

## MASTER

### Portfolio management, dimensions of success and value generation a Monte-Carlo simulation model

Caballero Rosas, J.A.

*Award date:*  
2014

[Link to publication](#)

#### **Disclaimer**

This document contains a student thesis (bachelor's or master's), as authored by a student at Eindhoven University of Technology. Student theses are made available in the TU/e repository upon obtaining the required degree. The grade received is not published on the document as presented in the repository. The required complexity or quality of research of student theses may vary by program, and the required minimum study period may vary in duration.

#### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain

Eindhoven University of Technology  
Wednesday, 6<sup>th</sup> August 2014

# Portfolio Management, Dimensions of Success and Value generation

---

By J.A. (Andres) Caballero Rosas

BSc Industrial Engineering – Universidad EAFIT 2004  
Student identity number 0825767

In partial fulfilment of the requirements for the degree of

**Master of Science  
in Innovation Management**

**Supervisors:**

Prof. Dr. E.J. Nijssen, TU/e, ITEM

Dr. Ir. B. Walrave, TU/e, ITEM

Ir. M. Kluitman, Bicore

Ir. J. Goorden, Bicore

TU/e School of Industrial Engineering & Innovation Sciences  
Series Master Theses Innovation Management

**Subject headings:** New Product Development, Portfolio Management, Simulation, Value Maximization, Portfolio Balance, Strategic Alignment.

# Portfolio Management, Dimensions of Success and Value generation

*A Monte-Carlo Simulation Model*

BSc. J.A.(Andres) Caballero Rosas

Supervisors:

Prof. Dr. E.J.(Ed) Nijssen, TU/e, ITEM

Dr. Ir. B.(Bob) Walrave, TU/e, ITEM

MSc. M.(Maarten) Kluitman, Bicore

MSc. J.(Jac) Goorden, Bicore

Final Version

Eindhoven, August 2014



# Acknowledgment

This MSc (Master of Science) thesis is the result of my graduation project which I have conducted at Bicore from February to July 2014. This graduation project is the concluding part of my studies of the Master program Innovation Management at the faculty of Industrial Engineering and Innovation Sciences, at Eindhoven University of Technology.

I would like to express my special appreciation and thanks to my supervisor Professor Dr. Ed Nijssen. I really value his feedback and support, and the cordial meetings to discuss progress and questions. His insights and suggestions were crucial to get the right track in the early stages of the project and gave me confidence to make the right decisions during the project. I would also like to thank my second supervisor, Dr. Bob Walrave, whose expertise in the research method was essential to get the appropriate direction in the more fundamental areas of the model. Also his good attitude towards the assignment is something I highly value.

My supervisors at Bicore Maarten Kluitman and Jac Goorden, always facilitated my work and provided expert input. I am very grateful to them. Not only their guidance, time and advice were key aspects for my work, but also the fact that they made me feel very welcome at the office and gave me the opportunity to contribute with relevant topics for the company. This is also extensive to the Bicore's team in general, colleagues, interns and bosses, who were all the time truly supportive.

A special thanks to my dear group of friends in Eindhoven, both Internationals and locals. They made this experience worth it and enjoyable. Besides all the cordial and unforgettable moments during this couple of years of the Master, I learned a lot from them and to some extent it has been applied in this final work. Of course, I would like to thank my group of friends back home. They have supported the decision of pursuing this dream and always have been an engine for improvement in my life, which incentivized me to strive towards my goal.

I would also like to thank my family, who supported me from the distance, and lovely gave me their hand in this important moment of change in my life. The values and principles taught by them are the ones that still keep me going in the right way. At the end I would like to express deep appreciation to my beloved fiancée Carolina who was always very caring and patient about this big endeavor of studying abroad and always understood what it really was about. She never failed to be there. Thank you!

Andres Caballero  
Eindhoven, August 2014



# Executive summary

## Introduction

A vital stage of the new product process is the pre-development evaluation stage where product selection decisions are made. This stage is known as the New Product Portfolio Management and is defined as the dynamic decision process of evaluating, selecting, prioritizing, and allocating resources to product development projects (Cooper, Edgett & Kleinschmidt, 1998). Decision-making in Portfolio Management is becoming a major research trend in the innovation literature, though what successful NPD portfolio management truly means and how firms can achieve it remains unclear (Kester, Hultink & Griffin, in press). A successful new product portfolio has commonly been framed in three dimensions, i.e. Value Maximization, Balance and Strategic Alignment (Cooper et al., 1998). Yet, research has not provided a strong body of empirical evidence in how a successful portfolio drives bottomline firm's results which constitutes a gap in literature that this master thesis intends to address. The purpose of this study is to have a better understanding of the mechanisms underlying the value generation consequences of a NPD successful portfolio. This will be achieved by building a simulation model incorporating the rationale of the NPD project selection decisions embedding the three dimensions of success. Because of the nature of this graduation project, Bicore, as firm endorsing the study, can benefit from the findings and implications as they are addressed directly to their processes and FLIGHTMAP's functionality.

## Literature Background

(1) Value maximization is the allocation of resources to maximize the overall value of the portfolio in terms of a main company objective, such as profitability, return on investment or brand value. It is defined in terms of monetary value and determined by the presence of high impact projects on the portfolio (Cooper et al., 1998). (2) A balanced NPD portfolio reflects an optimal spread in individual NPD project risk (Cooper et al., 1998). From Modern Portfolio Theory, a balanced NPD portfolio can be understood as a combination of projects that all together have an appropriate risk/reward ratio. (3) Strategic alignment in portfolios refers to the extent to which the NPD portfolio is in line with the strategic aspirations of the firm (Kester, 2011). Strategic portfolios strengthen a competitive advantage, fit organizational capabilities and enable the firm for sustainable future growth (Smit & Trigeorgis, 2006).

## Methodology

A simulation model will reproduce the main rationale of portfolio-building using the three dimensions of success. Two experiments and sensitivity analyses were conducted to check the effect on the portfolio value creation of each heuristic.



## Results

The larger the number of projects under evaluation, the larger the amount of returns to be obtained, even with the same amount of resources. Moreover, the three heuristics show significant differences when compared to each other, being the strategic alignment heuristic the one with the largest returns (Figure 1a), and the balance heuristic the one with highest chance to create positive value. Value maximized portfolios are unstable (largest variation, see Figure 1b) and do not support a corporate strategy.

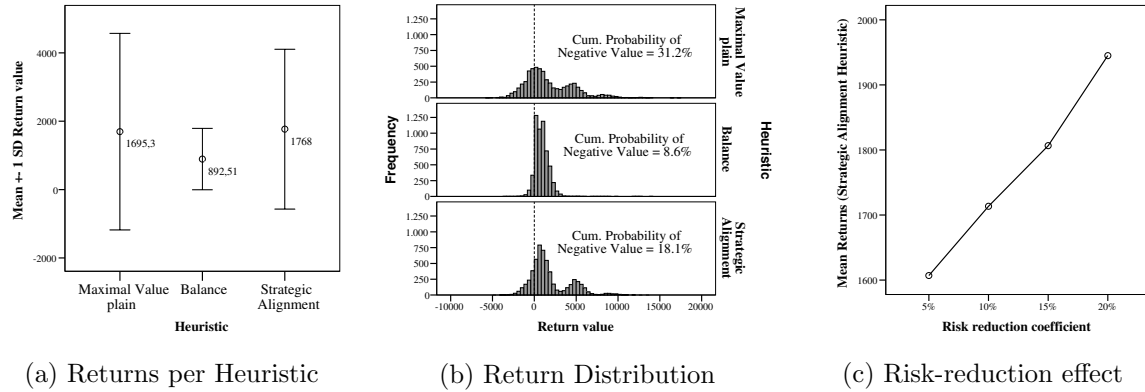


Figure 1: Difference among groups -Returns- and Risk-reduction effect

For Strategic aligned portfolios, no effects were found on the returns when the proportion of exploration varies between 10% and 40%. Significant effects were found on portfolio returns when the strategic alignment heuristic has larger values for risk-reduction due to project synergies and interrelatedness (Figure 1c). The larger the number of projects building synergy on each other, the larger the returns to be obtained due to a risk-reduction effect.

## Managerial Implications

Each portfolio dimension of success entails contrasting outcomes when returns, portfolio newness and strategic adherence are evaluated. Each dimension offers different benefits and drawbacks (see Table 1). The effects of choosing strategic portfolios result in reinforcing a competitive advantage, enabling the firm for future growth and attaining the benefits of a risk-reduction effect. Managers should strive for refining the strategic assessment of the NPD projects in order to find portfolios that enable future growth and strengthen a competitive advantage. Moreover, managers should reinforce the benefits of building portfolios that match organizational capabilities so innovation risks are mitigated.

Aspect/Benefit	Value Maximization	Balance	Strategic Alignment
1. Highest expected value	Yes		
2. Highest realized value			Yes
3. Growth opportunities			Yes
4. Project synergy effects			Yes
5. Guarantee of positive returns		Yes	
6. Return stability (sure bet)		Yes	
7. Spending rationality		Yes	

Table 1: Benefits obtained from each Portfolio/Heuristic

---

Several practical implications can also be drawn for Bicare:

- Several criteria assessing the strategic fit of a project are already implemented in FLIGHTMAP. Bicare then should judge whether the strategic criteria and the way how it is processed in further computations can be improved. The aim is to find an equilibrium between an assessment that the user finds simple enough but still captures the relevant dimensions inherent to strategy, in such a way that the vagueness of this evaluation is mitigated. This also implies opportunities for consulting for Bicare: reducing the strategic assessment vagueness can be achieved through Bicare's expertise and partner consulting.
- FLIGHTMAP users can profit from evaluating and executing projects that are *not* related to corporate strategy but that can still enable future growth. This can be perceived as ambiguous since FLIGHTMAP ranks better the strategic-friendly projects. An improved user-experience in which FLIGHTMAP guides how to manage such initiatives is also a new area to be explored for future development. Real options reasoning is prescribed in literature for evaluating risky and unrelated-to-strategy projects with growth potential.
- FLIGHTMAP already enables the user to define project-to-project interconnections. It would be beneficial if the user can realize during the planning phase the positive effects of selecting interrelated projects when crafting the NPD portfolio. This implication should be taken carefully as it entails a considerable exploration of the risk management knowledge and involves an increment of the complexity of the project selection process.

## Conclusions

The present study reveals differences in the mechanisms of value generation of each of the three dimensions of success of Portfolio Management. Observations were taken from a simulation model's outcome and a set of experiments and sensitivity analysis were conducted.

The strategic dimension of portfolio building appears to be the one that contributes the most for value creation, however, the three dimensions do not operate independently. Portfolios that select strategic projects that at the same time maximize value, while giving room for exploration initiatives are the ones that consistently show better results. This measure is important for building future-proof portfolios, but the results also show the importance of not only selecting appropriately but also gaining benefits from a risk-management measure due to organizational capabilities fitness. On the other hand, balanced portfolios will guarantee smaller positive results, but at the expense of not gaining from the potential of radical and experimental innovations.

The results obtained allowed to present a set of practical implications for Bicare's processes and its portfolio management platform FLIGHTMAP. Managerial implications are also provided with value for portfolio management practitioners.



# Contents

<b>Contents</b>	<b>ix</b>
<b>List of Figures</b>	<b>xi</b>
<b>List of Tables</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Literature Review</b>	<b>3</b>
2.1 Defining Portfolio Management . . . . .	3
2.2 Elements of Decisions of Portfolio Management . . . . .	4
2.3 Drivers of decision in Portfolio Management . . . . .	5
2.3.1 The role of Politics . . . . .	5
2.3.2 The role of Intuition . . . . .	6
2.3.3 The role of Rationality . . . . .	6
2.3.4 Manager's individual traits . . . . .	7
2.3.5 Other antecedents and drivers . . . . .	7
2.4 Decision-making Models in Portfolio Management . . . . .	8
2.4.1 General Model of Decision-Making by Kester et al. (2011) . . . . .	8
2.4.2 Portfolio Dimensions, Impacts and Antecedents by McNally et al. (2013)	9
2.4.3 Strategic Orientation and Business Success in Portfolio Management by Meskendahl (2010) . . . . .	9
2.4.4 Ideation and Portfolio Management by Heising (2012) . . . . .	10
2.5 Dimensions of Success of a NPD Portfolio . . . . .	11
2.5.1 Value Maximization . . . . .	11
2.5.2 Balance . . . . .	12
2.5.3 Strategic Alignment . . . . .	13
<b>3 Problem Statement and Propositions</b>	<b>17</b>
3.1 Problem Statement . . . . .	17
3.2 Research objectives and contributions . . . . .	18
3.3 Proposition Development . . . . .	20
3.3.1 Proposition 1: The Effect of a Value Maximized Portfolio . . . . .	20
3.3.2 Proposition 2: The Effect of a Balanced Portfolio . . . . .	21
3.3.3 Proposition 3: The Effect of a Strategic Aligned Portfolio . . . . .	21

<b>4</b>	<b>Method</b>	<b>23</b>
4.1	Choice of Simulation approach . . . . .	24
4.2	Model Description . . . . .	25
4.3	Projects Generation Stage . . . . .	25
4.4	Projects Evaluation and Portfolio construction . . . . .	27
4.4.1	Measuring a Value Maximized Portfolio . . . . .	27
4.4.2	Measuring a Balanced Portfolio . . . . .	29
4.4.3	Measuring a Strategic Portfolio . . . . .	31
4.4.4	Measuring a Combined Portfolio . . . . .	33
4.5	Portfolios execution and Value Generation . . . . .	34
4.6	Summary of assumptions . . . . .	34
<b>5</b>	<b>Results</b>	<b>37</b>
5.1	Influence of Number of Projects under Evaluation . . . . .	38
5.2	Difference among Heuristics . . . . .	39
5.3	Effects of a Value Maximization Portfolio . . . . .	41
5.4	Effects of a Balanced Portfolio . . . . .	41
5.5	Effects of a Strategic Portfolio . . . . .	42
5.6	Testing the Propositions . . . . .	43
<b>6</b>	<b>Discussion and Managerial Implications</b>	<b>45</b>
6.1	Recall of the research question . . . . .	45
6.2	Discussion . . . . .	45
6.3	Managerial Implications . . . . .	49
6.4	Implications for Bicare . . . . .	50
<b>7</b>	<b>Conclusions</b>	<b>53</b>
7.1	Limitations . . . . .	53
7.2	Future research . . . . .	54
	<b>References</b>	<b>56</b>
	<b>Appendix</b>	<b>61</b>
<b>A</b>	<b>Main simulation program algorithm</b>	<b>61</b>
<b>B</b>	<b>Algorithm of the Value Maximization Heuristic</b>	<b>63</b>
<b>C</b>	<b>Algorithm of the Balance Heuristic</b>	<b>64</b>
<b>D</b>	<b>Algorithm of the Strategic Alignment Heuristic</b>	<b>65</b>
<b>E</b>	<b>Algorithm of the Portfolio Execution</b>	<b>66</b>

# List of Figures

1	Difference among groups -Returns- and Risk-reduction effect . . . . .	vi
2.1	General Model of Portfolio Decision Making (Kester et al. 2011) . . . . .	8
2.2	Portfolio Dimensions', Impacts and Antecedents (McNally et al., 2013) . . . . .	9
2.3	Strategic Orientation linked to Portfolio Management-Success (Meskendahl, 2010) . . . . .	10
2.4	Project Portfolio Success and Ideation Portfolio Management (Heising, 2012)	11
2.5	A Growth Portfolio (McGrath & McMillan, 2009) . . . . .	15
2.6	Antecedents and Consequences of the reviewed decision-making models . . . . .	16
3.1	A schematic Value Maximized Portfolio . . . . .	20
3.2	A schematic Balanced Portfolio . . . . .	21
3.3	A schematic Strategic Aligned Portfolio . . . . .	22
4.1	Simulation Model Outline . . . . .	25
4.2	Single Simulation Run for 15 NPD projects -Value Max. Heuristic- . . . . .	28
4.3	Single Simulation Run for 15 NPD projects -Balance Heuristic- . . . . .	30
4.4	Single Simulation Run for 15 NPD projects -Strategic Alignment Heuristic- . . . . .	32
4.5	Single Simulation Run for 15 NPD projects -Combined Heuristic- . . . . .	33
4.6	Quadratic Risk Reduction Function (15 NPD projects, RRC = 5%) . . . . .	35
5.1	Sensitivity analysis: Number of Projects on Portfolio Returns . . . . .	39
5.2	Difference among groups -Returns- . . . . .	39
5.3	Effects of each Heuristic on Newness and Strategic Score . . . . .	40
5.4	Distribution of Portfolio Budget Utilization . . . . .	40
5.5	Scatter: Portfolio Risk vs. Returns . . . . .	42
5.6	Sensitivity analysis: Risk-reduction factor on Returns . . . . .	43



# List of Tables

1	Benefits obtained from each Portfolio/Heuristic . . . . .	vi
2.1	Portfolio Management decision-making drivers and studies . . . . .	5
3.1	Major differences between two studies (Kester et al., in press; McNally et al., 2013) . . . . .	18
4.1	Simulation approaches according to Davis et al. (2007) . . . . .	24
4.2	Model Input Parameters . . . . .	26
5.1	First Experimental Design and Results (Factor: # of Projects) . . . . .	37
5.2	Second Experimental Design and Results . . . . .	38
5.3	Descriptive statistics for the Value Maximization Heuristic . . . . .	41
5.4	Descriptive statistics for the Balance Heuristic . . . . .	41
5.5	Descriptive statistics for the Strategic Alignment Heuristic . . . . .	43
5.6	Testing the Propositions . . . . .	44
6.1	Benefits obtained from each Portfolio/Heuristic . . . . .	49





# Chapter 1

## Introduction

“A successful new product does more good for a firm than anything else that can happen, [...] yet, the new product process is exceedingly difficult” (Crawford & Di Benedetto, 2011, p. 6). A vital stage of this new product process is the pre-development evaluation process where product selection decisions are made. This stage is known as Product Portfolio Management (McNally, Durmuşoğlu & Calantone, 2013). Decisions at this stage are both critical and difficult. Critical because of the huge amount of resources that are at stake. According to Mr. Marijn E. Dekkers, CEO of the German chemical and pharmaceutical Bayer AG, 50% of his time is dedicated to tackle the huge challenge of deciding how to best allocate the yearly US\$3.1 Billion R&D Budget. So no doubt that New Product Portfolio Management is in the head of Top Management in innovative firms as complex and essential. On the other hand, the difficulty of these decisions occurs as there is limited amount of reliable information regarding customer demand, specific design requirements, and required investments (Chao & Kavadias, 2008). In addition, as one known and prolific author on the field has stated, the strategy of a firm is materialized in the moment the firm’s managers decide how and where to allocate its resources (Cooper et al., 1998). New product portfolio management is then a “powerful strategic weapon” as it is a central building block for implementing the intended strategy (Meskendahl, 2010) and is defined as the dynamic decision process of evaluating, selecting, prioritizing, and allocating resources to product development projects (Cooper et al., 1998).

Decision-making in Product Portfolio Management is becoming a major research trend in the innovation literature, and despite several calls in literature for more research, what successful NPD portfolio management truly means and how firms can achieve it remains unclear (Kester et al., in press). Extant research has elaborated on the drivers that motivate the decision-making process in portfolio management such as Politics (Bentzen, Christiansen & Varnes, 2011; Christensen, 2003; Christiansen & Varnes, 2008; Kester, 2011; Weissenberger-Eibl & Teufel, 2011), Intuition (Hart, Hultink, Tzokas & Commandeur, 2003; Kahneman, 2011; Yahaya & Abu-Bakar, 2007), Rational models (Kester, Hultink & Lauche, 2009), psychological and social-psychological characteristics of organizational members (McNally et al., 2013) and others (Chao, Kavadias & Gaimon, 2009). Some authors have also focused on the consequences of the decisions made at the portfolio management stage (Heising, 2012; Kester, 2011; Killen, Hunt & Kleinschmidt, 2008; McNally et al., 2013; Meskendahl, 2010). A successful new product portfolio has commonly been framed in literature in three dimensions, i.e. Value Maximization, Balance and Strategic Alignment (Cooper et al., 1998). Value Max-

imization is when the optimal ratio between resource input and return is achieved; balance is when the NPD portfolio is harmonious in different type of project parameters such as their risk/reward characteristics; and strategic alignment when the NPD portfolio reflects the firm's strategic business priorities (Kester et al., in press). Yet, research has not provided a strong body of evidence in how a commonly accepted successful portfolio drives bottomline firm's results and there is still a lack of empirical evidence on the understanding on how portfolios that attain these three goals will ultimately drive firm's value generation.

Regarding this last point, Menke, a portfolio management expert has raised a question that might sound obvious: Does Good New Product Portfolio Management lead to Realized Value? As most R&D organizations use extensively portfolio management, common sense would tell that portfolio management does create value. Yet, "realized value can only be achieved by downstream organizations that receive and effectively use the assets and capabilities delivered by the R&D effort. The intrinsic value potential of these assets and capabilities can be substantially increased or decreased by the quality of the people and processes in these receiving organizations. This makes it almost impossible to accurately attribute realized value to R&D portfolio management efforts" (Menke, 2013, p. 35). There are studies finding correlations between successful products and good practices on portfolio management (Killen et al., 2008), but only a few empirical studies identify a link between what is accepted as a successful portfolio and metrics of firm performance and value creation (Kester et al., in press; McNally et al., 2013). Yet these studies have disparate results. Not having a solid stream of evidence supporting the effects of good portfolio management in value creation constitutes a gap in literature that this master thesis intends to address by the means of a Monte-Carlo simulation model.

Accordingly, the purpose of this study is to better understand how a value maximized portfolio, a balanced and a strategic portfolio may entail relevant differences when it comes to value generation, and how different type of portfolios are achieved under different assumptions and criteria, of course, distinguishing the results that such portfolios will bring about in terms of portfolio newness and strategic fit. This will be achieved by building a Monte-Carlo simulation model that incorporates the effects on value generation when portfolio management decisions are made by attaining the three widely accepted successful portfolio management goals, i.e. Value Maximization, Balance and Strategic Alignment (Cooper et al., 1998). This purpose is in line with Bicore's expectations. Bicore as the firm endorsing this study, aims at having a deeper knowledge of the underlying mechanisms of the decisions made in the portfolio management process and the consequences in the firms' results. Thus, the outcome of this graduation project serves as input for further improvement of FLIGHTMAP<sup>1</sup> as well as a contribution for Bicore's partner consulting activities. In addition to this set of prescriptions, Bicore can keep and extend the developed model for posterior research.

The structure of the document is as follows: First, an extensive literature review on the portfolio management decision-making research is provided. Next, a formulation of the problem statement and the research question will be presented along with a set of propositions underpinned in literature and reasonable assumptions. An in-depth explication of the research method and the model description is presented in the method chapter. Next, the document presents the results of experiments, sensitivity analyses and the proposition testing, followed by a discussion. The document closes with the conclusions, limitations and further research.

---

<sup>1</sup>FLIGHTMAP is the software platform developed by Bicore as its Portfolio Management Solution

## Chapter 2

# Literature Review

### 2.1 Defining Portfolio Management

NPD Portfolio management is concerned with methods and tools that ensure effective resource allocation among an ensemble of innovation efforts (Chao & Kavadias, 2008, p. 138). Perhaps the most widely accepted definition of Portfolio Management has been given by Cooper and colleagues: “Portfolio Management is a dynamic decision process, whereby a business’s 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” (Cooper et al., 1998, p. 3). Kester and colleagues state that the set of activities carried out during the portfolio management process “will enable the firm to grow profitably over the long term” (Kester, Griffin, Hultink & Lauche, 2011, p. 641). Cooper et al. argue that portfolio management is multifaceted and complex, for instance, technical staff can see it as a selection process of the right projects to foster the right innovation in the firm; the financial staff can see it as the process by which financial resources are allocated efficiently; strategists see it as a selection of strategic correct portfolios, and so on (Cooper et al., 1998). Not only has this variety of perspectives made this field complex. Kavadias and Chao affirm that also as causes of complexity are the resource scarcity, the different projects interactions, the outcome uncertainty and the dynamic nature of the problem (Kavadias & Chao, 2008).

The early literature in this field has approached the topic as an optimization technique problem with the aim to allocate in the most efficient way the resources of the firm. These first studies with high academic and scientific rigor, were not intended to be actually implemented, and their feasibility was not a major concern, consequently, most of these studies resulted in little impact in real practice (Cooper et al., 1998). Literature on portfolio management has an extensive amount of game-theoretical analysis that are not of wide use in practice and it remains as a research challenge to connect these strategic models to the prescriptive literature (Hauser, Tellis & Griffin, 2006). More recent studies have been proposing new product portfolio methods as financial models, scoring models, and probabilistic, behavioral and mapping approaches (Cooper et al., 1998). In a review of the existing portfolio management literature, Kavadias and Chao split the decision making approaches in three kinds: First, at the firm and strategic level, second, as an allocation of resources in NPD programs and third, as a project selection at the tactical level. They note that literature related to the first kind of decision making, i.e. strategic level, has been reduced to only “best practices” and rules of

thumb which have been recorded through case studies with low empirical support (Kavadias & Chao, 2008). On the contrary, they note that literature is more abundant for the lowest level of decision making: project selection at the tactical level, where such allocation problem is approached as an optimization problem. Regardless of the theoretical value of such studies, Kavadias and Chao suggest that their applicability and impact in real contexts remain low (Kavadias & Chao, 2008). This suggest that an integral perspective of portfolio management with practical impact is still missing in scientific research, which reinforces the motivation of the present study.

## 2.2 Elements of Decisions of Portfolio Management

Portfolio management decisions involve three main type of project choices, i.e. project selection, project termination and project/product deletion (Kester et al., 2009). It is a common mistake to see portfolio management as a mere project selection process (Cooper et al., 1998).

Project selection represents the major decision that is normally made in portfolio management. This decision has normally been treated in literature as a decision process that use financial and operations research theories in order to rationally decide the best NPD project to undertake, so the firm ultimately obtains a profitable and balanced portfolio (Hauser et al., 2006; Kester et al., 2009). Not always the information at hand is entirely reliable and many uncertainties plague this decision process, which is why some firms have started treating portfolio decisions as options i.e. probabilistic financial methods (Kester et al., 2009). This issue is more salient for radical new products. A well-known study from Hart et al. in Dutch and English firms, shows how the screening project criteria change across the different stages of the NPD process, where mostly intuition, market potential and technical feasibility govern the decisions made at the early stages (Hart et al., 2003).

Project termination decisions are relevant, as they “free up resources that create room for better NPD opportunities” (Kester et al., 2009, p. 329). Project termination is the process of ending NPD projects that are in development (Kester, 2011). The project termination decisions have been widely addressed in literature and are considered to be a difficult business decision to make. Drawing from several authors, Kester et al. illustrate how such decision takes place, and what mechanisms underlie for such decision to be made. When a project has shown signs of low probability of success and should therefore be discontinued, managers already have an emotional attachment to the project and can perceive its termination as a personal failure (Kester et al., 2009). This escalation of commitment has received wide attention in the literature, and experimental settings have allowed to understand its sources and under what conditions it occurs. Still though, literature lacks a connection between termination decision challenges and to how firms organize and execute their overall portfolio decision-making processes (Kester et al., 2009). Additionally, escalation of commitment has been addressed mostly in innovation and psychological research only in individual contexts, whereas the portfolio management context occurs mostly in group environments. As a last conclusion drawn by Kester regarding termination, termination decisions represent an important aspect of NPD portfolio decision-making, which still research has not yet provided with sufficient knowledge of its antecedents and consequences, specifically in the context of the portfolio management in a firm (Kester, 2011).

Product deletion decisions, considered as an expected step during the maturity and declining phase of products, are decisions that are triggered by several factors: Organizational

and Environmental conditions, and Situational and Product related issues (Avlonitis, Hart & Tzokas, 2000). Even though there is a research effort in this field, deletion decisions have not been integrated in the context of the overall product portfolio management system (Kester et al., 2009). It is interesting to note that, if one revises again the portfolio management definition given by Cooper et al. (1998) stated in 2.1, this definition involves the selection and termination of projects, and the deletion of current products, but literature has focused its prescriptive methods mostly around the selection decisions when new projects emerge. Kester declares that “product deletion research since 1970 has only received limited research attention. Although each one of these studies provided some interesting insights, there is little cohesion across them, [...] without investigating how firms make deletion decisions” (Kester, 2011, p. 58).

Further, some innovation scholars argue that portfolio decision-making is more than a calculative rational decision and more than an optimization resource allocation problem. They argue in favor of process models in which appropriate decisions replace rational decisions (Christiansen & Varnes, 2008).

### 2.3 Drivers of decision in Portfolio Management

In this section, a set of decision-making drivers will be briefly explained. Several drivers are present when managers make decisions related to portfolio management. Among the different drivers that were found in literature, Table 2.1 shows the set of five drivers along with the most prominent authors in each field.

Driver /Antecedent	Studies
Politics	Career concerns (Christensen, 2003); Attention paid (Bentzen et al., 2011); Appropriate decisions instead of rational decisions (Christiansen & Varnes, 2008); Political games (Weissenberger-Eibl & Teufel, 2011); Ambiguity, Interests, Conflicts and Leadership style (Kester, 2011)
Intuition	Uncertainties and ambiguity (Yahaya & Abu-Bakar, 2007); Bias and Heuristics (Kahneman, 2011); Intuition dominates early stages (empirical findings) (Hart et al., 2003)
Rationality	Synoptic Formalism and procedural rationality (Kester et al., 2009)
Managers' individual traits	Personality characteristics and traits (McNally, Durmusoglu, Calantone & Harmancioglu, 2009)
Other individual drivers	Funding authority and incentives (Chao et al., 2009)

Table 2.1: Portfolio Management decision-making drivers and studies

#### 2.3.1 The role of Politics

Portfolio decision making is more than a calculative rational decision and more than an optimization resource allocation problem (Christiansen & Varnes, 2008). In their study, Christiansen and Varnes suggest that decision makers do not undertake calculative rational decisions; instead, they make appropriate decisions. These appropriate decisions are based in three processes: the process of self-awareness, the process of recognition and the process of search and recall (Christiansen & Varnes, 2008, p. 89). They also observe the existence of power plays and the fact that decisions are influenced by the others' insights and established rules. In most companies, the resource allocation and the patterns of innovations are profoundly influenced

by a balance of the mechanisms of corporate profit, i.e. things required for the company to grow and profit, and the personal success, i.e. if participating in the project enhances the career opportunities of talented employees (Christensen, 2003). Certain business units and their managers attract more attention than others which is evidence of the important role of organizational politics and power plays (Bentzen et al., 2011). Bentzen et al. declare under different rationales (from Herbert Simon, Mintzberg and Dijksterhuis previous works) that attention determines the quality and satisfaction of decision-making processes. How good and satisfactory decisions are, depend on the amount of attention paid rather than a deliberate calculative behavior (Bentzen et al., 2011). Drawing from past literature on organizational politics, Wissenberger-Eibl & Teufel state that “organizational decision-making, particularly with respect to decisions that allocate resources within organizations, is inherently political in nature and cannot be fully understood within frameworks that overlook this dimension of the process” (Weissenberger-Eibl & Teufel, 2011, p. 53). Further, in her thesis, Kester gives a comprehensive overview of how the politic behavior unfolds in the NPD project selection. People at organizations have different motivations (resulting from functional, hierarchical, professional and personal factors) and such differences motivate people to use political tactics so they can obtain outcomes that serve their own interests. Such tactics involve observable actions in which some kind of power is used in order to influence decisions (Kester, 2011).

### 2.3.2 The role of Intuition

Strategic NPD decision-making is about predicting the success of product or technology in the market, predicting reaction of competitors, suppliers and customers, and assessing how a product plan and strategy will work out based on scarce control of the future. The consequences are that senior managers deal with risk, high uncertainty and ambiguity. “Incomplete information about the future and past experience are only able to give some guidance to a limited extent. This explains why we see more intuition than empirical analysis employed in making decisions in dealing with strategic NPD management issues” (Yahaya & Abu-Bakar, 2007, p. 1130). Hart et al. empirically found that in the initial stages of the NPD process, intuition takes a major role in the input for decision making. Its importance is lowered as the process continues to the later stages (Hart et al., 2003). Kavadias and Chao, who have taken a position oriented to see the portfolio management decision-making as an optimization and exact problem, state that intuition and heuristic rules take place in the NPD decision making as managers have misunderstood the aim of portfolio management and consider it as a simple “balancing” task (Kavadias & Chao, 2008). Kahneman explains how two systems govern individual decision making, i.e. System 1: which provides fast answers, uses heuristics, is unconscious and automated, but not exactly rational, and System 2: which provides slow answers and uses careful judgment and attentive analysis. Decisions made by System 1, make use of heuristics, which are mental shortcuts that reduce complex tasks of assessing probabilities and predicting values to more simple judgmental operations (Kahneman, 2011). Interestingly, he makes a call to not trust intuition in unstable environments, which is the typical situation in new product development.

### 2.3.3 The role of Rationality

Using a grounded theory approach, Kester et al. identify three genres that describe a unique set of portfolio management practices: Formalist reactive, Intuitive and Integrative. As ra-

tionality makes an extensive part of the strategic decision-making literature, I will draw short comments about the relation between rationality and portfolio decision making, mostly based on Kester et al.'s results from their study (Kester et al., 2009). For this, an explanation of the Formalist reactive genre will be explained as this is the genre dealing with the normative and rational approaches in portfolio management. Formalist reactive firms use rigid planning processes, relying mostly in quantitative criteria and financial methods for assessing and deciding on NPD projects. The theory behind this genre is called Synoptic Formalism. Synoptic formalism emphasizes *procedural rationality* in decision making and relies on the use of a comprehensive set of alternatives containing as much relevant information as possible, so managers arrive to an optimal decision (Kester et al., 2009). In general, scientific research suggests that rational decision processes, along with politics and intuition, take place during portfolio management decision-making.

### 2.3.4 Manager's individual traits

Another important set of authors of recent literature of Portfolio management decision-making, suggest that “rather than organizational or environmental factors, personality characteristics largely explain management influence on innovations” (McNally et al., 2009, p. 128). Psychological forces have an impact on organizational change; therefore, manager dispositional traits appear to play an important role in new product portfolio management decisions. A trait is a measurable dimension of behavior and drawing from psychological and personality literature, McNally et al. identified a set of managers' dispositions that stood up in their explorative study, concerning with portfolio management decision making. They identify these traits as follows:

1. Change resistance: “individual tendency to resist or avoid making changes, to devalue change generally, and to find change aversive across diverse contexts and types of change” (p. 134).
2. Ambiguity tolerance: “person's capacity to accept the absence of information about the range of probabilities of possible outcomes” (p. 134).
3. Analytic cognitive style: “consistent manner in which individuals approach perceptual and intellectual activities such as problem-solving” (p. 134).
4. Leadership style: “extent to which leaders behave democratically or autocratically” (p. 134).

### 2.3.5 Other antecedents and drivers

Chao, Kavadias and Gaimon posited in their study the effect that explicit incentives as wage compensation and implicit incentives as manager's career concerns may take an important role in the balance between radical and incremental innovations in a firm (Chao et al., 2009). Their model proposes firstly that funding authority, (i.e. the capacity to decide whether to invest actual revenues in actual NPD funding or not) has significant implications for both the structure of incentives and the allocation of resources. This means that the more funding authority the manager has, the more resources will be invested in the development of new products. In addition, a positively relation exists between incentives and the tendency to allocate resources in R&D. More exactly, the level of explicit incentives (i.e. wages) and the



level of implicit incentives (i.e. career concerns) affect both the tendency of managers to allocate R&D resources.

## 2.4 Decision-making Models in Portfolio Management

Further, four selected decision-making model frameworks are shown. Criteria as relevance of the author, comprehensiveness, and publication dates were considered to be selected as the most insightful frameworks found in current literature. At the end of this subsection it will become more evident how the different proposed decision drivers play the role of antecedents to create value-maximized, balance and strategic portfolios, that ultimately lead to certain consequences at the firm level.

### 2.4.1 General Model of Decision-Making by Kester et al. (2011)

Drawn from four in-depth case studies and by using grounded theory, Kester and colleagues propose a comprehensive decision-making model in the context of Portfolio Management. In general, effectiveness in portfolio decision making is attained when a portfolio mindset is reached, a right focus is dominant for the right projects, and when decisions are made in an agile way. Such effectiveness is the result of the interaction between three kinds of decision processes: evidence based (i.e. detailed information is debated by decision makers), power based (i.e. domination goals of some individuals or subgroups over others) and opinion based processes (i.e. decisions are based on opinions and experiences of decision makers). In their framework, domain-based inputs as cross-functional collaboration, critical thinking and market immersion, are associated with the evidence-based processes. Organizational politics are associated with power-based decision making. Managerial intuition is associated with opinion-based decision making. Finally, the framework suggests that firm cultural factors, - i.e. trust, collective ambition and transformational leadership- are associated with the already mentioned input generating processes. The way how they hypothesized all these interrelations is what is shown in Figure 2.1.

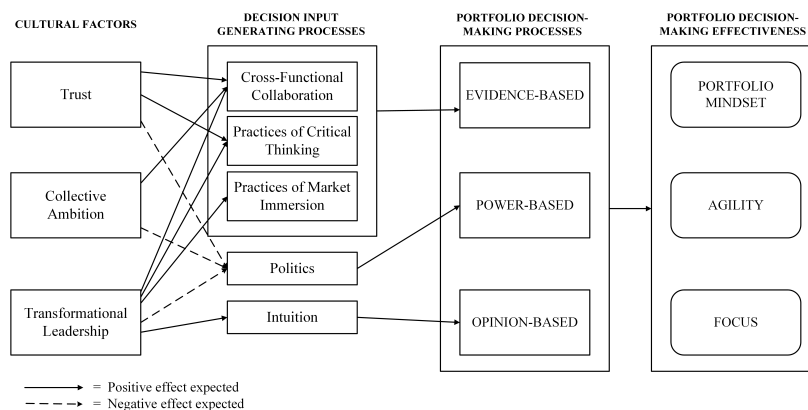


Figure 2.1: General Model of Portfolio Decision Making (Kester et al. 2011)

Portfolio Decision-making Effectiveness predicts the construction of successful portfolios (i.e. high value, balanced and strategic) which subsequently leads to market performance (Kester et al., in press).

### 2.4.2 Portfolio Dimensions, Impacts and Antecedents by McNally et al. (2013)

Based on their previous study already mentioned in the drivers and antecedents section (McNally et al., 2009), McNally and colleagues elaborated on a model that considers individual manager's dispositions, and mediated by the traditional Portfolio Management dimensions, i.e. Value maximization, Balance and Strategic Fit (Cooper et al., 1998), result in positive effects on NPD performance and Firm Performance (McNally et al., 2013).

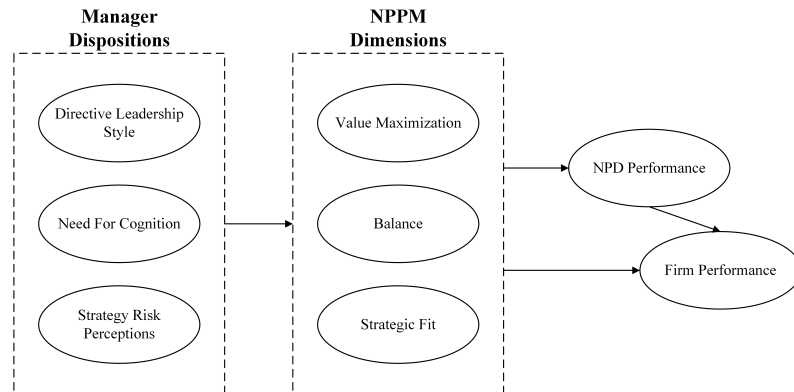


Figure 2.2: Portfolio Dimensions', Impacts and Antecedents (McNally et al., 2013)

This model (shown in Figure 2.2) has a difference with the one proposed by Kester et al., as the latter considers individual manager traits, and the former involves an interaction of several antecedents that exist in the organization as a whole. Building upon their previous study (McNally et al., 2009), and drawing from organizational information processing theory, they operationalized managers' dispositional traits in three constructs, namely, Directive Leadership Style, Need for cognition, and Strategy Risk Perceptions. The importance of this model is that it connects firms' consequences (or impacts) with the antecedents of the managers' dispositions and the portfolio management dimensions of success.

### 2.4.3 Strategic Orientation and Business Success in Portfolio Management by Meskendahl (2010)

In an attempt to integrate business strategy to firm success, Meskendahl proposes a coherent and integral framework that considers strategic orientation, project portfolio structuring, project portfolio success and business success. Project portfolio management appears as a powerful building block to execute the stated business strategy and to ultimately obtain business success. The scope of this framework is for projects related to R&D and IT projects and it builds upon the widely accepted portfolio management dimensions of success (Cooper et al., 1998), however, Meskendahl argues that the dimension maximal financial value should be split up in two separate dimensions, namely (1) "the average single project success of the portfolio regarding the fulfillment of time, budget, quality, and customer satisfaction objectives, as well as (2) the use of synergies between projects within the portfolio, which covers the interdependencies between projects" (Meskendahl, 2010). In Figure 2.3, Project Portfolio Success shows this split dimensions, and the other two suggested by Cooper et al., namely, Strategic Fit and Portfolio Balance.

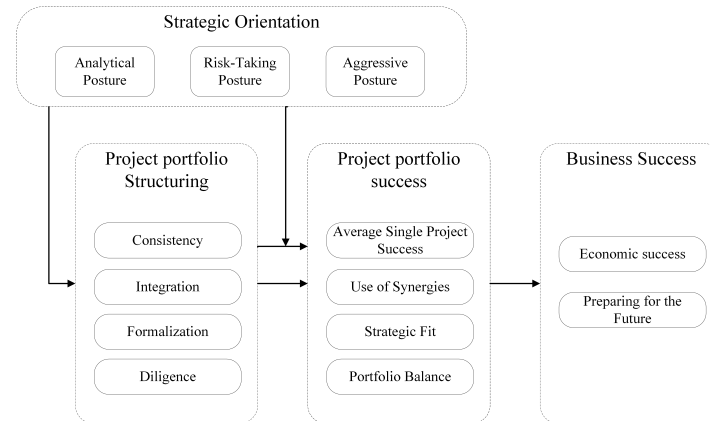


Figure 2.3: Strategic Orientation linked to Portfolio Management-Success (Meskendahl, 2010)

The Project Portfolio Structuring construct, proposed by Meskendahl, is the one that has more relation with the decision-making mechanisms. In particular, Integration, Diligence and Formalization are the constructs that include to a medium extent the already explained mechanisms considered by Kester et al.’s (2011) model. Integration “includes the extent to which all relevant functions are involved as well as their different perspectives are accounted for in the process” (p. 812) which has a relation with the Kester et al.’s opinion-based decision making processes. Diligence is “the degree to which scenarios are used, interdependencies are considered, and the mix of innovative and long-term projects is accounted for” (p. 812). Formalization considers the degree of overall process formalization, the transparency of rules and processes and the use of suitable and accurate data, and explicit and objective criteria (Meskendahl, 2010). Diligence and formalization have a relation with the Kester et al.’s evidence-based processes. The introduced model remains available for empirical validation and its major contribution in the fact that it extends the already two aforementioned models by relating the construct Strategic Orientation as an antecedent of portfolio management success and subsequently business success.

#### 2.4.4 Ideation and Portfolio Management by Heising (2012)

Heising introduces a type of portfolio management called Ideation Portfolio Management whose basic concept proposes that “ideas should be further developed into concepts and then into project proposals and which of these proposals should then become projects should be decided from a project portfolio management perspective” (p. 583). The aim is to feed the subsequent project portfolio management with a sufficient flow of project proposals that will bring high value and strategic support to the organization. In addition, Heising argues that ideas flowing from such process would have faster implementation times. In general, project portfolio success is suggested as a dependent construct, and ideation portfolio management as its antecedent. Front end success serves as a mediator between these two constructs (Heising, 2012). This framework (shown in Figure 2.4) is based on a sound review of literature and from preliminary validations gathered by interviews with practitioners from various industries.

The ideation portfolio management is suggested under the idea that organizations are able to generate a vast number of ideas, but the challenge is to generate and find good ideas. A first construct of idea portfolio management is strategic positioning of ideation. The aim

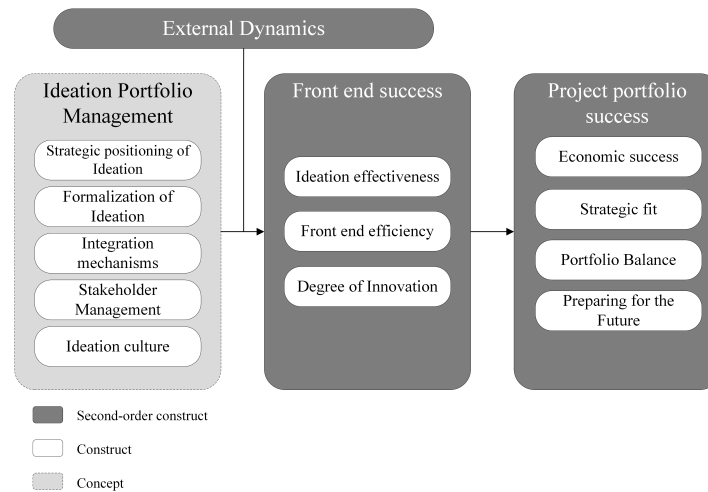


Figure 2.4: Project Portfolio Success and Ideation Portfolio Management (Heising, 2012)

is that the firm is able to set the tone for its idea generation and pre-project phase. Formalization/Institutionalization of ideation process refers to the ability of the firm to influence the activities that are crucial for innovation success by controlling the process. Integrations Mechanisms refers to the incorporation of mechanisms of integration of ideation portfolio management into the downstream processes of project portfolio management. He posits that personnel, technocratic and financial integration are positively related to front end success. Stakeholder management refers to the influence of success that stakeholders have, and as well to the notion that stakeholders serve as fertilizer, promoting the growth of ideas. Finally, ideation culture refers to the pivotal role that the climate for innovation can have in the success of new product development.

The importance of Heising's study is that it tries to elaborate on a discontinuity existing between the ideation and the project portfolio management concepts. Even though the model does not detail further mechanisms of decision-making processes, it brings a different approach when consolidating the set of antecedents of portfolio management decision-making that are found in scientific literature.

## 2.5 Dimensions of Success of a NPD Portfolio

Current literature has accepted three dimensions to outline the goals of portfolio management, and most of the scientific studies related in this review base their findings on such dimensions (Cooper, Scott & Kleinschmidt, 2004; Cooper, 2006; Heising, 2012; Kester et al., 2011; Killen et al., 2008; McNally et al., 2013; Meskendahl, 2010). These dimensions were identified by Cooper and colleagues (Cooper et al., 1998) as the common denominators that dominate the thinking (either implicitly or explicitly) of the firms they studied. Each one of the three dimensions will be explained in the following subsections.

### 2.5.1 Value Maximization

Cooper and colleagues define value maximization as the allocation of resources to maximize the overall value of the portfolio in terms of a main company objective, such as profitability,

return on investment, brand value or likelihood of success. In general, maximal value is defined in terms of monetary value and determined by the presence of high impact projects on the portfolio (Cooper et al., 1998). One major preoccupation for firms is to obtain a maximal value of the portfolio when it comes to allocating resources. The objective may vary according to the firm's needs, which means that the value of the portfolio can be measured in terms of long-term profitability, or return on investment, likelihood of success, or some other objectives (Cooper et al., 1998). Put in other words, value maximization can also be understood as the ratio between resource input and value output, in relation to a business objective of the firm, and is generally defined in monetary terms (Kester, 2011). Because of the high levels of uncertainty on innovation projects in the early stages, and based on Expected Utility Theory, a portfolio manager maximize the value of his/her portfolio by choosing between risky or uncertain prospects and by comparing their expected utility values, i.e. the weighted sums obtained by adding the utility values of outcomes multiplied by their respective probabilities (Mongin, 1997). Expected Utility theory is vastly used in economics to explain choice under uncertainty.

Regarding the consequences of having a value maximization portfolio, only some very recent studies shed some light of the positive effect that a maximal value portfolio may have on firm's performance and market performance. Inconsistent results are found as in one study, maximal value portfolio does not significantly relate to firm performance (McNally et al., 2013), whereas in the other study there is a highly significant effect of maximal value portfolios and market performance (Kester et al., in press). Some plausible explanations are provided for such counterintuitive findings. McNally and colleagues suggest that having value maximized NPD portfolios does not constitute a competitive advantage as most NPD managers would strive for the same strategy of finding highly profitable portfolios. Killen found that companies using the financial methods of project selection did not result in obtaining highly valuable projects (Killen et al., 2008). It remains unclear what would be the direction and significance of the effect, as the few recent studies have different and even opposite results.

### 2.5.2 Balance

According to Cooper et al., a balanced NPD portfolio reflects an optimal spread in individual NPD project risk (Cooper et al., 1998). According to this definition and drawing from Modern Portfolio Theory, a balanced NPD portfolio can be understood as a combination of assets or NPD projects that all together have an appropriate risk/reward ratio. Modern portfolio theory states that for a certain level of risk, there exist a portfolio (combination of projects) with the highest amount of return, or in the opposite direction, for a certain expected return there exist a portfolio that will deliver it at a minimum level of risk (Markowitz, 1952). This notion of portfolio balance can therefore be understood as a clear analogy of the diversification concept proposed by the modern portfolio theory. Kester agrees that portfolio balance is the characteristic that most closely relates to the diversification aspects highlighted in modern portfolio theory (Kester, 2011).

But risk is not the only dimension associated to a balanced portfolio. The balance dimension also considers a good spread in product newness (from incremental and all the spectrum until a breakthrough), the balance between a short-term and a long-term focus, and the balance across the different types of markets that the firm serves (Bordley, 2003) and across the various stages of the NPD process (Cooper et al., 1998). Still, the notion of balance is very subjective, and it depends on the strategy of the firm (Cooper et al., 1998), the environmental

complexity and environmental instability (Chao & Kavadias, 2008). Compared to its peer dimension, i.e. value maximization, balance is hardly tractable and it is found in practice that companies strive to build balanced portfolios through mapping methods (bubble diagrams) which rely more in a subjective assessment rather than an exact numeric value comparison. Balancing high-risk breakthrough projects with more near-returns incremental projects is one of the most difficult, yet critical, components of R&D portfolio decision-making (Matheson & Menke, 1994). According to Kester, defining the constitution of an ideal NPD portfolio balance might be relatively difficult, and it is easier to identify an unbalanced portfolio (Kester, 2011). Typical unbalanced portfolios have too many projects that are predominantly incremental in nature, with short-term business results.

Recent research has provided evidence of the positive relation between balanced performance and firm performance (McNally et al., 2013) as well as market performance (Kester et al., in press). Opposite to Value Maximization and Strategic alignment, Kester et al. find that portfolio balance has no direct link to market performance, but operates through the other two dimensions of NPD portfolio success, i.e. strategic alignment and maximal portfolio value (Kester et al., in press), whereas in McNally et al.'s study, only balance matters for NPD and firm performance given that increasing balance is associated with improved performance, and "balance ensures a diverse mix of projects that not only enhances firm performance but also decreases risk by improving the financial value of radical innovations while reducing the likelihood of firm failure" (McNally et al., 2013, p. 256). It remains for further validation, what would be the right link between balanced portfolios and firm/market performance, i.e. direct or mediated.

### 2.5.3 Strategic Alignment

The aim of this goal, -regardless of all other considerations-, is to ensure that the final portfolio of projects has a strategic alignment with the corporate business strategy. In his study, Meskendahl states that the concept of strategic fit originally stems from organizational research with a main premise that business performance is the result of fit between factors such as strategy, structure, technology or environment (Meskendahl, 2010). According to Cooper and colleagues, some firms ensure that active projects are on-strategy when resource allocations genuinely reflect the desired strategic directions of the business. In order to avoid leaving strategy in just words -or nice documents-, strategy must be operationalized in terms of where the business spends money (Cooper et al., 1998). In an empirical study, Carbonell-Foulquié and colleagues found that strategic alignment is one the most important criteria used by managers in the early stages of the NPD process (i.e. New product concept) as this is a distinguishing factor of successful new products (Carbonell-Foulquié, Munuera-Alemán & Rodríguez-Escudero, 2004). Furthermore, they propose that there are two approaches to establish strategic alignment: by attaining strategic fit, i.e. "do all your projects fit strategically? Are they consistent with your business strategy?" (p. 84), and by attaining strategic priorities, i.e. answering questions such "does the breakdown of your spending reflect your strategic priorities?" (p. 84). Interestingly, Cooper and colleagues found that, often companies have a disconnection between what is *stated* in strategy and what really is *executed* as strategy.

Other authors suggest that the firm's strategy can be translated in a set of measurable objectives throughout the organization. For instance, Bremser and Barsky based a strategic alignment framework for R&D portfolios using the Balance Scorecard approach, which

considers four different dimensions to assess strategic performance: customers perspective, internal business processes, learning and growth and financial performance (Bremser & Barsky, 2004). In general, the balance scorecard framework is a management system designed to link and align the organization with its strategy at all levels in a clear fashion (Kaplan & Norton, 1996). A slight different perspective is used by other authors. According to Liberatore, R&D project selection requires consideration of multiple criteria whose relative importance is contingent on the objectives and strategies of the sponsoring organization and the nature of the R&D activity itself. Instead of using a balance scorecard approach in order to deploy strategic objectives to R&D terms, Liberatore uses an Analytic Hierarchy Process approach. In sum, the strategic alignment of a specific R&D portfolio is the prorated sum of the score values of a specific portfolio in those dimensions that managers consider relevant to attain a firm's strategy (Liberatore, 1988). Englund and Graham give a good example of portfolio strategic alignment to strategy in an innovative real setting by using an Analytic Hierarchy Process approach. From an experienced point of view, they suggest that firms obtain more value when selecting R&D projects based on the strategic goals, but unfortunately what is found in practice is that firms usually got in trouble by focusing on technology or financial factors before determining the link to strategic goals (Englund & Graham, 1999). Calantone and colleagues also provide an example of using AHP as a systematic way to support the screening decision using criteria as fitness of the firm's capabilities with certain NPD initiative (Calantone, Di Benedetto & Schmidt, 1999).

The strategic alignment dimension also describes the long-term opportunities and benefits for the company that result from the portfolio management process. It is mostly related to the competencies and new technologies that are generated and developed in a specific portfolio and how this will position the company towards competitors (Heising, 2012). Smit and Trigeorgis recall the existence of contradictory views of strategy. One view is that strategic flexibility is valuable. Especially in turbulent environments where there are changes quite frequently, flexibility in strategic investment decisions allows firms to optimize their investments and value creation. The other view, states that strategic commitment can be valuable. When a firm commits to an investment or strategic plan (irreversibly), it can influence the strategic moves of its competitors (Smit & Trigeorgis, 2006). The former view is based on the idea that dynamic capabilities would make adapt the firm in environments of rapid technological change. In the latter view, the competitive advantage is leveraged by the existence of internal resources and capabilities of the firm. According to Abell, companies should pursue parallel strategies, one of them focusing on today's capabilities while simultaneously developing new capabilities for the future (Abell, 1999). In line with his reasoning, MacMillan and McGrath state that future's sources of revenues are part of the strategic decisions that are made when configuring portfolios (MacMillan & McGrath, 2002). In addition, one of the most enduring ideas is that a firm's long-term success depends on its ability to exploit its current capabilities while simultaneously exploring fundamentally new competencies (March, 1991). Exploration initiatives call for less attention to the current organizational strategy whereas an emphasis on routine development is given by exploitation initiatives (Greve, 2007). Even though the exploration/exploitation and real-option theory for valuing future growth opportunities belong to different bodies of research, they coincide that there must be certain balance between the support of core-strategy ideas, as well as the support for divergent-strategy ideas when it comes to building a strategic and growth new product portfolio. In Figure 2.5, it is shown that tomorrow's growth is based on strategic options where still high uncertainty is present (McGrath & MacMillan, 2009).

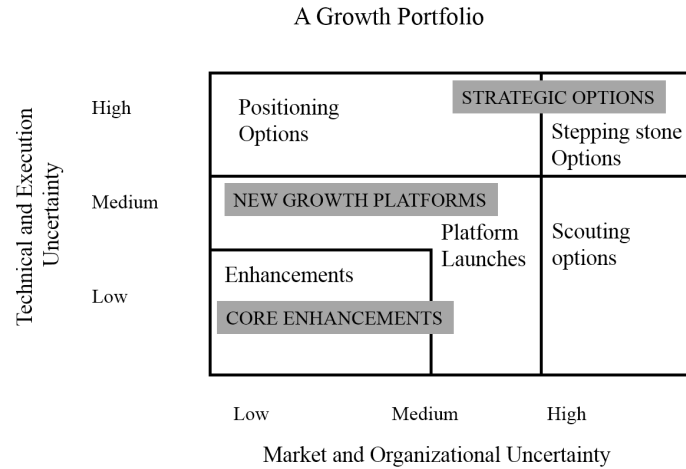


Figure 2.5: A Growth Portfolio (McGrath & McMillan, 2009)

But what are the mechanisms through which uncertain and risky but still promising initiatives will succeed the NPD process once they are selected in a strategic portfolio? According to Jemison, a firm’s performance can be optimized by aligning its capabilities to its environment, business strategy and organizational processes (Jemison, 1987). This indicates that the higher the alignment of a NPD project with the firm’s organizational capabilities, the higher the chances of success. In the realm of Marketing, risks are associated to the ambiguities about the types and extent of customers needs that can be satisfied by a specific technology or new product (Mu, Peng & MacLachlan, 2009). Therefore, among other ways, marketing risks can be managed easier when there is reliable and available information about customer’s preferences and requirements. In addition, customers are more positive towards trusted and committed companies (Mu et al., 2009) which in turn reduce marketing risks. This indicates that marketers can manage marketing risks when the new NPD initiatives fit the firm’s marketing capabilities. In the realm of technology, the concept of innovation fields state that multiple, thematically related innovation projects stimulate synergies among them and the effect of such synergies contribute to a more continuous stream of significant innovations compared to innovations that only focus on single products or businesses (Salomo, Talke & Strecker, 2008). This concept of innovation field orientation is a synonym of other concepts also known in literature as new growth platforms, technology-market domains and strategic arenas. In their study, Salomo and colleagues find that when deliberately companies specify and manage innovation fields, more successful and more innovative product portfolios were found as there is a development of dynamic capabilities, resources sharing and knowledge spillovers across related innovation projects (Salomo et al., 2008).

In an early study, Kester cites different authors that indicate that having strategically aligned portfolios may contribute to achieving NPD and firm performance (Kester, 2011), however, and similar to the Value Maximization dimension, only very recent literature has brought some evidence of the positive relation between strategic aligned portfolios and firm performance (McNally et al., 2013) and market performance (Kester et al., in press). Again, findings are contradictory as McNally et al. find no significant effect in the relation maximal value and firm performance, whereas Kester and colleagues find a positive significant relationship in maximal value-market performance.



As a conclusion for the above written literature study, four different decision-making models were discussed, several drivers were also covered and a common ground area was detected: the dimensions of success (or goals as called by other authors) of portfolio management. Each revised decision-making model uses different approaches when trying to explicate the antecedents and mechanisms behind the decision-making processes. One thing they have in common (and this is to a large extent in most portfolio management literature) is that portfolio management success is measured on the widely accepted criteria proposed by Cooper et al.(1998). Three of the four models are able to connect how the antecedents of portfolio management decision-making will result in eventual consequences at the firm level success. Figure 2.6 shows a simplified scheme of the models reviewed in this search.

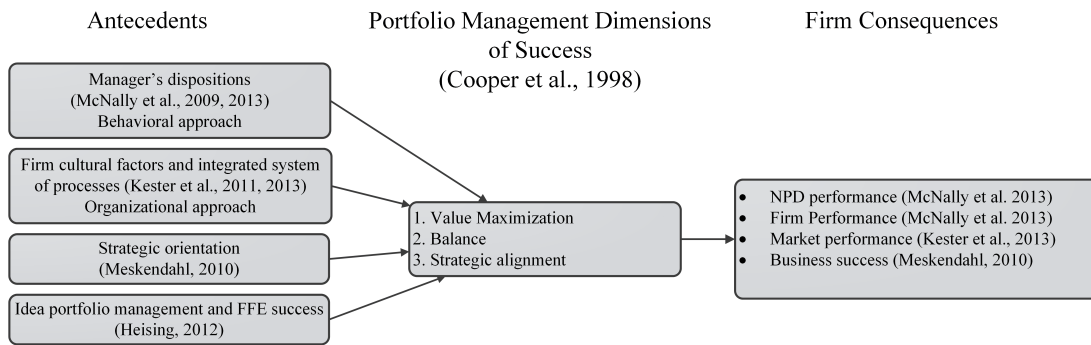


Figure 2.6: Antecedents and Consequences of the reviewed decision-making models

## Chapter 3

# Problem Statement and Propositions

### 3.1 Problem Statement

Strategic Project Portfolio Management is about selecting the best set and mix of projects to deliver future benefits (Menke, 2013). As exposed in the theoretical background, in a benchmark study, portfolio management experts Cooper, Edgett and Kleinschmidt found that the “best” project portfolios are the ones that accomplish three main firms objectives: maximization of value (i.e. returns), strategic balance and strategic alignment (Cooper et al., 1998). These findings have remained widely accepted in both, literature and practice and further large-scale benchmark studies have shown their importance (Cooper et al., 2004; Killen et al., 2008; Menke, 2013). Yet, the portfolio management literature is still limited in providing empirical evidence that shows how appropriate portfolio management leads to firm performance and value generation. From the literature review, only two studies address this question with the aim to find empirical evidence, however with disparate results (Kester et al., in press; McNally et al., 2013). Table 3.1 shows the major differences between these two studies.

As shown in Table 3.1, these two studies result in disparate outcomes. In the first study, Balance is the only dimension linked significantly to Firm Performance. The other two dimensions do not have a significant link. On the contrary, the second study suggest a more intricate relation among the three portfolio dimensions and the consequences (i.e. Market Performance) where balance is mediated by the other two dimensions and result with significant effects. Despite of these different results, both studies claim to obtain high reliable scales for measuring the new product portfolio dimensions of success, and when analyzed in further detail, both studies address and define the constructs in a similar fashion.

Managers are aware of the existing trade-offs when it comes to deciding the resource allocation of new products. For example, breakthrough projects can potentially deliver higher values, but at a risk expense and in a longer term and short term incremental projects are linked to lower but faster revenues (Kavadias & Chao, 2008). So managers must understand how to decide and what criteria to use when allocating their R&D resources. For this end, knowing how the three portfolio dimensions of success operate to create value is of paramount importance for practitioners and portfolio management scholars. Some studies’ findings suggest that firms relying only on the financial dimensions of the new products portfolio are

Author	Framework	Major Differences
(Kester et al., in press)		<p>Mediated relation between success factors and market performance.</p> <p>Significant effects found.</p> <p>Key role of the Balance dimension</p>
(McNally et al., 2013)		<p>Direct hypothesized links.</p> <p>Only balance has significant effects on NPD and Firm performance</p>

Table 3.1: Major differences between two studies (Kester et al., in press; McNally et al., 2013)

linked to poorer performance (Cooper, Edgett & Kleinschmidt, 2001). In addition, anecdotal evidence from one of Bicare’s clients suggests that relying only in balancing the portfolio across different criteria will lead to stagnant growth.

Because of the already given reasons, the research problem can be stated as *disparate evidence relating the consequences on firm’s success of the three portfolio decision making dimensions of success*. The managerial question can also be derived from the previous facts: which of the success dimensions of the new product portfolios would lead the firm to more value creation? Not knowing how a so-called successful portfolio drives company’s value creation constitutes certainly a managerial dilemma for practitioners who allocate R&D resources with the goal to create value for their companies.

### 3.2 Research objectives and contributions

Drawing from the previously mentioned managerial dilemmas, the aim is to provide additional evidence that could clarify the true role of a successful portfolio in the value creation of the firm, and with the motivation to contribute with a relevant topic for practitioners and for consulting firms in the field as Bicare, I state the following as the research question of this Master thesis:

*What are the effects of the portfolio dimensions of success in the value creation of the firm?*

In finding an answer to this question, three sub-questions shall be responded in order to guide the research approach:

- What are the main drivers and antecedents of the portfolio management decision-making process?
- What are the main mechanisms and rationales underlying the three portfolio dimensions of success?
- What are the main differences in the resulting returns (value generation) from the execution of portfolios built under each of these dimensions?

The purpose of this breakdown is to influence the literature search in the portfolio management decision-making with a broader scope. The second question will serve to understand the specifics of the portfolio dimensions of success and to guide how such dimensions will be modeled. Finally, the third question will lead the way in which the outcomes of the study are analyzed and interpreted, as well as to introduce the research method. Ultimately, by following this order an answer for the general research question can be provided.

In addition, in order to tackle the research question, a set of propositions must be developed from literature and practical insights from Bicare's experts. Further, by the means of a simulation model a proposition testing shall be performed. Accordingly, this Master thesis aims at fulfilling several objectives and intends to contribute with the understanding of the decision making processes in the portfolio management practice. The objectives are stated as follows:

- To add a new approach to the analysis of value creation generated by the decisions made in a portfolio management process (a stochastic Monte-Carlo simulation model)
- To add evidence to the existing knowledge of how the different criteria of portfolio success would ultimately end in value generation. The study will attempt to show which criteria significantly delivers more value when compared to the other two criteria.
- To provide implications of use in practice, so that managers and consultants would know the consequences of using different criteria when making decisions related to new products project selection. Some implications will be addressed directly to Bicare's consulting activities or suggestions for improvements in FLIGHTMAP.

### 3.3 Proposition Development

Based on extant literature and reasonable assumptions, a set of propositions will be developed. The propositions will be split in three subsets, each corresponding to each of the three portfolio management dimensions of success.

#### 3.3.1 Proposition 1: The Effect of a Value Maximized Portfolio

A value maximized portfolio will be composed of the most valuable NPD projects in terms of returns. It is widely accepted the notion that the most valuable portfolios are composed by the more radical-like, riskier and expensive NPD projects (Chao & Kavadias, 2008). Figure 3.1 schematically depicts this situation. In addition, those selected (highly valuable) projects may or may not be supporting how the company wants to compete in the future, i.e. strategy, or whether the projects are encapsulated into an appropriate risk/reward distribution. Only the maximization of a proxy like returns is the variable to be considered, therefore we propose the following:

*Proposition 1a: Value Maximized portfolios will deliver the highest return possible. Due to higher risks involved, returns will tend to be unstable.*

*Proposition 1b: Value Maximized portfolios will have a tendency to favor the selection of more radical-like projects.*

*Proposition 1c: Value Maximized portfolios will have no specific tendency to favor or disfavor strategic meaningful projects.*

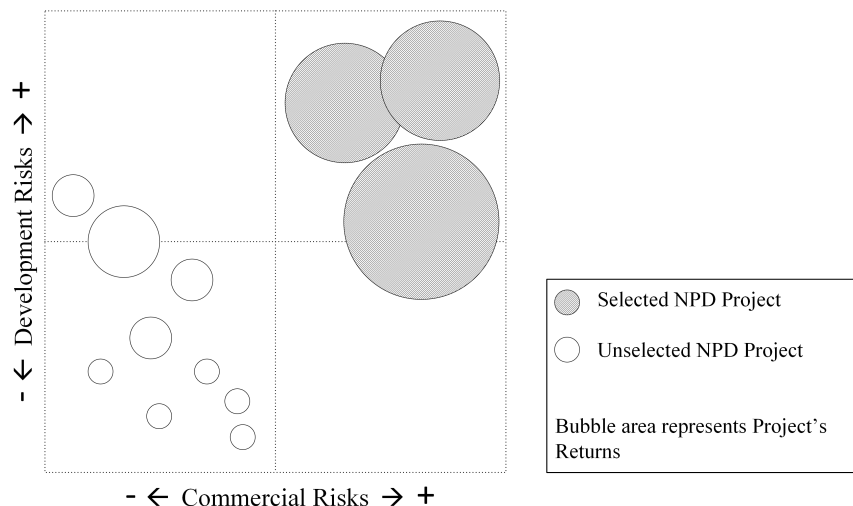


Figure 3.1: A schematic Value Maximized Portfolio

### 3.3.2 Proposition 2: The Effect of a Balanced Portfolio

Due to a diversification effect (Markowitz, 1952), Balanced Portfolios will end up with lower expected returns as smaller projects become attractive because of their lower level of risk. In a search for a perfect risk/reward ratio the portfolio will schematically look as the one shown in Figure 3.2. Furthermore, this portfolio will not have a tendency to favor or disfavor more strategic-like projects. On the contrary, the portfolio newness will include an even combination of radical and more incremental projects because of the diversification effect. We therefore propose:

*Proposition 2a: Balanced portfolios will deliver lower levels of return when compared to Value Maximized portfolios, though, the selected set of projects will form a portfolio with lower levels of variability (i.e. risks) which constitutes a surer investment bet.*

*Proposition 2b: Balanced portfolios will consist of both incremental and more radical-like projects.*

*Proposition 2c: Balanced portfolios will not entail higher or lower levels of portfolio strategic value, nonetheless, these portfolios will portrait values for strategic adherence that reach medium values.*

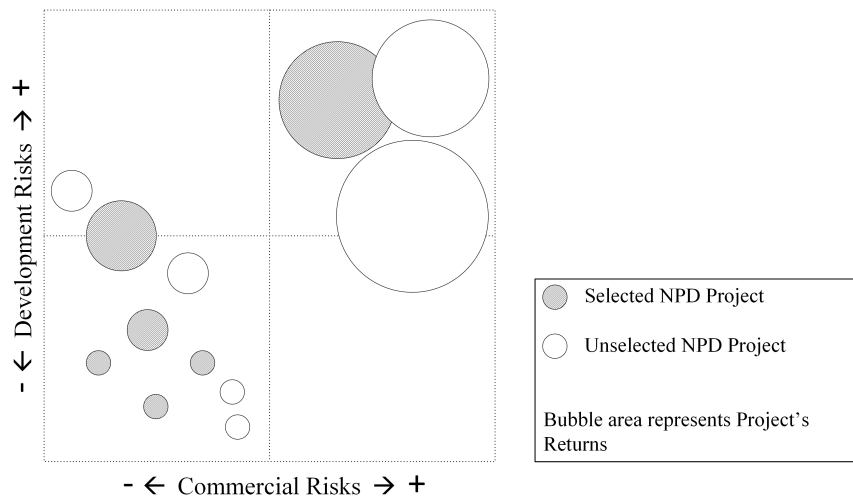


Figure 3.2: A schematic Balanced Portfolio

### 3.3.3 Proposition 3: The Effect of a Strategic Aligned Portfolio

Due to a synergy obtained from selecting interrelated NPD projects, Strategic Aligned portfolio's returns will be positive and with an order of magnitude similar to those returns obtained through the Value Maximized heuristic. Drawing from innovation field orientation literature (Salomo et al., 2008) we can anticipate that strategic aligned projects will benefit from a risk reduction due to a fit of projects with the organizational capabilities (Jemison, 1987). In addition, a more strategic aligned portfolio will not end up with higher values for portfolio

newness. This means that strategic portfolios will not have a predominance for radical or incremental projects. Figure 3.3 depicts such situation. Because of these reasons, we propose the following:

*Proposition 3a: The Strategic alignment heuristic will result in lower returns when compared to the Value Maximization heuristic, however, due to the effect of risk reduction for project synergies, the Strategic alignment heuristic will lead to higher returns when compared to the Balance heuristic.*

*Proposition 3b: Strategic aligned portfolios will consist of both incremental and more radical-like projects.*

*Proposition 3c: Strategic aligned portfolios will entail higher alignment with the corporate strategy and will favor a few exploration initiatives for future growth.*

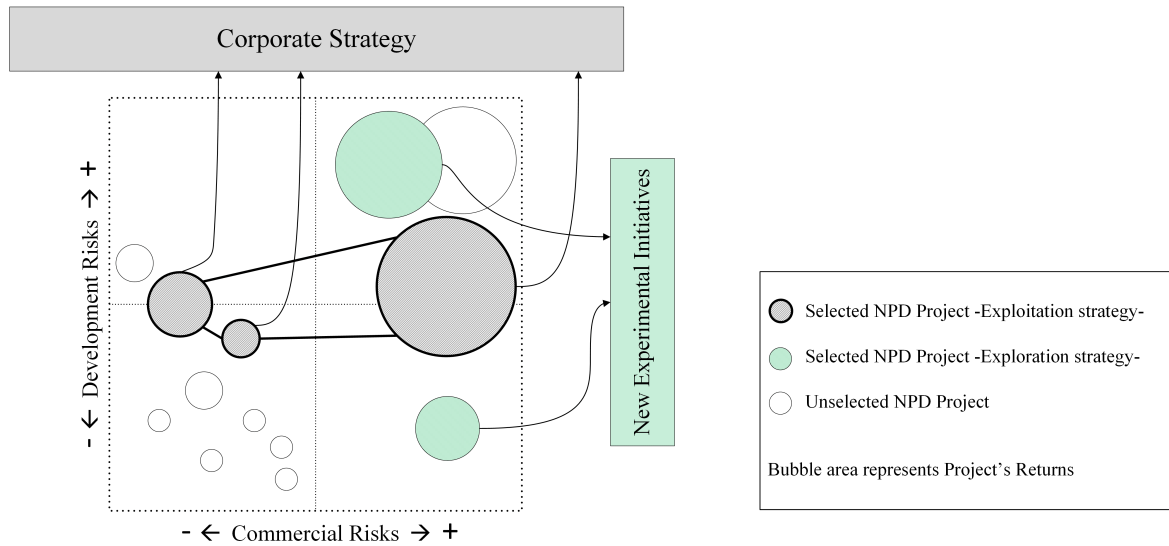


Figure 3.3: A schematic Strategic Aligned Portfolio

## Chapter 4

# Method

In order to test the previously stated propositions (Chapter 3) and to perform sensitivity analyses, an experimental setting that draws observations from a simulation model will be conducted. Some studies employ Organizational Simulation in order to run experiments and understand the mechanisms of R&D value creation (Bodner & Rouse, 2007) and to answer questions like whether it is more cost effective to mature technologies within the R&D system or within an acquisition program (Pennock & Rouse, 2008). Simulation models are also found in literature as a tool for optimizing portfolio allocation decisions in pharmaceutical R&D environments (Blau, Pekny, Varma & Bunch, 2004; Zapata, Varma & Reklaitis, 2008). Davis and colleagues state that simulation can provide superior insight into complex theoretical relationships among constructs, particularly in this context, in which challenging empirical data limitations exist, and when the theoretical focus is longitudinal, nonlinear, or processual (Davis, Eisenhardt & Bingham, 2007). In their study, they acknowledge the usual purpose of simulation in descriptive research and in explorations, though they argue for simulation as a proper method for theory development when simple theory exists. What they mean by simple theory, is the undeveloped theory that has only a few constructs and related propositions with modest empirical ground, and includes basic processes that may be known but that still have interactions that are only vaguely understood (Davis et al., 2007). Yet, simulation relies on some theoretical understanding of the phenomena under study, so a computational representation can be constructed, enabling further processes like verification and experimentation (Davis et al., 2007).

In addition, because of the nature of the portfolio management process, the following arguments add support to a potential use of a simulation approach for this study:

- The simulation model would allow to reproduce the three different decision making criteria that are considered in literature and practice to determine the new products portfolio success. This indicates that the interventions made by managers could be manipulated, otherwise not possible but in experimental settings, and perhaps with no reliable results. It creates a “computational laboratory” that allows researchers to experiment. Costs and time would definitely favor the use of a simulation model.
- The probabilistic nature of the portfolio management process, i.e. due to uncertainties, can be captured by a simulation model using probability distributions and stochastic processes. Many possible alternatives can be computed in a reasonable amount of time.



- Internal validity is achieved because of the computational rigor which demands a precise specification of constructs and assumptions (Davis et al., 2007).

Because of the aforementioned reasons and for the time limitations associated to this master thesis research, a simulation model that allows us to better understand portfolio decision making with the firm's consequences is considered the most suitable approach to fulfill the stated research objectives.

## 4.1 Choice of Simulation approach

There are different approaches to use when undertaking a simulation model study. The aim of this subsection is to provide arguments supporting why a stochastic process approach is the adequate one for fulfilling the research objectives. In Table 4.1 the five different simulation approaches proposed by Davis and colleagues are listed. In addition, Table 4.1 briefly explains the main characteristics of each approach as well as the kind of research it applies with more suitability.

Simulation Approach	Focus	Suitable for the research question
System dynamics	Focuses on how causal relationships among constructs can influence the behavior of a system (Sterman, 2000). Applicable for understanding the behavior of systems with complex causality and timing. It relies on deterministic differential equations (Davis et al., 2007). High levels of abstraction (Borshchev & Filippov, 2004)	No
NK fitness landscapes	A system is conceptualized as a set of N nodes and K interaction among the nodes. This approach focuses on how rapidly and effectively a modular system adapts to reach an optimal point, especially when interactions among the system components are crucial. It is associated with research questions that involve optimization, searching and problem solving. Less useful when uniqueness of nodes (e.g. in this case NPD projects) is a central interest.	No
Genetic Algorithms	Optimization approach with roots in biology. Focus on the adaptation of heterogeneous agents through evolutionary stochastic processes. Research questions are typically framed in terms of adaptation rates (e.g. learning) and whether a dominant form emerges.	No
Cellular automata	Mostly used in the physical sciences. Uses the concept of spatial relatedness which captures the degree to which agents influence each other.	No
Stochastic Processes	Flexible approach that enable researchers to custom design their simulations. Sources of stochasticity can be used in the form of stochastic distributions.	Yes

Table 4.1: Simulation approaches according to Davis et al. (2007)

Because of the non-deterministic nature of the process to be modeled, and for the compatibility with the research question, the stochastic processes simulation approach in the form of a Monte-Carlo simulation appears to be the most suitable one to carry out the research.

## 4.2 Model Description

The simulation model structure shown in Figure 4.1 corresponds to the main outline that will be used throughout this chapter to explain the model. The multistage approach used for building the model can be summarized in four major stages: projects creation, portfolio construction, portfolios execution and computation of value generated. In general, starting from an identical set of projects, portfolios will be built using different criteria. A parallel evaluation of the portfolios execution will be carried out and the value generated of each portfolio will be stored for further analysis. The process will be repeated for multiple times so sufficient observations will allow statistic analyses (See Algorithm 1 in Appendix A). The model was built in Matlab as this tool provides the computation power required, along with the use of the Financial and Statistics toolboxes. A detailed explanation will be now given for each stage of the model.

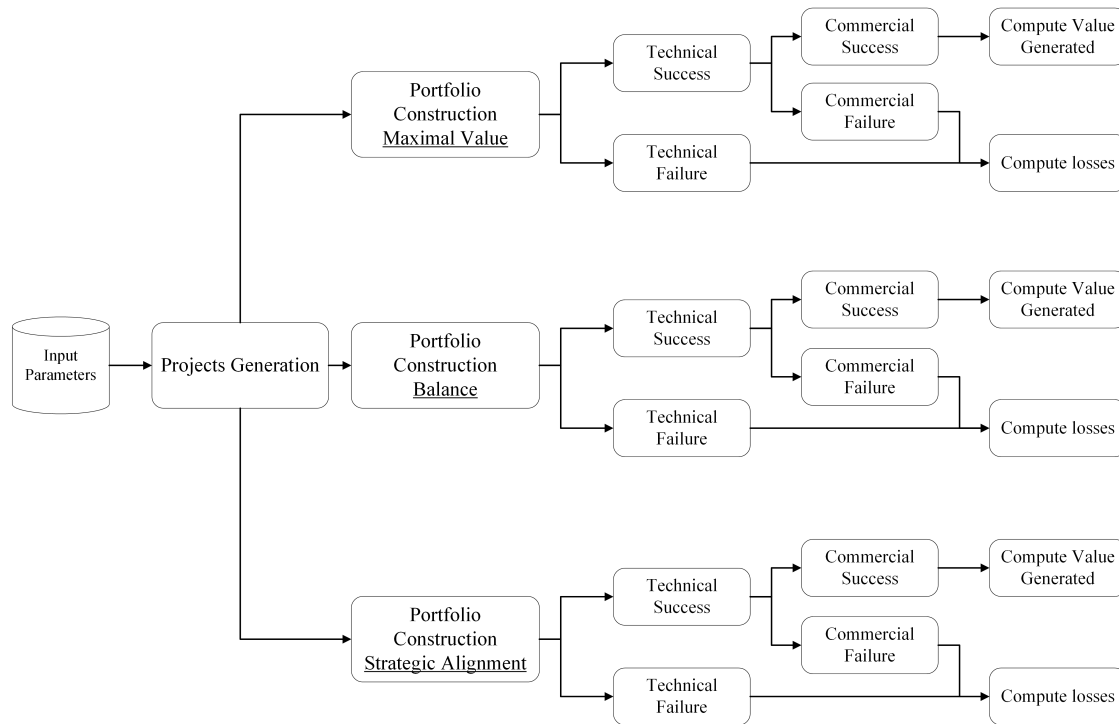


Figure 4.1: Simulation Model Outline

## 4.3 Projects Generation Stage

In this stage is where the model reads the input parameters and builds up a set of new product projects. The new created projects come along with a complete set of figures enough to build a “business case”. It is from these figures that projects can proceed to further evaluation. The parameter *Project Newness* constitutes the starting point of calculation for the rest of the projects’ attributes. In Table 4.2, each of the input parameters is explained, as well as the numeric values that they take.

Parameter	Explanation	Value
Newness Profile	States the probability whether a project is Incremental, New to the Firm or a Breakthrough. Values must sum up to 1.	Incremental = 0.7, New to the Firm = 0.2, Breakthrough = 0.1 (Barczak, Griffin & Kahn, 2009; Kleinschmidt & Cooper, 1991)
Number of Projects	Projects to be created for a simulation run.	Default value = 15. Max = 20 due to computation capacity.
Interest rate	Risk-free rate used to compute Discounted Cash Flows	Default value = .08
Development costs	A triangular probability distribution is set for each type of project, i.e. Incremental, New-to-Firm or Breakthrough with the form $tri[\min, \text{mostlikely}, \max]$	Incremental = $tri[65,70,100]$ New to the Firm = $tri[90,140,190]$ Breakthrough = $tri[180,360,650]$
Commercialization costs	Idem	Incremental = $tri[190,210,300]$ New to the Firm = $tri[260,420,530]$ Breakthrough = $tri[500,1100,2000]$
Expected net inflows	Idem	Incremental = $tri[300,350,525]$ New to the Firm = $tri[400,700,1050]$ Breakthrough = $tri[600,2500,3750]$
Technical Risks	A uniform probability that defines the range that technical failure probability takes. It is defined for each type of project, i.e. $U=[\min, \max]$	Incremental = $U[0,0.3]$ New to the Firm = $U[0.25,0.5]$ Breakthrough = $U[0.45,0.7]$
R&D Budget	Available budget for developing and commercializing a set of projects during a simulation run. Counts as a portion of the overall costs.	$0.65 \times \sum (\text{CommCosts} + \text{DevCosts})$
Commercialization Risks	Uniform probability distribution that determines the rate of failure of the commercialization stage when the development has been successful. Based on (Ajamian & Koen, 2002; Barczak et al., 2009; Castellion & Markham, 2013; Kleinschmidt & Cooper, 1991)	Incremental = $U[0,0.2]$ New to the Firm = $U[0.1,0.3]$ Breakthrough = $U[0.25,0.4]$
Development time	Development time in years for a type of project. Based on (Barczak et al., 2009).	Incremental = 0 New to the Firm = 1 Breakthrough = 3
Project Newness(recalculated)	Contribution value to the Portfolio Newness. Use expanded in Section 4.4.1.	Incremental = 1 New to the Firm = 3 Breakthrough = 7
Strategic Alignment Score	Extent to which the project fits the strategic goals of the firm (Kester et al., in press). This is an independent variable that has no relation with the rest of the project attributes.	$SAS = \begin{cases} 15 & \text{if } U[0,1] \leq 0.6 \\ 1 & \text{if } U[0,1] > 0.6 \end{cases}$
Budget shared for exploration	Percentage of the available budget to devote for future growth and exploration initiatives. The complement to 100% will be devoted to exploitative initiatives	20%
Risk Reduction Factor (RRF)	Extent to which the technical and commercialization risk can be reduced due to the synergy obtained after selecting a high aligned portfolio. It is determined by a Risk Reduction Coefficient (RRC) which states the maximum reduction value when all the projects selected are interrelated and strategically aligned.	$RRF = RRC * (2SPR - SPR^2)$ where, $RRC \in [0.05, .1, .15, 0.2]$ and $SPR = \frac{\text{AlignedProjects}}{\text{SelectedProjects}}$

Table 4.2: Model Input Parameters

Triangular distributions were found to be useful for costs and revenues attributes calculations. This type of distribution is typically used for simulations as the distribution of cost and revenues are not known for sure, but estimated “good” guesses can be made for the most likely values (Kleijnen & van Groenendaal, 1992). In the case of the *technical* and *commercialization risks*, as well as for the *project newness*, uniform distributions were used, basing the assumptions on literature where it was possible. With these initial parameters, a set of attributes is calculated for each project using Monte-Carlo evaluations of the *project newness* value (See Algorithm 2 in Appendix A). These attributes represent the information that portfolio managers have available when assessing new product projects.

## 4.4 Projects Evaluation and Portfolio construction

The following subsections contain the explanations of how projects are evaluated using the business case information available (i.e. attributes) and how the portfolios are built using the three different Heuristics: Value Maximized Portfolio, Balance Portfolio and Strategic Alignment Portfolio.

### 4.4.1 Measuring a Value Maximized Portfolio

Cooper and colleagues define maximization of value as the allocation of resources to maximize the overall value of the portfolio in terms of a main company objective, such as profitability, return on investment, brand value or likelihood of success. In general, maximal value is defined in terms of monetary value and determined by the presence of high impact projects on the portfolio (Cooper et al., 1998).

A prior way to operationalize the measure of maximal value portfolio was found in Kester (2011). In her study, Maximal portfolio value ( $\alpha = .78$ ) reflects the extent to which a firm’s composition will help them achieve their long-term growth and profitability goals. This scale has four items as follows: the extent to which the firm has high impact projects in the NPD portfolio; the extent to which the firm has maximized the return from their portfolio in the past; the extent to which the firm expects to maximize future profitability with the current NPD composition; and the extent to which the firm expects to maximize market sales growth with the current NPD portfolio composition (Kester, 2011).

From the different value generation metrics that are available, the discounted cash flow (e.g. Net Present Value) is the most utilized one as an accepted measure of the return of a NPD innovation project (Barczak et al., 2009; Blau et al., 2004; Liberatore, 1988). Cooper and colleagues suggest that in order to maximize the value of a portfolio, a rank ordering of the NPV (or other financial metric) and choosing the top projects until budget is consumed, will deliver such maximization (Cooper et al., 1998). Other authors differ from this view as they treat this project selection as a combinatorial optimization problem (Bodner & Rouse, 2007). In the latter approach, the project selection is done through the resolution of a knapsack problem, which selects a subset of the potential projects to maximize the value of the selected projects in such a way that it also meets a budget constraint on the cost of the selected projects (Sahni, 1975). The simple rank ordering of the projects suggested by Cooper might miss the fact that there is a better combination of projects, such that with the less amount of budget used, it can also deliver the highest NPV possible. For this reason, treating this

maximization as a knapsack problem is the approach to be used in the simulation model to find the portfolio that maximizes return, and further details are shown in Algorithm 3 in Appendix B. This approach was implemented in the model by using a dynamic programming code (Strandmark, 2009).

The following expression defines the maximization of a portfolio's NPV given the projects' costs and overall budget:

$$\max \sum_{i=1}^n \text{NPV}_i * x_i \quad \text{subject to} \quad \sum_{i=1}^n (\text{Costs}_i * x_i) \leq \text{Budget} \quad \text{where} \quad x_i \in [0, 1] \text{ and } n$$

refers to the number of projects and  $i$  refers to each project's index.

### The Newness Score and Strategic Score of a Portfolio

Once a portfolio is built (with any heuristic), two additional metrics will be calculated for further analysis. The project attributes *Project Newness* (recalculated) and *Strategic Alignment Score* are assigned in the first stage where the NPD projects are generated (see Section 4.3). After the portfolio is formed, a scalar dot product of the selected portfolio (which is a binary vector) and the project newness vector will result in the Newness Score of the portfolio.

In the case of the Strategic Alignment score, an adherence indicator will be calculated using the logic of Schaminée (2013). This metric reflects the extent to which certain portfolio is aligned with the budget breakdown between exploration and exploitation NPD projects. Values closer to 100 mean that the current portfolio expenses follow a desired explore/exploit proportion (Schaminée, 2013).

Figure 4.2 shows that for an example run with 15 projects, this heuristic chooses highly valuable and risky projects until the budget is consumed (left). As this heuristic is not influenced by any metric related to strategy, the plot on the right shows a low level of adherence when it comes to find an Explore/Exploit proportion.

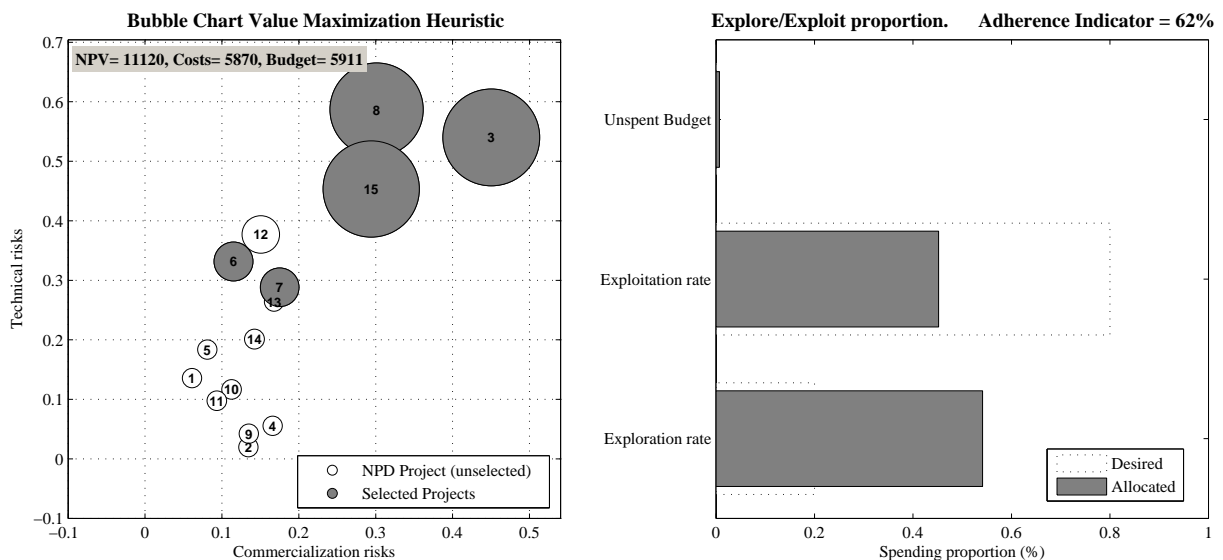


Figure 4.2: Single Simulation Run for 15 NPD projects -Value Max. Heuristic-

To conclude this subsection, it can be stated that this first heuristic finds the portfolio that maximizes returns of all possible portfolios. This first heuristic fulfills the guideline of the first dimension of success of NPD portfolios, i.e. Value Maximization (Cooper et al., 1998).

#### 4.4.2 Measuring a Balanced Portfolio

According to Cooper et al., a balanced NPD portfolio reflects an optimal spread in individual NPD project risk (Cooper et al., 1998). Following this definition and drawing from Modern Portfolio Theory, a balanced NPD portfolio can be understood as a combination of assets or NPD projects that all together have an appropriate risk/reward ratio.

Both Kester et al. and McNally et al. used similar scales inspired on the work of Cooper and colleagues. Those scales include questions as how the firm spreads the NPD projects in the following aspects: the number of projects the firm has in development compared to the available resources; the spread of NPD projects across the various stages in the development pipeline; the amount of incremental versus radical NPD projects; the extent to which the firm has mitigated their portfolio risk across different types of projects; and the extent to which the NPD projects in the portfolio are intended to serve growing versus mature markets (Kester et al., in press; McNally et al., 2013).

In order to operationalize the concept of portfolio balance for the simulation model, it is required to introduce the notion of the Mean-Variance Efficient Frontier and establish certain assumptions. As it was stated previously, Modern Portfolio Theory assumes that an investor is risk averse and in the trade-off risk/reward the investor will always prefer the less risky portfolio for a certain level of expected return. In this context, the proxy for risk is determined by the variance of the portfolio, which in some way is composed by the variance of every single project (Markowitz, 1952). The set of these efficient portfolios is what is known as the *efficient frontier*. In rigorous terms, the optimal portfolio structure can be defined as the quadratic optimization problem of finding the weights  $x_i$  that assure the least portfolio risk  $\sigma_\rho^2$  for an expected portfolio return of  $r_\rho = r^*$ , and reads as follows (Maringer, 2005):

$$\begin{aligned} \text{Min } \sigma_\rho^2 \quad \text{subject to} \quad & \sigma_\rho^2 = \sum_i \sum_j x_i \cdot x_j \cdot \sigma_{ij}, \quad r_\rho = r^* \text{ (a specified vector of returns),} \\ & r_\rho = \sum_i x_i \cdot r_i, \quad \text{and} \quad \sum_i x_i = 1 \quad \text{where} \quad x_i \in \mathfrak{R}_0^+ \forall i \end{aligned}$$

By definition, all the potential portfolios are placed either on the efficient frontier curve or underneath the curve. It is not possible to find portfolios above the frontier. As explained in Section 4.1, the value of newness determines the rest of the attribute values of the NPD projects in this model, and for higher levels of newness, the more variance for costs and for expected revenues, as well as for technical and commercialization risks. The same goes for the development time. To larger values of newness, the longer the development time. Because of this definition, it can be assumed that there is an implicit correlation of the newness value and risks, costs and time. This same assumption is used in the theoretical framework for new product development portfolio proposed by Chao and Kavadias (2008).

By using the efficient frontier concept, all the potential portfolios can be computed in a simulation run and it is possible find the return and risk value of each possible portfolio. From modern portfolio theory it can be argued that finding the *feasible* portfolio with the

highest return/risk ratio will guarantee the achievement of the best balanced portfolio, and because of the already stated assumptions, it can be expected that the found portfolio is not only balanced in terms of risk but also in newness and development time terms. In Figure 4.3 (upper-left), the number of potential portfolios is represented by the blue dots (determined by the possible combinations in a set of 15 NPD projects, i.e.  $2^{15} = 32768$  portfolios). The best risk-balanced portfolio (black star in Figure 4.3 upper-left) has to fulfill two conditions: first, it has to be feasible, i.e. the costs of incurring in such portfolio are lower than the available budget, and secondly, it must have the highest reward/risk ratio. Modern Portfolio Theory and its Mean-Variance Efficient Frontier concept is a powerful tool to operationalize the balance dimension of a portfolio and to reduce the subjective bias that is always present when assessing this dimension. Because of the use of this approach, the simulation model has to have a bounded number of projects to be analyzed. The number of potential portfolios is determined by the number of possible combinations of projects. This value is given by the expression  $2^n$ , where  $n$  is the number of NPD projects. Because of the exponential nature of this progression, the simulation model will only receive project sets no larger than 20 NPD projects. The Algorithm 4 in Appendix C expands on the details of this second heuristic.

In order to have a visual assessment of the balance of the obtained portfolio, a bubble chart and a efficient frontier curve in Figure 4.3 summarizes the selected portfolio using the above mentioned heuristic. Typically, portfolios found by the above explained algorithm include a combination of more valuable and riskier projects with a dose of more incremental-like projects (right in Figure 4.3). An important part of the budget remains still unspent and low levels of strategic adherence are achieved (lower-left in Figure 4.3). To conclude this subsection, the above explained method serves to calculate a balanced portfolio which constitutes the second heuristic for portfolio construction in this simulation model.

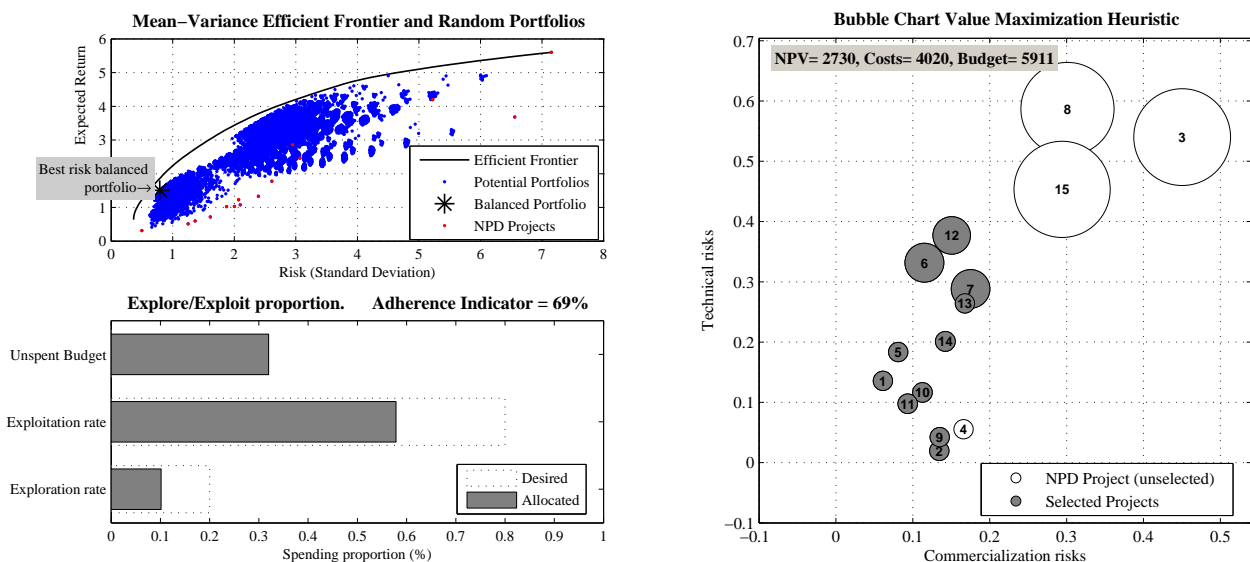


Figure 4.3: Single Simulation Run for 15 NPD projects -Balance Heuristic-

### 4.4.3 Measuring a Strategic Portfolio

Strategic alignment refers to the extent to which the NPD portfolio is in line with the strategic aspirations of the firm (Kester, 2011). Kester distinguishes three dimensions to measure how firms rate their portfolios in terms of strategic alignment: The extent to which the projects fit with specific markets or technology areas defined by the firm's business strategy; the extent to which the portfolio incorporates projects that contribute to achieving the firm's strategic goals; and the extent to which the portfolio resource allocation reflect the strategic priorities of the firm. In this last one, the priorities can be expressed as a breakdown of the R&D spending.

Another author, suggest that the strategic considerations to be evaluated in R&D project selection are the core competencies of the firm, the successor technologies, gap analysis and projects as options (Martino, 1995). In the Balance Scorecard approach, which is a strategic planning and management tool that measures organizational performance against strategic goals, four perspectives are used for such assessment, namely, financial performance, customer perspective, internal business processes and learning and growth (Kaplan & Norton, 1996). Liberatore and Englund et al. suggest the use of the Analytic Hierarchy Process as framework to breakdown the accomplishment of the strategic goals of the firm in different subcriteria by using a rigorous and consistent mathematical way. In particular, Englund et al. suggest the assessment of strategic alignment of a R&D project in criteria such as Customer Satisfaction, Employee Satisfaction, Business Value and Process Effectiveness (Englund & Graham, 1999). Liberatore proposes this breakdown into Manufacturing capabilities criteria, Technical (pertaining to R&D and Engineering) criteria, Marketing capabilities criteria and Financial criteria (Liberatore, 1988).

Other stream of research state that the strategic alignment should incorporate a measure of how the portfolio adds to the current strategic objectives, as well as how the portfolio opens new grounds for strategic growth. Such new grounds for growth contain by definition high levels of uncertainty. For instance, Smit and Trigeorgis propose the calculation of a financial term that includes the impact of both, volatility and managerial flexibility/adaptability in an uncertain environment. Such calculation is done by using a real options approach (Smit & Trigeorgis, 2006). Through the options lens, strategy is seen as a process of organizational resource-investments choices (or options), which makes that strategic change occurs when flexibility options are exercised, therefore, options form the choice mechanism that underlies strategy (Bowman & Hurry, 1993). Likewise, McMillan and McGrath propose the framework shown in Figure 2.5 in which projects are evaluated in terms of how new and risky they are against the firm's capabilities. More radical-like projects that are riskier in nature are evaluated using a real option approach and in such a way, a growth potential value is calculated. In general projects are categorized in two large groups, i.e. growth options and core enhancements and they claim that the real strategic choice is done when these proportions are defined. Projects only fight for resources against those projects within the same category. Therefore, a strategic portfolio is the one that has the highest adherence to the desired spending distribution (MacMillan & McGrath, 2002).

The exploration of new possibilities (which demands risk taking, experimentation, innovation and new knowledge acquisition), and the exploitation of old certainties (which demands refinement, efficiency, implementation, execution and existing knowledge improvement) and how to preserve the appropriate balance between them, is what is known in the organizational learning literature as the Exploration/Exploitation trade-off (March, 1991). Both exploration



and exploitation processes are essential for organizations and maintaining the right balance constitutes a primary factor in system survival and prosperity (March, 1991). Returns from exploration are systematically less certain and have limited visibility in the short run when compared to exploitation. Nevertheless, firms require explorative investments in order to increase their ability to adapt their strategy over time and avoid the so-called *success trap* (March, 1991). This stream of thinking is in line with the above mentioned R&D strategic management and the real option thinking as it also considers that new product portfolios must tackle to some extent the need to open new grounds for future growth, i.e. exploration initiatives.

In order to operationalize a clean and unidimensional measure of the strategic fit of a NPD project, a rather strong simplification should be made. *Project Strategic Alignment* is defined as the extent to which a certain project fits with the strategic criteria that firm’s managers have already agreed upon. The criteria that managers have agreed upon is an idea that will not be simulated in the model. Instead, what will be measured is the level of fit to that criteria and it will be mathematically tractable through an indicator called *adherence indicator* explained in Section 4.4.1. An independent random variable will reproduce this value and for projects whose strategic fit value is above certain cut-off value, they are declared as with low alignment. Likewise, projects under the cut-off value will be declared as projects with a relevant alignment with the actual core strategy and therefore these projects are interrelated. Moreover, based on the prescription of McMillan and McGrath, a strategic decision should be made upfront: what proportion of the available Budget is the firm willing to invest in Exploitation projects and what proportion in Explorative initiatives (shown in Table 4.2, a parameter defines this upfront decision). Next, projects with high alignment to the actual corporate strategy will be screened in terms of how much return they will bring and using a *knapsack* algorithm the best selection of these projects will be chosen until budget for exploitation is used. A similar process will be applied to the exploration initiatives using the respective budget. The Algorithm 5 in Appendix D explains how this is achieved.

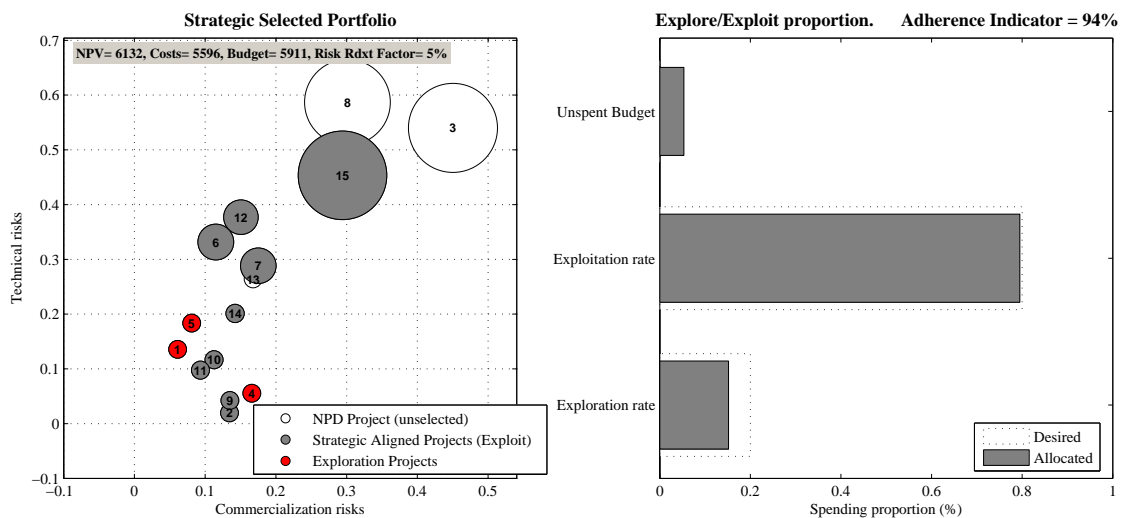


Figure 4.4: Single Simulation Run for 15 NPD projects -Strategic Alignment Heuristic-



## 4.5 Portfolios execution and Value Generation

Once projects are selected, projects must be developed and commercialized. Only until then, some value generation in the form of profits will be observed. Sales and profits are both short-term indicators of firm performance commonly used in firm-level studies of innovation whereas long term financial performance uses normally stocks returns and share prices (Kang & Montoya, 2014).

For the development and commercialization stages, defined probability distributions are the ones that determine whether a project is successful or not in the form of a typical Monte-Carlo simulation. In general, a multistage investment approach will be used, which means that only technically feasible projects proceed for further investment. Value generated (or return) will be the computation of the difference of how much was invested and how much was obtained as a net revenue for the executed portfolio. The detail of how these computations are done is shown in Algorithm 6 in Appendix E.

## 4.6 Summary of assumptions

The simulation model operates under several key assumptions that were mentioned throughout the model description. This section explicitly states these assumptions.

- Portfolio decisions are made under rational economic mechanisms in heuristics Value Maximization and Balance. The business case comparison determines whether a project is selected or not.
- The project newness will ultimately determine the risk, the costs, the development time and the benefits of a project. In general, newness is ascendent in risk, costs, time and expected incomes.
- All projects have complete information to build a business case. The project evaluation, portfolio construction and portfolio execution are done instantaneously.
- The R&D Budget is not constant for all simulation runs. Moreover, the budget is tied to the innovation costs and for the simulations, the Budget equals to 65% of the costs. There are no inflation effects.
- In the Balance heuristic, portfolio risk uses portfolio variance as proxy.
- A balanced portfolio is the one with the highest reward/risk ratio compared to all other possible portfolios.
- 60% of NPD projects are aligned to strategy, the rest are completely unaligned, there is no middle ground. The extent of this alignment is not considered in the model. A random variable represents this alignment, and it mimics a prior subjective judgment made by portfolio managers.
- The extent to which the portfolio is aligned to strategy is given by the adherence of the R&D spending to a certain predefined explore/exploit proportion.
- Aligned-to-strategy projects benefit from organizational capabilities and therefore will have a risk reduction. This notion is expanded in the next subsection.

- After portfolio building, there is no further intervention regarding project selection decisions. The portfolio is executed immediately.
- Costs and revenues are static. This means that during portfolio execution, projects realize the values stated in the business case with no additional variations.
- Competition and other externalities are not modeled. It is assumed that the variable Expected revenues incorporates the fluctuations of project revenues.

#### A note for Risk Management in the Strategic Alignment Heuristic

As explained in Section 2.5.3, by choosing related projects in terms of strategy, field orientation and capabilities, the firm can expect a risk reduction. This applies for projects aligned with strategy and it will be modeled by the following function with the behavior shown in Figure 4.6:

$$RRF = RRC * (2SPR - SPR^2) \text{ where, } RRC \in [0.05, .1, .15, 0.2] \text{ and } SPR = \frac{\text{AlignedProjects}}{\text{SelectedProjects}}$$

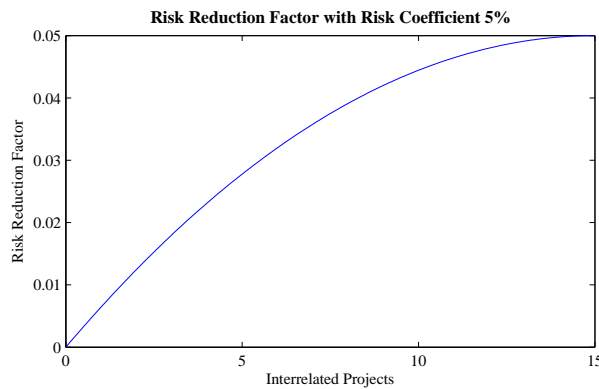


Figure 4.6: Quadratic Risk Reduction Function (15 NPD projects, RRC = 5%)

The RRC factor represents the maximum reduction factor expected when all selected projects are interrelated. It may take discrete values of 0.05, 0.1, 0.15 and 0.2 for experimentation purposes, but in general it is a continuous variable. SPR represents the ratio aligned/selected projects. The Risk Reduction Factor RRF is the calculation that expresses the risk reduction gained due to an observed alignment among projects. The effects of Risk Reduction are also incorporated in the Combined Heuristic.



# Chapter 5

## Results

This chapter will present the obtained results from the sensitivity analysis and group comparisons performed from the simulation outputs. First, a general remark of the experimental design will be mentioned. Secondly, a group comparisons will be performed for each heuristic and next an analysis of the results of the runs for each portfolio building heuristic are presented.

### Experiment 1

The first experiment will check the influence of having evaluated more or less NPD projects to build portfolios with each heuristic. A sensitivity analysis will be performed with a single factor: *number of projects*. The rest of the parameters will remain with static values: Risk reduction coefficient = 5%, Budget Proportion for Exploration = 20%, R/D Budget = 4500. Table 5.1 shows the configuration of this experiment along with the results. Each experiment will be simulated 530 times, which was calculated using the formula Standard Error of Mean =  $\sigma_{Return}/\sqrt{n}$  with an expected accuracy of 7% of the mean and confidence of 95%. For the sake of simplicity, this sensitivity evaluation will not consider the Combine Heuristic.

Heuristic	# of Projects		Returns			S.E.M. Mean
	Level	N	Mean	S.D.	S.E.M	
Value Maximization	8	530	698	1112	48	0.069
	11	530	1035	1317	57	0.055
	14	530	962	1287	56	0.058
	17	530	1024	1392	60	0.059
	19	530	1138	1456	63	0.056
Balance	8	530	636	540	23	0.037
	11	530	782	612	27	0.034
	14	530	909	697	30	0.033
	17	530	958	636	28	0.029
Strategic Alignment	19	530	983	599	26	0.026
	8	530	710	957	42	0.059
	11	530	872	1021	44	0.051
	14	530	1069	1120	49	0.046
	17	530	1090	1067	46	0.043
	19	530	1183	1189	52	0.044

Notes: S.E.M. = Standard Error of Mean

Table 5.1: First Experimental Design and Results (Factor: # of Projects)

## Experiment 2

Table 5.2 shows the second experimental design consisting of two factors and four levels (2x4 factorial design). The number of runs for each one of the 16 ( $4^2 = 16$ ) experiments was calculated using the same logic as in Experiment 1, with a Standard Error not exceeding 8% of the mean. Each experiment will be run with the initial parameter values explained in Table 4.2 in the previous chapter, however, the factors to be manipulated are shown in Table 5.2. The treatment variation in the factors will only have effect on the Strategic Alignment Heuristic.

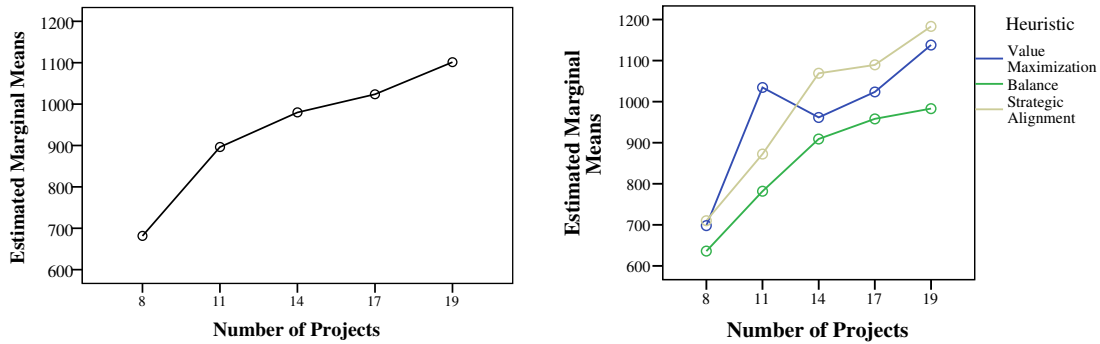
Heuristic	N	Factor 1	Factor 2	Returns		Newness		Strat. adherence		%Budget used		S.E.M. Mean
		Level	Level	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Value Maximization	5600	-	-	1695	2876	21	5	0.74	0.18	0.97	0.02	0.022
Balance	5600	-	-	893	898	13	6	0.6	0.24	0.7	0.28	0.013
Strategic Alignment	350	5%	10%	1596	2173	17	5	0.87	0.13	0.87	0.12	0.073
	350	5%	20%	1585	2236	18	5	0.90	0.10	0.90	0.10	0.075
	350	5%	30%	1565	2331	18	5	0.90	0.09	0.90	0.08	0.080
	350	5%	40%	1682	2428	18	5	0.91	0.07	0.91	0.07	0.077
	350	10%	10%	1670	2217	17	5	0.86	0.14	0.86	0.14	0.071
	350	10%	20%	1771	2332	18	5	0.89	0.11	0.89	0.10	0.070
	350	10%	30%	1773	2471	18	5	0.92	0.07	0.92	0.06	0.074
	350	10%	40%	1640	2319	18	4	0.91	0.07	0.92	0.06	0.076
	350	15%	10%	1453	2104	17	5	0.87	0.14	0.86	0.14	0.077
	350	15%	20%	1776	2053	18	5	0.89	0.11	0.89	0.10	0.062
	350	15%	30%	1889	2441	18	5	0.91	0.08	0.91	0.07	0.069
	350	15%	40%	2109	2497	18	5	0.91	0.07	0.91	0.06	0.063
	350	20%	10%	1963	2345	17	5	0.87	0.13	0.87	0.12	0.064
	350	20%	20%	2025	2480	18	5	0.90	0.09	0.90	0.08	0.065
	350	20%	30%	1869	2341	18	5	0.90	0.07	0.91	0.07	0.067
	350	20%	40%	1924	2502	18	4	0.91	0.08	0.91	0.07	0.070

Notes: Factor 1 = Risk Reduction Coefficient; Factor 2 = % of Exploration;  $\frac{S.E.M.}{Mean}$  calculated for *Returns*

Table 5.2: Second Experimental Design and Results

## 5.1 Influence of Number of Projects under Evaluation

The number of projects under evaluation shows a significant variation on the value generated by the portfolios  $F(4, 7935) = 37.658, p < .01$  (Figure 5.1a). When observed differentiated by Heuristic, the interaction effect is significant ( $F(8, 7935) = 1.694, p < .1$ ) which means that the difference exists in the returns when evaluated per Heuristic (Figure 5.1b). The returns are ascendent with the number of projects under evaluation more notably for the Strategic Alignment Heuristic, even when the budget boundary is static. For the sake of simplicity, these results do not include the Combined Heuristic.

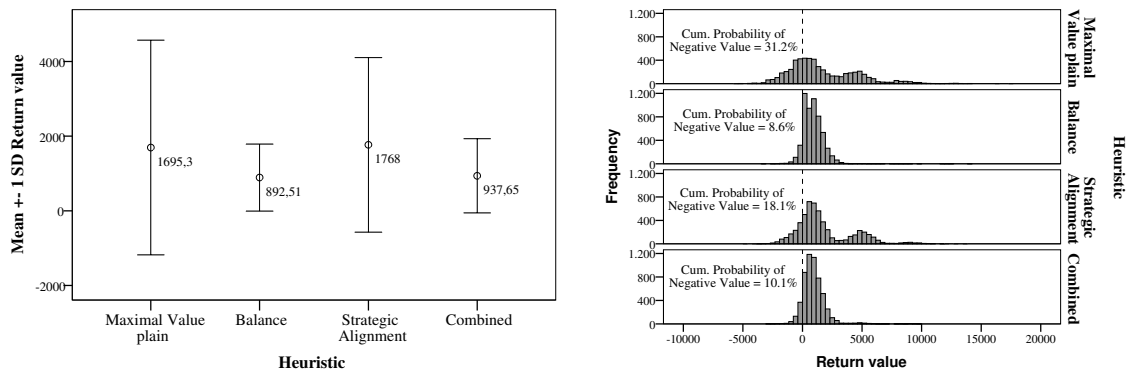


(a) Number of Projects (b) Interaction #Projects X Heuristic

Figure 5.1: Sensitivity analysis: Number of Projects on Portfolio Returns

## 5.2 Difference among Heuristics

In an effort to simulate the three dimensions of success in the more contrasting way possible, the first exploration of the results will address the difference in the value generation in the form of returns that result of each heuristic application. In general, the application of each heuristic will end up with significant differences among the three groups when it comes to portfolio returns  $F(3, 6580) = 188.7, p < .001$ . Figure 5.2a shows the difference of the four different returns confirming in this model that each heuristic will produce diverse results. Not only returns vary for each heuristic. Figure 5.2b shows the frequency dispersion of returns along the four heuristics under study. It is clear how a wider dispersion is present in the maximal value and strategic alignment heuristics. These results give partial support to propositions  $P_{1a}$  (value maximization will bring highest but unstable returns) and  $P_{3a}$  (strategic alignment will bring intermediate returns). Proposition  $P_{2a}$  is fully supported as balance obtains the lowest and more stable returns.



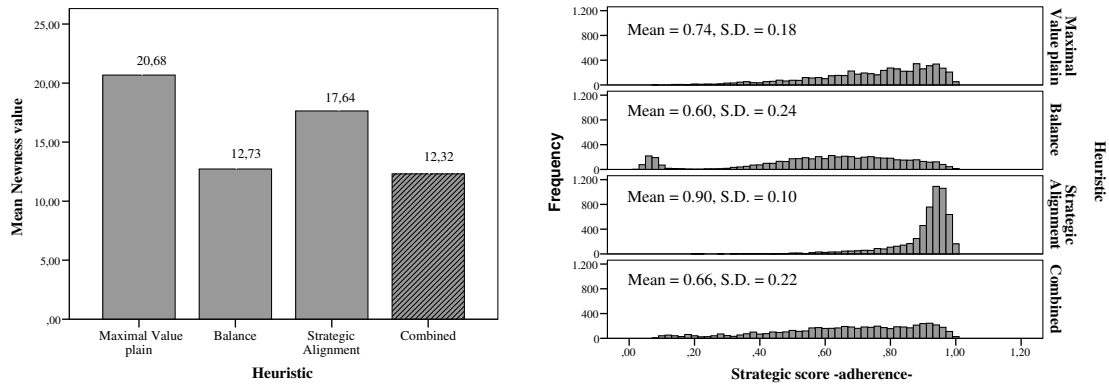
(a) Obtained returns per Heuristic (b) Frequency Distribution (Returns)

Figure 5.2: Difference among groups -Returns-

Significant differences are also found among the groups when the other two metrics are evaluated: Portfolio Newness and the Portfolio Strategic Score. Significant differences in the case of Portfolio Newness  $F(3, 6987) = 2168.6, p < .001$  suggest that each heuristic will form



portfolios with different values of newness as shown in Figure 5.3a. Significant differences in the case of the Strategic Score are also found  $F(3, 6611) = 2209.3, p < .001$  and each heuristic will result in diverse values for strategic adherence (Figure 5.3b). From these results, proposition  $P_{3b}$  stating that strategic portfolios will be formed from radical and incremental projects, can be accepted. Likewise, proposition  $P_{3c}$  can be supported as strategic portfolios lead to the highest and stable strategic adherence score. On the contrary, proposition  $P_{2c}$  is rejected since balanced portfolios do not end with medium strategic adherence scores but with the lowest.



(a) Effect on Newness

(b) Effect on Strategic Alignment Score

Figure 5.3: Effects of each Heuristic on Newness and Strategic Score

### A note on Portfolio Budget Utilization

An additional post-hoc variable was measured. Portfolio Budget Utilization measures the proportion of money that is invested over the total R&D Budget available. The values obtained are: Value Maximization = 97%, S.D. = 2%; Balance = 70%, S.D. = 28%; Strategic Alignment = 90%, S.D. = 10%; Combined = 67%, S.D. = 21%. Figure 5.4 shows the distribution of this variable.

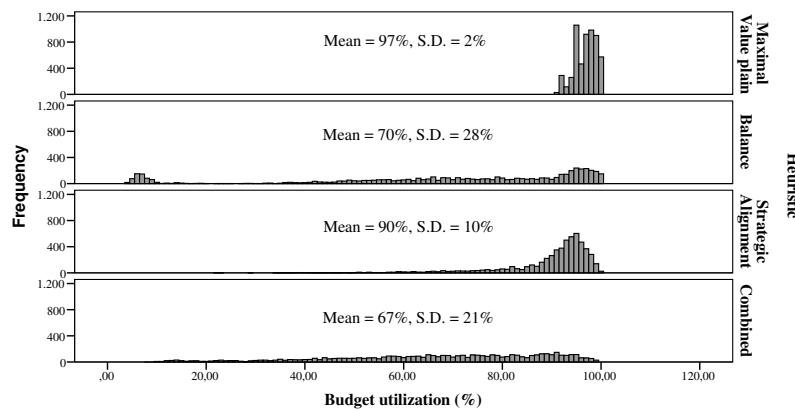


Figure 5.4: Distribution of Portfolio Budget Utilization

### 5.3 Effects of a Value Maximization Portfolio

As explained above, the Value Maximization heuristic intends to find the highest returns possible. As risks and strategy are not a proxy for optimization, this heuristic tends to be very disperse as shown in Figure 5.2b.

Measure	Mean	S.D.	Correlations			
			1.	2.	3.	4.
1. Portfolio Returns (VM Heuristic)	1695.31	2876.1	1			
2. Portfolio Newness	20.68	4.74	.18**	1		
3. Portfolio Strategic adherence	.74	.18	-.01	-.04**	1	
4. Portfolio Budget Utilization	.975	.019	.08**	.36**	-.01	1

Notes: \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

Table 5.3: Descriptive statistics for the Value Maximization Heuristic

Because return is ascendent in project newness, the heuristic will try to systematically choose more radical-like projects. Accordingly, correlations shown in Table 5.3 suggest this effect as a positive correlation is found between portfolio newness and portfolio returns ( $r = .18$ ,  $p < .01$ ), lending support to proposition  $P_{1b}$ . A very weak positive correlation is found between Portfolio Budget Utilization and Portfolio Returns ( $r = .08$ ,  $p < .01$ ) and no significant relation with Portfolio Newness. Finally, a Value Maximized portfolio does not necessarily mean a more strategic aligned portfolio, effect corroborated by weak or insignificant correlations between Portfolio Strategic adherence and the rest of the variables, which lends support to proposition  $P_{1c}$ .

### 5.4 Effects of a Balanced Portfolio

Balance Portfolio metrics show higher values of significant correlation. Table 5.4's results show that portfolios' returns are ascendent with portfolio newness ( $r = .36$ ), portfolio strategic adherence ( $r = .16$ ) and portfolio budget utilization ( $r = .16$ , all  $p < .01$ ). Furthermore, obtaining higher levels of strategic alignment is associated to more radical-like portfolios ( $r = .52$ ,  $p < .01$ ) and to higher levels of budget spending ( $r = .91$ ,  $p < .01$ ). The direction of the correlation coefficients is as expected.

Measure	Mean	S.D.	Correlations			
			1.	2.	3.	4.
1. Portfolio Returns (Balance Heuristic)	892.51	897.54	1			
2. Portfolio Newness	12.73	5.59	.36**	1		
3. Portfolio Strategic adherence	.60	.24	.16**	.52**	1	
4. Portfolio Budget Utilization	.70	.28	.16**	.52**	.91**	1

Notes: \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

Table 5.4: Descriptive statistics for the Balance Heuristic

The logic of Modern Portfolio Theory states that to higher levels of risk, the higher the expected returns. For each portfolio selected in the Balance Heuristic, a value of risk and expected return is shown in Figure 5.5 in blue. Once the portfolio is executed, i.e. developed and commercialized, a value of actual return is shown in Figure 5.5 in green. As portfolios have been selected using the  $\max(\text{reward}/\text{risk})$  proxy, the scatter plot depicts the almost perfect linear relation between expected return and risk. On the other hand, when the actual outcome is measured, there is a departure from the linear relation. Once executed, balanced portfolios can still bring lower returns than expected, and a systematic behavior of the algorithm is to throw low risk portfolios and just a few radical-like portfolio initiatives. Because of the predominance of incremental projects, proposition  $P_{2b}$  is not supported. In addition, this predominance can also explain the higher values for correlations in the balanced portfolio (see Table 5.4). As incremental projects have a smaller variance when compared to more radical-like projects, this makes that the the size of the correlation coefficients are higher than expected due to a large number of observations. This fact however does not change the interpretation of the results.

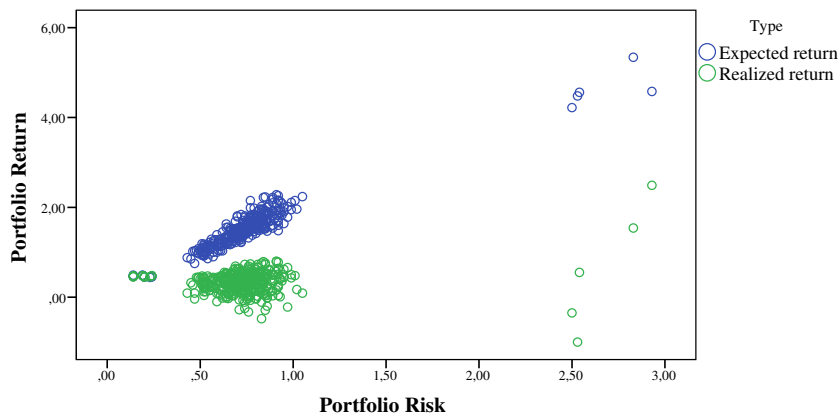


Figure 5.5: Scatter: Portfolio Risk vs. Returns

## 5.5 Effects of a Strategic Portfolio

Strategic alignment positively relates to the value of returns as a weak significant effect is found in this relationship ( $r = .12$ ,  $p < .01$ ). As in the other two heuristics, newness is ascendent with portfolio returns ( $r = .27$ ,  $p < .01$ ). In addition, the more the budget is fully spent, the higher values of strategic adherence are to be obtained ( $r = .45$ ,  $p < .01$ ). The extent to which the firm commits to higher budget share for exploration initiatives, i.e. Exploration rate, does not seem to drive to higher or lower expected returns, whereas the effect of being able to reduce risk due to the selection of strategically aligned projects has a positive but rather small correlation with portfolio returns ( $r = .04$ ,  $p < .01$ ). Despite the small size of this effect, this lends support to proposition  $P_{3a}$ .

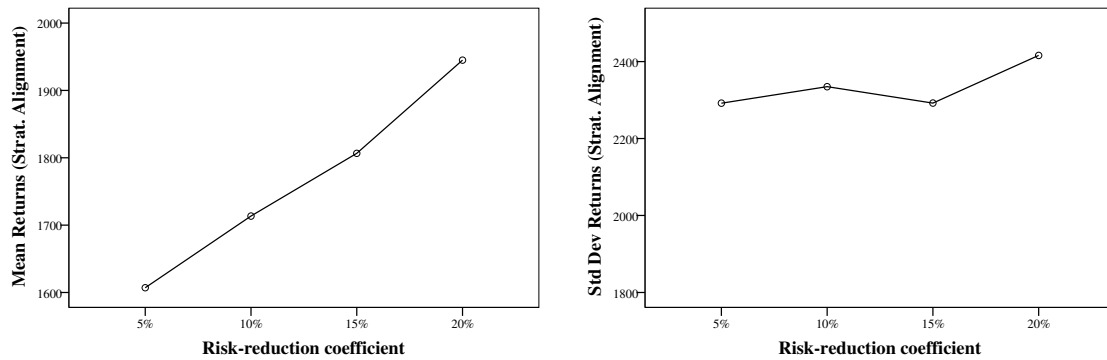
After performing an ANOVA mean comparison, it was found that the Exploration rate does not have an effect on return ( $F(3, 5563) = 1.28$ ,  $p = .278$ ), which is in line with the

Measure	Mean	S.D.	Correlations						
			1.	2.	3.	4.	5.	6.	
1. Portfolio Returns (Strat. Alingmt. Heuristic)	1768	2334	1						
2. Portfolio Newness	17.64	4.82	.27**	1					
3. Portfolio Strategic adherence	.89	.10	.12**	.45**	1				
4. Portfolio Budget Utilization	.90	.10	.12**	.45**	.99**	1			
5. Exploration rate	.25	.11	.02	.09**	.15**	.18**	1		
6. Risk reduction factor	.11	.05	.04**	-.03*	-.02	-.02	-.14**	1	

Notes: \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$

Table 5.5: Descriptive statistics for the Strategic Alignment Heuristic

correlation score discussed above. On the other hand, the Risk-reduction coefficient does have an effect on Portfolio Returns ( $F(3, 5585) = 5.287, p < .01$ ). This effect is visually evident in Figure 5.6a along with the standard deviation in Figure 5.6b. This also provides support to confirm proposition  $P_{3a}$ . To finalize, a potential interaction effect between Exploration rate and Risk-reduction coefficient was not found.



(a) Risk-reduction on Returns (Mean)

(b) Risk-reduction on Returns (Std. Dev)

Figure 5.6: Sensitivity analysis: Risk-reduction factor on Returns

## 5.6 Testing the Propositions

After evaluating the results, a qualitative assessment should be made to test the propositions. In general, what is expected to be found is shown by the simulation results. It is positive that the crafted heuristics were able to show contrasting results so conclusions are drawn with more certainty, and it is possible to see how each heuristic departs from each other in the metrics that were computed. Table 5.6 expands on each proposition test and provides the arguments to prove or disprove each item. Since the simulation model is assumption-driven, causal statements should not be made, however, because of the strong base on literature for parameters refining and because of the accepted theories used for building the algorithms, internal validity can be assured. Nevertheless, conclusions must be drawn with special precaution.

	Proposition	Argument	Confirmed
$P_{1a}$	Value Maximized portfolios will deliver the highest return possible. Due to higher risks involved, returns will tend to be unstable	Value Maximized portfolios will choose the highest DCF portfolios in the planning phase, however, after execution, highest returns are obtained by a different portfolio, i.e. Strategic (see Figure 5.2). Results are highly unstable when compared to other heuristics (Mean = 1695, S.D. = 2876)	Partial
$P_{1b}$	Value Maximized portfolios will have a tendency to favor the selection of more radical-like projects	Clear tendency to favor radical-like projects, i.e. newness score Mean = 21, S.D. = 5.	Yes
$P_{1c}$	Value Maximized portfolios will have no specific tendency to favor or disfavor strategic meaningful projects	Value maximized portfolios do not have a specific tendency to favor portfolios with larger levels of strategic adherence (Mean = 0.74, S.D. 0.18 and Figure 5.3b upper)	Yes
$P_{2a}$	Balanced portfolios will deliver lower levels of return when compared to Value Maximized portfolios, though the selected set of projects will form a portfolio with lower levels of variability (i.e. risks) which constitutes a surer investment bet	Balanced portfolios are the portfolios with the lowest return gained and with the lowest variability (Mean = 893, S.D. = 898 and Figure 5.2a)	Yes
$P_{2b}$	Balanced portfolios will consist of both incremental and more radical-like projects	There is a combination of incremental and new-to-the-firm projects, with a concentration on incremental ones and hardly ever radical projects are chosen (Newness score = 12.7, S.D. = 6. Visually in Figure 5.3a and 5.5)	No
$P_{2c}$	Balanced portfolios will not entail higher or lower levels of portfolio strategic value, nonetheless, these portfolios will portrait values for strategic adherence that reach medium values	There is no mechanism that establishes pursuing a strategy in the Balance heuristic; only the project variability, covariance and the proxy reward/risk are entered in the computation, therefore, strategy does not drive balance. In addition, the strategic adherence is the lowest (Mean = 0.6, S.D. = 0.24). See Figure 5.3b for Balance	No
$P_{3a}$	The Strategic alignment heuristic will result in lower returns when compared to the Value Maximization heuristic, however, due to the effect of risk reduction for project synergies, the Strategic alignment heuristic will lead to higher returns when compared to the Balance heuristic	Planned NPV values for this portfolio are lower than the Value Maximized portfolios, however, the values obtained after portfolio execution are the highest, due mainly by two factors: the use of an optimization logic and the risk reduction effect.	Partial
$P_{3b}$	Strategic aligned portfolios will consist of both incremental and more radical-like projects	Results from the portfolio newness score for this portfolio suggest that there is a combination of radical and incremental projects (Mean = 17.6, S.D. = 4.8). Newness score is 39% larger than balance's newness and -15% than value maximization's newness	Yes
$P_{3c}$	Strategic aligned portfolios will entail higher alignment with the corporate strategy and will favor a few exploration initiatives for future growth	This portfolio leads to the largest value of strategic adherence (Mean = 0.9, S.D. = 0.1) and therefore it favors the predefined quota of exploration projects enabling future growth	Yes

Table 5.6: Testing the Propositions

## Chapter 6

# Discussion and Managerial Implications

In order to open the Discussion chapter, the research question postulated in the Section 3.2 will be recalled. This will serve to initiate the discussion of the findings provided in the previous chapter (Chapter 5) while giving an answer to the research question.

### 6.1 Recall of the research question

After stating the managerial problem and motivations for conducting this study, Section 3.2 introduces the research question:

*What are the effects of the portfolio dimensions of success in the value creation of the firm?*

In order to find an answer to this question, three sub-questions were stated with the purpose to guide the research approach. The first question was intended to lead the literature review in the vast field of portfolio management decision-making. The second question had as purpose to narrow down the literature search in order to find specific input that served to reproduce the dimensions of success in a simulation model. The third question was intended to frame the data analysis from the simulation model outcome. What concerns the general research question is the topic developed in the following sections in the form of a discussion of the results obtained from the experiments and sensitivity analyzes.

### 6.2 Discussion

Does “good” portfolio management lead to realized value? Menke (2013) posed this question as there was no evidence of how “good” portfolio management will generate positive bottom line results for the firms. In his study, a large scale benchmarking survey in portfolio management, the top best-practice used by companies found was: *to pursue the three overarching objectives in the portfolio management process: strategic alignment, strategic balance, and return maximization* (Menke, 2013). So “good” portfolio management entails the notion of using these three goals. The results of this master thesis provide support to the assumption that good portfolio management does generate value. Because of the research perspective of this study, the three overarching goals have been analyzed individually, however, in practice

they are used simultaneously with the diversity of methods and tools available (Cooper et al., 1998; Menke, 2013). Our approach allows us to better understand the underlying mechanisms present in each heuristic. The starting point was to confirm whether the end results of each heuristic were contrasting between each other, and our results suggest that in fact they are. In the rest of this section, the results of each type of portfolio will be discussed.

### **The Value Maximization Portfolio**

The value maximization heuristic is the one that with the least information input is still able to throw top returns. This is not a surprise. Many portfolio management studies tackle the challenge of project selection from an operations research perspective in which the Discounted Cash Flows are optimized (Chao et al., 2009) and likewise did our algorithm. However, results are not entirely promising for this heuristic. Only maximizing value does not necessarily mean neither that there will always be positive results nor that the portfolio will position the firm in a competitive position, for today and for the future. For instance, according to our results, there is a chance of obtaining negative returns of almost 1/3 (31%) and the dispersion is the highest among the heuristics (Mean 1695, S.D. 2876), which makes it a risky bet. This heuristic does not provide either an acceptable value of strategic adherence (74%) which means that even for such risky bets, the company will hardly guarantee a strategic competitive position for today and for the future. The term myopic applies to this heuristic: not everything is about the money and indeed, portfolio management is about making smart decisions in a multidimensional context. Cooper and other studies have found that most of the companies overemphasizing on methods that only favor the financial maximization dimension were linked to poorer firm performance (Cooper et al., 1998; Killen et al., 2008), even though it is considered by managers as the most relevant criteria for choosing projects. “A focus on value maximization is simply the price of entry but does not differentiate the portfolio in a meaningful and profitable way” (McNally et al., 2013, p. 257).

### **The Balanced Portfolio**

“If a firm’s NPD portfolio is not appropriately balanced, it may be difficult to achieve strategic and financial portfolio objectives” (Kester et al., in press, p. 24), however, our results suggest the opposite. Finding a strict balance will make that mostly positive returns are usually obtained (92% of the evaluations are  $> 0$ ), but the average of the returns are as low as the half of what is normally obtained using the value maximization and strategic alignment heuristic. In addition, as the efficient frontier approach omits the proxy related to strategic alignment, results suggest that a balanced portfolio will not position the firm in a competitive position neither for the present nor the future. At this specific point it has to be acknowledged that the balance dimension includes balancing sub-dimensions as risk, time-to-market, newness and market segments, whereas our model only includes the risk perspective and time-to-market and newness were assumed by correlation and by suggestion of other author (Meskendahl, 2010). So balance remains as a sure bet if the firm is flexible enough to tackle incremental initiatives that are unrelated to its organizational capabilities.

When confronted to what was postulated in Proposition  $P_{2c}$  (balance portfolios will reach medium strategic adherence), results indicated the opposite. A reason for this is that the heuristic does not have any mechanism other than finding the max(reward/risk) value which makes that attributes as strategic alignment are omitted. Regarding portfolio newness, still

a better portfolio newness spread could be expected, however only incremental initiatives get closer to this max(reward/risk) value. Moving towards the risky side (right side of the efficient frontier curve) searching for higher returns will not outweigh the risks that are required to take. This makes that only incremental in nature portfolios are selected, which brings an explanation for not supporting  $P_{2b}$ .

One characteristic of this heuristic is the fact that it has the lowest score of budget utilization (70%, S.D. = 28%), which means that almost 1/3 of the R%D Budget remains safe. It is up to the firm's policies to establish how to interpret such situation, but common sense would tell that this is a desired condition in case of austerity. The fact that an agile firm can rapidly free-up resources in the portfolio constitutes a contribution to achieve NPD portfolio balance (Kester et al., in press). McNally et al. suggest that only balance matters in the link NPD portfolios-firm performance, as balance "not only enhances firm performance, but also decreases risk by improving the financial value of radical innovations while reducing the likelihood of firm failure" (McNally et al., 2013, p. 256). This last statement is analogical to the main premise of Modern Portfolio Theory that underpins the algorithm in the balance heuristic: a collection of assets can face lower overall risk than either individually, as diversification lowers risk even if assets' returns are not negatively correlated (Markowitz, 1952), yet the conclusion is not the same. In one hand, it is arguable the way a balanced portfolio is selected under the efficient frontier, and our reasoning was that the best portfolio is the one that has the maximum reward/risk ratio, as suggested by Cooper et al. (1998). This might not be what other authors understand by balance. For instance, Graves and colleagues look for portfolios under the efficient-frontier assuming that a risk-averse decision maker will require that any increase in risk is at least offset by an increase in return, and by using unitary comparisons, the best balanced portfolio would be the one that decreases the least in terms of returns vs. the decrease in risk, against the competing portfolios (Graves, Ringuest & Case, 2000). Post-hoc analysis using this reasoning were performed, and results suggest that returns would be still less than the value maximization heuristic and still with the same variability observed in the value maximization heuristic, which means that Graves et al.'s approach is a risky bet. On the other hand, it has to be acknowledged that balance is a subjective concept and our operationalization is strict (i.e. max(reward/risk), which ultimately results in either, outstanding portfolios with high returns, or acceptable returns with the lowest risk. The latter situation is the one that persist in our simulation results (Figure 5.5). However, what is found in practice is that this strict notion of balance is not used. Managers spread risk and allocations in a subjective way, according to their risk-profile level. A risk-taker innovative firm might consider a balanced portfolio as the one that favors radical innovation and compensates risk with some incremental initiatives. Because of the rational approach of the simulation model, this last situation is not comprised in how we understood balance and how we made it tractable in the model, and perhaps it constitutes a signal of why NPD portfolio decision-making is not entirely a rational activity as it also includes subjective judgment, intuition and politics (Christensen, 2003; Christiansen & Varnes, 2008; Hart et al., 2003; Kester, 2011; Yahaya & Abu-Bakar, 2007). Managers perception of the importance of portfolio balance is linked to best-performing firms (McNally et al., 2013).

### **The Strategic Aligned Portfolio**

Christensen states that there are two different descriptive models to understand how resources are allocated. A first, rational, top-down decision-making process in which senior managers



weight alternative proposals for investment in innovation, and those projects who fit strategy and yield enough profit, are then selected for resource allocation. The second descriptive model of resource allocation states that innovation proposals are generated from deep within the organization and not from the top. The middle managers play a “critical but invisible role in screening these projects [...], and work to package the proposals for their chosen projects in ways geared to win senior management approval” (Christensen, 2003, p. 94-95). Perhaps, the heuristic that best embodies the first rational top-down approach described by Christensen is the strategic alignment heuristic, which is the result of a stepwise evaluation: first choose the good aligned projects, then from this set choose the most profitable, just as said by Christensen, and this means that a value maximization is incorporated in the second step. The implications of this result is that strategic alignment shall not be understood solely as a capability-friendly project seeking dimension, as strategic choices must also be profitable and generate value. The same is observed in the real options literature in which a call option value is computed to decide upon strategic choices (MacMillan & McGrath, 2002; McGrath & MacMillan, 2009; Smit & Trigeorgis, 2006). Despite the efforts to keep the strategic alignment heuristic as separated as possible from the other heuristics, strategic project selection must include an economic value assessment and therefore it results in better overall marks for returns. For instance, this heuristic scores the highest for portfolio return and strategic adherence, and it accounts for the consequences of allocating resources in endeavors where current capabilities fulfill the innovation challenges. Because there is always room for exploration initiatives, which entails a risk-taker behavior, there are 82% of chances of obtaining positive value, much better than the 69% chances of using the value maximization heuristic but still lower when using the constrained balance heuristic, i.e. 92%. Because strategic portfolios are composed of interrelated NPD projects, a risk reduction effect is observed and therefore a boost in portfolio returns is gained (Figure 5.6b), which makes that this portfolio shows the best results in portfolio returns (Mean 1768, S.D. 2337). Better returns were expected from this heuristic when compared to the balance heuristic, but Proposition  $P_{3a}$  did not posit a better result when compared to the Value Maximization heuristic. The boost due to risk-reduction is what explains the partial acceptance of Proposition  $P_{3a}$  as initially this heuristic does not bring the highest expected returns, but only when is executed it overpasses the Value Maximization heuristic.

Despite the fact that giving more room to exploration initiatives shows an increment in portfolio returns (Figure 5.6a), the effect of the variation on the Explore/Exploit proportion resulted in no significant effects on portfolio returns. It is true that in giving more room to exploration, the algorithm would choose better combinations for strategically-unrelated projects and therefore, a slightly positive behavior is shown. However, the model does not include external factors as environmental complexity and environmental instability (Chao & Kavadias, 2008), or environmental dynamism and environmental competitiveness (Walrave, van Oorschot & Romme, 2011). These externalities are known in literature to influence the effect on value creation according to different proportions between radical/incremental and the exploration/exploitation proportion.

Despite the importance and good results shown by strategic portfolios, this dimension is not perceived by all managers as relevant (Cooper et al., 1998) and may constrain innovative choices (McNally et al., 2013). Barczak et al. found that in practice 74% of managers have a specific new product strategy to guide portfolio decisions (86% the best, 69% the rest) (Barczak et al., 2009).

**General remarks to discuss**

Killen et al. found some evidence in Australian firms that strategic project selection methods (e.g. strategic buckets) and portfolio mapping methods (e.g. bubble diagrams) are correlated to better alignment with business strategy and with better balance in portfolios respectively. Regarding financial methods there was no evidence of firms resulting with higher value projects in the portfolio (Killen et al., 2008). Our results are consistent with this study. The solely condition of maximizing returns is itself too risky and myopic, and should be incorporated with the other dimensions in order to obtain better results. Furthermore, the strategic alignment heuristic is more sensitive to obtain more valuable portfolios when more NPD projects are under evaluation (Figure 5.1b) due to the benefits of linking more related projects together which increases synergy and better use of resources and subsequently a risk reduction.

Throughout the Results and Discussion chapters it has become evident the trade-offs that are present when evaluating portfolios. Each type of portfolio/heuristic brings about benefits in different aspects. Table 6.1 summarizes these aspects and the portfolio/heuristic that better fulfills them.

Aspect/Benefit	Value Maximization	Balance	Strategic Alignment
1. Highest expected value	Yes		
2. Highest realized value			Yes
3. Growth opportunities			Yes
4. Project synergy effects			Yes
5. Guarantee of positive returns		Yes	
6. Return stability (sure bet)		Yes	
7. Spending rationality		Yes	

Table 6.1: Benefits obtained from each Portfolio/Heuristic

**6.3 Managerial Implications**

Some scholars argue that portfolio management literature is full of rules of thumb and best practices with little theoretical ground (Kavadias & Chao, 2008). This study intends to provide a better understanding of the consequences of having certain type of NPD portfolios and therefore some practical implications can be drawn. Our results suggest that the larger the extent projects build synergy on each other, the higher the chances to obtain positive returns and to mitigate associated innovation risks. Managers should strengthen the predefined statement of the innovation strategy, for instance, by declaring a PIC (Product Innovation Charter, see (Crawford & Di Benedetto, 2011)) so the new products strategy has a clear direction where it must go and where it must *not* go. This way managers can guarantee a solid stream of NPD strategy-related initiatives, and build portfolios that fit the current organizational capabilities and benefit from a risk reduction effect. But this risk mitigation effect is not an automatic outcome: managers should encourage a good coordination among the functions involved in the NPD process.

The strategic dimension of a NPD project is complex dimension to assess. In the experience with the Portfolio Management solution -FLIGHTMAP-, users encounter more difficulty judging their projects in the strategic dimension, whereas, the financial figures which can be more unreliable in the Fuzzy Front End, are in general better understood. So, managers and their teams should devote special interest in defining how to assess a project in the strategic dimension, as this evaluation will weed out irrelevant (though still financially attractive) initiatives and keep the real promising ones.

By having a solid stream of NPD initiatives and having more projects under evaluation, better portfolios that deliver larger economic benefits are more likely to be obtained. This might sound obvious, however, this effect applies particularly for portfolios that seek to gain a competitive advantage through a strategic alignment, and with a lesser extent to portfolios that merely seek to balance innovation risks. Even though there is a discontinuity in the phases of ideation and portfolio management (Heising, 2012), our results suggest that managers aiming for future-proof portfolios should then encourage the implementation of a proper ideation management as having more alternatives to evaluate will lead to more valuable strategic portfolios.

Lastly, balancing the portfolio in the strict sense of what balance implies, will surely prevent financial losses in the short term, but will hold back the company to enter in riskier but more promising portfolios. Strict risk balance can ultimately lead the firm to stagnant growth. Instead of strictly balancing the portfolio in risks, our results suggest that companies should have some risk compensation with sure NPD incremental investments and more risky and promising initiatives. Firms should learn to explore and experiment at lowest cost possible. If risky and promising options are cultivated in the right way they will turn out to deliver their full potential. Crafting a future-proof portfolio that enables sustainable growth is not only about obtaining immediate financial returns and corporate strategy-friendly projects. It is also about being observant and flexible to start new initiatives unrelated to the actual core strategy of the firm. Therefore, managers should encourage the compensation of risk with more incremental projects and simultaneously managers should stimulate the venture in exploration projects and learn to learn cheap and fast. The approach suggested by McGrath (2009) called *Discovery-driven planning* encourages the experimentation at lowest cost possible for risky new ventures (McGrath & MacMillan, 2009).

## 6.4 Implications for Bicare

The findings and the above mentioned implications also serve specifically for Bicare's activities. Most of the implications for Bicare include suggestions for improvements in FLIGHTMAP. Some other implications involve suggestions for process improvement, in particular with the partner consulting activities:

- FLIGHTMAP has already embedded several criteria assessing the strategic fit of a project. This feature allows some level of user customization and it is done mainly in a qualitative basis. The FLIGHTMAP development team at Bicare should judge whether the strategic criteria and the way how it is processed in further computations can be improved. For instance, using quantitative metrics or allowing the user to give weights to the strategic scores that form a general strategic score. The aim is to find an equilibrium between an assessment that the user finds simple enough but still captures the relevant dimensions inherent to strategy, in such a way that the vagueness of this

evaluation is mitigated. Techniques as fuzzy logic or analytical hierarchy process would allow to convert human judgments into quantitative metrics that can be used in further portfolio comparisons and computations.

- Results from the Strategic alignment heuristic suggest that by combining the financial and strategic aspects of projects, acceptable portfolios that deliver value can be created. Currently, the FLIGHTMAP model considers separately this two components. By emulating the strategic alignment heuristic, projects that have strategic importance and at the same time are valuable in financial terms, would be visible to form a good portfolio.
- Reducing the strategic assessment vagueness also implies opportunities in consulting for Bicare: through Bicare's expertise, this vagueness can be reduced with consulting activities on the customers' site.
- FLIGHTMAP users can profit from evaluating and executing projects that are *not* related to corporate strategy but that can still enable future growth. This can be perceived as ambiguous since FLIGHTMAP ranks better the strategic-friendly projects and the user might find it difficult to spot strategic-unrelated projects. A new category can be added to the current options for strategic fit: the spectrum from *Absent* to *Excellent* can now include a category like *Potential New Venture*. An improved user-experience in which FLIGHTMAP guides how to manage such initiatives is also a new area to be explored for future development. Real options reasoning is prescribed in literature for evaluating risky and unrelated-to-strategy projects with growth potential, and the input that is required for it is almost fully available in the current FLIGHTMAP model. For instance, Bodner and Rouse showed in a simulation study how R&D creates more value when real options metrics are used instead of the conventional discount of cash flows, i.e. NPV (Bodner & Rouse, 2007).
- FLIGHTMAP already enables the user to define project-to-project interconnections. It would be beneficial if the user can realize during the planning phase the positive effects of selecting interrelated projects when crafting the NPD portfolio. This implication should be taken carefully as it entails a considerable exploration of the risk management knowledge and involves an increment of the complexity of the project selection process.



# Chapter 7

## Conclusions

Using a Monte-Carlo simulation approach, this study examines the consequences of building NPD portfolios under the rationale of the three dimensions of success widely accepted in portfolio management literature and practice: value maximization, balance and strategic alignment. It was found that the three heuristics will drive the firm to economic value generation, however with strong differences in the mechanisms in how they deliver value. When maximizing the value of a portfolio, normally risky and highly valuable projects are preferred, while achieving a balance consists of choosing a combination of mostly certain and incremental projects. Strategically aligned portfolios will consist of projects that are valuable but at the same time of projects that fit the corporate objectives. Projects that incentive experimentation take also part in the strategically aligned portfolios. All this makes that value maximized portfolios are riskier in nature and have the largest probability of failure. Opposite was found for balanced portfolios with the lowest probability of value destruction but with a lower extent of value delivered and missing the potential of riskier initiatives. Strategic portfolios entail the largest value delivered and intermediate deviation, given the effect of risk mitigation inherent to selecting projects that fit with corporate capabilities.

The trade-offs that came apparent in the results were exposed in the discussion session, as well as the managerial implications for portfolio managers and for specific processes at Bicore with particular recommendations for FLIGHTMAP. In the case of this study, the venture of riskier portfolios instead of balanced portfolios turn out to be more favorable for value creation, of course with appropriate risk management, thus enabling the firm to deliver positive and sustainable value.

### 7.1 Limitations

When reviewing this research, a number of limitations have to be acknowledged. First, as does any simulation study, the model built for this study makes various simplifying assumptions. Many of them were based in literature, nevertheless some specific characteristics of a real portfolio management environment are deliberately omitted. For example, elements that capture externalities such as Environmental turbulence and Environmental competitiveness are excluded. This makes that only internal factors are considered and therefore important aspects such as rate of exploration did not show effect in the results when the case normally is otherwise. In addition, some assumptions allow to simulate a very specific organizational context. For instance, the firm under study has 10% of chances of having radical projects

and 20% of new-to-the-firm projects. Even though these numbers are averages from what is found in practice (Barczak et al., 2009), this proportion differs across industries and companies, therefore drawing generalizations is not recommended for a particular industry. This artificiality threatens the external validity of the research.

Secondly, even though the project took into consideration the input from portfolio management experts as well as the use as much as possible of figures brought from literature, some numbers were assumed as “good” guesses with triangular distribution functions and the calibration process made no use of real databases. This lack of confrontation with a real setting implies a threat in the face validity of the simulation model. Nevertheless, the results are valuable as in simulation, the researcher is more interested in understanding proportions, comparisons and directions rather than the exact numbers resulting from the study (Kleijnen & van Groenendaal, 1992). Recognizing this limitation, motivated the use of more contrasting heuristics to emulate the dimensions of success.

Third, the study focuses on the value creation mechanisms of successful portfolios. The model measures this construct in the medium term basing the calculation on economic mechanisms. This creates an ambiguity since value creation of strategic portfolios are partially realized in the long term, specially for the experimental initiatives. This fact is not captured by the proposed model and authors like Kang et al. suggest that firm performance of strategic portfolios has two components: short-term performance (project returns) and long-term performance (stock returns) (Kang & Montoya, 2014) whose implications might not be the same. Therefore, the findings of our work related to value creation have to be assessed with care when interpreting short and long-term performance.

## 7.2 Future research

Not only the above mentioned limitations but also the outcomes from the study suggest a fertile ground for future research. First, the results show the importance of building strategic portfolios and experimenting with unrelated-to-strategy projects. It has been widely suggested that such projects should be assessed under a real options perspective rather than the discounted cash flows perspective used in this study. Building a model that captures this reasoning and more sophisticated metrics for volatility would be an interesting way to understand value creation for highly uncertain projects.

It would also be appropriate to include in a future model the effects of using a Discovery-driven approach (McGrath & MacMillan, 2009), which incorporates actions for learning and experimenting with stepping stone options. Further management interventions in the project management arena can be included to see how the dimensions of success are moderated by the execution engine of the firm. Our model explored on the risk management field, but for sure this can be expanded to more management processes related to new venturing. Stochastic processes seem to be appropriate to tackle this challenge.

In order to cover one of the limitations, the model can also be expanded, and it can include certain externalities which would allow to understand and perceive the effects of the variations of the explore/exploit proportion. Moreover, an extended model can also see the consequences of building portfolios incorporating the dimensions of success, but this time with different aspects of firm performance, for example the ones suggested by Kester et al. (in press): market effectiveness and customer satisfaction.

Finally, entering in the realm of finances and stock markets, it would be very interesting

to complete the model including the effect of strategic portfolios on the stock value of the firm in the long term. In this way, the growth opportunities component inherent to strategic portfolios could be analyzed better with such approach.



# References

- Abell, D. F. (1999). Competing today while preparing for tomorrow. *Sloan Management Review*, 40(3), 73–81.
- Ajamian, G. M. & Koen, P. A. (2002). Technology Stage-Gate: A Structured Process for Managing High-Risk New Technology Projects. In P. Belliveau, A. Griffin & S. Somermeyer (Eds.), *The PDMA Toolbook for New Product Development* (pp. 267–295). New York: John Wiley & Sons, Inc.
- Avlonitis, G. J., Hart, S. & Tzokas, N. (2000). An Analysis of Product Deletion Scenarios. *Journal of Product Innovation Management*, 17(1), 41–56.
- Barczak, G., Griffin, A. & Kahn, K. B. (2009). PERSPECTIVE: Trends and Drivers of Success in NPD Practices: Results of the 2003 PDMA Best Practices Study \*. *Journal of Product Innovation Management*, 26(1), 3–23.
- Bentzen, E., Christiansen, J. K. & Varnes, C. J. (2011). What attracts decision makers' attention?: Managerial allocation of time at product development portfolio meetings. *Management Decision*, 49(3), 330–349.
- Blau, G. E., Pekny, J. F., Varma, V. A. & Bunch, P. R. (2004). Managing a Portfolio of Interdependent New Product Candidates in the Pharmaceutical Industry. *Journal of Product Innovation Management*, 21(4), 227–245.
- Bodner, D. A. & Rouse, W. B. (2007). Understanding R&D Value Creation with Organizational Simulation. *Systems Engineering*, 10(1), 64–82.
- Bordley, R. (2003). Determining the Appropriate Depth and Breadth of a Firm's Product Portfolio. *Journal of Marketing Research*, 40(1), 39–53.
- Borshchev, A. & Filippov, A. (2004). From System Dynamics and Discrete Event Practical Agent Based Modeling: Reasons, Techniques, Tools. In *The 22nd international conference of the system dynamics society*. Oxford, England.
- Bowman, E. H. & Hurry, D. (1993). Strategy through the Option Lens: An Integrated View of Resource Investments and the Incremental-Choice Process. *The Academy of Management Review*, 18(4), 760–782.
- Bremser, W. G. & Barsky, N. P. (2004). Utilizing the balanced scorecard for R&D performance measurement. *R&D Management*, 34(3), 229–238.
- Calantone, R. J., Di Benedetto, A. & Schmidt, J. B. (1999). Using the Analytic Hierarchy Process in New Product Screening. *Journal of Product Innovation Management*, 16(1), 65–76.
- Carbonell-Foulquié, P., Munuera-Alemán, J. L. & Rodríguez-Escudero, A. I. (2004). Criteria employed for go/no-go decisions when developing successful highly innovative products. *Industrial Marketing Management*, 33(4), 307–316.
- Castellion, G. & Markham, S. K. (2013). Perspective: New Product Failure Rates: Influence of Argumentum ad Populum and Self-Interest. *Journal of Product Innovation*

- Management*, 30(5), 976–979.
- Chao, R. O. & Kavadias, S. (2008). A Theoretical Framework for Managing the New Product Development Portfolio: When and How to Use Strategic Buckets. *Management Science*, 54(5), 907–921.
- Chao, R. O., Kavadias, S. & Gaimon, C. (2009). Revenue Driven Resource Allocation: Funding Authority, Incentives, and New Product Development Portfolio Management. *Management Science*, 55(9), 1556–1569.
- Christensen, C. M. (2003). *The Innovator's Dilemma: the revolutionary book that will change the way you do business* (1st ed.). New York: HarperBusiness Essentials.
- Christiansen, J. K. & Varnes, C. (2008). From models to practice: decision making at portfolio meetings. *International Journal of Quality & Reliability Management*, 25(1), 87–101.
- Cooper, R. G. (2006). Managing Technology Development Projects. *Research Technology Management*, 49(6), 23–31.
- Cooper, R. G., Edgett, S. J. & Kleinschmidt, E. J. (1998). *Portfolio Management for New Products* (1st ed.). New York: Perseus Books.
- Cooper, R. G., Edgett, S. J. & Kleinschmidt, E. J. (2001). Portfolio Management for New Product Development : Results of an Industry Practices Study. *R&D Management*, 31(4).
- Cooper, R. G., Scott, E. & Kleinschmidt, E. J. (2004). Benchmarking Best NPD practices-ii. *Research Technology Management*, 47(3), 50–59.
- Crawford, M. & Di Benedetto, A. (2011). *New Products Management* (Tenth ed.). New York: McGraw-Hill.
- Davis, J. P., Eisenhardt, K. M. & Bingham, C. B. (2007). Developing Theory through Simulation Methods. *The Academy of Management Review*, 32(2), 480–499.
- Englund, R. L. & Graham, R. J. (1999). From Experience: Linking Projects to Strategy. *Journal of Product Innovation Management*, 16(1), 52–64.
- Graves, S. B., Ringuest, J. L. & Case, R. H. (2000). Formulating Optimal R&D Portfolios. *Research-Technology Management*, 43(3), 47–51.
- Greve, H. R. (2007). Exploration and exploitation in product innovation. *Industrial and Corporate Change*, 16(5), 945–975.
- Hart, S., Hultink, E. J., Tzokas, N. & Commandeur, H. R. (2003). Industrial Companies Evaluation Criteria in New Product Development Gates. *Journal of Product Innovation Management*, 20(1), 22–36.
- Hauser, J., Tellis, G. J. & Griffin, A. (2006). Research on Innovation : A Review and Agenda for Marketing Science. *Marketing Science*, 25(6), 687–717.
- Heising, W. (2012). The integration of ideation and project portfolio management - A key factor for sustainable success. *International Journal of Project Management*, 30(5), 582–595.
- Jemison, D. B. (1987). Risk and the Relationship among Strategy, Organizational Processes, and Performance. *Management Science*, 33(9), 1087–1101.
- Kahneman, D. (2011). *Thinking, Fast and Slow*. London: Penguin.
- Kang, W. & Montoya, M. (2014). The Impact of Product Portfolio Strategy on Financial Performance: The Roles of Product Development and Market Entry Decisions. *Journal of Product Innovation Management*, 31(3), 516–534.
- Kaplan, R. S. & Norton, D. (1996). *The balance scorecard: translating strategy into action*. Boston: Harvard Business School Press.

- Kavadias, S. & Chao, R. O. (2008). Resource allocation and new product development portfolio management. In *Handbook of New Product Development Management* (1st ed., pp. 135–163). Amsterdam: Elsevier.
- Kester, L. (2011). *New Product Development Portfolios - Identifying the antecedents and consequences of decision-making processes* (Pd.D. thesis). Delft University of Technology.
- Kester, L., Griffin, A., Hultink, E. J. & Lauche, K. (2011). Exploring Portfolio Decision-Making Processes\*. *Journal of Product Innovation Management*, 28(5), 641–661.
- Kester, L., Hultink, E. J. & Griffin, A. (in press). *An Empirical Investigation of the Antecedents and Outcomes of NPD Portfolio Success* (No. Accepted for publication in the *Journal of Product Innovation Management*).
- Kester, L., Hultink, E. J. & Lauche, K. (2009). Portfolio decision-making genres: A case study. *Journal of Engineering and Technology Management*, 26(4), 327–341.
- Killen, C. P., Hunt, R. A. & Kleinschmidt, E. J. (2008). Project portfolio management for product innovation. *International Journal of Quality & Reliability Management*, 25(1), 24–38.
- Kleijnen, J. P. C. & van Groenendaal, W. (1992). *Simulation: a statistical perspective*. Chichester, England: John Wiley & Sons, Ltd.
- Kleinschmidt, E. J. & Cooper, R. G. (1991). The Impact of Product Innovativeness on Performance. *Journal of Product Innovation Management*, 8(4), 240–251.
- Liberatore, M. J. (1988). A Decision Support System linking R&D projects selection with Business Strategy. *Project Management Journal*, 19(5), 14–21.
- MacMillan, I. C. & McGrath, R. G. (2002). Crafting R&D project portfolios. *Research Technology Management*, 45(5), 48–59.
- March, J. G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1), 71–87.
- Maringer, D. (2005). *Portfolio Management with Heuristic Optimization: Advances in Computational Management Science*. Dordrecht, The Netherlands: Springer.
- Markowitz, H. (1952). Portfolio selection\*. *The Journal of Finance*, 7(1), 77–91.
- Martino, J. P. (1995). *Research and Development Project Selection*. New York: John Wiley & Sons, Inc.
- Matheson, J. E. & Menke, M. M. (1994). Using decision quality principles to balance your R&D portfolio. *Research Technology Management*, 37(3), 38–43.
- McGrath, R. G. & MacMillan, I. C. (2009). *Discovery-driven growth : a breakthrough process to reduce risk and seize opportunity*. Boston: Harvard Business Press.
- McNally, R. C., Durmuşoğlu, S. S. & Calantone, R. J. (2013). New Product Portfolio Management Decisions: Antecedents and Consequences. *Journal of Product Innovation Management*, 30(2), 245–261.
- McNally, R. C., Durmusoglu, S. S., Calantone, R. J. & Harmancioglu, N. (2009). Exploring new product portfolio management decisions: The role of managers' dispositional traits. *Industrial Marketing Management*, 38(1), 127–143.
- Menke, M. M. (2013). Making R&D Portfolio Management More Effective. *Research-Technology Management*, 56(5), 34–44.
- Meskendahl, S. (2010). The influence of business strategy on project portfolio management and its success - A conceptual framework. *International Journal of Project Management*, 28(8), 807–817.
- Mongin, P. (1997). Expected Utility Theory. In J. Davis, W. Hands & U. Maki (Eds.), *Handbook of Economic Methodology* (pp. 342–350). London: Edward Elgar.

- 
- Mu, J., Peng, G. & MacLachlan, D. L. (2009). Effect of risk management strategy on NPD performance. *Technovation*, 29(3), 170–180.
- Pennock, M. & Rouse, B. (2008). The Costs and Risks of Maturing Technologies, Traditionally Vs. Evolutionary Approaches. In *5th annual acquisition research symposium: Creating synergy for informed change, Monterey CA* (pp. 106–125).
- Sahni, S. (1975). Approximate Algorithms for the 0/1 Knapsack Problem. *Journal of the ACM*, 22(1), 115–124.
- Salomo, S., Talke, K. & Strecker, N. (2008). Innovation Field Orientation and Its Effect on Innovativeness and Firm Performance. *Journal of Product Innovation Management*, 25, 560–576.
- Schaminée, I. (2013). *Portfolio Management KPIs* (Master Thesis). Eindhoven University of Technology.
- Smit, H. T. J. & Trigeorgis, L. (2006). Strategic planning: valuing and managing portfolios of real options. *R&D Management*, 36(4), 403–419.
- Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. New York: McGraw-Hill.
- Strandmark, P. (2009). *Dynamic Programming of 0-1 Knapsack problem*. Found in Matlab Central.
- Walrave, B., van Oorschot, K. E. & Romme, a. G. L. (2011). Getting Trapped in the Suppression of Exploration: A Simulation Model. *Journal of Management Studies*, 48(8), 1727–1751.
- Weissenberger-Eibl, M. a. & Teufel, B. (2011). Organizational politics in new product development project selection: A review of the current literature. *European Journal of Innovation Management*, 14(1), 51–73.
- Yahaya, S.-Y. & Abu-Bakar, N. (2007). New product development management issues and decision-making approaches. *Management Decision*, 45(7), 1123–1142.
- Zapata, J. C., Varma, V. A. & Reklaitis, G. (2008). Impact of tactical and operational policies in the selection of a new product portfolio. *Computers & Chemical Engineering*, 32(1-2), 307–319.



# Appendix A

## Main simulation program algorithm

---

**Algorithm 1** Main simulation program

---

```
1: Set number of simulation runs =  $w$ 
2: Set Number_of_projects, Risk-reduction_coefficient, Exploration_rate
3: Set probability of having an Incremental project  $P_{incremental} = 0.7$ 
4: Set probability of having a New to the Firm project  $P_{ntf} = 0.2$ 
5: Set probability of having a Breakthrough project  $P_{breakthrough} = 0.1$ 
6: Set interest rate  $r = 0.08$ 
7: for Incremental, New-to-the-Firm and Breakthrough type of project do
8:   Initialize the following distribution functions1:
9:   Triangular distribution for Development costs  $\leftarrow$  tri[min,most likely,max]
10:  Triangular distribution for Commercialization costs  $\leftarrow$  tri[min,most likely,max]
11:  Triangular distribution for Expected inflows  $\leftarrow$  tri[min,most likely,max]
12:  Uniform distribution for Development risks  $\leftarrow$  U[min,max]
13:  Uniform distribution for Commercialization risks  $\leftarrow$  U[min,max]
14:  Initialize Development time: Incremental  $\leftarrow$  0; NtF  $\leftarrow$  1; Breakthrough  $\leftarrow$  3
15: end for
16:  $k \leftarrow 1$ 
17: repeat
18:   Generate projects (see Algorithm 2)
19:   Build Value Maximization Portfolio (see Algorithm 3)
20:   Build Balance Portfolio (see Algorithm 4)
21:   Build Strategic Alignment Portfolio (see Algorithm 5)
22:   Portfolio Execution (see Algorithm 6)
23:   Store Value_generated $w$  for each heuristic
24:    $k \leftarrow k + 1$ 
25: until  $k = w$ 
26: return Value_generated matrix
```

---

<sup>1</sup>Parameters for initializing triangular and uniform distributions are shown in Table 4.2

---

**Algorithm 2** Generate projects

---

**Require:**  $i \in 1, 2, \dots$ , Number of Projects

```

1: for all  $i$  do
2:   newness $_i$  = random[0,1]
3:   if newness $_i \leq P_{incremental}$  then
4:     Development_costs $_i$  = random from triangular distribution (Incremental)
5:     Commercialization_costs $_i$  = random from triangular distribution (Incremental)
6:     Net_Inflows $_i$  = random from triangular distribution (Incremental)
7:     Development_risks $_i$  = random from uniform distribution (Incremental)
8:     Commercial_risks $_i$  = random from uniform distribution (Incremental)
9:     Development_time $_i$  = 0
10:    Newness_recalculated $_i$  = 1
11:  else if newness $_i > P_{incremental}$  and newness $_i \leq (P_{incremental} + P_{ntf})$  then
12:    Development_costs $_i$  = random from triangular distribution (Ntf)
13:    Commercialization_costs $_i$  = random from triangular distribution (Ntf)
14:    Net_Inflows $_i$  = random from triangular distribution (Ntf)
15:    Development_risks $_i$  = random from uniform distribution (Ntf)
16:    Commercial_risks $_i$  = random from uniform distribution (Ntf)
17:    Development_time $_i$  = 1
18:    Newness_recalculated $_i$  = 3
19:  else if newness $_i > (P_{incremental} + P_{ntf})$  then
20:    Development_costs $_i$  = random from triangular distribution (Breakthrough)
21:    Commercialization_costs $_i$  = random from triangular distribution (Breakthrough)
22:    Net_Inflows $_i$  = random from triangular distribution (Breakthrough)
23:    Development_risks $_i$  = random from uniform distribution (Breakthrough)
24:    Commercial_risks $_i$  = random from uniform distribution (Breakthrough)
25:    Development_time $_i$  = 3
26:    Newness_recalculated $_i$  = 7
27:  end if
28: end for
29: Set R&D_Budget =  $0.65 * \sum_i (\text{Development\_costs}_i + \text{Commercialization\_costs}_i)$ 

30: for all  $i$  do
31:   strategic_alignment $_i$  = random[0,1]
32:   if strategic_alignment $_i \leq 0.6$  then
33:     Project $_i$  is Strategically aligned
34:   else
35:     Project $_i$  is NOT Strategically aligned
36:   end if
37: end for

```

---

## Appendix B

# Algorithm of the Value Maximization Heuristic

---

**Algorithm 3** Build Value Maximization Portfolio

---

**Require:**  $i \in 1, 2, \dots$ , Number of Projects

1: **for all**  $i$  **do**

2: 
$$\text{NPV}_i = \frac{\text{Net\_Inflows}_i}{(1+r)^{\text{Development\_time}_i}} - \frac{\text{Commercialization\_costs}_i}{(1+r)^{\text{Development\_time}_i}} - \text{Development\_costs}_i$$

3: 
$$\text{ROI}_i = \frac{\text{Net\_Inflows}_i / (1+r)^{\text{Development\_time}_i}}{(\text{Commercialization\_costs}_i / (1+r)^{\text{Development\_time}_i}) + \text{Development\_costs}_i} - 1$$

4: **end for**

**Require:** All  $\text{NPV}_i$  must be  $\geq 0$  otherwise  $\text{NPV}_i \leftarrow 0$

5: Run KNAPSACK optimization with input<sup>1</sup>:

6:  $\text{NPV}_i$ ;  $\text{Costs}_i = \text{Development\_costs}_i + \text{Commercialization\_costs}_i$ ; and  $\text{R\&D\_Budget}$

7: **return**  $\text{Portfolio}_{\text{ValueMax}}$  is a binary vector: 1  $\leftarrow$  Selected Project; 0  $\leftarrow$  Not selected project

---

---

<sup>1</sup>Logic implemented by Strandmark (2009) as a building block for Matlab



## Appendix C

# Algorithm of the Balance Heuristic

---

### Algorithm 4 Build Balance Portfolio

---

**Require:** ROI Matrix with  $n$  observations for each project <sub>$i$</sub>  {Monte-Carlo approach}

- 1: Returns <sub>$i$</sub>   $\leftarrow$  average(ROI Matrix)
  - 2: ROI\_std\_dev <sub>$i$</sub>   $\leftarrow$  Standard Deviation (ROI Matrix)
  - 3: covariances  $\leftarrow$  covariance(ROI Matrix)
  - 4: Calculate efficient frontier with PORTOPT function of Matlab<sup>1</sup>:
  - 5: Use input: Returns <sub>$i$</sub> ; ROI\_std\_dev <sub>$i$</sub> ; and covariances
  - 6: Compute possible portfolios using ALL\_POSS function<sup>2</sup>. Input: Number\_of\_projects
  - 7: **return** Binary matrix with size  $2^{\text{Number\_of\_projects}}$  x Number\_of\_projects
  
  - 8: **for all**  $j$ , where  $j$  is the binary matrix row index representing each possible portfolio **do**
  - 9:   Portfolio\_cost <sub>$j$</sub>   $\leftarrow$  Portfolio <sub>$j$</sub>  · (Development\_costs + Commercialization\_costs)
  - 10:   **if** Portfolio\_cost <sub>$j$</sub>   $\leq$  R&D\_Budget **then**
  - 11:     Portfolio\_feasibility <sub>$j$</sub>  is **true**
  - 12:   **end if**
  - 13:   weights <sub>$j$</sub>   $\leftarrow$   $\frac{\text{Portfolio}_j \times (\text{Development\_costs} + \text{Commercialization\_costs})}{\text{Portfolio\_cost}_j}$
  - 14:   Compute Portfolio\_return <sub>$j$</sub>  and Portfolio\_risk <sub>$j$</sub>  using PORTSTATS function<sup>3</sup>
  - 15:   using input weights <sub>$j$</sub>
  - 16:   Ratio <sub>$j$</sub>   $\leftarrow$  Portfolio\_return <sub>$j$</sub> /Portfolio\_risk <sub>$j$</sub>
  - 17: **end for**
  
  - 18: Portfolio<sub>Balance</sub> is a Portfolio <sub>$j$</sub>  such that max(Ratio <sub>$j$</sub> ) **and** Portfolio\_feasibility <sub>$j$</sub>  is **true**
  - 19: **return** Portfolio<sub>Balance</sub> is a binary vector: 1  $\leftarrow$  Selected Project; 0  $\leftarrow$  Not selected project
- 

---

<sup>1</sup>Requires Financial-Toolbox installed

<sup>2</sup>Available at Matlab Central

<sup>3</sup>Requires Financial-Toolbox installed

## Appendix D

# Algorithm of the Strategic Alignment Heuristic

---

**Algorithm 5** Build Strategic Alignment Portfolio

---

**Require:** strategic\_alignment computation (defined in Algorithm 2 in Appendix A)

**Require:**  $i \in 1, 2, \dots$ , Number of Projects

```
1: for all  $i$  such that Project $_i$  is Strategically aligned do
2:   Run KNAPSACK optimization with input
3:   NPV $_i$ ; Costs $_i$  = Development_costs $_i$  + Commercialization_costs $_i$ ; and R&D_Budget * (1-
   Exploration_rate)
4:   return Portfolio $_{exploitation}$  is a binary vector: 1  $\leftarrow$  Selected Project; 0  $\leftarrow$  Not selected project
5: end for

6: for all  $i$  such that Project $_i$  is NOT Strategically aligned do
7:   Run KNAPSACK optimization with input
8:   NPV $_i$ ; Costs $_i$  = Development_costs $_i$  + Commercialization_costs $_i$ ; and R&D_Budget * Explora-
   tion_rate
9:   return Portfolio $_{exploration}$  is a binary vector: 1  $\leftarrow$  Selected Project; 0  $\leftarrow$  Not selected project
10: end for
11: Merge vectors Portfolio $_{exploitation}$  and Portfolio $_{exploration}$  into a single binary vector
12: return Portfolio $_{strategic.algn}$  is a binary vector: 1  $\leftarrow$  Selected Project; 0  $\leftarrow$  Not selected project

13: synergy_rate  $\leftarrow \frac{\sum_i \text{Portfolio}_{exploitation}}{\sum_i \text{Portfolio}_{strategic.algn}}$ 
14:  $rc \leftarrow$  Risk_reduction_coefficient
15: Risk_reduction_factor  $\leftarrow (-rc * \text{synergy\_rate}^2) + (2 * rc * \text{synergy\_rate})$ 
16:  $rf \leftarrow$  Risk_reduction_factor
17: return  $rf$ 
```

---

## Appendix E

# Algorithm of the Portfolio Execution

---

**Algorithm 6** Portfolio Execution and Value computation

---

**Require:** number of simulation runs =  $w$  **and**  $i \in 1, 2, \dots, \text{Number of Projects}$

- 1: **for all** Selected portfolios: Portfolio<sub>Value\_Max</sub>; Portfolio<sub>Balance</sub>; Portfolio<sub>strategic\_algn</sub> **do**
- 2:   **if** Portfolio to execute is  $\neq$  Portfolio<sub>strategic\_algn</sub> **then**
- 3:     **for all**  $i$  in Portfolio<sub>Value\_Max.i</sub> and Portfolio<sub>Balance.i</sub>, where  $i$  is project index **do**
- 4:       Set tech\_random <sub>$i$</sub>   $\leftarrow$  random[0,1]
- 5:       Set comm\_random <sub>$i$</sub>   $\leftarrow$  random[0,1]
- 6:       **if** (Portfolio<sub>Value\_Max.i</sub> **or** Portfolio<sub>Balance.i</sub>) = 1 **and** tech\_random <sub>$i$</sub>  > Development\_risks <sub>$i$</sub>  **then**
- 7:          Compute cost of having developed Project <sub>$i$</sub>   $\leftarrow$  Development\_costs <sub>$i$</sub>
- 8:          **if** comm\_random <sub>$i$</sub>  > Commercial\_risks <sub>$i$</sub>  **then**
- 9:            Compute cost of having commercialized Project <sub>$i$</sub>   $\leftarrow$  Commercialization\_costs <sub>$i$</sub>
- 10:          Compute Revenues of Project <sub>$i$</sub>   $\leftarrow$  Net\_Inflows <sub>$i$</sub>
- 11:       **else**
- 12:          Compute cost of having commercialized Project <sub>$i$</sub>   $\leftarrow$  Commercialization\_costs <sub>$i$</sub>
- 13:       **end if**
- 14:       **else if** (Portfolio<sub>Value\_Max.i</sub> **or** Portfolio<sub>Balance.i</sub>) = 1 **and** tech\_random <sub>$i$</sub>   $\leq$  Development\_risks <sub>$i$</sub>  **then**
- 15:          Compute cost of having developed Project <sub>$i$</sub>   $\leftarrow$  Development\_costs <sub>$i$</sub>
- 16:       **end if**
- 17:     **end for**
- 18:   **else**
- 19:     **for all**  $i$  in Portfolio<sub>strategic\_algn</sub>, where  $i$  is project index **do**
- 20:       Set tech\_random <sub>$i$</sub>   $\leftarrow$  random[0,1]
- 21:       Set comm\_random <sub>$i$</sub>   $\leftarrow$  random[0,1]
- 22:       **if** Portfolio<sub>strategic\_algn.i</sub> = 1 **and** tech\_random <sub>$i$</sub>  > (Development\_risks <sub>$i$</sub>  \* (1 -  $rf$ )) **then**
- 23:          Compute cost of having developed Project <sub>$i$</sub>   $\leftarrow$  Development\_costs <sub>$i$</sub>
- 24:          **if** comm\_random <sub>$i$</sub>  > Commercial\_risks <sub>$i$</sub>  \* (1 - Risk\_reduction\_factor) **then**
- 25:            Compute cost of having commercialized Project <sub>$i$</sub>   $\leftarrow$  Commercialization\_costs <sub>$i$</sub>
- 26:          Compute Revenues of Project <sub>$i$</sub>   $\leftarrow$  Net\_Inflows <sub>$i$</sub>
- 27:       **else**
- 28:          Compute cost of having commercialized Project <sub>$i$</sub>   $\leftarrow$  Commercialization\_costs <sub>$i$</sub>
- 29:       **end if**
- 30:       **else if** Portfolio<sub>strategic\_algn.i</sub> = 1 **and** tech\_random <sub>$i$</sub>   $\leq$  Development\_risks <sub>$i$</sub>  \* (1 -  $rf$ ) **then**
- 31:          Compute cost of having developed Project <sub>$i$</sub>   $\leftarrow$  Development\_costs <sub>$i$</sub>
- 32:       **end if**
- 33:     **end for**
- 34:   **end if**
- 35:   **for all**  $i$  **do**
- 36:     Value\_generated <sub>$w$</sub>  =  $\sum_i$  (Revenues <sub>$i$</sub>  - Comm\_costs <sub>$i$</sub>  - Dev\_costs <sub>$i$</sub> )
- 37:   **end for**
- 38: **end for**
- 39: **return** Value\_generated <sub>$w$</sub>

---