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Creating a framework for effective Innovation Project Portfolio Management

An integrated framework for selecting the right innovation projects

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Master Thesis Project

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''The whole is greater than the sum of the parts''
Aristotle, 350 B.C.

Key words: Innovation Project Portfolio Management framework (IPPM), Inter-organizational innovation activities, effective IPPM, integrated framework for effective IPPM.

Executive Summary

Most firms have more ideas for innovation projects than the R&D budget can support. On top of that, the industry of firm-X is characterized with long development cycles and expensive full scale testing. Therefore, it takes these firms a long time to actually see effects in form of the returns on their investments. Selecting the right innovation projects becomes very important for the long term survival of these firms. Innovation Project Portfolio Management (IPPM) has the potential to bring considerable benefits to structure the Innovation Project Portfolio (IPP) of these organizations, being a mindset where portfolio thinking is central. However many tools used for IPPM are based upon unreliable information or implicit judgment reducing the effectiveness. The design of an integrated and effective IPPM framework and understanding the factors that affect this framework are central in this research.

This thesis describes the design of such an IPPM framework for the industry of firm-X, which is based on firm-X. It has been investigated at firm-X how the following aspects affect the IPPM decision making process: long term, top-down/bottom-up innovation approach, technological push & pull, formality of IPPM approach, and inter-organizational innovation activities. These aspects are important because they are affected by the choices made in the IPPM decision making process. Especially the collaboration of inter-organizational innovation activities can increase the value of R&D and also increase the performance of the current IPP.

To conduct this research first of all a literature study was undertaken to understand the concepts related to IPPM and investigate contemporary tools for IPPM. Next, the current framework at firm-X is assessed by analyzing internal documents and conducting open interviews. Thirdly semi-structured interviews have been executed in two rounds with respectively 13 and 5 respondents from firm-X to find out how the aspects central in this study affect the IPPM decision making process. Finally, the results of the preceding are used to design an integrated and effective IPPM framework.

The results show that top down/bottom-up innovation approach, a long term focus, and technology push & pull can be integrated in the framework. The interviews show in contrast to the theory that not all innovation projects should be aligned with the strategy, in particular innovation projects that are radical and young need to be given space to develop. The reason why this is done, is because it is often difficult to assess whether these innovation projects fit the strategy.

The literature study and the research conducted at firm-X leads to a set of requirements for the new framework. The general framework consists of four steps, 1) measuring the current IPP state, 2) indicating the desired IPP state, 3) comparing the two states, 4) use the outcome of step three to adjust the current IPP state to approach the desired IPP state. This framework will help to reduce implicit judgment in the decision making process and will create a more systematic approach to select the right innovation projects. This integrated approach should lead to achieving the three goals of effective IPPM: strategy alignment, value maximization and creating balance IPP. The four steps of the general framework just discussed are transformed into a framework that is applicable at firm-X is based on a strategic bucket approach, technology roadmapping, and expected commercial value (ECV) calculations. Traditionally the strategic bucket approach is used to divide the R&D budget over

one set of buckets. In the new framework the strategic bucket approach is operationalized by dividing R&D over multiple sets of buckets. This is done by dividing the R&D budget over four sets characteristics of innovation: 1) Technology Readiness Levels (TRL's), 2) parts of the value chain, 3) product groups and 4) key technologies. These four characteristics lead to four sets of independent strategic buckets that indicate the current IPP state. The desired state of the R&D budget over the different TRL's and parts of the value chain were indicated in interviews (with firm-X employees), therefore allowing an easy comparison of the current and the desired IPP state. The desired state of the Product Groups (PG) and Key Technologies (KT) is dependent on both the business environment and strategy. An ECV calculation of all the future products (indicated in the technology roadmap) will indicate the importance of each PG and KT for the future of firm-X, which can be seen as an indication of the desired state for the PG and KT.

This approach enables that the four innovation characteristics of the framework can be balanced at the same time. Also, technology roadmaps that show development logic limit the number of IPP combinations. The aforementioned method in turn helps in choosing a specific path for selection of innovation projects that match the four desired states of TRL, parts of the value chain, PG and KT. It is due to these characteristics that the effect of inter-organizational innovation activities can easily be incorporated to see its effect on the current IPP state.

Finally during the thesis also the supporting tools have been developed for the framework, meaning that an excel basis has been developed where all the innovation projects can be summarized and then automatically the graphs of the four characteristics for the current and desired IPP state are created. Also a program has been written in the matlab environment that can read the excel file and then produces the technology roadmaps. In this way the new IPPM framework can be supported, increasing the speed and the creation of the evidence based decision making process in IPPM.

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TU Delft

List of Abbreviations

Commonly used abbreviations, listed further in the report, are clarified below.

Assy	Assembly
BL	Business Lines
DEF	Defense
DM	Decision Making
ECV	Expected Commercial Value
F	Fuselages
Firm-X	The firm in which this thesis project has been executed
FML	Fiber Metal Laminate (key technology of firm-X)
FMLC	Fiber Metal Laminate Centre (Research institute)
IPP	Innovation Project Portfolio
IPPM	Innovation Project Portfolio Management
KBE	Knowledge Based Engineering
KT	Key Technology
KTM	key Technology Manager
Firm-Y	sister firm of firm-X that is also managed by firm-X
MB	Metal Bonding (key technology of firm-X)
MT	Management Team (of firm-X)
M2I	Materials to Innovate (Research Institute)
M&D	Movables & Doors (product group of firm-X)
NPD	New Product Development
NRC	Non Recurring Cost
OEM	Original Equipment Manufacturer
PG	Product Group
PGM	Product Group Manager
PPM	Project Portfolio Management
R..	Requirement (followed by the number)
RC	Recurring Cost
RFP/RFQ	Request for Proposal / Request for Quote
R&D	Research & Development
SCM	Supply Chain Management
SP	Special Products
TO	Technology Office (internal department of firm-X)
TP	Thermoplast (key technology of firm-X)
TPRC	Thermo Plastic Research Centre (Research Institute)
TRL	Technology Readiness Level
TRM	Technology Road Map
TS	Thermoset (key technology of firm-X)
TSC /TSG	Technology Steering Committee / Group (internal department of firm-X)
T&M	Tools & Methods (internal department of firm-X)
T&W	Tails & Wings (product group of firm-X)

Preface / Acknowledgements

As a result of the past six months of work, I am able to deliver the master thesis report for the master Management of Technology (MoT) of Technical University Delft. It has always been my goal to combine the thesis of MoT with a challenging internship. The opportunity for the internship came unexpectedly from firm-X, for which I would like to thank Sidney Stokkers who connected me to the right person in this firm.

During this five months internship I have worked together with Anindia Rahmiwati who also did her master thesis in a related topic. Together we managed to face our problems and also worked together occasionally to get our results. It has been a good time and we have also become good friends during this thesis period.

In addition, I would also like to thank some people for the help with this thesis. First of all I would like to thank my supervisor at firm-X, for his never ending enthusiasm is a great motivator and he has helped me well in answering all my questions and providing information where he could. Likewise, I would like to thank my first supervisor Erik den Hartigh who has been a great supervisor even though he lives in Turkey and welcomed his newborn son during this period, he always made sure he was available if necessary and gave good remarks. Moreover, I would like to thank my second supervisor Haiko van der Voort, though we didn't met often he gave some good remarks that have improved the report. Likewise, I would like to give a special thanks to Linda Kester (assistant professor NPD at the faculty Industrial Design of the TU Delft). Her research is related to what I have done and I have used a part of her model. Even though she wasn't officially my supervisor we did met a few times and she helped me very well in benchmarking my thoughts and in validating my model. Also, I would like to thank all the respondent (from firm-X) of the interviews for their time and effort, which helped me understand a vital part of my thesis.

Last but not least, I would like to thank my family and friends who have been supporting me for the past six months and have not seen me as often as they would like to.

When I look back at this semester, I find it has been an interesting but challenging time. In the beginning it was quite challenging to align demands from firm-X with those from the TU Delft but after a while it worked out just fine. At firm-X I received a great opportunity not only to see this firm from the inside, but also had the opportunity to work with so many experienced people.

Chapter 1 Introduction

The industry of firm-X is characterized by long development phases and high investments. Due to these characteristics, it takes quite a long time before these companies can see returns on their investments. Also currently more competitors are entering the market and so competition is increasing, therefore these companies need ways to secure their future revenues. One way to do so is by innovation. For today's high tech business innovation is essential in order to stay competitive and successful (Drucker, 1999). The increasing complexities of technologies in addition to shortened product life cycles are also forcing firms to rely on R&D as a source of strategy (Mikkola, 2000). But most firms have more ideas for innovation projects than there R&D budget can support. Therefore, due to this reason and the aforementioned mechanisms shows that it is important that in the future, these firms are able to select the right innovation projects.

This report describes the subject of Innovation Project Portfolio Management (IPPM) framework design in order to link innovation with the strategy. The research took place in firm-X located in the Netherlands. Firm-X is an innovative specialist that designs, develops and produces structures and electrical systems for OEM's. At firm-X two interesting phenomena were observed: firstly, firm-X currently has a broad portfolio of products and technologies and secondly, firm-X also has a set of R&D projects. This would leads to two questions: what should be improved is a clear relationship between the vision / missions and the future products to be offered to current and new customers, and what are the technologies that need to be developed. Ideally, the innovation project portfolio (IPP) balances the future revenues, the risks and the efforts for the development. It also gives directions to the Management Team to decide on innovation budgets and it sets targets for the internal and external R&D communities.

1.1 Research Problem / Previous Research

To stay successful in the long term firms constantly need to innovate and stay ahead of the competition. Innovation is an inherent unstructured process, (Drucker, 1985) states that ''the orderly and predictable decisions on which a business rests, depend increasingly on the disorderly and unpredictable process of innovation''. Also these days many firms with multiple innovation projects evaluate their technologies from a portfolio's perspective in which a set or a subset of R&D projects is evaluated together, in relation to each other (Mikkola, 2000). With almost universally limited R&D budgets and large numbers of potential projects that could be pursued, the ability to consistently select optimal project to fund is vitally important (Coldrick, Lawson, & Ivey, 2002).Therefore effective IPPM is paramount for long term success.

According to (Barczak, Griffin, & Kahn, 2009); a total of 69% of firms report the use of a formal, cross-functional process for IPPM in 2004 (which has been an increase of 9% since 1995). Here, 15% percent of the firms indicate that they have an informal approach and only 6 percent indicates no process at all. This result indicates that firms want a more systematic approach to organize their innovation process. Firm-X as many other firms today have a limited R&D budget, but in order to still prepare for the long term success this R&D budget should be used most effectively. As stated in the introduction, firm-X wants to improve the relationship between vision / mission and product / developments today to use the R&D budget effectively. The way firm-X wants to do this, is by introducing a more systematic approach for managing the Innovation Project Portfolio (IPP) through aligning the portfolio more to strategy, balancing the portfolio, maximizing the value and managing the entire portfolio as one. Many tools have been created to map the projects and assist in the decision making of project selection, but literature describes that those tools still use a lot of implicit judgement and no integrated framework has been developed. So how to design a framework that can meet firm-X requirements remains a question in both literature and for firm-X.

1.2 Research Questions

This section is going to introduce the objective and the research questions of this thesis report.

1.2.1 Objective

The current state of innovation projects at firm-X is not managed together in a portfolio. To stay successful in the future firm-X wants to link innovation to strategy and manage it systematically as a balanced, strategically aligning the IPP and maximizing its value. The extant literature has mostly focused on processes for managing individual projects. There is little known about how firms actually make strategic innovation portfolio decisions and how they can be more effective (Cooper, Edgett, & Kleinschmidt, 2000a). The extant literature focuses only on internal innovation projects and does not focus on the effect of inter-organizational innovation activities among innovation projects on innovation project selection. Providing an integrated solution portfolio management has only been executed for project portfolio selection (Archer & Ghasemzadeh, 1999) approaches. So currently, there is no such an integrated model for IPPM. The research will be a design type of research and it will address a design gap for many firms on how to design a framework that will balance, maximize value and align the innovation portfolio; the latter containing internal and inter-organizational innovation projects (through funding or collaboration). It is also an exploratory research that attempts to understand what the effect of inter-organizational innovation activities is on IPPM. Therefore the objective of this research is:

Designing an integrated framework for effective** IPPM.*

Integrated IPPM framework*: A framework that describes and facilitates techniques and tools for the entire IPPM process (connecting all IPPM activities in a single framework).

Effective IPPM **: A framework that pursues the three goals of effective IPPM described by (Cooper & Edgett, 2001) in the decision making process.

1.2.2 Research Questions

Based on the aforementioned objective, the main research in this research project intends to provide insight how the tools and techniques should be used to incorporate the inter-organization innovation activities. Therefore (derived from the objective) the main research question is formulated as:

How to create an integrated framework for effective IPPM?

The question focuses on how the integrated framework can facilitate effective IPPM and would be required to create such a framework. To answer these two objectives, four sub-research questions have been developed.

Before the actual design of the framework can be made, we first dive deeper into the mechanism of IPPM, as we need to know the tools and techniques that are available to understand what is required. This brings us to the first sub-question:

Sub-question 1: What are the current state of the art IPPM tools and practices in the literature that can be used for the design of an effective IPPM framework?

a) What is an integrated and effective IPPM?
b) Which tools give insight into these dimensions of effective IPPM?
c) What other dimension affect effective IPPM?

With a good understanding of definitions and tools, the next step is to understand what the current state of the innovation framework at firm-X is? Hence, the second sub-question is:

Sub-question 2: What is the current situation of the innovation system at firm-X?

From the current tools still nothing can be said about a new framework. Therefore using a stakeholder analysis and interviews, requirements can be developed for the new framework, based on industry specifics and firm's specifics. This leads to the third sub-question is:

Sub-question 3: What are the requirements of the members of firm-X for a framework for effective IPPM?

a) Which internal stakeholders are affected by the IPPM framework?
b) What requirements at firm-X can be identified from stakeholder analysis and interviews?

Then, from the previous three questions a set of requirements can be developed and use to design a framework. The new framework can then be compared to the theory of chapter two to see the link and differences between the two. This results in the fourth research sub-question:

Sub-question 4: Which parts of the new framework are different from theory?

1.2.3 Scope

The scope of the research (and so the generalizability) is the industry of firm-X, which has long development cycles but is also currently a growing industry. This research focuses on how to do the right innovation projects and not on how to do innovation projects right. Also, it focuses on allocating R&D budget to innovation projects and not on allocating budget to R&D, which is assumed to be fixed.

NPD is not part of innovation, for the reason that innovation is seen as the technology development while NPD is the design of the new products. Because the design of the new products is specific per customer, it is therefore not seen as innovation and thus lies outside the scope for this thesis.

The scope is also limited by the type of industry of firm-X itself, which is highly competitive.

1.3 Research Approach

The industry of firm-X is quite unique with its long developments phases and resource intensive research. In such an industry in which innovation goes slow and also has high research cost then

IPPM decision making process is quite important for the long term survival of the firm. Because of the long developments cycles decisions take longer to be taken and can be studied in more detail, which is why it is chosen to do the research at firm-X.

The research is going to take place at firm-X. The research will incorporate designing and artifact while also being explorative by nature. It is therefore that this research wants to investigate the problem in its real life context. As describe by (Yin, 1981) the need for a case study research arises when; 1) an empirical inquire must examine a contemporary phenomenon in its real life context, and especially when, 2) the boundaries between phenomenon and context are not clearly evident.

The research will be a single case study with a single unit of analysis because the unit of analysis is the entire IPP at a single firm (firm-X) However all projects inside the IPP are analyzed separately. The design of the IPPM framework will be the final deliverable of this research. In this section the methodology for this research will be explained. The main research question has four sub-questions and each sub-question has its own method or methods of investigation, this can be seen in table 1.3.1.

Table 1.3.1: Summary of RQ's and methods

Research Question #	*Chapter #*	*Method(s) used*	*Executed through*
Sub-question 1	2A & 2B	Literature study	Literature review
Sub-question 2	3	Analysis of current innovation framework	Analysing internal documents
			Interviews with members of firm-X
Sub-question 3	4	Stakeholder mapping	Analysing internal documents
			Interview with head of TO
		Interviews about innovation framework	Semi-structured interviews
		Analyses of performance of current IPP	Analysing internal documents
			Interviews with head of TO and head of R&D
Sub-question 4	5	Compare requirements	Results of chapter 2, 3 & 4
		Design of the framework	Design with requirement from first three RQ's
		Validation	Validate with expert, members of firm-X and requirement list
Main-Question	6	Synthesis	Compiling the research questions

1.4 Report structure

This report is organized as is indicated in figure 1.4.1. In chapter 2 the theoretical background of the research is presented, it has been divided into two sub-chapters, 2A includes the key terms and an overview of related IPPM literature and in 2B some issues with the IPPM method are discussed, and a conceptual model is set-up. Firm-X is introduced in chapter 3 along with the discussion of the current innovation framework at firm-X. Then in chapter 4 a stakeholder mapping and interviews are presented. Chapter 2, 3 and 4 all create requirement for the new framework and in chapter 5 these requirements are used to design an integrated framework for effective IPPM for firm-X, it is also validated through an expert (Linda Kester, assistant professor at industrial design TU Delft) and member of firm-X. Finally, chapter 6 deals with the synthesis of all the results into a general framework, conclusions, limitations, academic and managerial implications and recommendations for future research will be discussed. The report also comes with a set of Appendices.

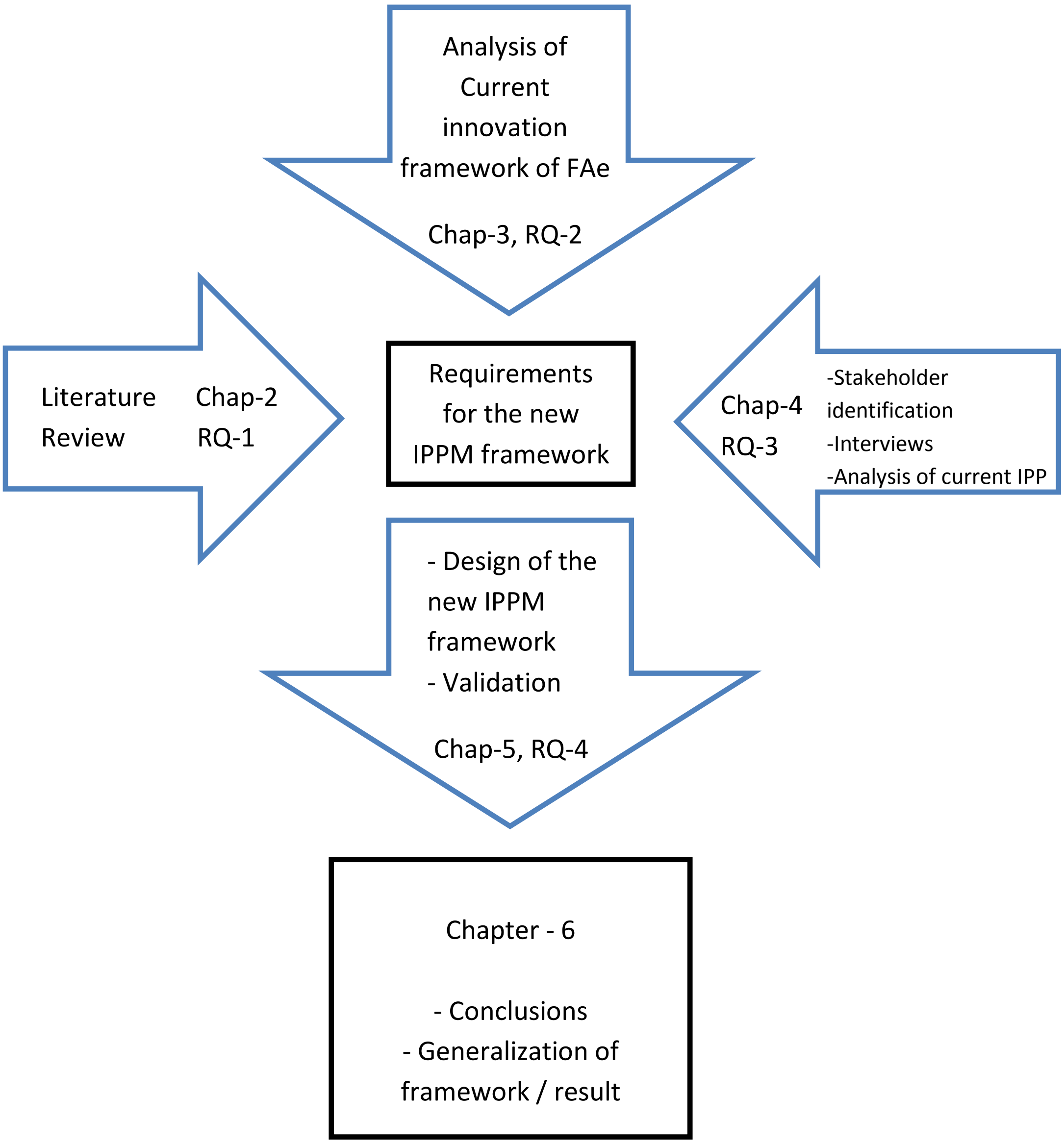


Figure 1.4.1: Report structure visualization

Chapter 2A: Literature study

In order to develop an integrated framework for IPPM first it needs to be understood what IPPM does and how it works. This chapter is divided in two sub chapters 2A & 2B. Chapter 2A deals with the extant literature on IPPM and chapter 2B with the issues of the extant literature. At the end of this chapter, a conceptual model is proposed. In section 2.1 the term innovation is discussed in the context of firm-X because it helps to scope down the concept for this research. Then the key terms will be defined according to the literature in section 2.2. When the key terms are known then section 2.3 will discuss innovation project management. Where section 2.3 focuses on individual innovation projects section 2.4 will focus on the whole portfolio approach, effective goals for IPPM will be introduced and factors that can measure the IPP will be summarized. In section 2.5 a limited set of tools for IPPM described in the literature will be introduced. Then this chapter will be finalized with a short summary of the discussed literature in section 2.6.

2.1 Innovation

The term innovation is the primary concept in this thesis. Though many definitions are available this research will try to apply the terminology most applicable to firm-X, this limits the scope of the research, however it has also influence on the generalizability which will be discussed later in the report.

In its most basic form the concept of innovation is 'new ness' (Gupta, Tesluk, & Taylor, 2007). (Ven, 2005) Reasons that ''as long as the idea is new to the people involved, it is treated as innovation even though others may look on it as mere imitation''. (Gupta, Tesluk, & Taylor, 2007) Reasons in his article that most ideas emerge as novel recombination's of old ideas, ''if only utterly new ideas to the world would make the concept innovation, then it would make the concept almost empty and devoid of any connection with ground level reality''. In order not to lose the connection with ground level reality or in this case the connection with the innovation organization at firm-X a definition of innovation which is most applicable to firm-X will be developed.

The higher management of firm-X views 'new product development' not as innovation. Innovation is seen as the development of new technologies or new applications of technology or new manufacturing processes, all of which are new to the firm and produce added value. New product development is seen as the application of the innovations (technology), especially because each product is specific for each customer. Firm-X wins contracts by selling innovative technologies. Official documents at FIRM-X describe Innovation as 'a first application of a new idea in a product' (firm-X, 2012).

Innovation project portfolio management (IPPM) is the focus of this thesis and it is related to development of ideas into new products, or in other words technology development. IPPM therefore limits the scope of innovation only to technology development. Technology development can be seen as a broad concept that contains: technologies development or new applications of technology or new manufacturing processes e.g. design tools development, new materials development, structures technology development, or manufacturing process improvements. So the innovation is related to the products that firm-X produces. Innovation in this context does not include activities related to actual commercialization, marketing or distribution. Another reason for firm-X to see technology development as innovation only is because firm-X develops technology that is necessary to develop products, customers buy the products because of the technology behind it.

Technology Readiness Levels (TRL's) indicate the level of maturity of a technology and are used to measure maturity of all the technologies that FIRM-X is developing. TRL measurements will receive more attention later on in the report but it needs to be understood that there are 9 TRL's and that innovation can occur on each of those levels. The first six levels are developed in the R&D department & Product Group (PG) department. At TRL 6 the technology is mature enough to be applied to a product for a customer, in other words selling the technology is possible. Then if the technology is sold in a product then that program will do the remaining innovation and the finance of the remaining three TRL levels is related to that project. Therefore the IPPM can be limited to innovations from TRL 1-6. Figure 2.1.1 shows a TRL division as indicated by NASA.

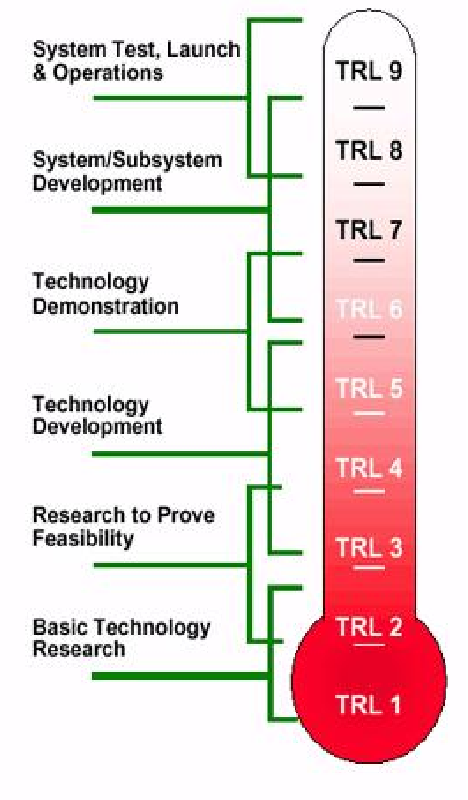


Figure 2.1.1a: TRL measurements, source: NASA TRL division

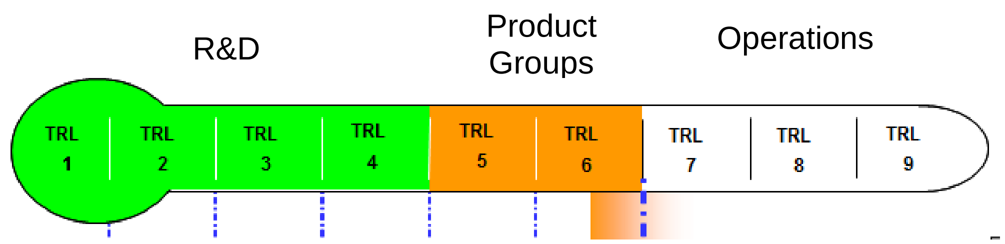


Figure 2.1.1b: TRL measurements, source: Firm-X (KTM presentatie algemeen)

Another important distinction in innovations is whether innovation is radical or incremental, the two types on innovation have impact on portfolio management a short explanation from the literature about both types are: According to (McDermott & O'Connor, 2002), the incremental innovations are the improvement or refinement to the current products and relatively minor extensions to existing process of production. While the radical innovations are the development or application of significantly new ideas into new technologies which are distinct from current and existing markets. In the same article (McDermott & O'Connor, 2002) describe the difference of these radical and incremental innovations which can be measured on these four dimensions: 1) Technological uncertainty, 2) Technical inexperience, 3) Business inexperience and 4) Technological cost.

Based on this entire section, the following definition of innovation will be used for the rest of this thesis report: Innovation is the development of technology, new applications of technology or new manufacturing processes*, only for TRL 1-6, which result in a product or manufacturing process that is new to firm-X. On top of that it does not include activities related to actual commercialization, marketing or distribution.*

2.2 Portfolio Management Terminology, Key Concepts

Before discussing project portfolio management some definitions of key concepts will be discussed to enhance the understanding of and create a clear difference between the key terms.

> Project: A project is temporary in that it has a defined beginning and end in time, and therefore defined scope and resources (PMI, 2013). At firm-X the scope of innovation projects is not always clear especially for young and radical innovation projects, but they are still seen as projects.
>
> Project management: The British standard for project management is the planning, monitoring, and control of all aspects of an individual project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance (Roger, 1999).
>
> Project Portfolio: a grouping of projects or programs that share and compete for the same resources. Portfolios can be managed at an organizational or functional level (APM, 2013). Portfolios are often used to reduce risk of the portfolio.
>
> Innovation Project Portfolio (IPP) is a portfolio of innovation projects.

Now the essential concept of IPPM has been defined, the concept of IPPM itself can be discussed.

> Innovation Project Portfolio Management (IPPM) ''is a dynamic process whereby a business list of active and R&D projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be accelerated, killed, or deprioritized; and resources are allocated and reallocated to the active projects'' (Cooper R. G., 1999a). A set of or a sub-set of projects is evaluated together, in relation to each other (Mikkola, 2000). In the same article IPPM is described as: IPPM is about making strategic choices-which markets, products and technologies our business will invest in. It is about resource allocation – how you will spend your scarce engineering, R&D and marketing resources. It focuses on project selection – on which new product or development projects you choose from the many opportunities you face. And it deals with balance – having the right balance between numbers of projects you do and resources or capabilities you have available (Cooper, Edgett, & Kleinschmidt, 1999b). In this research the focus is on innovation portfolio, therefore the project portfolio management is only related to issues with innovation portfolio. Finally Kester adds that IPPM is a way of thinking not just a tool where the portfolio is central instead of individual projects (Kester, Linda, 2012).

Portfolio decision making should be centralized, as the portfolio manager should have an overview on the entire innovation portfolio. In his paper on decision making Simon writes about bounded rationality. Portfolio decision making is based on Bounded rationality where the best choice among all the possibilities, is just the best solution under the circumstances (Simon, 1997). To summarize shortly, IPPM contain all the tasks from evaluating, selection, ranking and allocating resources to all active and new innovation projects.

Another topic discussed in this thesis is the effect of inter-organizational innovation activities on IPPM and therefore this concept is defined below.

<u>Inter-Organizational Innovation Activities:</u> Inter-organizational activities is defined as the partnership between at least two organizations whereby their resources, capabilities, and core competencies are combined to pursue mutual interests in developing, manufacturing, or distributing goods or services (Bierly & Coombs, 2004). Inter-organizational innovation activities can be described as a more limiting concept of collaboration activities because it is only applied to activities related to innovation. It is a concept of open innovation whereby collaboration can occur with governments, research institutes or enterprises.

These concepts of section 2.1 and 2.2 are the key terms for the rest of this report and the following sections and chapters will build on these concepts.

2.3 Innovation Project Management

As discussed in chapter 1 nowadays many firms still assess all their innovation projects individually but don't assess the relation among the innovation projects. Therefore this section will discuss this individual project approach and will compare it with the portfolio approach.

2.3.1 The three Stage Gate Generations for Individual Project Management

Stage gate is a widely adopted approach for project management, this section is a short summary on the history of stage gate models. The first generation of stage gates did exactly what the name suggests, it is a set of pre described points in the development of a product / project at which it is assessed to continue or kill the innovation project. The process adds discipline to the projects but doesn't reduce the risk (Cooper R.G., 1994a). This stage gate approach is only for individual projects/product, so the relation among projects and synergy among projects is not assessed. The first generation indicates that for different phases in the development of a product / technology different assessment criteria should be used. The second generation introduces multidisciplinary team into the stage gate process for assessing the projects, something which the first generation didn't had. Also now the stage gate process spans the entire product life, from idea creation to launch of the product, not only the product development phase. The third generation stage gate is a more portfolio management tool which has fuzzy gates (conditional go decisions) and looks at all the innovation projects in the portfolio instead of only one at the time. The focus in the literature until now has been on processes for managing individual innovation projects, such as Stage Gate processes, or on individual innovation project decision making. There is little knowledge about how firms actually make strategic innovation portfolio decisions (Kester L. , 2011) and (Cooper, Edgett, & Kleinschmidt, 2002).

2.3.2 Stage Gate and Project Funnel, Portfolio Approach

These days the portfolio approach of stage gate model is increasing being used in today's landscape. The portfolio approach can show interrelatedness among projects and partners. The portfolio approach means that the portfolio consists of a set of projects all being in different stages of the development process, this can be visualized in project funnel that is visualized in figure 2.3.1 The figure shows the project funnel applicable to firm-X, it distinguishes the different phases in the development process of a product.

The funnel shows a converging funnel for the innovation phase and a diverging funnel for the product design phase (which is not a part of innovation but it is drawn for completeness). The product design funnel is diverging because from the many technologies that are developed even more different products can be developed, but this does not necessarily need to be this way in reality. However every product is unique for each customer and so each design has specific innovations related to that product and the product-technology combination.

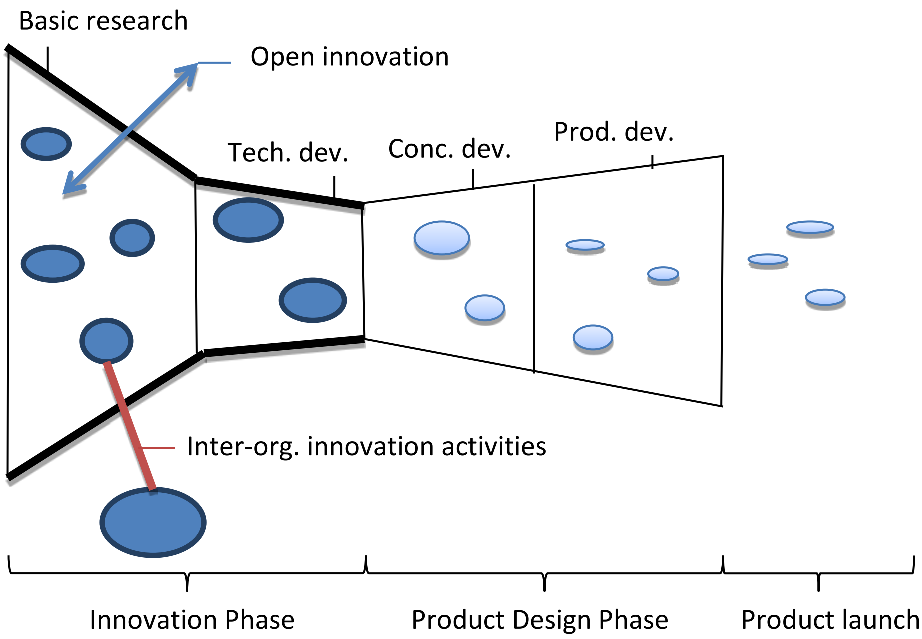


Figure 2.3.1: Project funnel at Firm-X

Project portfolio management differs from innovation project portfolio management (IPPM) by factors described by (Coldrick, Lawson, & Ivey, 2002), the article states that project selection in innovation portfolio is complicated by uncertainty, interrelation of projects, changing of projects over time and success factors that are difficult to measure. IPPM is a critical task of innovation because it affects a firm's sensing, seizing, and transforming of innovation opportunities, on this basis it may also influence the survival of firm in general (Coulon, Holger, Ulrich, & Vollmoeller, 2009). IPPM is about managing the innovation projects such that it will yield the best result.

2.4 Innovation Project Portfolio Management (IPPM)

To capture value from innovation two central issues firms have to deal with; 1) doing innovation projects right, and 2) doing the right innovation projects (Cooper, Edgett, & Kleinschmidt, 2002). Much literature has focussed at project level which relates to doing projects right. Less attention has been paid to innovation project portfolio at corporate level. This section will discuss an innovation portfolio framework and a set of factors to measure performance of an innovation project portfolio.

2.4.1 Innovation Project Portfolio Process / Approach

This section will describe a general applicable approach towards IPPM and this will also serve as a basis for the conceptual model. This section serves as a first step towards the final conceptual model at the end of chapter 2B.

Coopers definition of IPPM from section 2.2 is a description of what IPPM is about, in short: IPPM is a dynamic process whereby a business list of active new product and R&D projects is constantly updated and revised. In this process, new projects are evaluated, selected and prioritized; existing projects may be accelerated, killed, or deprioritized; and resources are allocated and reallocated to the active projects. All these tasks and choices should lead to the three goals for effective IPPM which were also described by Cooper. The author of this report divided the previous described definition of IPPM into tasks, choices and goals as is indicated in figure 2.4.1. These tasks and choices describe what IPPM does and should lead to the three goals for effective IPPM also defined by (Cooper & Edgett, 1997), these three goals will be explained in more detail in section 2.4.2. The three tasks are put before the choices because first the projects should be evaluated before any choice can be taken. It can be reasoned that selection and prioritizing innovation projects already lead to decision about how much resources to allocate but for now this should not be a problem because the main point is that the projects should be evaluated.

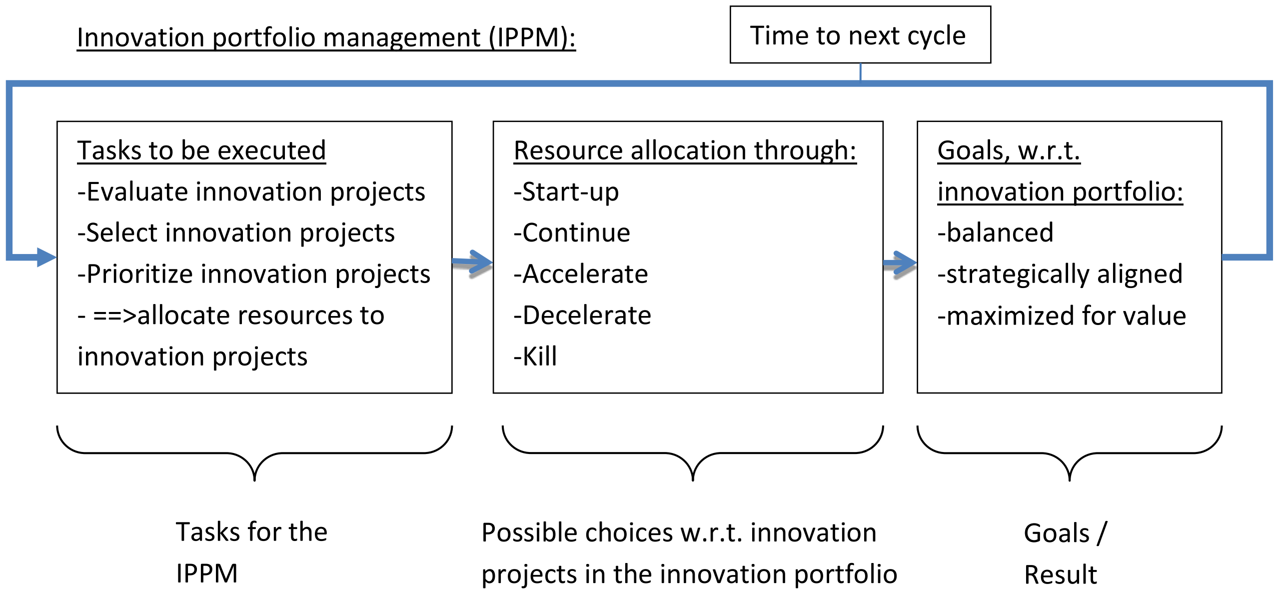


Figure 2.4.1: Innovation Project Portfolio management (IPPM) tasks, choices & goals

A major part of IPPM is the decision making process as discussed in the former paragraph. This paragraph focuses on different decision making approaches such rational, political and intuitive decision making as a short background for the rest of this report. IPPM is a decision making process and so it is important how these approaches relate to the IPPM. (Kester, Griffin, Hultink, & Lauche, 2011) Describe the rational political and intuitive decision making approaches in terms of evidence-, power-, and opinion based. They are described as:

> *Evidence based decision making: Evidence based decision making is the process by which firms use objective information and empirical evidence, while understanding the underlying assumptions, to build an objective decision making rationale.*
>
> *Power based decision making: results when an unequal distribution of power allows more powerful or individuals to make decisions that reflect their personal interests.*
>
> *Opinion based decision making: based on overall feelings and personal experience to build a subjective decision making rationale.*

In the research amongst 189 firms with 378 respondents (Kester, 2011) conclude that evidence based decision making has positive effect on both balance and strategic alignment and political powered decision making has a negative effect on both balance and strategic alignment. Results indicate that firms aim for an effective IPPM decision making process should combine evidence with opinion based decision making while reducing the amount of political power in their decision making process. Political power may achieve positive effects under certain circumstance e.g. if inequality in power distribution is large. Because firm-X is a firm in the Netherlands which has a culture of no high power inequality therefore in the remainder of this report it is assumed that effective IPPM decision making should be achieved through evidence and opinion based approach, which means that implicit judgement should be minimized and experience from employees should be leveraged. For the IPPM framework this means that the framework should support evidence based decision making environment because the opinion based decision making will come in automatically with the experience of the employees working with the model. From this the first requirement for the new framework can be developed, which is:

R1:	The new IPPM framework should support an evidence based decision making approach.

Now the decision making processes have been discussed another way of looking at the IPPM approach is given by Markowitz. (Markowitz, 1952) Describes the process of how to do the right projects and divides it into two stages. The first stage starts with observation and experience and ends with beliefs about the future performances of available securities. The second stage starts with the relevant beliefs about future performance and ends with the choice of portfolio. In other words, the description of Markowitz describes that a portfolio starts with observing how the current state is of the portfolio, then secondly make expectations of what this portfolio will do in the future, thirdly also make expectation of new opportunities in form of new technologies or new customers. Then finally these steps should be compared with each other to make decision to adjust the IPP.

This description can be summarized in the following four steps:

1) Measure performance of current IPP.
2) Develop expectation of future performance of current IPP.
3) Develop expectation of the new opportunities.
4) Compare step 1 until 4 and make suggestions to adjust the portfolio

Construction of conceptual model:

The model of Cooper and the description of Markowitz in the last two paragraphs lead to the construction of a conceptual model. The start of the conceptual is made in this section and the model will be further developed in chapter 2B. The conceptual model is visualized in figure 2.4.2 and can be divided in four steps for execution.

Step one: in the top of the figure the current state of the IPP should be measured, which is the current performance, in Coopers model (figure 2.4.1) this is the evaluation of the current innovation projects, in Markowitz model it is the first step out of five, this leads to the second requirement;

R2: The new IPPM framework should be able to measure the current state of the IPP state.

Step two: the desired state is an indication of how the IPP should look like and is stated in the top right of figure 2.4.2. The desired state creates a direction for the firm to pursue. Cooper indicated this in his definition by the three goals for effective IPPM (these goals will be discussed in later sections of this chapter). Also when the desired state is given and can be compared (in the third step), then this indication of the desired will reduce implicit judgement because higher management does not need to reason themselves how the desired state should look like, and so a clear direction can be pursued instead of many directions of each of the members of the decision making process, this leads to two requirements for the new framework:

R3: The new IPPM framework should be able to create in indication of desired IPP state.
R4: The new framework should reduce implicit judgement in the IPPM decision making process.

Step three: the link between the current IPP state and the desired IPP state in figure 2.4.2 is where the comparison of these two IPP states will occur. This can be seen as the selection and prioritizing as given by Cooper in figure 2.4.1 whereas Markowitz describes it as 2nd and 3rd step. To compare the current IPP and new opportunities tools should be used that can compare current state and future innovation projects / opportunities. So from the model it can be reasoned that to be able to compare the two states the same set of factors should be used for both. This leads to another requirement:

R5: The new IPPM framework should be able to compare the current and desired IPP state.

Step four: the possibilities are compared and adjustments are suggested to adjust the portfolio that will lead to a new IPP state, this state does not need to be the same as the desired state but it should closer than the current IPP state. This can be done by the decision making process of Cooper in figure 2.4.1 where projects can be started, continued, accelerated, decelerated and killed, for Markowitz this is the fourth step. This leads to another requirement for the new framework:

R6: The new IPPM framework should be able to indicate how to adjust the current state towards the desired state.

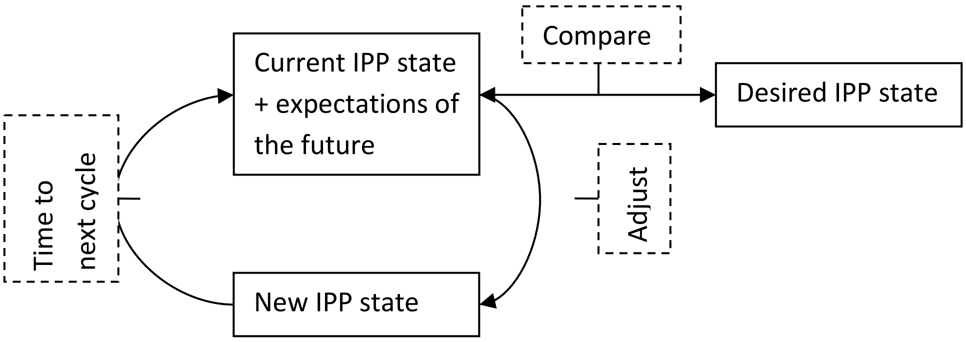


Figure 2.4.2: General portfolio cycle

The adjustments in the fourth step lead to a new IPP state because the desired state might not be possible to reach due to multi-dimensional nature of this desired state. This process starts then again when a new cycle starts and keeps repeating because the IPPM is a continuous process of revising and updating. This approach has many difficulties that still need to be solved, as indicated by the PhD dissertation from (Kester L. , 2011) where she explains that many firms still have no insight / oversight in their current IPP. Also there is still gap in understanding in which dimensions to use to measure the current state of an IPP and what the desired state is. (Herps, Mal, Halman, Martens, & Borsboom, 2003) discuss a framework of Robert G. Cooper for strategic buckets, which has 8 steps, 1) Determining long term objectives, 2) Key Strategic Dimensions (KSD) should be chosen, 3) dividing the KSD into strategic buckets, 4) categorising existing projects over strategic buckets, 5) determine desired spending per bucket, 6) difference of the levels compared, 7) ranking current projects, and finally 8) measures taken to close the gap. This 8 step approach can also be seen as the same approach as in the conceptual model in figure 2.4.2. The original article of Cooper however could not be found.

To shortly summarise the model. In step one: The current IPP state is measured, in step two: An indication of the desired state should be developed, then in step three: the desired and current state are compared and finally in step four: current state and new opportunities are compared to the desired state so it can be decided how to adjust.

2.4.2 Portfolio framework

This section will describe a framework as is currently given implicitly in most literature, it describes the effective goals for IPPM, and also factors for measuring those effective goals.

Little is known about how to achieve innovation portfolio success (Kester L. , 2011). Cooper describes three main goals for effective IPPM: 1) Alignment with strategy, 2) balanced portfolio and 3) maximization of value of the portfolio. The simultaneous achievement of these goals result in better projects portfolios. However, there is a constant conflict among these goals that limits the achievement of an optimum portfolio (Maicon G. Oliveira, 2010). (Kester L. , 2011) describes that it is not known how these goals interact, which dimension are more important and how to achieve an NPD portfolio that is strategically aligned, balanced and that delivers maximum value therefore she starts with making a beginning in this research. It has not proven difficult to assign scores to a set of projects during the assessment phase, it remains difficult to select a balanced portfolio of projects on those scores (Nabil N.Z. Gindy, 2006). The three goals for effective IPPM lead to another requirement for the new IPP framework:

R7: The new IPPM framework should lead to three goals of effective IPP.

According to project management literature, a portfolio has to be balanced along multiple dimensions to provide the best value to the organization, there is however no consistency about which dimensions to include (Meskendahl, 2010). In an overview article about tools for managing the innovation portfolio (Coulon, Holger, Ulrich, & Vollmoeller, 2009) describes the available tools in the literature and also states that future research could help to identify key activities in corporate innovation portfolio management, depending on company size and industry. The same article states that how top management decides and what the influencing factors are apart from hard facts and figures constitutes an important avenue for further research.

The project portfolio management literature doesn't seem to focus on or least doesn't distinguish projects executed internally in the firm to project executed in innovation activities with other firms. After allocation of resources to an inter-organizational innovation activities innovation project it is more difficult to change as the commitment is higher. Therefore it makes sense to look at those projects from a portfolio perspective more closely and estimate the impact on the portfolio when allocating the resources. But if the assessment of those projects is different from internal projects is not yet understood nor investigated. Also Erik den Hartigh could not connect the network literature and portfolio management literature. Linda Kester said this was a good point for further research.

As stated before in this section (Cooper & Edgett, 2001a) defined three main goals for effective IPPM, they are: 1) alignment of strategy in Innovation Project Portfolio (IPP), 2) balance of the IPP, and 3) maximization of IPP value. However some of the literature suggest that there is a fourth and a fifth goal: 4) to select the right number of innovation projects (Cooper & Edgett, 1997) and 5) to ensure portfolio sufficiency versus overall product innovation goals, these last two goals have received considerable less attention in the literature (Killen, Hunt, & Kleinschmidt, 2007). (Kester, 2009) Investigates among Dutch firms these first three factors in more depth and concludes that a portfolio balance is an antecedent to achieving a strategically aligned portfolio and also an antecedent to develop a portfolio that delivers maximal value. Another key finding is that the positive effect of balance on market performance may be fully mediated by strategic alignment and maximal portfolio value as can be seen in the Figure 2.4.3. Market performance is defined in three aspects (customer satisfaction, market effectiveness and profit).

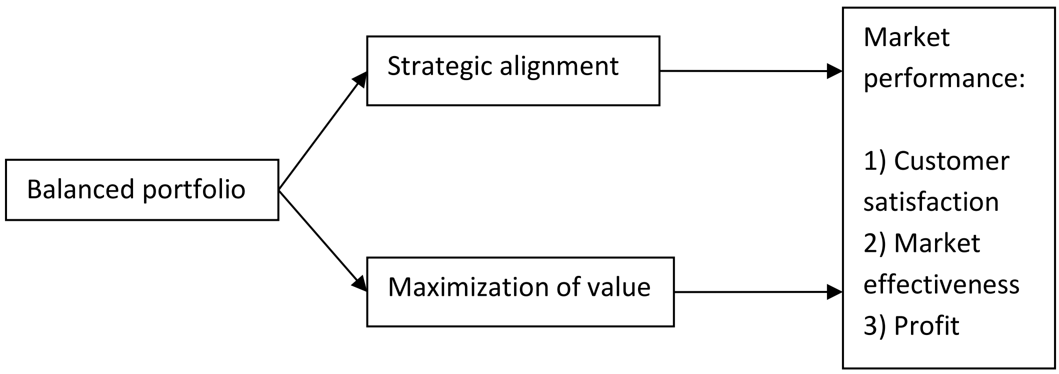


Figure 2.4.3: Part of decision making model, source L. Kester 2011.

In the following text the three goals of effective innovation portfolios will be discussed in more detail. Previous research didn't assume balance to be an antecedent of strategic alignment or maximization of value, in her research (Kester, New product development portfolio's, 2009) argues that corporate venturing literature may also yield results that may support the result.

2.4.3 Strategic alignment, first goal for effective IPPM

The business strategy describes the way in which a firm decides to compete in the industry in comparison to its competitors (Varadarajan & Clark, 1993). Alignment of strategy means the extent to which all the projects inside the portfolio are aligned with the strategy according to (Cooper, Edgett, & Kleinschmidt, 2004a). A strategically aligned portfolio is one in which the portfolio resource allocation decisions reflect the strategic priorities of the firm. Cooper suggests that alignment of strategy improves the performance however such a relation lacks empirical evidence (Kester, 2011). Despite the acceptance of strategic fit as one of the major objectives of IPPM, the literature on it is limited. (Cooper & Edgett, 2001a) States that all the innovation projects in the portfolio should be aligned with the strategy, others however don't agree with this statement and have a more practical view where they state that many strategies inside firms are so broad that almost everything will fit the strategy. Also sometimes it is not clear which direction an innovation project will go into so it is hard to say if it fits the strategy.

2.4.4 Maximization of value, second goal for effective IPPM

The overall portfolio should maximize the value, this can be measured in different forms, it can be financial values, strategic values or brand value among others.

Cooper found in its research that the best performing firms, in terms of NPD performance, more often indicated that their portfolio contained high value projects (37.9%) for the best performers, versus (21.9%) for average performance and (0%) for the worst performers (Cooper, Edgett, & Kleinschmidt, 2004a) but Cooper only focuses on maximizing financial value.

As described above maximization of value and strategic alignment of the innovation project portfolio have a direct effect on market performance. (Kester, 2009) Focused maximization of value of the Innovation Project portfolio (IPP) on monetary. Maximization of portfolio value reflects the extent to which a firm's IPP composition will help them achieve their long-term growth and profitability goals, and can be measured with four items, which are: 1) the extent to which the firm has high impact projects, 2) the extent to which the firm has maximized the return from their portfolio, 3) the extent to which the firm expects to maximize future profitability and 4) market sales growth with the current innovation project portfolio.

2.4.5 Balancing the portfolio

Balancing the IPP is making sure that the portfolio contains a desired balance according to a number of parameters (Cooper, Edgett, & Kleinschmidt, 1999b). What the desired balance is, which parameters should be included and how to get that desired balance are some of the questions that should be answered in order to balance the portfolio.

Balancing a portfolio can be done with a wide variety of factors and the use of different balancing factors lead to different results. According to Cooper there are four goals of effective IPPM and the right number of projects is the fourth factor for effective portfolio management but (Kester, 2011) among others argues that this is part of balancing the portfolio.

There are many methods available to assess innovation project portfolios. Most organizations follow merely financial measures to evaluate and assess their business success (Meskendahl, 2010), however they do not yield the best results according to (Cooper, Edgett, & Kleinschmidt, 2004a). These financial tools don't work effectively in early stages of product or technology development because uncertainty and risk are high. (Cooper R. G., 2007) Wrote 'as one manager stated: It's like trying to measure a soft banana with a micrometer! Our evaluation tools assume a level of precision far beyond the quality of the data available''. In an empirical research among 205 U.S. companies by (Cooper R. G., 1999a) conclude that strategic models followed by scoring portfolio management models tend to produce much better results. They also conclude that benchmark firm's view that portfolio management is very important, they have an established, explicit and formal method, they use multiple portfolio methods and finally they conclude that the quality of the portfolio method appears to have much more impact if the method fits management style.

According to project management literature, a portfolio has to be balanced along multiple dimensions to provide the best value to the organization, there is however no consistency among which dimensions to use (Meskendahl, 2010). According to (Chao, Kavadias, & Gaimon, 2009) success for project portfolios on new product developments requires the balancing between short-term benefits from incremental improvements of existing products and long-term benefits achieved through radically new products and services. (Killen , Hunt, & Kleinschmidt, 2008) Constitute project type, risk level, and resource adequacy as relevant criteria for portfolio balancing. (Meskendahl, 2010) States that many criteria named in the literature are not independent on each other and so the dimensions have to be adjusted to the area of application.

2.4.6 Difficulties in project evaluation

A difficulty in evaluating projects in a portfolio is that projects are in different stages of development and perhaps each stage different evaluation criteria should be used. On top of that project valuation is difficult to use when it comes to radical innovation projects because data may be unreliable or highly biased (Kavadias, Loch, & Tapper, 2004). In portfolio all projects individually can be compared with criteria and then overall criteria for innovation portfolio can be applied to measure the overall performance of the portfolio.

Projects are assessed individually and then the values of all projects together can be assesses to measure the portfolio value on a specific dimension.

Most frequent criteria to approve the new product concept were product quality, sales volume, project total cost, alignment with firm's strategy, and window of opportunity (Pilar Carbonell-Foulquie, 2003).

Usage and criteria change over the stages of development. Strategic fit dimensions stand out in approving the new product concept. Technical feasibility dimension is mostly employed in approving the new product concept and product prototype. The usage of customer acceptance dimension is notably high throughout the entire development process. Financial performance dimension stand out near the end of the development process. Market opportunity criteria are primarily used early on in the NPD process and after product launch (Pilar Carbonell-Foulquie, 2003).

2.4.7 Factors for assessing an innovation portfolio

The amount of factors that can be used in IPPM is large, in table 2.4.1 a set of factors has been compiled from the literature, and perhaps this is not all of it. In chapter three firm specific factors to firm-X will extend the list.

The difficulty in choosing a set of factors is that the factors are related to each other, e.g. radical development goes together with higher risk. Success is the outcome of firm and innovation project related factors; a single magical factor does not seem to exist (Madique & Zirger, 1984). How to get a set of factors that can effectively manage the portfolio is the question. The right set of factors is very important because when balancing the wrong set of factors, the portfolio can be directed in the wrong direction with all its consequences for the firm.

Table 2.4.1: Factors and corresponding article.

Factors	Described by
Incremental vs. radical new products and services (balance: new products, improvements, cost reductions, maintenance & fundamental research)	Coulon, 2009
Risk vs. return	Cooper, 1997
Maintenance vs. growth	Cooper, 1997
Project type and resource adequacy	Killen, 2007
Inventive merit	Cooper, 1994a
Durability of the competitive advantage	Cooper, 1994a
Financial reward	Cooper, 1994a
Competitive impact of technologies	Cooper, 1994a
Probability of success (technical or commercial success)	Cooper, 1994a
Investment required	Cooper, 1994a
Time to completion (long vs. short term)	Cooper 1994a
Right amount of projects	Cooper 1994a

Not all factors are equally important, some of those factors are driving and other factors are just the consequence of those driving factors, therefore it should investigated which factors are driving and which are the consequence. What is of main importance of each factor is that it gives reliable information about the innovation project or the portfolio (it should not be based on implicit judgement of the manager assessing the project or portfolio) so that it will give a good overview of the state of the IPP, this leads to the next requirement:

R8:	The new IPPM framework should be based on reliable & quantifiable information.

2.5 Tools to support portfolio decision making

The factors described in section 2.4 will be a measure for how the innovation projects and so the IPP state is evaluated. Measuring the factors for all projects and mapping it will give an overview of the current IPP state. Visualizing the factors will be done with several tools and this section will discuss the most commonly used tools. In section 2.4.1 the four steps of the conceptual model have been stated and in this section for each tool it will be discussed in which of the steps it can assist. To shortly repeat the model. In step one: The current IPP state is measured, in step two: an indication of the desired state should be developed, then in step three: the desired and current state are compared and finally in step four: current state and new opportunities are compared to the desired state so it can be decided how to adjust the IPP.

The IPP decision making process is characterized by uncertain and changing information, dynamic opportunities, multiple goals and strategic considerations, interdependence among projects, and multiple decision makers and location (Cooper & Edgett, 1997). Throughout the years many tools have been developed to help the portfolio decision making process. Table 2.5.1 gives an overview of the type of tools and indicates in which of the three goals of effective IPPM can be measured. The table has been reduced from its original shape to limit its scope to models applicable to firm-X. It has been reduced for complex financially return based (such as: linear, dynamic and integer programming with respect to the innovation projects) or probability based models for IPPM. The reason behind this decision is because the uncertainty of these models is extensive due to long development phases and will therefore probably give a wrong overview of the IPP. (Cooper R. G., 1999a) Also shows that financial methods give the worst results. A last remark why complex financial or probability models will not be used is because firm-X has not implemented any formal approach for IPPM therefore first a solid basis for IPPM should be set-up before it can be investigated how to use those other models. The bubble diagrams in section 2.6.1 will give one financial/probabilistic model for completeness.

Table 2.5.1: Innovation portfolio management tools and their application, source: Coulon et al. 2009 and Cooper 2001

Innovation portfolio management tools	section	1 Value Maximization	2 Balance	3 Strategy
Bubble diagrams	2.5.1	x	x	X
Roadmaps	2.5.2	x	x	X
Scoring models	2.5.3	x	x	X
Decision trees	2.5.4	x	x	
Strategic buckets	2.5.5	x	x	X
Check lists	2.5.6	x	x	X

2.5.1 Bubble diagrams

Bubble diagrams can be used to show multiple dimensions at once and mostly occurs in a two dimensional form. All the innovation projects can me mapped in one graph to give an overview of the entire portfolio. According to (Cooper R. G., 1994a) there are two approaches, firstly the strategic decision group method which is financially based and looks at expected commercial value and probability of success such as the BCG matrix. Secondly Cooper describes the Arthur D. Little approach in (Cooper R. G., 1994a) which argues that the financial methods of the first approach are meaningless and can be harmful to the firm. Therefore Arthur D. Little approach considers a number of key qualitative characteristics of each innovation project, and maps this on two dimensional plots, endless numbers of plots can be made but with experience the firm can find the maps that fit them best. The characteristics are: fit with corporate strategy, inventive merit, strategic importance, durability of competitive advantage, financial reward, competitive impact of technologies, probabilities of success, and investment required, those factors can differ per firm. In figure 2.5.1 an example of a bubble diagram can be seen, it shows market growth versus, market share but also visualize the expected turnover per technology.

Bubble diagrams can map all the innovation projects to show the performance of the entire IPP but still the manager needs to decide how the IPP should look like (what the desired state is of the IPP). Therefore it gives room for implicit judgement and so it is difficult to decide how to adjust the IPPM. Therefore this tool only assist in step one of the conceptual model.

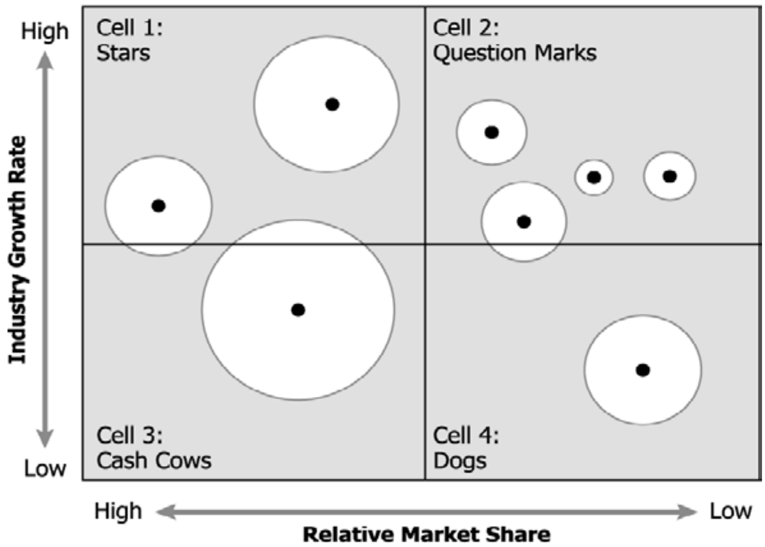


Figure 2.5.1: BCG matrix, source: (Hill & Jones, 1998)

2.5.2 Roadmapping

Technology road-mapping since its first application at Motorola has been applied to many firms, it has the potential to provide a bridge between all the tactical decisions processes, different business functions, and organizations through the common element of time (Whalen, 2007).

The term road-mapping tends to imply certainty and clarity of purpose in an uncertain and complex world, and often the world is used to describe traditional strategic plans of foresight and initiatives. Many different meanings of the term road-mapping are in use but they have in common the desire to capture a high level, synthesized and integrated view of strategic plan's, in a simple graphical or tabular format. Roadmaps can take various forms but they all seek to answer three questions; 1)

Where are we going? 2) Where are we now, and 3) How can we get there (Phaal, Farrukh, & Probert, 2004)? It is important to keep in mind that any enterprise planning framework (like roadmapping) will only be successful if it is derived from the key planning and decision processes of the organization in question (Whalen, 2007). Technology roadmapping starts with a need, not a pre-defined solution (Garcia & Bray, 1997). Also the maturity of the roadmap can never exceed the maturity of strategic thinking at any stage in the funnel.

There are three generations of roadmapping where the last one is still emerging. The first generation is aimed at technology forecasting, the second generation is aimed at improving technology planning decision and the third generation is aimed at producing integrated technology management activities (Nabil N.Z. Gindy, 2006) and (Beeton, Phaal, & Probert, 2008) divides it up into two; exploratory goal of TRM or goal oriented. Technology roadmapping is a strategic tool and it is key to understand the strategic context. It is often claimed that the process of developing a roadmap is more valuable than the roadmap itself, because of the associated communication and consensus between the functions and organizations (Muller, 2009).

Many styles of roadmapping are available but it can be generalized to a multiple-layer format mostly with three layers, 1) the top layers is concerned with the purpose of the organization aspires (typically firm level)('know-why'), 2) the middle layer of the roadmap is concerned with the mechanism through which the purpose is achieved ('know-what') and 3) the bottom layer of the roadmap is concerned with the resources (including technology) that must be marshalled and integrated to develop the delivery mechanisms ('know-how').

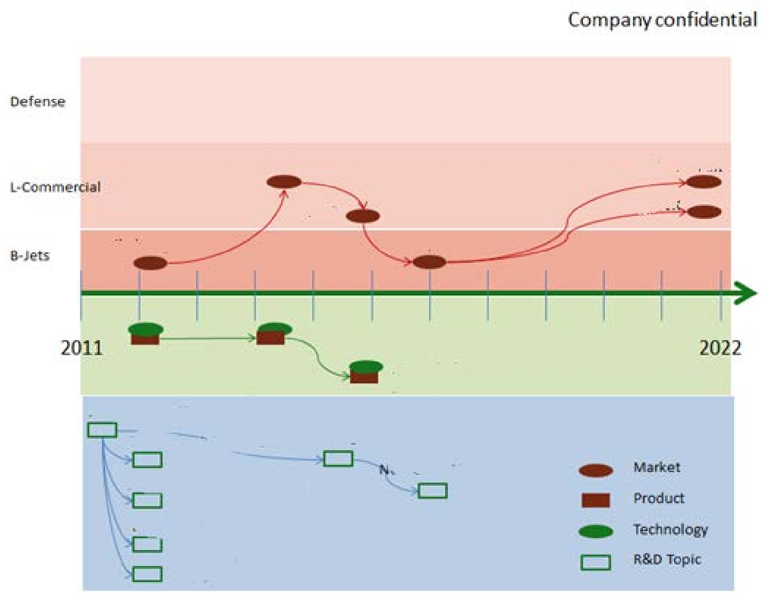


Figure 2.5.2: Example of a TRM, internal source firm-X, TRM 2011

A key benefit of the approach is the communication associated with the development and dissemination of roadmaps, particular for aligning technology and commercial perspectives, balancing market 'pull' and technology 'push' (Phaal & Muller, strategy, 2009).

Caution must be taken to make sure the whole organization uses the same symbols and style in making roadmaps, to make them aligned and coherent. Also it must be known that the roadmap is a snapshot of a ‘rolling’ strategy at any moment in time and it must be therefore periodically updated so emphasizing ownership and accountability is important. Two main challenges of implementing the approach were developing the first roadmap, and maintaining the roadmap on an on-going basis (Phaal, Farrukh, & Probert, 2004). A community of practice, together with a steering group can support the development of an effective roadmapping system.

The technology roadmap is not really a decision making tool but more of an enterprise planning framework. It can give overview, development logic and the relations between all the innovation projects, products and final goals of the firm. The tool can show how the desired state in terms of where the firm wants to be. The roadmap can be the result of strategy and new ideas originated bottom-up. This tool cannot show how the current state looks like, it only shows what kind of projects you do but not the performance those projects. The TRM does shows all the other innovation projects which is the basis for comparison but as said before it only shows which projects and not the performance of those projects, the development logic in the projects can assist in deciding how to adjust the portfolio but perhaps not on its own because not all four steps of the IPPM approach are met. To summarise the technology roadmapping can help in step two and four of the conceptual model.

2.5.3 Scoring models

Scoring models or ranking models order a list of project to a set of criteria. It can rank order multiple criteria without becoming too complex. The model does not consider constrained resources, it is largely based on uncertain data and is doesn’t consider balance of projects. The difference between scoring models and ranking models is that a scoring model has measures for each criterion whereas ranking just looks at all the criteria at once and then orders the projects.

This model only shows how the current IPP state looks like and not what the desired IPP state is. Therefore it leaves implicit judgement in comparing the current state to a desired state and so it is difficult to make good decisions for effective IPPM. So this model can only assist in step one of the conceptual model.

2.5.4 Decision trees

Decision trees show the possible paths a firm can take and what the results are for each path, allowing managers to make informed decisions (Coulon, Holger, Ulrich, & Vollmoeller, 2009). Decision trees solve the problem of sequential decisions between successive decisions. This model once again only shows the current IPP state and can support further decision making through analysis of this current state, no comparison is made with a desired state so if suggestions for adjustment are made this is decided on implicit judgement. Therefore this model can only assist in step one of the conceptual model.

2.5.5 Strategic buckets

NPV calculatios tends to disfavour advanced technology due to long term pay-off or low probability of success. Inlight of these challenges, the goal of a strategi bucket is to earmark resource for radical NPD programs (Chao & Kavadias, 2008). Strategic buckets is a collection of NPD programs that are

aligned with a particular innovation strategy (Chao & Kavadias, 2008). This is a top-down strategy approach. Higher management decides according to the business strategy how they want to allocate resources into separate strategic buckets. It is a tool to ensure the right mix of innovation projects.

The buckets build fire walls between buckets by earmarking specific amount of resources for different buckets. (Cooper R. , 2006)Then per bucket a ranking of projects can be made to select projects inside a bucket. A major strength is that the firm links spending to the business strategy, so spending will reflect the strategic priorities of the firm. (Cooper & Edgett, 2001a). Another advantage of strategic buckets is that they allow in each bucket other criteria for ranking the innovation projects (Cooper, Edgett, & Kleinschmidt, 2002).

This model has the potential to indicate a desired state through assessing the business environment and the strategy which will give an indication of how the R&D budget should be allocated. This model doesn't show the current performance nor does it compare the current with the desired state. It does give direction of how to adjust the portfolio when the current state is assessed. Therefore this model can assist in step two and four of the conceptual model.

(Cooper, Edgett, & Kleinschmidt, 2001b) Compiles a list of factors that are commonly used to split R&D budget in separate buckets and it can be seen in table 2.5.2.

Table 2.5.2: Dimensions used to split R&D spending into buckets (Cooper, 2001).

Rank order	Dimensions
1	Type of market
2	Type of development: maintenance, exploratory, frontier research, systems, line extensions
3	Product Line
4	Project Magnitude: minor/major impact
5	Technology Area
6	Platform Types
7	Strategic Thrust (against strategies in the plan)
8	Competitive needs

2.5.6 Checklist

Checklist is a tool that only checks if a project has met a certain set of requirements. It has been applied to stage gate models where projects are assessed for certain criteria to see if they can be allowed to the next phase. This tool can only assess existing projects and therefore this model only can show the current IPP state, which means that this model only can assist in step one of the conceptual model.

2.5.7 Other ways to support IPPM

Other ways of supporting the portfolio system is by applying formal procedures in the innovation phase. Formal procedures can range from clear WP description to centralized stage gate reviews.

(Cooper, Edgett, & Kleinschmidt, 2004a) Indicated that the performance of the IPPM increases when the framework fits the management's style of higher management, therefore this leads to another requirement for the framework:

R9:	The new IPPM framework should fit management's style.

2.5.8 Reflection of Tools

Many tools plot all the innovation projects in one tool to see performance of the entire portfolio, in this way also new innovation projects can be added to see what their effect is on the IPP.

(Parviz & Levin, 2006) Describe that many tools still contain highly implicit judgement and from the conceptual model it can be reasoned why many tools create implicit judgement in the IPPM decision making process. It is reasoned in this theses is that many tools create implicit judgement because they only measured the current state of the IPP or only the desired state. Therefore the managers need to reason themselves how the current or desired state looks like.

In table 2.5.3 all the tools have been mapped out over the four steps as already has been discussed in section 2.6.1 until 2.6.6. The four steps of the IPPM approach described in section 2.4.1 and they are:

1) Measuring the current IPP state (plotting performance of all the current innovation projects).
2) Developing an indication of the desired IPP state,
3) Comparing the current IPP state & new possibilities for innovation projects with the desired state and
4) Decide on adjustments for the IPP state.

Table 2.5.3: Tools mapped for the four steps of IPPM approach

Type of tools	step 1: current IPP state	step 2: desired IPP state	step 3: Comparing	step 4: Adjusting current IPP	Can assess external effect of inter organization innovation activities
bubble diagrams	X				X
technology roadmaps		x		x	
Scoring models	X				X
Decision trees	X				X
Strategic buckets		x		x	X
Check Lists	X				X

As can be seen in table 2.5.3 none of the tools can assist the IPPM decision making process in all four steps and none of the tools can assist in step three on its own because no tool can help in both measuring the current and desired state such that a comparison is possible. Therefore these tools have to be combined in order be able to have all four steps and reduce the implicit judgement in the process, the use of multiple tools used is also supported by results of (Cooper, Edgett, & Kleinschmidt, 2001) where the best performing firms use of average 2.43 tools. There will always be some implicit judgement because data can be ambiguous or strategy can be ambiguous which will lead to wrong measurement of the performance of innovation projects and so wrong understanding of the current state or to a wrong indication of desired state because the strategy is interpreted in a different way than it was meant for.

2.6 Summary chapter 2A

This first part of chapter 2 focuses on the key concepts and definitions used in this report and also describes a general and rational framework from which a specific IPPM framework can be designed.

IPPM is a dynamic process where a business list of active and new R&D project is constantly updated and revised. It is a way of thinking where the portfolio is central instead of individual projects. IPPM can be described as selecting, evaluating, prioritizing and allocating resources to innovation projects, through starting new innovation projects and through continuing, accelerating, decelerating or killing existing innovation projects. This has been formulated in a conceptual model which has four steps: 1) the current innovation portfolio is measured 2) an indication of the desired IPP state should be identified 3) The current IPP state and the desired IPP state should be compared and 4) changes to the current IPP state should be made that lead to a new IPP state. When a framework can handle these four steps then in this thesis it is called an integrated framework because all steps are approached formally and this reduces implicit judgement in the decision making process. Also the decision making process should be based on evidence based decision making. The IPPM approach should ideally lead to an effective IPP which is that it balances, strategically aligns, and maximizes the value of the IPP.

Chapter 2B: Literature study, Issues to systematic IPPM framework

This chapter is a continuation of the chapter 2A. The success of the systematic method introduced in chapter 2A depends on many characteristics of the industry. This chapter will introduce some of these characteristics and in later parts of this thesis the effect of these characteristics on the IPPM framework will be investigated in more detail. The first characteristic in section 2.7 is the approach to IPPM, should it be very rational and systematic as is discussed in chapter 2A or should be informal and opportunistic. In section 2.8 technology pull vs. technology push as innovation drivers will be discussed. Then section 2.9 discusses the strategic approach of IPPM, top-down or bottom-up approach, should all projects be aligned with strategy? Section 2.10 the internal IPP is extended with inter-organizational innovation projects. Then in section 2.11 the conceptual model of section 2.4 is extended and explained. Finally section 2.12 will summarize the entire chapter (2A & 2B) by answering the first research question.

2.7 Organic vs. Systematic innovation approach, Why NOT IPPM?

Even though (Cooper, Edgett, & Kleinschmidt, 2001b) shows us that the best performing firms indicate a formal / rational method, however in reality this might not be the best method for each firm, therefore this section focuses on the issue of why not to use a formal / rational IPPM approach. This section doesn't lead directly to requirements for the new framework because it first needs to be investigated if the organic or formal approach is the best approach for firm-X, this will be done in chapter 4 where it will lead to requirement for the new framework. Also then it can be said if the previous developed requirements in chapter 2A with respect to the systematic approach are valid to use.

Robert Cooper has been one of the key contributors to the IPPM literature and has been regularly cited in this thesis as well. He is positive about the use of IPPM and in many of his works he discusses the problems firms face when they don't apply IPPM (Cooper R. G., 1999a), (Cooper, Edgett, & Kleinschmidt, 2004a) & (Cooper & Edgett, 2001a). But in his writings he doesn't discuss the advantages of not having an IPPM method or in other words he doesn't discuss the disadvantages of IPPM.

Portfolio management adds a certain amount of systematics and formality to the innovation framework. A more systematic process is less flexible and so the firm is less adaptable to dynamics of the environment or sudden opportunities. The loss in flexibility gives focus / stability of the innovation portfolio in return, especially with an industry that has a long term focus it is not good to switch too much in innovation project because that is a waste of resources. (Faems, Looy, & Debackere, 2005) State that collaborative innovation projects fail often due to lack of flexibility and adaptability, this indicates that a certain level of flexibility in the IPP is required. On the other hand (Cooper & Edgett, 2001a) states that focus (or in other words the right number of projects) is the fourth characteristic of effective IPPM and therefore this characteristic is important as well. Therefore the level of formality should be a combination of those two. Also when systematics decreases then the rationality goes down because more room is created for an opportunistic approach.

Table 2.5.1: Example of effect of formality

Less Systematic		More Systematic	
Flexibility	Up	Flexibility	Down
Focus / stability	Down	Focus / stability	Up
Rationality	Down	Rationality	Up

This discussion can be linked with the discussion about intended and emergent strategy for innovation, where intended (or top-down) strategy creates more formality in the process and for the bottom-up (emergent) strategy creates flexibility in the process. The bottom-up innovation approach is also not according to strategy alignment of Cooper who says that every project in the portfolio should be aligned with strategy.

Another point is that tools & techniques used for resource allocation range from very simple to very complex, notwithstanding there is a high degree in implicit judgement in many of these systems (Parviz & Levin, 2006).

During the design of the portfolio management framework it needs to be noticed that certain problems can occur with portfolio management so that the right precautions can be taken. The following paragraphs will address the most critical of those issues.

First of all there is an inverted U shaped relation between product portfolio complexity and firm performance. The economies of scale and scope experienced with increasing product diversity eventually diminish as strategic responses resulting from increased commercialization capabilities become inefficient (Stephanie A. Fernhaber, 2012).

Another problem that happens with portfolios is fire fighting. Fire fighting is the unplanned allocation of resources to fix problems discovered late in a product's development cycle (Repenning, 2001). Especially in portfolio with too many projects (portfolio overload) and underestimation of work packages can results in delay of work. Fire fighting at one project can result in fire fighting in other projects so fire fighting can be a self-reinforcing circle and has negative effects on employee's motivation, confusion of customers and lack of overview (Repenning, 2001).

Escalation of commitment is the difficulty in killing projects, many firms find it difficult to kill projects, the project funnel is a tunnel instead. Resources are wasted and development of the right projects goes too slow. (Gerrits, 2008) Suggest that organization could create a project tunnel only when a clear picture of the future portfolio exists. This is never the case for breakthrough innovation, therefore projects should be killed throughout the process.

Lacking of a formal method: A problem that occurs is that managers rely too much on their gut-feeling (implicit judgement) and experience instead of evidence based arguments. This can result in choosing the wrong projects and that is a waste of resources.

2.8 Technology Push vs. Pull approach for IPPM

This section discusses technology push and technology pull as an innovation driver. They are related to the technology roadmap and have already been partly discussed. This section focuses on hot the IPPM framework should deal with these two approaches from literature. Just as section 2.7 this section doesn't lead directly to requirements because if first needs to be investigated how firm-X wants to deal with this, this will be investigated in chapter 4 in more detail.

(Herstatt & Letti, 2004) Describe technology push as a situation where an emerging technology or a new combination of existing technologies provides the driving force for an innovative product and problem solution in the market place. Also they describe technology pull as a process where the product or process innovation has its origins in latent, unsatisfied customer needs in the market place. Which approach to use for which innovation projects depends on the choice of the firm. Both approaches have their own effect on the IPPM and success of the products because there is a difference in R&D investment required, technology uncertainty, development time, market uncertainty to name a few.

2.9 Top-down vs. Bottom up Innovation approach, a dialogue

During the description of the models in section 2.5 top-down and bottom-up innovation approach past by in the discussion. The two different approaches to innovation can also be described as intended strategy and emergent strategy where the combination of the two will lead to a dialogue. This section will discuss the two of them and discuss the influence on the innovation portfolio. This section doesn't lead directly to requirements for the new framework because this also needs to be investigated at firm-X how they want to deal with this and what effect that has on the IPPM framework, which will be investigated in chapter 4.

Strategy can emerge as an intended strategy or emergent strategy, where the first one is a strategy as a plan and the second one as a pattern in the absence of intention (Mintzberg, Lampel, & Quinn, 2003). It can be related to IPPM as innovation can be managed from top-down where the strategy flows down to innovations (intended strategy) or innovation can be the result of a bottom-up approach where ideas originate without relation to the strategy (emergent strategy). The combination of the two results in a dialogue which will influence strategy. The two different strategic approaches have different effects on the firm, a bottom-up approach has the effect that ideas within the firm are used to create new products because the engineers / designers know the limits of what is technical possible and can design products with features that no-one ever thought of before. On the other hand a top-down approach creates a link with the business demand, what the customer requires and what is perhaps economically feasible. The two strategy approaches give rise to questioning the statement of (Cooper, Edgett, & Kleinschmidt, 2004a) where he stated that all projects in the portfolio should be aligned with strategy.

The weakness of a top-down innovation approach is that it suffers from the Soviet syndrome: eventually, discrepancies between your plans and the realities of the world. Research has repeatedly shown that firms often stick with a strategy for too long (Terwiesh & Ulrich, 2008).

2.10 Inter-organizational Innovation activities

Another aspect that is related to IPPM is inter-organizational innovation activities. Inter-organizational innovation activity is a concept of open innovation. According to (Schakenraad, 1993) most of companies within a high-tech sector are associated with cooperative R&D activities. This section will discuss inter-organizational innovation activities for innovation projects. This aspect also needs to be investigated in more detail in the further chapter to see its effect on IPPM, therefore no requirement will be developed for the new framework in this section.

An inter-organizational network is defined as the partnerships between at least two organizations whereby their resources, capabilities, and core competencies are combined to pursue mutual interests in developing, manufacturing, or distributing goods or services (Bierly & Coombs, 2004).

The observation that interorganizational collaoration has considerable potential to contriubute to the innovation strategy of the firm does not mean that all collaborations are successful, on the contrary, estimates suggest that as many as 60% of all alliances fail (Bleeke & Ernst, 1993). Most frequently cited reasons for failure of innovation activitiess are, unintended knowledge spillovers, learning races between partners, diverging opinions on intened benefits or lack of flexibility and adaptability (Faems, Looy, & Debackere, 2005).

In many industries there is a trend towards increasing developmental cost. As a consequence, critical component suppliers may not want to finance the development process on their own and mechanisms may need to be established to finance these critical suppliers (Lange, Muller-Seits, Sydow, & Windeler, 2012). Inter-organizational innovation activities to innovate can also occur as a strategic reason. On the other hand the commitment to inter-organizational innovation activities for innovation is higher than internal projects because when the innovation does not prove useful it is more difficult to back out, or reduce resources invested. At FIRM-X a manager even told:

''All the innovation activities projects have commitment to continue because of the innovation activities but the internal projects are killed when there is some kind of cash flow problem, so there is too little financial commitment to those internal projects''.

As has been discussed in the section about the research problem the IPPM literature focuses on internal innovation projects. There is also literature about networks of innovation but this literature does not focus on IPPM. Therefore the link between those two streams could not be found in the literature. In a portfolio internal projects can be killed or deprioritized when the firms thinks it's necessary however for inter-organizational innovation activities projects this is more difficult as commitment to continue is higher due to arrangements with the other firms, penalties or loss of trust might be resulting when quitting from such innovation activities. It can of course be attempted to change the content of the R&D projects but that is a different story.

Therefore this thesis wants to investigate how tools can measure the influence of the degree of innovation activities projects on the overall performance of the portfolio, how it should be measured and visualized. Therefore this means for the new framework that the performance overview of the current state should include the effect of inter-organizational innovation activities.

2.11 Conceptual Framework Development

This section will discuss the final conceptual model, the model was already introduced in section 2.4.1. The framework will be used to understand what an integrated framework is and how to design an integrated framework for effective IPPM.

The conceptual model has been combined from the IPPM approach by Cooper and Markowitz described in section 2.4 and the three goals for effective IPPM described by (Cooper & Edgett, 2001a) (which are balance, strategy aligned and maximize value). This combination is visualized in figure 2.11.1. The model consists of four steps and when the framework encompasses all these steps than it is called an integrated framework in this thesis. The reason all these steps should be facilitated by the framework is to be able to reduce the implicit judgement of the IPPM approach. As indicate with four numbers in figure 2.11.1 the four steps are: step one: measuring the current IPP state, step two: creating an indication of the desired state, step three: comparing the current and desired IPP state and step four: suggesting adjustments to the current IPP state that will lead to a new IPP state. On top of that the framework should fit the management's style because Cooper indicated that it will be more effective when it fits management's style.

In section 2.5 from the factors for the IPPM tools it is reasoned that some of those factors are driving and other are the consequence of those driving factors. From the conceptual model in figure 2.11.1 it can be questioned how the desired state should be described by those factors, which are driving and which ones are not.

In chapter 2B four issues to the rational IPPM approach are discussed that affect the success of the IPPM approach. The first is the level formality of the approach to see what is the right approach when, the second is a technology push or pull approach because it affects the requirements down flow, thirdly a top-down or bottom-up approach that has influence on the alignment with strategy of the innovation projects and fourthly is about inter-organizational innovation activities that will affect the current IPP state and therefore all these four issues impact the design of the framework. It will be investigated in the further chapters how firm-X wants to deal with these aspects and how they then affect each step in the conceptual model, therefore they will lead to requirements in later chapters.

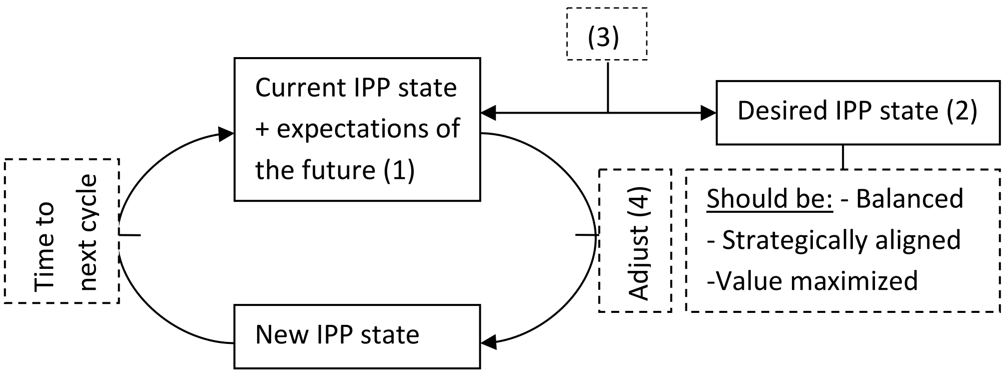


Figure 2.11.1: Conceptual framework

2.12 Answering research question 1

This section answers the first sub question of this thesis report question, which is: *What are the current state of the art IPPM tools and practices in the literature that can be used for the design of an effective IPPM framework?* The sub-question has three sub-sub questions which have been incorporated in this section. Everything in this chapter is based on a literature review. Also the requirements that can be developed from the conceptual model and the literature will be summarized in this section.

An IPPM approach can bring considerable benefits to the performance of an organizations IPP. This performance can be achieved by creating an effective and integrated framework for IPPM. An effective IPP can be created by focussing on three goals which are, balancing, value maximizing and aligning the portfolio with strategy. It has been reasoned in the conceptual model that an integrated framework can be achieved when the framework is based on four steps: 1) assessing the current IPP state, 2) indicating the desired IPP state, 3) comparing the current and desired IPP state and 4) suggesting adjustments for changing the current IPP into a new IPP state. A set of tools and factors have been identified form the literature in this chapter and it has been indicated to which of the four steps of the conceptual model each tool can assist. In this way it can be seen which tools have to be combined to get an integrated framework. This has been summarized in table 2.12.1.

Table 2.12.1 Tools mapped for the four steps of conceptual model and effect of inter-org. innovation activities.

Type of tools	step 1: current IPP state	step 2: desired IPP state	step 3: Comparing	step 4: Adjusting current IPP	Can assess external effect of inter organization innovation activities
bubble diagrams	x				X
technology roadmaps		x		x	
Scoring models	x				X
Decision trees	x				X
Strategic buckets		x		x	X
Check Lists	x				X

Many tools contain implicit judgement because they cannot create an indication of the desired state which means that the IPPM decision makers need to reason themselves what the desired state is, or the tool is based on unreliable data which depends on the implicit judgement of the manager assessing the innovation project or portfolio.

Furthermore some dimensions have been identified in the literature that affect IPPM framework. First of all the type of decision making approach affects the design of the framework and it has been indicated that an evidence and opinion based approach is the best approach for a framework for effective IPPM. Secondly it has been reasoned that a portfolio approach might not be the best solution at all times and it will a focus of this research to seek out when it is not the best approach. Thirdly the approach to top-down or bottom-up and a technology push or pull approach affect the design of the framework. Then finally it was identified that inter-organizational innovation activities have an effect on the IPPM but the literature only focuses on internal IPPM or network analysis and the connection between the two streams could not be found. During chapter 2A & 2B many requirements from the literature and the conceptual model have been developed and they have been summarized in the next box:

R1: The new IPPM framework should support an evidence based decision making approach.
R2: The new IPPM framework should be able to measure the current state of the IPP state.
R3: The new IPPM framework should be able to create in indication of desired IPP state.
R4: The new framework should reduce implicit judgement in the IPPM decision making process.
R5: The new IPPM framework should be able to compare the current and desired IPP state.
R6: The new IPPM framework should be able to indicate how to adjust the current state towards the desired state.
R7: The new IPPM framework should lead to three goals of effective IPP.
R8: The new IPPM framework should be based on reliable & quantifiable information.
R9: The new IPPM framework should fit management's style.

Chapter 3: Introducing firm-X and its Current Innovation Framework

After understanding the literature background of IPPM, the next step is to be able to understand how to design a framework for effective IPPM; and where it is also important to understand the business environment. This will be investigated at firm-X. This chapter will describe the innovation system at firm-X. The structure of this chapter is as follows first in section 3.1 the business environment will be discussed and then in section 3.2 the organization of the innovation framework at firm-X will be discussed. Then in section 3.3 the issues from the literature discussed in chapter 2B will be related to the current innovation framework. This chapter will be end with an answer to research question two in section 3.4.

The method used for this chapter to start analysing, is done by first looking at the internal documents describing the innovation framework and organization of firm-X (firm-X Aerostructure, 2012) (firm-X, 2012). After going through these reports, five interviews have been scheduled with the manager of Technology Office (TO) to understand the innovation framework better. Also the technology annual reports from 2011 and 2012 have been read to understand the strategic focus of the innovation portfolio (firm-X, 2011) (firm-X, 2012). Then the overview of the R&D budget has been created by assessing all the descriptions of all the innovation projects and improvement agenda projects and current technology roadmaps. Also individual interviews have been executed with Key Technology Managers (KTM's), Product Group Managers (PGM's) to discuss the framework used for the current technology roadmaps and how it can be improved.

3.1 Business environment

firm-X is inside the industry of firm-X. The technology development cycles of new products in this industry can take years until decades. Because it takes so long, volatility in the environment can influence the success of innovations. Researchers (Cozijnsen, Vrakking, & Ijzerloo, 2000) argue that only one out of every five projects ever initiated is viable, and that in this combination (with the long development cycles and the expensive full scale testing) shows that it is important to select the right innovation projects for the survival of these firms, because these firms are much affected if the wrong choices are made. The major performance criteria are quite well known, where products needs to be lighter, cheaper and easier to produce with less maintenance during product life cycle and maintaining quality levels. Due to these characteristics and because the OEM's state quite clearly when they are launching new programs; planning the innovation development can make the innovation process understandable and can gives direction to which innovations to follow and when to finish them.

These days there is a shift occurring, where the focus from developing an as light as possible airplane is changing to cost reductions, sometimes even weight reductions are omitted in order to make the product cheaper. The industry of firm-X organized technology by three main characteristics: 1) product group, 2) technology and 3) volume, these three are always combined during development and design. They have major influence on design, manufacturing and financing of the product for both FIRM-X and the customer. Therefore these factors come back in how the organization is structured and so it comes back in the design, but it is also the way the customer understands the business. E.g. a certain technology can lead to different design methodologies when applied to a different product group, the volume has big influence on how it will be produced, and the bigger the volume the more automation is necessary.

3.2 Current Innovation Organization of firm-X

Firm-X innovation management states that it focuses on strategic direction, speed and results (firm-X, 2012), but in reality the strategic direction might be rather limited due to the opportunistic approach of firm-X. This section focuses how firm-X currently organizes its innovation process. First the R&D budget is discussed, followed by the organization of innovation, and thirdly the innovation strategy is discussed. Lastly, the technology roadmap will be discussed and then this section is summarized with all the factors and tools that are used in the current innovation framework.

3.2.1 Firm-X R&D budget

At the moment, FIRM-X has 18 formally financed R&D projects. 15 out of these 18 projects are inter-organizational innovation activity projects (Appendix D), those innovation activities may be in collaboration with other firms or with sources of funding. Besides the formal projects, there is time available for every employee to work on their own ideas but after certain time spend on the project a project description has to be filed on which it will be decided if the project may continue.

The source of innovation is the available budget, where firm-X innovation budget is consists of three parts, 1) the regular R&D budget, 2) the budget for the improvement agenda, and 3) memberships fees for innovation organisations (such as FMLC, TPRC and M2I). Members of firm-X indicated that the term R&D can sometimes be ambiguous, as R&D stands for Research and Development. The development part focuses of product development, which at firm-X is not a part of innovation. Therefore a better term would be Research & Technology (R&T), however, the general term in the business world is R&D.

In table 3.2.1, it can be seen that the total R&D budget is XXX k€, which consist of an R&D budget and membership fees to some research institutes. Then there is a special budget for an improvement agenda (XXXX k€) but this is not part of R&D so not included in the R&D budget. The R&D budget is roughly 1.05% of net sales, which is below the industry average which is 3.8% (Jaruzelski, Dehoff, & Bordia , 2005). The money used for R&D is the membership fees and the R&D budget which results in XXXX k€, from this budget XX% is spend on inter-organizational innovation projects, and this increases the effective R&D budget is XXXX k€ which is a multiplication of XXX times the R&D budget. This number has been calculated by formula 3.2.1, dividing the total innovation project cost for each innovation project by the number of years it is running (so it is assumed that the cost per year is the same). This effective R&D budget of XX million is the budget that firm-X can some influence, but doing so does not mean all the research will be useful to firm-X. From this XX million XX% comes through subsidy and working together with other firms, the remaining XX% is the R&D budget from firm-X. This XX a high percentage compared to other firms, for example, Embraer on average has 36 per cent over the year 2004 until 2011 (Diepeveen, 2013) and General Dynamics comes to an average of XX per cent over the years 2007-2012 (Noordman, 2013). For firm-X this is a good way to increase its innovation budget, for the benchmark data see appendix C.

$$inter - organizational\ innovation\ budget = \sum_{n=1}^{k} \frac{Total\ innovation\ budget_n}{\#\ of\ execution\ year_n} \quad 3.2.1$$

$$budget\ multiplier = \frac{inter-organizatinal\ innovation\ budget}{Total\ R\&D\ budget\ (which\ is\ R\&D\ budget+membership\ fees)} = \frac{inter-organizational\ innovation\ budget}{3{,}529}\ [k€] \quad 3.2.2$$

Where k = the number of innovation project in the IPP

The subsidy granted to firm-X by the government in R&D budget is XXX k€. In the Netherlands, there is almost no subsidy available anymore; because, the government offers revolving funds, which means when innovation is going to be marketed, the fund needs to be paid back. Firm-X also received money from the government for every hour spent on innovation, but that money goes into the full profit loss account of firm-X, so it is not directly added to the R&D budget. The numbers in table 3.2.1 have been calculated by assessing all the individual innovation projects descriptions and summing up the numbers, an overview of the projects that lead to these results can be found in Appendix D.

Table 3.2.1: Financial overview of innovation portfolio, generated at firm-X, THE RESULTS HAVE BEEN SCRAMMBLED FOR PROTECTION OF FIRM-X.

For year 2013	k€	k€
R&D budget	€ XXXX	
Membership fees	€ XXX	+
Total R&D budget		XXXX
Part of R&D budget received through funding	€ XXX	
Total firm-X spending on inter-organizational innovation activities projects	€ XXXX	XX [%]
Internal project spending	€ XXXX	XX[%]
Total innovation budget (including innovation activities and subsidies)		€ XXXX
Multiplier of R&D budget through innovation activities and subsidy in the portfolio by R&D budget firm-X [no unit]		XXX [-]

3.2.2 Innovation Organization of firm-X

The three main characteristics of the business environment in the industry of firm-X as described in the former section are: 1) Key Technology, 2) Product Group and 3) Volume, in this paragraph it will be explained how this is organized at firm-X. It is based on open interviews with the manager of T) and (firm-X, 2012) (firm-X, 2012). The three characteristics have major influence on the design, the manufacturing process and the materials used (which is the golden triangle for designing structures). For example different key technologies require different designs or methodologies, each product has specific requirements that can be grouped and the volume aspect influences the manufacturing process.

To start with the first characteristic, firm-X has four key technologies recognized by their customers as differentiation from other aero-structures companies in the world, which are: 1) Fibre metal laminate (FML), 2) Thermoplastic composites (TP) 3) metal bonding (MB) and 4) thermoset composites (TS). These key technologies are the main innovation areas and, are together with Base Technologies (technologies already developed), applied in the products groups (PG). These PG's are the second characteristic of the business environment and they design the products. The PG is divided in three groups of airplane parts that are similar in design, they are: Tails and Wings (T&W), Movables & Doors (M&D) and Fuselages (F) and they design the product. The PG's supports the business lines (BL's) which sell the product, do the marketing & sales and is aided in this process by the R&D department of FIRM-X. The Business lines are the different markets that firm-X is focussing on, firm-X has six business lines and they are: Large Commercial, Defence Europe, Defence EU, Special Products, Business Jets, and Asia. In some documents Firm-Y is seen as the seventh BL. The BL's indicate the different markets and so indicate the different volumes that need to be produced per product.

Table 3.2.2: Double matrix organization of firm-X, there is no content added in the table, it is just to show the structure.

	BL: Commercial			BL: Defense			BL: Gears			BL: SP		
	T&W	M&D	F	T&W	M&D	F	T&W	M&D	F	T&W	M&D	F
TS												
TP												
FML												
MB												

T&W: Tools & Wings
M&D: Movables & Door
F: Fuselages

TS: Thermo Set
TP: Thermo Plast
FML: Fibre Metal Laminate

MB: Metal Bonding

Before continuing the story about the innovation organization another topic is first briefly introduced which are the Technology readiness Levels (TRL). TRL is a common standard with a nine point scale to assess technology maturity on a certain set of criterions. It is based on the NASA system, which introduced the concept in 1995. In this way it is known how mature the technology is, what still needs to be done and an indication can be given of how much money & time is necessary to finish the innovation project. In other words, it is an indication how far the project is in the innovation project funnel. There is a distinction between project newness and TRL; which is that project newness is a measure of how radical the innovation is, and TRL is a measure of technology maturity, e.g. an incremental innovation can still have a low TRL level while the newness is not so high.

In Appendix A the TRL definition for firm-X is included for completeness. A difficulty in the approach is that for every criterion another TRL Level can be identified, and sometimes even some higher level can be executed while some lower layers are still not met all for the same criterion. This makes it difficult to really give one value to the Technology. How to solve this problem is up to firm-X and is left out of the scope of this thesis. The head of TO indicated during an interview certain cost drivers should be identified to find out what is most costly to innovate and that could be a measure to indicate at which TRL level a certain technology is.

Now the TRL is explained is can be discussed how the TRL is divided over the firm-X organization, which can be found in figure 2.1.1b. PG's in combination with the KT's are in charge of the innovation. In many cases FIRM-X relies on external parties for their developments firm-X, as they say firm-X is the integrator of innovations. Innovations at FIRM-X are currently developed for technology readiness level (TRL) of 6, which means technology is developed until: System/subsystem model or prototyping demonstration in a relevant end-to-end environment. The R&D department is in charge of the innovation during TRL 1-4, for TRL 5-6 the PG's are in charge of the innovations as it is more related to real products. From TRL level six firm-X is confident enough to sell the technology without having much cost to make the technology work. From that moment the business lines will take it over to bring it to TRL level 8 or 9, but they can only start when the technology is sold in a products otherwise the technology development is not continued. In appendix A, a specification of the TRL measurement and division of TRL can be found. Table 3.2.2 is a visualization of the matrix structure the firm-X has, the PG's (horizontal axis) support each BL and per PG with KT (vertical axis) combination products are designed.

Another part of the innovation organization at firm-X is the value chain. This can be divided into roughly four groups related to innovation, and they are: 1) material development, 2) technology / concept development, 3) supporting technology development and 4) manufacturing / assembly technology. Each group has its own added value to the firm.

3.2.3 Innovation Strategy

Firm-X has an innovation strategy that has four key elements which are built around the concept of 'Crafting' which firm-X calls it's unique knowledge of integrator experience. The strategy focuses on customer focus, one billion in revenues to be able to invest in large programs and to stay a tier 1 supplier. Next firm-X is globally focused with subsidiaries in China, India, Singapore, Romania, and Brazil. Last but not least firm-X focused on innovative solutions or as they call it 'super specialist'; where 'specialist' focuses on the specialist knowledge that firm-X has in the key technologies, and 'super' because they are the only firm in the industry that has integrator knowledge.

The innovation strategy at firm-X is documented (see appendix D). Most employees know the corporate 4 strategic goals but the innovation strategy is not so well-known.

The innovation strategy can be summarized as: *''through new, disruptive technologies firm-X fulfils its customer requirements. Firm-X focuses on 1) customer orientation, 2) innovation leadership, and 3) product orientation. Driven by distinctive technologies and early customer involvement firm-X focuses on most complex, integrated structures by penetrating the high volume segment of the market of firm-X (accelerated, autonomous growth, go-to-market strategy). Distinctive innovations are supported through in house methods, Knowledge Based Engineering (KBE) tools and industrial application methods, assuring a shortened time to market and guaranteed robust introduction of technologies (process innovation, life cycle management). Firm-X therefore, continuously invests in improvement of its key technologies. The approach is based on co-development, partnerships and open innovation (open innovation, funding), to ensure maximum value for its investments''* (firm-X, 2012)

The increasing global competition reduces profit margins also on top of that firm-X has a relatively low innovation budget only 1.8 per cent of the revenues. These two facts require a new business model as visualized in figure 3.2.1. This is why firm-X is practicing open innovation through licensing, collaborating and funding frameworks. FIRM-X wants to develop technologies towards all the major aircraft manufacturers. Before a technology can be used on big programs (such as for Airbus or Boeing), it will be launched on smaller programs (like business jets or helicopters).

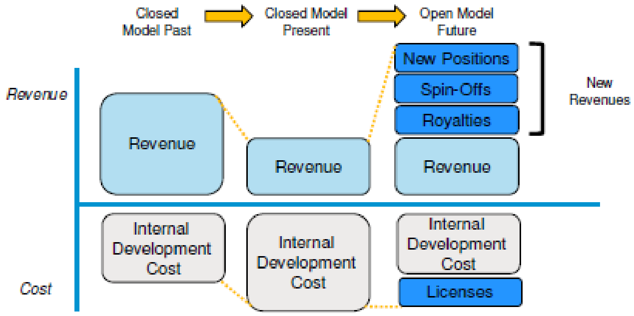


Figure 3.2.1 Revenue model the industry of firm-X, Source: internal documents at firm-X.

3.2.4 Framework for excellent innovation management

firm-X has a framework for innovation management and they call it their excellent innovation management framework which is visualized in figure 3.2.3 based on (firm-X, 2012). It consist of three layers; in the top layer the Business Lines investigate what the position is of the technologies of firm-X in the marker, what needs to be developed and what the options are from market view. Then in the second layer the innovation projects are managed, the TO fill the innovation fnnel and assesses each projects (TRL assessments, etc). Finally the third layer focuses on the individual project management, where it follows the progress of the projects, and supports the daily management.

This framework for excellent innovation can be measured with five levers which are 1) Innovation strategy, 2) innovation portfolio, 3) innovation efficiency & speed, 4) innovation results/profitability, and 5) innovation organization and culture. The levers can be visualized together in a spin diagram, an example is shown in figure 3.2.2, the technology annual report doesn't state about this diagram at all, so how much this is really used can be questioned. Lever 1 & 5 focus on the context / conditions for successful innovation, lever 2 focuses on the portfolio of initiatives to achieve breakthroughs, lever 3 focuses on the effective execution and opportunities for acceleration and lever 4 focus the effective introduction and management of maturity.

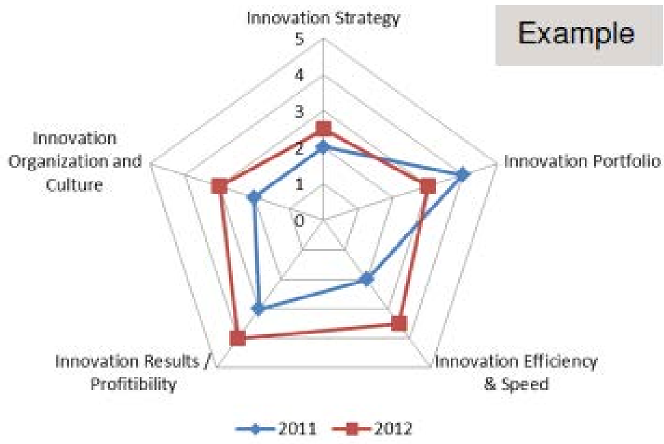


Figure 3.2.2: Spin diagram of excellent innovation management levers: source internal document from firm-X

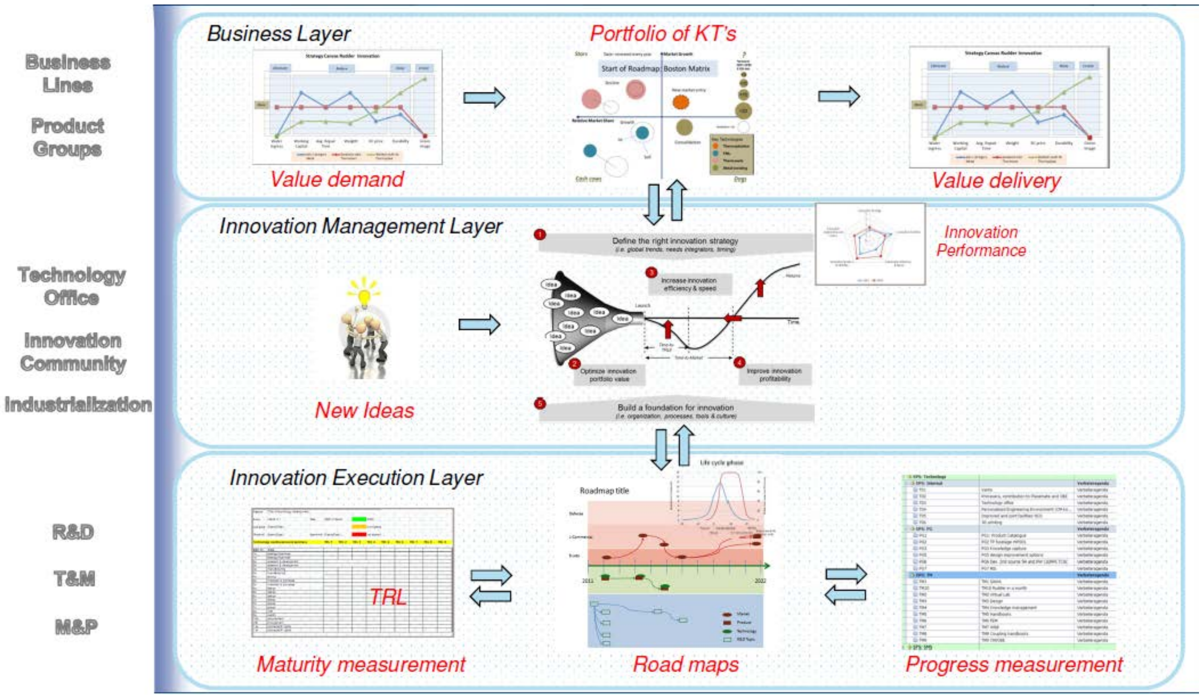


Figure 3.2.3: Framework for Excellent Innovation Management

3.2.5 Current Technology Roadmaps used at firm-X

This section will discuss the current technology road-mapping framework with its problems and will also discuss the possible changes made to these roadmaps that have been approved by firm-X. It is based on open interviews with KTM's, PGM's and the manager of TO.

Current situation:

Firm-X at the moment has 13 TRM's where 6 are focused specifically on 6 technologies and another 7 for T&M which is the internal development department for supporting programs for firm-X, an example of 2 roadmaps can be found in Appendix B.

In the old system there are three criteria / rules for TRM, and they are:

- Only items on a roadmap that already are being funded or have commitment to be funded
- All other subjects, project proposals and ideas are shown in the funnel but not on a roadmap
- Proposals to be written are on a list managed by the technology office based on the funnel

The roadmaps are based on the BCG matrix and for every technology that is specified in the BCG matrix ideally there should be a TRM but at the moment that is only available for 6 major technologies.

Problems with current TRM:

The technology roadmapping framework currently in use has some problems and is not really used to much. Therefore this section states the major problems of the roadmapping framework which will lead to a new design in chapter 5. The problems have been identified by open interviews with all the KTM's and PGM's, the interviews have mostly been led by the manager of the TO.

The first reason is that TRM doesn't clearly state which PG or KT should do the innovation so there is not an easy link with the organization of firm-X. Secondly, the roadmaps are difficult to understand and are not really used because the TRM doesn't specify TRL or time indication, duration of innovation projects or the link between the products and innovation projects. In addition, the TRM also does not indicate what kind of innovation it is (is it material level, integration or assembly level, etc.). Because of the three criteria the TRM only shows innovation projects that are funded but doesn't show projects that should be done in the future and is therefore not an enterprise planning tool. When innovation projects shown that are not funded then the roadmap can do what it is meant for and show multiple roads to the goals of the firm. Another point of attention of the TRM is that at the moment the content of the TRM is solely inspired on a bottom-up approach. Because of that bottom-up approach a clear direction is not visible in the TRM.

3.2.8 Factors and Tools used in the current innovation framework

Firm-X always had a strong focus on technology even during their bankruptcy they knew that that would be force that will create new opportunities. This drive pushed them to stay innovative, but besides this approach, the project selection of innovation projects was the result of opportunism and what seemed good at first; later on showed that reviews on innovation projects were hardly executed and that will lead to the off balance of the innovation project portfolio. In this section the tools currently used at firm-X will shortly be discussed.

From internal documents the following set of tools were found to be present at firm-X, some of them are applied others are just present or just sometimes.

Tools used at firm-X:

- SWOT analysis of IPP at firm-X: This method looks at the strengths, weaknesses, opportunities and threats of the IPP. This tool is focused on the entire IPP and not at individual projects.
- Excellent innovation management framework: This tool as described in the former section measures the excellence of the management framework for innovation.
- BCG-matrix: The BCG matrix plots the relative market share vs. market growth for the main technologies. According to head of TO this data is the result of guessing and not of in depth analysis.
- Innovation canvas: The innovation canvas is a visualization of different properties for specific product & KT combination and shows if those properties should be eliminated, reduced, raised or created. This tool then shows the user ideas for creating new innovations.
- TRL measurements: TRL levels have been discussed before, in short it is a measure of the maturity of a technology.
- TRM: The TRM has been discussed before as well, it is a enterprise planning framework.
- Project Funnel: The project funnel is a visualization of innovation projects over the different innovation phases.
- Primavera: Is a project management tool that is used for projects in product development to measure and manage: progress, timing, resource management.
- Flightmap: Flight map is an innovation project management tool that can map innovation projects for several factors, such as: NPV, Risk, strategic score, customer value driver, business unit, market unit, actual stage, type of market, cost. Many of these factors have not got any rationale behind it, so it has not been based upon some solid data, but only data from the innovation project manager, therefore the use of this data for IPPM can give a wrong indication. It van even be used to manipulate the data to give some projects more importance to make sure it is chosen and therefore these factors are not used.

The factors indicated in the tools just described are the following:

- Type of PG indication
- Type of technology indication
- Volume of the product
- Relative market share of the technology
- Market growth of technology or products
- NPV
- Risk
- Strategic score
- Customer value driver
- Actual stage
- TRL measurements
- Cost of innovation projects

Following requirement 8 which says the new IPPM framework should be based on reliable and quantifiable information, therefore the list of factors at firm-X can be reduced to a set that gives this reliable data. This limited set of factors is not a general requirement that says it has to be used for a general framework but it can be used for the framework at FIRM-X therefore the following set of factors can be used for the design of the new framework.

Type of factors from FAe for reliable information:

- Type of PG indication
- Type of technology indication
- Volume of the product
- TRL measurements
- (Allocated) Cost of innovation projects

The five levers of the excellent innovation framework are not added in this list, because they focus on measuring the quality of the innovation management framework; and so don't directly measure the IPP performance for IPPM. The current system uses a lot of factors, but the quality of that data remains questionable, e.g. relative market share is based on estimation.

3.3 Issues from IPPM literature discussed for the current IPPM framework

This section discusses the issues introduced in chapter 2B but in this case with respect to the current innovation framework. In section 3.3.1 the current approach whether it is organic or systematic will be discussed, in the next two sections technology push vs. pull and the top-down vs. bottom-up approach of the current innovation framework will be discussed and then the inter-organizational aspect will be discussed in section 3.3.4. Then this section ends with summarizing the problems of the current innovation framework.

3.3.1 Organic vs. Systematic approach in current innovation framework

Firm-X has an opportunistic approach where the focus of projects selection is on individual characteristics of the innovation projects. The inter-relation between projects is not assessed. But also comparing projects in different stages is not done because that is not possible in an individual projects selection method. Firm-X has many inter-organizational innovation projects and that is also the result of an opportunistic approach, which was discussed with the manager of TO. Projects have been chosen because the opportunity passed by, so this can be seen as an organic approach to managing innovation.

3.3.2 Technology push vs. pull in current innovation framework

It is difficult to say if firm-X has a more technology push or technology pull approach, because the products are specific for each customer therefore what for one customer is push can be pull for another customer. So what can be said is that it is a combination of the two.

3.3.3 Top down vs. bottom-up in current innovation framework

At the moment, the approach at FIRM-X is merely a bottom-up approach, where many ideas from engineers have led to a diversified portfolio of technology capabilities that drives firm-X; however there is a big difference in the maturity of each technology.

3.3.4 Inter-organizational innovation activities in current innovation framework

At FIRM-X many projects are executed in inter-organizational innovation activities, and are mainly projects that need considerable research; so sharing the cost of research allows FIRM-X to get the required research done with considerable small R&D budget of only 1.05% of the revenues. Other reasons to collaborate are due to a strategic reason, to get closer to the customer or work better together in the value chain.

Most innovation activities programs are low TRL level technology innovation projects or are industry wide problems; such as chromium free processes in 2014 because of policy restrictions. The inter organizational innovation activities programs are the result of the opportunity to work closer with the customer, prepare with other in the value chain, reduce R&D cost of projects by sharing the cost and risk, or a combination of these arguments.

During open interviews, it was observed that a lot of innovations are also done in the product groups. In addition, when a technology is applied to the product, the implementation phase of technology of a product or process can result in innovative solutions for both technology and process. This is mostly not done in any form of inter-organizational innovation activities because, it is firm-X specific technology but important is that these innovations developed in product groups is not part of the R&D budget but part of the Non-Recurring Cost (NRC) of a specific product. Therefore, the innovation budget is larger than only the R&D budget.

Firm-X has a number of partnerships in which it gives money and the procedure to do research is formal and clear and because of that it has a good chance of succeeding, especially because those partnerships exist for a number of years already. Firm-X creates partnerships with customers and or firms in the value chain; it does not collaborate with competitors otherwise, innovation activities leads to more competition.

Industry roadmap gap filling occurs in inter-organizational innovation activities. Radical technologies are developed together to reduce uncertainty, risk, and the cost of development; while also to stay strong as a cluster which can be seen as a strategic reason. Together the whole roadmap will be filled and also innovation activities from the final customer is sought to create commitment to the technology from the customer to apply the technology in the products.

The inter-organizational innovation activities enlarge the R&D budget as explained in section 3.2.1. This increase in R&D money has its effect on the balance of the IPP and therefore the effect of the inter-organizational innovation activities should be measured in the current state (first step of conceptual model) in order to balance the IPP. This leads to a next requirement:

R10: The measurement of the current IPP state should include the effect of inter-organizational innovation activities to get a better overview of the IPP performance.

3.3.5 Problems IPPM framework

Now the problems of the TRM have been discussed the problems of the innovation project selection framework will be discussed.

The selection of the innovation projects happens on individual project characteristics and so there is no portfolio mind set. Innovation projects are not compared to each other and it results in a very opportunistic portfolio that has no clear direction with the strategy. On top of that many projects are sold too early to the customer before the technology is actually mature. But a good step forward has already been taken by incorporating TRL measurement in a formal setting to see the state of each project. At the moment this TRL measurement has only been executed for a few innovation projects resulting in unexpected low TRL assessments. Selling the technology too early results in shifting the innovation to the non-recurring phase of a project and that leads to cost overrun due to unexpected innovation cost, time over run and fire fighting in the projects. Because there is no clear connection with the strategy there is no real development logic in the portfolio and that result in to little down flow of requirements. Then finally because there is no portfolio mind set and many tools that use unreliable data the selection process of projects has a lot of implicit judgement. This has been summarized in short:

- No IPPM framework
- No links between strategy and innovation projects
- Projects take too long
- Fire fighting in current projects
- No development logic among innovation projects
- No down flow of requirements from customer to innovation projects, or to design
- Implicit judgement in selecting innovation projects and allocating resources

These problems have a basis for the start of this research and many of the previous requirements but also some new requirements can be added.

R11:	The new IPPM framework should clearly create development logic between the different set of innovation projects.
R12:	The new IPPM framework should facilitate in a better down flow of requirements

3.4 Answering research question-2

This section will answer research sub-question 2: *What is the current situation of the innovation system at firm-X* (the sub-sub-questions have been incorporated in the answer)? This section discusses therefore the current state of the innovation framework used at firm-X and also discusses the TRM framework. Also the requirements that have been developed in this chapter are summarised here.

The innovation organization is dependent on the business environment, and can be characterized as having long development cycles and R&D intensive due to expensive full scale testing. On top of that firm-X has compared to the industry a limited R&D budget of 1.05% of the revenues. With these mechanisms it is important for firm-X to select the right innovation projects for the long term survival of the firm. However through inter-organizational innovation activities this R&D budget is increased 9.15 times to over xx million euro which can be affected by firm-X.

The number of customers in the industry of firm-X and their products are limited and therefore most opportunities can be identified long before they become reality and this can help to sketch a rough future that can be used for planning and decision making. The current state of the innovation system as it is used in firm-X can be described as opportunistic and focused on individual project selection so the portfolio approach is not central, therefore the goals for effective IPPM are not managed at all. The industry is quite stable due to its long term focus and some requirements don't change, and they are: Products need to be lighter, cheaper, and easier to produce (with less maintenance and keeping quality levels high). Also the industry works with three important characteristics, they are: product group (PG), Key Technology (KT), and Volume are always together because they influence each other and have major effect on the innovations, design, manufacturing and materials used for the products. Firm-X has no clear link with strategy as a result of their opportunistic approach. Also firm-X often sells the technology before TRL 6 which leads to innovation to be required in the non-recurring phase of product development; where this results in fire fighting, cost overrun and delay.

Several tools that are used at the moment at firm-X are: technology road-mapping, technology readiness level measurements, SWOT analysis, an innovation canvas, a project management tool is available but not used and there is a measurement framework for measuring the excellence of the innovation performance. These tools indicate a set of factors that are key to the industry, or key to the innovation projects. These factors are scoped for reliable information and they are summarized here together with two requirements developed in this chapter for the new framework, and they are:

Type of factors from FAe for reliable information that can be used:

- Type of PG indication
- Type of technology indication
- Volume of the product
- TRL measurements
- (Allocated) Cost of innovation projects

R11: The new IPPM framework should clearly create development logic between the different set of innovation projects.

R12: The new IPPM framework should facilitate in a better down flow of requirements

Chapter 4: Stakeholder Analysis and Interviews at firm-X

This chapter looks at the people that have to work with the innovation framework, they have to work with it and therefore their input is important for the design of the new IPPM framework and for its success. First, a stakeholder mapping is executed to understand what groups are related to the innovation system and which individuals are related to those groups. In the second stage, the semi-structured interviews have been executed among members of the innovation organization to understand their views on different aspects of the IPPM. And, during the second round of interviews, details of the first round of interviews have been discussed. This chapter concludes by answering research question three.

4.1 Stakeholder Analysis Approach

The IPPM decision making process has many stakeholders. This section will discuss the organization of these stakeholders, explain their positions, relation to others and their interests.

According to (Pitman, Strategic management: a stakeholder approach, 1984) a stakeholder in an organization is (by definition) any group or individual who can affect or is affected by the achievement of the organization's objectives, (Varvasovszky & Brugha, How to do (or not to do)... A stakeholder analysis, 2000) add that a stakeholder also has an interest in the issue. The purpose of doing a stakeholder analysis, is to understand how the complex innovation project portfolio management decision making process comes about and from that understanding increase the performance of the innovation portfolio. The IPPM decision making process is a foremost internal business and therefore the stakeholder analysis shall therefore be internal as well except for the part of inter-organizational innovation activities. Here it will be attempted to find the influence of the firms/institutes firm-X works together with on the innovation project portfolio.

Authors (Varvasovszky & Brugha, How to do (or not to do)... A stakeholder analysis, 2000) explain how to do stakeholder analysis; the first step is to identify different component of the policy issue or problem. The second step is to map the positions of the actors in relation to the issue as well to each other. The issue under investigation is the IPPM, how to balance, align with strategy and maximize the value of the IPP. As described in the definition of IPPM in section 2.2 there are a set of tasks that can be undertaken for effective IPPM, this is composed together in figure 2.4.1. During the stakeholder analysis, it is important to find out what the effect of each stakeholder is on the IPPM tasks, possible portfolio choices and the effect of the results on each stakeholder.

4.2 Stakeholder Identification by Organizational Structure of firm-X

This section will discuss the organizational structure of firm-X and will try to identify the stakeholders, the relations amongst them. In section 4.3, the stakeholder analysis of this section will be extended with interviews where the perception of some individual stakeholders will be analysed.

In the following paragraphs, the stakeholders identified that have some relation with innovation, R&D etc. to see their position and interest towards the IPPM decision making process.

Executive Board FIRM-X Technologies:
The executive board is the highest management layer at FIRM-X Technologies, it has an overview on all the FIRM-X firms and wants to make it a growing successful company where all the FIRM-X companies are working together in delivering airplane parts, they call it 'Crafting' and they have the statement "Crafting is greater than the sum of its parts" (FIRM-X Technologies, 2013). The executive board approves the strategic direction of all the FIRM-X companies and divides the R&D budget among the firms. The executive board consists of members of each of the four FIRM-X firms and a few staff members.

Firm-X & firm-Y Management Team:
One layer below the executive board is the Management Team (MT) of firm-X and firm-Y. This group consists only of members from firm-X & the CEO, six in total. Firm Y is managed together with firm-X because firm-Y is quite small and related to firm-X. This group develops the strategic direction and operational guidance to firm-X. Because most of the departments of firm-X are present in this meeting it has a combination of bottom-up and top-down views towards innovation.

Business Lines (BL):
Firm-X consists of six BL's as discussed in section 3.2, this is a management group basically doing the marketing, they discuss with customers about the products and opportunities. These members have a top-down view of what the customer wants. They discuss with the high level management of the customers and arrange the proposals and contracts.

Technology Steering Committee (TSC):
The TSC is the group that develops the R&D strategy for firm-X; and it consists of Key Technology Managers (KTM's), Product Group Managers (PGM's), industrialization director, CTO and Material and Processes manager. The members of this group all have a bottom-up view to technology, except for the chairman, who wishes to combine it with more top-down view. This group meets every 3 to 4 months to discuss strategy and approves the IPPM decisions made by TO.

Supportive departments a top-level:
The supportive department at FIRM-X Technology level (the overseeing firm of all the smaller, specialized FIRM-X firms) contains Public Affairs and Brussels Office. These two departments contain one person, who has no affinity with engineering, but supports the business of FT with mostly financing opportunities for the innovation projects. The power is very limited and they do not have a top-down nor bottom-up view with respect to the innovation approach.

Supportive department at firm-X level:
These supportive departments are organized at firm-X level and consist of the patent department, finance department and the legal department. These supportive departments don't have much influence or power on the IPPM, they advise on problems.

Technology Office (TO):
All the members who are in the TO, are also in TSC. The TO consists of a chairman, the head of technology, the head of PG's & KTM's. Their tasks are to translate roadmap plans into actions and monitoring the progress. They also manage the external innovation projects as well as that they are the focal point for obtaining subsidies and discuss critical & complex operational issues.

Tools & Methods (T&M):
Tools & Methods is a department in FIRM-X which develops tools and methods for firm-X internally. They mostly work on projects of the improvement program, which contains many incremental innovation projects of the improvement agenda (none of, which are not part of R&D budget). The power and influence of this group on the IPPM is therefore not big. But, if they execute their work correctly they can reduce cost of design significantly.

Product Group Managers (PGM's):
There are three PGM's who oversee the product groups, the PG develop the technology from TRL 4 to 6, in this area the customer requirements should already be more specific and therefore they have a more market view towards innovation. The budget is spent the same as for the lower TRL projects, by allocating resources or time for people to work on the innovation projects.

Key technology Managers (KTM's):
There are three KTM and four key technologies (or KT's), because one KTM oversees two KT's. They are the focal point for all the R&D projects related to their Key Technology from TRL 1-4. These people hear form the engineers about all kinds of opportunities. Those engineers talk to the customer's engineers, thus bringing new information about opportunities to firm-X. This group has a bottom-up approach to innovation, and it is in this group that most of the new ideas for R&D projects are developed.

Innovation community:
This group consists of ±30 members, It should fill the innovation funnel with new ideas. This is executed through LIFT (Lets Innovate FIRM-X Together) a program for improvements at own and SIP (Sustainable Innovation Platform).

Reflection of Stakeholder Identification:
The organizational structure of firm-X showes that there is a group of people that comes back in many groups related to the innovation system. These people are the: KTM's, PGM's, BLM's and some individuals such as the head of PG's, head of TO and the MT. This group of people will as such form an interesting group for the individual interviews, because they know what is going on in all the different parts of the organization.

The structure also indicates a certain group which can do portfolio decision making, because these groups are already present it will make implementation easier. The groups are the TSC for the big lines meet every three months, as well as arrange a meeting with the TO for the short term changes.

4.3 Interviews

In Chapter 2 the literature suggested some requirements for the design of the IPPM framework. The design of the IPPM framework will also be influenced by industry specific requirements and firm specific requirements. Through semi-structured interviews with managers from firm-X it is attempted to obtain and understand these requirements and combine them with the requirements from literature to come to a design for the IPPM framework. The first four questions are focussed on the perceptions of the respondents to IPPM, the other questions are directly related to managing the IPPM. The aspects discussed (in order of execution) during the interviews are:

Table 4.3.1: Interview topics discussed before in this report

Interview question	Interview question	Discussed in section
1	Organic vs. Systematic Approach	2.7 & 3.3.1
2	Technology push vs. Technology pull	2.8 & 3.3.2
3	Top-down vs. Bottom-up innovation approach	2.9 & 3.3.3
4	Long term vs. Short term focus	2.10
5	Innovation budget over TRL	2.1 & 3.2.2
6	Innovation budget division over the value chain	3.2.2
7	Type of criteria for measuring IPP performance	2.4.7 & 3.3
8	Balance the IPP	2.4.5
9	Maximize value	2.4.4
10	Inter-organizational innovation activities	2.4.3 & 3.3.4

1) Organic vs. systematic approach towards IPPM (formal vs. informal approach): The approach of the IPPM framework can be at one end of the spectrum very organic and free, where there is room for opportunistic behaviour, and at the other end it can be very systematic and formal with many procedures. The advantages and disadvantages of both approaches have been discussed in section 2.4 and 2.5. This question investigates where firm-X should be in this spectrum and for what for reasons. During the interviews it will be investigated when which approach is most suitable, which one will fit firm-X best when keeping in mind the strategic goals of the firm and what is the effect on the design of the IPPM framework. The relevance of this question is to find out if a organic or systematic IPPM approach is the right way forward for firm-X. Also from interviews it can be investigated which approach gives what effect on the design of the framework.
2) Technology pull & push: As is indicated in chapter 2.8 technology push and pull are two approaches driving innovation and bringing products to the market. Those different approaches lead to different ways in getting requirements and goals for the innovation projects. Therefore it is investigated what kind of approach should be used, and what the effect each approach has on the IPPM.
3) Top-down vs. Bottom up innovation approach: (Cooper & Edgett, 2001) Describe that all projects should be in line with strategy, but is that really so? It can sometimes be difficult to say if a bottom-up innovation project fits to strategy if it is a very new idea or sometimes a strategy is to vague that simply every innovation project will fit with the strategy. So it this question has to do with the view from Cooper about all projects being in line with the strategy. It can also be a part of definition because (Cooper & Edgett, 2001a) describes bottom-up innovation as a process where 'good decision on individual projects, and portfolio will take care of itself'. However (Terwiesh & Ulrich, 2008) state bottom-up innovation 'using innovation to redefine strategy' meaning that not all project are in line with the strategy, so this question focuses on how to deal with these two approaches in the framework.
4) Long term vs. short term focus: The industry of firm-X is characterized by long term development cycles as indicated in chapter 3.1, therefore what is the effect on IPPM decision making process? Does a long term industry with a systematic approach or with an opportunistic approach work better?

5) Innovation budget division over the TRL: The innovation project funnel of section 2.3.2 indicates the amount of project during the development stages until a new product can be designed. A TRL measurement is a concept to measure how far the technology is inside this project funnel. When combining all the innovation projects together an overview of the portfolio over the funnel is created, but this also leads to the question how an ideal project portfolio funnel should look like and one way to measure this is how the R&D budget is divided over the different TRL. This question focuses on how an ideal project funnel should look like. It wants the respondents to indicate how they think that an funnel should like through indicating how much percentage of the R&D budget should be spend on the first 6 TRL. It is also explained that in the beginning there are more projects in the funnel and that project cost per TRL can be very different.
6) Innovation budget division over the Value Chain: Now we know how an R&D budget division over the project funnel looks like but another division of the R&D budget can be made over the value chain. To indicate what parts of their own value chain is important for the firm and its future. R&D budget division over value chain is important for firm-X because firm-X sees itself an integrator of innovation, therefore collaboration is important and therefore the firm should know where it want to focus on and don't spend resources on projects which should be executed by contractors. The relevance is to find out what effect the R&D budget division over de VC, is it only strategy or does it depend on other factors?
7) Type of criteria for measuring IPP performance: The tools that will be used for the selection of the innovation projects indicate certain factors. To understand which factors, how many, and which combination will result in the best framework for effective IPPM (strategically aligned, balanced IPP, and maximized IPP or value). A list of factors from the literature and firm-X specific factors as discussed before in section 3.3 are combined and it will be researched which factors will be most important and why. Appendix G shows all the factors and they are combined. The relevance of this question is to find out which factors are driving and which factors are the result of those driving factors, because using all the factors will make IPPM very complicated. Therefore a set of comprehensible factors that give reliable information should be used. Also it should be investigated which factors can be used where in the conceptual model, finally how this all then related to a framework for effective IPPM.

The following three question have been discussed in the second round of interviews, first it was attempted to find out what effect the first 7 questions have on the three effective goals of IPPM, but only result for strategic alignment was really useful, therefore the question how to balance and how to maximize value will be done in the question 8 and 9. Finally a question was focussed at what the effect is of inter-organizational innovation activities with regard to IPPM, this is relevant because it is not yet understood how to incorporate this effect and what to do with it in the IPPM decision making process.

8) Balance the IPP: Because in the first round of interviews the factors were not giving many result with regard to the three goals of effective IPPM this question will try to understand how to balance the IPP in order to get requirements for the design of the framework.
9) Maximize value: Through this aspect comes back in other aspects as well this aspect is discussed in detail in the second round of interviews to get specific ideas/requirement for the design of the IPPM framework.
10) Inter-organizational innovation activities: This aspect deals with the effect of inter-organizational innovation activities on the IPP performance. It results in different balancing requirements and perhaps therefore affects the design of the framework.

Things that will not be discussed during the interviews are the design of TRM which has been designed in other interviews also the size of the R&D budget will not be discussed because it is assumed to be fixed for the coming 5 years. The interview questions can be found in Appendix D he interviews are executed in two phases. The first 7 aspects of the interview is executed with the 13 respondents, after analysing the results a second round is executed which deals with aspect 8 until 10. The second round is executed with only 5 of the respondent (the head of TO, two PGM's, KTM & BLM) due to limited time. The questions 6 and 7 answered in 4.3.6 and 4.3.7 not only use interview results but these results are also compared to an analysis of the current IPP project data.

The selection of respondents for the interviews has been made with respect to function and relation to the IPP from the stakeholder mapping in section 4.2. A list of all respondents can be found in Table 4.3.2. Everyone in the table has something to do with innovation or with IPPM as can be seen in the column that gives function description. It is attempted to have a broad range of views, therefore all the KTM and PGM have been interviewed because of their direct relation with R&D. Also two BL managers have been interviewed to get also the marketing perspective and finally a risk manager and cost engineer have been interviewed to also get the input from these points of views towards the IPPM.

Table 4.3.2: Individual members of interest for the interviews

#	Function	Interview round
1	PGM M&D	1
2	Head of R&D & KTM TS	1 & 2
3	BLM BJ	1 & 2
4	BLM Airbus	1
5	PGM Helicopters	1 & 2
6	PGM T&M	1
7	head of Cost Engineering	1
8	KTM MB & FML	1
9	KTM TP	1
10	Head of PG's	1
11	PGM F	1 & 2
12	Head of TO	2
13	VP Technology	1
14	PMO Risk Management	1

In the following paragraphs the results of the interview for each question will be summarised and finished with a short conclusion.

4.3.1 Organic/ Informal vs. Systematic / Formal IPPM approach

This aspect is focused toward what should be the approach for firm-X IPPM. Most respondents indicate that there should be two approaches, firstly an organic (informal) approach for the idea-generation phase, the real front-end phase where the first attempts of observing a concept and acknowledging its technical prospects. The second is a systematic (formal) approach for the more expensive part of the innovation project that happens at a higher TRL. When the idea is more clear and a first proof of principle has been established then the cost of the projects will increase significantly because more expensive test have to be carried out, and therefore this part of the process should be organized systematically. Respondents indicate that a formal approach should contain a timeline, boundaries, scope requirements like normal projects in the design phase. The Vice President Technology even indicates that from a certain TRL level the innovation project becomes a normal project with a scope, requirements and goals to achieve within a certain budget, in his words he calls it 'Innovation is also just work'. The question though remains what is exactly the right border to decide when an innovation project should be made a formal project. Out of thirteen respondents there is one respondent that indicates that the process should not be formal at all because ''there is still much uncertainty and a concrete design has not been formed, but perhaps he indicates the same as the others that the idea generation should be organically organized. Every respondent does agree that the project selection should not be based on ad hoc decisions.

The respondent's offer many ideas for creating a systematic (formal) IPPM practices, but not so many ideas are suggested how to establish an informal (organic) approach for the low TRL / new idea generating phase. The head of PG's state that FIRM-X misses a good review tool for innovation projects and that a vertical overview of the whole value chain / supply chain is not present. On top of that after the execution of the innovation projects better use should be made of the captured knowledge. The next two paragraphs will discuss how to implement the two approaches.

Systematic (Formal) approach: To create a more formal and systematic approach to IPPM the respondents give the following ideas. The use of TRM's, TRL's and the down-flow of requirements should be key into creating more effective organization for the higher TRL levels, management control, scope & requirements, scheduling, risk management & opportunities, financial management, stakeholder engagement, organizational governance, resource management. Respondents also indicate that a central committee should be present that consist of the same members every evaluation round and it should be a multi-disciplinary team (as is consistent with definition of IPPM, section 2.2). In this way all ideas will be viewed from different views but also no idea will be lost somewhere because one person thinks it is not a good idea, as is also consistent with the literature of IPPM.

Organic (informal) approach: To create the organic approach for the early idea generation respondents state that the central committee should give no limitations except for clear boundaries towards the financial cost and there should be some relation to the firm goals. Another respondent indicates that those early phases should not be focused towards a goal too much, but managing should be executed by asking a lot of open question and steering only very little, a pragmatic approach which can be changed all the time would be convenient for the organic approach.

What is also clear from respondent's answers is that the innovation approach should pay more attention to requirement down-flow so that innovation projects can be scoped much better. It can also be concluded that an informal approach (non IPPM) is preferred when new project are still in an uncertain phase, there are no scope & requirements, and it is not clear if it fits strategy or not. A formal IPPM approach is preferred when the focus of the innovation projects becomes clearer and scope & requirements are present.

Literature suggests that a formal IPPM approach should be used where every innovation project is treated the same, but the results from the interviews indicate that a combination of a formal and informal method should be applied. Most tools in the literature disfavor advanced technology projects. The only tool in the literature (section 2.5) that creates room for innovation projects that are new and not in line with strategy is the strategic buckets method which can allocate a special bucket to these kinds of projects. firm-X does this already quite well because there are several programs that give resources and time to new ideas to start-up, however for the ideas that are in a further stage and according to the interviews those types of projects can be managed in a more formal way, not so opportunistic and free as is occurring at the moment.

Now it has been concluded that a formal approach is necessary for one phase this then validates the design of such a formal approach and this again then validates the requirements (Requirement 1 until 9 discussed in section 2.12) that already have been developed with respect to this formal approach.

Conclusion / requirements:

From this section the respondents indicate that there are two phases in the innovation project cycle the idea generation phase which is a very fluid phase with lots of unknowns and uncertainty, maybe even the applicability is not known and therefore for this group a non-IPPM approach should be used. The second phase is when the concept is clearer and will be really focused on making the technology ready for applicability, then it is more a normal project with scope and in this phase a rational IPPM approach is preferable. Therefore the new framework should facilitate both phases.

According respondents firm-X misses a good review tool for innovation projects. For the systematic approach a central multidisciplinary committee should be present to evaluate all the ideas, scope & requirement should be originating from the customer. For the organic approach, no scope should be present. firm-X should make better use of the captured knowledge (this is not part of project selection so not a requirement for the new framework).

From these conclusions two requirements can be deduced, the first 12 requirements are developed in chapter 2A & 2B and chapter 3 therefore the counting continues from there:

R13:	The new IPPM framework should facilitate two phases for innovation projects, firstly a very fluid phase for low TRL innovation projects (no scope requirements) and secondly a formal phase for higher TRL innovation projects.
R14:	The new IPPM framework should have a central multidisciplinary committee that executes the IPPM decision making.

4.3.2 Technology Push vs. Pull

In question one it was already indicated by some of the respondent that requirement down flow is important and this questions focuses on how the technology push or pull approach affects the requirement down flow. Whether firm-X should focus on technology push where firm-X should creating new ideas for technology that the customer hasn't thought of, or focus on technology pull which means that firm-X should keep up with enabling technologies and develop technologies that the customer wants.

The respondents answers range from a more technology pull point of view to completely focusing on technology push. All respondent stress that it should be a combination of both technology push and pull but from the results it cannot be concluded which approach is more important for firm-X because the answers are so much different. So let's look at the reasons why the respondents stress one or the other approach:

Push approach: To distinguish from customer's demands and become the innovation leader that firm-X wants to be. It is suggested to guide the push project carefully and try to visualize customer requirements for the new product / technology that firm-X has in mind. Also it is suggested only to do push when backed up with a steady stream of revenues. In the execution phase of an innovation project the final goal of a push project should not be forgotten, sometimes a product without a goal can be better killed.

Pull approach: This approach can be very beneficial to keep up with enabling technologies. It is said that the customer can change its mind in terms of which technology to put on the aircrafts on the other hand pull mostly has a better requirement down flow because it is the direct customer demand.

Many technologies start as a push but later on will be a pull from the customer, this happens often when the product has been flying on another airplane, therefore there is a stepping stone approach for innovative products which means that new technologies are often e.g. first applied on business jets (which have a more experimental attitude) and use that as a stepping stone to the larger aircraft manufacturers.

Conclusion / requirements: According to the respondents the new IPPM framework should allow a combination of both technology push and pull. Technology pull has an easier down flow of requirements because the customer knows better what it wants, this results in the following requirement.

R15:	The new IPPM framework should be able to assist a combination of both technology push and technology pull.

4.3.3 Bottom-up vs. Top-down IPPM approach

This question focused on a top-down and bottom-up approach towards innovation. Top-down means that the projects are in line with strategy and are executed by demand of the upper management. Bottom-up means that projects are initiated in lower levels of the firm and perhaps have no direct relation to the strategy. It was investigated how firm-X should deal with both approaches. Most respondent answer that firm-X should focus mostly on a top-down approach but with room for bottom-up ideas because for some innovation projects because sometimes you can't say if a project fits the strategy especially in the early stages, so this seems to indicate that not all projects should be in line with strategy. There are some respondents that indicate that only a top-down approach should be used but there are none that indicate that only a bottom-up innovation approach should be used. It is suggested that for innovation projects in the idea generation and low TRL should be allowed to have bottom-up innovation. In higher TRL levels all projects should be top-down, so in line with strategy. For higher TRL the spending increases and that's why it is important to make the right decision so therefore it should be in line with the strategy.

For bottom-up ideas there should be a process in place to address the strategy. Technology development is not a final goal for firm-X but revenues and creating new opportunities for the firm is the final goal for firm-X. Therefore projects that are not in line with strategy should be killed or given to other firms to develop as one respondent suggested.

For top-down it should be noted that the strategy should not be too limited and also not to high-level. Many respondents indicate that the current strategy is missing some level of detail and many have given their own interpretation to it, which might be dangerous if the interpretation doesn't match what is meant by upper management.

Conclusion / requirements: For firm-X the new framework should assist in dealing with both bottom-up and top-down ideas. Bottom-up ideas for low TRL projects because sometimes it can't be envisioned if it fits the strategy or not, and for higher TRL levels all projects should be in line with strategy. Perhaps strategy should be defined more detailed so that it is easier to grasp what is in line and what is not. Coopers statement which says that all projects should be in line with strategy can be limiting the performance of IPPM because many young projects from which it can't be said if it fits the strategy, this result in the next requirement:

R16:	The new IPPM framework should assist with bottom-up ideas for low TRL-projects because sometimes it can't be envisioned if it fits the strategy or not, and for higher TRL levels all projects should be in line with strategy.

4.3.4 Long vs. Short Term

This question deals with the question whether firm-X should focus on the long term with systematic approach or on the short term through an opportunistic approach and what the influence of these approaches is towards how to manage the IPPM. In the interviews it became clear that a short term focus is contra to innovation as it results more in operational excellence instead of innovation leader. Firm-X wants to be an innovator therefore it should focus more on the long term. This indicates that innovations that are started should have a long term focus. The long term focus is mainly for the large radical innovation projects, for the incremental innovation projects there is no long term focus necessary. Incremental projects go by a different budget at firm-X. The effect of the long term focus therefore indicates the type of innovations that needs to be done from a market perspective.

Conclusion / requirements: From this question the requirement for the framework is to show the long term focus of the innovation projects.

R17:	The new IPPM framework should be able to focus on the long term.

4.3.5 TRL balance

This section focuses on the R&D budget division over the TRL levels that have to do with R&D. In this section and following sections in this sub-chapter the graphs are made by executing multiple methods, through interviews data is collected about the views among members of firm-X and secondly an analysis is made of the current IPP by analyzing data about each project characteristics.

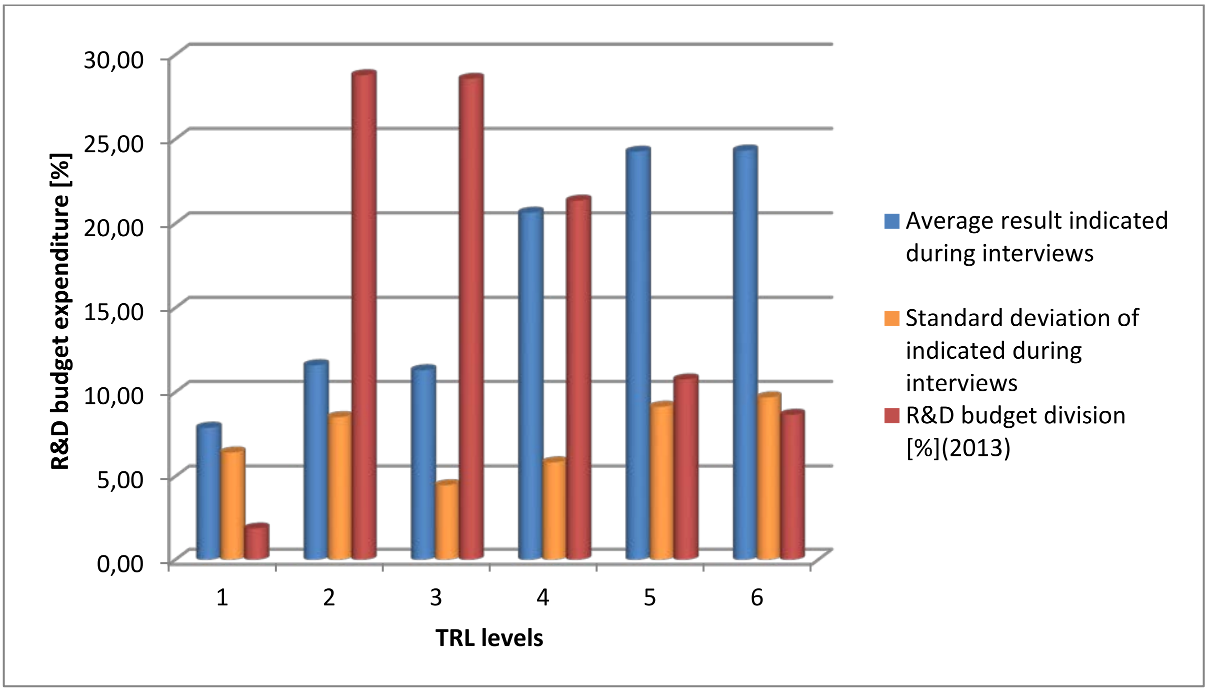


Figure 4.3.1: Average result of R&D budget division over TRL division indicated during the interviews compared to the current division.

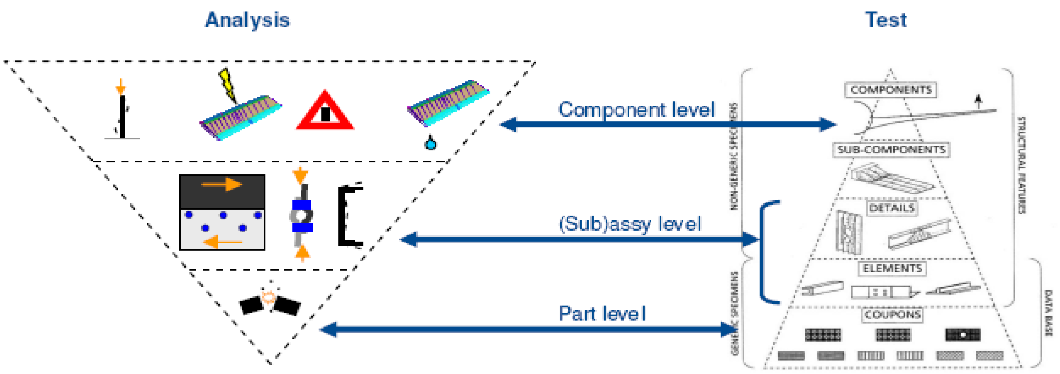


Figure 4.3.2: Analysis and test pyramid besides each other, Source: internal Firm-X document (Stress methodology Development, support and maintenance plan)

Figure 4.3.1 shows the R&D budget division over the first 6 TRL levels indicated during the interviews and also maps the current R&D budget division of the IPP over the TRL levels. The current R&D division of 2013 over de TRL levels is calculated by taking the budget of each project for the year 2013. From figure 4.3.1 it can be seen that most of the money should be spend on TRL 4, 5 & 6. Most people indicate (blue columns of figure 4.3.1) that this is where most of the money is spent because full scale tests have to be executed in these levels. This can also be seen in figure 4.3.2 where the amount of test examples are reduced, but the size of the test specimen increases per TRL level and also the amount analysis increases which means that the cost will increase. Some respondents indicate that these higher TRL levels are the regions where FIRM-X gets its own added value as the low TRL levels are more general knowledge. Some respondents even add that the first three TRL levels should be executed in inter-organizational innovation activities (collaboration) with universities to suppress these costs. One respondent indicated that TRL-6 is sometimes executed together with the customer, because this level represents an integrated flying test specimen and when that is executed together with a customer then the cost can be shared and improve the test results. This also results in reduced cost for TRL-6. From figure 4.3.1 the current R&D division over the TRL levels indicated with the red columns is quite different compared to blue columns indicated in the interviews. The red columns indicate how firm-X spends its R&D budget. The red columns have been gathered during an interview with the Technology Office manager and the R&D manager who estimated the TRL levels of each project, because not every innovation project has had a formal TRL assessment which will happen in the near future. As can be seen in figure 4.3.1 the division of R&D budget over the different TRL levels indicated in the interviews does not match the current R&D budget division. A possible reason indicated by the head of TO is that at the moment projects are not managed. There are no reviews of the innovation projects and that results that scope requirements are not clear which then results in researchers muddling through to find a solution but this costs a lot of money. Something that cannot be seen when comparing the individual results of the respondents is that all the engineers (KTM's and PGM's) indicate the same results and that only a BL manager and a Risk manager have a very different view on how R&D budget should be divided over the TRL levels. They indicate the inverse results where most of the money should be spend on low TRL projects. However there is one manager that indicates the same results as the engineers. This means that perhaps some of the managers have a different perception on cost of innovation.

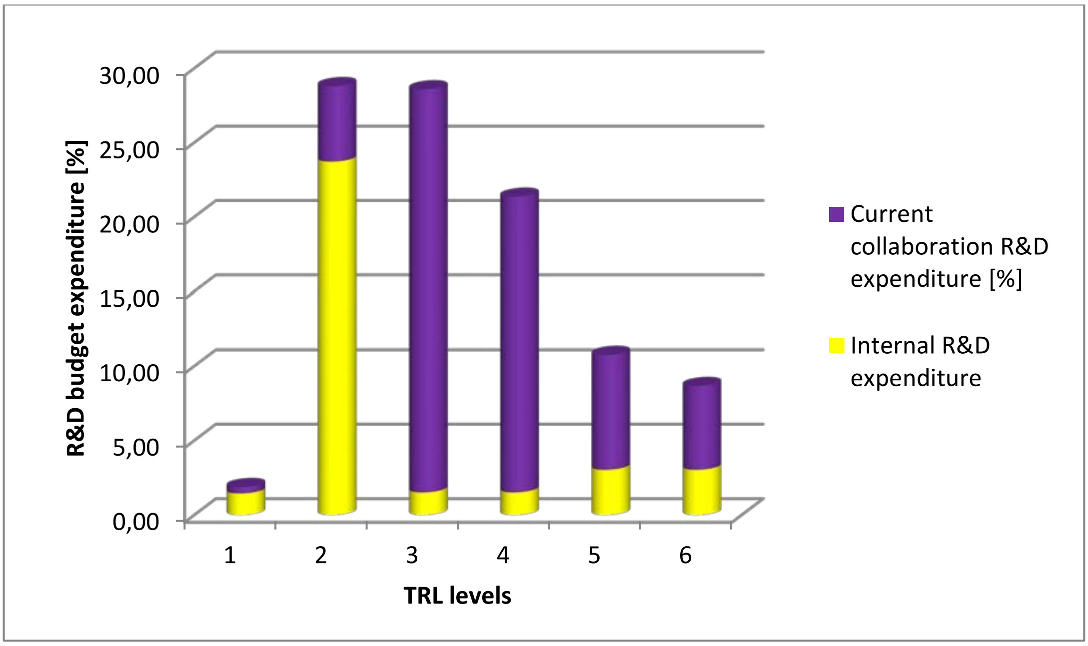


Figure 4.3.3: Internal and innovation activities R&D budget expenditure [%]

Figure 4.3.3 indicates for the R&D budget expenditure per TRL level how much is spend on internal R&D projects and on inter-organizational innovation projects in percentage, for clear understanding the total length of each column in figure 4.3.3 equals the green columns in figure 4.3.1. During earlier interviews the manager of the Technology Office (TO) explained that many inter-organizational innovation projects are for low TRL innovation projects. Figure 4.3.3 shows that most of the inter-organizational innovation projects are spend for medium to higher TRL-levels, this was an unexpected finding, if this is good or bad results that depends on the strategy. For higher TRL levels it was expected that it cost more money so it is good to share the costs but on the other side the higher TRL levels are more interesting for firm-X because this is what FIRM-X sells to its customers therefore some respondents indicate that this knowledge should not go to the competitors. Low TRLs are basic research that can be executed by research institutes. On the other side this is not the research that firm-X sells so not too many projects should be in this phase. In any case firm-X should have a discussion where their added value is to understand where to collaborate and where not.

Conclusion: The results in figure 4.3.1 can indicate how the R&D budget division over the different TRL levels should be spending and can perhaps be guiding in the project selection process to get a balanced IPP. The indicated R&D budget division over TRL is not a specific requirement for the framework but as can be seen later in the design of the framework it will be used as a guideline.

4.3.6 Value Chain division

A same kind of division as for the R&D budget division for TRL levels can be made for the value chain (limited only to the parts of the value chain that are related to technology innovation). The division has been made in: 1) material development, 2) new technology or new concept development, 3) supporting technologies (e.g. T&M at firm-X) and 4) manufacturing / assembly technology.

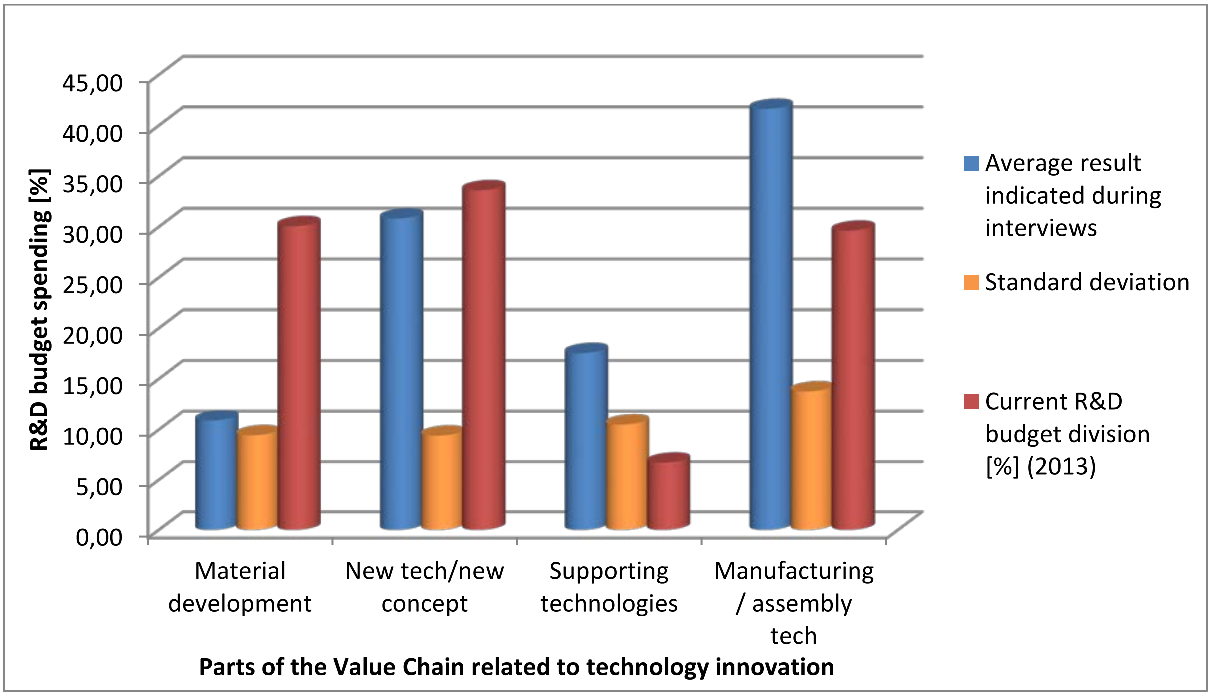


Figure 4.3.4: R&D budget division among part of the Value Chain related to innovation on technology, indicated during interviews, both average and standard deviation.

During the interviews the blue and orange columns of figure 4.3.4 have been gathered, the red columns follow from analysis of the current R&D budget over the different innovation projects. Figure 4.3.4 shows that when comparing the current expenditure with the indicated level during the interviews too much is spent on material development and too little on supporting and assembly technologies. During the interviews most engineers indicate that material development is not a main business for firm-X, they use the materials for the innovation and therefore only a small part of the R&D budget is used to do some specific material development or work together with material firms to get materials that they need. It should be noted that the results of the red columns (the current R&D expenditure divided over the value chain) in figure 4.3.4 is the result of analysis of internal reports, educated guesses by the writer of this report, and thirdly through discussion with the head of TO and head of R&D. Many respondents indicate that many problems occur during manufacturing and assembly and that therefore more innovation is necessary in this area. Others argue that problems in manufacturing or assembly are the result of designs flaws and therefore they give also importance to new technology / new concept. It has to be noted that firm-X is very expensive in manufacturing compared to its competitors. Therefore manufacturing and assembly cost reduction should also be pursued.

Conclusion: The results in figure 4.3.4 can indicate how the R&D budget division over the different parts of value chain should be divided, and can perhaps be guiding in the project selection process to get a balanced IPP. The division of R&D budget between internal and inter-organization innovation of figure 4.3.3 should perhaps be leading to a discussion over the added value of firm-X over the value chain and TRL levels. The indicated R&D budget division over parts of the value chain is not a specific requirement for the framework but as can be seen later in the design of the framework it will be used as a guideline.

4.3.7 Factors used in Tools for IPPM

As indicated before there are many factors that can be used to assess a portfolio of innovation projects. Which factors can measure the performance to show a representing portfolio performance and can facility the decision making process is the question of this topic. A limited selection of type of criteria has been shown to the respondent and they indicated the importance in their opinion. The result is shown in figure 4.3.5, the vertical axis has an importance scale (not important at all, not very important, neutral, reasonable important, very important, where 5 is very important and 1 is not important at all.

As can be seen in figure 4.3.5 the averaged results indicate that almost all factors are important, there is no factor that been indicated unimportant. Because not so much can be said about the importance of each factor related to other factors it was decided to do more specific questions about how to deal with two goals of effective IPPM: balance, and maximize value. Therefore it has been decided that this would be the focus of the second round of interviews. It is also suggested by a respondent to have a look at projects that have been killed directly and investigate why they have been killed.

Conclusion / requirements: The results indicate that almost all factors are perceived as important and therefore this approach has perhaps not been successful as most respondents found it too difficult because of the inter relatedness of many factors. Therefore there are no requirements for this section.

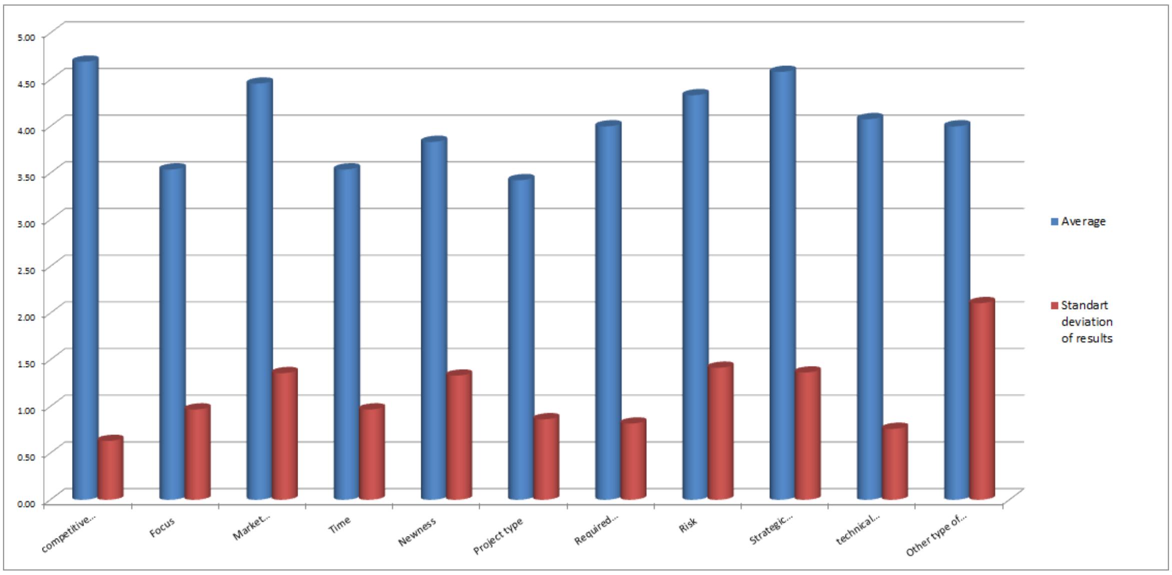


Figure 4.3.5: indication of importance of each factor during the 13 interviews, average results, the full picture can be found in Appendix E

4.3.8 Balance of IPP

The five respondents give a variety of answers, but the implication of the answers are quite the same, which is a balance of cost/revenues and probability of success should be used to create balance. Also competitive advantage is named a few times which should be achieved by looking at the opportunities at the market and using the strategy to translate it into to clear products which are competitive. One respondent found it too complex to give a good answer to the questions on the other hand also one respondent was able to state very clear, he stated 'A balance should be obtained over the KT's and the PG's'. Another respondent stated that the PG's should execute trade studies so that firm-X knows more what the customer want and which technology and product will deliver that for the best results.

Conclusion / requirements: Some respondents indicate that a balance of cost / revenues and probability of success should be used and others indicate a balance among the Key Technologies and Product Groups. No clear requirement for the new framework can be deduced. Comparing to literature study in chapter two, calculating cost of innovation project is according to the literature not such a good idea, the IPPM tools should use information that is reliable and gives a good picture of the performance but at the same time is also helpful in making decision that lead to the three aspects of effective IPPM. As the respondents could not give arguments why they indicate the factors for balance what they suggest, therefore there are no requirements are develop from this section.

4.3.9 Maximization of Value

All respondent explain that to maximize the value a clear vision of the demand of the market should be clear. One respondent adds that the biggest opportunities should be identified and that the innovation projects should be aligned for those opportunities. Sometimes innovation projects with a low TRL cannot be related to the product. On average the big integrators decide 6 year before EIS of a new airplane on which technology they want to apply and therefore the innovation of the technology should at least start 10 year before EIS of the new airplane. Onother respondent states that a balance of high risk + high revenues and moderate risk + moderate revenues should be leading to maximize the value.

Conclusion / requirement: A clear vision of the demand of the market should be known and for the biggest opportunities the innovation projects should be aligned to strategy which is also stated in section 4.3.4. This results in the next requirement:

R18:	The new IPPM framework should be able to create a clear vision of the demand of the market should to be able to maximize the value.

4.3.10 Inter-organizational Innovation Activities

During the interview the respondents give answers related to finance, that a balance should be found for different type of innovation activities and financing schemes. The manager of TO gives an interesting remark that firm-X does not need to be the biggest participant in the innovation activities, contrary sometimes the biggest party forgets to manage the others, so that is something that firm-X needs to take care of that the innovation activities is doing where it was meant for. There were no useful remarks made about how to deal with inter-organizational innovation activities in IPPM in this question.

<u>Conclusion / requirements:</u> firm-X should be aware of what the other parties are doing in the inter-organization innovation projects to get most out of the projects. The result did not lead to a specific requirement.

4.4 Answering research Question 3

This section will answer research sub-question 3: *What are the requirements of the members of firm-X for a framework for effective IPPM* (the sub-sub-questions have been incorporated in the answer)?

The innovation community at firm-X is large and divided over many parts of the firm, and therefore many people are involved. From the stakeholder mapping in section 4.2 it was seen that many individuals come back at multiple positions in particular the Key Technology Managers (KTM), the Product Group Managers (PGM) and some other individuals. Those people have been interviewed about aspects related to IPPM and the design of a framework for IPPM and that resulted into six requirements from the interviews for the design of the new framework. The six requirements from the interviews for the new framework are:

A short summary of the requirement developed during the interviews. From the interview many requirements can be made, for both firm-X specific but also for a general IPPM framework. First of all the framework should be facilitating low TRL projects with much freedom (no scope limitations) and for higher TRL levels it should be more formal with scope requirements for every projects, and all higher TRL innovation projects should be aligned with strategy. There should be a multidisciplinary committee present to evaluate all the innovation projects. The framework should also facilitate a combination of both technology push and pull and also the framework should be able to organize and assess bottom-up innovation projects and top-down innovation projects. The framework should be indicating a long term focus and also indicate how to make that future happen. Then for balancing the IPP an indication of the R&D budget over different TRL levels, of different parts of the value chain can be used to indicate a balance, and the same for the PG's and KT's. What is also important is that there should be a clear vision of the demand of the market so that the value for future products can be maximized, these requirements can be summarized in the following box.

R13:	The new IPPM framework should facilitate two phases for innovation projects, firstly a very fluid phase for low TRL innovation projects (no scope requirements) and secondly a formal phase for higher TRL innovation projects.
R14:	The new IPPM framework should have a central multidisciplinary committee that executes the IPPM decision making.
R15:	The new IPPM framework should be able to assist a combination of both technology push and technology pull.
R16:	The new IPPM framework should assist with bottom-up ideas for low TRL-projects because sometimes it can't be envisioned if it fits the strategy or not, and for higher TRL levels all projects should be in line with strategy.

R17:	The new IPPM framework should be able to focus on the long term.
R18:	The new IPPM framework should be able to create a clear vision of the demand of the market should to be able to maximize the value.

Also from the interviews a desired state for a division of the R&D budget over first six TRL and parts of the value chain have been indicated which can be used in the design of the framework.

When comparing the interview results to the theory of chapter two then some interesting findings can be found. First of all a non-IPPM approach and IPPM approach can be present at the same time but for different parts of the innovation system. It was indicated that a non-IPPM approach would be preferred when scope & requirements and relation to strategy of innovation projects are not clear. When scope & requirements and relation to strategy (so for higher TRL) are clear than a rational IPPM approach is preferred.

Then finally the statement of Cooper in the theory where he says that all projects should be in line with strategy is perhaps a limiting condition because for projects that are radical and low TRL it is sometimes unclear if it fits strategy or not and so many projects are then most likely not initiated, therefore it was suggested to have a fluid phase with a non-IPPM approach where lots of freedom is given to projects with respect to scope & requirements.

Chapter 5 Design of the Framework

This chapter will elaborate on the design of the integrated framework for effective IPPM. The design is based on the requirements of the literature, internal documents and from the interviews at firm-X. First in section 5.1, the requirements from chapter 2, 3 & 4 are stated and from there the design of the new framework is explained using a four step approach from sections 5.2 until 5.5 (according to the conceptual model mentioned in chapter 2). Later, in section 5.6 all the remaining requirements that have not been discussed before will be discussed. Section 5.7 the implementation of the framework is discussed and the framework is validated through an interview with an expert and the representatives of the firm-X in section 5.8. Finally, in section 5.9 this chapter is finished by linking the model to the theory and answering research question four.

The industry of firm-X has long development cycles and therefore planning is very important, opportunities that pass by suddenly will have to be developed with existing technologies, in other words you cannot prepare for the unexpected. The literature gives many tools / techniques for IPPM and it is clear that those methods need to be based on reliable information that gives a good representation of the reality.

5.1 Requirements for new framework from chapter 2, 3 & 4

This section will summarize all the requirements of the previous chapters for new framework, as this is done by restating the requirements from answers to the sub-questions for chapter 2 and 3, and for chapter 4 the conclusions of all the questions for the interviews have been used for creating the requirements. Only the order in which the requirements are presented has been changed for convenience of explanation.

5.1.1 Chapter two (Literature)

The conceptual model developed in chapter two is based on the IPPM approach described in the literature by (Cooper & Edgett, 1997) & (Markowitz, 1952).The model is indicated in figure 2.11.1, but is repeated here once more for convenience. It starts first with measuring the current IPP state, then secondly an indication of the desired IPP state should be developed, in the third step a comparison is made with a desired IPP state, and in the fourth step adjustments are executed into the direction of the desired state and that will lead to a new IPP state. This four step approach of this framework will be discussed in this chapter.

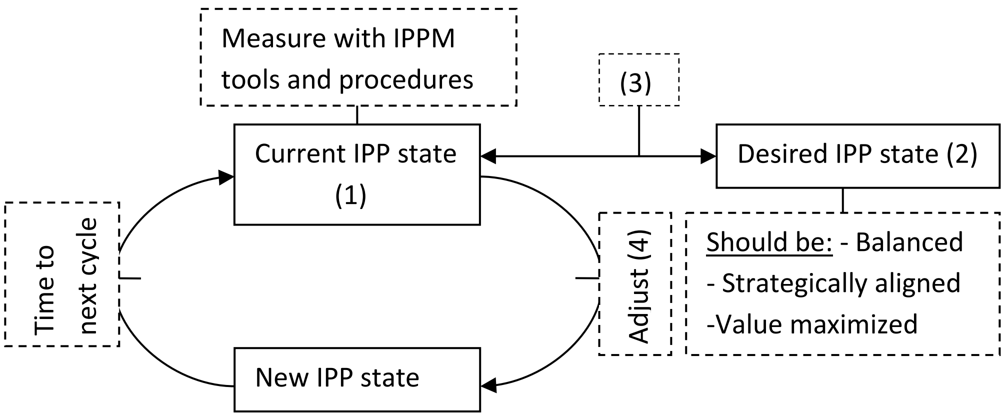


Figure 2.11.1: Conceptual framework serves as a basis for the design of the IPPM framework

The conceptual model leads to the following set of requirement for the design of the framework:

R1: The new IPPM framework should support an evidence based decision making approach.

R2: The new IPPM framework should be able to measure the current state of the IPP state.

R3: The new IPPM framework should be able to create in indication of desired IPP state.

R4: The new framework should reduce implicit judgement in the IPPM decision making process.

R5: The new IPPM framework should be able to compare the current and desired IPP state.

R6: The new IPPM framework should be able to indicate how to adjust the current state towards the desired state.

From the first six requirements and table 2.5.3 (which describes for each tool if it can assist in the four steps of the conceptual model); a combination of tools can be selected for the framework. In this case the combination of Technology Roadmaps, strategic buckets and a bubble diagram type of tool will be the basis for the framework. This will satisfy the first five requirements, and how these requirements are satisfied will be explained in the next sections of this chapter. Then, by consulting from the literature, another set of requirements can be added.

R7: The new IPPM framework should lead to three goals of effective IPP.

R8: The new IPPM framework should be based on reliable & quantifiable information.

R9: The new IPPM framework should fit the management style.

Requirement 7 and 9 can be validated only after the design of the framework and requirement 8 will depend on the factors of chapter 3.

5.1.2 Chapter 3 (Current Innovation framework and business environment)

The business environment of firm-X uses a set of key factors, which give reliable information. Because other factors can add value, means that this is not a hard requirement, but more of a list to choose from and where add more factors to the current list is:

- Type of PG indication
- Type of technology indication
- Volume of the product
- TRL measurements
- (Allocated) Cost of innovation projects

Also three requirements can be developed from some of the current problems with the innovation framework they are:

R10: The measurement of the current IPP state should include the effect of inter-organizational innovation activities to get a better overview of the IPP performance.

R11: The new IPPM framework should clearly create development logic between the innovation projects.

R12: The new IPPM framework should facilitate in a better down flow of requirements

5.1.3 Chapter 4 (Stakeholder mapping and Interviews)

In chapter 4 the stakeholder identification led to a group of respondent for the interviews. Many aspects related to IPPM (that were discussed in the literature study in chapter two) have been investigated at firm-X (mentioned in chapter four), which led to the following set of requirements:

R13: The new IPPM framework should facilitate two phases for innovation projects; firstly, a very fluid phase for low TRL innovation projects (no scope requirements) and secondly, a formal phase for higher TRL innovation projects.

R14: The new IPPM framework should have a central multidisciplinary committee that executes the IPPM decision making.

R15: The new IPPM framework should be able to assist a combination of both technology push and technology pull.

R16: The new IPPM framework should assist with bottom-up ideas for low TRL-projects because sometimes it can't be envisioned if it fits the strategy or not, and for higher TRL levels all projects should be in line with strategy.

R17: The new IPPM framework should be able to focus on the long term.

R18: The new IPPM framework should be able to create a clear vision of the demand of the market should to be able to maximize the value.

5.2 Step one: measuring the current IPP

In the first step the current IPP is measured to know how the IPP is performing. The current state can be measured with several measures. To be able to compare the current state with the desired state the factors need to be the same. Also reliable information should be used (requirement 8). It was indicated in chapter three that TRL, Key technologies, and Product Groups; give reliable information. From the interviews the Value Chain division, all important characteristics of the IPP performance are derived, which are then chosen to be used for the measurement of the performance of the current state and indication of the desired state.

By plotting the R&D expenditure of the individual innovation projects over the TRL levels (in different parts of the value chain, Product Groups or Key Technologies), then allows the budget division to calculate all these aspects to show how the R&D expenditure is balanced. This has already been done for the TRL level division and Value Chain division in chapter four, see the red columns of figure 4.3.1, figure 4.3.3 and figure 4.3.4.

The R&D budget division for PG vs. KT is shown in figure 5.2.1. Figure 5.2.1 indicates how the innovation projects are divided over the different PG's and KT's. The mapping only contains the R&D projects and not the improvement agenda projects which are internal incremental projects. They have their own budget, but they can be added to list if needed. Also the group 'enabling technologies' should be added to figure 5.2.1 as one of the PG's, because the enabling technologies also need to be kept up to date. The table shows how the projects are divided over the different markets that the firm is focusing on. In table 5.2.1 the financial division for the figure 5.2.1 is given for the firm-X R&D budget spending. The description of the projects related to each number in figure 5.2.1 can be found in appendix G.

The R&D budge division over the TRL can indicate how well the innovation funnel is balanced. The R&D budget division over the value chain and PG vs. KT indicates the strategic direction of the firm with regard to these two aspects. Then the R&D budget division over the value chain is an indication of how well it is balanced with respect what parts firm-X thinks add the most value to the products.

Table 5.2.1: Division or firm-X R&D budget over PG's & KT's

Product Groups / Key Technology	T&W	M&D	F	Total net cost per KT [k€]	Budget per KT [%]
TS	271	354	21	645	18%
TP	919	358	669	1,946	55%
FML	55	820	24	898	25%
MB	16	16	16	48	1%
Total net cost PG in [k€]	1260	1547	730		100%
Budget per PG [%]	36%	44%	21%	100%	

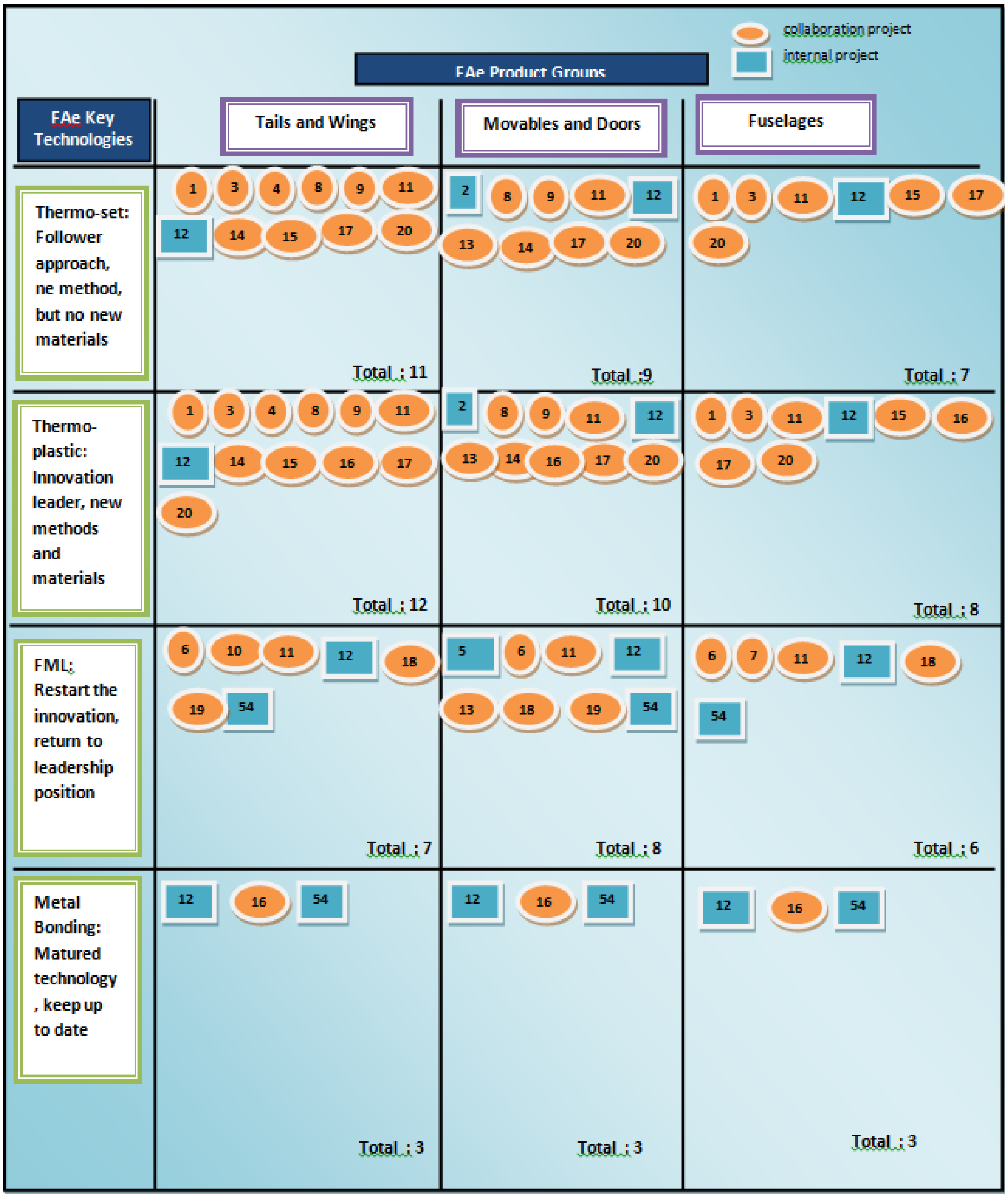


Figure 5.2.1: PG vs. KT mapping of the R&D projects

5.3 Step two: Developing an indication of a desired portfolio

The four aspects (TRL, PG, KT and value chain) that have been measured in step one should now be compared to a desired state. This desired state should then be a guideline, where the IPP should be directed towards. Because in step three, the desired and current state will be compared, the factors that are used to assess the portfolio should also be used to indicate the desired state. Therefore, this section explains for the R&D budget division over the TRL, the Value Chain parts, the PG's and the KT's how the division should be.

The first aspect that is discussed is the R&D budget division over TRL levels. The interviews indicates a balance that shows an increasing trend towards higher TRL levels, this indicated TRL level division should be the desired state and therefore the first guideline is as follows:

> <u>Guideline 1:</u> *The IPP should be guided towards a selection of projects that matches a R&D budget division as indication through interviews by the blue columns in figure 4.3.1, or another TRL division that firm-X expects to be representing the desired state. The goal is to create a well-balanced project funnel that produces the most effective output of projects.*

A similar guideline can be developed for the R&D budget division over the Value Chain, however this division should be the result of a strategic decision. In the interviews, it is indicated that the material development part of the value chain should not be so high and that this can be a strategic decision. Thus the second guideline says:

> <u>Guideline 2:</u> *The desires IPP state for the R&D budget division over the value chain can depend on strategic focus of the firm, in the interviews it is indicated that it should be divided as is indicated by the blue columns in figure 4.3.4.*

For the third guideline the focus is on the balance of the PG's and KT's. These two aspects are set by a strategic direction and the business environment. Because these two aspects are affected by both strategic and business environment, considerations on how a balance is to be found cannot be indicated by the interviews. This means that for the balance of the PG's and KT's requires a different approach than the first two guidelines. The story starts with the Technology Roadmap's (TRM's), but before that the new design of these TRM's needs to be explained.

<u>New technology Roadmaps:</u>

Section 3.2.5 discusses problems with the old TRM's, these problems have been addressed and a new road-mapping framework has been set up. Figure 5.3.1 shows an example of the design of a new TRM, no real data is used, and an explanation of the symbols used can be found in figure 5.3.2.

Firm-X uses a double matrix organization (PG's, KT's & BL's), and the TRM should be applicable to this structure. For this to happen, 16 TRM's will be developed for each PG & KT combination, for which the third aspect of the double matrix (the BL's) can be found in the TRM. This is the most convenient way for the KTM & PGM to organize the roadmap for the innovation phase.

The TRM has 3 layers: the first one containing the opportunities identified in external environment (all the new aircraft programs that will be developed in the future), they are visualized with the Entry Into Service date (EIS), this layer is the same for each TRM. The second layers contains the products that can be offered to the customers, this can be the result of customers asking firm-X or firm-X trying to be selected for a product by the customers. For each product in this layer; a timeline indicates the development time for the product, the open circle indicates the Request for Proposal, (this is when the customer decided on a technology). It is at this (open circle) point the technology needs reach at least TRL-6 (internal decision of firm-X, to make sure that not too much non-recurring cost are spend on technology development). The small diamond indicates when the customer sells the airplane to his customer, and then the vertical bar indicates when the first product needs to be delivered to firm-X customer. Finally, the third layer contains the innovation projects necessary to get the technology on time to TRL-6. This layer is divided into steps of innovation process (material technology, design technology, component technology, sub-assembly and final assembly), to see if any gaps are left over.

The roadmap can be filled with content in two ways. The first one is a top-down approach, where from layer-1 a translation (with use of the strategy) is made from programs to the products that firm-X wants to offer (including which technology to use). With the products identified, a translation to innovation projects necessary to get the technology on time at TRL-6, and this action will result in projects for the third layer. The second approach is a bottom-up approach, where good ideas for new technologies are developed (which have no direct link to demands of the customer), but perhaps can lead to good new products in the future. For the sake of convenience only two projects have been drawn for the third layer. Those ideas can also be put on the roadmap, and later-on a specific path is chosen on the roadmap because not everything will be possible due to budget restrictions.

The development logic is created by linking product clearly to technology, and clear steps for the innovation process are indicated to make sure no steps are forgotten. This can be seen in figure 5.3.1 by the dashed lines, which indicate that specific innovation projects should be finished before a product can be brought into service. And another dashed line indicates that a specific product should be finished before the Entry into Service (EIS) date. Because the EIS date is set by the customer the products and innovation projects can be planned on the expected amount of work. Also, if knowledge is already developed in an earlier product than this can visualized in the third layer by leaving gaps in the sub-layers of this third layer.

The technology roadmaps are created with a Matlab (.m file) program that analyses data from the opportunities, products and innovation projects from an excel file and transforms it into sixteen unique TRM's (for each PG & KT combination). Appendix M contains an example of such a roadmap. This roadmap uses the same framework as discussed in the next paragraphs the only difference is that it has a little different shape which is the result of the way it is programmed. In this way the roadmaps can be changed with one click of a button by adjusting the data in the excel file and running it again with the Matlab executable. Because it is easier to adjust the technology roadmap it can be kept up to date easier and also everyone will use the same lay-out in the TRM as is specified by the Matlab program. Using the same lay-out throughout the firm is also suggested in the literature as very important to the success of technology roadmapping by (Phaal, Farrukh, & Probert, 2004).

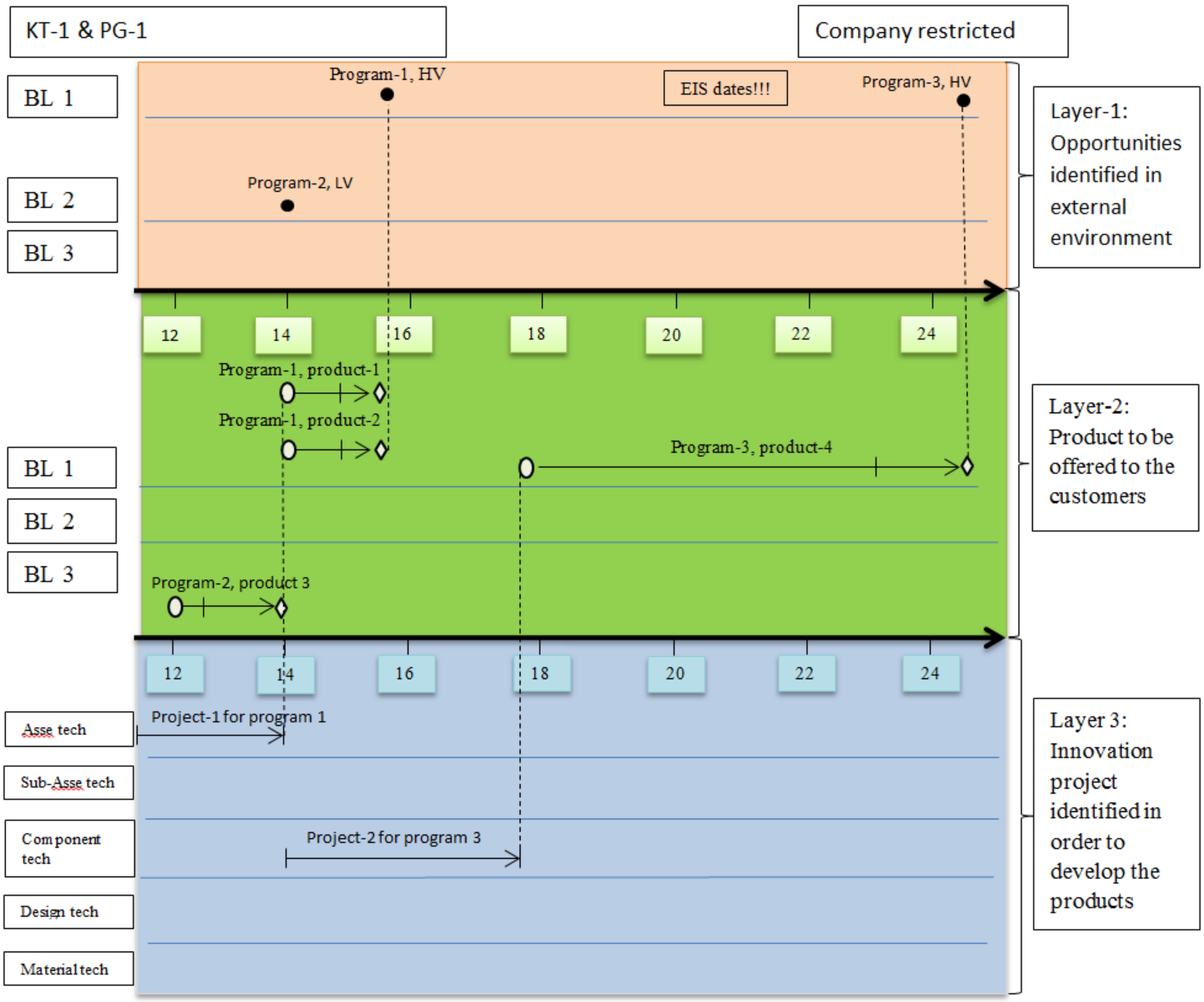
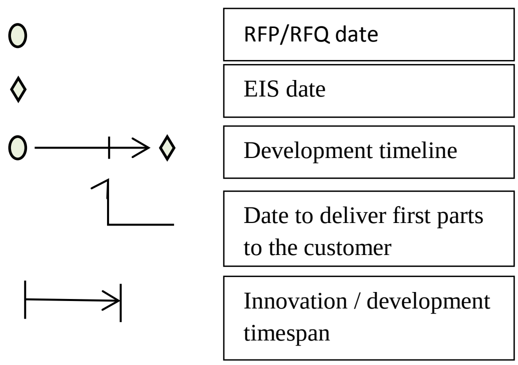


Figure 5.3.1: Example of a TRM for firm-X.



LV Low Volume
MV Medium Volume
HV High Volume

Figure 5.3.2: Explanation symbols in TRM of figure 5.3.1

Now the new TRM is explained a guideline can be set-up for the desired balance of the PG's and KT's.

The financial models in the literature are based upon the fact that they calculate; and rank order the innovation projects by, Net Present Value (NPV), Expected Commercial Value (ECV), or Internal Rate of Return (IRR) of innovation projects and dividing it by R&D cost. They also allocate resources to innovation projects form the top until they run out of resources, to maximize the value (Cooper & Edgett, 2001). In this way, there is no relation among projects in terms of technology related or stepping stone relation. In reality, it is hard to separate innovation projects. Because products and the complementary innovation projects are related to each other. Also, there is development logic of the innovation projects and so separating all innovation projects individually to compare is not that easy. Especially when time frames are long, it is difficult to do this rank ordering, because it can result to be very unbalancing in terms of time; e.g. big projects in the far future can unbalance the requirements significantly. Also, with the financial methods tend to disfavour technology advanced innovation projects due to the long term pay-off or lower probability of success (Chao & Kavadias, 2008).

To create a guideline for the R&D budget division over the PG's and KT's; it is suggested to look at all the opportunities available in the foreseeable future (new aircraft programs, first layer of TRM), and they can identified for many years in advance (≈10-15 years) in the industry of firm-X. From those opportunities with the current strategy, a plan is made which products (in combination with a technology) to deliver to the new platforms. Then Expected Commercial Value (ECV) is calculated for those products which are then reduced with a weight factor to calculate the expected value. An ECV calculation is chosen, because it has been reasoned that the product that can be delivered to an airplane stay the same only the technology changes, and also with increasing competition from a low wage country as China. Therefore, the prices of the product will probably not increase and so an estimate of current prices can be an indication for future prices. When summing up the expected value for the different technologies or product groups and dividing by the total expected revenues; a R&D budget division over the Product Groups and Key Technologies is developed. From this values guidelines for balancing the portfolio can be developed to guide how much of one technology should invested but it does not say which projects to select that should be selected with other tools. The products to be offered are the result of strategy, and so a technology importance is indicated by this strategy.

The ECV method wants to create a ranking of KT or PG importance for the future of the company and does not want to calculate the financial feasibility of products (as an NPV calculation shows). For this reason and because this might result in lower ranking for future technology projects, therefore in this approach the ECV does not assess the time value of money.

With this ECV calculation of the future product the foreseeable future is used to create an indication of how important a certain technology is to the future of firm-X. This importance can then be seen as an indication of the desired state. Different technologies are given a chance. And the expected value is a result of the strategy because the products on the TRM follow from the strategy and capabilities of the firm. Therefore this method is a combination of both financial models and strategic buckets. This method results in the following guideline:

> Guideline 3: *The desired state for R&D budget division over Product Groups and Key Technologies can be indicated from ECV calculations of envisioned products from the TRM.*

The guideline indicate the importance of a KT or PG for the future of firm-X, it is however not a measure for the amount of innovation necessary to create that future, but an indication of how important a certain PG or KT is for the firm. Therefore, the user should reason with the innovation projects and the guideline gives an importance for the use of each innovation project. The guideline can also indicate and help to choose a specific path/direction in the TRM; allowing it to function as a measure to look at how to balance the R&D budget over the PG and KT's.

To test out this method a selection of two BL's are made as an example. The example contains products from the business line Business Jets (BJ) and large Commercial (LC). These two have been chosen, because of the stepping stone approach of applying technology first to a BJ and when it has proved itself, it can then try to apply the technology to a product on a LC aircraft. The example is worked out in Appendix H. The result are shown in table

As stated before the ECV is calculated by assessing the revenue stream of each product envisioned in the TRM and later multiplied with a weight factor. In the following example calculations are executed with and without a weight factor to see the effect of it. The first thing to do is to explain the rationale behind the weight factor. The weight factor should be based upon probability of success, level of importance of innovation (due to time distance, less innovation money is spend on products far into the future then on products close to EIS), and amount of R&D necessary (if product is built to print then less R&D is perhaps necessary), these weights can be determined during a discussion of the central IPPM committee. For the following example, the weight factors have been developed through discussion with several members of firm-X. The results of the ECV calculation can be seen in tables 3.5.1ad.

Tables 5.3.1a-d: Result of example of revenue based guideline, top-left: indicated R&D budget division over KT without weight factor, top-right: indicated R&D budget division over PG's, bottom-left: Indicated R&D budget division over KT with weight factor, bottom-right: Indicated R&D budget division over PG's with weight factor.

No weight factor	Min.	Max.
TS	8.10%	3.41%
TP	55.09%	55.22%
FML	36.81%	41.37%
MB	0.00%	0.00%

No weight factor	Min.	Max.
M&D	23.07%	11.32%
T&W	12.52%	8.53%
F	64.42%	80.14%

Weight factor	Min.	Max.
TS	21.30%	9.33%
TP	27.73%	31.15%
FML	50.97%	59.52%
MB	0.00%	0.00%

Weight factor	Min.	Max.
M&D	25.93%	12.13%
T&W	7.82%	6.03%
F	66.26%	81.85%

The results show that the division of R&D budget changes significantly for the KT's when the weight factor is applied. The reason for that result is, firstly due to the fact that a A30x is a large revenue program in TP which receives a low weight, and because it is so far in the future. From these results, it can help understand what is going on in the future and this can form a basis for a discussion how the innovation budget should be balanced with regard to the PG's and KT's. There is a smaller difference for the PG's. The difference in Max & Min is given in table's 5.3.1a-d, and is stated because the experts have given a range of values for the total amount of ship sets or the revenue stream per ship set. Apparently in this example, there is no Metal Bonding (MB) applied to any product because the results for MB are zero. The difference between those minimal and maximal values can be quite big e.g. 16% difference for table no weight factor & Fuselage (top right table) and that can make the results less accurate but it still can indicate some direction of how the R&D budget should be allocated. The entire calculation can be found in appendix H.

The approach of the TRM is based on all innovation projects that have a scope and so an indication of the cost can be given. One of the requirements is also that the framework creates room for the fluid phase for very new ideas. These projects will not be indicated in the TRM, but a special budget is already allocated for these projects, which is the 'new ideas'. It can be said that this is another bucket only focused on this phase.

<u>Limitations of the revenue model are:</u>

This model of the expected revenue for balancing the innovation portfolio is of course not perfect and in this section a few limitations are discussed.

- Sometimes it is unknown what the percentage of a new technology will be in a future product, assuming 100% new technology might give errors for the balancing. On the other hand firm-X says it is an integrated of new innovations so the innovations lead to the revenue and not the existing technologies.
- There is uncertainty in the expected revenues that is given to each product.
- The framework does not show the cost, so an optimization of cost cannot be executed. It is assumed that all products in their totality need to be commercial viable.
- The model is not prepared for sudden changes, but you cannot plan for the unexpected.
- It should be checked how the group 'Enabling Technologies' can be incorporated in the revenue model, as also innovations should be done in this group, perhaps the BL can already make an indication how much percentage of one technology will be in a specific product. Then automatically enabling technology will receive its part
- The ECV calculations that lead to a balancing guideline for the PG's and KT's does not say that when it is balanced like this, so that each bucket has enough money to prepare for the future. It is based on the importance of each KT or PG to the firm, but is not related to the innovation cost to get the technology that is necessary for the products.

<u>Summary of this section:</u>

This section explains how to indicate the desired state for the R&D budget division over four factors, the TRL, the parts of the value chain, the PG's and the KT's. The approach leads to three guidelines. Guideline 1 and 2 indicated an R&D budget division over the TRL and value chain based upon the interviews of section 4.3. The third guideline indicates a R&D budget division over the PG's and KT's which is based on a percentage of PG's or KT's in the future products through an ECV calculation off the future products. This indicates an importance of each PG and KT for the firm. This method is a strategic bucket methodology but it has several ways of dividing the buckets at the same time, every division is for another characteristic of the innovation framework.

5.4 Step three: Comparing Current IPP state & new opportunities with desired IPP state

Now that the guidelines are developed to indicate how the IPP should be like, it should be possible to compare the current IPP to the desired IPP. This needs to be done by the central committee. The comparison is easy, as the result of step one and two can be directly compared because they have the same factors. The comparison of R&D budget over TRL levels and parts of the value chain are shown in figure 4.3.1 and figure 4.3.4. The comparison of R&D budget over PG's and KT's can be done by comparing table 5.2.1 (current state) with table's 5.3.1a-d (desired state).

5.5 Step four: Deciding on adjustments for the Current IPP state

After comparison adjustments can be decided upon to change the IPP to a new state. To get an IPP that matches all the guidelines is probably an ideal, and with a trial and error approach the central committee should try to achieve this.

The trial and error approach to create an IPP (that is according to the guidelines) can be executed with the help of for example an excel sheet. All the projects can be mapped for the characteristics mentioned above. Then with use of a an Excel file, a program can be developed where the user can choose a set of innovation projects, for which the excel program calculates how the division of R&D budget over the TRL, value chain, PG's and KT's to check it with the guidelines. Then set of innovation projects chosen can be adapted in a few rounds to change the portfolio towards the guidelines.

The set of projects chosen should not be a random combination of innovation projects such that it fits the guidelines, but it should a set of projects to is related to each other. To assess a set of related innovation projects the TRM can help out, because the TRM shows the inter relation of innovation projects. The guideline can help to choose a specific path in the TRM and then the innovation projects should be found that fit with this road and the guidelines. The guidelines are not set in stone, rather they should be argued and reasoned with, and perhaps many good reasons can be given for an IPP that is unbalanced according to these guidelines. The guidelines indicate and help to focus the IPP in a certain direction started from the strategy. They are a systematic approach in managing the IPP. The combination of the TRM and the guidelines can help to select the innovation projects for the IPP.

The framework suggested in this chapter contains several guidelines that divide the R&D budget into different buckets. The guidelines focus on characteristics of the innovation organization such as TRL, the value chain, and the matrix organization which is divided amongst product groups and key technologies. However, every guideline divides the R&D budget into different buckets that complement each other as is visualized in figure 5.5.1. The R&D budget division over TRL balance and the different PG's can be executed at the same time, and both indicate a different balance. The four guidelines are perhaps difficult to obtain and that can lead to some implicit judgement because higher management now needs to decide how to deal with this. Radical or incremental innovation projects are not specially focused on, because innovation projects (may it be radical or incremental) are all combined in the TRM's. The guidelines and the interrelation of projects to products will result in a choice of products, therefore the level of radical or incremental innovation projects is the result of the translation of strategy into the TRM's. The result of the guidelines and of course the result of the decision making process.

For the fluid phase a special bucket is developed and it is not included in any of the other analysis, therefore there is also no guideline to steer this bucket. The total R&D budget is then divided as in figure 5.5.1. Where TRL1 to TRL is are the six strategic buckets for TRL 1-6 and the same for the others, PG stands for Product Group, KT stands for Key Technology and VC stands for Value Chain. Figure 5.1.1 shows that TRL 1 and 2 are in the rational where all innovation projects have scope, budget and are in line with the strategy. Earlier, it was discussed that low TRL levels don't need to have scope or be in line with strategy. Which means that for the projects in the fluid phase, money can be supplied.

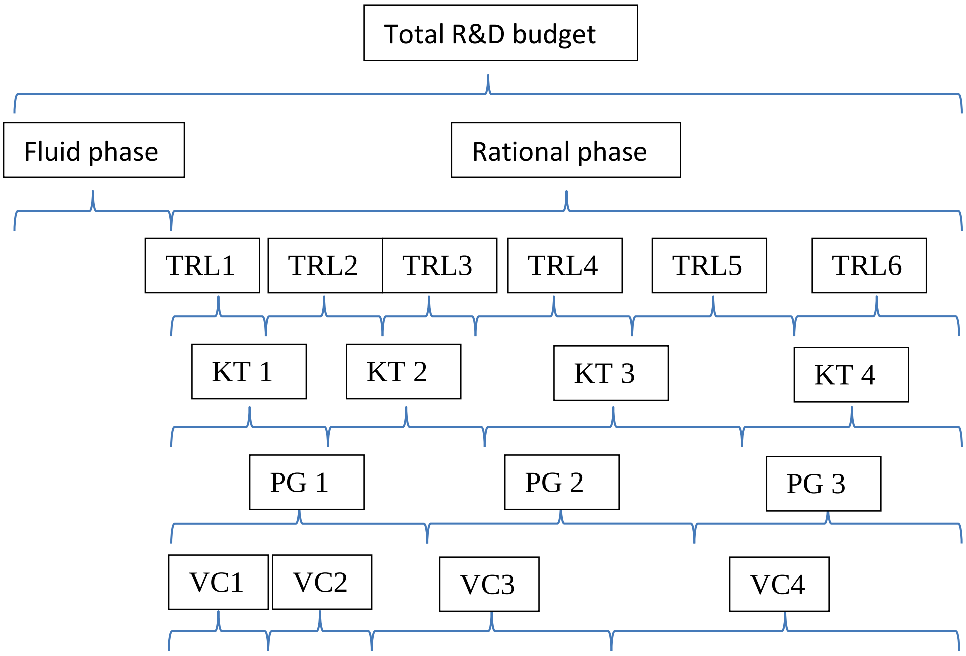


Figure 5.5.1: Division of R&D budget into strategic buckets

5.6 Other Requirements

In section 5.1 all the requirements have been summed-up and in section 5.2 until 5.5 the new framework is explained through the four steps of the conceptual model. Because every step is executed the requirements 2, 3, 5 & 6 have been satisfied and it can be called an integrated framework. The integrated framework reduces the implicit judgement and also the framework is based on reliable information by using the factors indicated in section 5.1.2 this means that requirements 1 and 4 also have been satisfied. In this section it will be discussed how the other requirements also have been met in the new framework.

7) The three goals are achieved by balancing the portfolio through strategic buckets over the four aspects (KT, PG, TRL, and value chain), optimizing the value of the IPP through assessing ECV calculations, strategically aligning by translating strategy into products, and creating a development logic of innovation products that lead to those products. The article (Kester, 2011) shows that balance leads to maximize value and strategy alignment, therefore balance is given the most importance through the strategic bucket approach.

8) The new framework is based on factors that are indicated by firm-X to be reliable, where TRL measurements are executed through assessments in teams, in PG and in KT (and where it has also been indicated which part of the value chain is a description of the technology). The allocated cost is also given per project therefore information is not based on implicit judgement.
9) If the framework fits managements style, which will be discussed in the next section about validation of the mode.
10) The effect of inter-organizational innovation activities can be incorporated in the measurement of the current IPP state by adding the extra amount of R&D budget over the R&D budget division over the four aspects (KT, PG, TRL & parts of the value chain). This will be explained in more detail in section 5.6.1 because it is quite elaborate.
11) Development logic is created through the TRM, opportunities, products and innovation projects are linked to each other on a timeline.
12) The development logic created in the TRM should facilitate a better down flow of requirements. On top of that the new TRM is more linked to the innovation organization at firm-X, therefore this should lead to a better understanding of the TRM and by doing so lead to a better sense of what needs to be done in the company (which will support people to know what they should be doing and that can lead to a better down flow of requirements).
13) The new framework supports the fluid and formal phase. There is a separate strategic bucket for the fluid phase see figure 5.5.1 and that phase can be organized very organically. The formal phase is the rest of the R&D budget, which can be organized more formally as explained in section 5.2 until 5.5.
14) The new IPPM framework should have central multidisciplinary team for filling in content of the roadmaps, and selecting the right innovation projects supported by the guidelines and graphs.
15) Technology push and pull lead to a different way of getting the requirements from the customer, and both can be supported by the new framework.
16) Bottom-up and Top-down innovation approach is also both possible, because both can be incorporated in the TRM same argument as requirement 15. The bottom-up ideas, however, are only allowed for low TRL projects where it is not clear if it fits the strategy.
17) Long term focus is possible, because the TRM visualizes the entire foreseeable future.
18) The market demand is visualized in the TRM in the top layer and the requirement down flow should create a clear vision of the demand of the market.

All requirements have received attention in the design, requirement 8 can however only fully be assessed after implementation of the framework at firm-X.

5.6.1 Incorporating inter-organizational innovation activities in overview of current IPP state

Requirement number 10 is to incorporate the effect of the inter-organization innovation activities into the IPPM framework, specifically focusing on the project selection and resource allocation. This section will explain how to incorporate this effect into measurement of the current IPP state (step one of explained in section 5.2). The R&D budget divisions over (PG's, KT's, TRL's and parts of the value chain) can easily be adapted for the increase in R&D budget through inter-organizational innovation activities (collaboration or funding), and will results in a different current state. This section will explain how to do that and will give examples of firm-X.

Due to inter-organizational innovation activities the amount of R&D increases because different partners together spend on the same research. The R&D budget division over the different aspect affected by inter-organizational innovation activities can be calculated by adding the R&D money that partners spend on Work Packages of innovation projects of interest to firm-X to the current state of the innovation division over the different characteristics. In this way the total amount of research that firm-X has access to and can influence can be calculated. In the following graphs the effect of inter-organizational innovation activities on the portfolio is indicated. It has been calculated with internal document of firm-X and educated guesses by the writer of this report about which WP's of the projects are of interest to firm-X (some of the WP in innovation projects are not of interest to firm-X, but are in the projects because the partners want it there).

The framework should use the graphs that include the effect of inter-organization innovation activities because that gives a better representation of the performance of the current IPP state and so will increase the quality of the IPPM decisions. Especially at firm-X incorporating the effect of inter-organization innovation activities can change the overview of the current IPP state quite significantly because they engage in so much inter-organizational innovation activities (section 3.2).

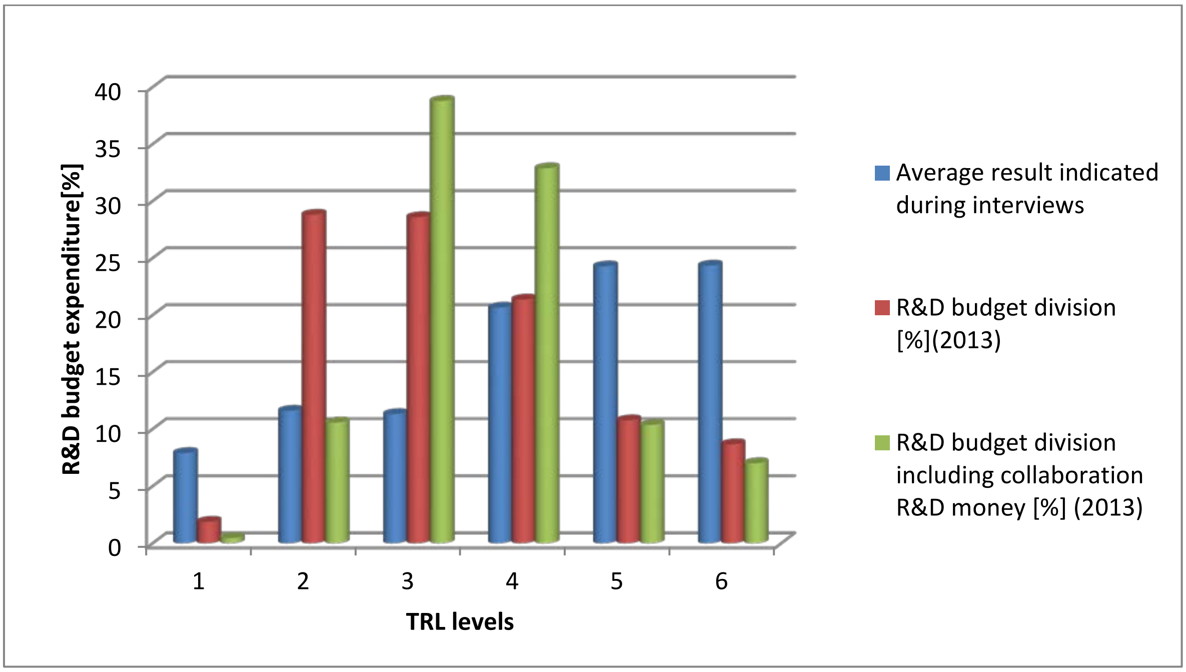


Figure 5.6.1: R&D budget division over TRL, blue: indicated in interviews, red: firm-X 2013 R&D budget division, green: 2013 R&D budget division + innovation activities R&D money for 2013

Figure 5.6.1 shows that the R&D budget division updated for the inter-organizational innovation activities effect (the green columns) is already more towards a good balance compared to the R&D budget division on its own, still more should be spend on TRL-6. In figure 5.6.2 the absolute number are shown, but still more should be spend on TRL-6, and perhaps also on TRL-5.

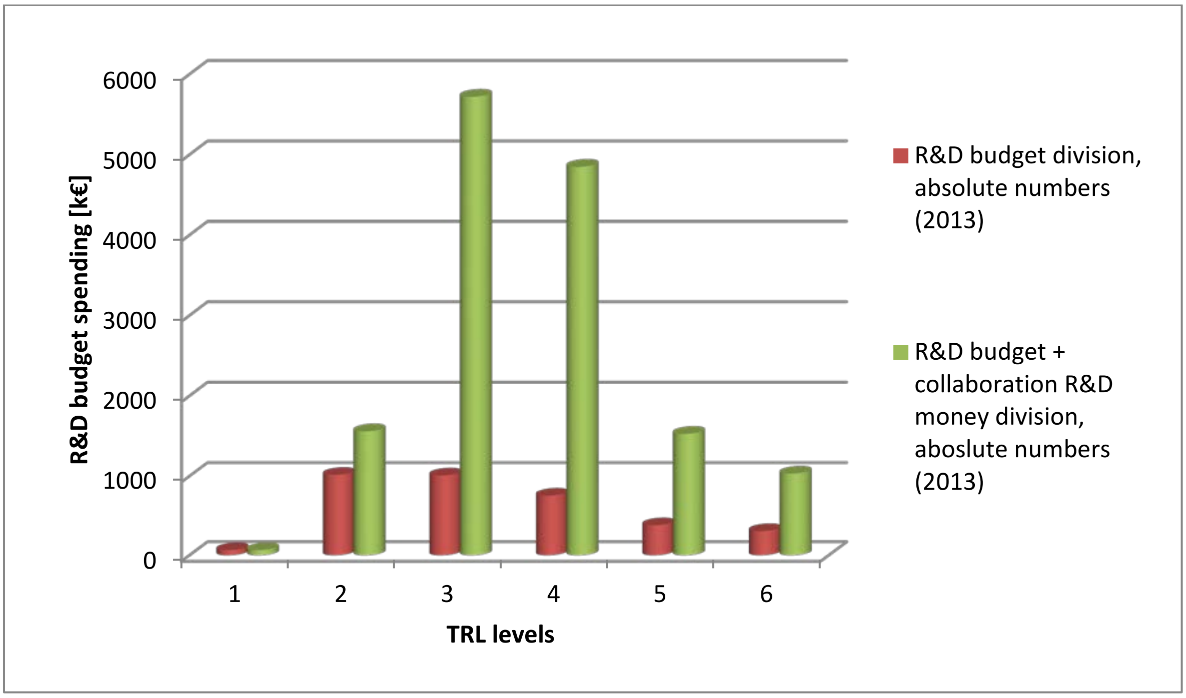


Figure 5.6.2: Absolute R&D budget spending per TRL-level for both R&D budget and the increased R&D budget due to innovation activities.

Figure 5.6.3 shows the division of R&D budget over the parts of the value chain, which was indicated in the interviews; comparing it to the current R&D budget division over the value chain and the R&D budget division (over the parts of the value updated for the effect of inter-organizational innovation activities). The normal R&D budget and updated R&D budget are quite close to each other. To improve the balance, perhaps less should be invested in material development and more into supporting technologies. In figure 5.6.4 the absolute numbers show that the innovation activities show how much the budget increases due to innovation activities.

TAPAS II, Aflonext, JI SFWA & JTI eco-design are four innovation activities innovation projects, which have so many partners that the (research) budget is quite big, that it serves as an example in illustrating what a big difference there can be between the normal R&D budget and the updated R&D budget for innovation activities.

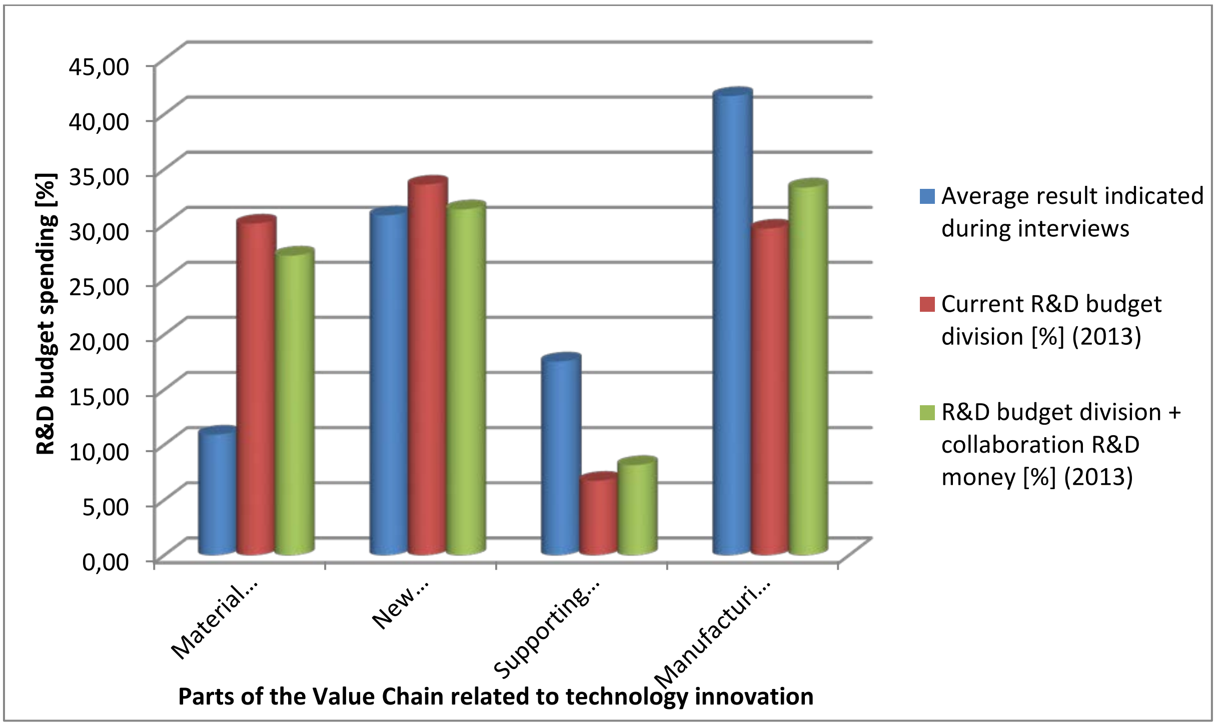


Figure 5.6.3: R&D budget division over parts of the Value Chain, blue: indicated in interviews, red: firm-X 2013 R&D budget division, green: 2013 R&D budget division + innovation activities R&D money for 2013

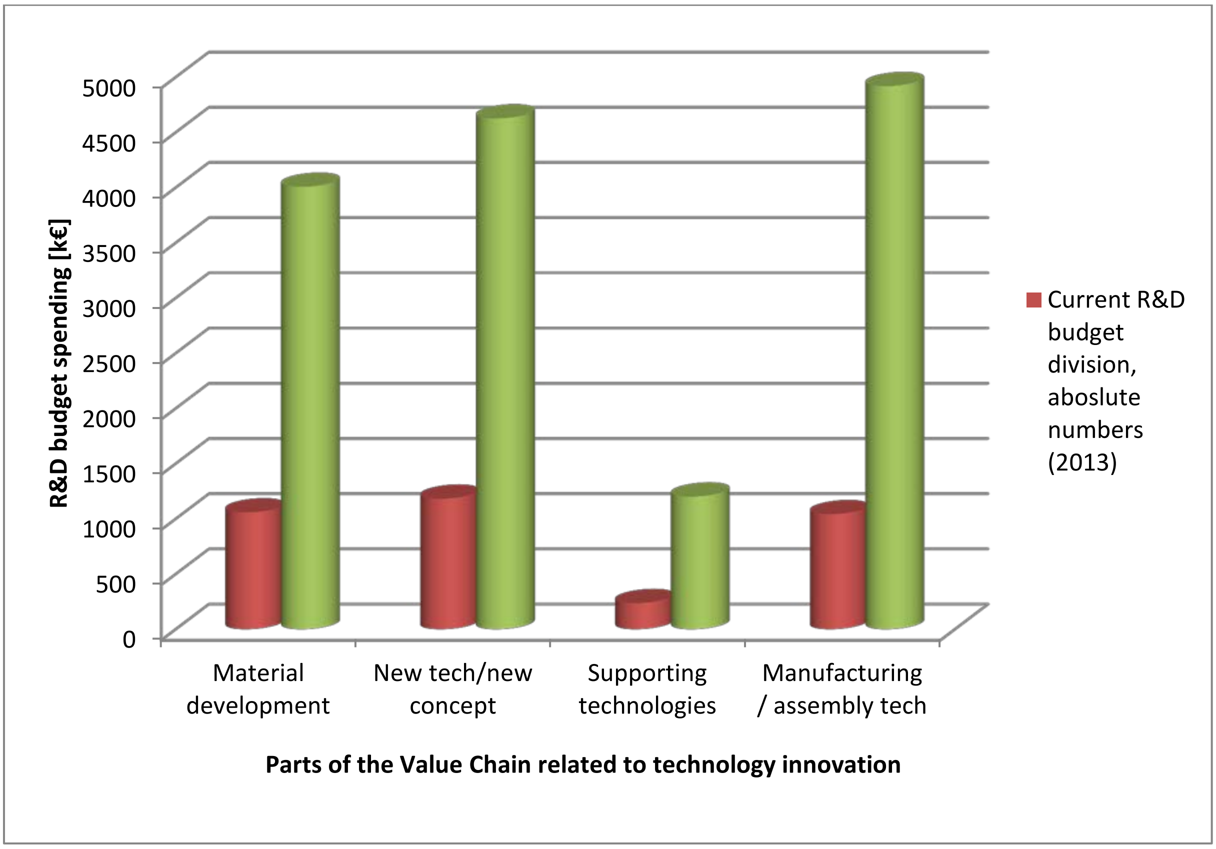


Figure 5.6.4: Absolute R&D budget spending per part of the Value Chain for both R&D budget and the increased R&D budget due to innovation activities.

TRM:

In table 5.6.1 the financial division of table 5.2.1 is updated for the effect of the inter-organizational innovation activities. Also in this table, you can find an extra row and column is added to show the ratio of the updated R&D budget for innovation activities divided by the normal R&D budget. With strategy, a balance should be indicated how the division of projects should look like. The tool doesn't state what to do, instead points out that the division should be resulting from the strategy. Therefore, the selection committee should reason with the tool, and by doing so, they can see directly what the effect of their decision is on the IPP. In figure 5.6.5 and figure 5.6.6 the R&D budget division over PG's and KT's is compared for current R&D division, and the R&D division updated for the effect of inter-organizational effect. Also, an indication is given how much (ratio number) the inter-organizational innovation activities do increase the current R&D spending of those specific buckets.

Table 5.6.1: Division or firm-X R&D budget & R&D money through innovation activities over PG's & KT's

Product Groups / Key Technology	T&W	M&D	F	Total net cost per KT [k€]	Budget per KT [%]	Ratio of total net cost increase due to inter-organizational innovation activities
TS	2898	714	40	3651	19.43	5.66
TP	6741	721	3883	11346	60.37	5.83
FML	2865	843	30	3739	19.89	4.16
MB	19	19	19	58	0.31%	1.20
Total net cost PG [k€]	12523	2298	3973		100 %	
Budget per PG [%]	66.64	12.23	21.14	100%		
Ratio of total net cost increase due to inter-organizational innovation activities	9.94	1.49	5.44			

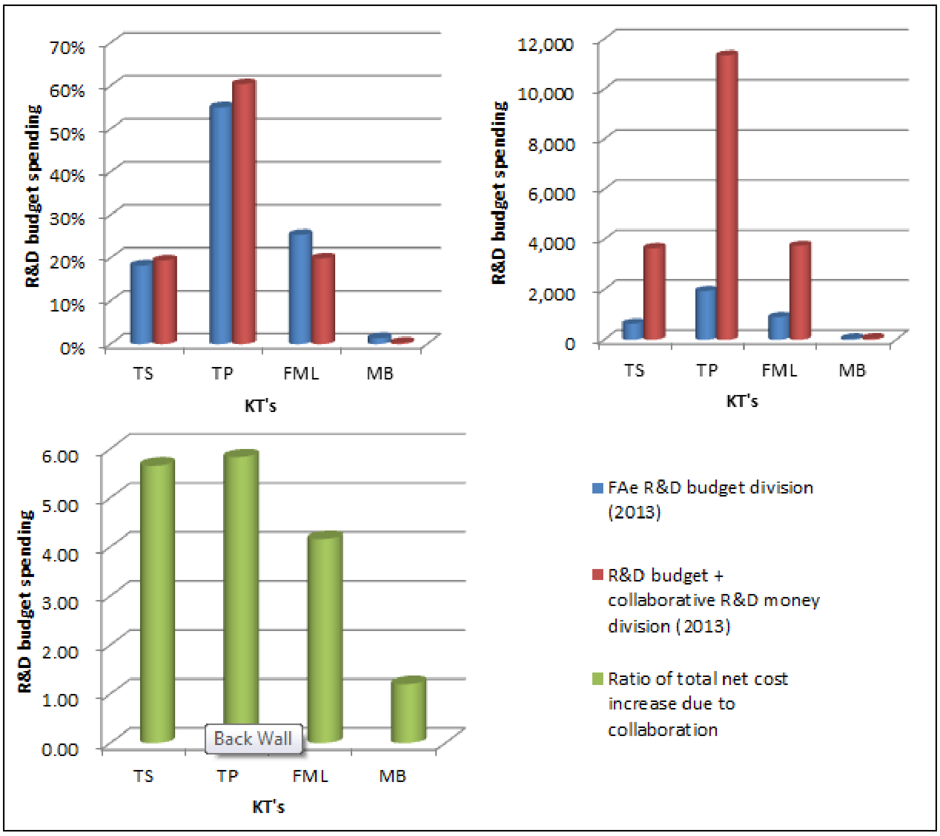


Figure 5.6.5: R&D budget division over KT's

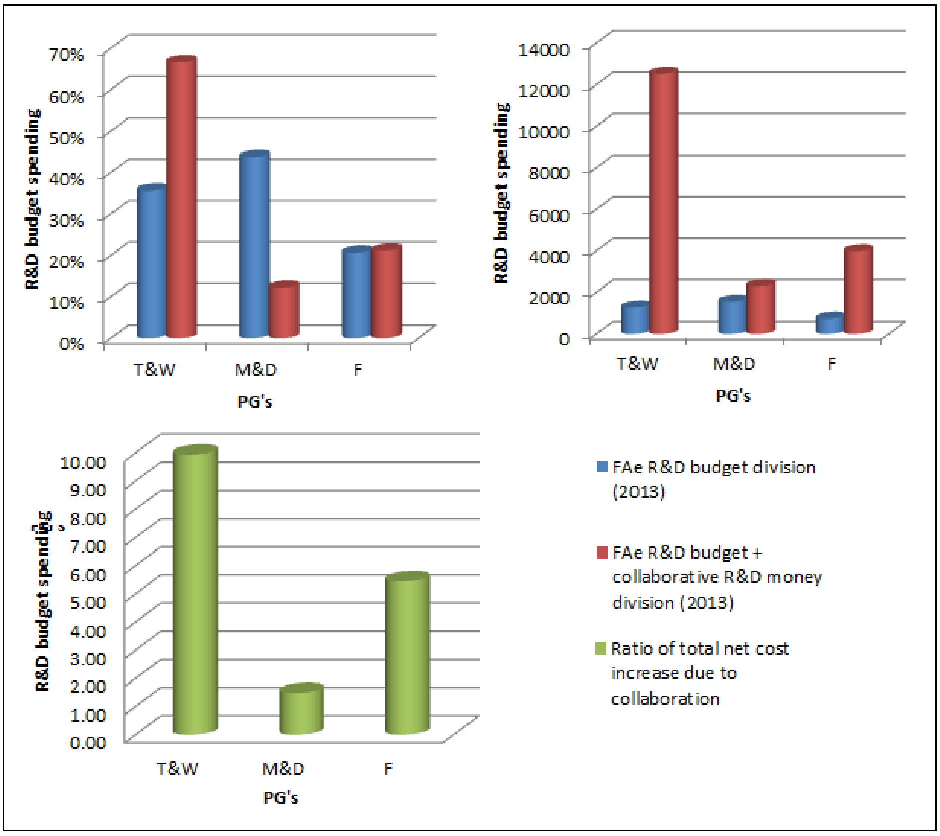


Figure 5.6.6: R&D budget division over PG's

5.7 Implementation

This section discusses how the framework can be implemented in firm-X. The framework consists of a technology roadmapping and strategic bucket approach, and these will be discussed in this order.

As discussed in section 5.3 the technology roadmaps are created with a Matlab (.m file) program that analyses data from the opportunities, products and innovation projects from an Excel file and transforms it into sixteen unique TRM's (for each PG & KT combination). The Matlab program will increase speed of the technology roadmapping process at firm-X significantly, when compared to the old process, because roadmaps can be updated on the spot. The updating of the Excel sheets, and in turn the updating of the roadmaps, should be the responsibility of one office (suggesting the TO), so that all the data from the different departments will be entered in the Excel document.

This Excel document can then also be used for the strategic bucket approach. Because all innovation projects and products are already in the excel file, it is easy to calculate the division of the R&D budget over the characteristics of the innovation organization (TRL's, parts of the value chain, PG's & KT's). The Excel file automatically generates the graphs for these characteristics in the same form as the graphs in chapter 4 and 5. When the data in the Excel file is updated, then these graphs are automatically updated. This means that the TO has the overview of the performance of the current and desired IPP state, and should be able to make the portfolio decision with respect to the innovation projects. When this is implemented firm-X only need to have some meetings, where they will discuss the indicated desired states of the R&D budget over the TRL levels and parts of the value chain to discuss (depending on whether they want to keep this desired state or if for some reasons another state would be more preferable).

5.8 Validation of model

This section will discuss the validation of the model, first the model will be discussed with Linda Kester (assistant professor NPD at TU Delft) who is an expert in strategic decision making processes. Secondly the model will be discussed with firm-X, to see if they think it will fit firm-X and its management style.

<u>Interview with expert: Linda Kester (took place Wednesday 18-06-2013):</u>

Linda Kester is an assistant professor at faculty Industrial Design and focuses in her own research she focuses on the strategic decision making process of the NPD process. During the interview, she indicated that she thinks that the model will give an overview. She thinks even harder criteria for the guidelines should be given or examples how to implement the tool, otherwise she thinks there will still be too many projects for the available resources. She said, as mentioned in her articles, that most firms don't have an overview of their current portfolio; which makes it very difficult to decide on how to continue. Therefore, she thinks this model can help to give this overview. She also suggested that a guideline for the opportunities can be developed (which can indicate which opportunities are most important) and help to give a rationale for the other guidelines. On top of that, she thinks this is also some kind of strategic bucket tool, which is validation of what has been written in former chapter.

Validation of Framework with members of firm-X (Took place on Tuesday 25-06-2013):

There is no validation through actual implementation, but only possible by assessing the thoughts of the members of firm-X, when this framework was presented on the 25th of June. Topics that were discussed are: to see if the model fits the management style of firm-X, and if they have any remarks or new requirements for the new framework.

After presenting the framework and the results, Head of new concept development asked a question about a deeper understanding of the TRLs. He suggested that it should be investigated where the money comes from to get the current technologies from TRL 1-9, as it must come from somewhere. If that is understood, then it would perhaps lead to a better understanding of how the balance should be.

Personally, I would say that this is not a good method. Because currently too little is spent on TRL 5 and 6, which is why these costs are transferred to the PG's during the design of the products, and that eventually leads to longer design cycles (delay), cost overrun, and fire fighting (because everyone is solving problems that already should have been solved). The new proposed method will prepare technologies for TRL 6, therefore relieving some sectors of fire-fighting, letting the process become clearer and (hopefully) more effective.

At the end of the meeting, the attendants suggested that the method will be used by the TO to assist them in their work of managing the IPP. Therefore, it is concluded that this method can assist firm-X in IPPM, but if it really fits management style remains a question that is to be answered after implementation. This is because in the meeting, there was too little time to really see if it fit the management style.

5.9 Answering research Question 4

This section will answer research sub-question 4: *Which parts of the new framework are different from theory?* This section compares the new framework, as explained in this chapter, to the literature chapter and discusses the differences. The framework developed is a combination of strategic buckets, financial method and technology roadmaps. It is based upon the conceptual framework based upon literature in figure 2.11.1. However, there are a few aspects different from literature and that is what will be discussed here.

Existing literature describes Strategic Buckets as a breakdown of the R&D budget into several smaller portions specified to certain buckets that define where management desires the development money to go to. The spending of R&D money can then be seen as a reflection of the strategic priorities of the firm. The strategic buckets build firewalls between buckets by earmarking specific amount of resources for different buckets (Cooper R. , Managing technology development projects, 2006). The literature describes that higher management should make a ranking of the buckets. and then allocate the resources. Next, they should rank the projects inside the buckets. and then allocate resource until all resources are gone.

In this framework, it is suggested that the R&D budget is not divided into one set of strategic bucket (as done in the literature), but into several sets of strategic buckets. Every set of strategic bucket is a different way of how to divide the budget over a certain set of buckets. Each set of strategic buckets is not interacting with another set, because it has to do with the overall budget division. For the four characteristics of the innovation organization, a set of strategic buckets can be applied that divide the R&D budget (see figure 5.5.1) over the strategic buckets of each characteristic. It results in a four dimensional division of the R&D budget. By assessing all the characteristics separately, to get the right division of R&D budget over each characteristic, then according to the guidelines make it possible for all characteristics to be managed. Dividing the R&D over several characteristics will also balance the IPP for all of these characteristics. All the four guidelines are based on balancing, to strategically align and to a lesser extent be focused on value maximization; all of which will therefore lead to effective IPPM.

Optimizing the IPP state can lead to reducing the allocated resources for one set of projects, as indicated by the guidelines. According to (Parviz & Levin, 2006), this is good as he states "optimization: Only a fraction of the required resources are assigned to a given project, with the full knowledge that reduced resources will delay the delivery of the specific project, on the premise that increasing the resource pool is not in the best interest of the enterprise and that resources can be used better elsewhere". The guidelines that have been developed, indicate when resource can be better used elsewhere in the organization. By keeping those guidelines in mind, paths can be chosen in the technology roadmap that fit the guidelines, and thus create development logic.

The developed framework compares the entire foreseeable future with the IPP, and how it can be achieved; therefore balancing the IPP for the entire foreseeable future. The framework also incorporates the effect Inter-organizational innovation activities. This is done, because it affects the amount of R&D expenditure over the different characteristics (TRL, value chain, PG's and KT's). In the literature there is not much written about how to incorporate the effect of inter-organizational innovation activities in the IPPM decision making process, and therefore this can be a suggestion how to connect internal and external innovation portfolios for IPPM decision making.

Chapter 6: Synthesis

This chapter will combine all the answers from the four sub-questions that have been discussed in the previous chapters. In addition, the final design of the new framework in chapter 5 will also be deliberated in order to answer the main research question. Section 6.1 contains the conclusions, whereas in section 6.2 recommendations are made for further improvement of the framework for firm-X. Section 6.3 discusses the research limitations and options for further research and this chapter then ends on a last note about validation and a reflection of the results respectively in section 6.4 and 6.5.

6.1 Conclusions

This section focuses on the conclusions of this thesis, which will encompass the conclusions from the interviews and the conclusions from the design of the new framework, combining both will result in answering the main research question: *How to create an integrated framework for effective IPPM?*

An IPPM approach can bring considerable benefits to the performance of an IPP. This performance can be achieved by creating an effective and integrated framework for IPPM. The framework designed in chapter 5 will be generalized in this section. To explain the generalization, the model developed from the literature in figure 2.4.2 is updated, as can be seen in figure 6.1.1. An effective IPP can be created by focussing on three goals which are; balancing, value maximizing and aligning the IPP with strategy. It has been reasoned in the conceptual model, that an integrated framework can be achieved when the framework is based on four steps: 1) assessing the current IPP state, 2) indicating the desired IPP state, 3) comparing the current and desired IPP state and 4) suggesting adjustments for changing the current IPP into a new IPP state as indicated in figure 6.1.1. This has been explained as part of the first research question that focuses on the current state of the literature. Also a set of factors and tools have been identified and they have classified over the four steps of the conceptual model.

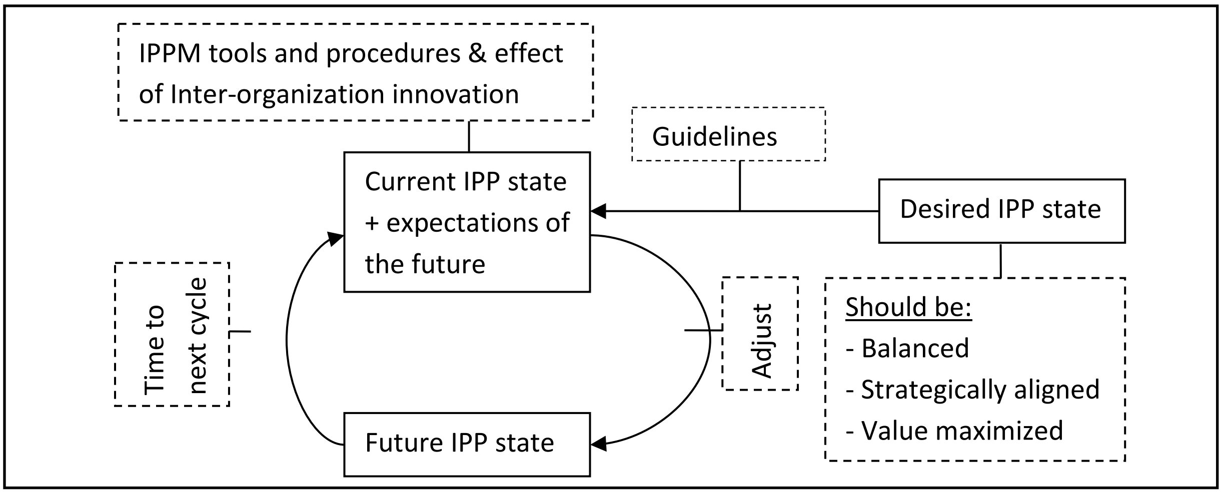


Figure 6.1.1: Approach for an integrated framework that can be used for design of an effective IPPM framework

The second sub-question focuses on the current framework for organizing the innovation at firm-X. The innovation organization is dependent on the business environment, and the industry of firm-X can be characterized as having long development cycles and R&D intensive due to expensive full scale testing. On top of that, firm-X has compared to the industry a limited R&D budget of 1.05% of the revenues. However, through inter-organizational innovation activities this R&D budget is increased. With these mechanisms in place, it is important for firm-X to be able to select the right innovation projects for the long term survival of the firm. The current selection process of the innovation projects is based on individual project selection by individual project characteristics, so a portfolio mind set is not central in this selection procedure. Therefore, portfolio characteristics are not known and this in combination with a short term focus and fire-fighting results in an opportunistic portfolio of innovation projects.

The third sub question investigates during interviews what the perspective is of many members of the innovation organization, with respect to several aspects related to a framework for IPPM. The results indicate that a formal approach will work for the innovation projects that are developed to a certain extent, so that scope and requirements are clear. For projects with a low TRL and radical nature, a less formal approach would suit better. These two results indicate that a two phase model for the selection of innovation projects is preferred. Furthermore, the same thing can be said for the relation with strategy; as for those young and radical projects, it is not always clear if they fit strategy. Thus, for such innovation projects, constraining them to align with strategy can limit the chance of selecting successful innovation projects. Technology push and pull has its effect on the way the requirements are flowing down during the execution of the innovation projects and have less effect on IPPM decisions. Finally, the effect of inter-organizational innovation activities can be significantly influencing the current IPP state.

In the fourth sub-question the design of the new framework is discussed and compared to the extant literature. The conceptual model describes how to create an integrated framework. These four steps have been transformed into a framework that can be applied at firm-X. The framework is based upon a strategic bucket approach, technology roadmaps, and a financial ECV approach; and this combination makes sure all the four steps are executed in such a way, that implicit judgement is reduced in the IPPM process. Also, other factors have been chosen that give reliable information to further reduce the implicit judgement.

Traditionally the strategic bucket approach is used to divide the R&D budget over one set of buckets. In the new framework, the strategic bucket approach is operationalized by dividing R&D over multiple sets of buckets. This is done by dividing the R&D budget over four sets characteristics of innovation: 1) Technology Readiness Levels (TRL's), 2) parts of the value chain, 3) product groups and 4) key technologies. These four characteristics lead to four sets of independent strategic buckets that indicate the current and desired IPP state. The current IPP state can be measured by mapping R&D expenditure of the all the current innovation projects over these four characteristics of the innovation organization. The desired state of the R&D budget over TRL and parts of the value chain is indicated in the interviews because it an industry specific characteristic. The desired state of R&D budget division over the PG's and KT's depends on both the business environment and the strategy and is therefore based on an ECV calculation from the indicated products in the TRM. These products are the results from a strategic translation of the opportunities identified and bottom-up innovation ideas that lead to products from which an ECV calculation. After this step, each PG and KT is summed up to indicate how important each PG or KT is for the future of the firm. It is not an indication of how much resources are required to make that future happen. However, higher management needs to decide how to interpret these guidelines and translate it into how much resources per KT or PG is necessary to make that future happen. For the TRL and value chain, the guidelines indicate how the resources should be balanced so it leads to effective IPPM, it is an indication when resources can be used better elsewhere in the firm, hereby reducing implicit judgement. These four guidelines divide the R&D budget in four sets of strategic buckets all of which are not inter-related. The strategic bucket approach in the literature only focuses on one set of strategic buckets and not on multiple sets of buckets at the same time. The strategic buckets build firewalls between the buckets, by earmarking specific amount of resources for each bucket. Because the four sets of buckets are not inter-related, they can be used to balance while maintaining the firewall in each set between the buckets. When the current state is known, and for the same indicators for the desired state are obtained; then a path inside the TRM can be chosen. This is the way that the framework can help to assist the decision making process for IPPM.

This approach can be used in the industry of firm-X, because it has long development cycles and a limited set of customers; thus allowing planning and opportunity identification to be done for a manageable size. The new framework will also look to the entire foreseeable future of the firm, instead of only to a short term.

In turn, the framework incorporates the effect of inter-organizational innovation activities, by taking the extra R&D money into account that was obtained through collaboration (and which will affect the current state). Incorporating this effect is important for firms who spend a lot on collaboration, because it can affect the current IPP state quite significantly, therefore it is suggested to always incorporate this effect.

With the guidelines and the technology roadmaps that show development logic set in place, will in turn limit the number of IPP combinations. This helps in choosing a specific path for selection of innovation projects that match the four desired states of TRL, parts of the value chain, PG and KT. This will always allow the link with strategy to be maintained and the presence of development logic. With the use of all these tools and guidelines together, implicit judgement can be reduced quite significantly.

The conceptual model shows a structured way to check and see if the framework you developed misses any steps and if you need another method or tool to supplement the framework. Authors (Cooper, Edgett, & Kleinschmidt, 2001b) stated that the best performing firm's use multiple methods, but it is not indicated which combination is used. The conceptual model can be a model for firms to assess which tools are required to satisfy all the steps in the model to create an integrated framework.

The main research question is: *How to create an integrated framework for effective IPPM?* The question is for a big part already answered in the previous paragraphs and the following paragraphs will merely be a reflection of what is discussed.

The design of an IPPM framework is for each firm different and shall always depend on firm and industry characteristics. This thesis attempted to create a better understanding of some of these characteristics; such as technology push and pull, top-down and bottom-up approach, organic vs.

systematic IPPM approach, long term focus and effect of inter-organizational innovation activities and its effect on the IPPM which is discussed in the previous paragraphs.

The results indicate that an organic approach is necessary for young and radical projects but the design focuses mainly on the systematic approach because that's the parts what can be designed. From the conceptual model it has been reasoned that with this four step approach, implicit judgement can be reduced while increasing the evidence based decision making for this systematic approach; and that it should lead to an effective IPPM. The framework suggested for firm-X has been explained in the paragraph above.

During the thesis, the supporting tools have also been developed for the framework; meaning that an Excel basis has been developed where all the innovation projects can be summarized and allow the program to automatically create the graphs of the four characteristics for the current and desired IPP state. Also, a program has been written in the Matlab environment that can read the Excel file, and then produces the technology roadmaps. In this way the new IPPM framework can be supported, increasing the speed and the creation of the evidence based decision making process in IPPM.

In short the added value of this thesis is:

- The new framework suggests using multiple sets of strategic buckets to balance several characteristics that are not related to each other.
- Focusing the selection of innovation projects based on an indication of the current and desired IPP state. This current and desired IPP states is based on characteristics that describe the innovation performance and that finally lead to an effective IPPM in order to reduce the implicit judgement & increase the evidence based decision making.
- The interviews indicate that a non-IPPM approach might be very useful for the organic phase of the IPPM framework, where the project scope, the requirements and alignment with strategy is not clear yet. These innovation projects should be given some room to develop further.
- It also identifies that IPPM literature focuses on internal projects only and network analysis doesn't focus on managing the portfolio, and suggests those two streams should perhaps be connected. In the new framework an approach of incorporating the extra R&D money through collaboration is used, to see the balance of the current portfolio.
- Development of the supporting tools is used to implement the framework to increase the speed of IPPM.

6.2 Recommendations for firm-X

In section 5.2 until 5.6 the new framework for selecting the right innovation projects for firm-X is discussed. Later on, in section 5.7, it is indicated how to implement this framework. The framework and its implementation still give room for some further improvement of the framework and this section will discusses some of the things firm-X can do to improve this, and they are:

1) Further research should be executed to get a detailed design for the technology roadmaps for T&M. This group has been left outside the discussion in this thesis report, because it is more related to the improvement agenda than the R&D program.

2) The framework suggested in chapter 5 indicates with strategic buckets how to allocate budget and it was suggested that with a TRM projects can be selected. More research at

firm-X during implementation should be done, in order to reveal what other tools are convenient and can support the selection of the right innovation projects, e.g. a risk tool can be added etc.

3) Though risk has not been a focus of this report attention has been paid to this topic during the execution of the thesis project. In Appendix H the results have been shortly described. It is recommended to do a risk assessment session for individual innovation projects to measure the risk and develop mitigation plans for effective project management. The innovation projects that were indicated to test this approach are the projects which have TRL levels at 5 or 6 (suggested by head of R&D). Therefore, the following four projects are nominated as a first attempt to investigate how the risk analysis might help in innovation projects, they are: TAPAS-II (Txxx1), Thermoplastic control surface devices (TID01) and JTI Smart fixed wing (TYD01).

4) Firm-X should have a multi-disciplinary team to develop the content of TRM's, which includes managers from BL's, PG's and KTM's. The main reason is due to the fact that everyone has a different knowledge for each part of the TRM, but also because all of those groups have their own contacts with the customers. They should have regular meetings in groups where they discuss their views and update the roadmap if necessary. It is suggested to give more attention to these meetings in the beginning, because setting up the roadmap for the first time will be more time consuming than only updating it.

5) Firm-X should have a discussion of the desired state of the R&D budget over the value chain and the TRL levels. At the moment, they are indicated by the average results of the interviews. In a discussion this desired IPP state should be debated to find out about the different views from people that are related to the innovation organization (maybe PGM, KTM & BLM) to get a better feeling of what is important to firm-X. This discussion should lead to a confirmation of the indicated desired state found in the interviews or it should lead to another desired state (with some rationale behind it).

6) In many of the open interviews during the six months thesis it was indicated that firm-X should make sure that technology is not sold before TRL-6; and if it is sold earlier then the customer must be made aware so that good agreements can be made. This should be done to make sure that there is no unexpected cost overrun or delay of the project due to unexpected problems with the new technology, and this also should then reduce fire-fighting.

6.3 Limitations and further research

This section discussed the limitations of this research and recommendations for further research.

The interviews are all executed in firm-X, therefore the results are from one case study only. This limits the validity, because the concept of innovation is the primary concept of this thesis and because the definition is focused towards firm-X therefore limits the applicability. The definition focuses only on the technology development in the manufacturing industry not to new product design therefore the tools developed can be used in high tech companies that have the same view on innovation. Only because TRL 1-6 is used does not necessarily limit the applicability because the tools that are developed can be extended to include the TRL 7-9.

The characteristic of measuring the performance of the IPP are general characteristics of many innovation organizations. Every IPP has different technologies or different PG's, the value chain is a general concept as well as TRL; therefore these parts of the new framework should be applicable to many other firms in the high tech manufacturing industry.

The framework is developed for the industry of firm-X, to be more specific the framework can be used for commercial manufacturing industry. This industry is characterized by long development phases, but also with clear opportunities. The planning makes sense and allows the tool to not only be applicable to the industry of firm-X, related industries that have the same kind of characteristics can also use this model.

For firms that have only top-down or bottom-up approach, only have an technology push or pull, focus on short term or don't depend on inter-organizational innovation activities then the framework should still be applicable, only the execution phase will change. For those cases the way the technology roadmap is filled will change but the guidelines for the project selection will stay the same.

From these limitations opportunities for further Research arise, and they are:

1) Further research from an academic perspective could focus on the innovation system in other industries and also non-manufacturing industries (such as service based industries) to see the effects of the aspects on the design of the IPPM framework and its effectiveness.

2) The effect of other characteristics of innovation affecting the design and effectiveness of the innovation framework could also be investigated (e.g. firm's size, industry, etc). This can be both for a better academic understanding but also for firm-X specific.

3) It could be further investigated what tools can be combined with the proposed framework in order to select the right innovation projects. This can be both for a better academic understanding but also for firm-X specific.

4) For a better academic understanding more research should focus on understanding the effect of inter-organizational innovation activities on the project selection. That can mean in terms of selection criteria, balancing requirement or even strategically directions. Basically the gap between network portfolio management and IPPM should be linked.

5) To make the guidelines that indicate the desired state in the framework is more applicable, further research could be done to understand for what reasons a balance indicated by the guidelines can be neglected and so should be different. This can be both for a better academic understanding but also for firm-X specific.

6) Further research should be executed to validate the conceptual model that has been compiled from the literature in figure 2.11.1.

6.4 Validation

During this thesis the concept of IPPM has been investigated. The methods that have been used include, a literature study for theoretical background, analysis of internal document, and open interviews to analyse the current innovation framework. Semi-structured interviews have also been used for the perceptions of the stakeholders with respect to IPPM, and finally the framework is validated by an expert.

The open interviews have been chosen to understand the current innovation framework and to understand the issues with it, it is case specific therefore open interviews have been selected. For the perceptions of the stakeholders with regard to the IPPM framework, a semi-structured interview has been used and that can be used to repeat this research to increase the reliability of the results.

The new framework has also been tested by using the current innovation project data to measure the current state and compare it to the desired state of the interviews. It could be seen that there is a gap between the two, even when the inter-organizational innovation activities are included. This indicates that the model can do what it is meant for, however implementation can show if it works for adjusting the portfolio as well.

6.5 Reflection

Generalizing the results would probably be possible for many manufacturing industries that have a long term focus and are not very dynamic. The long term focus will create a clear focus and because of this long term focus the industry should not be so dynamic. When the industry is too dynamic then the long term focus will change too often which will waste scarce resources on wrong projects. The future opportunities of firm-X can be reasonably well predicted therefore the planning of the roadmap can support the innovation organization quite significantly.

Then balancing the IPP based on the characteristics of the innovation organization and the strategy translation of the future opportunities in the TRM can give an indication of the future and how the IPP should be balanced. Therefore for these kinds of industries it would make sense to use such an approach for IPPM. The characteristics of innovation (division of innovation over product groups, key technologies, TRL or parts of the value chain) used to balance the portfolio are common for most innovative firms which makes it easy to implement the approach in other firms.

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Appendix A: TRL measurement

Table A1-5: TRL definition for firm-X, source internal firm-X document

Item nr.	Area	TRL1	TRL2
1a	strategy/business	technology can be considered as	usefulness of technology for specific
1b	strategy/business	technology is useful alternative for already	cost effectiveness and/or weight
2a	research & development	technology has been demonstrated and	producibility aspects have been analysed
2b	research & development	0	specific demonstration product(detail) has
3a	manufacturing	technology has been (roughly) analysed	producibility aspects have been analysed
3b	manufacturing	0	requirements concerning specific facilities
4a	tooling	technology has been (roughly) analysed	tooling philosophy has been reviewed by
5a	materials & proceses	technology has been checked with	material and process specifications have
5b	materials & proceses	technology has been (roughly) analysed	material properties have been (roughly)
6a	design	technology has been checked with	feasibility of technology has been checked
6b	design	technology has been checked with	specific design features and constraints
6c	design	0	technology has been (roughly) analysed
7a	stress	technology has been checked with	feasibility of technology has been checked
7b	stress	technology has been checked with	specific stress features and constraints
7c	stress	0	testplan for next technology step has been
8a	cost	technology has been (roughly) analysed	technology has been (roughly) analysed
9a	quality	technology has been checked with	inspection requirements have been
10a	procurement	technology has been checked with	material supplier and/or (if relevant) tooling
10b	procurement	0	0
11a	contracts/IP rights	technology has been checked with	situation with respect to patents and/or
11b	contracts/IP rights	technology has been checked with	contracts and NDA's (if relevant) have

Item nr.	Area	TRL3	TRL4
1a	strategy/business	potential applications of the technology are	specific application for specific
1b	strategy/business	make or buy decision regarding technology	consequences of introduction of new
2a	research & development	(sub-)components have been identified	primary and secondary processes have
2b	research & development	preliminary manufacturing guidelines have	0
3a	manufacturing	(sub-)components have been	selected details investigated with respect
3b	manufacturing	process windows and effects of defects	activities related to material and process
4a	tooling	preliminary tooling concept (if relevant) has	preliminary tooling guidelines issued and
5a	materials & proceses	preliminary material and process	preliminary material and process
5b	materials & proceses	material qualification plan has been	consequences of full scale production
6a	design	(relevant) design concepts have been	(sub-)component product definition has
6b	design	preliminary design guidelines have been	(if required and relevant) additional design
6c	design	0	preliminary design guidelines have been
7a	stress	coupon tests have been defined, tested	coupontests have been defined, tested
7b	stress	(relevant) stress concepts have been	stress calculations on demo product(-
7c	stress	preliminary stress guidelines are compiled	(if required and relevant) additional stress
8a	cost	rough cost estimate for technology and	cost information concerning technology
9a	quality	SHE analysis has been reported and	SHE related to material and process
10a	procurement	relevant suppliers have been approved	preliminary situation with respect to
10b	procurement	cost of equipment for envisaged	information concerning materials,
11a	contracts/IP rights	relevant actions concerning license or	IP status is reviewed and approved
11b	contracts/IP rights	IP strategy has been approved	0

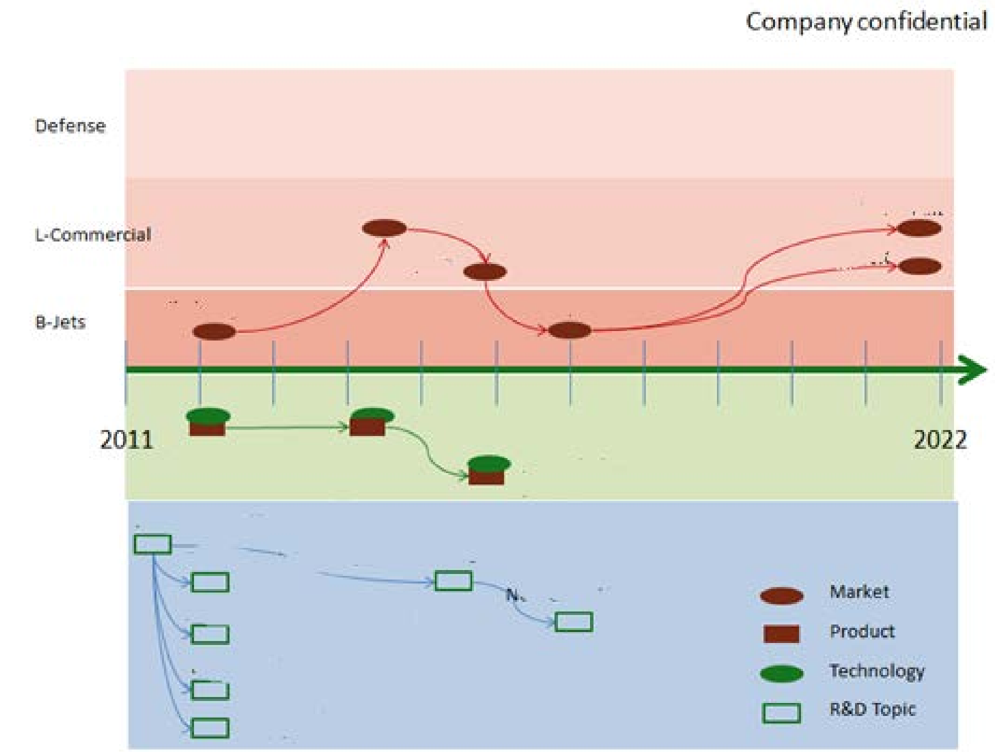
Item nr.	Area	TRL5	TRL6
1a	strategy/business	business case (if relevant) has been	marketing and business managers are
1b	strategy/business	0	decision concerning flying or non-flying
2a	research & development	producibility aspects have been studied	project management for design and
2b	research & development		0
3a	manufacturing	manufacturing information has been	(schematic) product has been
3b	manufacturing	contribution to design, FAI and evaluation	participate in evaluation concerning cost
4a	tooling	tooling philosophy has been reported and	participate in evaluation concerning cost
5a	materials & proceses	TH's (material specifications) and	FE and FP, NDI and reference data have
5b	materials & proceses	chemical resistance of materials	participate in evaluation concerning cost
6a	design	design guidelines and protection against	design of (schematic) component with
6b	design	improvements resulting from tests have	participate in evaluation concerning cost
6c	design	0	0
7a	stress	test results (including fatigue) of coupons	stress calculation of (schematic)
7b	stress	stress calculation of (sub-)component has	analysis of test results of aged product
7c	stress	0	preliminary certification process has been
8a	cost	final report on cost of introduction of new	final report concerning development cost
9a	quality	final report on SHE of new technology and	quality plan has been reviewed with
10a	procurement	procurement specifications have been	participate in evaluation concerning cost
10b	procurement	suppliers for materials and equipment have	0
11a	contracts/IP rights	documentation and publications have been	IP status has been reviewed and
11b	contracts/IP rights	IP strategy has been analysed and	0

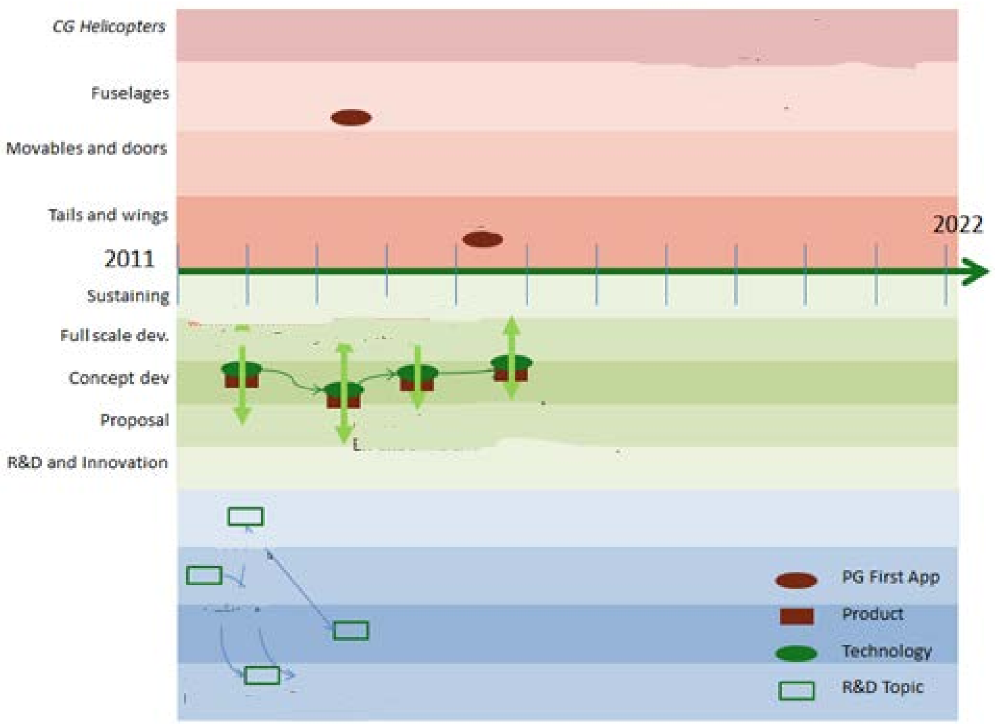
Item nr.	Area	TRL7	TRL8
1a	strategy/business	technology readiness can be	strategy has been adapted to new
1b	strategy/business	marketing has been informed concerning	active marketing for new applications is
2a	research & development	assistance concerning manufacturing of	plans for further development of the
2b	research & development	0	0
3a	manufacturing	manufacturing of component has been	series production has been evaluated and
3b	manufacturing	contribution to design, certification, FAI and	component(s) have been delivered to
4a	tooling	application of tooling has been evaluated	participate in evaluation concerning cost
5a	materials & proceses	contribution to design, certification, FAI and	information regarding support and NC's
5b	materials & proceses	participate in evaluation concerning cost	participate in evaluation concerning cost
6a	design	design of product with new technology	design of product with new technology
6b	design	design guidelines are checked regarding	participate in evaluation concerning cost
6c	design	0	0
7a	stress	stress calculation of product with new	component has been certified
7b	stress	stress calculations and methodology are	information regarding support has been
7c	stress	tests (including fatigue) have been	0
8a	cost	0	0
9a	quality	quality procedures have been analysed	quality plan has been reviewed with
10a	procurement	participate in evaluation concerning cost	participate in evaluation concerning cost
10b	procurement	0	0
11a	contracts/IP rights	IP status has been reviewed and (if	IP status has been reviewed and
11b	contracts/IP rights	0	0

Item nr.	*Area*	*TRL9*
1a	strategy/business	new opportunities have been defined
1b	strategy/business	final report on development and lessons
2a	research & development	new developments based on market pull
2b	research & development	0
3a	manufacturing	manufacturing and assembly activities
3b	manufacturing	recommandations for further improvements
4a	tooling	0
5a	materials & proceses	(if required) material and process
5b	materials & proceses	0
6a	design	(if required) design changes have been
6b	design	0
6c	design	0
7a	stress	NCR's are analysed and (if required)
7b	stress	tests regarding repair procedures have
7c	stress	0
8a	cost	0
9a	quality	NCR's have been analysed and (if
10a	procurement	(if required) second sources for materials
10b	procurement	0
11a	contracts/IP rights	IP status has been reviewed and altered (if
11b	contracts/IP rights	0

Appendix B: Current Technology Roadmaps of firm-X

This appendix will show two examples of the current TRM of firm-X, the first roadmap is related to a technology and the second roadmaps will for T&M. The content has been removed but the framework is still visible. First is regular TRM, the second one TRM is for Tools & Methods which use a slightly different framework because the products are developed for internal use and not external.





Appendix C: Innovation budget data benchmark

Table C1: percent of innovation budget through innovation activities or subsidy, multiple firms.

Year	Embraer	General Dynamics	Firm-X
2004	66.67%	-	-
2005	33.33%	-	-
2006	26.67%	-	-
2007	9.09%	30.77%	-
2008	46.15%	30.88%	-
2009	37.04%	44.44%	-
2010	40.00%	50.00%	-
2011	30.00%	54.17%	-
2012	-	65.63%	-
2013	-	-	80.16%
average	36.12%	45.98%	80.16%

Source Embraer (Diepeveen, 2013) and source General dynamics is (Noordman, 2013).

Appendix D: Semi-Structured Interview

<u>First round of interview questions:</u>

In the results in section 4.3 question 1 and 2 have been combined in one result.

1. Firm-X is looking for a more systematic approach to their innovation portfolio approach (in choosing the right projects: evaluating, ranking & choosing innovation projects and allocating resources to it), do you think a more opportunity driven IPP or a more systematic approach is better for the IPPM for firm-X, and why? In your opinion how can firm-X introduce a more systematic approach towards doing the right innovation projects and doing the innovation projects right? In other words, what kind of systematic processes would work for you in the part you play in the innovation projects?
2. In your opinion how do you want to achieve the type of approach that you indicated in question 1? In other words, what kind of procedures, tools or techniques would you apply.
3. Do you think that firm-X has a technology push or technology pull strategy? In your opinion how much should firm-X focus on a technology push or pull strategy? Perhaps interviewee can indicate how much of innovation budget should be spend on both types?
4. Do you think every innovation project in the innovation project portfolio should be aligned with strategy? Meaning that firm-X should have only a top-down innovation approach or also a bottom-up innovation approach?
5. Does firm-X need a long term or a short term strategy, and why?
6. How do you think the TRL balance (for TRL 1-6) of firm-X should look like? (please fill in the table 1), and explain why you chose for this division.
7. How do you think the R&D budget should be balanced over the different part of the value chain where innovation occurs, (please fill in the table 2). Or does the interviewee think that this TRL budget division cannot be assessed before hand? Do you think the TRL balance will look differently for the other three FIRM-X firms?

Table D1: TRL innovation budget division

TRL	Budget %
1	
2	
3	
4	
5	
6	
Total	100%

Table D2: Value chain division of budget

	Material development	Operations		Manufacturing / assembly technology
		New Technology / concept	Supporting technology	
budget %				

8. Which set of type of criteria from table 3 for the Innovation Portfolio do you think would show a good overview of the portfolio? Which set of factors do you think together will give a good overview of the innovation project portfolio?

Table D3: Type of criteria and importance

Type of criteria	not important at all	not very important	Neutral	reasonable important	very important	why?
Competitive advantage						
Focus (the amount of projects)						
Market expectation (expected revenues of technology or product)						
Time (project duration, and balance of long vs short term projects)						
Newness (radical vs incremental projects)						
Project type (which KT, PG or part of value chain)						
Required resources /Cost						
Risk (probability and consequence)						
Strategic focus and alignment of each innovation project						
Technical feasibility						
Other type of criteria						

<u>Second round of interview questions:</u>

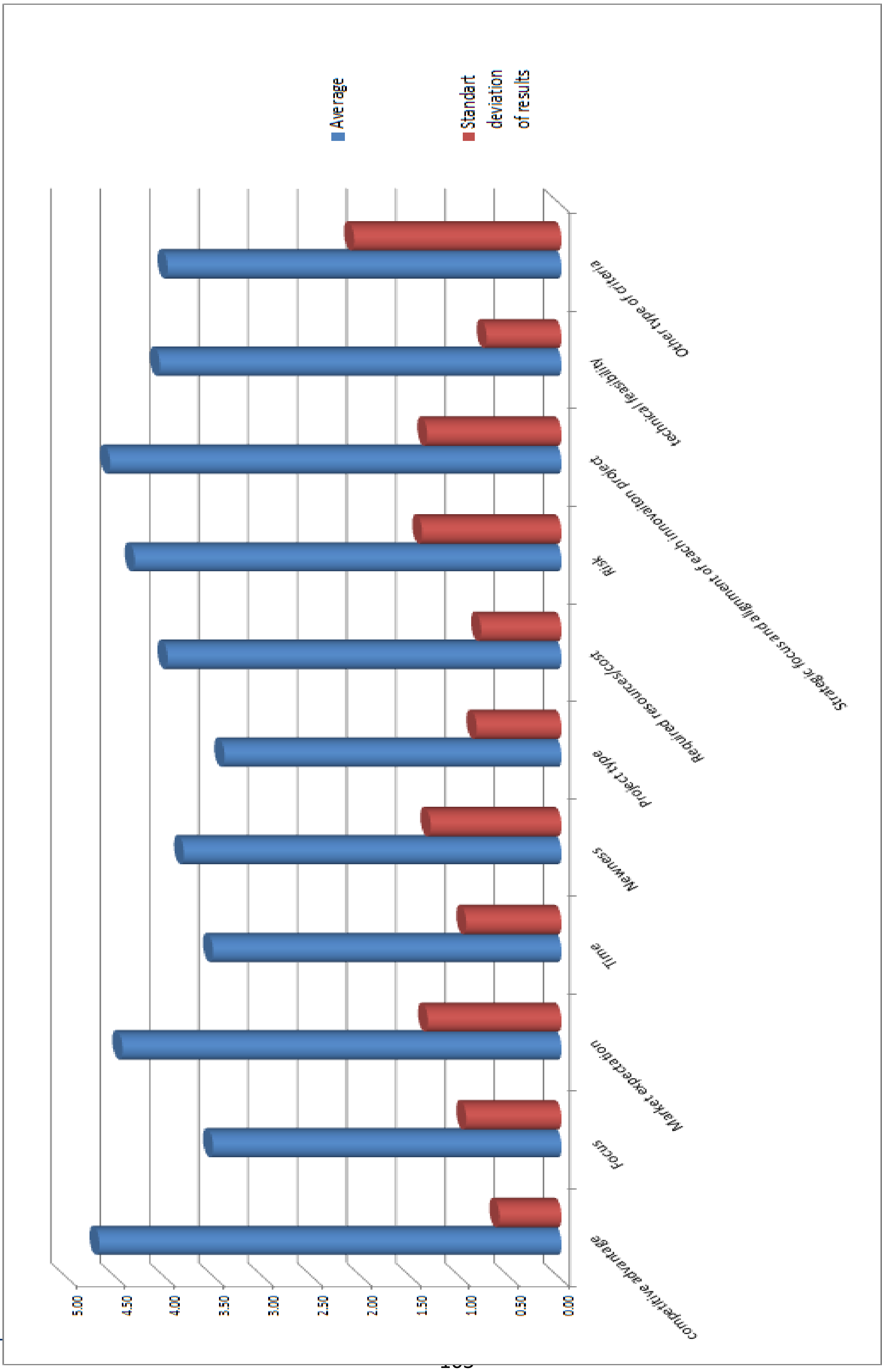
9. How should IPP be balanced?

10. How should the value of IPP be maximized?

11. What is the effect of inter-organization innovation collaboration on IPPM and how should it be dealt with in selecting the right projects?

Appendix E: Results indicating Importance of Factors

The results are gathered in the interviews, in Appendix D it is question 8 and in the rest of the report it is question 7.



Appendix F: Example of revenue model for PG &KT guideline

The boxes that are yellow indicate that the minimum and maximum are the same value.

Table F1: Information per product to calculate total expected revenues

Platform	Product	PG	EIS	KT	Expected revenues per SS kUS$	
A350-1000	OBF	M&D	2018	TS	1.100	1.100
A320-NEO	Fuselage	F	2019	FML	300	800
A30X	Fuselage	TP	2028	TP	225	600
A20-NEO	Rudder	M&D	2019	TP	100	100
Bombardier	Movables	M&D	2021	TP	100	200
Bombardier	Empennage	T&W	2021	TP	500	600
Cessna Longitude	Empennage	T&W	2020	TP	400	500
Cessna Longitude	control surfaces	M&D	2020	TP	100	150

Table F2: Total expected revenue calculation per product without weight-factor

		Total # of SS		# of production years		Expected Revenues, no weight factor	
Platform	#SS/yr	min	max	min	max	min kUS$	max kUS$
A350-1000	40	300	300	7.5	7.5	330.000	330.000
A320-NEO	250	5000	5000	20	20	1.500.000	4.000.000
A30X	250	5000	6250	20	25	1.125.000	3.750.000
A20-NEO	250	5000	5000	20	20	500.000	500.000
Bombardier	35	700	875	20	25	70.000	175.000
Bombardier	35	700	875	20	25	350.000	525.000
Cessna Longitude	40	400	600	10	15	160.000	300.000
Cessna Longitude	40	400	600	10	15	40.000	90.000
					Total	4.075.000	9.670.000
						Ratio total	2,37

Table F3: Total expected revenue calculation per product with weight-factor

		Expected Revenues times weight factor	
Platform	Weight factor	min kUS$	max kUS$
A350-1000	0.95	313.500	313.500
A320-NEO	0.5	750.000	2.000.000
A30X	0.2	225.000	750.000
A20-NEO	0.1	50.000	50.000
Bombardier	0.2	14.000	35.000
Bombardier	0.1	35.000	52.500
Cessna Longitude	0.5	80.000	150.000
Cessna Longitude	0.1	4.000	9.000
	Total	1.471.500	3.360.000
		Ratio total	2,28

Appendix G: Factors from Literature and firm-X specific

(1) Comes from chapter 2 which describes the literature stud
(2) comes from chapter 3 which described current innovation framework at firm-X.

From: (1) literature or (2) business	Factor	Measure of	Level of operationalization	Factors are indicator of	Can also indicate
1	Short vs long term	Time balance	Project & firm level		
1	Time to completion	Time indication, indication of resources required	Project & firm level	Time	Required resources
1	Incremental vs radical	Newness balance, amount of uncertainty	Project & firm level		Time and req. resources
1	Inventive merit	Newness	Project & firm level	Newness	
1	Risk vs return	Expected return & Risk	Project & firm level		
1	Financial reward	Expected return	Project level		
1	Probability of success	Expected return	Project level	Expected return	Risk
1	Investment required	Financial cost	Project level	Cost	
1	Competitive impact of technology	Competitive advantage	Project & market level		
1	Durability of competitive advantage	Competitive advantage	Project & market level	Competitive advantage	
1	Maintenance vs. growth	Market expecation	Project & market level	Market expectaction	
1	Project type and resource adequacy	Balance of innovation phases	Firm level	Project type	
1	Fit with business or corporate strategy	Measure of alignment with strategy	Firm level	Strategic Alignment	
1	Right amount of projects	Focus	Firm level	Focus of IPP	

From: (1) literature or (2) business	Factor	Measure of	Level of operationalization	Factors are indicator of
2	PG	Project type	Project & firm level	
2	BL	Project type	Project & firm level	Project type
2	Customer value drivers	Market value	Project & firm level	
2	Market share	Market share	Firm Level	
2	Market growth	Market growth	Firm Level	Market Expectation
2	Data quality	Correctness of data	Project Level	Risk indication
2	Volume	Size of work, investment, return, etc.	Project Level	expected return
2	TRL	Technology maturity	Project & firm level	Technology maturity
2	Net innovation cost	Innovation cost that FAE pays	Project & firm level	
2	Gross innovation cost	Total innovatin project cost (including sub	Project & firm level	
2	EAC	Full project cost	Project & firm level	Cost
2	Risk	Risk	Project & firm level	Risk
2	Strategic value	Strategic fit	Project & firm level	Strategic alginment
2	Value Chain (of yourself and customer)	Size of work, investment, return, etc.	Project & firm level	Type of work

Appendix H: Risk

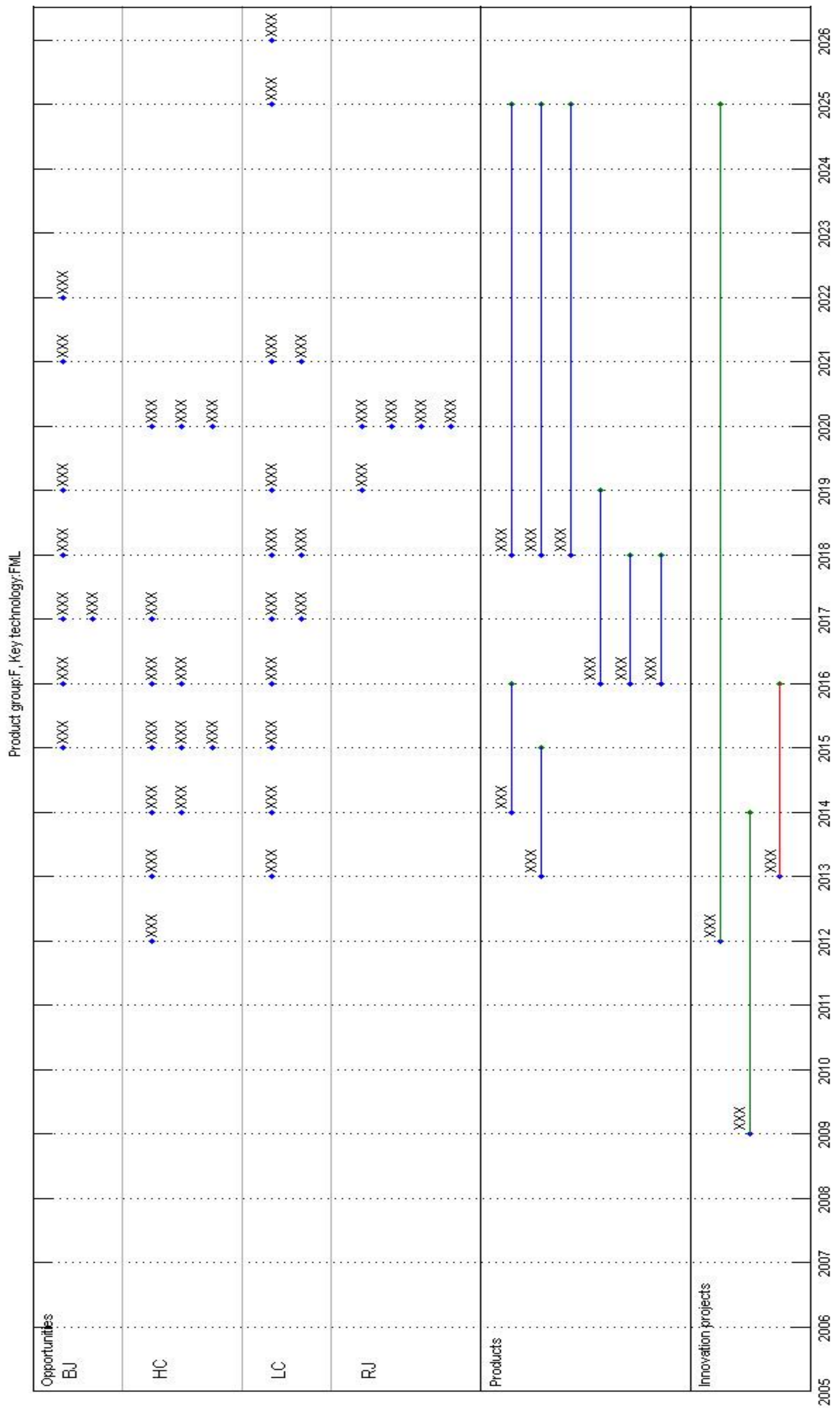
Another tool that should not be forgotten and is indicated quite important in the interviews is risk assessment of innovation projects, this section explains some ways to deal with this.

Besides the individual risk assessment which can be used to organize the individual projects there is also portfolio risk: what is the risk of one project in relation to another and what effect does that have on the performance of the product portfolio. To measure these risks the framework will suggest looking at the TRM to check if all innovation projects lead to the products and if any innovation projects are missing. This is a top-down approach for the bottom-up approach there is a risk of not leading to any product and taking therefore resources from other projects. Therefore these risks can be mapped for the portfolio to see what the effects are. This risk assessment should then be executed by the multidisciplinary teams just like risk assessment for normal projects.

During two interviews with a PMO-risk manager and another interview with the technology office manager and the head of R&D it has been discussed how to measure risk and use it for portfolio management. A risk tool can be used to identify risk of individual innovation projects. This can be executed by using a TRL analysis for the current state and subsequently identifying for the TRL goal what the risks are for each project. The risk manager thinks it is important to do this for every project but the head of R&D does not agree because he thinks that the value of the risk assessment doesn't outweigh the cost of the analysis. On top of that he thinks that the risk assessment in low TRL projects can limit out of the box thinking because risk mitigation plans narrow down the possibilities too much, therefore he suggest to do risk measurements starting from TRL-5.

Appendix K: New Technology Roadmap

This section shows an example of one of the sixteen TRM's, in this case it is filled with scrambled data. In the top layer it can be seen that the opportunities are identified and translated into product in the layer below. This second layer indicates a short timeline indicating when the design should start and finish. Then in the third layer another timeline indicates when and what innovation projects should be executed. This graph is created in a matlab environment (.m file) that analyses data from the opportunities, products and innovation projects from an excel file and transforms it into sixteen unique TRM's (for each PG & KT combination).


Product group:F, Key technology:FML
Opportunities
BJ
HC
LC
RJ
Products
Innovation projects
XXX
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026