BCFI, SCFI, and NSCFI models can be calculated by using equations 10-13 (Liu & Liang 2015; Liu et al 2011):

$$CFI = \frac{SD_{experience} \times SD_{expectation}}{importance\ index \times gap\ index \times development\ index} - 1 \tag{10}$$

$$BCFI = \frac{SD_{expectation}\ index \times SD_{experience}\ index \times performance\ index}{importance\ index \times gap\ index \times development\ index} \tag{11}$$

$$SCFI = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[experience_{(i)}\right]^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[experience_{(i)}-10\right]^2} \times Performance\ index}{Gap\ index \times Development\ index \times Importance\ index} \tag{12}$$

$$NSCFI = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[experience_{(i)}\right]^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[expectation_{(i)}-11\right]^2} \times Performance\ index}{Gap\ index' \times Development\ index' \times Importance\ index'} \tag{13}$$

In the equations, the n represents the number of respondents.

From each model, the resource allocation indexes (RAI) were calculated and the results from the models using relative subattribute values were presented in graphical form and compared to each other. The relative critical factor values were determined by dividing an individual value with the sum of corresponding critical factor model values (Liu et al 2011). The average resource level was determined as a multiplicative inverse number of the subattributes (equation 14). One-third deviation around the average resource level was used as an upper and lower limit values. The specific subattribute was considered to be in balance if the subattribute value was between the range of one-third deviations of the average resource level. Accordingly, the subattribute was considered to be under resourced if the value of the subattribute was lower than one-third deviation of the average resource level, and over resourced if the value of the subattribute was over than one-third deviation of the average resource level respectively.

$$Average\ resource\ level = \frac{1}{number\ of\ subbattributes} \tag{14}$$

The trend of the subattributes inquired in the S&R-questionnaire was determined by comparing the past and the future values of each subattributes. The trend shows how the subattributes changes between the past and the future timeframe. If both the past and the future timeframe values of a subattribute was in the range of one-third deviation of average resource level, there were considered to be no change in the trend of a subattribute and the trend was labelled as the "same".

The trend was considered to be “worse”, if the values changed from balanced to under or over resourced. Accordingly, the trend was considered to be “better”, if the values changed from under or over resourced to balanced subattribute. If both the past and the future timeframe values of a subattribute were under or over resourced, but the future timeframe values of the subattribute was moving towards or further to the balanced resource-level, the trend was also considered to be “better” or “worse” respectively (Liu et al 2011).

6.3. Analytical hierarchy process

AHP method was created by Thomas L. Saaty as a multi-objective, and multi-criterion decision-making tool that helps to evaluate different attributes pairwise. The method provides a framework for problem solving by breaking down the problem and prioritizes them to in each hierarchy (Saaty 1984: 285-286). The method enables to evaluate alternative elements together and makes them comparable in a quantitative way (Toshev & Takala 2010: 14-18). It has been used in a variety of problems in different industries as a decision-making tool among both managers and researchers. It takes priorities of different alternatives into consideration and weights them based on their level of importance. The aim of the method is to find the best solution available for each problem (Saaty 1980: 4).

The AHP method also gives concrete results for rational decision-making process and enables its users to tackle complex issues by laying them in hierarchical structure. The scale used in AHP-process range between 1 to 9 for least important to absolute value, with 1 meaning that both of the criteria are equally important. The relative score for each attribute is determined by taking into account all the relevant criteria and their pairwise comparisons, so that all of the elements and alternatives are evaluated in the lowest level as well (a. Takala, Hirvelä, Liu & Malindžák 2007: 326-344).

The AHP-questionnaire used in this study consisted of subjective evaluation of priority weights on how the main attributes mentioned in chapter 6.1 have been divided in the case companies for the past 3-5 years based on the empirical experience of the respondent, and how the respondent expects them to be divided for the next 3-5 years in the case company. The questionnaire was consisted of 6 pairwise questions of the 4 different main attributes, where all the main attributes were compared to each other (figure 14). The AHP-questionnaire used in this study is described in Appendix 3.

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Development	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation

Figure 14. Pairwise comparison of the main attributes.

The AHP-questionnaire results were analysed with Expert Choice EC11.5 AHP software (Expert Choice, United States) and Excel spreadsheet software (Microsoft, United States). Based on the answers, an inconsistency ratio (ICR) was also calculated. The ICR gives information about the consistency of the comparative answers in the AHP-questionnaire and discriminates between contradictory answers. The ICR can be computed as follows (equation 15):

$$ICR = \frac{\frac{\lambda_{max}-n}{n-1}}{RI} \tag{15}$$

In the equation the λ_{max} is the average of the weighted sum values of the attributes, the n represents the number of the criteria, and RI represents the random index matrix (table 7) developed by Thomas Saaty (1980), based on the size of the attributes (Mu & Pereyra-Rojas 2018: 13-15).

Table 7. Inconsistency for randomly generated matrix (Saaty 1980: 21).

n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

6.3.1. Innovation strategy index

The analytical model for innovation strategy was also used to calculate the innovation strategy index (ISI) of the case companies in four different groups using the technology, knowledge, development, and co-operation attributes. The ISI takes into account the four main criteria, which are evaluated with the AHP method. The ISI can be presented with the equation 16 (a. Takala et al 2007).

$$ISI = f_{ISI}(T, K, D, C) \tag{16}$$

Where the *T* represents technology, *K* represents knowledge, *D* represents development, and *C* represents co-operation.

The normalized weights of the main attributes in ISI-model are calculated with the equations 17-20 (Liu 2013: 2821-2814). The normalized values are used in order to emphasize the value for Co-operation, as according to the equations the sum of T', K', and D´ is 1. This concludes that the sum of T', K', D', and C' is < 1.

$$T' = \frac{T}{T+K+D} \tag{17}$$

$$K' = \frac{K}{T+K+D} \tag{18}$$

$$D' = \frac{D}{T+K+D} \tag{19}$$

$$C' = \frac{C}{T+K+D+C} \tag{20}$$

In the equations above the *T* represents technology, *K* represents knowledge, *D* represents development, and *C* represents co-operation.

The innovation strategies evaluated in this study were inside-out open innovation strategy, outside-in open innovation strategy, closed innovation strategy, and coupled open innovation strategy. The method was originally developed for detection of preferable operations strategy type (b. Takala, Kamdee, Hirvelä & Kyllönen 2007: 110-112). The results derived from AHP method were applied to identify the innovation strategy type of the case companies. Furthermore, the equations 21-24, that represent analytical models for ISI, were used to determine the innovation strategy for each case company.

$$IO = \emptyset \sim 1 - \left(1 - T\%^{\frac{1}{3}}\right)(1 - 0.9 \times D\%)(1 - 0.9 \times K\%) \times C\%^{\frac{1}{3}} \tag{21}$$

$$OI = \lambda \sim 1 - 1(1 - C\%)\left[ABS[(0.95 \times T\% - 0.285) \times (0.95 \times D\% - 0{,}285) \times (0.95 \times K\% - 0.285)]\right]^{3} \tag{22}$$

$$CI = \varphi \sim 1 - \left(1 - K\%^{\frac{1}{3}}\right)(1 - 0.9 \times D\%)(1 - 0.9 \times T\%) \times C\%^{\frac{1}{3}} \tag{23}$$

$$Co = \frac{1}{2}(Inside - out + Closed\ innovation) \tag{24}$$

In the equations above the *IO* represents inside-out OI strategy, the *OI* outside-in OI strategy, the *CI* closed innovation strategy, and the *Co* coupled OI strategy respectively. The *T* represents technology, *D* development, *K* knowledge, and *C* co-operation attributes respectively.

The equations 21-24 are modified from manufacturing strategy index developed by Takala et al (2007 b.). These analytical models have been used globally in more than 100 case company studies (Liu & Takala 2009: 1-19). The same equations are also applied to calculate the innovation strategies of RAI in each critical factor group using weighted values of technology, knowledge, development, and co-operation derived from S&R method.

6.4. Responsiveness, agility, and leanness -model

The responsiveness, agility, and leanness (RAL) -model supports the theory of analytical models that uses four main attributes, e.g. technology, knowledge, development, and flexibility. Originally the RAL-model has been created to evaluate success factors in logistics operations, but it can be used in all operations and manufacturing strategies as well. The RAL -model has been validated and used in companies of all sizes from different industries (Si, Takala, Liu, Toshev, & Tang 2008: 1915-1919). The model has been later modified by Takala (2002) by taking product and production perspective into consideration.

The RAL-model is based on the equilateral shape triangle that reviews the innovation strategy. The triangle is formed by the normalized weights of the main attributes either by RAI or AHP methods. The sides of the triangle represent the values for responsiveness, agility, and leanness. The responsiveness is considered as the "speed by which the system satisfies unanticipated requirements", the agility is considered as the "speed by which the system adapts optimal cost structure", and the leanness "minimizes waste in all resources and activities" (b. Takala et al 2007).

The shape of the triangle is determined by the lengths of the sides and the angles formed by the corners of the sides. These values enable to form a diagram that indicates the innovation strategy and the competitive group of the case companies (figure 15A). The triangle will always be symmetric when all the variables of technology, knowledge, development, and co-operation are 1. In this case the sides, responsiveness, agility, and leanness, are equal and the triangle can be defined by using a unit circle drawn outside the RAL-triangle (figure 14B). The radius of the outside circle represents the values of the innovation strategies. Accordingly, the inner circle helps to determine the angle between the innovation strategy line segments.

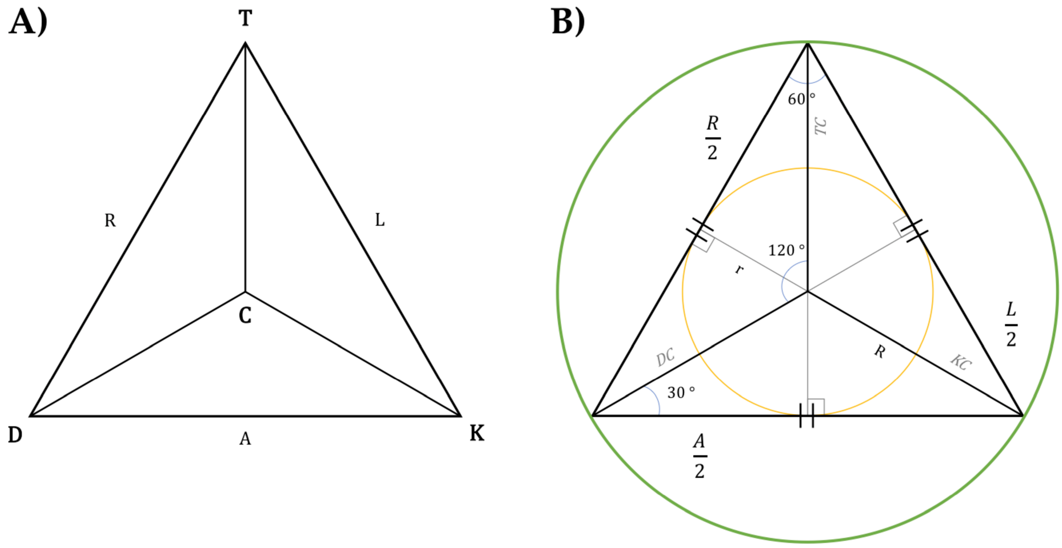

Figure 15. The responsiveness, agility, and leanness -model. A) the *R* represents responsiveness, the *A* agility, and *L* leanness. The *T* represents technology, the *K* represents knowledge, the *D* represents development, and the *C* represents co-operation. B) The triangle area is determined based on the radius and angles inside the equilateral triangle.

The triangle area represents the total innovation potential of the companies. The area of the triangle can be computed by the equation 25:

$$Area = \frac{1}{2}\sin 120°\, TC \times KC + \frac{1}{2}\sin 120°\, KC \times DC + \frac{1}{2}\sin 120°\, TC \times DC \qquad (25)$$

The innovation strategy obtained from ISI and RAI are laid out as triangle supported by theory of holistic RAL -model that describes the innovation orientation of the case companies (Liu & Liang 2015). The innovation triangle was defined by the ISI amplitudes of outside-in (ISI_O) strategy, inside-out (ISI_I) strategy, and closed innovation (ISI_C) strategy. Accordingly, the resource triangle was defined by the RAI amplitudes of outside-in (RAI_O) strategy, inside-out (RAI_I) strategy, and closed innovation (RAI_C) strategy from each case companies' values obtained from AHP- and S&R-questionnaires respectively.

The ISI triangle describes the innovation strategy of the case companies based on the assumptions of the decision-makers, while the RAI triangle employs the actual resource allocation used to achieve the determined innovation strategy of the company. The ultimate innovation strategy of the case companies was determined by the shape of the triangles (figure 16).

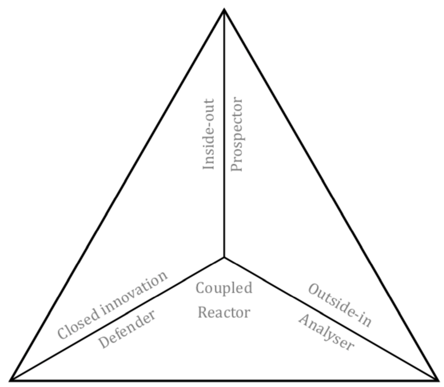

Figure 16. Innovation strategy and resource allocation index triangle. Comparison of innovation and aggressiveness strategy.

In the optimal innovation strategy both the ISI and RAI triangles are aligning together. Because the main attributes and subattributes are corresponding to quality, cost, time, and flexibility criteria, the aggressiveness strategy typology is used as well (Miles & Snow 1978: 20-40).

6.5. Sustainable competitive advantage

SCA was first suggested by Roy Lubit as a knowledge-based approach for competitive advantage of the companies. It is based on the theory that knowledge of doing is more important than the access to specific resources. Therefore, to develop knowledge as a sustainable core competence, the knowledge should be spread inside the company and avoid it to spread outside of the company (Takala, Shylina & Tilabi 2014: 66-77).

The SCA method used in this study is a tool to assess the functionality of the innovation strategy in the companies. In the SCA analysis two periods were taken into consideration. The SCA method helps to determine whether the internal resource allocation supports the innovation strategy of the companies. In this study the mean absolute percentage error (MAPE), root mean squared error

(RMSE), and maximum absolute deviation (MAD) were used to determine the risk level of the innovation strategy by the SCA. The MAPE, RMSE, and MAD was determined by equations 26-28 (Tasmin, Takala, Bakr, Shylina, Nizialek & Che Rusuli 2016: 73-85).

$$MAPE = SCA = 1 - \sum_{\alpha,\beta,\gamma} \left|\frac{BS-BR}{BS}\right| \tag{26}$$

$$RMSE = SCA = 1 - \sqrt{\sum_{\alpha,\beta,\gamma} \left(\frac{BS-BR}{BS}\right)^2} \tag{27}$$

$$MAD = SCA = 1 - max_{\alpha,\beta,\gamma} \left|\frac{BS-BR}{BS}\right| \tag{28}$$

In the equations, the BS represents the inside-out, outside-in, and closed innovation triangle angle values in the ISI model and the BR represents the inside-out, outside-in, and closed innovation triangle angle values in the RAI model. The SCA values of the MAPE, RMSE, and MAD relates to the amount of how the resource allocation supports the companies' innovation strategy. The closer the SCA values are to 1, the more consistent the resource allocation and innovation strategy are (a. Takala, Koskinen, Liu, TAS & Muhos 2013: 45-54).

6.6. Weak market test

For a new model constructs, three market tests have been proposed. The first one is the weak market test (WMT), which means a person responsible in a case company is willing to use the constructed model. The second test is called semi-strong market test (S-SMT), which means that the constructed model is widely accepted by the case companies. The third test is called the strong market test (SMT), and it means that the new constructed model is systematically used in the case companies to produce competitive results compared to its counterparts (Kasanen, Lukka & Siitonen 1993: 241-264). As this study is the first attempt to quantitatively model the innovation strategy of the case companies with these models, it aims to satisfy the WMT and also pave the way for the future market tests that are defined by the constructive research approach (CRA). The WMT proposes that the constructed model has business interest even though it does not indicate that this new constructed model will bring any direct economic benefits to the case companies (Kasanen et al 1993). To pass the WMT it is enough that the case company has adopted the CRA (Lindholm 2008: 343-358).

In this study the WMT was tested in all four case companies, which helps to generalize these results on a wider scale of customers. The WMT was also used to validate both the RAI and the ISI results derived from the S&R- and AHP-questionnaires. During the WMT, all of the obtained results were presented to the case companies executive without any analysis of the company's innovation strategy. It was also asked how the determined results meets the reality, and what actually has been the company's innovation strategy during the past 3-5 years of period and according to the company's strategy, what it will be for the next 3-5 years of period. The case companies were also asked to give reasons why they think the company has and will pursue for the certain innovation strategy in order to be sure that respondents in the WMT has understood the categorization of different innovation strategies.

7. RESULTS

This chapter describes the results of the case companies that was analysed in the study. The information presented in this chapter is confidential, and therefore acronyms are used instead of the official company names. The source of the information is not disclosed in the text nor the list of reference.

7.1. Case company 1

7.1.1. Resource allocation index

The fluctuation of the resource allocation model values was highest in the CFI and BCFI models, and moderate in the SCFI model. In general, the values were higher in these models compared to the NSCFI model. The deviation between the past and the future values were high in the BCFI model and low in the SCFI and the NSCFI models, although the SCFI model did stress more the minor differences in the answers than the NSCFI model (figure 17).

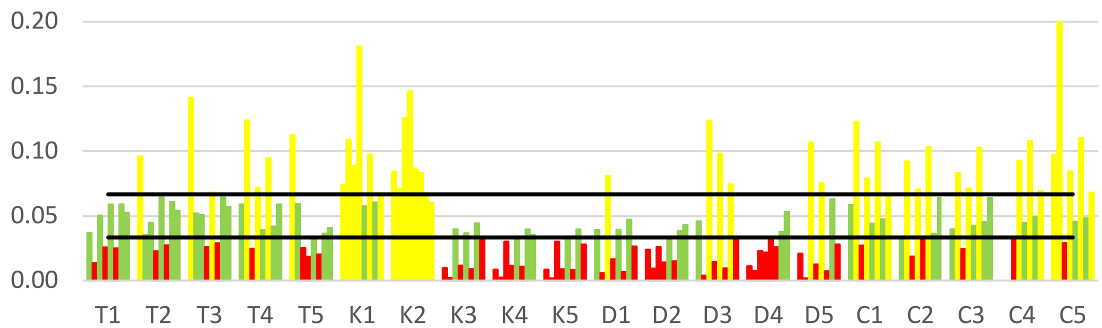

Figure 17. Resource allocation model results of CC1. The results for each subattribute from left to right are P-CFI, F-CFI, P- BCFI, F-BCFI, P-SCFI, F-SCFI, P-NSCFI, and F-NSCFI. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

Because the SD was 0 in the CFI model numerator, both the past and the future values in the "C4: expertise in other markets" attribute were 0 as well. The future values of the "C5: collaboration management" attribute was more than 3 times of the upper limit value. The resource allocation was under resourced in following subattributes: “K3: the cost of intellectual property”, “K5: value of own intellectual property”, “D1: time used for basic research”, “D3: internal product development ideas”, and “D5: own research & development” in all of the resource allocation models. The trend between the past and the future values was shown to be better in the subattribute “D3: internal product development ideas” in all other resource allocation models except the CFI model. All the trends of the subattributes in the resource allocation models are described in Appendix 4.

The performance compared to competitors were scattered among different main attributes (table 8). The knowledge and the development attributes were considered to perform better compared to competitors by the majority of the respondents. However, the co-operation attribute was considered to perform worse compared to competitors in opinion of all respondents and the answers to the technology attribute were scattered between the "worse", "same" and "better".

Table 8. The performance comparison to competitors in CC1. The highest values in different attributes are marked in bold.

Attributes	**Worse**	**Same**	**Better**
Technology	0.33	0.33	0.33
Knowledge	0	0.33	**0.67**
Development	0.33	0	**0.67**
Co-operation	**1.00**	0	0

7.1.2. Innovation strategy index

The distribution of the technology, knowledge, development, and co-operation in the past timeframe were 0.060, 0.564, 0.375, and 0.045 respectively. The corresponding distribution in the future timeframe were 0.548, 0.158, 0.294, and 0.227 respectively (figure 18). The corresponding priority weight values for the same main attributes in the past timeframe were 0.167, 0.444, 0.389, and 0.100 and for the future timeframe 0.400, 0.267, 0.333, and 0.250 respectively.

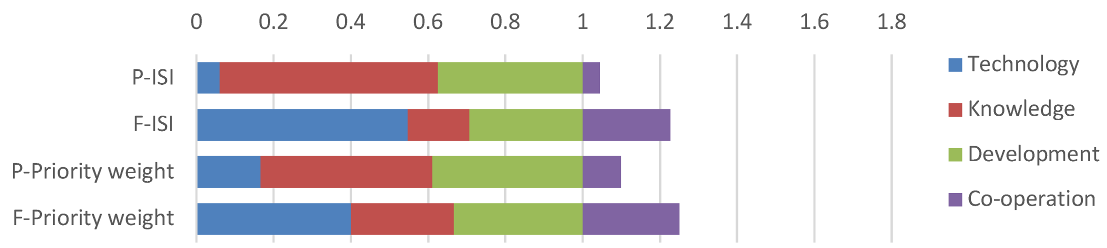

Figure 18. The main attribute distributions in the CC1.

The ISI model values correlated with the priority weight values in both past and future timeframe (figure 18). The SD for the main attributes varied between 0.010 to 0.085 in the past timeframe and between 0.016 to 0.105 in the future timeframe. The ICR for the past timeframe was 0.031 and for the future timeframe 0.004.

7.1.3. Responsiveness, agility, and leanness -model comparison

The ISI model results correlated with the priority weight results in both RAL -model in timeframes. In the past timeframe, the highest values in the ISI and the priority weight models was the closed innovation strategy, and in the future timeframe the highest values were in the outside-in OI strategy (figure 19).

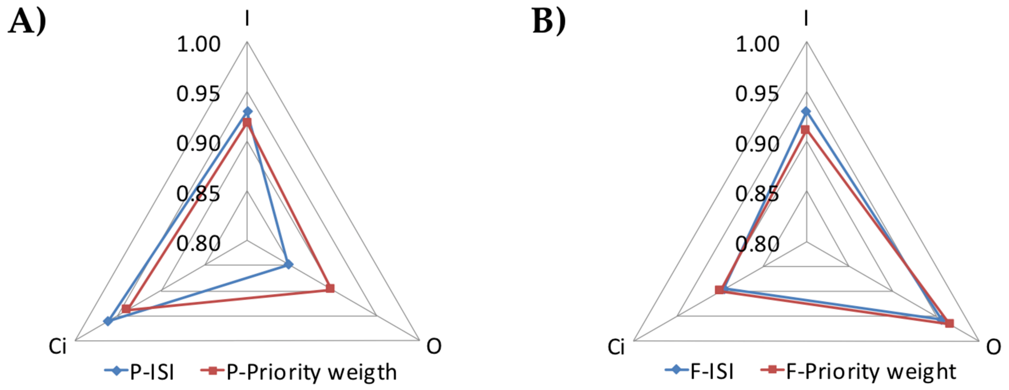

Figure 19. Innovation strategy index and priority comparison in CC1. Responsiveness, agility, and leanness -model A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represents outside-in open innovation strategy, and the *Ci* represents the closed innovation strategy.

None of the RAI models did not correlate with the ISI model in the past timeframe. In the future timeframe, the NSCFI model correlated the best with the future ISI model showing the highest values for the outside-in OI strategy (figure 20). In the CFI model the Closed innovation values were significantly lower compared to the other RAI models or ISI model in the past timeframe. However, the past timeframe BCFI, SCFI, and NSCFI models showed similar results with each other, but in the future timeframe only BCFI and SCFI correlated together. Neither of these models were consistent with the past and the future ISI models.

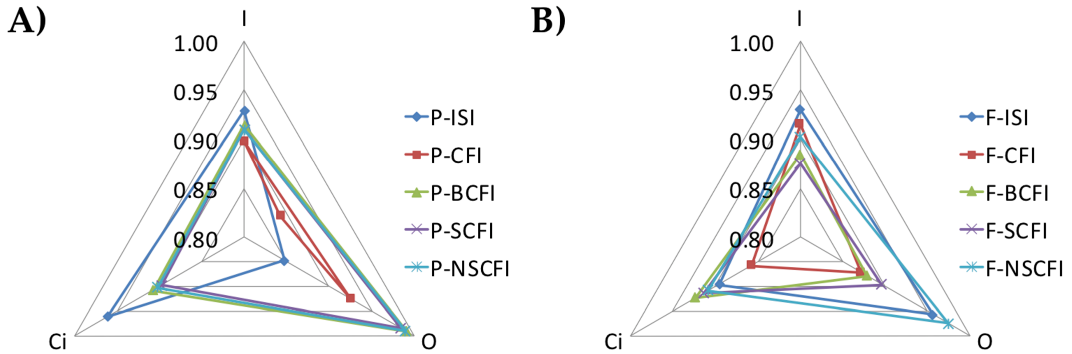

Figure 20. Responsiveness, agility, and leanness -model comparison of CC1. Innovation strategy and resource allocation index models A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

In the past timeframe the order of the innovation strategy models was the same in the ISI and priority weight models. In both models the order of the innovation strategy types was Closed innovation > Coupled > Inside-out > Outside-in (table 9). In all of the RAI models the order of the innovation strategy types in the past timeframe was Outside-in > Inside-out > Coupled > Closed innovation. In the future timeframe the order of the innovation strategy models was the same in the ISI and the priority weight models. In both models the order of the innovation strategy types was Outside-in > Inside-out > Coupled > Closed innovation.

Table 9. Innovation strategy results of different models in CC1. The highest values in each are marked in bold.

PAST TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0.9293	0.8473	**0.9612**	0.9454
Priority weight	0.9186	0.8977	**0.9393**	0.9289
CFI	0.8975	**0.9252**	0.7567	0.8271
BCFI	0.9147	**0.9914**	0.9075	0.9111
SCFI	0.9103	**0.9844**	0.8972	0.9037
NSCFI	0.9099	**0.9901**	0.9023	0.9061
FUTURE TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0.9301	**0.9564**	0.8955	0.9128
Priority weight	0.9118	**0.9657**	0.8994	0.9056
CFI	**0.9152**	0.8717	0.8574	0.8863
BCFI	0.8850	0.8788	**0.9233**	0.9041
SCFI	0.8755	0.8961	**0.9136**	0.8946
NSCFI	0.9022	**0.9741**	0.9087	0.9055

7.1.4. Sustainable competitive advantage

In the past timeframe the highest SCA values was achieved with BCFI model and in the future timeframe with NSCFI model respectively (table 10). The highest values in the past timeframe were 0.7888 in MAPE, 0.8698 in RMSE, and 0.8993 in MAD. The highest values in the future timeframe were 0.9482 in MAPE, 0.9682 in RMSE, and 0.9741 in MAD respectively.

Table 10. Sustainable competitive advantage values in CC1. The highest values in each model are marked in bold.

PAST TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.7077	0.8064	0.8472
BCFI	**0.7888**	**0.8699**	**0.8993**
SCFI	0.7876	0.8683	0.8988
NSCFI	0.7844	0.8672	0.8972
FUTURE TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.9299	0.9539	0.9644
BCFI	0.8927	0.9314	0.9476
SCFI	0.9094	0.9448	0.9557
NSCFI	**0.9482**	**0.9682**	**0.9741**

7.2. Case company 2

7.2.1. Resource allocation index

There were some fluctuations in the resource allocation model values with isolated subattributes in case of CFI, BCFI, and SCFI models. In these models the future values for the "T2: use of external technology" -attribute was almost 3 times of the upper limit value (figure 21). In other attributes the variation between past and the future values were moderate. In general, the fluctuation was lowest in the NSCFI model. The resource allocation was under resourced in the subattributes "K2: cost of publications", and "D1: time used for basic research" in every other resource allocation model, expect the CFI model. In the CFI model the "cost of publications" was over resourced in both the past and the future timeframe with the trend getting closer to balanced, and the "time used for basic researched" was balanced in both the past and the future timeframe with the trend remaining same. The trend between the past and the future values was shown to be better in the subattribute "T2: use of external technology" in all of the resource allocation models. In addition, the trend for subattribute "D5: own research & development" was shown to be better in every other resource allocation model, except the CFI model. All the trends of the subattributes in the resource allocation models are described in Appendix 5.

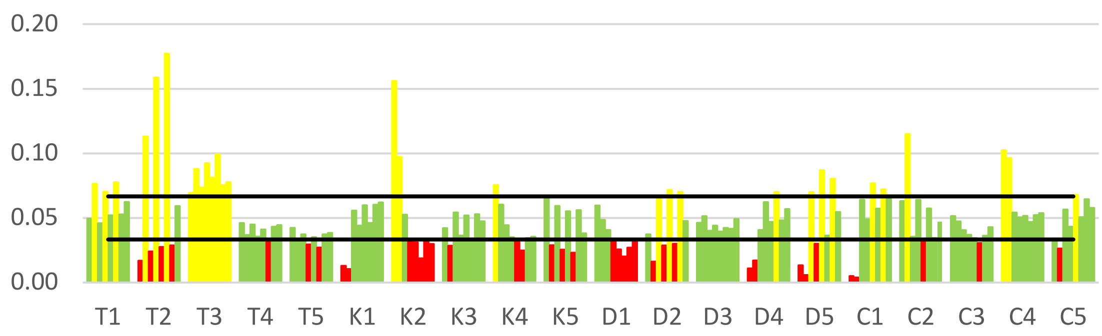

Figure 21. Resource allocation model results of CC2. The results for each subattribute from left to right are P-CFI, F-CFI, P- BCFI, F-BCFI, P-SCFI, F-SCFI, P-NSCFI, and F-NSCFI. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

The performance compared to competitors were evaluated to be the same among the different main attributes (table 11). However, the development attribute was considered to perform either worse or the same as compared to competitors based on the opinion of the respondents.

Table 11. The performance comparison to competitors in CC2. The highest values in different attributes are marked in bold.

Attributes	**Worse**	**Same**	**Better**
Technology	0	**0.60**	0.40
Knowledge	0	**0.80**	0.2
Development	**0.40**	**0.40**	0.20
Co-operation	0	**0.80**	0.20

7.2.2. Innovation strategy index

The distribution for the technology, knowledge, development, and co-operation in the past timeframe were 0.119, 0.180, 0.701, and 0.262 respectively. The corresponding distribution in the future timeframe were 0.555, 0.282, 0.163, and 0.553 respectively (figure 22). The ICR for the past timeframe was 0.115 and for the future timeframe 0.060. The priority weights for the corresponding main attributes were 0.313, 0.188, 0.500, and 0.200 in the past timeframe and 0.357, 0.214, 0.429, and 0.300 in the future timeframe respectively.

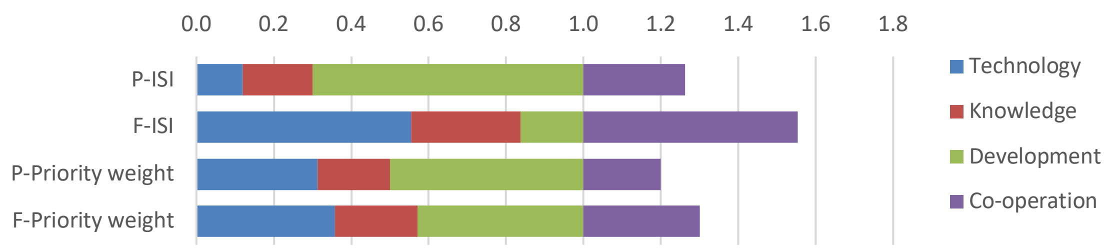

Figure 22. The main attribute distributions in the CC2.

The main attribute ISI model values correlated moderately with the priority weight values in both the past and the future timeframe (figure 22). The SD for the main attributes in the past scenario varied between 0.005 to 0.142 and between 0.048 to 0.188 in the future timeframe.

7.2.3. Responsiveness agility, and leanness -model comparison

The main attribute ISI model results of the past timeframe did not correlate in the RAL -model with the priority weight values derived from the AHP-questionnaire. However, the results did correlate in the future timeframe (figure 23). In the past timeframe the highest value in the innovation strategy was in the closed innovation strategy based on the ISI model and in the outside-in OI strategy based on the priority weight model. In the future timeframe the highest values in the innovation strategy were in the outside-in OI strategy both in the ISI and the priority weight models.

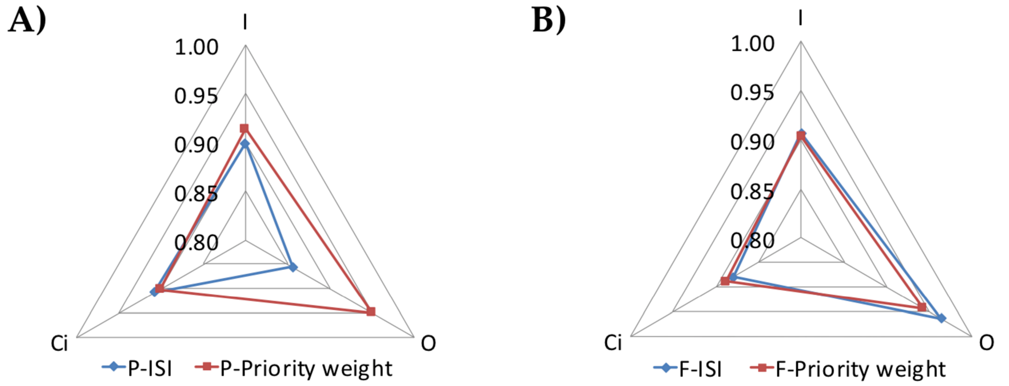

Figure 23. Innovation strategy index and priority comparison in CC2. Responsiveness, agility, and leanness -model A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent the closed innovation strategy.

From the RAI models the SCFI and the NSCFI models correlated best with the ISI models in both timeframes. The CFI and BCFI models did not correlate in the past timeframe but did correlate in the future timeframe (figure 24). In the past timeframe the BCFI, SCFI, and NSCFI models were consistent with the ISI model, and gave highest values to the closed innovation strategy. In the future timeframe all of the RAI models were consistent with the ISI model and the highest values were in the outside-in open innovation strategy.

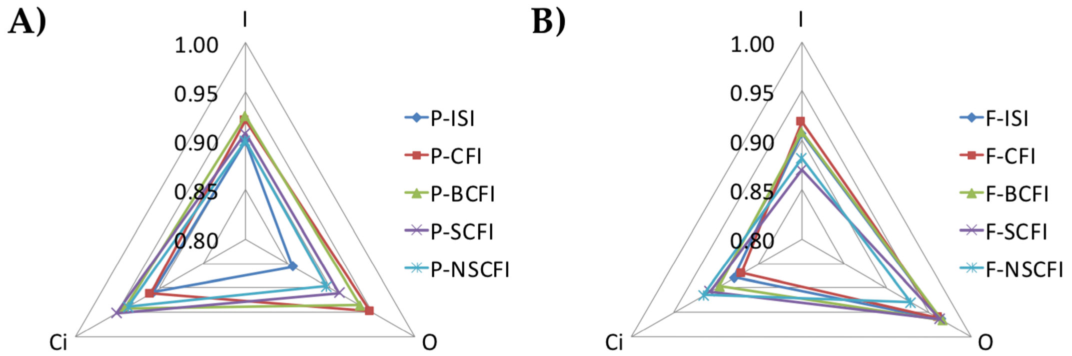

Figure 24. Responsiveness, agility, and leanness -model comparison of CC2. Innovation strategy and resource allocation index models A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

In the past timeframe the order of the innovation strategy was Closed innovation > Coupled > Inside-out > Outside-in in the ISI model, and Outside-in > Inside-out > Coupled > Closed innovation in the priority weight model (table 12). The NSCFI model did correlate with ISI model in the past timeframe. In the future timeframe the order of the innovation strategy models was the same in the ISI and the priority weight models: outside-in > inside-out > Coupled > Closed innovation.

Table 12. Innovation strategy results of different models in CC2. The highest values in each are marked in bold.

PAST TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0.8994	0.8560	**0.9082**	0.9038
Priority weight	0.9141	**0.9502**	0.9011	0.9076
CFI	0.9206	**0.9473**	0.9111	0.9159
BCFI	0.9248	0.9352	**0.9420**	0.9334
SCFI	0.9078	0.9108	**0.9517**	0.9297
NSCFI	0.8997	0.8960	**0.9380**	0.9189
FUTURE TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0.9068	**0.9636**	0.8793	0.8930
Priority weight	0.9036	**0.9430**	0.8879	0.8958
CFI	0.9188	**0.9609**	0.8703	0.8945
BCFI	0.9086	**0.9654**	0.8966	0.9026
SCFI	0.8701	**0.9634**	0.9073	0.8887
NSCFI	0.8817	**0.9287**	0.9150	0.8983

7.2.4. Sustainable competitive advantage

In the past timeframe the highest SCA values was achieved with the NSCFI model and in the future timeframe with BCFI model respectively (table 13). The highest values in the past timeframe were 0.9575 in MAPE, 0.9728 in RMSE, and 0.9784 in MAD. The highest values in the future timeframe were 0.9807 in MAPE, 0.9883 in RMSE, and 0.9906 in MAD respectively.

Table 13. Sustainable competitive advantage values in CC2. The highest values in each model are marked in bold.

PAST TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.9035	0.9401	0.9529
BCFI	0.9384	0.9622	0.9699
SCFI	0.9503	0.9683	0.9748
NSCFI	**0.9575**	**0.9728**	**0.9784**
FUTURE TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.9786	0.9862	0.9892
BCFI	**0.9807**	**0.9883**	**0.9906**
SCFI	0.9384	0.9582	0.9689
NSCFI	0.9207	0.9515	0.9614

7.3. Case company 3

7.3.1. Resource allocation index

There were some fluctuations in the resource allocation values with isolated subattributes in case of CFI, BCFI, and SCFI models. In these models, the past values for the "D3: internal product development ideas" was more than 2 times of the determined upper limit value (figure 25). In other subattributes the fluctuations were high only in some specific cases. In general, the fluctuation was lowest in the NSCFI model. The resource allocation was under resourced in the subattributes "D1: time used for basic research" and "D2: control of own intellectual property" in all of the resource allocation models. Accordingly, the trend between the past and the future timeframe was shown to be better in the subattributes "D3: internal product development ideas" and "C1: business model management" in all of the resource allocation models. All the trends of the subattributes in the resource allocation models are described in Appendix 6.

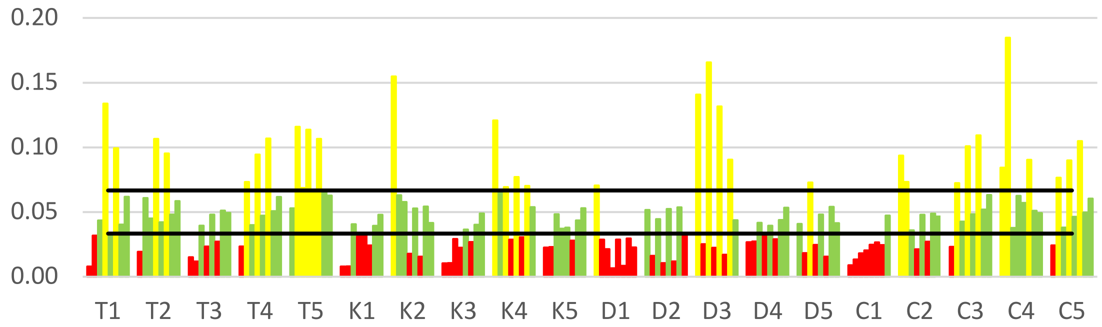

Figure 25. Resource allocation model results of CC3. The results for each subattribute from left to right are P-CFI, F-CFI, P-BCFI, F-BCFI, P-SCFI, F-SCFI, P-NSCFI, and F-NSCFI. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

The performance compared to competitors were evaluated to be the same among most of the attributes (table 14). However, the knowledge attribute values were scattered between the worse, same, and better values.

Table 14. The performance comparison to competitors in CC3. The highest values in different attributes are marked in bold.

Attributes	**Worse**	**Same**	**Better**
Technology	0.33	0.**67**	0
Knowledge	0.33	0.33	0.33
Development	0	**0.67**	0.33
Co-operation	0.00	**0.67**	0.33

7.3.2. Innovation strategy index

The distribution for the technology, knowledge, development, and co-operation in the past timeframe were 0.491, 0.152, 0.357, and 0.108 respectively. The corresponding distribution in the future timeframe were 0.606, 0.128, 0.267, and 0.061 respectively (figure 26). The ICR for the past timeframe was 0.156 and for the future timeframe 0.111. The priority weight for the corresponding main attributes were 0.444, 0.222, 0.333, and 0.100 in the past timeframe and 0.500, 0.250, 0.250, and 0.200 in the future timeframe respectively.

Figure 26. The main attribute distribution in the CC3.

The main attribute ISI model values correlated well with the priority weight values in both the past and the future timeframe (figure 26). The SD for the main attributes in the past timeframe varied between 0.006 to 0.049 and between 0.012 to 0.098 in the future timeframe.

7.3.3. Responsiveness agility, and leanness -model comparison

The main attribute ISI model results of the past timeframe did correlate moderately in the RAL-model with the priority weight values derived from the AHP-questionnaire. However, the results did not correlate in the future timeframe (figure 27). In the past timeframe the highest value in the innovation strategy was in the inside-out OI strategy based on both the ISI model and priority weight model. In the future timeframe the highest values in the innovation strategy were in the inside-out OI strategy in the ISI model and outside-in OI strategy in the priority weight model respectively.

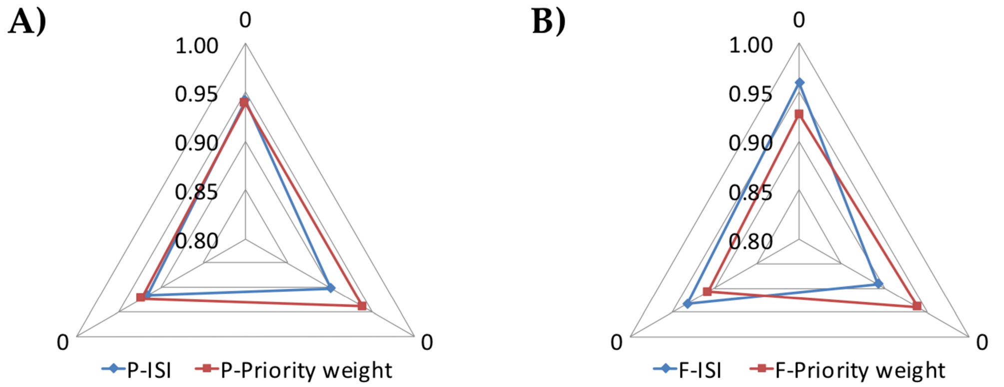

Figure 27. Innovation strategy index and priority comparison in CC3. Responsiveness, agility, and leanness -model A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent the closed innovation strategy.

From the RAI models the BCFI model correlated best with ISI model in the past timeframe. In the future timeframe none of the models correlated with the ISI model (figure 28). In the past timeframe the highest values in the BCFI model were inside-out OI strategy. Although, the highest value in CFI model was inside-out strategy, the pattern of the triangle did not correlate with the ISI model.

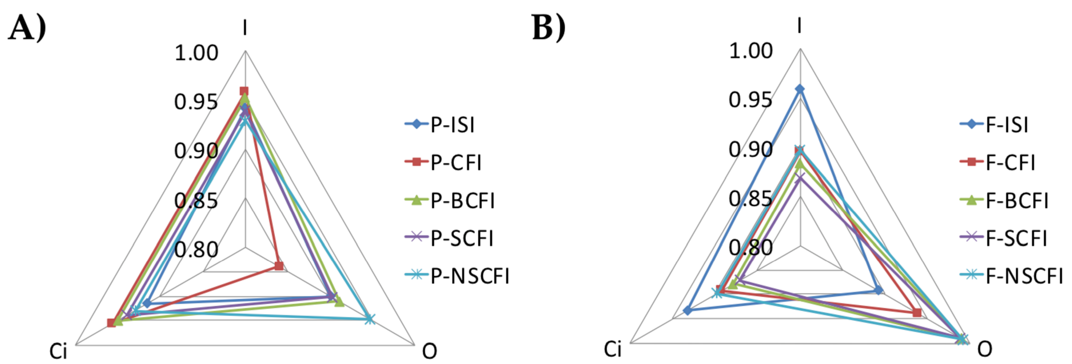

Figure 28. Responsiveness, agility, and leanness -model comparison of CC3. Innovation strategy and resource allocation index models A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

In the past timeframe the order of the innovation strategy was Inside-out > Coupled > Closed innovation > Outside-in in the ISI model, and Inside-out > Outside-in > Coupled > Closed innovation in the priority weight model (table 15).

The order of the innovation strategy types in the future timeframe ISI model was the same as in the past timeframe.

Table 15. Innovation strategy results of different models in CC3. The highest values in each model are marked in bold.

PAST TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	**0.9411**	0.9010	0.9159	0.9285
Priority weight	**0.9384**	0.9384	0.9231	0.9308
CFI	**0.9576**	0.8404	0.9561	0.9568
BCFI	**0.9523**	0.9109	0.9503	0.9513
SCFI	0.9380	0.9027	**0.9393**	0.9386
NSCFI	0.9288	**0.9471**	0.9295	0.9291
FUTURE TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	**0.9592**	0.8923	0.9324	0.9458
Priority weight	0.9275	**0.9397**	0.9078	0.9176
CFI	0.8955	**0.9379**	0.8920	0.8937
BCFI	0.8826	**0.9904**	0.8783	0.8804
SCFI	0.8685	**0.9882**	0.8711	0.8698
NSCFI	0.8966	**0.9912**	0.8975	0.8970

7.3.4. Sustainable competitive advantage

In the past timeframe the highest SCA values was achieved with the BCFI model and in the future timeframe with CFI model respectively (table 16). The highest values in the past timeframe were 0.9719 in MAPE, 0.9228 in RMSE, and 0.9860 in MAD. The highest values in the future timeframe were 0.8834 in MAPE, 0.9276 RMSE, and 0.9432 in MAD respectively.

Table 16. Sustainable competitive advantage values in CC3. The highest values in each model are marked in bold.

PAST TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.8908	0.9318	0.9460
BCFI	**0.9719**	**0.9828**	**0.9860**
SCFI	0.9713	0.9822	0.9857
NSCFI	0.9458	0.9631	0.9734
FUTURE TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	**0.8834**	**0.9276**	**0.9432**
BCFI	0.8075	0.8821	0.9061
SCFI	0.7966	0.8749	0.9009
NSCFI	0.8269	0.8933	0.9157

7.4. Case company 4

7.4.1. Resource allocation index

There were some fluctuations in the resource allocation values with isolated subattributes in case of CFI, BCFI, and SCFI models. In these models, the future values for the "D3: internal product development ideas" was almost 2.5 times of the determined upper limit value (figure 29). In other subattributes the fluctuations were high only in some specific cases. In general, the fluctuation was lowest in the NSCFI model. The resource allocation was under resourced in the subattributes "K2: cost of publications" and "D1: time used for basic research" in all of the resource allocation models. The trend between the past and the future timeframe was shown to be better in the subattributes "T5: use of high-quality contract research" and "K1: cost of core competence" in the NSCFI model. All the trends of the subattributes in the resource allocation models are described in Appendix 7.

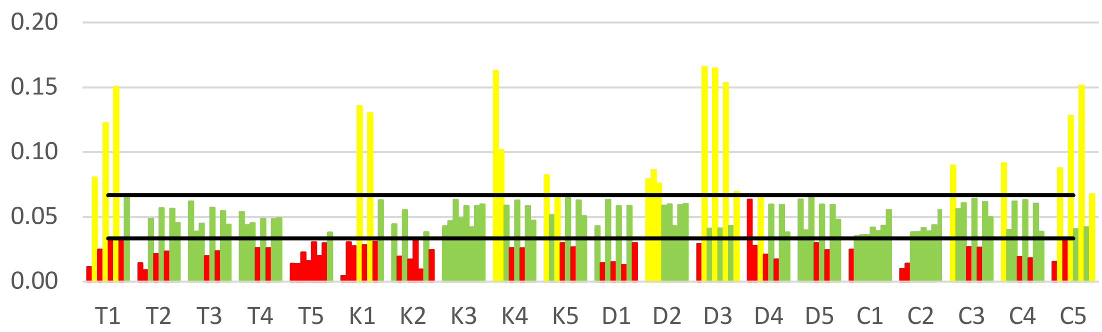

Figure 29. Resource allocation model results of CC4. The results for each subattribute from left to right are P-CFI, F-CFI, P- BCFI, F-BCFI, P-SCFI, F-SCFI, P-NSCFI, and F-NSCFI. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

The performance compared to competitors were evaluated to be the same among most of the attributes (table 17). Only the performance of the knowledge attribute values was evaluated to be better.

Table 17. The performance comparison to competitors in CC4. The highest values in different attributes are marked in bold.

Attributes	**Worse**	**Same**	**Better**
Technology	0	**1.00**	0
Knowledge	0	0.33	**0.67**
Development	0	**0.67**	0.33
Co-operation	0.33	**0.67**	0

7.4.2. Innovation strategy index

The distribution for the technology, knowledge, development, and co-operation in the past timeframe were 0.061, 0.356, 0.584, and 0.210 respectively. Accordingly, the distribution in in the future timeframe were 0.620, 0.284, 0.095, and 0.089 respectively (figure 30). The ICR for the past timeframe was 0.419 and for the future timeframe 0.030. The priority weight for the main attributes were 0.267, 0.200, 0.533, and 0.250 for the past timeframe, and 0.438, 0.250, 0.313, and 0.200 for the future timeframe respectively.

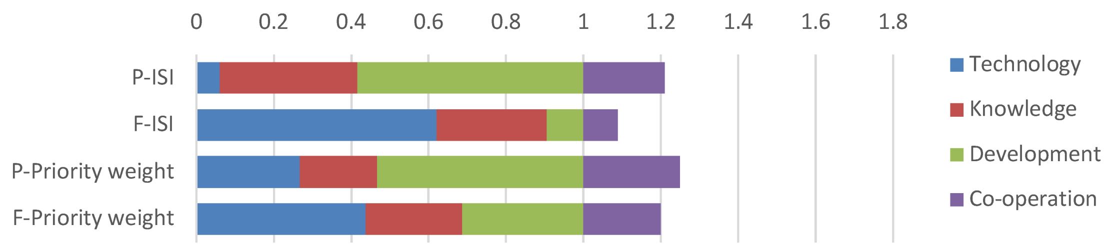

Figure 30. The main attribute distribution in the CC4.

The main attribute ISI model did not correlate with the priority weight values in neither of the timeframes (figure 30). The SD for the main attributes varied between 0.028 to 0.146 in the past, and from 0.024 to 0.146 in the future perspective.

7.4.3. Responsiveness agility, and leanness -model comparison

The main attribute ISI model results of the past and the future timeframe did not correlate in the RAL -model with the priority weight values derived from the AHP-questionnaire (figure 31). In the past timeframe the highest values in the innovation strategy was in the closed innovation strategy based on the ISI model and outside-in OI strategy based on the priority weight model. In the future timeframe the highest values were in the inside-out OI strategy based on the ISI model and outside-in OI strategy based on the priority weight model respectively.

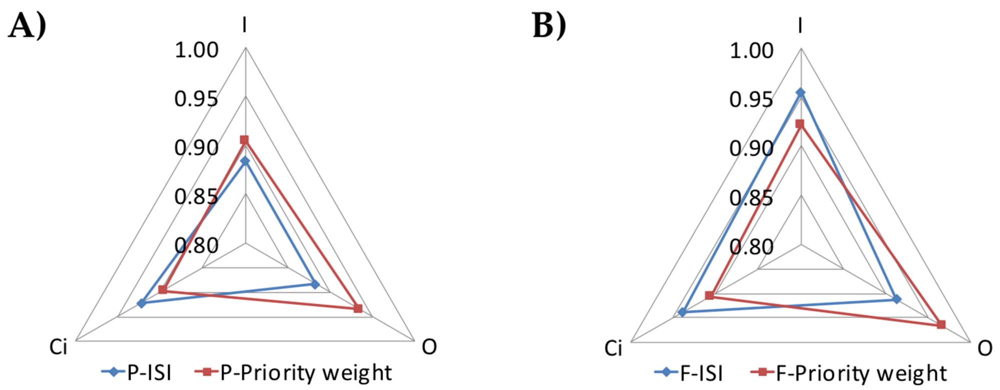

Figure 31. Innovation strategy index and priority comparison in CC4. Responsiveness, agility, and leanness -model A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent the closed innovation strategy.

From the RAI models the CFI and BCFI correlated best with the ISI model in the past timeframe. Accordingly, in the future timeframe the SCFI model correlated best with the ISI model (figure 32). The SCFI and NSCFI models were inconsistent with the ISI model and gave highest values to outside-in OI strategy in the past timeframe. In the future timeframe the highest value in the SCFI model was inside-out OI strategy. The other CFI and NSCFI models were consistent with each other, but neither of these models did not correlate with the ISI model.

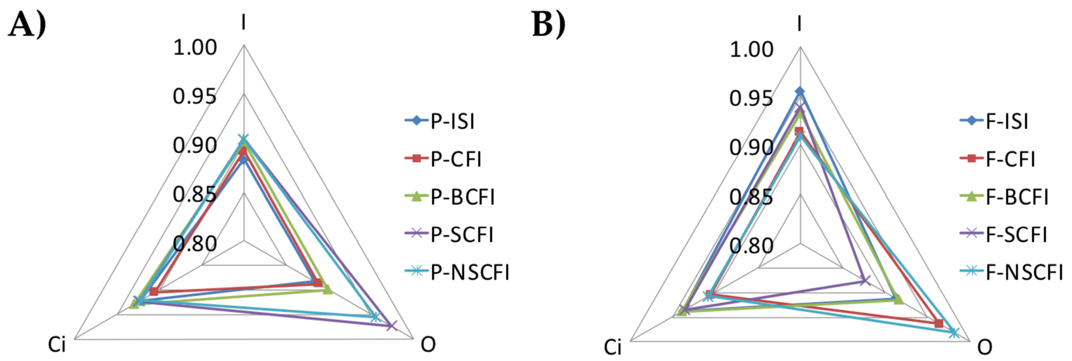

Figure 32. Responsiveness, agility, and leanness -model comparison of CC4. Innovation strategy and resource allocation index models A) in the past timeframe, and B) in the future timeframe. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

In the past timeframe the order of the innovation strategy was Closed innovation > Coupled > Inside-out > Outside-in in the ISI model, and Outside-in > Inside-out > Coupled > Closed innovation in the priority weight model (table 18). In the future timeframe the order of the innovation strategy was Inside-out > Coupled > Closed innovation > Outside-in in the ISI model, and Outside-in > Inside-out > Coupled > Closed innovation in the priority weight model.

Table 18. Innovation strategy results of different models in CC4. The highest values in each model are marked in bold.

PAST TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0.8836	0.8831	**0.9222**	0.9029
Priority weight	0.9043	**0.9345**	0.8966	0.9005
CFI	0.8922	0.8880	**0.9049**	0.8985
BCFI	0.9015	0.8993	**0.9295**	0.9155
SCFI	0.9042	**0.9738**	0.9236	0.9139
NSCFI	0.9038	**0.9554**	0.9220	0.9129
FUTURE TIMEFRAME				
	Inside-out	**Outside-in**	**Closed innovation**	**Coupled**
ISI	0**.9553**	0.9127	0.9383	0.9468
Priority weight	0.9215	**0.9665**	0.9057	0.9136
CFI	0.9135	**0.9636**	0.9051	0.9093
BCFI	0.9324	0.9153	**0.9396**	0.9360
SCFI	**0.9391**	0.8762	0.9356	0.9374
NSCFI	0.9093	**0.9821**	0.9078	0.9085

7.4.4. Sustainable competitive advantage

The highest SCA values was achieved with the BCFI model in both the past and the future timeframe (table 19). The highest values in the past timeframe were 0.9875 in MAPE, 0.9228 in RMSE, and 0.9860 in MAD. The highest values in the future timeframe were 0.9707 in MAPE, 0.9820 in RMSE, and 0.9852 in MAD respectively.

Table 19. Sustainable competitive advantage values in CC4. The highest values in each model are marked in bold.

PAST TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.9704	0.9816	0.9850
BCFI	**0.9875**	**0.9922**	**0.9936**
SCFI	0.9057	0.9410	0.9534
NSCFI	0.9254	0.9524	0.9632
FUTURE TIMEFRAME			
	MAPE	**RMSE**	**MAD**
CFI	0.8961	0.9365	0.9489
BCFI	**0.9707**	**0.9820**	**0.9852**
SCFI	0.9662	0.9778	0.9833
NSCFI	0.8743	0.9228	0.9382

8. ANALYSIS

This chapter analyse in depth the resource allocation and ISI results from the case companies used in this study. The results from each case company is validated by comparing the results to the WMT results obtained by interviewing the respondents. The name and information presented by the respondents are treated as confidential information and therefore they are not disclosed in this chapter. nor the list of reference.

8.1. Case company 1

8.1.1. Resource allocation

From the resource allocation point-of-view, the NSCFI model is the best model for innovation resource allocation analysis in small sample volumes. In this model the deviation of the answers between respondents has only a minor affect to the individual resource factor values (figure 33). The comparison among the past and the future timeframe SCA shows that the resource allocation follows the ISI model better in the future timeframe than in the past timeframe.

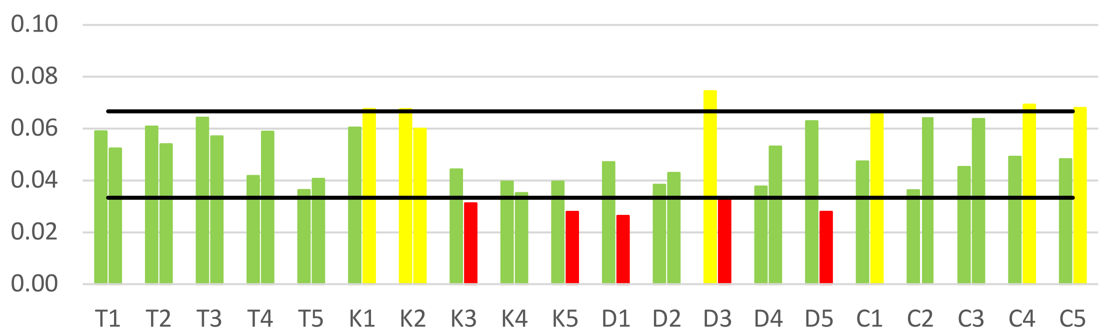

Figure 33. Normalized scaled critical factor index results of CC1. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

In the past timeframe all the values in different SCA models were below 0.79 and therefore not considered to be high. In the future timeframe most of the SCA model values were above 0.90, which makes the general risk level less than 10 %

in all of the future timeframe SCA models. This confirms that the resource allocation in general follows the case company's future innovation strategy well. However, no specific RAI model supports both of the ISI models in both timeframes simultaneously.

8.1.2. Innovation strategy

In the ISI model the past timeframe innovation strategy type is closed innovation as the individual values for different innovation types are highest in this case and significantly above the average value of different innovation types. the future timeframe the innovation strategy type is outside-in OI based on the ISI model as the individual values for different types are highest in this case as well and also above the average values of the innovation types (table 20).

Table 20. Innovation strategy type results of CC1.

	Past	**Future**
Inside-out	0.9293	0.9301
Outside-in	0.8473	0.9564
Closed innovation	0.9612	0.8955
Coupled	0.9453	0.9128
AVG	0.9208	0.9237
SD	0.0507	0.0260
CV-%	5.50 %	2.81 %
Area	1.0804	1.1167
ICR	0.031	0.004

The SD of the innovation strategy types are above 0.015, which implies that there is sufficient variation between the innovation types in the past timeframe. The coefficient of variation (CV-%) of 5.50 % further supports this fact. In In the future timeframe the SD of the innovation strategy types are also significantly above 0.015, which stands for the fact that there is sufficient variation between the innovation strategy types in this case as well. The CV-% in the case of the future timeframe is 2.81 % which is lower than in the past timeframe but still high enough to point out that there is one innovation strategy type that stands out from the other innovation strategy types. The ICR values are below 0.30 in both the past and the future timeframe ISI models, which confirms that the answers are reliable and supports the results to be used in decision-making process (c. Takala, Shylina, Forss & Malmi 2013: 65-75). The total innovation potential based on the triangle area in the past is 1.0804 and the total innovation potential in the future 1.1167. From the past and future triangle area is also possible to determine that the total innovation potential will grow 3.35 % from the past innovation experience to the future innovation expectation.

8.1.3. Weak market test

According to the WMT, the empirical experience of company's innovation strategy for the past timeframe have been closed innovation strategy based on the fact that the innovation resources have been mostly assigned to their own R&D. Accordingly, the expectations for the future timeframe innovation strategy of the company is outside-in OI strategy due to their ambition to seek in-organic growth from external technologies and innovations (figure 34).

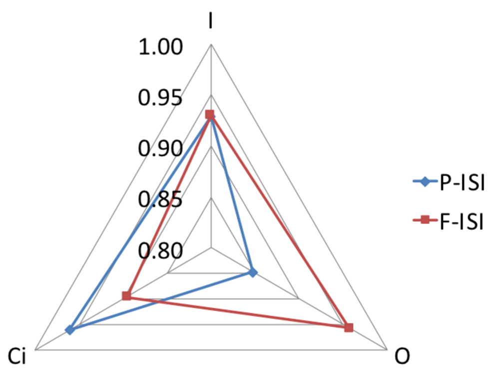

Figure 34. Innovation strategy index models of CC1. The past and the future timeframe innovation strategies in responsiveness, agility, and leanness -model. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

The case company also incorporates inside-out innovation type currently in the past and the future timeframe as well. However, this innovation strategy type is not considered as important as the closed innovation strategy in the past timeframe nor the outside-in innovation strategy in the future timeframe. Based on the WMT the past experience and the future expectations are well in line with the past and the future timeframe ISI model results.

8.2. Case company 2

8.2.1. Resource allocation

for the resource allocation, the NSCFI model is the best model for resource allocation analysis in small sample volumes in CC2 as well. In this model the deviation of the answers between respondents had also only a minor affect to the individual resource factor values (figure 35). The comparison among the past and the future timeframe SCA models shows that the resource allocation for the subattributes follows the ISI successfully in both timeframes.

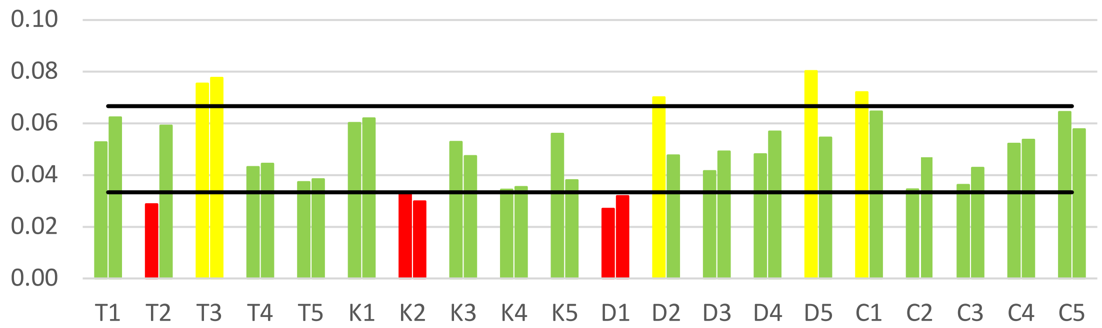

Figure 35. Normalized scaled critical factor index results of CC2. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

In both the past and the future timeframe all the SCA values were above 0.90, which makes the general risk level less than 10 % in all of the SCA values at both timeframes. This supports the fact that the resource allocation follows the case company's innovation strategy very well in both timeframes. However, no specific RAI model supports both of the ISI models in both timeframes simultaneously in the case of CC2 neither.

8.2.2. Innovation strategy

In the ISI model the past timeframe innovation strategy type is closed innovation as the individual innovation strategy values are highest in this case. However, the value for the coupled OI strategy is also relatively high compared to the closed innovation strategy value. The value for the closed innovation type is only slightly above the average values of the innovation types. In the future timeframe the innovation strategy type is outside-in OI strategy based on the ISI model as the individual values are highest in this case as well, and significantly above the average values of the innovation strategy types (table 21).

Table 21. Innovation strategy type results of CC2.

	Past	**Future**
Inside-out	0.8994	0.9068
Outside-in	0.8560	0.9637
Closed innovation	0.9082	0.8792
Coupled	0.9038	0.8930
AVG	0.8918	0.9107
SD	0.0242	0.0371
CV-%	2.71 %	4.07 %
Area	1.0236	1.0905
ICR	0.115	0.060

The SD of the innovation strategy types are above 0.015, which implies that there is sufficient variation between the innovation types in the past timeframe even though the CV-% of 2.71 % is only marginally elevated. In the future timeframe the SD of the innovation strategy types are also above 0.015, which supports that there is sufficient variation between the innovation strategy types in the future timeframe as well. In the future timeframe the CV-% is 4.07 %, which is high enough to draw the conclusion that there is only one model that stands out from the other innovation types. The ICR values are below 0.30 in the past and the future timeframe ISI models in case of CC2 as well. Therefore, it can be concluded that the answers in case of the CC2 are also reliable and supports the results to be used in the decision-making process (b. Takala et al 2013). The total innovation potential based on the triangle area in the past is 1.0236 and in the future 1.0905, which implies that the total innovation potential will grow 6.54 % from the past innovation experience to the future innovation expectation.

8.2.3. Weak market test

According to the WMT, the empirical experience of the company's innovation strategy for the past timeframe have been closed innovation strategy, because majority of the innovations have been done in-house in the company. Accordingly, the innovation strategy for the future timeframe innovation strategy is outside-in OI strategy due to the increasing plan to license products that can be sold to the case company's customers (figure 36).

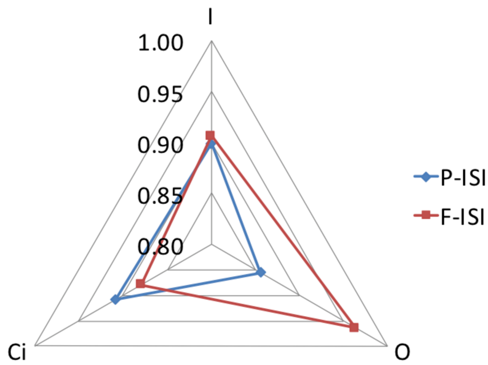

Figure 36. Innovation strategy index models of CC2. The past and the future timeframe innovation strategies in responsiveness, agility, and leanness -model. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

The coupled innovation strategy was raised up as a future innovation strategy, but during the interview these innovation operations turned out to be included to the outside-in innovation strategy type. This confusion was due to the misunderstanding of the descriptions of the different innovation strategy types. Based on the WMT test the past experience and the future expectations of the innovation strategy types are in line with the innovation strategy types of the past and the future timeframe ISI models.

8.3. Case company 3

8.3.1. Resource allocation

The NSCFI model is the best model for innovation resource allocation analysis in CC3 in small sample volumes as in the case of CC1 and CC2 as well. In this case the deviation of the answers between different respondents had only a minor affect to the individual resource factor values (figure 37). The comparison among the past and the future timeframe SCA shows that the resource allocation for the subattributes follows the ISI better in the past timeframe than in the future timeframe.

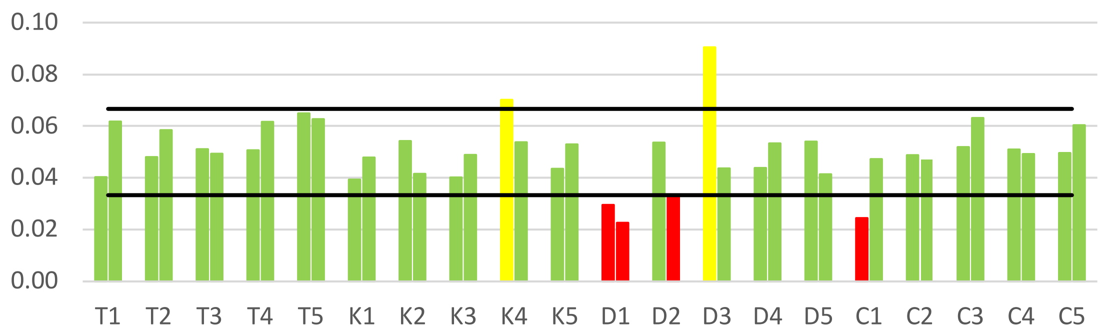

Figure 37. Normalized scaled critical factor index results of CC3. Red indicates that the subattribute is under resourced, yellow indicates that it is over re-sourced, and green indicates that it is in balance.

In the past timeframe almost all of the SCA values are above 0.90, which converts to the general risk level less than 10 % in all of the past timeframe SCA models. Accordingly, in the future timeframe majority of the SCA are below 0.90, which makes the general risk level more than 10 % in majority of the future timeframe SCA models respectively. This implies that there are issues around the case company's future innovation strategy. Additionally, no specific RAI model supports the future ISI model, which also supports the fact that there might be issues around the future innovation strategy in the case company.

8.3.2. Innovation strategy

In the ISI model the past timeframe innovation strategy type is inside-out OI strategy as the individual innovation strategy values are highest in this case and moderately above the average value of different innovation types. In the future timeframe the innovation strategy type is inside-out OI strategy, because the value of this innovation strategy is the highest and sufficiently above the average value of the innovation types (table 22).

Table 22. Innovation strategy type results of CC3.

	Past	**Future**
Inside-out	0.9411	0.9592
Outside-in	0.9010	0.8923
Closed innovation	0.9159	0.9324
Coupled	0.9285	0.9458
AVG	0.9216	0.9324
SD	0.0172	0.0289
CV-%	1.86 %	3.10 %
Area	1.0978	1.1182
ICR	0.156	0.111

The value for coupled OI strategy seems to be relatively high as well in the past timeframe. The SD of all the innovation strategy values was 0.0172, which is only slightly above the threshold of 0.015, but points out that there is variation between the innovation strategy types in the past timeframe. However, the CV-% of 1.86 % supports the coupled OI strategy as it implies that the dispersion around the values are low. In the future timeframe the SD of the innovation strategy types is even higher than in the past timeframe and significantly above the threshold of 0.015. This stands for higher variation between the innovation strategy types than in the case of the past timeframe. The CV-% in the case of the future timeframe is 3.10 %, which is also higher than in the past timeframe and supports the inside-out OI strategy type even further. The ICR values are also below the 0.30 in case of both the past and the future timeframes, from which it can be derived that the answers in case of CC3 are also reliable and they support the results to be used in the decision-making process (b. Takala et al 2013). The total innovation potential based on the triangle area in the past timeframe is 1.0978 and in the future timeframe 1.1182. Based on these, the innovation potential is expected to grow 1.19 % from the past innovation experience to the future innovation expectations.

8.3.3. Weak market test

In the WMT, the empirical experience of company's innovation strategy has been controversial based on the interviews. Majority of the answers points out that the innovation strategy in the past and the future timeframe has been coupled OI strategy (figure 38).

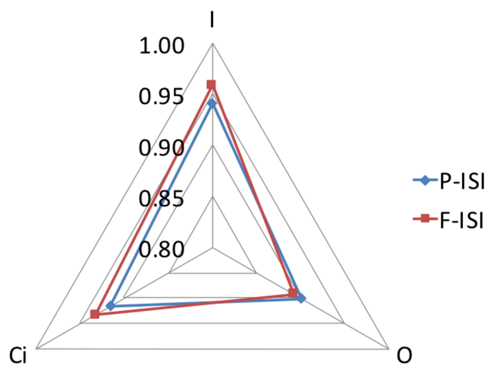

Figure 38. Innovation strategy index models of CC3. The past and the future timeframe innovation strategies in responsiveness, agility, and leanness -model. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

However, the closed innovation and the inside-out OI strategies was mentioned as well. The reason for the coupled OI strategy is that all the three strategies: inside-out, outside-in, and coupled OI strategies are in place in the CC3. According to the case company, their strategy comprises of acquiring other companies and external technologies. For this purpose, they have dedicated business development personnel and channels for seeking interesting targets. Crowdsourcing also helps the company to back up their idea gathering process and diffusion to a market. Additionally, they have separate funding model for those ideas that does not directly belong to under the funding of any current business development project. They also do strategic co-operation agreements with SMEs and they have sold in the past some of their operations, which do not fit into their future vision of the business.

As the CC3 operates on wider scale of OI strategy landscape, it is hard to determine the priority innovation strategy for the company based on the ISI model. However, based on WMT the result of the ISI model and pattern of both the past and the future RAL -model triangles cannot be excluded either (figure 38). Because of this, it can be determined based on the WMT that the past experience and future expectations are in line with the innovation strategy types in both the past and the future timeframe ISI models.

8.4. Case company 4

8.4.1. Resource allocation

The NSCFI model is the best model for innovation resource allocation analysis in small sample volumes as in the other case companies. The deviation of the answers between different respondents had only minor affect to the individual resource factor values (figure 39). The comparison among the past and the future timeframe SCA shows that the resource allocation for the subattributes follows the ISI better in the past timeframe than in the future timeframe.

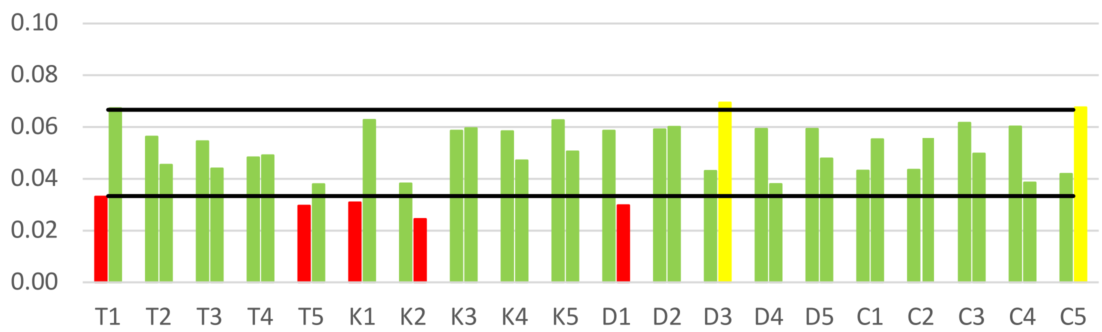

Figure 39. Normalized scaled critical factor index results of CC4. Red indicates that the subattribute is under resourced, yellow indicates that it is over resourced, and green indicates that it is in balance.

In the past timeframe all of the SCA values are above 0.90 and the highest one almost 1. Therefore, it can be concluded that the general risk is significantly less than 10 % in all of the past timeframe SCA models. In the future timeframe the SCA values are also good and above the 0.90, which also implies that the risk is similarly less than 10 %. Additionally, no specific RAI model supports both of the ISI models in both timeframes simultaneously in the case of CC4 neither.

8.4.2. Innovation strategy

In the ISI model the past timeframe innovation strategy type is closed innovation strategy as the individual innovation strategy values are highest in this case and sufficiently above the average value of different innovation types. In the future timeframe the highest value for the innovation strategy type is in the inside-out OI strategy, but the closed innovation strategy and coupled innovation strategy are relatively high as well and over the average value of the innovation strategies (table 23). The SD was 0.0186, which is above the threshold of 0.015, and implies that there is sufficient variation between the innovation types in the past timeframe. Additionally, the CV-% of 2.08 % also supports that closed innovation type comes to prominence from the other innovation types. the SD for the future timeframe is 0.0184 and. The CV-% in the future timeframe, however, is 1.96 % which supports the coupled innovation strategy type is the most prevalent.

Table 23. Innovation strategy type results of CC4.

	Past	**Future**
Inside-out	0.8836	0.9553
Outside-in	0.8831	0.9127
Closed innovation	0.9222	0.9383
Coupled	0.9029	0.9468
AVG	0.8980	0.9382
SD	0.0186	0.0184
CV-%	2.08 %	1.96 %
Area	1.0434	1.1364
ICR	0.419	0.030

The ICR values of the past timeframe was above the threshold of 0.30, but below the threshold in the future timeframe. Therefore, the past timeframe results need to be treated with caution and the inconsistency of the answers needs to be taken into account. However, the ICR value of future timeframe is ten-fold below the threshold and supports the results to be used in the decision-making process (b. Takala et al 2013). The total innovation potential based on the triangle area in the past timeframe is 1.0434 and in the future timeframe 1.1364. Based on these values, the total innovation potential is expected to grow 8.92 % from the past innovation experience to the future innovation expectations.

8.4.3. Weak market test

In the WMT, the empirical experience of company's innovation strategy has been closed innovation strategy with exception of few external suppliers. However, at the moment the company is in a situation where it moves forward to coupled OI strategy by forming closer relationships with their business partners. Nevertheless, based on the WMT test results the past experience and the future expectations of the innovation strategy types are in line with the innovation strategy types derived from the past and future timeframe ISI models despite of the high ICR-value from the past timeframe ISI results (figure 40).

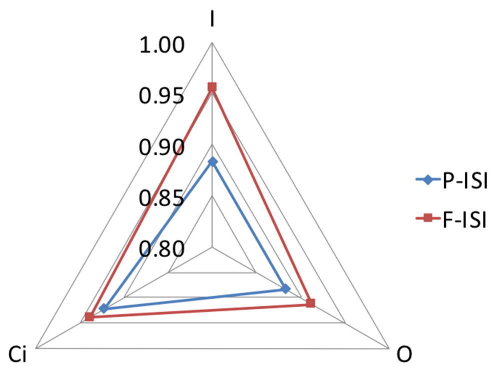

Figure 40. Innovation strategy index models of CC4. The past and the future timeframe innovation strategies in responsiveness, agility, and leanness -model. The *I* represent inside-out open innovation strategy, the *O* represent outside-in open innovation strategy, and the *Ci* represent Closed innovation strategy.

9. DISCUSSION

From the four resource allocation models, the NSCFI model seems to work the best in resource allocation purposes because it has the lowest fluctuation due to the minor differences in the answers in the small sample volumes. However, the model does not seem to support the ISI model derived from the AHP-questionnaire. According to the results of this study, there are no single RAI model that would fit the ISI model in all of the four case companies in both the past and the future timeframe simultaneously. This can also be confirmed by the SCA values of MAPE, RMSE, and MAD, as in all of the case companies the highest SCA values are determined for different RAI models.

Based on the results from the case companies, the ISI model correlates well with the past and the future innovation status. However, the coupled OI strategy is problematic as it usually includes many types of OI strategies beneath it as described in chapter 3.2. This means that the coupled OI strategy needs to be determined based on other specifications as well in addition to the individual innovation strategy type values.

10. CONCLUSIONS

Based on the results of this study there are no correlation between the RAI models derived from the resource allocation values and innovation strategy determined from the ISI model (RQ1). None of the specific RAI models individually support the ISI model based on the SCA. However, it is possible to evaluate the SCA based on the concurrence of all the four RAI and SCA models (RQ2). The past and the future ISI models did correlate with the WMT in all of the companies evaluated (RQ3). The results in the past and the future timeframe ISI were substantially different when compared to results obtained by Chesbrough & Brunswicker (2013) in their OI survey, at least in the case of CC3 and CC4.

In the survey performed by Chesbrough and Brunwicker (2013) for the medium-high-technology and the high-technology industry MNEs, more than 82 % of these companies claimed to have been practicing OI in late 2012. In addition, on average 78 % of the respondents in that survey across industries claimed to have been practising OI by the end of 2012 (Chesbrough & Brunswicker 2013: 2-8). Accordingly, Lichtenthaler et al (2011) identified a group companies which absorb external technologies without transferring their own technologies to external parties. A pharmaceutical company that relies on outside-in OI and collaboration with other pharmaceutical and biotechnology companies was given as an example of this group. Within this group, the companies pursue also quite open inside-out OI strategy, but the implementation of this strategy is impeded by the NSH tendencies (Lichtenthaler et al 2011). The results from this specific study on the other hand correlates well with the results obtained in this study.

In knowledge-intensive industries, as biotechnology and pharmaceutical industry, OI seems to have demand in out-licensing and in-licensing business model to expand the current business opportunities and revenue of the companies. However, in this study, like described by Gassman & Enkel (2004) the inside-out OI strategy seems to play minor role compared to the outside-in OI strategy. This may be due to the lack of sufficient market place for this kind of transactions and because of the low capacity of venture capital compared to the other Nordic and European Economic Area (EAA).

Another important factor to the results can be the strategic use of IPR, which according to Brem et al (2017) can have a negative effect to the revenue in SMEs that are engaging in OI operations. This can have affect to the use of inside-out OI strategy as it needs extensive use of internal IPR of the companies which also has relatively high transaction costs in case of SMEs and limits its use in the inside-out OI operations of the companies (Bogers, Bekkers & Grandstrand 2012: 37-58).

Despite the fact that OI will definitely make innovation more efficient in companies, it will also make innovation management more complex as well. Policy makers and science hubs plays an important role for providing a market place for inside-out and outside-in OI strategies. These hubs can work as a platform for coupled OI strategy as well. This progress has already taken place in EEA under the Horizon 2020 program for research and innovation that uses Open innovation 2.0 paradigm approach. Previous research has also discovered that companies can choose one primary OI strategy, but also integrate some elements from other core OI strategies as well (Gassman & Enkel 2004). It has been shown that this study enables holistic measurement of innovation performance in companies using OI processes. It also provides tools for executives to evaluate the company's current and future emphasis of innovation and its management.

The limitation of this study is that the developed model uses only four different innovation strategy types. Although, the closed innovation, inside-out, outside-in, and coupled OI strategies represent the most recognized strategy types of OI, it leaves a lot room for interpretation for other subtypes of innovation, such as UI, RI, and DI. In addition, the AHP method was experienced as laborious to fill in context of the ICR, which was turn-out to be critical for the validity of the results. Nevertheless, the analytical side of this research can be considered as a good start for further research with more extensive group of research subjects.

10.1. Future research

In the future, this novel method to evaluate the front-end innovation strategy should be validated in companies from various industries as well, such as medium-high-technology, medium-low-technology, and low-technology manufacturing industries, ICT and other service industries, FMCG industry, and NGOs. The S-SMT and SMT should be used in addition to the WMT to further validate the method. Although the innovation strategy of the companies is based on the attributes measured with the analytical model, it does not mean that other innovation types are not present in the case companies analysed. In most cases all the types of innovation strategies exist in the company's innovation strategy, but they are hard to detect and evaluate.

The way how secondary innovation strategy types affect to the overall innovation needs to be resolved and determined. This relationship should be evaluated in the future studies as well, as it might have substantial impact to the way how companies exploit the major innovation strategies in their innovation process. One approach to this would be to utilize the subattributes, that was used in the S&R-questionnaire, in the AHP-questionnaire as well. However, the limitations of this approach need to be considered as it can turn out to be too laborious to use, which will affect to the managerial implications of the model.

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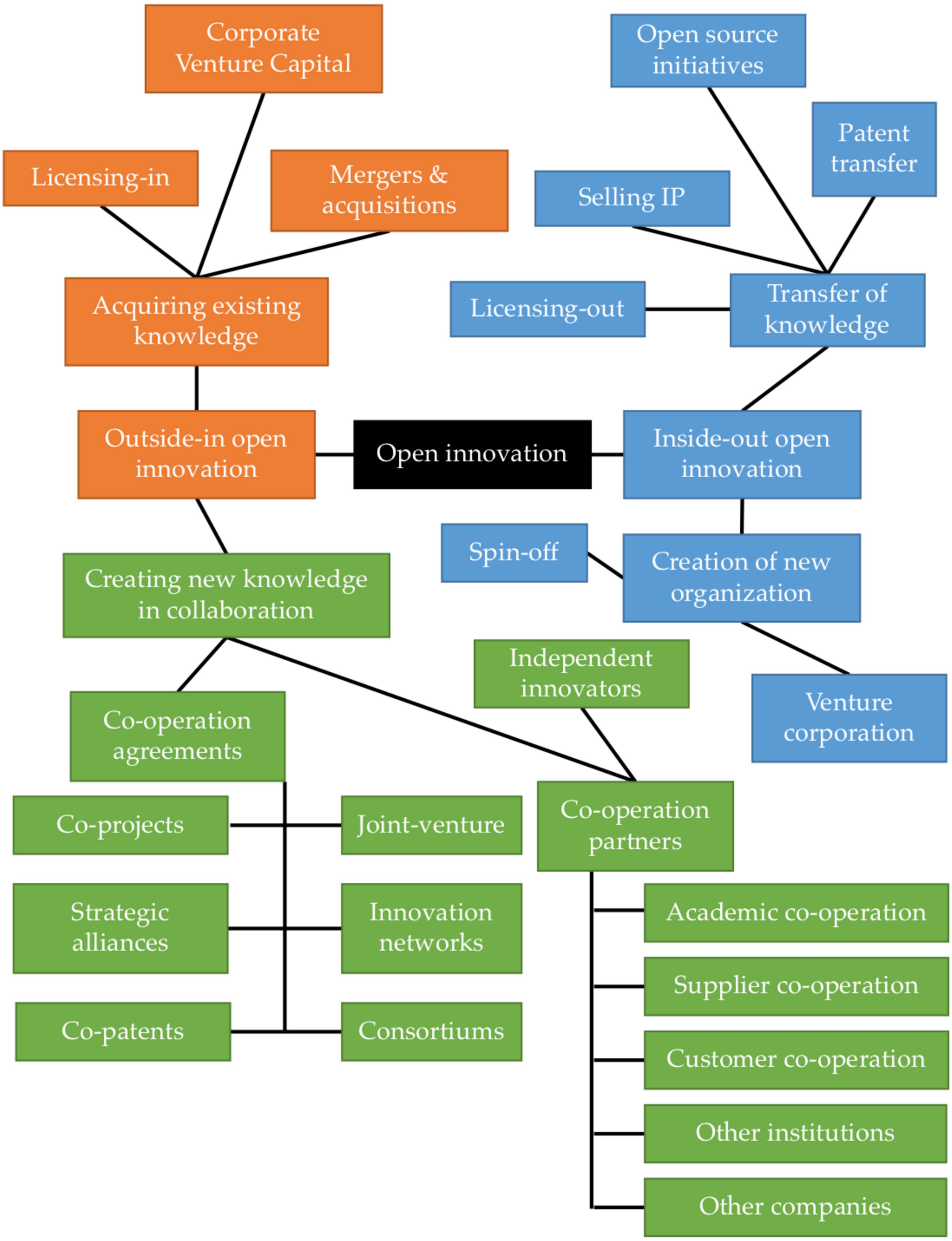
APPENDIX 1. Mechanisms of open innovation (Adapted from Torkkeli et al 2007).



APPENDIX 2. Sense and respond questionnaire used in open innovation case study.

Attributes	Current experience	Future expectations	Experience of how important the attribute has been in the past 3-5 years?			Expectations of how important the attribute will be in the next 3-5 years?			How the attribute is performing compared with competitors?		
	(1-10)	(1-10)	worse	same	better	worse	same	better	worse	same	better
RESOURCE INPUTS IN MULTI CRITERIA OPEN INNOVATION STRATEGY											
Technology											
Knowledge											
Development											
Co-operation											
RESOURCE INPUTS IN OPTIMIZING TECHNOLOGY COMPETENCE											
1.1. Use of leading-edge technology											
1.2. Use of external technology											
1.3. Use of external product development ideas											
1.4. Use of external intellectual property											
1.5. Use of high-quality contract research											
RESOURCE INPUTS IN OPTIMIZING KNOWLEDGE COMPETENCE											
2.1. Cost of core competence											
2.2. Cost of publications											
2.3. Cost of intellectual property											
2.4. Cost for attending to alternative markets											
2.5. Value of own intellectual property											
RESOURCE INPUTS IN OPTIMIZING DEVELOPMENT COMPETENCE											
3.1. Time used for basic research											
3.2. Control of own intellectual property											
3.3. Internal new product development ideas											
3.4. Timing in current market											
3.5. Own research & development											
RESOURCE INPUTS IN OPTIMIZING CO-OPERATION COMPETENCE											
4.1. Business model management											
4.2. Venture management											
4.3. Outsourcing management											
4.4. Involvement in other markets											
4.5. Collaboration management											

APPENDIX 3. Analytical hierarchy process questionnaire used in open innovation case study.

Main open innovation strategy priority weights

	Technology %	**Knowledge %**	**Development %**	**Co-operation %**
Past 3-5 years	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.
Future 3-5 years	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.	Click or tap here to enter text.

Past pairwise comparison of the open innovation main criteria

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Development	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation

Future pairwise comparison of the open innovation main criteria

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Knowledge	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Development
Technology	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation
Development	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Co-operation

APPENDIX 4. Trend between past and future values of CFI, BCFI, SCFI, and NSCFI models in CC1.

Subattribute	**CFI**	**BCFI**	**SCFI**	**NSCFI**
T1: use of leading-edge technology	WORSE	WORSE	WORSE	SAME
T2: use of external technology	BETTER	WORSE	WORSE	SAME
T3: use of external product development ideas	BETTER	WORSE	BETTER	SAME
T4: use of external intellectual property	WORSE	BETTER	WORSE	SAME
T5: use of high-quality contract research	BETTER	WORSE	WORSE	SAME
K1: cost of core competence	WORSE	WORSE	WORSE	WORSE
K2: cost of publications	BETTER	WORSE	BETTER	BETTER
K3: cost of intellectual property	WORSE	WORSE	WORSE	WORSE
K4: cost for attending to alternative markets	WORSE	WORSE	WORSE	SAME
K5: value of own intellectual property	WORSE	WORSE	WORSE	WORSE
D1: time used for basic research	WORSE	BETTER	WORSE	WORSE
D2: control of own intellectual property	WORSE	WORSE	WORSE	SAME
D3: internal product development ideas	WORSE	BETTER	BETTER	BETTER
D4: timing in current market	WORSE	WORSE	WORSE	SAME
D5: own research & development	WORSE	BETTER	BETTER	WORSE
C1: business model management	WORSE	BETTER	WORSE	WORSE
C2: venture management	WORSE	BETTER	BETTER	SAME
C3: outsourcing management	WORSE	BETTER	WORSE	SAME
C4: expertise in other markets	SAME	BETTER	WORSE	WORSE
C5 collaboration management	WORSE	BETTER	WORSE	WORSE

APPENDIX 5. Trend between past and future values of CFI, BCFI, SCFI, and NSCFI models in CC2.

Subattribute	**CFI**	**BCFI**	**SCFI**	**NSCFI**
T1: use of leading-edge technology	WORSE	WORSE	WORSE	SAME
T2: use of external technology	BETTER	BETTER	BETTER	BETTER
T3: use of external product development ideas	WORSE	WORSE	WORSE	WORSE
T4: use of external intellectual property	SAME	SAME	WORSE	SAME
T5: use of high-quality contract research	SAME	WORSE	WORSE	SAME
K1: cost of core competence	WORSE	SAME	SAME	SAME
K2: cost of publications	BETTER	WORSE	WORSE	WORSE
K3: cost of intellectual property	WORSE	SAME	SAME	SAME
K4: cost for attending to alternative markets	BETTER	SAME	WORSE	SAME
K5: value of own intellectual property	BETTER	BETTER	BETTER	SAME
D1: time used for basic research	SAME	WORSE	WORSE	BETTER
D2: control of own intellectual property	WORSE	BETTER	BETTER	BETTER
D3: internal product development ideas	SAME	SAME	SAME	SAME
D4: timing in current market	BETTER	SAME	WORSE	SAME
D5: own research & development	WORSE	BETTER	BETTER	BETTER
C1: business model management	WORSE	SAME	BETTER	BETTER
C2: venture management	WORSE	SAME	BETTER	SAME
C3: outsourcing management	SAME	SAME	WORSE	SAME
C4: expertise in other markets	BETTER	SAME	SAME	SAME
C5 collaboration management	WORSE	SAME	BETTER	SAME

APPENDIX 6. Trend between past and future values of CFI, BCFI, SCFI, and NSCFI models in CC3.

Subattribute	**CFI**	**BCFI**	**SCFI**	**NSCFI**
T1: use of leading-edge technology	BETTER	WORSE	WORSE	SAME
T2: use of external technology	BETTER	WORSE	WORSE	SAME
T3: use of external product development ideas	WORSE	WORSE	WORSE	SAME
T4: use of external intellectual property	BETTER	WORSE	WORSE	SAME
T5: use of high-quality contract research	WORSE	WORSE	WORSE	SAME
K1: cost of core competence	BETTER	WORSE	WORSE	SAME
K2: cost of publications	BETTER	WORSE	WORSE	SAME
K3: cost of intellectual property	BETTER	WORSE	WORSE	SAME
K4: cost for attending to alternative markets	BETTER	BETTER	BETTER	BETTER
K5: value of own intellectual property	BETTER	SAME	WORSE	SAME
D1: time used for basic research	BETTER	WORSE	WORSE	WORSE
D2: control of own intellectual property	WORSE	WORSE	WORSE	WORSE
D3: internal product development ideas	BETTER	BETTER	BETTER	BETTER
D4: timing in current market	BETTER	WORSE	WORSE	SAME
D5: own research & development	WORSE	BETTER	WORSE	SAME
C1: business model management	BETTER	BETTER	BETTER	BETTER
C2: venture management	BETTER	WORSE	WORSE	SAME
C3: outsourcing management	BETTER	WORSE	WORSE	SAME
C4: expertise in other markets	WORSE	SAME	WORSE	SAME
C5 collaboration management	BETTER	WORSE	WORSE	SAME

APPENDIX 7. Trend between past and future values of CFI, BCFI, SCFI, and NSCFI models in CC4.

Subattribute	**CFI**	**BCFI**	**SCFI**	**NSCFI**
T1: use of leading-edge technology	BETTER	BETTER	BETTER	BETTER
T2: use of external technology	WORSE	WORSE	WORSE	SAME
T3: use of external product development ideas	SAME	WORSE	WORSE	SAME
T4: use of external intellectual property	SAME	WORSE	WORSE	SAME
T5: use of high-quality contract research	WORSE	WORSE	WORSE	BETTER
K1: cost of core competence	BETTER	BETTER	BETTER	BETTER
K2: cost of publications	WORSE	WORSE	WORSE	WORSE
K3: cost of intellectual property	SAME	SAME	SAME	SAME
K4: cost for attending to alternative markets	BETTER	BETTER	BETTER	SAME
K5: value of own intellectual property	BETTER	BETTER	WORSE	SAME
D1: time used for basic research	WORSE	WORSE	WORSE	WORSE
D2: control of own intellectual property	WORSE	BETTER	SAME	SAME
D3: internal product development ideas	BETTER	WORSE	WORSE	WORSE
D4: timing in current market	WORSE	BETTER	WORSE	SAME
D5: own research & development	SAME	BETTER	WORSE	SAME
C1: business model management	BETTER	SAME	SAME	SAME
C2: venture management	BETTER	SAME	SAME	SAME
C3: outsourcing management	BETTER	WORSE	WORSE	SAME
C4: expertise in other markets	BETTER	WORSE	WORSE	SAME
C5 collaboration management	BETTER	BETTER	WORSE	WORSE