MASTER

Financial valuation of game-changing R&D projects

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Abstract

This study focuses on financial valuation of radical R&D projects at Philips Research. We propose a valuation model to support Philips' decision-making processes for project prioritization and selection. The valuation model takes into account stage-gating, multiple scenarios and is risk-adjusted. Through Monte Carlo simulation a distribution of valuation outcomes is generated. Thereby, a case study shows the application of the valuation model in practice. Finally, the valuation model has proven to function as a discussion platform and, as such, can be used by decision-makers to justify R&D expenditures prior to the launch decision.

Management Summary

High-technology companies face high levels of uncertainty, especially, with regard to the development of required technology and prediction of future markets. In dynamic environments, those companies aim to allocate their resources as efficient as possible, in order to create high-value project portfolios. The goal of this study is to aid Philips Research in its decision-making process for project selection through the development of a valuation model that allows for a prioritization of innovation projects based on their forecasted financial value. Thereby, this financial valuation gives senior management the justification to commit R&D expenditures prior to the launch decision.

Game changers

This study focuses on a specific type of innovation projects, namely game changers. Philips Research provides the following definition of a game changer:

"The market and competitive landscape will be disrupted via a radical innovation, with the intent to significantly increase our market share."

In order to develop a valuation model, the characteristics and value drivers of game changers have been studied. First, the innovation front-end consists of the exploratory, proof-of-concept and development stage, each completed with a certain success probability. Second, the innovation back-end copes with high levels of market uncertainty and we assume that it consists of a growth, mature and decline stage, according to the product lifecycle model.

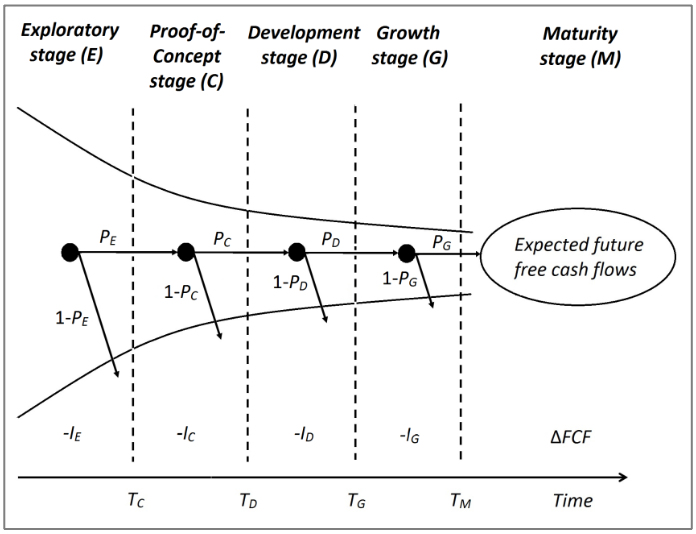
A game changer creates value through either an increase in sales volume, a price premium per product and/or cost savings per product. These value drivers are incorporated into the game changer's expected revenues and EBITA margin. Thereby, another important characteristic of game changers is the existence of a Philips' related market. A game changer might impact Philips' existing market (e.g. through cannibalization) and the game changer's value has to be adjusted accordingly.

Valuation model

Due to high levels of uncertainty, it is inadvisable to base an investment decision on the outcomes of a single scenario. Therefore, the model distinguishes three scenarios (pessimistic, most likely and optimistic). The basic part of the model gives insight into the risk-adjusted NPV (rNPV) for each scenario. Furthermore, a Monte Carlo simulation is conducted, whereby the Monte Carlo simulation randomly generates input values for uncertain input parameters based on the PERT distribution. For a certain project, future cash flows can be simulated several thousands of times, resulting in a distribution of potential future outcomes. Overall, the model is an extension of the NPV method, represented as a multi-scenario Monte Carlo valuation model, including stage-gating and adjustment for risks.

The first figure on the following page provides a conceptual representation of the model. At the end of stage *n*, a project either continues to the next stage with success probability P_n or is abandoned with probability ($1-P_n$). Furthermore, a stage starts at time T_n and the front-end stages require R&D investments I_n. From maturity onwards, there is a zero probability of

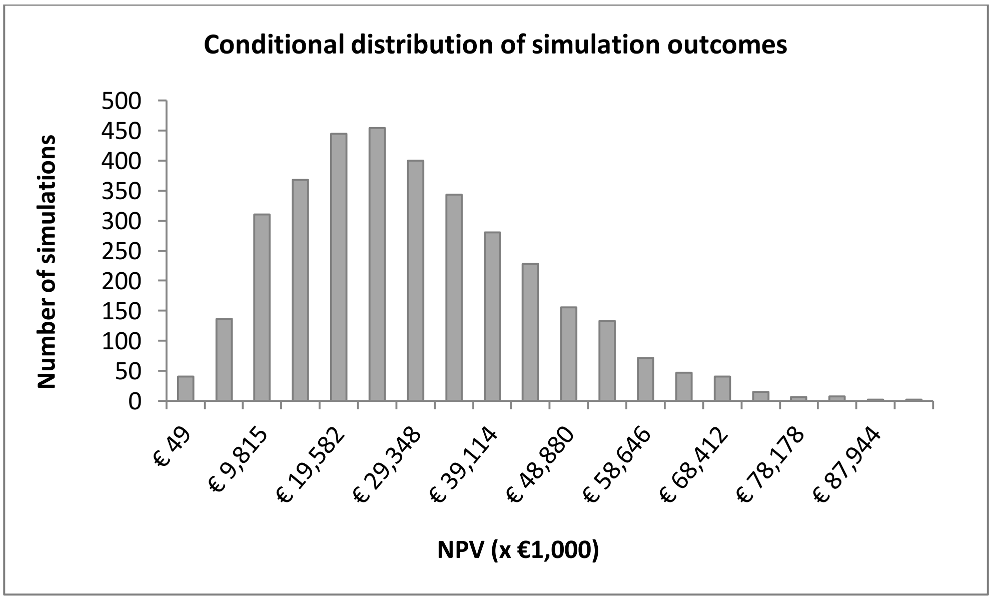
abandonment and the impact of the game changer on total free cash flows (ΔFCF) is determined. All future cash flows are discounted, adjusted for risks and summed, resulting in a risk-adjusted NPV.



Valuation results

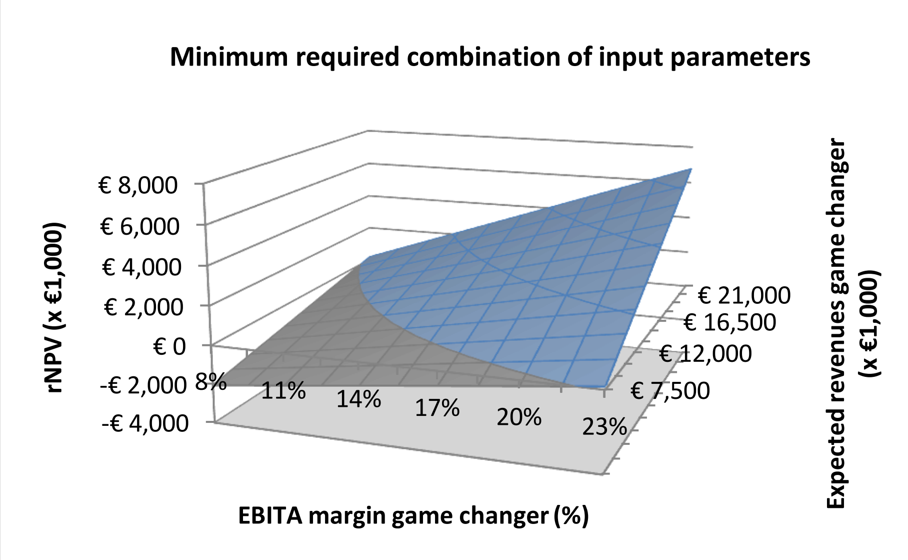
The model's required input values for the three scenarios are obtained via internal discussion, desk research and market analysis. Thereby, risk analysis for each of the front-end stages is required to determine success probabilities. Then, free cash flow calculations for the three scenarios provide insight into the rNPV outcome and other commonly used metrics (e.g. basic NPV, payback period and revenue growth).

Although the risk-adjusted NPV outcomes can be considered positive, additional analysis gives insight into the estimated risk and value distribution. Therefore, a Monte Carlo simulation provides average NPVs per stage in case of abandonment and a conditional value distribution of market outcomes in case of maturity (see figure below).



Then, next to the scenario-based calculations, the model is also able to find the input values' minima, which are required to make the investment decision acceptable. It is possible to vary two of the game changer's input parameters simultaneously (e.g. expected revenues and EBITA margin). Through such an analysis it is possible to determine which combination of those input parameters is minimally required (see figure below), given the success probabilities and required R&D investments. Philips Research has to determine whether these requirements are realistic to achieve.

Overall, the model functions as a discussion platform and, as such, enhances decision-making for project prioritization and selection. Integration of the valuation tool for project management is valuable, since through the acquisition of required input values new insights can be obtained. As a result, the valuation tool can verify whether a business case is commercially viable and can justify an investment decision, to support rational decision-making.



Major recommendations for Philips Research

First, Philips Research should identify which metrics are best to evaluate and compare projects. Based on this Master's thesis, rNPV is recommended as primary financial valuation approach. Other metrics (e.g. ROI, expected revenue growth and expected payback period) should be evaluated on their applicability. For example, it is not recommended to use ROI for decision-making in an innovation context. Early-stage innovation projects lack profits, so the formula for ROI does not hold, and ROI excludes risks and time value of money. However, though rNPV is recommended, it can never be the only approach for decision-making and other, non-financial, methods have to be considered.

Second, accurate estimates of the valuation model's input parameters are essential, as it affects output quality. The business side of Philips (e.g. business analysts and financial controllers) can play a major role in the acquisition of input values because of their business knowledge, which is valuable for game changers in particular. Therefore, increased communication and collaboration between Philips Research and Philips' business is recommended.

Preface

Eindhoven, August 6th, 2013

This report is the result of my Master's thesis project which I conducted in partial fulfilment of a double degree program, consisting of a Master of Science degree in Operations Management and Logistics at Eindhoven University of Technology and a Master of Science degree in Finance at Tilburg University. I have conducted this project at Philips Research, from February 2013 to August 2013.

First, I would like to seize the opportunity to thank my supervisor of Philips Research, dr. Ronald Wolf, for giving me the opportunity to conduct my Master's thesis project at the department of Strategy and Business Development. Ronald, without your business knowledge and willingness to help, it would have been impossible to complete this project successfully. Thereby, lunching at the Strip with Ronald and other colleagues increased my (technical) knowledge significantly.

Second, I would also like to thank dr. Arun Chockalingam of Eindhoven University of Technology and prof. dr. Ronald Mahieu of Tilburg University, with whom I could have constructive discussions on my thesis. Arun, I highly appreciate the fact that your door was always open in case of any pressing questions. And Ronald, your former experience in financial modelling in an innovation context came in handy. Arun and Ronald, it has been a pleasure to work with you.

By finishing this Master's thesis project my wonderful life as a student comes officially to an end. As a student I have been blessed with many unforgettable experiences and I am grateful for all the friends I have been able to make during those years. Without them I would have never had such an amazing couple of years.

Last but absolutely not least, I would also like to express my gratitude to my family for their ongoing support. Especially my mother, Ingrid Hofstra, with her unconditional reliance and encouragement, allowed me to reach this milestone.

Jerom Nieuwenhuizen

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1 Introduction

High-technology companies face high levels of uncertainty, especially, with regard to the development of required technology and prediction of future markets. In dynamic environments, those companies aim to allocate their resources as efficient as possible, in order to create high-value project portfolios. These portfolios support future competitiveness and profitability. The goal of this study is to aid Philips Research in its decision-making process for project selection through the development of a valuation model that allows for prioritization of innovation projects based on their forecasted financial value. The remainder of this chapter provides a description of the project context and company, respectively, under study.

1.1 Project context

1.1.1 Competitive pressure in high-technology sector

In a highly competitive and fast-paced environment, it is increasingly important for a company to be innovative and to grasp new business opportunities. Hannah (1998) shows that of the 100 largest global corporations in 1912, only 20 companies were still on the list in 1995. In order to remain competitive, companies strive to become a winner in product innovation and to seize new business opportunities. Research reveals that best-performing businesses are much more resource-rich in new product development (NPD) than other businesses. As it seems, having the necessary resources in place, and ensuring that these resources are properly dedicated and focused, is one of the strongest discriminators between the best-performing businesses and the rest (Cooper et al., 2001). The best-performers' portfolios contain high-value new product projects, i.e. profitable, high-return projects with solid commercial prospects.

Key drivers in the high-technology sector include product differentiation, quality, time-to-market, and brand management. Increased competition, new technologies and product commoditization tighten the 'profit squeeze' (Mattyssens et al., 2006). As a result, companies have to focus on innovation to maintain a competitive position in a rapidly changing electronics and entertainment market. Leading companies, like Philips Electronics, address the challenges of developing new technologies and the need to provide ever-changing product ranges by entering into strategic alliances and outsourcing operations.

1.1.2 Organizing for breakthrough innovation

Existing technologies and business models are continually challenged (e.g. Ansari & Krop, 2012; Bergek et al, 2013). Known examples are Ryan Air challenging mainstream airlines with its no-frills model, and Apple and Google challenging Nokia with new mobile operating systems. While Sony took away market share from Kodak through the introduction of the digital camera, as the inventor of the Walkman, it is outpaced by Apple through the launch of a digital music player (iPod) and a new music distribution system (iTunes) (Ansari & Krop, 2012). Market landscapes are continually changing in the face of radical innovation; incumbent companies can maintain the dominant logic of their industries until technology matures and new business models arise. For example, in the music industry, dematerialization (from CDs to digital media) and low Intellectual Property (IP) rights over digital content led to a shift from business models based on selling products to offering services around products, as Apple showed with iTunes.

Discontinuous innovation is often the driver of sustained competitive advantage and shareholder value creation. As such, the ability to support radical innovation is an essential organizational competence. Differences in the ways firms are organized in both division of labor and division of knowledge affect their ability to manage technological change, including time to market new products (Kapoor & Adner, 2011). O'Reilly and Tushman (2004) use the term 'ambidextrous' to define firms with the ability to simultaneously pursue both incremental and discontinuous innovation, balancing search and stability. According to O'Reilly and Tushman (2004), organizations with an ambidextrous organizational structure are nine times more likely to create breakthrough products and processes, while at least sustaining their existing businesses. There is an ongoing interest of incumbent firms to have structured processes in place to support decision-making for project selection, as well as to have the capabilities that support the development and adaption of breakthrough innovation.

1.2 Company description

This Master's thesis project is conducted at Philips Research, the research organization of Royal Philips Electronics. The following sections contain brief descriptions of Philips Electronics and Philips Research, respectively.

1.2.1 Philips Electronics

Royal Philips Electronics N.V., a company founded in 1891 by Anton and Gerard Philips in Eindhoven (the Netherlands), is a global leader across its healthcare, lifestyle and lighting portfolio. Nowadays, Philips has sales of €24.8 billion, employs over 118.000 people, operates in more than 100 countries worldwide and spends about 1.8 billion euros (7.3% of sales) on research and development (R&D)[1].

Philips' mission is: *"improving people's lives through meaningful innovation"*, which means that Philips strives to make the world healthier and more sustainable through innovation.[1] Philips' activities are divided into three main operating sectors, namely healthcare, consumer Lifestyle and lighting.

1.2.2 Philips Research

Philips Research, founded in 1914, is one of world's largest corporate research organizations, employing about 1,500 professionals with 50 different nationalities. Philips Research has research centres in North America, Europe and Asia, and its main office is located at the High Tech Campus in Eindhoven. Furthermore, Philips Research's annual research budget equals approximately 1% of Philips' annual sales. [2]

Philips Research's mission is to improve people's lives through technology-enabled meaningful innovations, as co-creator and strategic partner for the Philips businesses and complementary open innovation ecosystem participants (Aalders, 2012). In order to reach this mission, the research activities at Philips Research play a significant role. These activities take place at the front-end of the R&D process, i.e. from trend spotting and ideation to proof-of-concept and, in some cases, first-of-a-kind product development. Examples of products which have their roots at Philips Research are the (LED) light bulbs, Ambilight television and Philips' wakeup light.

[1] Source: Royal Philips Electronics, Annual Report 2012
[2] Source: general website Philips Research, http://www.research.philips.com/about/index.html

1.3 Project outline

First, Chapter 2 provides more insight in the area of innovation management. It explains how companies organize for innovation, shows the importance of project (portfolio) management and discusses some commonly used valuation methods. Based on the discussion in Chapter 2 and Philips' current situation, Chapter 3 defines the problem as well as the associated research questions.

Then, in Chapter 4 the innovation projects under consideration, game changers, are discussed. A general description of game changers is given and the characteristics and value-drivers of those innovation projects are examined.

A model is developed for the financial valuation of game changers, which is discussed in Chapter 5. The first section of Chapter 5 describes the general use and goals of the valuation model, whereas the latter sections provide assumptions and calculations included into the model. In Chapter 6 the results of the model testing are discussed and a sensitivity analysis is performed. Then, an application of the valuation model is presented in Chapter 7, where a game changer and a growth option (based on this game changer) are analysed.

The proposed valuation model can be applied for project management, but can also be used in a portfolio management context. A discussion about the implementation in both areas is presented in Chapter 8. Finally, Chapter 9 provides an outline of the most important conclusions and implications. Based on the results and research limitations, recommendations for Philips as well as future research are proposed.

2 Innovation management

As stated in the introduction, companies have to manage their processes for innovation, in order to create a project portfolio with valuable and commercially solid innovation projects. This chapter expands on innovation management at Philips Research. In Section 2.1 the organization of innovation is explained, including a categorization of different types of innovation projects. Then, in Section 2.2 management of a portfolio of innovation projects is discussed and Section 2.3 elaborates on management of individual innovation projects. Finally, Section 2.4 briefly elaborates on three commonly used valuation methods.

2.1 Organizing for innovation

Companies aim to create shareholder's value, both in the short- and long-term. In order to create value on the short-term, companies require innovation projects that assure sustainable growth by focusing on current processes and conducting incremental product innovation. On the other hand, when firms fail to revitalize their future competitive position through development of new businesses and products, they risk eventual decline (Rice et al., 1998). Therefore, it is important to have innovation projects in place that focus on the short- as well as on the long-term.

When highly innovative projects are compared against smaller, lower-risk projects, the latter ones are typically considered to be more profitable. In general, a discontinuous innovation project is badly aligned with the operating's business rewards structure, due to its high levels of uncertainty, long time horizon, and relatively large investments (Rice et al., 1998). Thus, these projects contain high levels of risk (see Appendix I for a difference in definition between uncertainty and risk). So although risky innovation projects might have a potential long-term benefit for the firm, within a short time horizon the impact is negative, resulting in a preference for short-term projects. This then leads to an unbalanced project portfolio. Therefore, due to the differences between short- and long-term objectives, companies organize their innovation process through a categorization of projects into different innovation types, in order to assure a balanced portfolio.

The problem in innovation literature is that there is no unambiguous description of innovation types and there appears to be a shortfall in empirical work focusing on radical and really new innovations (Garcia & Calantone, 2002). Innovation projects are characterized as incremental, radical, breakthrough, disruptive, continuous, discontinuous, etc.. Thereby, the level of innovativeness depends on the particular view towards an innovation project, e.g. based on a company or industry perspective. Garcia and Calantone (2002) conclude that, after an extensive literature review, technological innovation projects can be categorized into three types, namely radical, really new and incremental. This classification is based on the level of technological and market discontinuity, whereby radical innovation projects, for example, score a high level of discontinuity on both factors.

Philips Research distinguishes four types of innovation projects, namely: (1) sustaining innovation, (2) game changers, (3) adjacencies and (4) emerging business activities (EBA). The first two types of innovation projects aim to serve the core of Philips and focus on markets where Philips is already active, with the goal to maintain and increase market share. The other two innovation activities aim to create new value spaces, in order to give Philips the opportunity to grow outside its core business and to reposition itself. See Table 1 for an overview.

Table 1: Overview of the four types of innovation projects at Philips Research

Core		New Value Spaces	
Sustaining Innovation No disruption to the market and competitive landscape; only incremental changes or portfolio extensions.	**Game changer** Disruption of market and competitive landscape via radical innovation; intent to significantly increase market share.	**Adjacency Program** New business creation in sector and business group scope. The proposition does not replace current Philips products.	**EBA** New business creation in Philips' scope, outside current sector scope.
Example A new product model of a Philips electrical shaver.	**Example** Philips' Senseo coffee pads system, in collaboration with coffee producer Douwe Egberts.	**Example** Chronic disease care at home which could reduce the frequency of hospital visits for chronic disease patients.	**Example** Development of intelligent ceilings by Philips Lighting through sensors and energy demand response triggers.

First, (1) sustaining innovation is a type of innovation that does not disrupt the existing market and competitive landscape. The objective of R&D projects within this category is to stay competitive in Philips' current markets and most often consist of incremental product changes or incremental portfolio extensions. Second, (2) a game changer is a more radical type of innovation activity. The objective of a game changer is to radically disrupt the market and competitive landscape with the intention to significantly increase Philips' market share. Third, (3) adjacencies are innovation projects which are new to Philips but leverage technologies or markets which belong to the core of Philips' activities. With an adjacency a new product-market combination is created, still falling within the scope of Philips' current business (i.e. within healthcare, consumer lifestyle or lighting). In contrast to adjacencies, (4) EBAs aim to create businesses outside Philips' current scope. So EBAs focus on launching innovation in markets outside healthcare, consumer lifestyle or lighting.

Due to this classification of innovation projects, there is an increased need to manage and evaluate different types of innovation projects, in order to create a balanced project portfolio. The following part discusses management of multiple types of innovation projects.

2.2 Project portfolio management

As stated in Section 1.1.1, having the necessary resources in place, and ensuring that these resources are properly dedicated and focused, is one of the strongest discriminators between best-performing businesses and the rest (Cooper et al., 2001). A company aims to find the best R&D project portfolio within its financial budget and technical capabilities that would provide a unique competitive edge for the corporation in the next decade (Yu, 2006). Although many organizations realize they can improve performance, reduce risk and earn a greater return on investments (ROI) through better portfolio management, they have difficulties with implementing such a system. Thereby, there is no industry best-practice (Cooper et al., 2001). A successful portfolio management strategy must comprise an end-to-end framework that methodically guides organizations from project selection through execution.

A main challenge for companies is that project portfolio management (PPM) decisions are made in a dynamic environment. Over time new information is obtained on currently active projects, the competition and the market. Thereby, new opportunities are discovered which have to compete for resources with existing projects. Portfolio decisions are based on possible future events and opportunities. Naturally, the information available today to make such decisions contains a lot of uncertainty and can be unreliable, resulting in an increase in complexity of decision-making. The problem at hand then becomes how both existing and new R&D projects should be valued, taking into account existing uncertainties and interrelations.

A benchmark by Novay (2011) shows that the performance of Philips Research's project portfolio is high when compared to companies in the same industry. At Philips Research, PPM is organized on the basis of an annual planning cycle and PPM is tightly related to strategy (Filippov et al., 2010). Especially this strategic alignment at Philips Research outperforms other companies, where on the other hand the allocation and use of resources is below industry average.

Availability of financial resources is limited and allocating these resources effectively and efficiently is a main driver of PPM. First, about 60% of Philips Research's budget comes from the three business sectors of the parent company. Another part of the funding is provided by the Board of Philips Group, which is meant for research that does not coincide with the existing business sectors, but what represents long-term (new business) opportunities. The amount of money required for all proposed projects is often substantially higher than the available budget. Therefore, the project proposals of each program go through a formal selection process. The program managers are responsible for the strategic alignment of their portfolio with the business and the selection process to compose the portfolio. The portfolio is evaluated annually along multiple criteria; e.g. strategic fit, its potential for improving the company's competitive position, balance between types of projects, probability of success and time to market.

2.3 Project management

An integral part of PPM is project execution. Project management is performed through a stage-gate process whereby a project is reviewed at each gate. After a review moment it is possible to abandon a certain project, which can have a variety of reasons (e.g. technological infeasibility or a negative market analysis). In this section management of individual innovation projects is discussed. First, Stage-Gate management at Philips Research is described and second, the evaluation of innovation projects is discussed.

2.3.1 Stage-Gate management

A best practices study by the Product Development and Management Association (PDMA) shows that the best performing companies integrate their innovation strategy across all levels of the firm. About 69% of those companies have a formal, cross-functional process for NPD

(Barczak, Griffin, & Kahn, 2009). Having a formal process is no longer a differentiator, and better performers are likely to have moved from simpler Stage-Gate® processes to third-generation types of NPD processes. Companies like Procter & Gamble (P&G), Emmerson Electric, ITT and 3M proved to apply the Stage-Gate management process in a profitable manner (Cooper, 2008). Cooper (2008, p. 214) defines a Stage-Gate process as follows:

"…a conceptual and operational map for moving new product projects from idea to launch and beyond – a blueprint for managing the new product development process to improve effectiveness and efficiency".

A Stage-Gate consists of a series of stages where the project team works on a certain phase of the project and obtains the needed information for analysis of the project. Each stage is followed by a gate, where the company makes a decision on whether or not to continue with the project, the so called go/no-go decision (Cooper, 2008). The exact application of the Stage-Gate model depends on the company and the processes within that company.

Philips Research also adopted a Stage-Gate management system (see Figure 1) and it consists of the following stages: Exploratory, Proof-of-Concept, and Development (also called, ECD). This management system focuses on the early stages of the NPD process and stages beyond Development (e.g. Testing & Validation, Launch and Post-Launch Review) are out-of-scope for Philips Research. At the end of each stage, at a gate, a project is evaluated on key criteria and a go/no-go decision is made. Within a stage different phases are distinguished and a project is checked for progress on certain milestones. Milestone success criteria have to be passed in order to continue to the next phase. The three stages are discussed below.

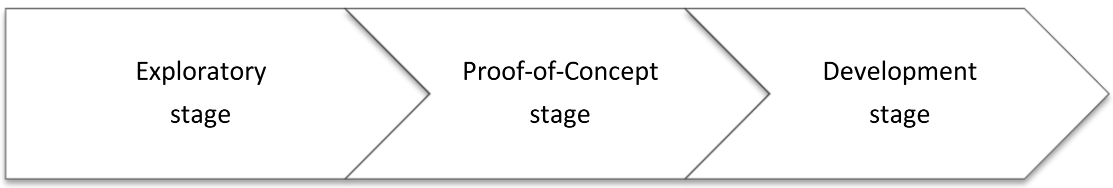

Figure 1: Stage-Gate management system as adopted by Philips Research

Within the Exploratory stage there is just one phase, namely the landscaping & opportunity recognition phase. The main goal of the exploratory stage is to generate a field of commercially promising ideas, which can be transformed into research projects. Tasks within this stage include, for example, a scan of technological & market trends and an analysis of the competitive position in possible markets. The deliverable of this stage is a research/business proposition which has to be further evaluated.

The second stage, Proof-of-Concept, consists of three phases, namely (1) technology creation, (2) principle creation and (3) function creation. This stage's aim is to understand the full scope and limitations of new ideas through laboratory research and to find a potential (technological) factor which could lead to abandonment of the project. In this stage all key technological issues have to be solved and the necessary performance data has to be gathered in order for engineers and marketers to continue to the next stage. The Proof-of-Concept stage delivers a validated business plan. Finally, this plan is assessed on whether there is a validated end-user insight and a validated market, and whether the selected product concept demonstrates a new product function.

In the third stage, Development, three phases are distinguished: (1) product concept, (2) product design and (3) engineering. Development takes place at one of the three business units of Philips (Healthcare, Lighting or Consumer Lifestyle). During the Development stage the first real product prototype is created and the product concept is elaborated upon in more detail. Thereby, detailed market studies are developed, including beta testing of the product in order to match product features with the customer, and sales are forecasted. Furthermore, pilot plants are built to test production and for healthcare products clinical trials are performed (if required). After the Development stage the product would be ready for commercial launch.

After development, the commercialization of the product takes place. Commercialization is not considered to be a separate stage of the Stage-Gate process, but it consists of the formal product launch and the growth phase of the product lifecycle.

2.3.2 Project evaluation

The strategic question facing senior management is whether to authorize the required R&D expenditures for a certain innovation project. Metrics can help to ensure that appropriate levels of consistency and objectivity are applied when evaluating different projects. However, R&D managers recognize that the evaluation process for discontinuous innovation projects differs significantly from that of incremental innovation projects (Rice et al., 1998). Valuation of innovation projects in the early stages of research is found to be extremely difficult due to preliminary information about the market and the, to be developed, technology.

Philips Research currently uses an evaluation scheme, in conjunction with their Stage-Gate management system, which evaluates projects at the end of each stage on multiple milestones. Due to preliminary information in the ECD stages, as mentioned above, and a lack of financial analysis tools, limited financial project evaluation is conducted at Philips Research.

Literature discusses the use of financial methods for project evaluation in an innovation context quite extensively. Cooper et al. (2001) find that 77.3% of businesses use a financial approach in portfolio management and project selection, where 40.4% use a financial method as the dominant approach. However, best performing companies rely much less (35.9%) on financial models and methods as a dominant portfolio tool than does the average company. Killen et al. (2007) confirm that financial methods are not the best primary PPM method. Cooper et al. (2001) also found that 47.5% of the best performing companies rely on three or more portfolio management techniques to select projects and to manage their portfolio. Therefore we may conclude that it is best to rely not solely on financial methods for project selection and portfolio management. However, it is important to use a combination of methods. It is beneficial for Philips Research to gain insight into the value distribution of market outcomes and to use this information as a base for decision-making in project selection. Thereby, also the process of obtaining market information about a certain business case can be valuable.

2.4 Valuation methods

Many financial methods have been developed to evaluate projects, businesses and investment decisions. This part provides a brief description of the most commonly used valuation methods in an innovation context, namely, net present value method, real options analysis and Monte Carlo simulation.

2.4.1 *Net Present Value*

A mainstream method to value investment decisions is the net present value (NPV) or discounted cash flow (DCF) method. When applying the NPV method, first, the present value of expected free cash flows is calculated. Then the present value of the investment costs is calculated and whenever the difference of the two is positive an investment should be made (Titman & Martin, 2011). Although underlying assumptions (e.g. discount rate, growth rate) are important and perhaps hard to determine, the basic idea is fairly simple.

The advantages of the NPV method are its relatively limited complexity and the ease of application in practice. However, according to Hayes and Gavin (1982) the NPV method undervalues investment opportunities by not taking into account project interdependencies and using high discount rates to hedge against uncertainties. Thereby, the NPV method ignores the value of creating options (Dixit & Pindyck, 1995). For example, an investment with a negative NPV might open up other investment opportunities when market conditions are favorable, which might make it a worthy investment. So the NPV method is unable to capture growth options from sequential investments (Myers, 1977).

Dixit and Pindyck (1995) state: *"The NPV rule is easy, but it makes the false assumption that the investment is either reversible or that it cannot be delayed."* So NPV assumes that the investment can be undone and the expenditures can be recovered in case market conditions are worse than expected, *or*, when the investment is irreversible, the firm can only invest now and one time only (Dixit & Pindyck, 1994). However, in reality irreversibility and the option to delay are important characteristics of investment decisions. Therefore, the ability to delay irreversible investment expenditures can profoundly affect the decision to invest (Dixit & Pindyck, 1994).

2.4.2 *Real options analysis*

Real options analysis is another method to value investment decisions. The real options approach should be a preferred method when (1) the environment is uncertain and when (2) managers can respond to changing circumstances by adjusting the way of implementation and/or management of the investment (Titman & Martin, 2011). The latter one, which can be described as flexibility, creates a beneficial asymmetry in the distribution of project value returns since upside opportunities can be fully exploited while downside losses are mitigated by not proceeding the project (Trigeorgis, 2005).

Management has to decide upon whether or not to commercialize the project, i.e. decide whether or not to make a major initial investment. Since the moment of launch might be a few years from now, the company is actually holding a call option on the investment, whereby the R&D investment costs can be considered to be the option premium. At the end of each stage of the R&D process, management has the option to continue, defer or end the project. In case of multiple stages, the valuation can be considered to be a compound option (i.e. a call option on a call option).

Flexibility to adjust your decision when more information is available may be valuable and real options analysis is an appropriate approach for sequential decision-making. Real options analysis is recommended to be more adequate than the conventional NPV method when valuing long-term R&D projects, which contain high levels of risk (Doctor et al., 2001).

Decision-makers who are aware of NPV's shortcomings determine ranges of values, using for example scenario analysis (Leslie & Michaels, 1997). Although the application of high, low and medium scenarios helps to bound uncertainty, it does not include variance into the valuation (Leslie & Michaels, 1997). Furthermore, real options analysis proved to produce better valuation results than other methods (e.g. Fernandes et al., 2011). On the other hand, according to Steffens and Douglas (2007) real options valuation is not applicable for the valuation of risky technology investments or ventures. Real options valuation takes into account market risk, while these types of projects mainly consist of firm specific risk. However, Steffens and Douglas (2007) do emphasize that 'real options thinking' is a valuable approach when valuing risky technology projects or ventures.

Matthews (2009) defines real options thinking as: *"an approach to project planning that extends the investment and risk modeling tools and methods, to provide engineers with a solid financial economic construct to incorporate into strategic thinking and contingency planning."* When taking a 'real options thinking' approach, one applies the real options logic without necessarily carrying out the detailed calculations. Furthermore, Mathews (2009) states a few rules of thumbs when applying real options thinking:

1. High level of uncertainty, so that it is sensible to wait for more information.
2. High level of uncertainty in order to considerate flexibility.
3. The investment decision is contingent on material assumptions or events.
4. The technology or product profitability is not in the current offering, but a future extension or derivative product with possible future growth.
5. Project updates and mid-course strategy corrections are anticipated.

2.4.3 Monte Carlo simulation

Another powerful method to value investment decisions, in an uncertain environment with managerial flexibility, is simulation. Boyle (1977) was first to introduce the Monte Carlo simulation method. In this method the process of generating returns on the underlying asset is simulated. According to Schwartz (2003), simulation can be considered applicable for valuation of R&D projects and patents using a real options approach.

Monte Carlo simulation has the ability to include hundreds of scenarios, including the ones with a low probability, which are potentially impactful on the project outcome. First, during a simulation round, at the end of each front-end stage there is determined whether the project continues to the next stage. This go/no-go decision is based on the given success probability.

Second, Monte Carlo simulation makes successive random draws of values from the input parameters, i.e. for each simulation run the combination of the project's input values is randomly generated. The Monte Carlo simulation generates multiple profit scenarios, whereby each scenario is valued using NPV mathematics.

3 Research approach

In this chapter the research approach is discussed. First, based on the previous chapters, the problem under study is defined in Section 3.1. Then, based on this problem definition the research questions and objectives are formulated in Sections 3.2 and 3.3, respectively.

3.1 Problem definition

Chapter 2 shows that it is a challenge for companies to develop a high-value and balanced project portfolio. Within Philips Research, the optimization of its PPM processes is a main subject of debate. In order to evaluate an entire portfolio of innovation projects, an assessment of individual innovation projects is required. Philips Research is progressing in the development of valuation methods for different types of innovation projects, starting with the creation of a financial valuation tool for adjacencies (Wolthuis & Wolf, 2013). The next step for Philips Research is the development of a valuation model for game changers.

Game changers contain a high level of uncertainty about future market outcomes, because of their innovativeness level. Though, since game changers operate in Philips' current business scope, a related market exists through which a lot of market data can be obtained. At the moment this market data is not fully incorporated into the decision-making process for project prioritization and selection of game changers (only at the end of the Development stage). Based on the project context described in Chapter 2, the problem is stated as follows:

> *There is insufficient understanding on the value drivers and expected financial performance of game changers, in order to support rational decision-making for project prioritization and selection.*

3.2 Research questions

First, one main research question is formulated that functions as the driver of the research project and which covers the entire problem context:

> **Main research question**
>
> *How to assess the financial attractiveness of game changers, in order to support rational decision-making for project prioritization and selection?*

In order to answer this research question, it is subdivided into three sub questions.

I. *What are the (financial) characteristics and value drivers of game changers?*

At first it is important to gain further insight in the type of early stage research projects under study, namely game changers. For this question the characteristics of a game changer are determined in order to define different types of game changers and to figure out its value drivers.

II. *What financial approach should be used to assess the financial attractiveness of game changers?*

The aim of the second question is to select a financial approach that allows for a valuation of game changers, while taking into account the characteristics of this type of innovation project (i.e. a method that takes into account high levels of technology risk as well as uncertainty about the impact of the innovation on the market (Δ)). The final goal is to determine the financial value-added of the innovation in comparison to the current market.

III. *How to evaluate a portfolio of game changers based on the financial attractiveness of game changers?*

A revealing task is to undertake a review of the current portfolio of active projects. First, the implementation of the valuation model at a portfolio level, in order to assess the value of the project portfolio, is discussed. The project portfolio can be characterized along key dimensions, which include the expected financial rewards and, for example, probabilities of success, time to completion or riskiness of the portfolio.

3.3 Research objectives

Based on the research questions a couple of research objectives are derived, namely:

I. *Provide insight into the characteristics and value drivers of game changers.*

II. *Develop a model to assess the financial attractiveness of game changers.*
   a. The model has to take into account the characteristics of game changers.
   b. The model has to be theoretically supported to create an academic basis.
   c. The outcomes of the model have to be valid.

III. *Develop a tool that allows Philips Research to assess the financial attractiveness of game changers.*
   a. The tool has to be easy to understand and practical in use.
   b. The tool requires as few input parameters as possible.

IV. *Provide insight into the financial evaluation of a portfolio of game changers.*

Thereby, the main aim of the Master's thesis project is that the outcome of the project is relevant and useful for Philips Research, while guaranteeing an academic level of study.

4 Game changers

As discussed in Section 2.1, Philips Research distinguishes four types of innovation projects, namely sustaining innovation, game changers, adjacencies, and emerging business activities. The aim of this Master's thesis project is to develop a financial valuation model for game changers. Recall the definition of a game changer as stated by Philips Research:

"The market and competitive landscape will be disrupted via a radical innovation, with the intent to significantly increase our market share."

In this chapter game changers are further evaluated. First, Section 4.1 provides a general description of game changers to obtain more insight into these radical innovation projects. Then, Section 4.2 describes the characteristics of game changers and Section 4.3 discusses value creation of game changers.

4.1 General description

The definition of a game changer, as developed by Philips Research, is not commonly referred to in literature. Thereby, as stated in Section 2.1, there is no unambiguous description of innovation types (Garcia & Calantone, 2002) and the level of innovativeness depends on the particular view towards an innovation project. For example, in a certain context game changers could be considered as radical innovation since these projects have a potentially large impact for Philips and on the general market. On the other hand, game changers can also be defined as incremental innovation, since these projects serve the core market and are related to existing products (e.g. a line extension). These different views make it difficult to place game changers in current literature. Therefore, instead of defining a game changer as e.g. disruptive, discontinuous or radical from a literature point-of-view, it is more useful to determine the characteristics of a game changer and to be able to classify a project as a game changer based on these characteristics.

According to Myatt (2010) a game changer creates an extreme, disruptive advantage or improvement. Myatt (2010) introduces SMARTS, an abbreviation for Simple, Meaningful, Actionable, Relational, Transformational, and Scalable, as an overview of the characteristics of a game changer. First, along the definition of Myatt (2010), most (not all) game changers are simple, which means realistic, cost effective, quick to adopt, and fast to implement. Second, game changers are meaningful due to a significant increase in value to the core business. Third, it is important that an idea can be commercialised, that it is actionable. Fourth, game changers enhance, extend, and leverage existing relationships, but also create new ones. Real game changers take into account the power of people and relationships, and game changers embody this in both their construction and implementation. Fifth, game changers are transformational, which means that a game changer causes change. Myatt (2010) states that it is impossible to experience improvement without transformation. Finally, a game changer should be scalable. Game changers are built with velocity and sustainability in mind and real game changers build upon themselves to catalyse other opportunities.

Rice et al. (1998) define a game changer as a discontinuous innovation project that has the potential (1) for a 5-10 times improvement in performance compared to existing products, (2) to create the basis for a 30-50 percent reduction in cost, or (3) to have new-to-the-world performance features. According to Rice et al. (1998) GE's digital X-ray, GM's hybrid vehicle, IBM's silicon-germanium devices and the Otis bi-directional elevator, are examples of game changers. These examples show the development of new technologies that did not lead to discontinuity in the existing market.

Overall, a game changer project has a relatively high level of risk in the mature phase, but there is also the potential to generate high returns. Game changers are innovation projects that have the potential to provide Philips with an 'unfair advantage' over competitors in Philips' core markets, i.e. creating an area of business that the competition simply cannot emulate. These advantages can relate to the development of completely new technology or to the execution of an innovative business model. Game changers based on technology and business model innovation are briefly discussed in Sections 4.1.1 and 4.1.2, respectively.

4.1.1 Technology-based game changer

A game changer can arise through the creation and exploitation of new technology. Anderson and Tushman (1991) define technological discontinuities as those rare, unpredictable innovations which advance a relevant technological frontier by an order-of-magnitude and which involve a fundamentally different product or process design. Technological discontinuities have been identified as major triggers of change in fast-evolving industries. Sabatier et al. (2012) note that technology discontinuities in an existing industry are confronted with an existing industrial organization, established market relationships and predictable collaboration patterns.

Illustrative example: Kodak and digital photography

Digital photography is considered to be a technology-based game changer. Sony introduced the first digital camera in 1981, but it took almost two decades before digital imaging took off. At first, too low capacity for digital image storage and too low home ownership of display devices held back the usage of digital cameras (Ansari & Krop, 2012). However, when the quality of images, storage capability and diffusion of home computers improved, the *'game'* in the photography industry changed significantly.

Although Kodak developed and patented many of the components of digital photography, this transformational technology has had a major negative impact for Kodak, because it failed to take advantage from the new technology (Lucas Jr. & Goh, 2009). Kodak underestimated the speed with which digital photography would be adopted and middle managers impeded the conversion from film to digital. Thereby, when photography moved from film to digital, the market landscape changed because of the entrance of new competitors, like HP, Lexmark, and Canon (Lucas Jr. & Goh, 2009). Kodak could not keep up, and in January 2012, it filed for bankruptcy. Lessons learned, it is important for management of incumbent companies to recognize the threats and opportunities of transformational technology, and to have the required capabilities for change in place.

A technology-based game changer can create its value through development of new-to-the-world performance features or through a significant reduction in costs. Technology innovation that results in a cost reduction can relate to both the product as well as the process (e.g. T-Ford). Not surprisingly, technology-based game changers possess high levels of technology risks. An illustrative example of a technology-based game changer is provided in the textbox.

4.1.2 Business Model-based game changer

As Chesbrough (2010, p. 354) states: *"A mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model."*

A game changer is not exclusively based on the development of new technology. It is also possible to generate high returns through innovation of the business model. Baden-Fuller et al. (2010) confirm an increased interest in the business model concept and emphasize the importance of business models for managers. The choice for a certain business model is typically considered as a key component of success.

An industry's dominant logic is defined as the general scheme of value creation and capture shared by its actors (Sabatier et al., 2012). The introduction of new business models challenges dominant industry logics. An example of a game changer based on business model innovation is that of online retailer Amazon. Their online business model is superior to that of competitors, since without corresponding costs of retail locations, Amazon has the opportunity to compete with prices almost impossible to match. Therefore, because of Amazon's competitive advantage it would be difficult to go after Amazon. Other business model innovations can be based on collaboration with other firms, as showed by Philips and coffee producer Douwe Egberts, who disrupted the private coffee market through the development of coffee machine Senseo®.

Furthermore, technological discontinuity and business model innovation is closely related, since a technological discontinuity has the potential to lead business model innovation (Sabatier et al., 2012). For major technological breakthroughs more time is needed to build and deploy the required assets and capabilities. Once everything is in place and new business models are created, the dominant logic is challenged (Sabatier et al., 2012). So it is possible that a game changer is based on technology as well as business model innovation. For example, Apple convinced most large incumbent labels to sell their content on iTunes (business model), while simultaneously introducing a successful playback device (technology), the iPod, on the market.

4.2 Characteristics

The aim is to predict the value of a game-changing business case, while the projects for that business case are currently in one of the ECD stages (see Section 2.3.1). It is important to distinguish between the front-end (ECD stages) and back-end (business/market) of innovation, due to its different characteristics. In Sections 4.2.1 and 4.2.2 the characteristics of game changers in the innovation front- and back-end are discussed, respectively.

4.2.1 Innovation front-end

First, game changers follow an ECD process (as described in Section 2.3.1), like other types of innovation at Philips Research. Due to extremely high uncertainties in the Exploratory stage, it is wise to only conduct a financial analysis of game changers during the Proof-of-Concept and Development stage. Especially during the Development stage, it is possible to make more reliable predictions of the future market, increasing the overall reliability of valuation outcomes. Second, Wolthuis and Wolf (2013) identified four types of risks apparent for adjacency projects, namely:

1. Technology risk: essential technological and scientific issues cannot be overcome.
2. Value proposition risk: no application for the technology, no market/end customer need, no understanding of technology benefits by the market/end customer and/or no fit with market.
3. Competitive risk: competitors claim a significant section of the market, resulting in a lower market share and high level of margin pressure.
4. Go-to-market risk: the product or service envisioned does not reach its potential customers, including factors as sales force capabilities, distribution channels, manufacturing capabilities and customer support.

Hereby, technology and value proposition risks are the main risk factors during the ECD stages, whereas competitive and go-to-market risks also appear during the growth stage. Since game changers go through the same stages as adjacency projects, the same categorization for risks involved is adopted for game changers. However, game changers have the characteristic of very high levels of uncertainty during the ECD stages. Dependent on whether the game changer is based on technology and/or business model innovation, the levels of technology or value proposition risk will be even higher, respectively. Thereby, compared with sustaining innovation projects, the required R&D investments during the early stages of innovation are relatively large for game changers.

4.2.2 Innovation back-end

Foster (1986) suggests that an industry evolves through a succession of technology cycles, whereby each cycle begins with breakthrough innovation (see Figure 2 for a representation). The new technologies have technical limits much greater than those of the previous generation technology. At first, the new technology displaces its predecessor during an era of substitution. When a dominant design is in place, i.e. the maturity phase is reached, a period of incremental change starts. During this maturity phase there is a shift in focus from competition to market segmentation and lowering costs (Anderson & Tushman, 1991). So when technology evolves, the nature of market competition changes as well, which is considered to be incremental or radical. In case of incremental change, the existing firms can keep up with competitors, where with radical change a more drastic transformation is required for existing firms to persist (Miranda & Lima, 2012).

Furthermore, Miranda and Lima (2012) state that technology evolution is essentially a continuous stream of discontinuities, where one technology is replaced by another following a time behaviour pattern described by an S-shaped curve. They show that there can be a significant difference in take-off time between new technologies, due to different innovation processes and technical requirements.

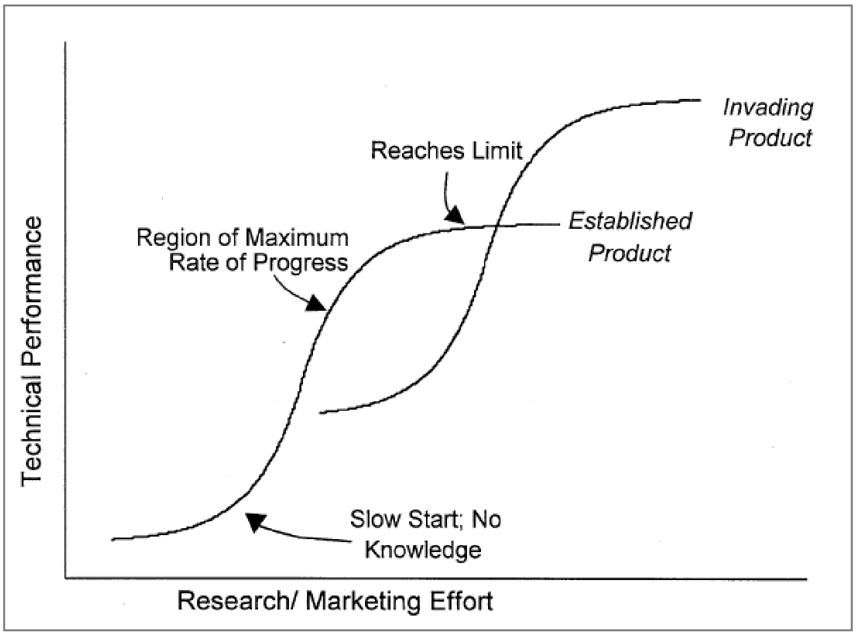

Figure 2: Technology/Marketing S-curve (Foster, 1986)

Game changers also follow a certain industry cycle, including a period of adoption, maturity and decline (i.e. a new era of substitution arises). In the back-end of innovation a game changer is characterized by the time of each period, which depends on the particular game changer and corresponding industry. Also the way value is created with the game changer for Philips, through an increase of market share, increase in price or decrease in costs, is an important characteristic of the back-end, as will be discussed in Section 4.3.

In an industry where Philips has agreed upon cross-licenses with other companies, it is more difficult to create a game changer for Philips. In such an industry it is harder to create a competitive advantage, since Philips has to share its intellectual property with other companies, resulting in a fast follow-up by those companies. In the end, a game changer can only be considered to actually be a game changer when it creates a major competitive advantage for Philips and thus, has significant impact on Philips' profitability (i.e. a game changer does not depend on its level of disruptiveness on the market).

4.3 Value creation

A value driver is an important factor that determines or causes an increase in the value of a project. It is relevant to determine the value driving factors of a game changer, in order to use these factors as input parameters for the valuation model. This section describes the factors of value creation and provides insight into the different scenarios of value creation.

4.3.1 Value drivers

The goal of innovation projects is to create value, whereby a game changer has the *potential* to create a significant amount of value. In order to create value with a game changer, the sum of the present value of future free cash flows (FCF) attributed to that particular game changer, has to be positive. This includes the subtraction of present values of required investments for the particular game changer.

The FCF as contributed by a certain game changer can be considered as the delta (Δ) of free cash flows, i.e. the difference in free cash flows between current conditions and conditions including the game changer. For each year a forecast is required of the expected FCF. Appendix II gives an overview of the determination of FCF in a certain year. Based on the information in Appendix II, the most important factors for value creation are determined. These factors are:

a) Increase of sales volume (#)
b) Price premium per product (€)
c) Cost saving per product (€)

The first factor represents an increase of total sales volume through the introduction of the game changer. The latter two factors result in an increase of the product margin (€), which is the difference between the selling price per product (€) and the cost per product (€). Either a price premium leads to an increase of revenues, or a cost saving decreases costs of goods sold (COGS), both scenarios resulting in an increase of the gross margin, which is given by:

$$\text{Gross Margin} = \frac{\text{Revenues - COGS}}{\text{Revenues}} = \frac{\text{Sales Volume} \cdot \ \ \text{Price - Cost}}{\text{Sales Volume} \cdot \text{Price}} \tag{1}$$

Every game changer might create its value differently, through either one of the factors or through a combination. The next section discusses three scenarios of value creation with a game changer.

4.3.2 Scenarios of value creation

The impact of a game changer on the market depends on (a combination of) factors of value-creation. Three scenarios are described, whereby it is expected that most game changers can be categorized into one of those scenarios.

Scenario one, presented in Figure 3, represents the situation without a change in total market share for Philips and also the total potential market remains equal. Although the total market share does not change, the introduction of the game changer leads to a reduction of Philips' existing market share, i.e. cannibalization of Philips' existing market. At the start of the mature stage, the increase of market share of the game changer is offset by a decline of Philips' existing market share. However, in this case value is not created through an increase of market share, but through an increase of gross profit margin. This scenario game changer can create significant value as long as the increase in margin is large enough to cover the investment costs.

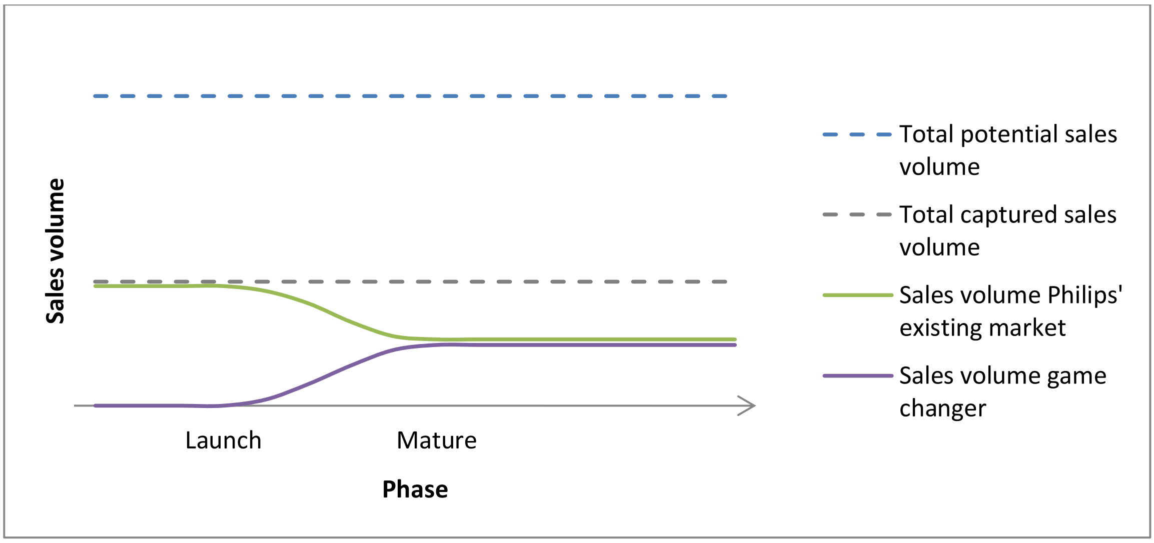

Figure 3: Scenario 1, total market share remains equal when introducing game changer

The second scenario (see Figure 4) represents the case where Philips' existing market remains equal, but where the total market share increases due to the introduction of the game changer. Thereby, the total potential market might also increases because of the game changer. So there is no cannibalization of Philips' current market and the value is created through an increase of market share, ceteris paribus.

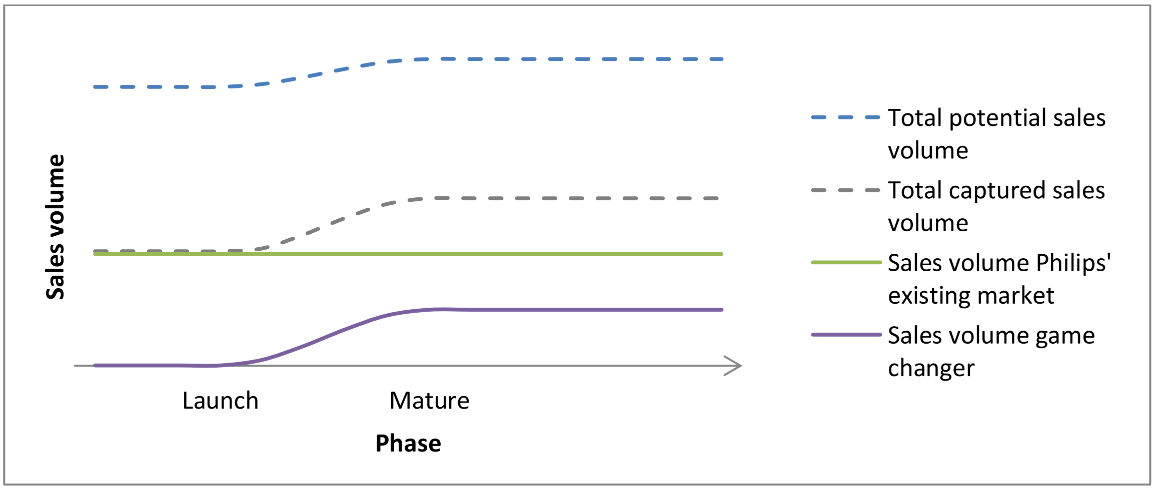

Figure 4: Scenario 2, increase of total market share with an equal Philips' existing market

In scenario three (presented in Figure 5) the total market share of Philips increases, but the market share of Philips' existing market declines. The decline of Philips' existing market share is compensated by a significant increase of market share of the game changer. Hereby the sales volume of the total potential market might also increases. For example, imagine you have a shop with only bikes and you would invent the electric bicycle. When you introduce the electric bicycle to the market and in your shop, you would cannibalize your market of regular bicycles. On the other hand, your total potential market increases since people who would initially buy a scooter, might now choose to buy an electric bicycle.

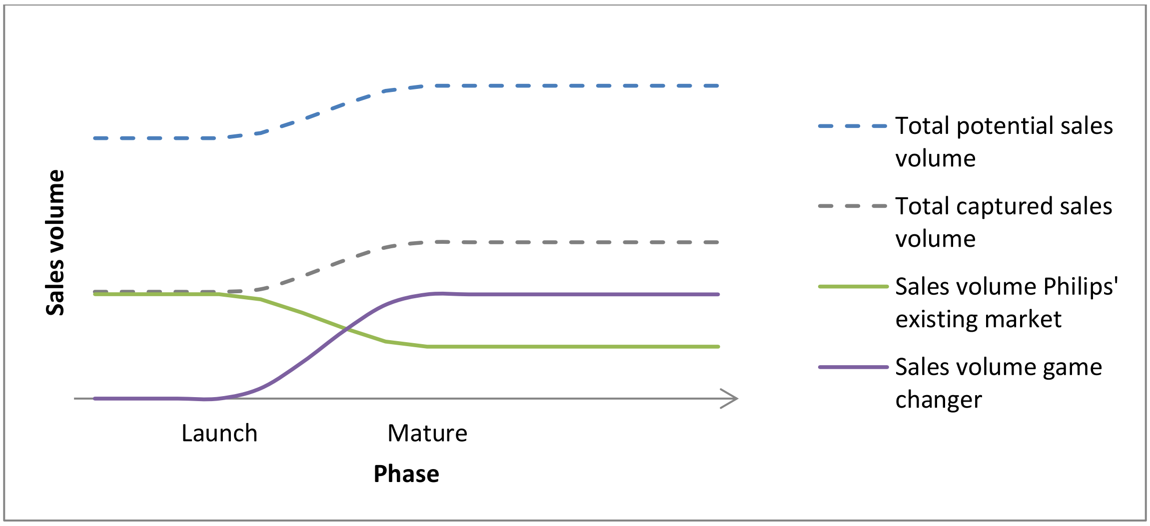

Figure 5: Scenario 3, increase of total market share with a declining Philips' existing market

Off course, these scenarios are not exclusive and different combinations are thinkable. For example, it is possible that a new technology leads to an increase of sales volume, while it also results in an increase of profit margin. Therefore, it is important that the valuation model takes into account the three factors of value creation independently, but also provides the opportunity to select a combination of factors.

5 Valuation model

The aim of this study is to develop a decision-support tool for R&D investment decisions. This tool should gain insight into the potential financial performance of game changers, while taking into account the characteristics and value drivers of game changers as discussed in Sections 4.2 and 4.3, respectively. Chapter 5 discusses the valuation model for game changers, with a general description in Section 5.1, a list of assumptions in Section 5.2 and an overview of the model's calculations in Section 5.3.

5.1 General description

A valuation model is developed, allowing for a financial valuation of game changers. The model takes into account high levels of technology and market uncertainty, both in the project's front- and back-end. Also managerial flexibility, which emerges through the option to abandon a project at the end of a certain stage, is included in the model.

First, as seen in Section 4.2.1, the innovation front-end consists of three stages and the probability on successful completion of a stage is based on four types of risk (technology, value proposition, competitive and go-to-market risk), as developed by Wolthuis and Wolf (2013). Incorporating the success probabilities (P_n) of each stage corresponds to a go/no-go decision at the end of each stage. Thus, including success probabilities indirectly takes into account technology uncertainties on the one hand, while on the other hand taking into account managerial flexibility through the option to abandon a project based on new market information. Implementing a stage-gate management system with success probabilities per stage, results in a decision tree (although, it appears more like a branch). See Figure 6 for a conceptual representation of the valuation model.

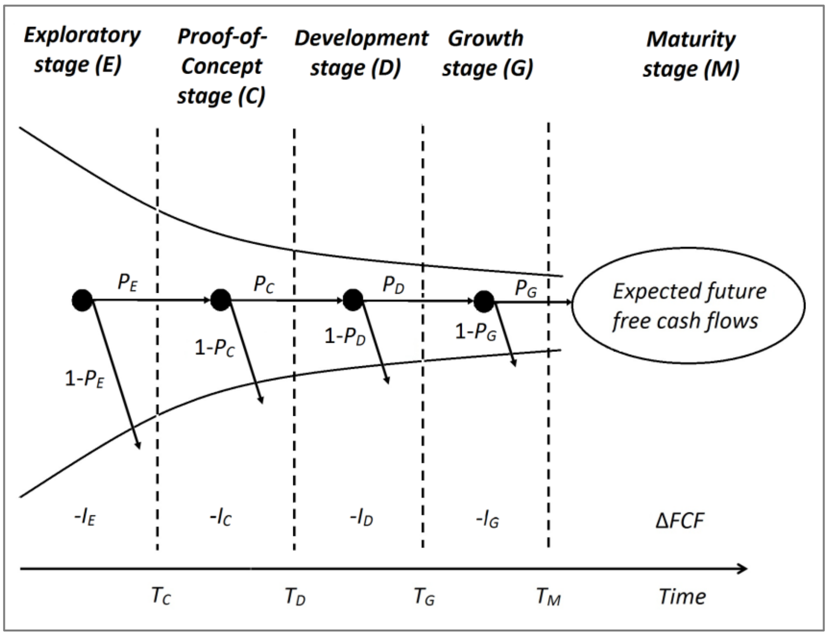

Figure 6: Conceptual representation of the risk-adjusted valuation model

The high-technology market is very dynamic due to high levels of variation in unit sales and price forecasts, which are based upon assumptions about the market (Mathews, 2009). Within such an environment, it is difficult to forecast future market outcomes. Therefore, it is a challenge to determine the financial attractiveness of an innovation project prior to investing in expensive product development and launching marketing efforts. Especially for game changers, the need for information required for long-term planning is probably higher because of high levels of risk and significant investment costs. NPV analysis is often based on a most likely scenario. Due to the high level of uncertainties, there are good reasons to be skeptical about a decision based solely on a most likely scenario, since it most probably holds a wrong value. Therefore, the model includes three scenarios, namely (1) a pessimistic (worst case) scenario, (2) a most likely scenario, and (3) an optimistic (best case) scenario. This results in a range of possible outcomes, providing a platform for discussion.

In contrast to the front-end, the four types of risk used during front-end stages are not used during the product lifecycle. Only a success probability for the growth stage is included, since the growth stage might reveal unwillingness in the market for innovation adaptation or strong competition, both leading to failure of reaching the expected sales potential. After a successful growth stage it is highly unlikely that a product is taken out of the market (see Figure 6 for an overview). However, the impact of commercialization depends on the values of input parameters, which are highly uncertain. Therefore, uncertainty of market outcomes is taken into account by including a range of possible scenarios.

While three different scenarios are analyzed with the model, the model should include as few input parameters as realistically possible. Thereby, input parameters which are constant for all game changers (e.g. tax and cost of capital) are brought to the background of the valuation tool in order to reduce the number of input parameters for the user. Also, a model feature that allows for sector selection makes it easy for a user to determine sector specific input values (e.g. Earnings before Interest, Tax and Amortization (EBITA) margin and gross profit margin). On the one hand this increases easiness of use, while on the other hand increasing reliability of input parameters. The latter benefit is reached through a decrease of uncertainty in input parameters due to partial removal of decision-maker's subjectivity on the value of input parameters.

Since this study focuses on game changers, for which an existing market exists, it is important to take into account the influence of the game changer on the existing market. Therefore, an analysis of Philips' existing market without game changer, as well as with game changer, is conducted. When the value of Philips' existing market decreases as a result of the introduction of the game changer (i.e. cannibalization), this decrease of value should be subtracted from the value created by the game changer. This results in the impact value of the game changer (ΔFCF). Furthermore, since value is created in the future, e.g. in 5 or 10 years, it is important to take into account the developments in the current and future market. Estimations are made about whether the market grows, remains steady or declines.

Over time, the aim is to reduce uncertainty in order to be better informed about whether to launch the product/technology. For game changers, all uncertainties before the launch decision are reduced during the development stage. Then, at the time of the launch decision, a manager is better able to determine the values of different value drivers and to make a decision on whether or not to continue with the project based on most recent information. The basic part of the model should provide insight into the average risk-adjusted NPVs (rNPV) of the different scenarios, which determines for each scenario whether it is justified to invest (rNPV should be larger than 0). Other commonly used valuation metrics at Philips Research, like expected impact on revenues and payback period, are used to underpin rNPV outcomes. Alternative results include the impact of the game changer on Philips' existing market value and on the total market value as well as the transformation of expected rNPV outcomes over time.

Then, also based on the three different scenarios, a Monte Carlo simulation can be performed. A Monte Carlo simulation can easily run the same project several thousands of times. For example, a project can be abandoned at the end of each front-end innovation stage based on the corresponding success probability and uncertain input parameters of the market are randomly selected from a PERT distribution. The uncertain input parameters that are generated at random from a probability distribution are (1) expected revenues of Philips' existing market, (2) expected growth rate of Philips' existing market, (3) revenues of game changer, (4) EBITA margin of game changer, (5) growth rate of game changer, and (6) price pressure of game changer. All these parameters are an estimate of a future value and contain, therefore, a level of uncertainty.

The PERT probability distribution is used for a couple of reasons. First, PERT is intuitive to use, since it requires three estimates, based on a minimum, most likely and maximum expected outcome. These values are easier to obtain during a discussion than, for example, a standard deviation, which would be required when using a normal probability distribution. Second, PERT allows for an asymmetrical distribution, which might be true for game changers, where the potential outcome (maximum value) can be very large, while the minimum and most likely scenarios hold a value closer together. See Appendix III for a comparison of PERT with the normal distribution and for an additional argumentation why PERT is preferred for this model.

As a result, Monte Carlo simulation computes the average NPVs per stage when a project is abandoned and gives the value distribution of market outcomes in case the entire product lifecycle is passed through.

All results of the financial valuation, along with market expectations, give senior management the justification to commit R&D expenditures (I_n) prior to the launch decision. This enables engineers and marketing analysts to advance the project to a state of readiness in preparation for the launch decision, while effectively reducing the uncertainty of that decision. Overall, the model is an extension of the NPV method, represented as a multi-scenario Monte Carlo model with an adjustment for risks. The model takes into account a stage-gate management process as well as uncertainty in future market outcomes. Model results function as a base for discussion between decision-makers, which is considered a key element for project prioritization and, in the end, selection.

5.2 Model assumptions

In order to decrease complexity of the model it is necessary to make assumptions of the represented reality. Therefore, the model is based on the following assumptions:

1. Input is provided as objective as possible through a combination of multiple expert opinions (e.g. senior management, project management and market analysts).
2. The four types of risk (see Section 4.2.1) are independent and uncorrelated.
3. Duration of stages is given in months.
4. A project can only be abandoned at the end of a stage, whereby the decision to abandon does not require additional investments nor does a project have residual value.
5. Investments during the ECD stages are determined on a yearly basis, but written off uniformly and on a monthly basis during the lifetime of a stage. Investments during the growth stage are also determined on a yearly basis, but decrease gradually until the stage of maturity is reached.
6. There is no depreciation of capital expenditures, i.e. all investments are depreciated immediately. Thereby, in a mature and steady business, depreciation and capital expenditures offset each other and the level of working capital remains equal.
7. Input parameters with regard to Philips' current existing market (market value, growth rate and EBITA margin) are known. Therefore, taking into account uncertainty of these input parameters is not necessary.
8. Among others, the EBIT margin and level of amortization is required for the calculation of free cash flows (Titman & Martin, 2011). Since amortization of a business case is difficult to forecast, we assume that the EBITA margin can be used as an approximation of the EBIT margin.
9. The EBITA margin for Philips' existing market *with* game changer is equal to Philips' current EBITA margin.
10. Philips' existing market behaves independently from the game changer market, i.e. both markets have independent growth rates, as determined per market. Thereby, Philips' existing market can adopt a different growth rate after launch of the game changer.
11. There are no sales until the beginning of the growth stage, whereby sales increase linearly until maturity. At the start of the mature stage the expected revenues of the game changer market are reached.
12. The game changer might deal with price erosion, which is taken into account as a yearly percentage of change in revenues. Philips' existing market does not cope with price pressure since it is operating in a steady business environment.
13. All future cash flows (investments as well as profits) are discounted with the same discount rate, given by the weighted average cost of capital (*WACC*).

5.3 Model calculations

This section provides the equations used for the calculation of free cash flows, as required for the NPV calculations. Sections 5.3.1 and 5.3.2 cover the equations used for Philips' existing market *without* and *with* game changer, respectively. Then, Section 5.3.3 gives the equations used for the game changer market, followed up by the calculations of the game changer's impact in Section 5.3.4. Finally, the (risk-adjusted) NPV calculations are provided in Section 5.3.5. Furthermore, see Appendix IV for a complete overview of parameters and variables.

5.3.1 *Cash flows Philips' existing market (excl. game changer)*

A game changer is a type of innovation project which has the likelihood of affecting a related business through its introduction. The impact on the existing market has to be taken into account when an investment decision for the game changer is made and the dynamics of Philips' existing market are included in the model. Both a scenario *without* a game changer as well as *with* a game changer is evaluated, in order to determine the impact of the game changer.

First, revenues of Philips' existing market (R_t^m) in month *t* are based on the current revenues of the existing market (R_0^m), whereby the market growth of the existing market (g^m) is taken into account. The equation looks as follows:

$$R_t^m = R_0^m \cdot (1 + g^m)^t \tag{1}$$

In the model the growth rate is provided based on a yearly basis, as is most common in a business environment. In order to use this growth rate in the calculations, it is recalculated as a monthly growth rate as follows:

$$g^{month} = (1 + g^{year})^{\frac{1}{12}} - 1 \tag{2}$$

Then, based on the revenues of Philips' existing market, it is possible to calculate the earnings before interest, tax and amortization ($EBITA_t^m$) in month *t*. Hereby the EBITA margin of the Philips' existing market is used (α^m). This results in the following equation:

$$EBITA_t^m = R_t^m \cdot \alpha^m \tag{3}$$

Finally, in order to obtain an approximation of the free cash flows of Philips' existing market (FCF_t^m) in month *t*, EBITA is multiplied by one minus the monthly tax rate (*Tax*). Since it is assumed that depreciation and capital expenditures offset each other, and that working capital remains equal in a steady market, these factors are not taken into account. Overall, free cash flows are calculated as follows:

$$FCF_t^m = EBITA_t^m \cdot (1 - Tax) \tag{4}$$

5.3.2 *Cash flows Philips' existing market (incl. game changer)*

When the game changer is introduced on the market, it is likely that the dynamics of Philips' existing market change, e.g. due to cannibalization. Therefore, the model specifies a new market value of Philips' existing market at the moment of reaching maturity for the game changer. For example, the game changer reaches maturity in year 5 and the market value of Philips' existing market is expected to decrease from 100 to 80 million euros. Then, in 5 years' time Philips' existing market has decreased to 80 million euros.

Until the market introduction of the game changer, i.e. until the start of the growth stage, Philips' existing market equals the market without game changer (as calculated by Equation 1). Then, when the game changer is launched (at time T_G), the revenues of Philips' existing market will linearly reach its expected revenues, with duration equal to the time of growth. Revenues of Philips' existing expected market (R_t^{em}) during the growth stage (i.e. from time T_G to T_M), in case a game changer is introduced, are calculated as follows:

$$R_t^{em} = R_0^m \cdot (1+g^m)^{T_G} - \frac{R_0^m \cdot (1+g^m)^{T_G} - R_M^{em}}{T_M - T_G} \cdot (t - T_G) \tag{5}$$

In Equation 5 the first term represents the revenues of Philips' existing market at the start of the growth stage (the growth rate is taken into account). The second term adjusts these revenues with a certain amount, depending on the month, in order to reach the expected revenues of Philips' existing market at the time of maturity.

Since the market might change dramatically when the game changer is included, the model also allows for a different market growth rate of Philips' existing market from maturity onwards. Then, revenues for Philips' existing market when the game changer has reached maturity depend on the expected revenues and the expected growth rate within this new market, whereby the growth rate starts from time T_M onwards. Thus, revenues of Philips' existing expected market from maturity onwards are given by:

$$R_t^{em} = R_M^{em} \cdot (1+g^{em})^{t-T_M} \tag{6}$$

Earnings before interest, tax and amortization for Philips' existing expected market ($EBITA_t^{em}$) and its free cash flows (FCF_t^{em}) are determined in an equal fashion as in a market without game changer. We assume that the EBITA margin of Philips' existing market remains the same in a market with game changer.

$$EBITA_t^{em} = R_t^{em} \cdot \alpha^m \tag{7}$$

and

$$FCF_t^{em} = EBITA_t^{em} \cdot (1 - Tax) \tag{8}$$

5.3.3 *Cash flows game changer market*

For the market of the game changer, sales will start during the growth stage. During this stage revenues will increase over time, until the expected revenues for the game changer are reached at the time of maturity (R_M^{gc}). Revenues during the growth stage (i.e. from time T_G until time T_M) are calculated as follows:

$$R_t^{gc} = \frac{R_M^{gc}}{T_M - T_G} \cdot (t - T_G) \tag{9}$$

During the mature stage of the product life cycle the market might grow with a certain rate (g^{gc}) and/or competition might put pressure (p) on revenues; these factors are taken into account during time of maturity. As a result, revenues during the mature stage are determined as follows:

$$R_t^{gc} = R_M^{gc} \cdot (1 + g^{gc} - p)^{t-T_M} \tag{10}$$

Finally, revenues during the decline stage are assumed to run linearly to zero over a period equal to the time of the decline stage. During the decline stage revenues are calculated as follows:

$$R_t^{gc} = R_M^{gc} \cdot \; 1 + g^{gc} - p \;^{T_{Dec}} \cdot \; 1 - \frac{1}{T_{End} - T_{Dec}} \cdot \; t - T_{Dec} \tag{11}$$

Now, revenues have been determined for the game changer's complete lifetime. Earnings before interest, taxes and amortization in each month ($EBITA_t^{gc}$) are calculated using an EBITA margin for the game changer (α^{gc}), since value creation for the game changer might be significantly different from that of Philips' existing business. The following equation is used to calculate the game changer's EBITA:

$$EBITA_t^{gc} = R_t^{gc} \cdot \alpha^{gc} \tag{12}$$

Then, an approximation of free cash flows can be determined for each month. As opposed to Philips' existing market, the game changer requires R&D investments during the different stages of innovation. Each innovation stage has a (potentially) different investment level. Since month t is part of a certain stage, the stage corresponding to month t is given by N_t, with N_t = 1,2,3,4. Since there are no other cash flows than R&D investments (I_{N_t}) during the innovation front-end, free cash flows (FCF_t^{gc}) are determined solely based on these investment expenditures. For t = 0 to t = (T_G – 1), free cash flows are calculated as follows:

$$FCF_t^{gc} = -I_{N_t} \tag{13}$$

For the growth stage also additional investments are required, e.g. extra R&D investments or marketing and commercialization expenditures. These investments start in the first month of the growth stage (T_G) and are assumed to decline gradually until maturity. This leads to the following equation for the calculation of cash flows during the growth stage:

$$FCF_t^{gc} = EBITA_t^{gc} \cdot \; 1 - Tax \; - \frac{I_4}{T_M - T_G} \cdot \; T_M - t \tag{14}$$

Finally, for the mature and decline stage of the game changer, free cash flows are determined equally to Equations 4 and 8, namely by:

$$FCF_t^{gc} = EBITA_t^{gc} \cdot \; 1 - Tax \tag{15}$$

5.3.4 Impact game changer

Main interest lies in the impact of the game changer market on Philips' total value creation, i.e. when considering the impact of the game changer a potential cannibalization of the existing market should be taken into account. First, the cash flows of the total market *with* game changer is determined (FCF_t^{tot}) as follows:

$$FCF_t^{tot} = FCF_t^{em} + FCF_t^{gc} \tag{16}$$

Then, the difference in cash flows between the total market *with* game changer and the market *without* game changer is calculated, which is considered to be the impact of the game changer on the total market (ΔFCF_t). This impact is determined as follows:

$$\Delta FCF_t = FCF_t^{tot} - FCF_t^{m} \tag{17}$$

5.3.5 *Risk-adjusted Net Present Value*

The net present value (NPV) method is commonly used to evaluate the value of a business or investment project. In order to obtain the NPV of the difference between a market *with* and *without* the game changer (ΔNPV), the future cash flows of the impact are discounted with a certain discount rate. In this model the weighted average cost of capital (*WACC*) is used as discount rate (see Appendix V for a discussion about cost of capital). Though we assume that the WACC is constant, the model could easily handle a time-varying WACC. Overall, ΔNPV is calculated with the following equation:

$$\Delta NPV = \sum_{t=0}^{\infty} \frac{\Delta FCF_t}{(1 + WACC)^{t}} \tag{18}$$

However, this NPV method views the project from a highly optimistic perspective, since there are actually high levels of risk involved during the innovation front-end, i.e. there is only a small probability that the cash flows will actually occur. Therefore, the NPV outcome has to be adjusted for the risks involved, resulting in a risk-adjusted NPV (*rNPV*). In order to determine the risk-adjusted NPV, the probabilities of success of the front-end stages are used, which are the probabilities that a project continues to a subsequent stage. Four risk factors (U_k) have been distinguished (see Section 4.2.1) and these risk factors are used to determine the success probabilities in a certain stage (P_n). The probability of success in stage *n* is determined as follows:

$$P_n = \prod_{k=1}^{4} (1 - U_{n,k}) \tag{19}$$

with,

n = 1,2,3,4

Then, with both the FCFs and success probabilities of the stages, it is possible to calculate the risk-adjusted cash flows ($rFCF_t$) with the following equation:

$$rFCF_t = \left(\prod_{n=1}^{n=N_t-1} P_n \right) \cdot \Delta FCF_t \tag{20}$$

Now, *rNPV* can be calculated similarly to the general NPV method, namely through discounting and summation of future cash flows:

$$rNPV = \sum_{t=0}^{\infty} \frac{rFCF_t}{(1 + WACC)^{t}} \tag{21}$$

6 Analysis

After a discussion about the model's underlying definitions and equations, the model is further analyzed. This starts with a verification and validation of the model, presented in Section 6.1. Then, Section 6.2 performs a sensitivity analysis and Section 6.3 draws some brief conclusions.

6.1 Verification and validation

Verification deals with the question whether the designed model is built correctly. Verification of the model is required in order to evaluate whether the model complies with the imposed specifications, i.e. it is checked whether the model acts as intended. First, the model has been analyzed through logical testing. For the logical testing a base case scenario is set up and a benchmark model (a model with simplified cash flow calculations) is used to verify the valuation model's results (see Appendix VI for the input parameters and testing results).

The model is used for the valuation of breakthrough innovation projects. Since these innovation projects are new-to-the-world and therefore a major lack of historical data is available on comparable projects, it is difficult to validate the model based on past innovation projects. However, Wolthuis and Wolf (2013) have developed a valuation model for adjacencies. It is possible to validate the valuation model for game changers, at least partly, based on this model.

Since the model for adjacencies does not take into account a possible impact on Philips' existing market, for the validation of the valuation model we assume that Philips' existing market does not change. When other input parameters are set equal in both models, the results are almost similar (see Appendix VI). An insignificant difference in outcomes is the result of small modelling differences; e.g. the discounting period is yearly for adjacencies and monthly for game changers and the valuation model for adjacencies models an S-curve for sales during the growth stage.

After the logical testing, the model is stress tested, whereby the limits of the input parameters are sought. Extreme values for the input parameters are put into the valuation model in order to check whether the model still behaves according to specifications. It is also highly useful for users to know the limits of the model.

A further elaboration on the logical testing and stress testing can be found in Appendix VI. The overall conclusion is that the benchmark model, the adjacency model and the valuation model for game changers yield similar results, which verifies the valuation model based on the logical testing. Also the stress testing did not lead to any complications, keeping in mind the model's boundaries.

6.2 Sensitivity analysis

For financial options the sensitivity analysis considers the change in option value due to a change in one of the key parameters, like the underlying asset value, volatility and exercise price (Haahtela, 2010). This also holds for the rNPV analysis, since by changing a single or even several parameter values required for the cash flow calculation, a decision maker immediately gains insight in how rNPV is affected.

First, it is valuable to identify the parameters that are most impactful for the final outcome, which allows you to focus on these parameters. Thereby, a sensitivity analysis also provides further insight into the behavior of the model. In order to evaluate the potential impact of each input parameter present in the model, values have been determined for each input parameter. It is important to note that each combination of input values results in different sensitivity analysis outcomes. An overview of the input values used for this sensitivity analysis can be found in Appendix VII.

A tornado diagram is used to give an overview of the sensitivity analysis results, which is partly presented in Figure 7 (see Figure 17 in Appendix VII for a complete overview of the results). For each input parameter the impact on the rNPV outcome is determined when the input parameter's value is increased by 10%. For example, rNPV increases by 41.23% when the game changer's EBITA margin is increased by 10% (i.e. the game changer's EBITA margin becomes 22% instead of its original 20%).

As results suggest, EBITA margin and expected revenues of the game changer have the largest effect on the rNPV outcome. Both input parameters are positively correlated with the final outcome. Also increasing success probabilities at the end of each stage would lead to an increase of rNPV. On the other hand, the investments and time of the front-end stages are negatively correlated with the rNPV outcome. An increase of the duration of the mature or decline stage results in an increase of rNPV. Finally, when the WACC or level of cannibalization is increased, rNPV decreases.

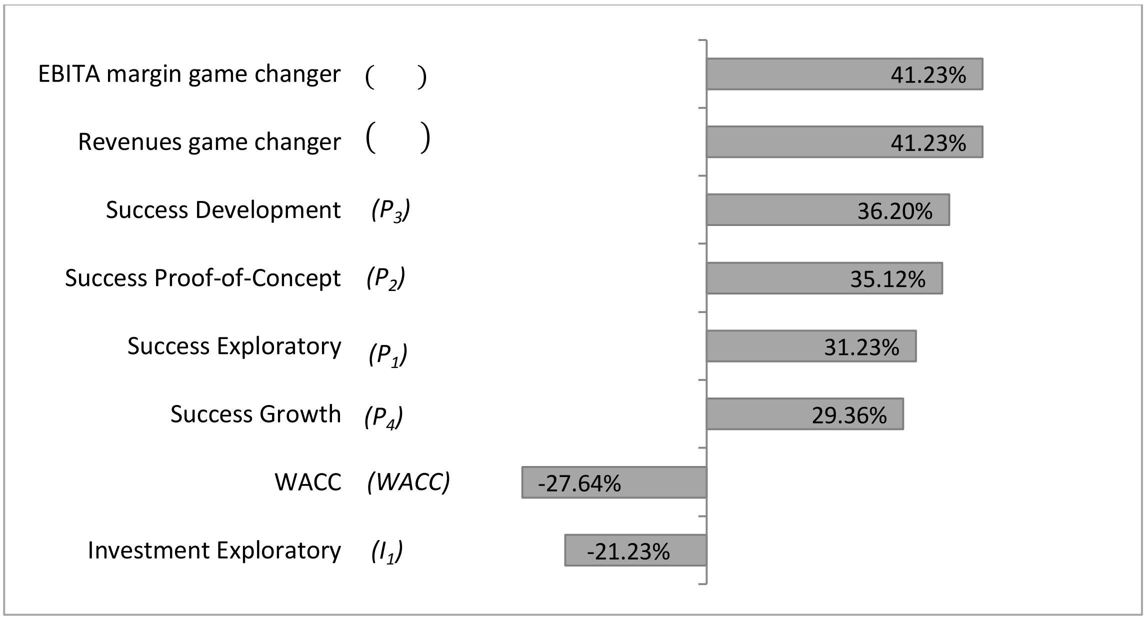

Figure 7: Part of sensitivity analysis results (+10% in input value) in a tornado diagram

6.3 Conclusion

Although there are difficulties with the model validation, based on the model testing and the sensitivity analysis it is safe to conclude that the valuation model complies with the imposed specifications. The valuation model is proven to be sound and behaves according to expectations. Now, in order to conduct a reliable financial valuation of a business case, the challenge lies in the estimation of input values. The following chapter takes up this challenge through the analysis of a business case.

7 Case study

This chapter shows the application of the valuation model based on a real-life case. Hereby, the aim is to perform an objective analysis of a game changer, so decision-makers obtain rational support for their investment or abandonment decision. First, in Section 7.1, a general description of the case is given. Then, Section 7.2 provides the results of the business case analysis and Section 7.3 gives the insights obtained through the analysis in the form of a conclusion.

7.1 General description

7.1.1 Game changer

Due to reasons of confidentiality, no substantive and detailed description can be given on the business case. The game changer under study takes place within one of Philips' sectors, whereby market X is the related Philips' market. In general, the project aims to develop a supporting tool for a certain Philips' sales channel. Initially the focus of the game changer is on Philips' existing business, i.e. increasing sales of Philips' products. A business model has been developed for each of the sales channels of Philips' products.

The game changer addresses the global market in which Philips' current sales are about € 422 million for related market X (see Appendix VIII for an elaboration on the input parameters). It could be possible that the game changer has an impact on Philips' related market when boosting sales of that particular sales channel. However, since it is not possible to distinguish between EBITA margins per sales channel and we assume that the expected total Philips' market does not decrease, there is no cannibalization of Philips' existing market.

The game changer is currently in the development stage and the probability of success at the end of this stage is expected to be 49%. Philips Research declares to have strong customer know-how and a competitive advantage through the resources in place, but the game changer might be easy to copy. However, the expectation is that, once consumers are attached to the new web-enabled tool, the churn rate is low.

Also the accompanied risks during the growth stage are determined, leading to a success probability of 70%. During the growth stage there are organizational risks, including potential risks of time and costs overruns, and there are risks concerning the management of third-parties. Furthermore, Philips does have a strong position in the key markets of the particular sector, with top three positions in different segments. This leads to limited competitive risks.

The required investments during the growth stage are 3 million euros, which include R&D investment costs as well as required marketing and selling expenditures. Furthermore, no additional (working) capital expenditures are required, since the game changer can make use of existing infrastructure. Thereby, because this infrastructure is already in place, Philips Research assumes that the EBITA margin for the game changer equals the gross margin.

Within Philips Research it is expected that the project has the potential to gain additional sales of €50 million, on top of the sales in Philips' existing market. Input values obtained internally are assumed to be the optimal scenario for the game changer, with expected additional revenues of € 50 million and an EBITA margin of 42%. Additional desk research has led to a most likely scenario, whereby revenues are expected to be € 23.2 million and the EBITA margin 25%. In this case the optimistic assumption that the gross profit margin can be used as EBITA margin is partly dropped. The pessimistic scenario assumes no additional sales and an EBITA margin of 7%, which is the 5-year average EBITA margin for that industry. See Table 13 in Appendix VIII for an explanation and complete overview of the input parameters used in the valuation of the game changer.

7.1.2 Growth option on game changer

When valuing an innovation project, it is important to take into account all aspects that could enhance or destroy value. A value enhancing factor can be a so called growth option, which considers the flexibility to entail an inter-related project. Here a potential expansion to e-retailing in market Y is considered as a growth option. However, other potential markets can be devised. Through this analysis the value of 'real options thinking' (as discussed in Section 2.4.2) becomes apparent.

The growth option focuses on the potential expansion to industries outside Philips' current scope. In this case, the growth option can be considered an adjacency (recall Section 2.1 for the definition of adjacencies). Thereby, in order to realize this potential expansion on the game changer, it is required to cooperate with third-parties. Collaboration with third-parties can be considered a business model innovation (as discussed in Section 4.1.2). Hereby, the required technology is already in place, but the dominant industry logic is disrupted through an innovation based on the business model.

We assume that this inter-related project is conducted sequential to the game changer, i.e. the game changer has to reach maturity in order to build a platform for the collaboration with third-parties and to gain significant competitive advantage. In such a case, technology risks are downsized to a minimum and investments are only required when the initial game changer becomes successful. Hence, Philips Research has the 'option' to invest.

Table 14 in Appendix VIII presents the input values that are used for the valuation of the growth option. First, there is no Philips' existing market, so these input parameters are not required. Second, we assume that the project for the growth option is currently in the proof-of-concept stage. The timing and success probabilities for the proof-of-concept and development stage are based on the development and growth stage of the game changer, respectively. This means that the growth option can only become successful when the game changer reaches maturity, so it is dependent on the game changer. Furthermore, at the end of the growth stage the success probability of actually reaching maturity is assumed to be 10%.

The expected revenues for the growth option are based on the revenues of online sales in market Y. In case the project becomes successful, we assume that Philips will be able to obtain a certain margin of the total addressable market. Furthermore, the EBITA margin is assumed to be around 20%. Additional explanation on the input parameters can be found in Appendix VIII.

7.2 Results

7.2.1 Game changer

This section shows the results of a financial valuation of the game changer, using the input values as provided in Appendix VIII. First, the game changer creates additional cash flows, which is presented in Figure 8, for the most likely scenario. As we can see in Figure 8, the early months require investments, after which the project takes the form of a product lifecycle. Furthermore, as assumed, the game changer has no impact on Philips' existing market.

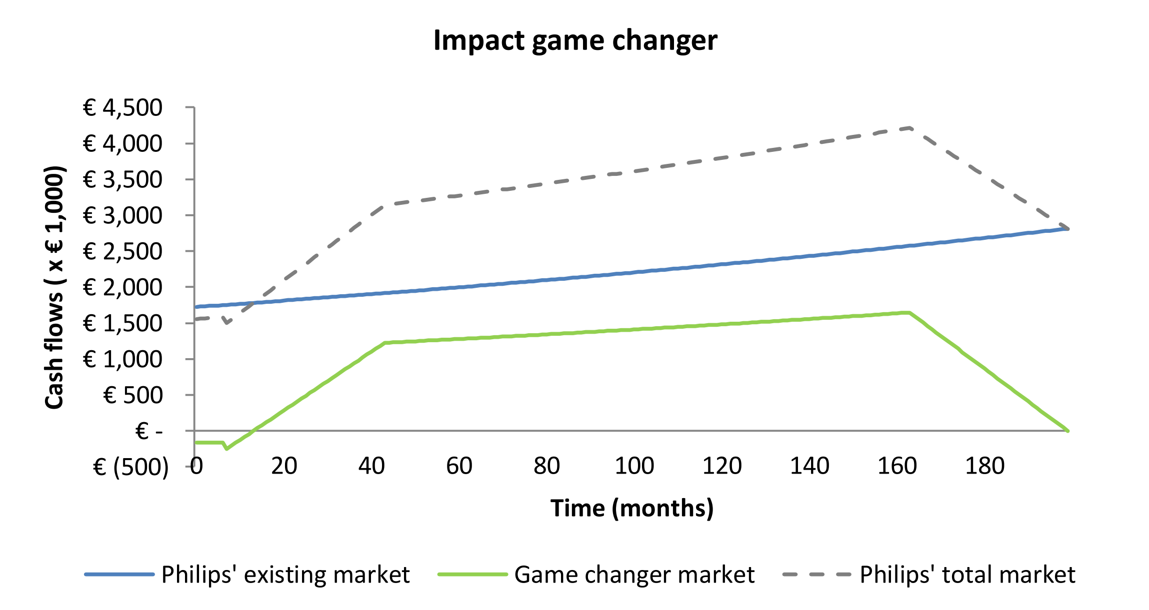

Figure 8: Impact of the game changer on the cash flows of Philips' market

Then, the outcomes of the (risk-adjusted) NPV analysis for the three scenarios are provided in Table 2. First, the pessimistic scenario has a negative outcome on both metrics. This is explicable since there are no revenues, while there is invested during the early-stages. In this case rNPV is higher than NPV, since in the rNPV calculations the investments during the growth stage are adjusted for the probability that they occur. Second, the most likely scenario has positive results on rNPV as well as NPV. This scenario shows that the project would be viable, taking into account the required investments and future potential revenues, while adjusting for risks. Third, the input obtained from Philips Research, the optimistic scenario, results in a highly profitable project.

Table 2: (Risk-adjusted) NPV results of game changer

Scenario	Risk-adjusted NPV		NPV	
Pessimistic	€	(3,147,325)	€	(5,249,084)
Most Likely	€	8,214,314	€	25,811,874
Optimistic	€	38,800,980	€	109,578,416

Figure 9 presents an overview of the free cash flows, the revenues and the cumulative free cash flows for the most likely scenario. The payback period equals 3.6 years. Furthermore, revenue growth after 5 years, based on the game changer and Philips' existing market, is expected to be 4.9%.

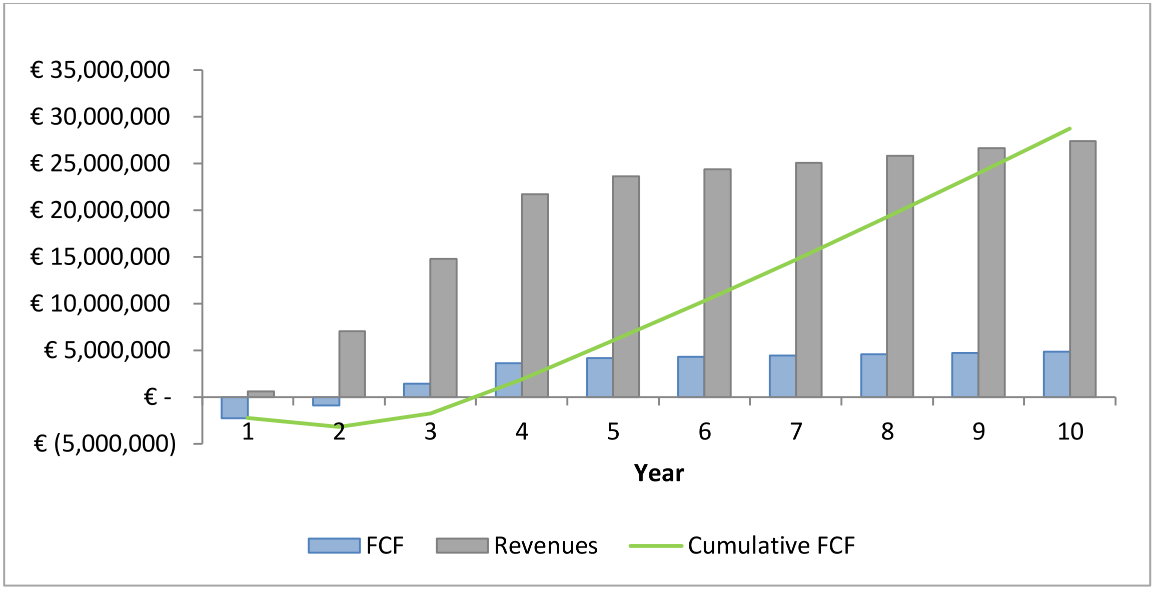

Figure 9: Free cash flows (FCF), Revenues and cumulative FCF per year

Though the risk-adjusted NPV outcomes can be considered positive, a further analysis should provide more insight into the dynamics of the project and its risk distribution. For example, it is highly unlikely that one of the specified scenarios will exactly occur. Therefore, a Monte Carlo simulation with 10,000 runs is used to create a distribution of possible future outcomes. Hereby, the values for uncertain input parameters are randomly selected from a PERT probability distribution that is plotted based on the pessimistic, most likely and optimistic scenario. A summary of the simulation outcomes is presented in Table 3. As we would expect, the percentage of abandoned projects is about equal to one minus the success probabilities. Furthermore, (necessarily) abandonment at the end of the development stage leads to the largest losses, where a project has a NPV of € -1,143,260, on average.

Table 3: Simulation summary, including average NPV outcome per stage, for game changer

Stage	Projects at start	Percentage at start	Abandoned at end stage	Percentage abandoned		Average NPV
Development	10000	100.0 %	5071	50.7 %	€	(1,143,260)
Growth	4929	49.3 %	1444	29.3 %	€	(369,177)
Mature	3485	34.9 %	None	None	€	26,445,650

The NPV outcomes for the simulated projects that reach the mature stage are presented in Figure 10, which results in a conditional distribution. When the mature stage is reached, the project has a NPV that ranges from € -4.83 million to € 92.83 million. The average NPV for a project in maturity is € 26.45 million.

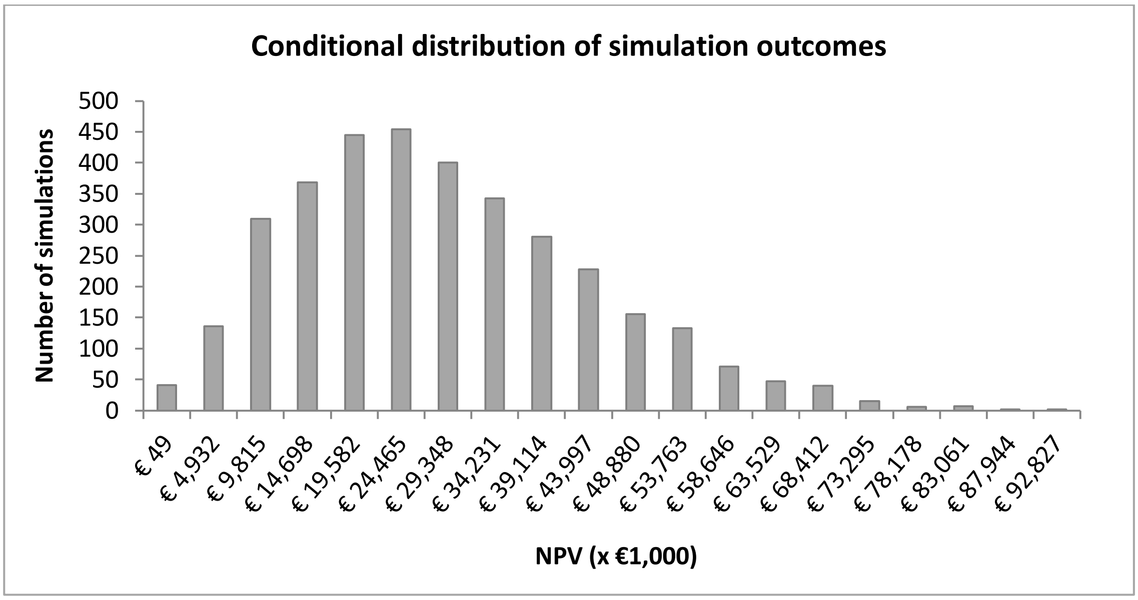

Figure 10: Distribution of simulation outcomes for projects that reach the mature stage

Next to determining the financial values based on the three scenarios, it is also interesting to find the input values' minima, which are required to make the investment decision acceptable. First, starting from Philips Research' expectation of € 50 million in revenues, the minimum required EBITA margin is about 3.5%. Second, when the EBITA margin is fixed at 42%, the minimum amount of revenues required in order to obtain a positive rNPV are about € 4 million (see Table 15 and Table 16, respectively, in Appendix IX).

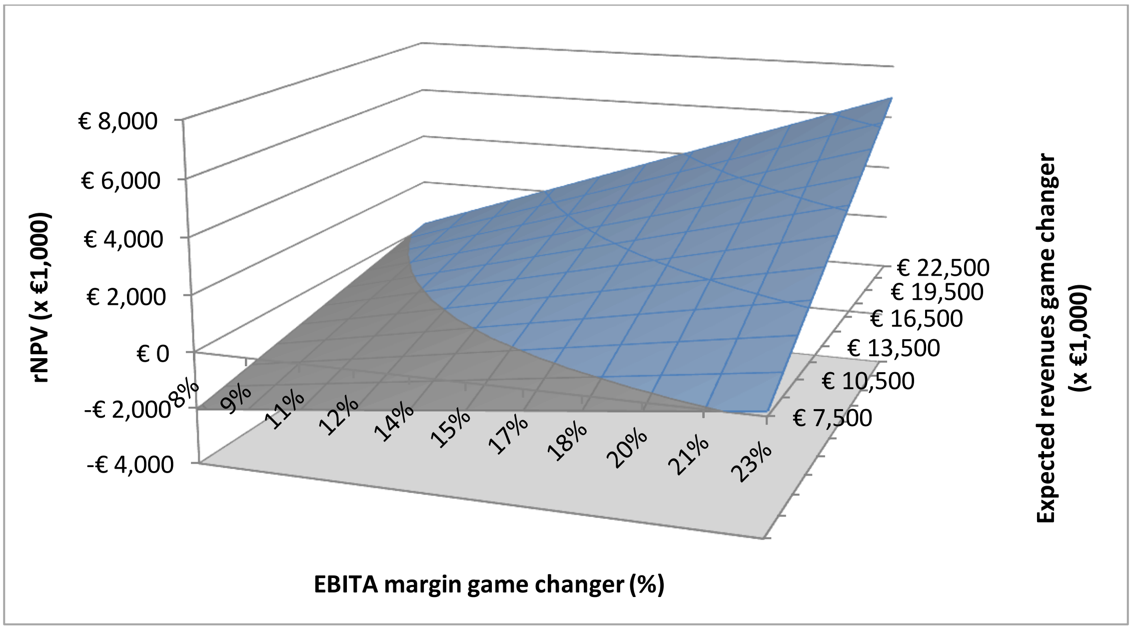

Figure 11: Surface plot of rNPV outcomes for combinations of expected revenues and EBITA margin

It is also possible to vary the game changer's expected revenues as well as its EBITA margin, in order to analyze which combination of those input parameters is minimally required to obtain a positive rNPV outcome. Such an analysis provides insight into the minimal requirements so Philips Research has the opportunity to determine whether these requirements are realistic. Figure 11 presents an overview of rNPV outcomes for different combinations of expected revenues and EBITA margin (see Table 17 in Appendix IX for a complete overview). This figure shows that the combinations of minimum required input values are well below the most likely scenario and significantly lower than the estimations by Philips Research.

7.2.2 Growth option on game changer

First, the results of the basic (risk-adjusted) NPV calculations are given in Table 4. These results show a positive rNPV outcome for both the most likely and optimistic scenario, which indicates that it is worthwhile to invest in the option. The range in (risk-adjusted) NPV outcomes is quite broad, which is due to the large range of expected revenues, indicating a high level of uncertainty in future outcomes.

Table 4: (Risk-adjusted) NPV outcomes of growth option

Scenario	Risk-adjusted NPV		NPV	
Pessimistic	€	(3,876,753)	€	(8,572,704)
Most Likely	€	3,838,431	€	85,344,576
Optimistic	€	15,580,590	€	231,158,832

Also for the growth option, a Monte Carlo simulation is conducted in order to gain insight into the potential distribution of outcomes. Table 5 presents a summary of a Monte Carlo simulation with 10,000 runs. This table shows the probabilities of abandonment per stage as well as the average NPV of the projects abandoned in a certain stage. First, the average NPV of all simulation outcomes is € 3,716,096, which corresponds to the rNPV of the most likely scenario in the basic calculations. Furthermore, largest losses occur when the project is abandoned at the end of the development stage; in such a case the average NPV is € -5,377,945.

Table 5: Simulation summary, including average NPV outcome per stage, for growth option

Stage	Projects at start	Percentage at start	Abandoned at end stage	Percentage abandoned	Average NPV	
Proof-of-Concept	10000	100.0 %	5126	51.3 %	€	(285,815)
Development	4874	48.7 %	1489	30.5 %	€	(5,377,945)
Growth	3385	33.8 %	3047	90.0 %	€	5,997,812
Mature	338	3.4 %	None	None	€	83,900,832

A further analysis of the mature stage, based on the Monte Carlo simulation, shows that the probability of reaching maturity for the growth option is equal to 3.4% and the average NPV of a project that is able to reach maturity is € 83,900,832. Figure 12 presents the conditional distribution of NPV outcomes for projects that reach the mature stage and as we can see, the range of outcomes is very large, indicating high levels of market uncertainty. Over time, uncertainty might decrease, leading to smaller ranges for input parameters and consequently to a smaller range of NPV outcomes.

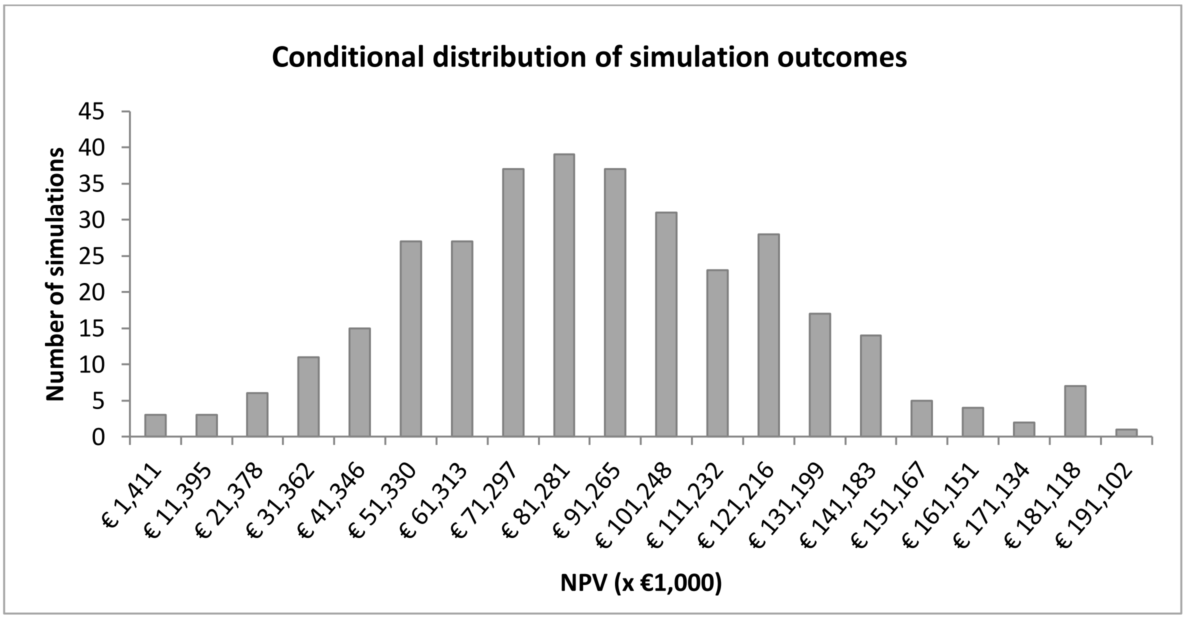

Figure 12: Distribution of simulation outcomes for the growth option in case of maturity

Also for the growth option, the EBITA margin and expected revenues are varied against each other in order to find the minimum required combination of input values (see Figure 13). Hereby the input parameters are varied between -50% and +50% of the most likely scenario. For example, when the expected revenues are € 56 million then the EBITA margin should be above 20%. Table 18 in Appendix IX also shows the area where the rNPV is large enough to offset the negative rNPV of the game changer in case of the pessimistic scenario (i.e. when rNPV of the growth option is larger than € 3,147,325).

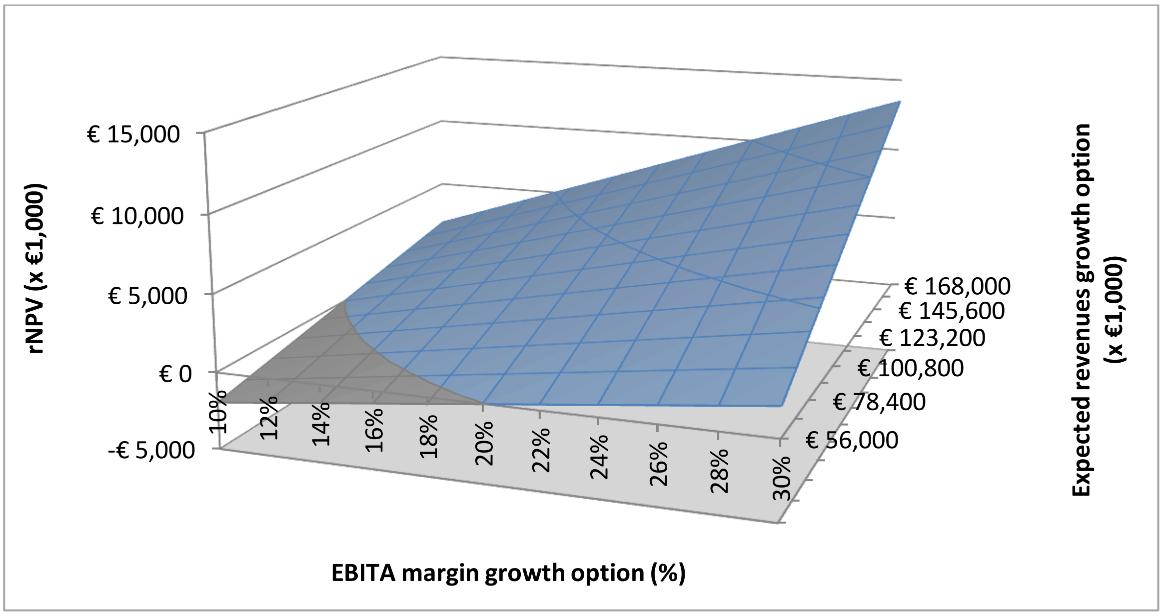

Figure 13: Surface plot of rNPV outcomes for combinations of expected revenues and EBITA margin

7.3 Conclusion

First, it is important to note that the game changer under study does not provide the opportunity to show the valuation model's full potential. For example, for this game changer cannibalization of Philips' existing market does not occur, whereas taking this into account in the valuation is an interesting model feature. Also, the project is already in development, so, overall, success probabilities are relatively high. Analysis of other game changers can improve insight into the full capabilities of the valuation model.

Second, when the input values obtained internally are found to be well-grounded by other decision-makers, then the project is financially attractive to continue investing. The project has a huge scalability, while the costs are relatively low. Especially when expectations of future outcomes have not changed in a few months' time, the game changer should be launched on the market. Further analysis also shows that the project can still be economically viable when the actual revenues and EBITA margin turn out to be significantly lower than expected.

Third, the developed valuation model provides insight into the potential value of a certain business case, whereby it is possible to define multiple scenarios. Therefore, it is not required to perform a valuation analyses based on a single combination of input parameters, but also gives the opportunity to explore additional scenarios.

Fourth, the rNPV of the growth option is positive, so it is advisable to start investing in such an expansion. The rNPVs of the game changer as well as the growth option can be summed, since both values represent a present value of future cash flows. Considering the value of potential growth opportunities can lead to a justifiable investment decision while the initial project might be considered marginal. Although the value of the growth option is based on rough assumptions, new knowledge is acquired about future expansion possibilities of the game changer, which can be used to underpin the investment decision for the game changer. 'Real options thinking' proves to be valuable for the final valuation outcome and, thus, for decision-making.

Fifth, it is also possible to perform a multidimensional sensitivity analysis, which results in the minimum required input values (given the success probabilities and required investments) in order to obtain a positive rNPV. Such an analysis is valuable, since it performs an analysis independent from estimated input values. The remaining question is whether the minimally required input values are realistic to achieve. Furthermore, it also possible to create a feasibility area based on multiple conditions (e.g. rNPV, payback period and revenue growth). Which conditions to select depends on the preferences of Philips' senior management.

Finally, the range of market outcomes is very broad and it might seem obvious that the actual future outcome falls somewhere within this range, but the main value is extracted from discussion that leads to the input values. Actually thinking about the project's value-drivers and risks allows the project team to focus on the important issues. When dealing with high levels of uncertainty, rationalization of decision-making processes in such an environment starts with an attempt of quantifying future outcomes.

8 Implementation

Previous chapters discussed the development of the valuation model, including an application of the model on a single case study. Now, Section 8.1 recommends on the use of the valuation model for project management in general and Section 8.2 discusses its use on a project portfolio level.

8.1 Project management

Acquisition of input values should become an integral part of project management processes, for example, included in the milestones at the end of each innovation stage. Thereby, it is important to guarantee the quality and reliability of input values as much as possible. A clear definition of the input parameters is required in order for a project team to obtain the correct input values. Also the use of multiple (expert) sources to obtain the input data will increase reliability of input parameters.

Some additional training on the use of the valuation model is necessary to teach project managers how to obtain input data and how to handle the model. Emphasizing the importance of the model for discussion and decision-making should lead to more support of the model. Project managers have to learn to determine the levels of success probabilities based on a framework which evaluates the levels of different risk factors. Through such a training program the model becomes embedded in the organization and obtaining input data becomes easier.

Training, as mentioned above, can also increase the awareness of ‘options thinking’. Although employees might already (unconsciously) do this, making ‘real options thinking’ explicit is the first step in quantifying the options. Thereby, it is interesting for Philips to obtain insight into the growth potential of a project and it is valuable for the project team to consider and explore those opportunities. Options thinking might lead to additional applications of the developed technology or service, and, therefore, to additional value creation.

The aim of the valuation model is to support discussion for decision-making about whether or not to continue a project. First, the acquisition of input data during project team meetings makes sure that everybody is on the same page. Second, another consequence is that it becomes clear for the project team whether it is realistic to continue with a project and it makes it easier for the project team to cope with a possible decision to abandon the project. In a worst case scenario, the decision-maker will most probably terminate the project immediately. A best case scenario would be that the project receives extra resources and will eventually be launched on the market. Third, analysis of multiple scenarios gives project management insight into the importance of decreasing time-to-market or decreasing the risk levels by mitigating uncertainties surrounding the project.

8.2 Project portfolio management

Although the valuation model is developed for game changers, the model also allows for a valuation of other types of innovation projects. Using the risk-adjusted valuation model for an evaluation of different types of innovation projects gives the opportunity to compare projects with completely different characteristics. It is also possible to prioritize projects within a certain category of innovation projects.

In order to start with an analysis of the project portfolio, data of different projects has to be available. A database needs to be created in which the valuation results are stored. Therefore, it is important to identify the key metrics on which to evaluate projects, since it is crucial that projects are analyzed equally to ensure a reliable comparison.

Another challenge is that projects are in different stages of development, while competing for the same resources. These projects have to be compared under different levels of (uncertain) information. It is a difficult task to compare or prioritize projects in the exploratory stage against projects in a further phase of development, because projects in the exploratory stage cope with higher levels of risk and require higher investment expenditures. It is important to create a balanced portfolio, with projects in different stages of development, in order to develop a sustainable portfolio in the long-term. So, Philips has to ensure that available budgets are divided equally among projects in different stages of development.

As for project management, also on a project portfolio level the valuation model outcomes functions as a discussion support tool. Projects in the same sector compete for resources, as resources (researchers) are dedicated to work on a certain topic and they cannot be transferred freely to any research project. Senior management is responsible for the allocation of resources to the different programs and with the model outcomes they are able to prioritize projects based on their expected financial performance. Figure 14 presents an example of a bubble diagram that can be used during a portfolio meeting, where projects are compared based on their rNPV, payback period and revenue growth. Further research at Philips Research should uncover the most valuable metrics to use for project portfolio analysis.

Furthermore, as concluded in Section 2.3.2, a project should never be evaluated solely based on its financial value. Philips Research also has to evaluate its project on factors like alignment with strategy (e.g. sustainability) and availability of resources. Additional research should discover other important factors for Philips Research to take into account for decision-making, to entail a project's full scope during a discussion.

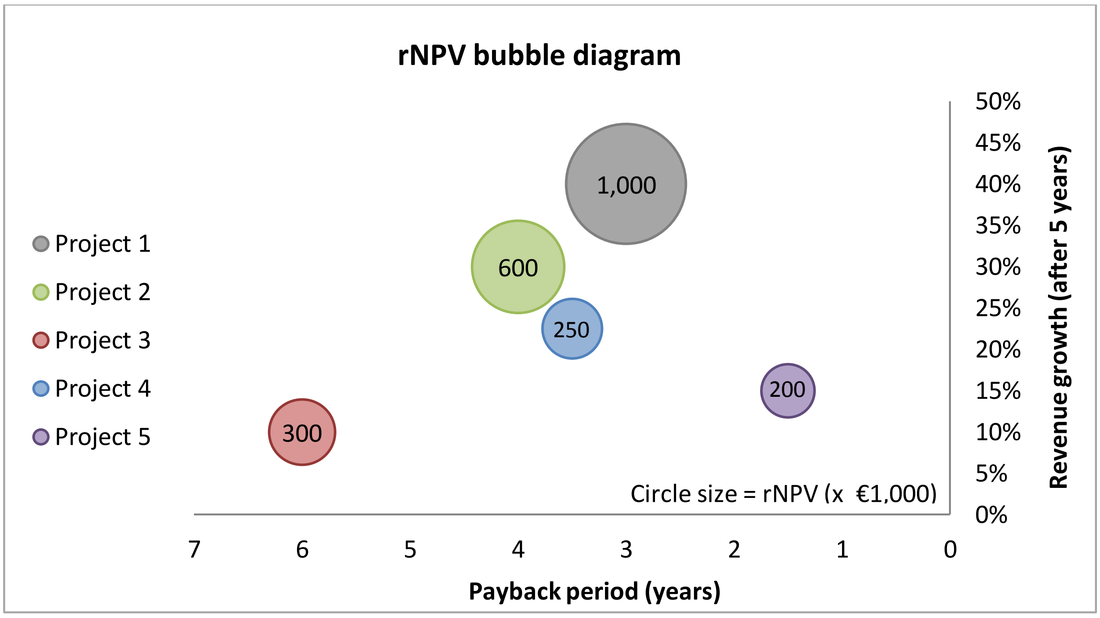

Figure 14: Example of graphical input for a project portfolio discussion

9 Conclusion

9.1 General conclusions

This study focuses on financial valuation of radical innovation projects for project (portfolio) management at Philips Research. Hereby, a valuation model has been developed to support Philips Research' decision-making processes for project prioritization and selection. The following main research question has been formulated (see Section 3.2):

How to assess the financial attractiveness of game changers, in order to support rational decision-making for project prioritization and selection?

In order to answer this question, three sub questions have been defined. An answer on those three questions is given throughout the report and this section provides the main conclusions for each of those questions. The first sub question has been stated as follows:

I. *What are the (financial) characteristics and value drivers of game changers?*

Philips Research defines a game changer as a radical innovation project; a type of project that has the potential to significantly increase Philips' market share. A game changer can achieve unprecedented improvements or performance features and can include major changes in technology regarding materials and functions, newness to the market and costs of goods sold. Though game changers have the potential to be highly profitable, they also cope with high levels of risks, especially during front-end stages.

After market introduction, a game changer is most likely to follow the characteristics of a product lifecycle, i.e. it is unrealistic to assume a business that operates into perpetuity after reaching a steady state. Value is created in the growth, mature and decline stages through (a combination of) market share increase, a price premium or a significant cost reduction. Another characteristic of a game changer is its potential impact on Philips' existing market, e.g. through cannibalization. This reduces the overall value of the game changer as we are interested in the added value on Philips' total worth. Overall, studying the characteristics of game changers and its value drivers leads to an increased understanding of game changers in general, but also provides insight into the differences with other types of innovation projects.

Then, after finding the characteristics and value drivers of a game changer, the goal is to translate these results into a financial model. The second sub question deals with the contrivance of such a model and has been formulated as follows:

II. *What financial approach should be used to assess the financial attractiveness of game changers?*

Section 2.4 introduces three valuation methods which are commonly used in an innovation context. The developed valuation model applies a combination of those methods. General NPV calculations are transformed by taking into account success probabilities of the front-end stages, so valuation outcomes are risk-adjusted. Due to the potential impact on Philips' existing market (e.g. cannibalization), the financial approach also includes (new) market dynamics of Philips' existing market and subtracts a potential negative impact from the valuation outcome of the game changer. Furthermore, the valuation method models multiple dynamics of the game changer market, such as market growth and price erosion, and it includes a product lifecycle to model the project's back-end. A financial valuation is performed based on the game changer's characteristics and value-drivers.

Thereby, the model allows for an analysis of multiple scenarios. Based on these scenarios, it is possible to conduct a Monte Carlo simulation. With a Monte Carlo simulation, the input values for uncertain input parameters are randomly generated based on a PERT probability distribution and future free cash flows for a project are simulated several thousands of times. A Monte Carlo simulation results in a range of potential future outcomes, providing insight into the distribution of risk and value, which is more valuable than simply a point-estimate.

Furthermore, multidimensional sensitivity analysis contributes to a more detailed analysis, independently from expected input values on the value drivers. Such an analysis allows Philips Research to determine the minimally required combination of revenues and EBITA margin in a future market to make the investment decision justifiable, given certain levels of risk and R&D investments in the innovation front-end. Decision-makers have to determine whether it is realistic to achieve these minimally required values.

Overall, the developed valuation model should be used for the evaluation of individual innovation projects, in order to justify R&D investment commitments for those projects. Thereby, the valuation model provides a discussion platform and creates awareness of a project's opportunities as well as pitfalls.

However, when dealing with hundreds of innovation projects, the goal is to optimize resource allocation. Therefore, projects have to be compared, in order to select the most (financially) attractive projects. As a result, the third sub question has been developed.

III. *How to evaluate a portfolio of game changers based on the financial attractiveness of game changers?*

The ultimate goal is to have a commercially viable and profitable portfolio of projects in place, for the short as well as the long term. A database has to be created where the valuation results are collected. Based on these results it is possible to create a priority list of all projects, and depending on the available resources projects should be selected. Visual representations based on different metrics can support management in their decision-making process for resource allocation. Furthermore, on top of a financial analysis, it is important to define non-financial metrics for the evaluation of a business case.

Overall, a hybrid valuation model is developed, which applies a combination of academic theories into a real-life setting. The required input values provide a platform for discussion, whereas the valuation results support decision-making for project prioritization and selection. A first step is taken towards the rationalization of the decision-making processes for radical innovation projects at Philips Research.

9.2 Limitations

First of all, it must be clear that we do not claim to have found the crystal ball for decision-making in an innovation context. No guarantees can be given of a specific future path, since many uncertainties underlie the development of the market. The developed model provides a platform for discussion and, as such, it can serve as a decision-support tool.

Model assumptions

Using a model in order to represent reality requires the development of assumptions about this reality. However, these assumptions (as given in Section 5.2) can be considered a limitation of the model, since a certain business case might behave differently than assumptions presume. For example, linear growth towards expected revenues and disregarding capital expenditures during the mature stage, are assumptions that might not hold for every game changer.

Reliability of input parameters

Another limitation of the valuation model is that is that researchers, often an important source for input values, have limited knowledge of the business environment and potential market outcomes. Therefore, input from a variety of experts is required (e.g. market specialists, senior management, researchers, and project management) and obtaining this data is a time-consuming process. Ideally, each input parameter is given by multiple people, in order to increase reliability. Input values can also be obtained through discussion sessions, in which consensus is reached about the expected values. It is a key challenge to achieve this for every project and to guarantee reliability of all input parameters.

9.3 Recommendations for Philips Research

Use of valuation model as integral part of project management

The valuation model is going to be used as a valuable tool for discussion creation within a project team or between the project team and decision-makers. We recommend Philips Research to embed such a valuation tool into the organization, in order to extract maximum value. First, integrating the tool into project management processes should be done by obligating the acquisition of input values, e.g. through setting milestones at the end of each stage. Second, training of project managers will increase recognition of the model's value and the reliability of input values.

Use of financial valuation metrics

It is important to define the metrics to be used for an evaluation and comparison of projects. Definitely in a research environment, there is limited availability of metrics that take into account high levels of uncertainty. For example, in a business environment Return on Investment (ROI) is a commonly used method, whereby the profits of a certain time period are divided by the investments made during the same time period. However, innovation projects at Philips Research require R&D investments but do not have any returns (yet). Thereby, this method does not adjust for risks and does not take into account time value of money. Therefore, this metric is not suitable for an evaluation of innovation projects and, hence, it should not be used for project selection.

We recommend Philips Research to use the rNPV method as primary financial valuation approach, since it outperforms other methods by including risks of innovation and taking into account the time value of money. Thereby, it is important to include multiple scenarios into an analysis. Never base a decision on a point-estimate, but rather use a distribution of rNPV outcomes by including uncertainties of the future market. Furthermore, rNPV can never be the only approach used for project evaluation and it should be considered mainly as discussion support-tool.

Increase user-friendliness of the valuation tool

The main goal of this study was not to develop a valuation tool that was user-friendly per se; functionality of the model was paramount. In order to increase the tool's user-friendliness, it is recommended to continue with the development of the tool (see Appendix X for the valuation tool's current user interface). For example, the feature that allows for sector selection has to be updated according to the sectors where Philips Research is operating. A software developer can even turn the model into a program that works outside Excel, so that codes are fully integrated and the probability on errors is reduced.

Increase communication between Philips Research and Philips' business

Accurate estimates are required for the valuation model's input parameters. The business side of Philips (e.g. business analysts and financial controllers) can play a major role in the acquisition of input values because of their business knowledge, which is valuable for game changers in particular. Therefore, increased communication and collaboration between Philips Research and Philips' business is recommended. Furthermore, Philips Research should explore other methods of obtaining accurate and reliable input data for the valuation model.

9.4 Recommendations for future research

Reconsider model assumptions

This study has made several assumptions (as discussed in Section 5.2) while developing the valuation model. Now, additional research could study the impact of the assumptions and perhaps adjust the model by changing or eliminating some of them. For example, we assume that WACC is constant, but the model's underlying software and codes can easily handle a time-varying WACC. Also the implementation of an S-curve during the growth stage, as done in the model of Wolthuis and Wolf (2013), might increase the representation of reality (although, the implications of an S-curve on the rNPV outcomes are expected to be minor).

Study other applications of valuation model

A model has been developed for financial valuation of game changers and, as the study showed, it is also feasible to use the model for the valuation of adjacencies. Future research should focus on the valuation of other types of innovation projects, while applying this model. Also for sustaining, more incremental, innovation, risks should be included and market uncertainty has to be taken into account.

Furthermore, the application of the model in other industries can be an interesting future research topic. For example, while this study is conducted in a high-technology environment, the biotechnology or pharmaceutical industry demonstrate similarities with respect to the levels of technology and market uncertainty. Therefore, the use of a risk-adjusted, stage-gated, multiple-scenario valuation model might have value in such industries as well.

Study the use of valuation model on a project portfolio level

As follow-up on the second recommendation, when all innovation projects are valued based on the same metrics (e.g. rNPV), the valuation model allows for a consistent project portfolio analysis. Future research should discover which valuation results are interesting for a portfolio analysis, which might not yet be included into the model. Based on these outcomes, the valuation model can be adjusted accordingly.

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11 Abbreviations

CAPM	Capital Asset Pricing Model
COGS	Cost of Goods Sold
DCF	Discounted Cash Flow
EBA	Emerging Business Activities
EBIT	Earnings before Interest and Tax
EBITDA	Earnings before Interest, Tax, Depreciation and Amortization
ECD	Exploratory, Proof-of-Concept and Development (stages)
FCF	Free Cash Flow
NPD	New Product Development
NPV	Net Present Value
PERT	Project Evaluation and Review Technique
PPM	Project Portfolio Management
PVFCF	Present Value Free Cash Flow
R&D	Research & Development
rNPV	Risk-adjusted Net Present Value
ROI	Return on Investment
ROIC	Return on Invested Capital
SG&A	Selling, General and Administrative Expenses
WACC	Weighted Average Cost of Capital

Appendix I: Definition uncertainty and risk

Uncertainty and risk cannot be considered equal, although it is often used interchangeable. As Knight (1921) states:

"Uncertainty must be taken in a sense radically distinct from the familiar notion of Risk, from which it has never been properly separated.... The essential fact is that "risk" means in some cases a quantity susceptible of measurement, while at other times it is something distinctly not of this character; and there are far-reaching and crucial differences in the bearings of the phenomena depending on which of the two is really present and operating."

Therefore, it is important to state an unambiguous and consistent definition of both terms. Hubbard (2010) defines uncertainty, risk and their measurement as follows:

Uncertainty	Lack of complete certainty, which means that there are multiple possible states. So it is impossible to exactly describe the 'true' outcome, value or state.
Measurement of uncertainty	Probabilities are assigned to each state of a set of possible scenarios.
Risk	A state of uncertainty where some of the possible states involve a loss or have an undesired effect.
Measurement of risk	A set of measured uncertainties, each with quantified probabilities and quantified losses.

According to Keizer and Halman (2007), an innovation strategy based on risk avoidance is no option. Therefore, proactive risk management is required, whereby risks are identified in the early stages of product development with time to influence the course of events. It is important to understand and recognize the underlying risks of a project, in order to make correct investment decisions.

Furthermore, Keizer and Halman (2007) state that risk is a three-dimensional concept, including outcome uncertainty (gaps between available and required knowledge, skills and experience), level of control (ability of manager to influence anticipated risk factors) and perceived impact on the desired project performance. A risk is perceived as high when certainty of outcomes is low, controllability of the project is low and the relative importance of the project is high.

Appendix II: Calculations of free cash flows

In order to calculate the NPV of a project or business, free cash flows for each future period have to be forecasted. These cash flows are then discounted by a certain discount rate, usually the cost of capital. Free cash flows are calculated as in Table 6.

Table 6: Calculation of Free Cash Flows (Titman & Martin, 2011)

Revenues
- Cost of Goods Sold (COGS)
- Selling, General & Administration expenses (SG&A)
- Research & Development expenses (R&D)
+ other business income
- other business expenses
Earnings before Interest and Tax (EBIT)
- taxes
+ depreciation & amortization
- changes working capital
- capital expenditures
Free Cash Flow (FCF)

Future outcomes of the input parameters required to calculate free cash flows are highly uncertain. Therefore, for the calculation of free cash flows of game changers, not all input parameters are taken into account. Overall, an approximation of free cash flows is used.

Appendix III: PERT distribution

The Project Evaluation and Review Technique, introduced by Malcolm et al. (1959) for the evaluation of a Missile Program of the U.S. Navy, is the first major computerized project-management decision support system (Trietsch & Baker, 2012). PERT focuses on creating and controlling projects in stochastic environments (Trietsch & Baker, 2012). The distribution of PERT is a version of the Beta distribution and requires three parameters, namely a minimum estimate (*a*), a mode (*b*) and a maximum estimate (*c*). This input is quite intuitive, in contrast to e.g. a standard deviation, and therefore applicable in project management.

The mean and variance of the PERT distribution are determined as follows:

$$\mu = \frac{a + 4 \cdot b + c}{6} \tag{22}$$

$$\sigma^2 = \frac{b - a \ \cdot \ c - b}{7} \tag{23}$$

The equation for the mean is used solely to determine the Beta distribution. This equation also shows that the mean for the PERT distribution is four times more sensitive to the most likely value than to the minimum and maximum values. Furthermore, the equation of a PERT distribution is related to the Beta distribution and the probability density function of the PERT distribution looks as follows:

$$f(x) = \frac{x - a^{\ \alpha - 1} \ c - x^{\ \beta - 1}}{B \ \alpha, \beta \ \ c - a^{\ \alpha + \beta - 1}} \tag{24}$$

Whereby,

$$\alpha = \frac{\mu - a \ \cdot \ 2b - a - c}{b - \mu \ \cdot \ c - a} \tag{25}$$

$$\beta = \frac{\alpha \ \cdot \ c - \mu}{\mu - a} \tag{26}$$

In the valuation model, the PERT distribution is used to incorporate uncertainty of input parameters into the valuation. Another often used distribution is the normal distribution, requiring a mean and standard deviation as input. It is possible to compare the normal distribution and the PERT distribution when b – a = c – b. The input for the normal distribution is derived from the mean and variance in the PERT distribution, with:

$$\mu = b \tag{27}$$

$$\sigma = \sqrt{\frac{b - a \ \cdot \ c - b}{7}} \tag{28}$$

As used in the valuation model, a simulation using the PERT and normal distribution is performed. Hereby 10,000 runs per distribution are used. As an example the growth in market share is used, with a pessimistic estimation (*a*) of 20%, a most likely estimation (*b)* of 30% and an optimistic estimation (*c*) of 40%. In the simulation, first a random value between 0 and 1 is generated, which is used as input for the inverse distribution function. The outcome of the inverse distribution function results in a value for the market share. A simulation with 10,000 runs results in Figure 15, which shows the results of the simulation for the PERT and Normal distribution.

A first advantage of PERT compared to the normal distribution, is that the latter one can hold values outside the range of 0.2 and 0.4 (it can even hold negative values if the parameter is chosen close to 0), whereas PERT falls exactly within the specified range. Thereby, the PERT distribution has a lower level of kurtosis, i.e. has a flatter top compared to the normal distribution and declines less rapid. For the rest, the normal distribution seems to yield similar results as the PERT distribution (when b-a = c-b).

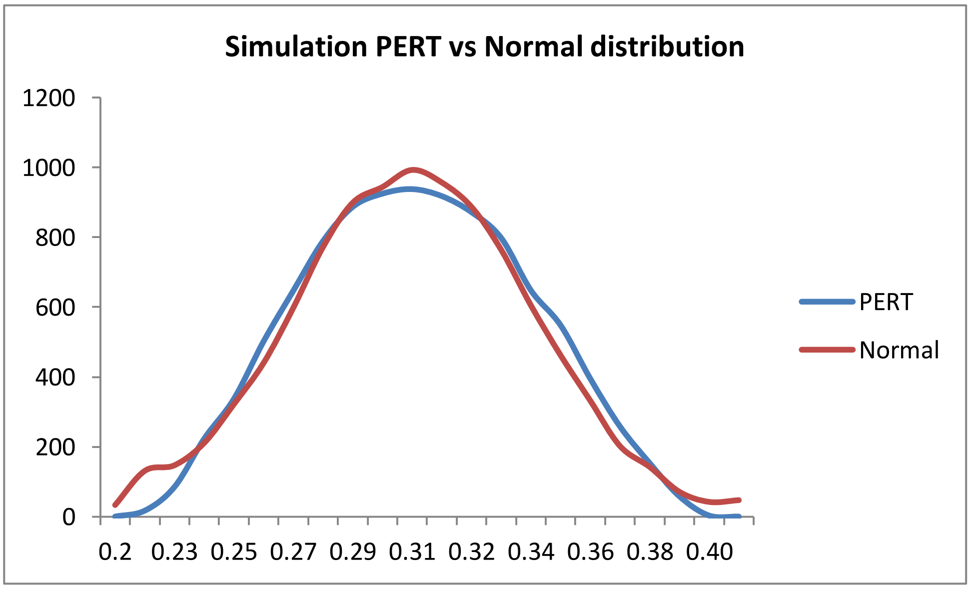

Figure 15: Simulation PERT and Normal distribution

Another advantage of the PERT distribution, compared to the normal distribution, is that the PERT distribution can be assymetrical to the mean (i.e. skewness > 0). For example, when the growth of market share is expected to be 20%, but the most optimistic value is 60%, the distribution becomes skewed to the right. This attribute might be very valuable in case of project management, since predictions of future outcomes might not follow a normal distribution. Figure 16 presents a graph for a rightly skewed PERT distribution (with a = 20%, b = 30% and c = 60%), based on a simulation with 10,000 runs.

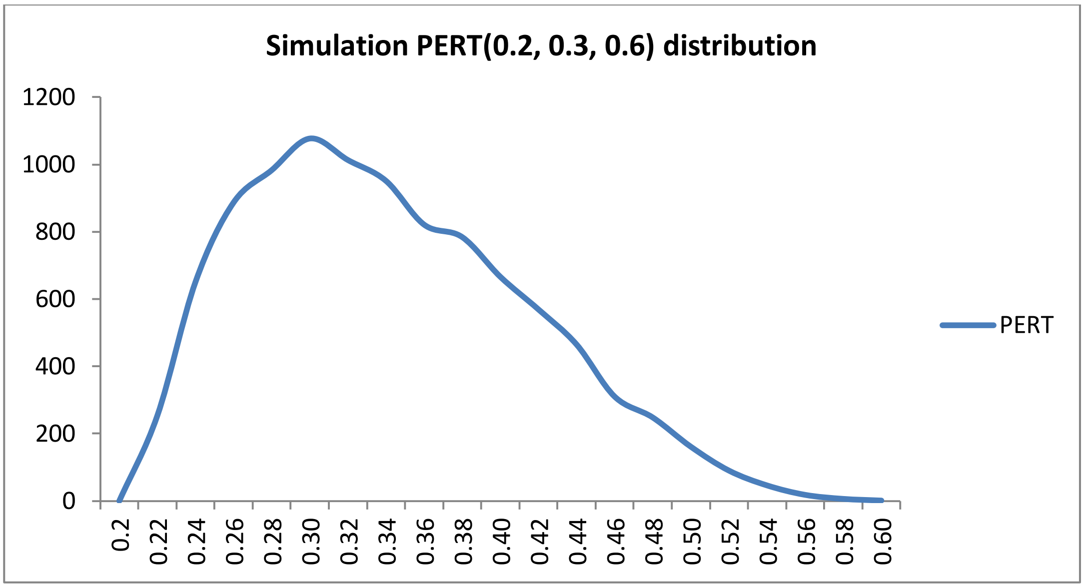

Figure 16: Simulation of PERT distribution with skewness > 0

Another great advantage of PERT is that the PERT distribution is much more intuitive than a normal distribution. For a user it is easier to provide a minimum, most likely and maximum value of an input parameter than a standard deviation, as is required for the normal distribution.

Appendix IV: List of parameters

The model's parameters are defined as follows:

Dependent variables

R_t	Revenues at time *t*	(€/month)
$EBITA_t$	Earnings before interest, tax and amortization at time *t*	(€/month)
FCF_t	Free cash flows at time *t*	(€/month)
$rFCF_t$	Risk-adjusted free cash flows at time *t*	(€/month)
ΔFCF_t	Impact game changer on free cash flows at time *t*	(€/month)
ΔNPV	Impact net present value of game changer	(€)
$rNPV$	Risk-adjusted net present value	(€)

Input parameters

I_n	(R&D) investments for stage *n*	(€/month)
P_n	Success probability of stage *n*	(%)
$U_{n,k}$	Level of risk for risk factor *k* at stage *n*	(%)
α	EBITA margin, EBITA as percentage of sales	(%)
g	Market growth rate	(%)
p	Price pressure	(%)

Constants

Tax	Tax rate	(%)
$WACC$	Weighted average cost of capital	(%)

Timing parameters

t	Time	(months)
T_C	Start proof-of-concept stage	(months)
T_D	Start development stage	(months)
T_G	Start growth stage	(months)
T_M	Start mature stage	(months)
T_{Dec}	Start decline stage	(months)

Other parameters

m	Indicator for Philips' existing market as a market *without* game changer
em	Indicator for Philips' existing market *with* game changer
gc	Indicator of game changer market
N_t	Corresponding stage of time *t*, with values 1,2,3,4 for the exploratory, proof-of-concept, development and growth stage, respectively
n	Stage, with values 1,2,3,4 for the exploratory, proof-of-concept, development and growth stage, respectively

Appendix V: Cost of capital

A discount rate is used to take into account the time value of money and to adjust the valuation outcome for the risks involved. The discount rate is based on the cost of capital, which equals the weighted average cost of capital (WACC) of Philips. There is a limited availability of studies that model the cost of capital for products in development, based on the importance of financing in high technology product development (Rzakhanov, 2012).

Rzakhanov (2012) suggests that discount rates for early stages of product development are greater than for later stages (i.e. Capital Asset Pricing Model (CAPM) beta is greater in early stages) and the beta appears to decrease monotonically as the project is further developed. However, a problem with implementing CAPM is that investment projects do not have directly observable betas, since investment projects are not traded securities. Therefore, in this valuation model the WACC of Philips as a company is used for the project's complete lifetime. In the valuation model the high levels of risks during the front-end stages are taking into account through success probabilities at the end of each stage.

The WACC is the average of the estimated required rates of return for the firm's interest-bearing debt (k_d) and equity (k_e). The weights (w_d and w_e, respectively) used for each type of funding are proportional to the amount present in the company. The cost of debt is adjusted downward by a factor 1 minus the tax rate (T), since interest expenses are tax-deductible. Then, WACC is calculated as follows:

$$WACC = k_d \ 1 - T \ w_d + k_e w_e \tag{29}$$

It is important to use market values of the firm's securities, which represent the relative value placed on the securities at the time of analysis. The same holds for the required rates of return, these should also reflect the current rates rather than the historical rates of return (Titman & Martin, 2011). Then, the cost of debt is typically determined by the yield to maturity on the firm's outstanding debt. The yield to maturity is based on the promised interest and principal payments, and is a reasonable estimate when risk of default is low.

Second, the cost of equity is the rate of return investors expect from investing in the firm's stock. A widely used method for estimating the cost of equity is the Capital Asset Pricing Model (CAPM). This model is based on the idea that stocks that contribute more to the volatility of a diversified portfolio should require a higher rate of return (Titman & Martin, 2011). The CAPM is given by:

$$k_e = k_{rf} + \beta_e \ k_m - k_{rf} \tag{30}$$

where,

k_{rf} = risk-free interest rate
β_e = equity beta, which represents the systematic risk of the company's common equity
k_m = overall market return based on all risky assets
$k_m - k_{rf}$ = expected equity risk premium

In order to determine Philips' WACC the required input parameters are obtained from Philips' annual report and from other public sources, of which the outcomes are presented in Table 7. The equity risk premium is the most obscure input parameter, although it has a high impact on the final WACC. Thereby, since Philips is a highly diversified company, the equity risk premium can be adjusted based on the specific sector or industry in which the project is conducted. In this case we obtain a WACC of 9.7%.

Table 7: Input values for determination of Philips' WACC

Total interest-bearing debt (x €M) [3]	€	3,560
Common shares issued *(x M)* [4]		916
Share price [4]	€	22
Market value equity (x €M)	€	20,096
Total market capitalization(x €M)	€	23,656
% debt		15.0%
% equity		85.0%
Cost of debt [5]		5.6%
Tax rate [5]		25%
Net interest rate		4.2%
Risk-free interest rate [5]		1.87%
Beta (levered) [6]		1.46
Equity risk premium [7]		6%
Cost of equity		10.6%
WACC		9.7%

[3] Source: Royal Philips Electronics, Philips Quarterly Report Q1 2013
[4] Source: www.google.com/finance, ticker code AMS:PHIA, accessed: June 6th, 2013
[5] Source: Royal Philips Electronics, Annual Report 2012
[6] Source: www.google.com/finance, ticker code NYSE:PHG, accessed: June 6th, 2013
[7] Source: www.pages.stern.nyu.edu, accessed: June 6th, 2013

Appendix VI: Model testing

Verification of the model is required in order to evaluate whether the model complies with the imposed specifications, i.e. it is checked whether the model acts as intended. First, the model is analyzed through logical testing. A base case scenario is determined and a benchmark model is used to check whether the valuation model's results are equal to those of the benchmark. After that, the model is stress tested.

Logical testing

A base case scenario is chosen whereby there is no cannibalization of Philips' existing market and the market does not grow. Furthermore, for the initial case there are no risks during the early stages, so all success probabilities are 100%. An overview of input parameters for the base case scenario is provided in Table 8. Thereby, the discount rate (*WACC*) is equal to 9% and the tax rate is 30%.

Table 8: Input parameters base case scenario

Philips' existing market			
Current market dynamics	***Most Likely***		
Revenues (x € 1,000)	€ 100,000		
Growth rate (%/year)	0%		
EBITA margin (%)	20.0%		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Market value (x € 1,000)	€ 100,000	€ 100,000	€ 100,000
Growth rate (%/year)	0%	0%	0%
Game changer market			
Stages	***Time (months)***	***Investment (x € 1,000/year)***	***Success probability (%)***
Exploratory	12	€ 1,000	100%
Proof-of-Concept	12	€ 1,000	100%
Development	12	€ 1,000	100%
Growth	36	-	100%
Maturity	60	-	-
Decline	36	-	-
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ 100,000	€ 100,000	€ 100,000
EBITA margin (%)	20.0%	20.0%	20.0%
Price pressure (%/year)	0%	0%	0%
Market growth (%/year)	0%	0%	0%

Base case scenario

Table 9 provides the results of the benchmark model when calculating an approximation of the cash flows. The benchmark model is calculated on a yearly basis, whereas the valuation model uses months, which results is just a minor difference in NPV outcome. Overall, these results indicate, on first sight, that the valuation model behaves according to specifications.

Table 9: Results base case scenario for benchmark model and the valuation model

Year	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Revenues	-	-	-	33,333	66,667	100,000	100,000
EBITA	-	-	-	6,667	13,333	20,000	20,000
Operating profit	-	-	-	4,667	9,333	14,000	14,000
Investments	1,000	1,000	1,000	-	-	-	-
Cash flows	(1,000)	(1,000)	(1,000)	4,667	9,333	14,000	14,000
PV cash flows	(917)	(842)	(772)	3,306	6,066	8,348	7,658

Year	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Revenues	100,000	100,000	100,000	100,000	66,667	33,333	-
EBITA	20,000	20,000	20,000	20,000	13,333	6,667	-
Operating profit	14,000	14,000	14,000	14,000	9,333	4,667	-
Investments	-	-	-	-	-	-	-
Cash flows	14,000	14,000	14,000	14,000	9,333	4,667	-
PV cash flows	7,026	6,446	5,914	5,425	3,318	1,522	-

NPV bench.	52,499
NPV model	52,411

Base case scenario as ongoing business

The valuation model as developed by Wolthuis and Wolf (2013) assumes an ongoing, steady business, from maturity onwards. In order to compare both models the time of the mature stage in the base case scenario is changed to 100 years (1200 months). Another important difference between the model by Wolthuis and Wolf (2013) and my model is that their model makes use of a Net Operating Capital ratio to determine (working) capital expenditures. Since for game changers no entirely new company is established, the Net Operating Capital ratio is not used in the game changer model. However, capital expenditures can be included as investments during the growth stage. In order to equalize both models, the capital expenditures in the model for adjacencies are zeroed. For the benchmark model a terminal value is calculated as soon as the mature stage is reached, using the following equation:

$$Terminal\ Value\ (TV) = \frac{Cash\ flows_6}{WACC} /\ 1 + WACC\ ^7 \tag{31}$$

Results of the benchmark model, the adjacency model and the game changer valuation model are shown in Table 10. The three models do not yield significantly different results, so we may conclude that the valuation model performs correctly when the duration of the mature stage is increased.

Table 10: Results of base case scenario assuming an on-going business

Year	1	2	3	4	5	6	Terminal value
Revenues	-	-	-	33,333	66,667	100,000	
EBITA	-	-	-	6,667	13,333	20,000	
Operating profit	-	-	-	4,667	9,333	14,000	
Investments	1,000	1,000	1,000	-	-	-	
Cash flows	(1,000)	(1,000)	(1,000)	4,667	9,333	14,000	
PV cash flows	(917)	(842)	(772)	3,306	6,066	8,348	85,094

NPV bench.	100,283
NPV adjac.	106,955
NPV model	107,873

Base case scenario including risks

Then, the base case scenario is changed into a scenario with risks, i.e. lower success probabilities. First a scenario with 100% risks is evaluated, which results in success probabilities of 0%. As expected, the valuation model provides a NPV outcome equal to the discounted cash flows of the exploratory investments (-0.96 M€). There is a difference with the benchmark model due to the interval of discounting, yearly versus monthly. Second, the success probabilities in the base case scenario are adjusted to 10%, 20%, 40%, 80%, respectively. Table 11 provides the results for the benchmark model and the valuation model when those probabilities are included. There is a minor difference due to discounting, but the model seems to behave in an appropriate fashion.

Table 11: Results of base case scenario with risks for the benchmark and valuation model

Year	1	2	3	4	5	6	7
Cash flows	(1,000)	(1,000)	(1,000)	4,667	9,333	14,000	14,000
PV cash flows	(917)	(842)	(772)	3,306	6,066	8,348	7,658
Risk - adjusted	(917)	(84)	(15)	26	49	67	49

Year	8	9	10	11	12	13	14
Cash flows	14,000	14,000	14,000	14,000	9,333	4,667	-
PV cash flows	7,026	6,446	5,914	5,425	3,318	1,522	-
Risk - adjusted	45	41	38	35	21	10	-

rNPV bench.	(636)
rNPV model	(692)

Base case scenario with varying time-to-market
Then the time-to-market of the base case scenario is adjusted. The valuation outcome is supposed to increase (decrease) when the time-to-market is shortened (lengthened), at least when future cash flows are positive. First the exploratory and proof-of-concept stages are decreased by 6 months and investments are doubled (since the required investments during a stage are assumed to remain the same). In this case the NPV outcome increases from 52.4 M€ to 57.2 M€, i.e. decreasing time-to-market with one year leads to a NPV increase of 4.8 M€. The NPV outcome of the benchmark model is 57.3 M€, which yields no significant difference.

Second, the time-to-market is increased with one year through adding half a year in both the exploratory and proof-of-concept stage. Hereby the required investments per year are multiplied by two-thirds, in order to keep total investments during both stages equal to 2 M€. The NPV outcome of the valuation model is 48.0 M€, which is a decrease of 4.4 M€ compared to the initial base case scenario. The benchmark model gives a result of 48.1 M€. Results indicate that also for the scenarios with different time-to-markets, the valuation model operates according to specifications.

Stress testing

Here the valuation model is tested when extreme values for the input parameters are used. First, increasing the duration of the mature stage significantly does not lead to any errors, but it makes the valuation model rather slow. Thereby, it does not have additional value to increase the time of the mature stage from, for example, 100 years to 1000 years (a difference in NPV of 15,072 euro on a NPV of almost 107.9 M€).

Then, when all input parameters have the same input values for the three scenarios, the PERT function still generates a random number from the PERT distribution, since the PERT function slightly adjusts the pessimistic value in order to work. Though, the range in simulation outcomes is very small. For example, for the base case scenario given above, the outcomes of the Monte Carlo simulation range within 100 euros. This difference is actually negligible, but at least is known how this range is generated.

In the case a certain stage is already passed, the required time for this stage should be set at 0 months and the success probability should equal 100%. Other input requirements, which are necessary in order for the valuation model to operate correctly, are as follows:

EBITA margin ≥ 0%;
Revenues ≥ 0;
Time ≥ 0;
Investments ≥ 0;
Cost of capital ≥ 0%;
0% ≤ Success probability ≤ 100%;
0% ≤ Tax rate ≤ 100%;

Appendix VII: Sensitivity analysis

In order to analyse the behaviour of the model, a sensitivity analysis provides meaningful insights. Table 12 gives an overview of the values for the input parameters and Figure 17 represents the results of the sensitivity analysis.

Table 12: Overview of input values for sensitivity analysis

Philips' existing market			
Current market dynamics	***Most Likely***		
Revenues (x € 1,000)	€ 100,000		
Growth rate (%/year)	0%		
EBITA margin (%)	20%		
WACC (%)	9%		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ 80,000	€ 80,000	€ 80,000
Growth rate (%/year)	2%	2%	2%
Game changer market			
Stages	***Time (months)***	***Investment (x € 1,000/year)***	***Success probability (%)***
Exploratory	12	€ 1,000	20%
Proof-of-Concept	12	€ 1,000	30%
Development	12	€ 1,000	40%
Growth	36	€ 1,000	80%
Maturity	120	-	-
Decline	36	-	-
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ 100,000	€ 100,000	€ 100,000
EBITA margin (%)	20%	20%	20%
Price pressure (%/year)	2%	2%	2%
Market growth (%/year)	2%	2%	2%

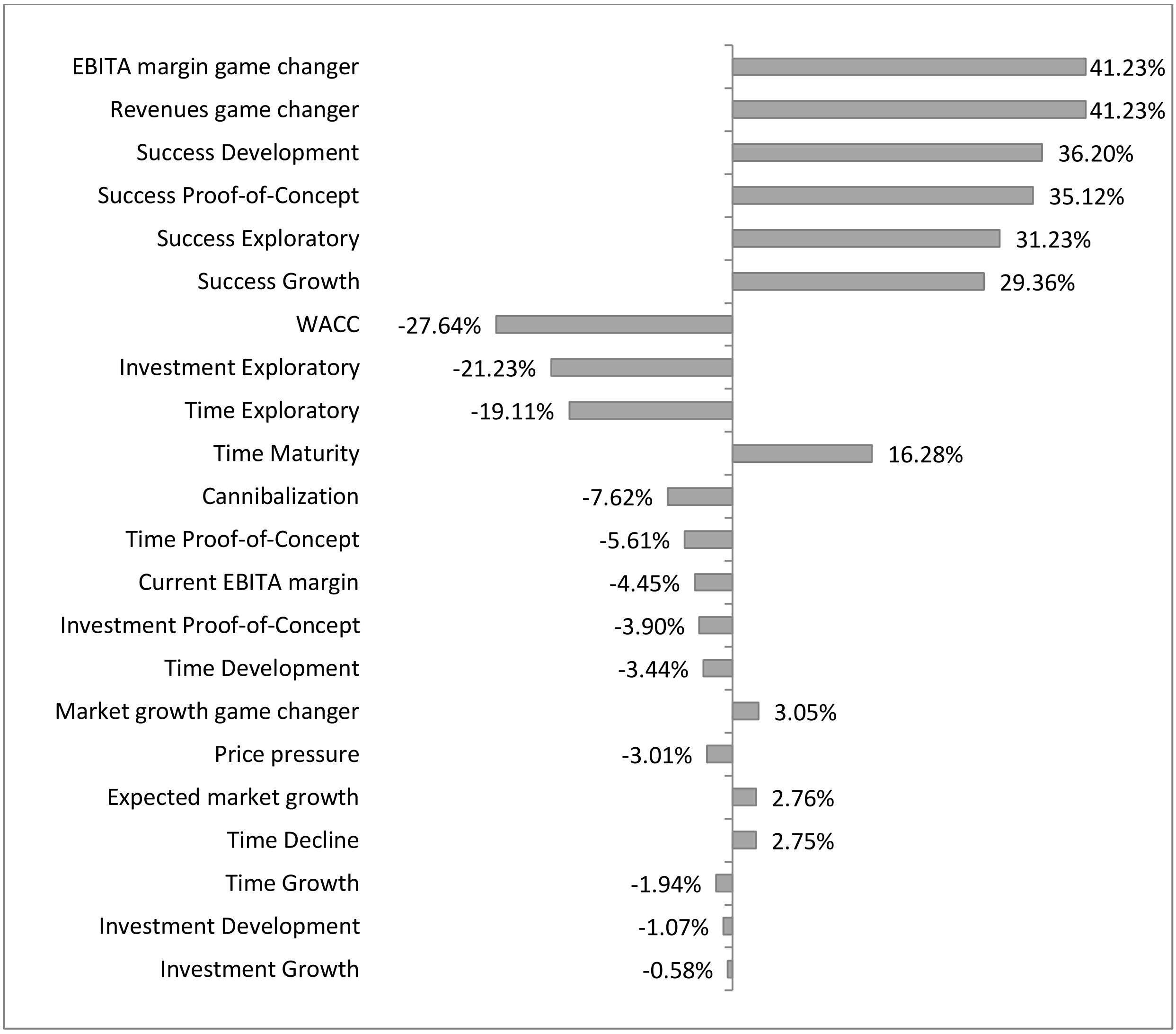

Figure 17: Sensitivity analysis results (+10% in input value) in a tornado diagram

Appendix VIII: Input values case study

Game changer

Table 13 provides an overview of the input values used for the valuation of the game changer. First, related market X has revenues equal to € 422 million. Since cannibalization is assumed to be zero, the expected Philips' existing market is equal to € 469 million (422 · $(1.03)^{(3+7/12)}$).

The input values for the game changer market are obtained through an internal discussion with project management, and hereby the input for the value drivers is used as optimistic scenario. For the most likely scenario, sales of that particular sales channel are assumed to represent 5.5% of total sales, equaling € 23.2 million (5.5% of € 422 million). So when sales of that sales channel would double through the introduction of the game changer, additional revenues equal € 23.2 million. Here, EBITA margin is assumed to equal 25%.

Table 13: Input values for game changer

Philips' existing market			
Current market dynamics	***Most Likely***		
Revenues (x € 1,000)	€ 422,000		
Growth rate (%/year)	3%		
EBITA margin (%)	7%		
WACC (%)	8.5%		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ 469,000	€ 469,000	€ 469,000
Growth rate (%/year)	3%	3%	3%
Game changer market			
Stages	***Time (months)***	***Investment (x € 1,000/year)***	***Success probability (%)***
Exploratory	0	€ -	100%
Proof-of-Concept	0	€ -	100%
Development	7	€ 2,000	49%
Growth	36	€ 3,000	70%
Maturity	120		
Decline	36		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	-	€ 23,200	€ 50,000
EBITA margin (%)	8%	25%	42%
Price pressure (%/year)	0%	0%	0%
Market growth (%/year)	2%	3%	4%

Growth option on game changer

For the growth option, Table 14 provides an overview of the input values used for the valuation. Since the growth option is comparable with an adjacency innovation project, there is no Philips' existing market.

Then, for the market of the growth option, the timing and success probability parameters for the proof-of-concept and development stage are based on the game changer project. Other parameters' values are based on assumptions.

Off course, also expected revenues are difficult to forecast, but based on an analysis of market Y a most likely scenario is determined. Total sales in Europe and the U.S.A. total € 753,836 million. The percentage of sales through the particular sales channel in market Y is found to be 7.4%, which results in € 55,783 million. When 20% of the potential customers can be reached, whereby Philips can obtain 1% margin, the potential revenues are € 112 million. Since these values are highly dependent on assumptions, the range of scenarios is set at +/- 100%.

Table 14: Input values for growth option on game changer

Philips' existing market			
Current market dynamics	***Most Likely***		
Revenues (x € 1,000)	€ -		
Growth rate (%/year)	0%		
EBITA margin (%)	0%		
WACC (%)	8,5%		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ -	€ -	€ -
Growth rate (%/year)	0%	0%	0%
Growth option market			
Stages	***Time (months)***	***Investment (x € 1,000/year)***	***Success probability (%)***
Exploratory	0	€ -	100%
Proof-of-Concept	7	€ 500	49%
Development	36	€ 2,000	70%
Growth	36	€ 3,000	10%
Maturity	120		
Decline	36		
Expected market dynamics	***Pessimistic***	***Most likely***	***Optimistic***
Revenues (x € 1,000)	€ -	€ 112,000	€ 224,000
EBITA margin (%)	15%	20%	25%
Price pressure (%/year)	0%	0%	0%
Market growth (%/year)	2%	3%	4%

Appendix IX: Results case study

Table 15 and Table 16 present the rNPV outcomes for several values of the game changer's EBITA margin and expected revenues, respectively, in case the other input values are as estimated by Philips Research. These tables provide insight into the minimum required values for the EBITA margin and expected revenues when the other value driver reaches its expected value.

Table 15: Minimal rNPV outcomes (x 1,000) when expected revenues are € 50 million

	EBITA margin game changer					
	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
€ 50,000	€ (699)	€ (209)	€ 281	€ 770	€ 1,260	€ 1,750

Table 16: Minimal rNPV outcomes (x 1,000) when EBITA margin is 42%

	Expected revenues game changer (x 1,000)					
	€ 2,500	€ 3,000	€ 3,500	€ 4,000	€ 4,500	€ 5,000
42%	€ (1,090)	€ (679)	€ (268)	€ 144	€ 555	€ 966

Table 17: minimum required combination of input game changer for rNPV (x € 1,000) > 0

Expected revenues game changer (x €1,000)	EBITA margin game changer (%) 7.5%	9.0%	10.5%	12.0%	13.5%	15.0%	16.5%	18.0%	19.5%	21.0%	22.5%
€ 7,500	-2045	-1825	-1605	-1384	-1164	-944	-723	-503	-282	-62	158
€ 9,000	-1825	-1561	-1296	-1032	-767	-503	-238	26	291	555	819
€ 10,500	-1605	-1296	-988	-679	-371	-62	246	555	864	1172	1481
€ 12,000	-1384	-1032	-679	-327	26	379	731	1084	1437	1789	2142
€ 13,500	-1164	-767	-371	26	423	819	1216	1613	2009	2406	2803
€ 15,000	-944	-503	-62	379	819	1260	1701	2142	2582	3023	3464
€ 16,500	-723	-238	246	731	1216	1701	2186	2671	3155	3640	4125
€ 18,000	-503	26	555	1084	1613	2142	2671	3200	3728	4257	4786
€ 19,500	-282	291	864	1437	2009	2582	3155	3728	4301	4874	5447
€ 21,000	-62	555	1172	1789	2406	3023	3640	4257	4874	5491	6108
€ 22,500	158	819	1481	2142	2803	3464	4125	4786	5447	6108	6770

Table 18: minimum required combination of input growth option for rNPV (x € 1,000) > 0

Expected revenues growth option (x €1,000)	EBITA margin growth option (%) 10.0%	12.0%	14.0%	16.0%	18.0%	20.0%	22.0%	24.0%	26.0%	28.0%	30.0%
€ 56,000	-1948	-1562	-1176	-791	-405	-19	367	752	1138	1524	1910
€ 67,200	-1562	-1099	-636	-173	289	752	1215	1678	2141	2604	3067
€ 78,400	-1176	-636	-96	444	984	1524	2064	2604	3144	3684	4224
€ 89,600	-791	-173	444	1061	1678	2295	2913	3530	4147	4764	5381
€ 100,800	-405	289	984	1678	2373	3067	3761	4456	5150	5844	6539
€ 112,000	-19	752	1524	2295	3067	3838	4610	5381	6153	6925	7696
€ 123,200	367	1215	2064	2913	3761	4610	5459	6307	7156	8005	8853
€ 134,400	752	1678	2604	3530	4456	5381	6307	7233	8159	9085	10011
€ 145,600	1138	2141	3144	4147	5150	6153	7156	8159	9162	10165	11168
€ 156,800	1524	2604	3684	4764	5844	6925	8005	9085	10165	11245	12325
€ 168,000	1910	3067	4224	5381	6539	7696	8853	10011	11168	12325	13482

Appendix X: User interface valuation tool