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Modelling the financial feasibility of a new business model: Sustainability measures "as-a-Service"

FINAL VERSION

Author:
C.J. (Casper) Bresters

Under supervision of:

Dura Vermeer Bouw Hengelo
ir. T. (Tine-Loes) Hemmes MBA

University of Twente
dr.ir. W.J.A. (Wouter) van Heeswijk
dr. B. (Berend) Roorda

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GLOSSARY

Civil sector: The civil sector, also referred to as construction sector, can be defined as the branch of manufacture and trade based on building, maintaining and renovating structures.

Conceptual model: A conceptual model can be defined as "an abstract representation of something generalized from particular instances" (Liu, Yu, Zhang, & Nie, 2011). Its purpose is to communicate, because an eventual simulation model cannot exist without a conceptual model (Robinson, Arbez, Birta, Tolk, & Wagner, 2015).

Discounted Cash Flow (DCF): This is a valuation method used to estimate the value of an investment based on its expected future cash flows. DCF analysis attempts to figure out the value of an investment today, based on projections of how much money it will generate in the future (Fernando, 2021a).

Discounted Payback Period (DPP): This method is similar to the Payback Period (definition below). It works the same, but it discounts future cash flows back to their present value so the investment and the stream of cash flows can be compared at the same time period (Hofstrand, 2013).

Dutch building decree ('Bouwbesluit'): The Dutch building decree is a collection of technical construction regulations to which all Dutch construction works (i.e. houses, offices, stores, hospitals, etc.) have to comply.

Dutch climate agreement ('Het Klimaatakkoord'): The Dutch climate agreement is part of the Dutch climate policy. The agreement includes several arrangement between various organisations and companies in the Netherlands to reduce CO_2-emissions. Most important goals included in the agreement are 49% reduction of CO_2-emissions in 2030 and 95% reduction in 2050 compared to 1990.

Energy transition: In general, this term refers to a significant structural change in an energy system (World Energy Council, 2014). In this research, this term refers to the current energy transition, which is mainly driven by the acknowledgement that global carbon emissions must be brought to zero and must replace fossil fuels for renewable energy sources. Section 1.3 gives further information on the energy transition.

Housing corporation: Housing corporations are organizations that are focused on constructing, managing and leasing qualitative good housing with affordable rent for persons with a relatively small wallet (social housing). An important characteristic of this kind of housing is that the rental incomes for the corporations are not profitable with reference to the establishment costs.

Internal Rate of Return (IRR): The IRR is a core component of capital budgeting and corporate finance. Businesses use it to determine which discount rate makes the present value of future after-tax cash flows equal to the initial cost of the capital investment. It allows investments to be analysed for profitability by calculating the expected growth rate of an investment's returns and is expressed as a percentage (Jassy, 2021). It provides a benchmark figure for every project that can be assessed in reference to a company's capital structure (Pinkasovitch, 2021).

Life Cycle Costing (LCC): LCC means considering all the costs that will be incurred during the lifetime of the product, work or service.

Modified Internal Rate of Return (MIRR): The MIRR assumes that positive cash flows are reinvested at the firm's cost of capital and that the initial outlays are financed at the firm's financing cost. By contrast, the traditional IRR assumes the cash flows from a project are reinvested at the IRR itself. The MIRR, therefore, more accurately reflects the cost and profitability of a project (Hayes, 2021b).

Net Present Value (NPV): The NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyse the profitability of a projected investment or project (Fernando, 2021c). The NPV analysis provides a currency denominated present value return from the investment (Pinkasovitch, 2021).

PaaS model: Refers to the business model 'Products-as-a-Serivce'. The PaaS model allows customers to purchase a desired result rather than the equipment that delivers the results. Under this model, companies offer the physical product and services to maintain a product's use through design, use, maintenance, reuse, remanufacture and recycling (Lacy & Rutqvist, 2015).

Payback Period (PP): The Payback Period refers to the amount of time it takes to recover the cost of an investment. Simply put, the Payback Period is the length of time an investment reaches a break-even point. The desirability of an investment is directly related to its Payback Period. Shorter paybacks mean more attractive investments. It is useful in financial and capital budgeting (Kagan, 2021). It provides insight into the liquidity of the investment (length of time until the investment funds are recovered) (Hofstrand, 2013).

Profitability Index (PI): The Profitability Index is the ratio of the present values of cash inflows and the present value of cash outflows (Alhabeeb, 2016). The PI is a variation of the NPV approach to comparing projects. Although the PI does not stipulate the amount of cash return from a capital investment, it does provide the cash return per dollar invested (Hofstrand, 2013).

Product-Service System (PSS): This term is a synonym of the PaaS model. In literature, this term is often used. However, the PaaS term is used instead of PSS, as this term is more often used in practice.

Risk premium: A risk premium is the investment return an asset is expected to yield in excess of the risk-free rate of return. An asset's risk premium is a form of compensation for investors. Its represents payment to investors for tolerating the extra risk in a given investment over that of a risk-free asset (Hayes, 2020b).

Transition management: The deliberative process to influence governance activities in such a way that they lead to accelerated change directed towards sustainability ambitions is defined as transition management (Loorbach & Rotmans, The practice of transition management: Examples and lessons from four distinct cases, 2010).

Weighted Average Cost of Capital (WACC): This is a calculation of a firm's cost of capital in which each category of capital is proportionately weighted. All sources of capital, including common stock, preferred stock, bonds, and any other long-term debt, are included in a WACC calculation.

SUMMARY

The Dutch existing housing stock should be completely energy neutral in 2050. Around 7 million houses have to be renovated to more sustainable conditions to achieve this goal. This number asks for a quick commence of the energy transition, but also demonstrates the amount of work that is prospected. It provides an opportunity for Dura Vermeer to safeguard an important position in the future market of the energy transition. One possible way of safeguarding this position is by reacting to the bottlenecks that currently withhold the energy transition from further progress. Several bottlenecks currently contribute towards stagnation in the energy transition of the existing housing stock. A new business model, the 'Products-as-a-Service' model (PaaS), seems promising in relieving bottlenecks. This research develops and validates a product-independent conceptual model that assesses the financial feasibility of the PaaS model applied to sustainability measures for housing corporations. The conceptual model links together all concepts needed to assess financial feasibility by showing the inputs, outputs and the final decision. It helps in understanding the contents of a financial feasibility analysis and enables the transition towards a calculation model. Figure 1 displays the conceptual model.

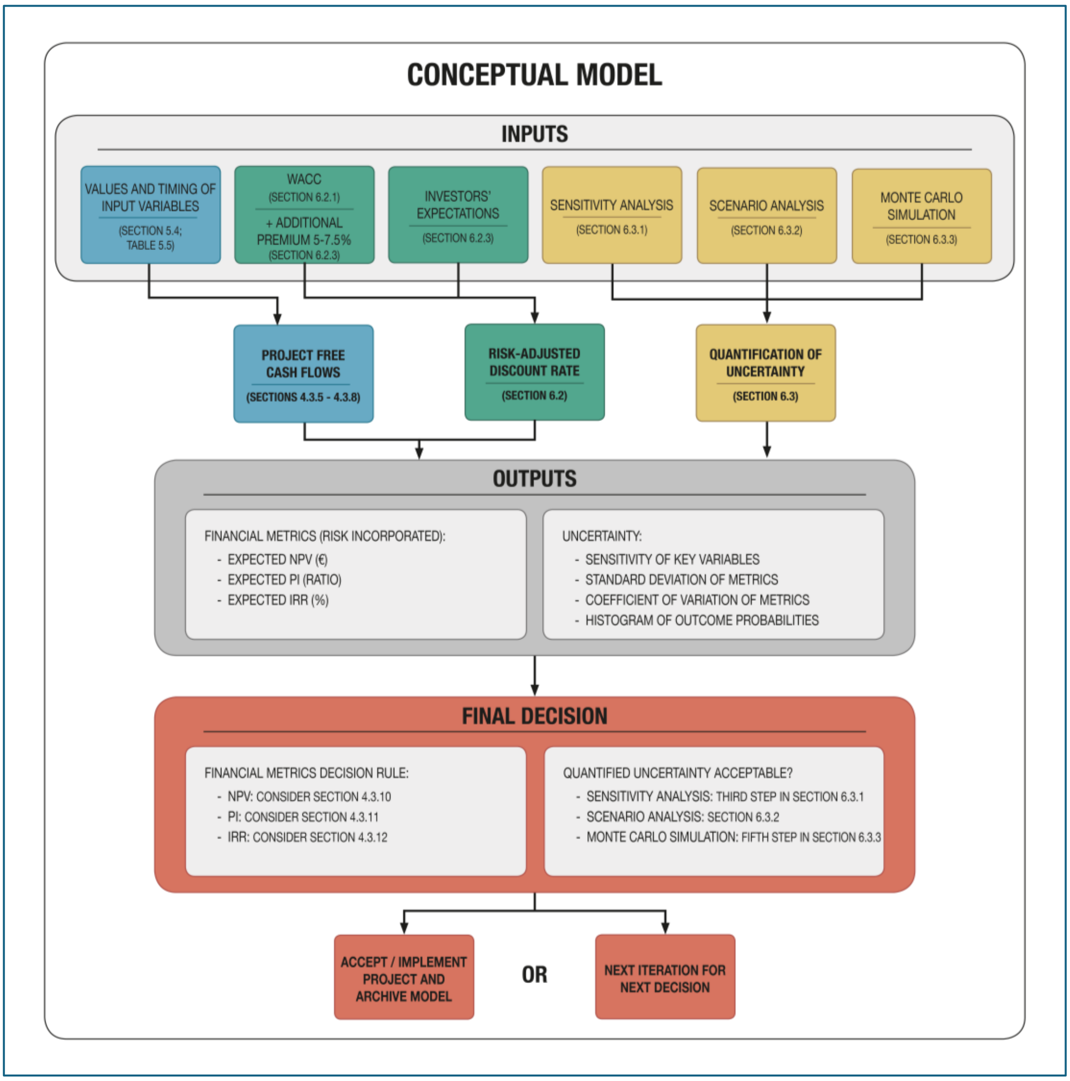

Figure 1 - Conceptual model of the financial feasibility a of PaaS proposition

The research also presents a roadmap that enables the transition from the conceptual model towards a calculation model. The proof of concept in this research validates the conceptual model by a walkthrough of the roadmap. The project of Winschoterdiep is used for the walkthrough; a renovation project in which the sustainability of student housing is improved. Excel was used as software for the calculation model. The research also provides an extensive manual for the Excel model. The proof of concept was a success and provides useful business insights into the financial feasibility of the project. It enables interpreting the financial feasibility in one glance, along with the uncertainties incorporated in the results. Thereby, the proof of concept validated the conceptual model. Useful (business) insights of the proof of concept are:

- The means of financial metrics (which take the time-value of money into account) determined with the base case, scenario analysis and Monte Carlo simulation are relatively similar to each other:
    - The NPV is around €30,000. This means that the expected value of future cash flows is €30,000 more worth than the initial investment of around €1,100,000.
    - The IRR is around 13%. That is equal to earning a 13% compound annual growth rate. The IRR is higher than the established risk-adjusted discount rate of 12.40%. This means that the returns from the investment are high enough to justify the risk of the investment in theory.
    - The PI is 1,033. This means that every euro invested in the project generates €0.033 in additional value.
- The risk-adjusted discount rate is 12,40% (including a risk premium of 5%, as advised by literature, since the PaaS proposition is a combination of an expansion of existing business and a new product);
- The yearly fee, material costs and WACC are the most important factors (the model is the most sensitive for these variables/parameters) and should, therefore, be determined with high accuracy;
- Resulting graphs of the Monte Carlo simulation are skewed to the right, meaning that the downside risk is greater than the upside potential.

Thus far, the main results of the research are described. To arrive at the given results, the report discusses three subjects/contents. These are used as input to the conceptual model and thereby arrive at the aforementioned proof of concept. First of all, the financial feasibility of a PaaS proposition can be assessed through the modelling of financial metrics or capital budgeting techniques. The conceptual model incorporates the Net Present Value (NPV), Profitability Index (PI) and Internal Rate of Return (IRR). All three are discounted cash flow techniques.

Secondly, identification of variables and parameters that influence the financial feasibility of a PaaS model is needed as input for the conceptual model. The variables/parameters are categorised into the lifecycle stages in which they (possibly) occur.

Lastly, considering involved risks and uncertainty is also an important part of assessing financial feasibility. Both are incorporated differently in the conceptual model. Project-specific risks are incorporated by adjusting the discount rate, which is done by adding a risk premium (5% - 7.5%, based on pre-specified project categories for which risk premiums are suggested by literature) to the WACC (which reflects the overall market risk of the company) or adjusting it to investors' expectations. Uncertainty is considered by three additional techniques, which are added to the conceptual model: sensitivity analysis (appoints the variables/parameters to which the model/project is the most sensitive), scenario analysis (provides a clear view of the project's performance under certain conditions) and Monte Carlo simulation (ties together sensitivities and input variable probability distributions). The techniques provide different forms of information about uncertainty. Therefore, they are all incorporated in the conceptual model.

Linking these subject/contents with each other establishes the conceptual model. Together with a practical roadmap, they enable the transition from the conceptual model towards a calculation model and thereby the assessment of a PaaS proposition's financial feasibility.

READING GUIDE

This reading guide gives a brief overview of the structure of this report. The report starts by introducing the research in Chapter 1. This chapter describes the relevance and background of the research. It also provides a more extensive description of the PaaS model and the characteristics of the model that should be taken into account in the remaining parts of the report.

Next, Chapter 2 further introduces the research by presenting the research goal, research model and the research questions. Hereby, a clear overview is given of the contents of the research.

Thereafter, the methodology of the research is described in the third chapter. Each section included in the methodology describes the methodology used for one particular research question. Thus, five sections together describe the methodology used for this research.

Subsequently, the fourth chapter elaborates on the first research question. The chapter is divided into three sections. In the first section, useful literature for the first research question is introduced. The second section focuses on the trade-off between six financial metrics and the selection of three metrics based on their advantages and disadvantages. The third part presents a roadmap that should be added to the conceptual model, which provides a step-by-step plan for modelling the selected financial metrics.

Next, Chapter 5 answers the second research question. It identifies the variables and parameters that influence a PaaS proposition's financial feasibility. The identification of these variables and parameters is an extension of the fifth step of the roadmap presented in the fourth chapter.

Afterwards, the third research question is elaborated on in Chapter 6. The first section describes the relevant literature for the third research question. The second part of the chapter describes the incorporation of risk in the conceptual model. Various methods are described for the incorporation and explained how these can be applied by Dura Vermeer specifically. The description of the incorporation of risk also serves as an extension to the ninth step of the roadmap (Chapter 4). The third part of the chapter presents three methods for the quantification of uncertainty: sensitivity analysis, scenario analysis and Monte Carlo simulation. The description of their practical application serves as an extension for the 13th step in the roadmap of Chapter 4.

Chapters 4, 5 and 6 elaborated on the most important contents that should be incorporated in the conceptual model. Subsequently, the seventh chapter of this report focuses on the development of the conceptual model. It starts with a brief literature study in the first section. The following four sections describe the textual representation of the model. After that, the textual representation is visualized for more clarity.

Thereafter, Chapter 8 presents the proof of concept that validates the conceptual model presented in the previous chapter. Each section incorporated in the eighth chapter elaborates on one of the steps incorporated in the roadmap of the fifth chapter.

Lastly, Chapter 9 and 10 finalize the report by respectively presenting recommendations for this research and the conclusion of the report.

1

INTRODUCTION

Prior research (Section 1.2) has demonstrated that progression in the energy transition of the existing housing stock currently stagnates. Several bottlenecks contribute to this lack of progression. New business models are needed to overcome stagnation and stimulate investments in the energy transition. This research will focus on exploring one promising business model: sustainability measures 'as-a-Service'. Prior research (previous master thesis of the author) and a preliminary investigation already elaborated on the context and relevance of the model, meaning that the main task ahead is testing its feasibility (Bresters, 2021). This first chapter introduces the research and gives an extensive description of the background for the research.

1.1 Dura Vermeer Bouw Hengelo

The research proposed in this report is executed at Dura Vermeer Bouw Hengelo (DVBH). At DVBH are currently more than 350 employees located. DVBH is incorporated in the division 'Construction and Real Estate' of the Dura Vermeer Groep. Therefore, the main projects executed and managed in Hengelo are building and renovation projects for housing and utility. This explains the interest in and relevance of the study presented in this report, as Dura Vermeer wants to explore a new business model to apply in future projects within the energy transition of the existing housing stock.

1.2 Context: prior research

This research is part of a double master graduation. Prior research was conducted as a master thesis for Civil Engineering & Management and focused on the energy transition of the existing housing stock. It analysed and identified bottlenecks that contribute to the current stagnation in the energy transition of the existing housing stock. The results of this study serve as input for the research described in this report, as they provide important context and background information.

1.3 Context: Energy transition

It all starts with worldwide climate change. Global temperatures have been rising in the last century, quantities and intensities of precipitation are increasing and more hot days are encountered yearly. The climate goals of Paris (2015) have been issued to prevent further global warming and decrease the effects coupled with global warming. The Dutch government translated these goals in 2018 (final approval in 2019) into the climate agreement ('Het Klimaatakkoord'). Strong ambitions are set in the area of CO_2 emissions, with the goal of 49% reduction in 2030 and even 95-100% reduction in 2050 (RIVM, 2020). This effectively brought the energy transition in the Netherlands to a start.

An 'energy transition' is defined as "a change in the state of an energy system as opposed to a change in an individual energy technology or fuel source" (Grubler, 1991). Historically, these changes have taken place several times and were mainly driven by the demand for and availability of different fuels (Smil, 2010). An example of such a transition seen in the past, was the transition from coal towards natural gas and nuclear energy in the sixties last century.

The foremost motivation for the transition is to limit the adverse effects of energy consumption on the environment (Frankfurt School, 2017). This includes reducing greenhouse-gas emissions and mitigating climate change (Owusu & Sarkodie, 2016). Therefore, since the adoption of the climate agreement of Paris, the energy transition to net zero carbon is defined as the downshift of fossil fuel production to stay within the carbon emissions budget to limit global warming to less than 1.5 °C (Rogelj, Forster, Kriegler, Smith, & Séférian, 2019). The current energy transition differs from transitions in the past as it is not economically driven, but mainly driven by acknowledging that global carbon emissions must be brought to zero. In this research, the term 'energy transition' specifically refers to this latter transition towards renewable energy sources.

In addition to the main driver being the acknowledgement that carbon emissions have to be brought to zero, the speed at which the transition in the energy sector needs to take place will be historically rapid (Sovacool B. K., 2016). Therefore, it is necessary to accelerate the energy transition to meet the climate targets of Paris (TNO, sd).

1.4 Context: Energy transition in the existing housing stock

One crucial sector and important part of CO_2-reduction strategies is the built environment (the existing building stock). The built environment is also a relevant sector for Dura Vermeer, as large renovation projects are a significant portion of their project portfolio. Future renovation projects will be influenced by the energy transition.

The main driver of the current energy transition is the acknowledgement that global carbon emissions must be brought to zero. This has strong implications for residential areas, as the built environment contributes largely to energy consumption and CO_2 emissions. Buildings account for 40% of the total final energy consumption in the EU. More than 80% of this energy consumption is used for heating and domestic hot water (European Commission, 2011). This presents an opportunity to reduce the consumption of (fossil) energy, with the built environment becoming a key sector in the energy transition.

From a contractors' point of view, the energy transition of residential areas is divided into new constructions and the existing building stock. This research will only focus on the existing housing stock. Several reasons justify a focus on the existing housing stock. First of all, the housing stock is an important part of the built environment. In terms of CO_2 emissions, the housing stock is responsible for 36% of total emissions (Ebrahimigharehbaghi, Qian, Meijer, & Visscher, 2019). Furthermore, it is significantly more complex to apply sustainability measures in the existing housing stock than in new constructions, because of (among other things) fewer degrees of freedom (Hohmann, 2019). Lastly, the renovation activity is expected to be greater than the construction and demolition activity in the future (Filippidou, 2018). Together, these arguments substantiate the focus on the energy transition of the existing housing stock.

The existing housing stock is also a key target within decarbonisation policies (Eker, Zimmermann, Carnohan, & Davies, 2018). In 2050 full energy neutrality should be achieved. The heating, hot water and installations in a building result in building-specific energy consumption. This consumption must be compensated by renewably generated energy to be energy neutral, thereby making it CO_2-neutral (TNO, 2021). Heat supply in the existing housing stock is currently highly dependent on natural gas (Bouw, 2021). As the usage of natural gas entails CO_2 emissions, the entire existing housing stock must be renovated towards more sustainable conditions and should eventually be disconnected from the natural gas network (Rijksoverheid, 2019).

1.5 Bottlenecks in energy transition

The transition needs and wants to gain momentum, yet it is observed that progression in the transition stalls (EIB, 2021). Just 8,000 houses were disconnected from the natural gas network in 2020, according to a report of the Dutch 'Planbureau voor de Leefomgeving' (PBL, 2020a). This number stands in stark contrast to the seven million existing houses. Although ambitions are set, the pace of renovating houses to more sustainable conditions is too slow to accomplish the goals set for 2050. Several bottlenecks contribute to this stagnation. In prior research, these bottlenecks are extensively analysed (Bresters, 2021). This section describes the most important findings of bottlenecks that contribute towards stagnation in the energy transition.

1.5.1 Deficit of financial resources

A deficit of financial resources contributes significantly to the stagnation of the transition. The origin of this bottleneck is twofold: on the one hand, installations are too expensive to achieve the far-reaching sustainability needed to disconnect houses from the natural gas network and on the other hand, the available budget at both municipalities (especially smaller municipalities) and housing corporations are too low to cope with the investments needed (Rijksoverheid, 2019). Most of the calculations show that renovations to create more sustainable conditions in houses are overall not viable (PBL, 2020b). Furthermore, general costs are often higher than expected, causing that financial feasibility comes into question (Dutch Ministry of Interior and Kingdom Relations, 2020; EIB, 2021). Therefore, the energy transition is not neutral in costs at the moment with current business models. This implies larger investments are needed. Municipalities and housing corporations often lack the financial power/budget to cope with these investments. This is further complicated by uncertainty in future natural gas tariffs. If no subsidies are granted, sustainable alternatives have to be paid from general resources by municipalities. These resources are often insufficient. Housing corporations also struggle with their budget, as they are legally fairly limited to earn investments back by rent. Concluding, a deficit of financial resources plays a major role in the stagnation of the energy transition.

1.5.2 Difficulty in choice for sustainable alternatives

A second bottleneck is that it is difficult to choose a suitable sustainable alternative (e.g. heating network and heating pump) to apply on a larger scale. In general, choosing a sustainable alternative appears to be difficult, since the technical development of alternatives is often not yet sufficient and at the same time technology is improving too quickly for clear choices. Furthermore, the fact that the challenge of sustainability is significantly bigger for the existing housing stock than for new constructions, is an important reason for the second bottleneck. The choice for certain sustainability alternatives depends on several factors, which are more diversified in the existing housing stock than for new constructions (De Leeuw, 2020). These factors include the type of house, age, condition and even geographical location (Rotmans, 2019). In practice, this bottleneck entails a bigger impact for private homeowners than for public housing, as types of houses are usually more varying in the private housing stock (Gemeente Hengelo, 2019). Every type needs possibly a different set of measures to achieve optimal sustainability. This hinders a clear choice for the application of a sustainable alternative. This should be taken into account with the development of a new business model, as it also hinders the choice of products offered in the business model.

1.5.3 Laboriously progress in creating support base amongst residents

The third bottleneck is that creating support base amongst residents appears to be laborious (Dutch Ministry of Interior and Kingdom Relations, 2020). Support base is important, since housing corporations need 70% of upvotes of tenants for their renovation projects and private homeowners are able to individually decide whether they invest in sustainability or not. Laboriously progress in creating support base amongst residents and homeowners has multiple causes. Residents are often indifferent against the goal of renovations (e.g. whether it is focused on general renovation or a renovation with the purpose of increasing sustainability) and they often need a decent amount of time to get used to the idea of renovation and make informed decisions (Blomsterberg & Pedersen, 2015; PAW, 2020). In addition, residents frequently lack knowledge of matter (for example why it is needed to disconnect from natural gas), do not sufficiently get involved by important stakeholders in the preparation of projects and often have limited feeling with the increase of living comfort they might enjoy after a renovation. Intensive contact with residents is needed to overcome these causes. As this contact is intensive and time-consuming, the bottleneck becomes presumably more significant during upscaling phases of gasless projects.

1.5.4 Interfaces between previous bottlenecks

In addition to these bottlenecks, noting the existence of cohesion between bottlenecks is important. Bottlenecks can mutually reinforce each other. Also the problem of the ‘weakest link’ applies: all things have to be right in order to reach sufficient progress and results, and this condition is rarely met (EIB, 2021). Figure 1.1 summarizes the interfaces between bottlenecks. The middle does not represent any specific bottleneck, but the bottlenecks all together cause stagnation in the Dutch energy transition. The bottlenecks and their interfaces were identified in prior research (Bresters, 2021) and are briefly clarified in this section.

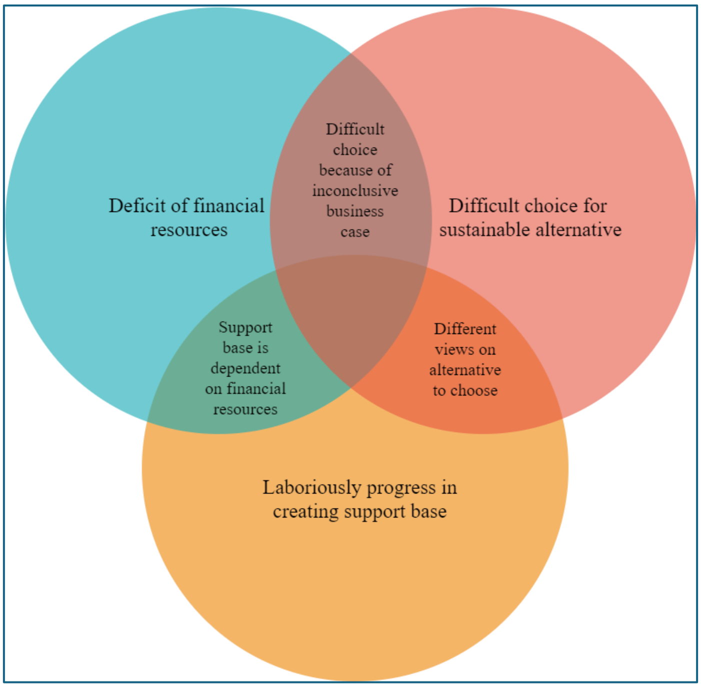

Figure 1.1 – Interfaces between bottlenecks. The circles represent the main bottlenecks. Their overlap represent the interfaces between the main bottlenecks.

The choice for a certain sustainability alternative would be easier if business cases were conclusive. New business models might ease this bottleneck, if they provide conclusive business cases. Support base amongst residents is dependent on financial resources for an important part, as shown by the results of prior research. A lack of support base only arises if residents experience negative consequences. Financial consequences are part of the most important negative consequences, since sustainability measures for tenants often result in an increase in rent and for private homeowners result in a significant initial investment. An affordable solution would logically create more support base amongst residents. Furthermore, research indicated that private homeowners rarely invest in sustainability measures if the payback times of those measures are longer than nine years (PwC, 2016). The last intersection between bottlenecks lies between a difficult choice for alternatives and a lack of support base. Residents often have different views on the alternative to choose compared to each other and to other stakeholders. This results in a lack of support base amongst residents.

To conclude, results of prior research indicated that the interfaces between a deficit of financial resources and other bottlenecks are experienced as most important. A more conclusive business case helps in overcoming stagnation in the energy transition. Therefore, the financial bottleneck is an important bottleneck to take into account within the development of a new business model.

1.6 The need for new business models

Prior research also indicated that housing corporations and municipalities (the most important stakeholders at the moment) currently apply a business case that is inconclusive and not viable. The national government and important stakeholders all focus on 'making volume', as it is generally believed that economies of scale supported by industrialization and standardization will lead to needed innovations and relief of bottlenecks. Therefore, most renovation projects to disconnect current housing stock from the natural gas network are large scale. Entire neighbourhoods are tackled as a whole to apply identical sustainability measures on a larger scale. The national government steers towards this business model/approach with policies. Grant schemes and the tax system all stimulate renovation projects on large scale. However, the results of prior research highlighted that applying this business model does not help in improving the stagnation of the energy transition. Business cases are often inconclusive, as on the one hand technology is too expensive and on the other hand municipalities and housing corporations lack financial power/budget to support further progress in the energy transition. Private homeowners also play a major role in sustainable improvements. This also impedes progress of the energy transition, since private homeowners are reserved in their investments in energy efficiency measures. Although less ambitious homeowners might experience financial advantages (Mulder & Van Heel, 2020), the overall picture is that investments are not yet viable for private homeowners (PBL, 2020b; TNO, 2019). From a financial point of view, private homeowners will only invest if measures are profitable (ING, 2019). As it is not obligatory for private homeowners to invest in sustainability for their homes until at least 2030 (ING, 2019), most of them will not make any investments in energy-saving measures, since the current business model does not offer sufficient stimulation for investments. All in all, the current business model is insufficient in stimulating progress in the energy transition and important stakeholders (e.g. municipalities and housing corporations) lack the budget to cope with the investments needed in this business model.

Therefore, new business models are needed in the market of the energy transition to make progress. In general, energy transitions are multidimensional, complex, non-linear and non-deterministic phenomena and, therefore, they are difficult to characterize (Blazquez, Fuentes, & Manzano, 2020). They require a transformation of actors and their conduct, of markets, and a change in existing regulations and policies (Sovacool & Geels, 2016). This shows the complexity involved with energy transitions. Furthermore, the current transition is more than only technical solutions, as also economic consequences and social aspects play important roles (TNO, 2021). Dura Vermeer might take an important role in the future energy transition by experimenting with new business models.

1.7 Proposition of a new business model: PaaS model

New business models should eventually lead to upscaling of the energy transition. For market parties such as Dura Vermeer, experimenting with new business models might eventually offer an entry to the developing market of the energy transition of the existing housing stock. Considering the background information of previous sections, the PaaS model (‘Products-as-a-Service’) is a promising business model, which will be explored in this research. This section explains the relevance of the model.

1.7.1 General background PaaS model

PaaS is a business model that allows customers to purchase a desired result rather than the equipment that delivers the results. The academic field often refers to the model as Product-Service Systems (PSS) (Rombouts, 2020). A PSS is an integrated bundle of products and services which aims at creating customer utility and generating value (Cho, Kim, & Lee, 2010). In comparison to the traditional form of adding value driven by the production process, competitive advantage today derives from the value provided through service use/function (Erkoyuncu, Roy, Shehab, & Cheruvu, 2011). With PSS, products are no longer simply sold. Instead, long-term contracts are entered into and hence the nature and length of the relationship between supplier and customer changes (Datta & Roy, 2010). All that is done in close collaboration with the customer, who becomes more of a ‘user’ of the service as opposed to a ‘consumer’ of a product. To that extent, the PaaS model is similar to a public-private partnership (PPP; especially since housing corporations are public parties). However, two differences distinguish the PaaS model from a PPP. First of all and most important, the ownership of the delivered product is shifted from the supplier/contractor to the client/government at the moment the product moves into its use phase with a PPP contract (Chao-Duivis, 2012), whereas the supplier remains the owner of the product(s) in the PaaS-model. The government always retains ownership of the facility and remains responsible for public service delivery in a PPP contract (Whiteside, 2016). Secondly, a leasing construction is not possible in a PPP, as payments are always based on an availability compensation under a PPP contract (Chao-Duivis, 2012).

An important characteristic of PaaS is that it aligns the provider’s and the customer’s goals for the product: high-quality products that last long, are used frequently, maintained impeccably, perform well, and are returned properly – all of which help reduce the cost of ownership for customers and increase the provider’s revenue. The PaaS model has been around for a long time in niche industries like car rental, construction tool rental, and aeroplane leasing and servicing. Technology and a new generation of financially strapped and environmentally conscious consumers provide opportunities to take the model to a much larger scale for many more products (Lacy & Rutqvist, 2015).

Besides software companies, manufacturers also move towards ‘as-a-Service’ business models. To encounter decreasing margins in various markets, manufacturing companies adapt by adding high-value services to their portfolio, following a transition to solutions providers commonly referred to as servitization (Classen, Blum, Osterrieder, & Friedli, 2019). Manufacturers are beginning to realize that the PSS model can help them to differentiate themselves from their competitors by offering more value to their customers than just the product itself could deliver (Lombardo, 2019). Several stakeholders are involved in the model. The most important stakeholders to consider are the manufacturer, service provider, customer and user. The (economic) ownership of the product (depending on the underlying contract structure) lies at the manufacturer, at the service provider or at a separate entity set up for this purpose (i.e. Special Purpose Vehicle) (Coalition Circular Accounting, 2020).

Various types of Product-Service Systems exist. In general, three types of PSS are distinguished according to the product-service ratio of the system (Kreye, Goh, & Newnes, 2009):

- Product-oriented PSS: The ownership rights of the material are transferred to the customer, in other words, the customer becomes the new owner of the product. A service arrangement ensures the utility of the product over a given period. Examples of this type of PSS are warranties and maintenance contracts.
- Use-oriented PSS: The ownership rights of the product stay with the producer. The customer purchases the use of the product over a given period. Examples include leasing and sharing schemes.
- Result-oriented PSS: The ownership rights stay on the side of the producer. The customer purchases the result or outcome of a product.

Whether the system’s value is based upon the product or the service changes along with the category in which the system is placed. This is visualized in Figure 1.2. The proposed system in this report belongs to the second category (use-oriented), since the ownership rights remains at the producer (Dura Vermeer in this case), but customers will still purchase the service of the product rather than the result or outcome of the product.

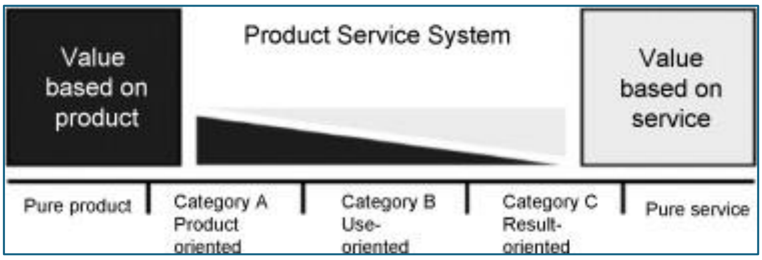

Figure 1.2 - PSS in perspective to products and services (Datta & Roy, 2010)

Category B and C encourage the producer of the product to improve the functional optimization of the product and its performance, because they stay accountable for it. The responsibility for a product’s whole life cycle or its ownership is transferred from the customer to the producer. Therefore, PSSs do not only consider the design and construction of a product, but the whole life cycle starting (Kreye, Goh, & Newnes, 2009). This should be taken into account for cost estimation and the financial feasibility study of the system.

Generally, the model offers benefits to both the customer and the provider. For customers, PaaS transforms large capital expenses into smaller operating expenses, allowing them to amortize the cost of the product throughout its life cycle. Additionally, the customer no longer assumes the risk of product failure or the responsibility for maintenance (both are included in the service). Finally, PaaS ensures that the customer will not be stuck with obsolete equipment, since the service includes upgrades. For the provider, PaaS delivers a consistent revenue stream, which is a more sustainable business model (Lombardo, 2019). Disadvantage is that the shift towards a PaaS model is complex and involves a major strategic implication with serious implications (Dimache & Roche, 2015).

Certain key factors contribute towards the successful adoption of the model. PSS is a competing and stable offering if it is 'affordable' from the perspective of the customer (affordability), the manufacturer (profitability) and the supplier (sustainability) (Bankole, Roy, Shebab, Cheruvu, & Johns, 2012). A key factor when developing offerings for PSS is to design the product and service from a life-cycle perspective, considering all the product's life-cycle phases. The integrated product-service life-cycle stages involves design, manufacturing, delivery and adaptation involving remanufacturing, recycling and value engineering (Datta & Roy, 2010).

Many factors have impact on successfully developing a PaaS model. Especially financial and legal factors influence the development. This report will mainly focus on the financial factors, as it has more common ground with the study for which this report serves as master thesis. This does not mean that legal factors should not be considered, since with PaaS it is crucial that the customer does not become the (economic) owner of the product. This might entail some legal difficulties, because the product will naturally be installed inside a house owned by a different stakeholder (Coalition Circular Accounting, 2020). Despite the relevance of legal factors, the emphasis of this report will be on the financial part of the business model.

1.7.2 Financial implications and cost estimation for PaaS/PSS

In literature, various scientific articles are written about financial subjects within PSS (e.g. cost estimation modelling techniques and risk/uncertainty). Servitization implies rethinking the revenue models and changing the way the product and service offerings are priced (Rapaccini, 2015). Cost assessment of such service offerings remains a challenge and has not been addressed extensively in the literature yet (Datta & Roy, 2010).

The life cycle of products becomes important when transforming a traditional business towards PSS, because it incurs a transition in costs from the customer to the provider. Due to this shift in cost ownership, Life Cycle Costing (LCC) is often used by providers to better understand the PSS costs spanning from design to the end-of-life (Kambanou & Lindahl, 2016). Various techniques are applicable within LCC to assess the costs of a product.

LCC is defined as the cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements. With it, the costs of purchasing the asset as well as the future costs of operating (including maintenance) and disposal/reuse of the item are being revealed. This forms the basis of future decisions concerning design, scheduling and planning (Kreye, Goh, & Newnes, 2009). It helps in effectively choosing between a number of competing alternatives. This can be at any stage of the project, but most potential lies in the early design stages. In that stage, most of the options are open for consideration and significant capital expenditure is yet to be committed. LCC is used in this research, as it aims to aid the decision-making process in the financial area within the design stage of future sustainability measures offered as a service.

LCC modelling techniques are based on the comparison to previous projects/products or on the cost of capital. Independent of the cost estimation technique used, a set of procedures are followed to make the costs and cash flows comparable to one another. To make this possible, the time value of money needs to be considered (Kreye, Goh, & Newnes, 2009). When a function is sold rather than ownership, cost structures should be arranged to support a new demand of cash flow. Moreover, new non-recurring, overheads and hidden costs become relevant (Adrodegari, Saccani, Kowalkowski, & Vilo, 2017).

Within cost estimation, also risk and uncertainty play important roles. LCC and cost estimation are disciplines that attempt to forecast the future, sometimes even a long way ahead in time, according to the project or product of concern. They consequently have to deal with the uncertainty introduced by factors such as life cycle events, discount rates, operation, and maintenance. Uncertainty is endemic to the processes of LCC. Thus, the treatment of uncertainty in an adequate way is essential for the success of the project (Kreye, Goh, & Newnes, 2009). Uncertainty derives from a lack of information or knowledge and causes an event to be known imprecisely or unknown. As well as being a source of negative outcomes, it can also create opportunities (Datta & Roy, 2010).

In contrast to uncertainty, risk only covers threats, where it is possible to assign probabilities to outcomes (Datta & Roy, 2010). In PSS, when defining a value proposition, a company should entail the risk component and define in advance how it is going to be shared among the actors involved in the new business model. Risk assessment and mitigation capabilities are required (Adrodegari, Saccani, Kowalkowski, & Vilo, 2017).

1.7.3 Relevance for the energy transition

Considering the bottlenecks described in earlier sections, the PaaS model offers advantages if applied to sustainability measures. First of all, the PaaS model in general is most relevant for products with high operating costs or where expensive price tags and long payoff times make it unappealing for customers to own (Lacy & Rutqvist, 2015). Sustainability measures meet especially the latter two, as they are often very expensive and most of them entail long payoff times.

Secondly, before creating a product as a service, or even converting an existing product to the PaaS model, manufacturers need to analyse customer needs and ascertain what additional features clients are willing to purchase (Lombardo, 2019). Many of the customer needs are identified based in prior research. Table 1.2 below briefly describes the potential advantages per bottleneck that the PaaS model offers if applied to sustainability measures.

Table 1.1 - Potential advantages of the PaaS model per bottleneck

Bottleneck	Potential advantages
Deficit of financial resources	Because of expensive installations, housing corporations and private homeowners often lack the budget to cope with investments needed for sustainability. With the PaaS model, an initial investment is not necessary, relieving this bottleneck.
Difficulty in choice for sustainable alternative	For this bottleneck alone, no significant advantages are offered by applying PaaS. However, it is an important bottleneck to take into account for determining the sustainability measure(s) that PaaS is applied to.
Laboriously progress in creating support base amongst residents	The same accounts for the third bottleneck as the previous bottleneck. The PaaS model has no significant advantages if this bottleneck is considered separately, but does offer advantages considering the interfaces (as described in the rows below).
Interface: Financial and difficult choice	The choice for sustainability measures is easier for housing corporations and private homeowners if a business model, such as the PaaS model, is financially viable. Multiple products can be included in the eventual model to choose from as a service, enabling customization for specific houses.
Interface: Financial and support base	Homeowners are unwilling to invest in sustainability measures if payback periods are longer than nine years. With the PaaS model the initial investment is made by the manufacturer or economic owner of the product. Hereby, the payback period becomes less important.
Interface: Difficult choice and support base	Stakeholders often have different views on the alternative to choose. The PaaS model applied to sustainability measures might relieve this bottleneck, as it might be easier to apply customization in every different type of house by incorporating modularity for example in the product(s) offered as a service.

In addition, a PaaS model stimulates the provider to develop a sustainable, future-proof product and incentivises taking into account technological innovation and adaptability in the design phase. The PaaS model often leads to better-maintained products, that can be optimised during their lifespan and as a result will last longer. Standardization and modularity are often applied to the product ensuring that parts can be easily adapted or replaced (Coalition Circular Accounting, 2020). These are all relevant incentives for the energy transition in general and can eventually lead to affordable products (or in the case of PaaS to affordable services).

The PaaS model also offers some benefits to the provider of the service. First of all, PaaS delivers a consistent revenue stream, which is a more sustainable business model (Lombardo, 2019). Secondly, the energy transition currently asks for new and feasible business models. This provides an opportunity for Dura Vermeer to gain an important position in the (future) market of the energy transition. Therefore, Dura Vermeer wants to perform research on the potential benefits and feasibility of the PaaS model applied to sustainability measures.

1.7.4 Template for developing a business model

This section introduces a template for the development of new business models (Jonker & Faber, 2020). The template is specifically designed for societal issues such as the energy transition, as it also takes other values than just financial values into account. The content and relevance of the template are outlined below.

In general, the template proposed by Jonker & Faber (2020) offers structure with a specific application. The structure helps in making some coherent choices to design a business model. It differs from templates for conventional business models, as it does not only lead towards the determination of the financial margin. Thereby, the profit in the template is not dominant. The big challenges are determining the negative and positive impact and the development of a business model that offers more than just one value. After all, the energy transition asks for organizations that contribute to solutions for the societal problems. Therefore, the template used by Jonker & Faber (2020) seems particularly suitable for the development of the proposed business model. The template itself consists of three phases, divided into several components:

1 Definition phase
- Occasion and context (why): What is the problem, opportunity or challenge and in what context is it located?
- Dream (for which): What is the eventual goal? What is going to make the difference?
- Proposition (how): What is the solution for the problem, opportunity or challenge?

2 Design phase
- Type of business model (logic): Which type of business model is applied to create value?
- Involved stakeholders (who): Who is involved in the business model?
- Strategy (route): Which route has been chosen to achieve the eventual goal?
- Choosing core activities (realization): What activities have to be undertaken to realize the strategy?
- External auditing (validating): What is the opinion of others? Is the chosen strategy the right way? Does it already exist? Is it allowed?

3 Result phase
- Determining impact (indicators): What are the positive and negative consequences of the proposed business model, for now and in the future?
- Value(s) creation (transaction forms): How are transactions modelled and what is exchanged? What values are created consequently?

Most steps of the template are already addressed by preliminary and prior research. The context of the energy transition and relevance of the PaaS model are described in previous sections. Furthermore, the goal of the development of the new business model is clear. Therefore, the development of the business model is currently located in the eighth step. The idea behind the business model seems viable, but its feasibility has yet to be determined. Feasibility analysis can consist of many parts, among others: technical, financial and legal feasibility. Financial feasibility analysis verifies the viability of the PaaS model applied to sustainability measures. The next subsection describes the contents of a financial feasibility analysis.

1.7.5 Financial feasibility analysis

A feasibility study in general is the initial design stage of any project or plan (Hofstrand & Holz-Clause, 2020b). It studies the viability of an idea. Feasibility studies determines if a company possesses the required resources or technologies and whether the proposal offers a reasonable return compared to the risks involved with the investment. Many types of feasibility studies exist - among others technical, financial, market and organization. This report focuses on financial feasibility.

Financial feasibility analysis is an analytical tool used to evaluate the economic viability of an investment (Björnsdóttir, 2010). It seeks the projected revenue and expenses, projects a financial narrative, and estimates project costs, valuations and cash flow projections (Laverty & Littel, 2020). A feasibility study is conducted during the first stages of project development, before financing is secured and a go/no-go decision has been made (Matson, 2000). The results indicate how the project will perform under a specific set of assumptions regarding technology, market conditions and financial aspects. Applied properly, it leads to the planned strategic structure of investment and necessary financing against the goal of earning above the cost of capital and creating shareholder capital (Helfert, 2001). It is often confused with a business plan, but their roles are very different. A feasibility study is a tool for investigating the viability of a prospective project, whereas a business plan is a tool for planning the actions needed to take the project proposal from an idea to reality (Hofstrand & Holz-Clause, 2020b). The feasibility study refines the initial business idea, while the business plan uses information from the feasibility study to further prepare the project to evolve into an operating business (Matson, 2000).

A financial decision depends on two specific factors: expected return and expected risk and uncertainty (the distinction is explained in Section 7.1.1). A financial feasibility analysis is a means for examining those two factors (Fabozzi & Peterson, 2003). Various tools exist to investigate the expected return and thereby the financial viability of a business idea. Known methods are for example Payback Period (PP), Net Present Value (NPV), Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR) (Björnsdóttir, 2010; Juwitaningtyas, Ushada, & Purwadi, 2015; Morales-Pinzón, Luruena, Rieradevall, Gasol, & Gabarrell, 2012). Each of these indicators provides useful information for making decisions, although NPV and IRR are most often applied in financial studies (Morales-Pinzón, Luruena, Rieradevall, Gasol, & Gabarrell, 2012).

The second factor is expected risk, which is also important for the funding cost and strategy of a new project or business model. Financing is one of the most essential parts of all projects. The financing structure can be different between projects and it often depends on the type of the investment, the risk level of investment, and the credit rating of the project owner. Project finance is a method of financing an economically capable project based on the expected cash flows generated by the project. For determining the financing of a project, assessment models should allow the user to perform sensitivity analysis, scenario analysis, and simulations to analyse the risk associated with the investment project. If the best alternative investment is e.g. depositing the money into a bank account, the extra risk involved in the investment project needs to be assessed and a risk premium added to the return of the best alternative investment. The risk premium has to be decided by the investor and the choice between investments depends on the investor's attitude towards risk, i.e. whether he is risk-averse or risk-seeking (Björnsdóttir, 2010).

One last remark should be taken into account with the outline of the research. For financial feasibility analysis, using mathematical models for the calculations makes it easier and less time consuming to update the analysis. It also makes it easier to conduct sensitivity analysis on key variables, which makes it possible for investors to envision different scenarios and possibly mitigate the risk associated with these variables. Furthermore, to create a clear and specific view of a business model's financial feasibility, exploration of the product offered as a service is necessary. This exploration is not included in the scope of this research (see also next chapter). Therefore, it is necessary to develop a model that is product-independent. In later stages of the development of the business model, the developed model should provide an easy and quick view of the financial feasibility if the product offered as a service is known.

1.7.6 Conceptual model for financial feasibility

Product choice and design for the eventual product offered 'as-a-Service' is not part of the scope of this research. Therefore, only a model can be drafted to test financial feasibility of the business model eventually. This research will focus on developing a conceptual model to quickly determine financial feasibility if a clearer view is developed on the offered product(s). A conceptual model can be defined as "an abstract representation of something generalized from particular instances" (Liu, Yu, Zhang, & Nie, 2011). Its purpose is to communicate, because an eventual simulation model cannot exist without a conceptual model (Robinson, Arbez, Birta, Tolk, & Wagner, 2015).

1.8 Conclusion

Previous sections described the context and background of the study. Several bottlenecks are currently encountered that contribute towards stagnation in the energy transition of the existing housing stock. A deficit of financial resources, difficulty in choice for sustainable alternatives, laboriously progress in creating support base amongst residents and interfaces between these three withhold the energy transition from progress. This research will study the financial feasibility of the PaaS model applied to sustainability measures, as it seems a promising model considering the comparison of bottlenecks with the characteristics of the PaaS model (Table 1.2). The PaaS model might contribute to relieving most of the bottlenecks encountered. Therefore, it offers several advantages to important stakeholders of the energy transition. Especially homeowners and housing corporations might benefit from the PaaS model applied to sustainability measures. Furthermore, it also offers some advantages for Dura Vermeer. The next chapter outlines and demarcates the research by describing its goal and research questions.

2

PROBLEM DESCRIPTION AND RESEARCH OUTLINE

This chapter of the research further introduces the research and its goals. It starts with describing the core problem of the research in Section 2.1. Next, in Section 2.2 the research goal is described based on the background of the research described in the previous chapter. Following, the research model is composed in Section 2.3. Both the research goal and the research model give the most important input for drafting the research questions in Section 2.4. Thereafter, Section 2.5 elaborates on the importance of the research. Finally, the desired results of the eventual research are described in Section 2.6. Verschuren & Doorewaard (2007) provide a framework to determine the core problem, research goal, research model and research questions. This framework is used in the corresponding sections.

2.1 Core problem

Dura Vermeer expects a growing market in renovation projects of the existing housing stock for improving sustainability. The growth within this specific market is currently stagnating as explained in the previous chapter. However, with the goals set by the national government, it is assumed that significant growth will eventually take place. Furthermore, Dura Vermeer wants to contribute to the market and gain an important position, taking into account the bottlenecks currently causing stagnation. Dura Vermeer is one of the market parties that might provide a business model needed to stimulate investments in sustainability. In this area, Dura Vermeer wants to perform research to elaborate on one of those promising business models. The context and background of this model are all clear, since it was already extensively discussed in prior research. The main task ahead is analysing the feasibility of the business model. The focus of this research is on financial feasibility by conducting a financial feasibility analysis and composing a conceptual model to easily and quickly analyse the financial feasibility of different products within the PaaS model.

Core problem

Dura Vermeer wants to gain an important position in the (future) market of the energy transition of the existing building stock by adopting a new business model (PaaS). The core problem is the unclear feasibility (especially its financial feasibility) of the model.

2.2 Research goal

This section gives an extensive description of the research goal. The research goal can be formulated by using the steps presented by Verschuren & Doorewaard (2007).

2.2.1 Step 1

First of all, it should be determined whether the research is theory or practice-oriented and whether the research tackles an action or a knowledge problem. The research is mainly practice-oriented as the financial feasibility of a new business model (the PaaS model) is analysed. The new business model offers new opportunities for Dura Vermeer in the energy transition of existing residential areas. For the second determination, first the definitions of action and knowledge problems are given. The definitions of both problems are as follows (Wieringa, Heerkens, Gervasi, & Zowghi, 2004):

- "Action problems consist of a difference between the way we perceive the world to be and the way we think it should be. We normally solve an action problem by changing the state of the world. As a side effect, this produces knowledge, and in special cases, this knowledge may even be sufficient to make the problem go away. By trying to implement a change, we may learn that the world is quite different from what we thought it to be and that it in fact already agrees with our desires. However, the general approach to solving an action problem is to change the world, not to change our perception of the world."

- "Knowledge problems consist of a lack of knowledge about the world. To solve a knowledge problem, we need to change the state of our knowledge, and when we do that, we try not to change the world. As a by-product of gathering knowledge we usually do change the world, e.g. by experimenting or by observing people (who thereby may change their behaviour). However, the intention still is to change our knowledge state without altering the state of the world."

To that extent, the proposed problem classifies as an action problem. The energy transition is an example of a problem in which we try to change the world to a world of which we think it should be. The problem in the energy transition is its current stagnation. By adjusting, inventing and developing new business models, one tries to change the world to solve the problem. Therefore, the proposed research tackles an action problem.

2.2.2 Step 2

Secondly, an exploration of the scope or project framework is needed to come up with the research goal. This is done by answering the following questions:

- What problems are encountered within the scope of the research?
  Current business model(s) applied in the energy transition is/are inconclusive. The way technologies are applied in this model is too expensive for important stakeholders as municipalities, housing corporations and private homeowners to cope with the investments needed. In other words, the energy transition of the existing housing stock asks for business models that are conclusive and viable. Dura Vermeer wants to gain an important position in the current and future market of the energy transition. Therefore, they are seeking affordable new business models.
- What is the background of these problems?
  The Dutch national government has set considerable ambitions for the near future in the Dutch climate agreement. In 2050, the entire housing stock has to be energy neutral. This asks for a quick commence of the energy transition. However, currently stagnation is observed, which prevents quick progress in the energy transition. Several bottlenecks contribute to this stagnation. The development of new business models helps in overcoming stagnation and in stimulating investments in the energy transition of the existing housing stock.
- In which direction does Dura Vermeer seek solutions?
  New and feasible business models are needed in the energy transition. A considerable part of Dura Vermeer's portfolio consists of renovation projects. Dura Vermeer wants to preserve their position in the market. As the energy transition asks for new and conclusive business models, Dura Vermeer seeks new business models and opportunities to safeguard its position in the market. The previous chapter already elaborated on the PaaS model and showed that this model offers several benefits that might contribute to relieving bottlenecks. It might offer one of the needed new business models. Therefore, Dura Vermeer seeks the solution in the development of the PaaS model applied to sustainability measures, especially since these installations are an important element of the investments for which stakeholders (housing corporations and private homeowners) lack budget. The preparation and elaboration of the development of the business model are already conducted by prior research. The next step is to examine if the model is feasible (in particular financially feasible).

2.2.3 Step 3

The third step for proper formulation of the research goal is determining which type of practical research is opted. Practice-oriented research is placed in one of the steps of the intervention cycle. The intervention cycle consists of five steps (Verschuren & Doorewaard, 2007):

1. Problem analysis: Mapping the problem that an organization faces. This step makes the difference clear between the current and the desirable situation.
2. Diagnosis: This step seeks to find the cause of the problem that is determined in the first step.
3. Design: The third step is about designing an intervention plan based on the problem analysis and diagnosis in the first two steps to give a solution for the problem.

4 Intervention: In the fourth step, the design of the third step is realised within the organization where the problem occurs.
5 Evaluation: Lastly, the fifth step should evaluate and control the realised intervention of the fourth step. This step concludes the intervention cycle.

The research in this report is design-oriented and located in the third step of the intervention cycle, as the first two steps of the cycle are already completed. Dura Vermeer already has a clear vision of the problem that currently occurs and what the desirable situation is. The problem is that the energy transition of the existing housing stock stagnates for which Dura Vermeer wants to develop a solution. The cause of the problem and the direction for a solution (second step of the intervention cycle) are also already known. Several bottlenecks are contributing towards stagnation. A further important contribution is caused by the inconclusive business model that several stakeholders currently try to roll out. The development of new and affordable business models is the direction in which solutions must be sought. As mentioned, one promising model is the PaaS model applied to sustainability measures. The research focuses on developing and designing this model as an intervention plan and solution, based on the problem analysis and diagnosis of the first two steps of the intervention cycle. Specific measures offered as a service are currently unknown. Therefore, the development of a model that assesses financial feasibility should be product-independent.

2.2.4 Step 4

The fourth and last step is the final phrasing of the research goal. It brings together the first three steps to formulate the correct research goal.

The goal of the research

The goal of the research is to design and develop a product-independent conceptual model that assesses the financial feasibility of a new business model, the PaaS model applied to sustainability measures, which Dura Vermeer can apply in (future) market of the energy transition of the existing housing stock.

2.3 Research Model

Before starting with formulating the research questions, it is useful to draft a global overview of the steps needed to achieve the research goal. This is visualized by developing a research model. A research model also helps to determine the theoretical background needed for the research. In this section of the report, the research model is designed and described.

For the development of the research model, the proposed approach by Verschuren & Doorewaard (2007) is used. The approach consists of 5 steps, which are executed to develop the research model (these are different steps than the steps used for the formulation of the research goal):
1 Determine the research goal/contribution;
2 Determine the research objects;
3 Determine the nature of the research perspective (theory or practice-oriented);
4 Determine which roads must be taken to come up with the conceptual model;
5 Description of the designed research model.

By completing these steps, a research model is designed. The goal and contribution were already determined in the previous section. Several steps have to be undertaken to reach this goal. These steps are displayed in the research model. The research model for this research is shown in Figure 2.1.

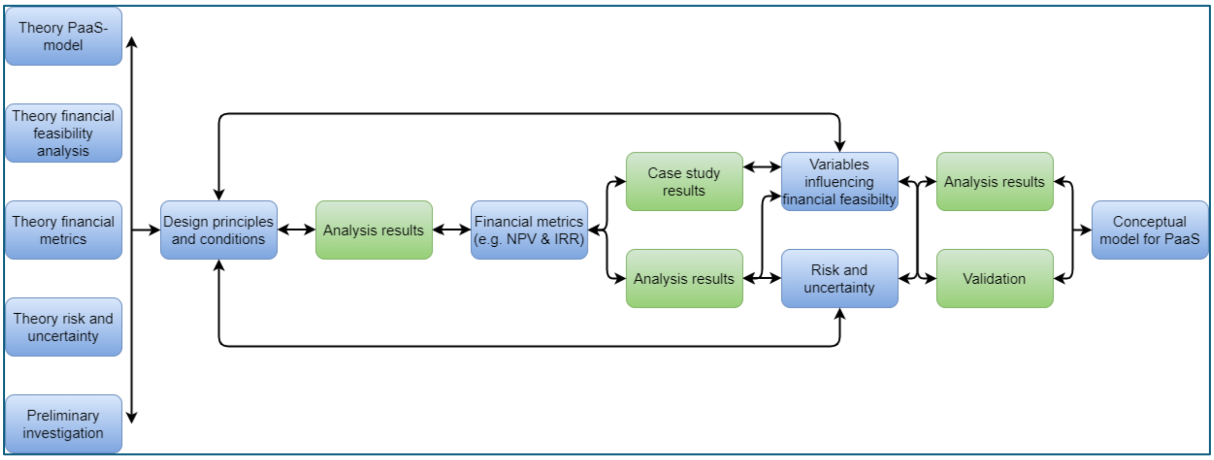

Figure 2.1 - Research model

The last step considering Verschuren & Doorewaard (2007) is a summarized description of the research model.

Summarized description of the research model

A study of theory about the PaaS model, theory of the contents of financial feasibility analysis, theory on financial metrics included in financial feasibility analysis and theory of risk and uncertainty (in which also quantification is included), as well as a preliminary investigation (including prior research) at Dura Vermeer, will deliver a list of design principles and design conditions needed as input for following steps in the research model. Analysis of the design principles and conditions leads to an elaboration on appropriate financial metrics (e.g. NPV and IRR) and the way these can be modelled. This, together with a case study and the design principles/conditions, serves as input for the exploration of variables/parameters influencing the financial feasibility of the PaaS model. The design principles/conditions together with the appropriate financial metrics are also input to the elaboration on risk and uncertainty (and their quantification). The research eventually merges the financial metrics, variables/parameters and risk/uncertainty in a product-independent conceptual model that examines the financial feasibility of sustainability measures incorporated in the PaaS model, which is validated by a proof of concept.

2.4 Research questions

This section presents the research questions that have to be answered to achieve the goal of the research. First, Section 2.4.1 elaborates on the research questions itself. The research questions are based on the research model presented in the previous section. Secondly, Section 2.4.2 shows the connection of the research questions with the research model. The connection with the research model demonstrates completeness of the research questions (Verschuren & Doorewaard, 2007).

2.4.1 Outline of research questions

In this section, the central research questions are presented. The central research questions are composed with the method 'dividing the research model' (Verschuren & Doorewaard, 2007). Therefore, the research questions correspond to the research model, which is presented in the next section. The central research questions are supported by several sub-questions. The research questions are as follows:

1 How can the financial metrics be modelled individually and product -independently?
- What financial metrics (e.g. NPV and IRR) are relevant for determining financial feasibility?
- Considering the variables influencing financial feasibility, how can the relevant metrics be modelled without selecting the product(s) that are eventually offered 'as-a-Service'?

2 Which variables/parameters influence the financial feasibility of the PaaS model applied to sustainability measures?
- What variables/parameters influence the financial feasibility of PaaS models in general (such as production costs and maintenance costs)?

- What measures (or activities), both technical and structural, are taken to improve the sustainability of the existing housing stock?
- Considering the measures, what impact does each individual measure potentially have on financial feasibility and what variables/parameters have to be taken into account?
- Can additional variables be identified based on similar cases in practice (validation by comparison with cases as for example 'Façades-as-a-Service' and leasing of houses)?

3 How can risk and uncertainty be quantified and incorporated in the conceptual model?
- What are the potential financial risks and what techniques can be used to incorporate risk in the conceptual model?
- What techniques can be used to incorporate uncertainties in financial metrics and thereby in the conceptual model?

4 How can the financial metrics and risk/uncertainty be combined in a product -independent conceptual model for the PaaS model applied to sustainability measures?

5 Does a proof of concept confirm the usefulness of the conceptual model?
- What product(s)/project can be offered/used as-a-Service to perform a proof of concept of the conceptual model?
- What are the values of the determined variables needed as input for the conceptual model?
- How can the conceptual model be validated by the proof of concept?

2.4.2 Connection of research questions to the research model

Figure 2.2 displays the connection of the research model with the research questions. Every central research question pertains to a certain part of the research model. The numbers of the research questions are placed in the corresponding dashed boxes to indicate to what part of the research model they belong. The connection of the research model to the central questions shows that by answering the central questions, the research goal is achieved. The design principles and conditions are not included in a dashed box, as these serve as input for all subsequent steps of the research model.

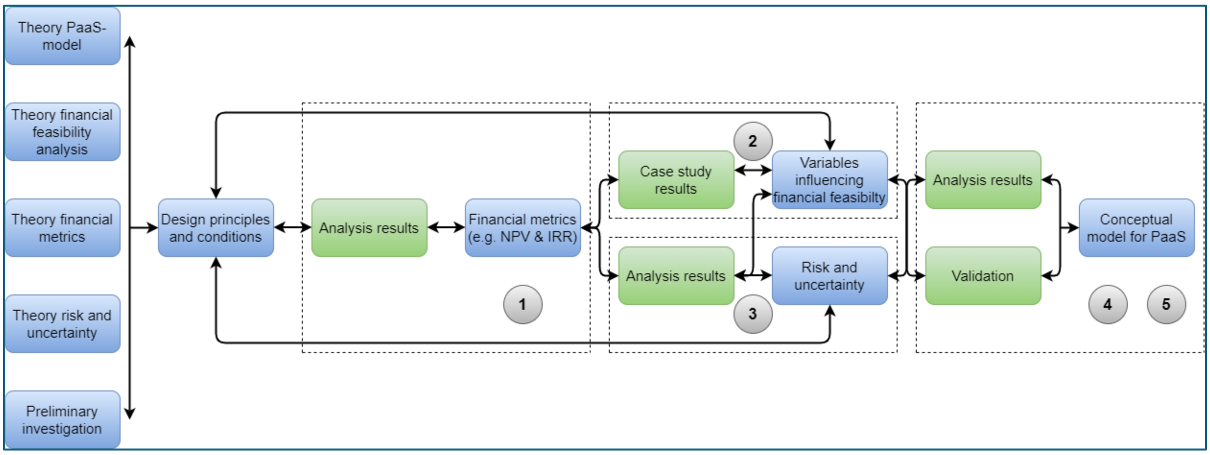

Figure 2.2 - Connection of the research questions to the research model

2.5 Importance of research

This section underlines the importance of the research. It will not only contribute to the knowledge of Dura Vermeer, but also to literature and the sector of the energy transition as a whole. First of all, the research fills a literature gap in the area of the general financial feasibility of the PaaS model. In general, cost assessment of service offerings remains a challenge and has not been addressed extensively in literature yet. Furthermore, the research will eventually provide a product-independent tool that models the financial feasibility of PaaS. Literature has not yet covered research that combines theory on financial feasibility analysis and theory on 'Products-as-a-Service'. Therefore, this research fills some existing gaps in literature. It complements literature in this area by combining it with additional subjects as risk and uncertainty. No scientific articles came forward that not only sought techniques for assessing financial feasibility (financial metrics), but also elaborated on the incorporation of risk and uncertainty in such a feasibility study.

Secondly, the research is also of importance for the energy transition as a whole. As mentioned before, the energy transition is currently stagnating. New and viable business models are needed in the energy transition to relieve bottlenecks that cause stagnation. The business model presented and analysed in this report provides a new business model that potentially improves progression in the energy transition. In this area, literature is very limited. Research to the energy transition is to a limited extent aimed at making progress in the energy transition with new business models. This research could, therefore, be an important addition to literature, although the practical implementation would also matter for an academic evaluation.

Lastly, the research is also important for Dura Vermeer. The development of a potentially successful new concept could serve as an entry to the developing market of the energy transition of the existing housing stock. This research helps in determining whether the new business model is indeed feasible.

2.6 Deliverables

This section describes and summarizes the eventual desired results of the research. Partial results of the research together must eventually form the desired result. This section only serves as a general overview of these desired results.

First of all, for every new idea the expected return has to be calculated. A desired result of the research is a clear view of financial metrics (such as the NPV and IRR) that should be used to determine the expected return and thereby the financial feasibility of the PaaS model applied to sustainability measures. As the specific product(s) offered as a service is/are yet unknown, the variables determined in the second partial result should be considered to eventually model the financial metrics.

Secondly, it is important to identify variables influencing the financial feasibility of the PaaS model applied to sustainability measures. The eventual model has to be product-independent, since the development of products offered as a service is not part of the scope of this research. Therefore, it is important to create a broad view on those variables. These variables are included in the conceptual model to develop a product-independent model. Furthermore, a clear view of variables influencing the financial feasibility also results in easier risk/uncertainty analysis, as variables can be analysed on their sensitivity within the model.

Thirdly, the financial decision depends on the way it is financed and the expected risk involved with the investment. A third partial desired result is, therefore, identification of techniques to determine the risks and uncertainty incorporated in the model. It is important to take the variables of the second partial result into account, as this might serve as important input for the determination of risks (by for example a sensitivity analysis) and thereby eventually the way the business model is financed.

Lastly, the partial results deliver the desired result of the research. Techniques for determining the expected return (and thereby financial feasibility) are merged with techniques to quantify uncertainty and expected risk into a conceptual model. This model must be product-independent to quickly determine the financial feasibility in later stages of the development of the business model, when a clearer view is created on the product(s) offered 'as-a-Service'. The usefulness and validation of the conceptual model is demonstrated by a 'proof of concept'. In the proof of concept, one specific (set of) measure(s) will is by calculating its financial feasibility.

3

METHODOLOGY

This chapter explains the methodology of this research. This report is roughly divided into five sections corresponding with the research questions. For every research question, different steps are needed for a complete answer.

3.1 Research question 1

The purpose of the first research question is to describe how financial metrics are modelled. To arrive at a sufficient answer, the research question is divided into two sub questions:

- How can the financial metrics be modelled individually and product -independently?
  - What financial metrics (e.g. NPV and IRR) are relevant for determining financial feasibility?
  - Considering the variables influencing financial feasibility, how can the relevant metrics be modelled without selecting the product(s) that are eventually offered 'as-a-Service'?

The goal of the first sub question is to select appropriate financial metrics to assess the financial feasibility of a PaaS proposition. Comparison of the contents of those techniques with the characteristics of the PaaS model appoints the most appropriate techniques. An answer to the second sub question must clearly describe how the selected financial metrics can be modelled. A roadmap is composed, which provides a clear guideline how one can model the financial metrics and transit to a sufficient calculation model. A roadmap is developed by comparing several sources from literature with each other and with practical examples of calculations of the selected financial metrics. The roadmap provides an answer to the second sub question.

3.2 Research question 2

The goal of the first research question is to identify factors/variables relevant for the financial feasibility of a PaaS proposition. Four sub questions support the second research question:

- Which variables/parameters influence the financial feasibility of the PaaS model applied to sustainability measures?
  - What variables/parameters influence the financial feasibility of PaaS models in general (such as production costs and maintenance costs)?
  - What measures (or activities), both technical and structural, are taken to improve the sustainability of the existing housing stock?
  - Considering the measures, what impact does each individual measure potentially have on financial feasibility and what variables/parameters have to be taken into account?
  - Can additional variables be identified based on similar cases in practice (validation by comparison with cases as for example 'Façades-as-a-Service' and leasing of houses)?

Firstly, factors and variables are identified that affect the financial feasibility of PaaS models in general. An extensive literature study is conducted to find these general factors and variables. Next, as this research is specifically focused on a PaaS model for sustainability measures, the next step is to complement the general factors and variables with factors/variables identified by assessing factors and variables affecting the Life Cycle Costs of various sustainability measures. To enable this extension to the factors and variables, first a list must be composed of sustainability measures that Dura Vermeer is able to offer in a PaaS proposition. The LCCs of sustainability measures is studied to answer the third sub question and complement the general factors/variables with factors/variables specifically revealed by the LCC of sustainability measures. Lastly, a case study of two cases must validate the results of the first three sub questions. Useful cases are 'Façades-as-a-Service' and 'Housing-as-a-Service', as these share some commonalities with the proposed PaaS model in this report.

3.3 Research question 3

The goal of the third research question is to elaborate on the way risk and uncertainty are incorporated in the conceptual model. Three sub questions are composed to sufficiently answer the third research question:

- How can risk and uncertainty be quantified and incorporated in the conceptual model?
- What are the potential financial risks and what techniques can be used to incorporate risk in the conceptual model?
- What techniques can be used to incorporate uncertainties in financial metrics and thereby in the conceptual model?

The first sub question focuses on the distinction between risk and uncertainty to enable answering the other two sub questions. Literature is studied to describe the distinction and to propose a start to incorporating risk and uncertainty in the conceptual model. After a clear description of the difference between risk and uncertainty, a description of methods and how they can specifically be applied by Dura Vermeer will answer the second sub question. Literature is used to find and describe methods to incorporate risk in the model. The theory found in literature are compared and applied to the characteristics of Dura Vermeer to arrive at clear roadmaps (step-by-step plans) for the application of those methods at Dura Vermeer specifically. With risks being incorporated in the model, the last sub question is answered, which focuses on the quantification of uncertainty. Again, literature is used to derive and describe methods that are commonly used to quantify uncertainty in models to assess financial feasibility. Theory is compared to the characteristics of the PaaS model proposed by Dura Vermeer to arrive at roadmaps to apply those methods and assess uncertainty specifically for projects proposed by Dura Vermeer.

3.4 Research question 4

The purpose of the fourth research question is the development of the conceptual model by combining the findings of the previous research questions: "How can the financial metrics and funding costs/strategy be combined in a product-independent conceptual model for the PaaS model applied to sustainability measures?" Literature is used to arrive at the definition of the conceptual model. Next, the framework of Robinson (2013) is used to develop a textual representation of the conceptual model. The following five steps are walked through and used as the methodology for the textual representation (Robinson, 2013):

1. Understand the problem situation;
2. Determine the modelling and general project objectives;
3. Identify the model outputs (responses);
4. Identify the model inputs (experimental factors);
5. Determine the model content (scope and level of detail), and identify any assumptions and simplifications.

For clarity, it is also useful to support the textual representation of the conceptual model with visualizations. For instance, process flow diagrams are useful for communicating the conceptual model.

3.5 Research question 5

The goal of the fifth and last research question is to validate the conceptual model. To answer this question, three sub-questions were composed to arrive at an answer:

- Does a proof of concept confirm the usefulness of the conceptual model?
    - What product(s)/project can be offered/used as-a-Service to perform a proof of concept of the conceptual model?
    - What are the values of the determined variables needed as input for the conceptual model?
    - How can the conceptual model be validated by the proof of concept?

The first sub-question focuses on the product(s) that are offered, or project that is used, for a proof of concept of the conceptual model. Presumably, a project is most useful for the proof of concept, as this will simplify matters (for example, the functional unit is much easier to derive for a project than for product(s) in general). Internal experts are consulted for an appropriate trade-off between renovation projects that can be used for the proof of concept. Next, the second sub-question seeks the values of the variables and parameters included in the conceptual model. Again, internal experts are consulted or interviewed to get the specific values for the project or product(s) used for the proof of concept. In total, three internal experts are consulted to arrive at relatively accurate inputs. Lastly, the third sub-question answers how the conceptual model is validated by the proof of concept. The first research question provides a guideline and roadmap that should be put in practice to validate the proof of concept. Various steps in this roadmap ensure the correct validation of the conceptual model. A peer review of the calculation model is the most important step to assure validation. The peer-review will be conducted by two external experts (both acquainted with these kinds of calculation models), the modeller and indirectly by the supervisors of this report.

4

RESEARCH QUESTION 1: MODELLING FINANCIAL METRICS

The fourth chapter of this research answers to the first research question: "how can the financial metrics be modelled individually and product-independently?" It is the first time services are offered by Dura Vermeer, introducing cost and benefit categories new to Dura Vermeer. Therefore, it is important to provide a clear description of the way financial metrics assess financial feasibility in the conceptual model. This chapter is divided into four sections to answer the second research question. First, Section 4.1 describes the literature available for the first research question. Secondly, Section 4.2 answers part a of the second research question. It selects the appropriate financial metrics to incorporate in an eventual model, based on the information provided in literature. Next, Section 4.3 describes the way relevant metrics can be modelled. It presents a roadmap to model financial metrics, without giving a software-dependent solution. Hereby, an answer is given to part b of the second research question. Lastly, Section 4.4 provides general recommendations for and limitations of modelling the financial metrics and wraps up the current chapter.

4.1 Literature: financial metrics

This section elaborates on financial metrics that are potentially used to assess the financial feasibility of the proposed business model. Numerous methods and techniques enable decision-making for investing in projects. In this section, the available methods are compared to each other. Furthermore, the section describes their advantages and disadvantages.

First of all, this report refers to techniques used to measure financial feasibility as 'financial metrics'. Literature often refers to them as 'capital budgeting techniques'. Capital budgeting is defined as the process of evaluating and selecting long term investments that are consistent with the business' goal of maximising wealth (Gitman, 2008). Unlike some other types of investment analysis, capital budgeting focuses on cash flows rather than profits. For example, non-expense items like debt principal payments are included in capital budgeting, because they are cash flow transactions (Hofstrand, 2013). Capital budgeting is important because it creates accountability and measurability. Alternative investment opportunities differ in many aspects such as the level of associated risk and their capacities to yield future returns. Therefore, the criteria for choice would be for the upper management to employ objective, quantitative, and credible methods to evaluate the proposed alternatives and select the best, especially in terms of higher profitability and less risk (Pinkasovitch, 2021).

Several methods exist to evaluate proposed alternatives. This part of the literature study is focused on the techniques applicable for this purpose. Capital budgeting techniques are divided into two categories: non-DCF (discounted cash flows) and DCF methods (Siziba & Hall, 2021). The Payback Period (PP) method is often used as a non-DCF technique. Discounted Payback Period (DPP), Net Present Value (NPV), Profitability Index (PI), Internal Rate of Return (IRR) and Modified Internal Rate of Return (MIRR) are all considered DCF techniques (Hermes, Smid, & Yao, 2007). The glossary at the beginning of this report described briefly what every technique entails. Gitman & Forrester (1977) divided the capital budgeting techniques into 'sophisticated' (mainly DCF methods) and 'unsophisticated' (mainly non-DCF methods). They saw a strong preference at companies for using sophisticated methods (for example, the NPV and IRR) as the primary tool of analysis. Within those primary tools of analysis, the IRR was the dominant technique. Their results further highlight that the most popular secondary (or supplementary) technique used was the payback period (Gitman & Forrester, 1977). More recent work shows that used methods do not significantly differ from a few decades ago (Siziba & Hall, 2021; Hermes, Smid, & Yao, 2007; Morales-Pinzón, Luruena, Rieradevall, Gasol, &

Gabarrell, 2012). From a purely theoretical point of view, the NPV method is the most accurate technique to evaluate projects. Non-DCF methods are less accurate (Hermes, Smid, & Yao, 2007). Capital budgeting theory favours the use of DCF techniques based on the time value of money. DCF techniques have become a dominant technique for evaluating capital budgeting decisions, particularly in large and more structured enterprises. However, due to limited managerial skills (particularly in SMEs), less complicated techniques continue to dominate capital budgeting decision making (Rossi, 2015).

Clear exploration of the advantages and disadvantages of the various methods allows for a selection of methods to use in the conceptual model. Although the specific product(s)/measure(s) offered as a service are unknown, the characteristics of the business model still justify choices for certain methods. Table 4.1 below is a summarization of advantages and disadvantages per technique based on the summary Fabozzi & Peterson (2003) provide in their book, supplemented with literature (Hofstrand, 2013; Alhabeeb, 2016; Surbi, 2017; Palmer, 2021; Pinkasovitch, 2021).

Table 4.1 - Summary of characteristics of evaluation techniques (Fabozzi & Peterson, 2003)

	Advantages	Disadvantages
Payback Period	1) Simple to compute.	1) No concrete decision criteria to shows whether an investment increases the firm's value.
	2) Provides some information on the risk of the investment.	2) Ignores cash flows beyond the payback period.
	3) Provides a crude measure of liquidity.	3) Ignores the time value of money.
		4) Ignores the riskiness of future cash flows.
Discounted Payback Period	1) Considers the time value of money.	1) No concrete decision criteria that shows whether the investment increases the firm's value.
	2) Considers the riskiness of the cash flows involved in the payback.	2) Calls for a cost of capital.
		3) Ignores cash flows beyond the payback period.
Net Present Value	1) Decision criteria that shows whether the investment will increase the firm's value.	1) Requires a cost of capital for calculation.
	2) Considers all cash flows.	2) Expressed in terms of money, not as a percentage.
	3) Considers the time value of money.	
	4) Considers the riskiness of future cash flows.	
Profitability Index	1) Decision criteria that shows whether an investment increases the firm's value.	1) Requires a cost of capital for calculation.
	2) Considers all cash flows.	2) May not give a correct decision when comparing mutually exclusive projects.
	3) Considers the time value of money.	
	4) Considers the riskiness of future cash flows.	
	5) Useful in ranking and selecting projects when capital is rationed.	
Internal Rate of Return	1) Decision criteria that shows whether an investment increases the firm's value.	1) Requires a cost of capital for decision.

	2) Considers the time value of money.	2) May not give a value maximizing decision when comparing mutually exclusive projects.
	3) Considers all cash flows.	3) May not give a value maximizing decision when choosing projects with capital rationing.
	4) Considers riskiness of future cash flows.	
Modified Internal Rate of Return	1) Decision criteria that shows whether the investment increases the firm's value.	1) May not give a value maximizing decision when comparing mutually exclusive projects with different scales or different risk.
	2) Considers the time value of money.	2) May not give a value maximizing decision when choosing projects with capital rationing.
	3) Considers all cash flows.	
	4) Considers riskiness of future cash flows.	

4.2 Comparison of financial metrics

Before exploring how financial metrics can be included in the conceptual model, first appropriate metrics have to be chosen. This section motivates which metrics are appropriate to include in the conceptual model.

Considering literature, companies use multiple techniques to assess their investment decisions. Firms should not use just one capital budgeting technique, but should apply at least two or three methods when evaluating a project (Hatfield, Hill, & Horvath, 1998). Inclusion of more metrics is more time-consuming, deliver a more unclear model and makes an eventual decision harder (as different techniques have different outcomes and ranking of projects). Literature in Section 4.1 recommends the use of DCF techniques. Therefore, mainly DCF techniques are considered. The techniques are individually discussed and various arguments substantiates inclusion or exclusion of techniques in the conceptual model.

Payback Period

The PP method is in particular useful for comparing projects with equal lives. Furthermore, if liquidity is a vital consideration, payback periods are of major importance. Both pros are not relevant for Dura Vermeer and the proposed business model, because of different life cycles of projects and the fact that Dura Vermeer will attract external funding for the investment (thus, liquidity is not a vital consideration). Besides, it also has significant drawbacks. Theory of capital budgeting explains PP's inferiority to DCF techniques by highlighting its neglect of the time value of money and cash flow beyond a cut-off date (Chittenden & Derregia, 2015). Therefore, this report recommends excluding the PP method for further application.

Discounted Payback Period

The DPP incorporates the time value of money (by applying a discount rate), but still ignores cash flows beyond the payback period. The argument to implement this method if liquidity is a vital consideration does not apply for the same reason as for the PP method. Therefore, the DPP technique will not be implemented in the conceptual model as well.

Net Present Value

Various sources mention that the NPV method is the most intuitive, accurate and sophisticated tool to use for capital budgeting and to assess financial feasibility. The NPV also allows decision-making if single independent projects are considered (Alhabeeb, 2016), which is useful for future projects. Furthermore, the NPV technique is an important method to project future cash flows within LCC/TLC, which is often used for cost estimation in a PaaS model. Therefore, the NPV is selected to incorporate into the conceptual model. More details of the NPV method can be found in Section 4.2.1.

Profitability Index
The PI is useful in addition to the NPV method as it enables factoring in the overall magnitude of projects. As it might be needed to compare projects of different magnitudes with each other, the PI will also be included in the conceptual model. Section 4.2.2 provides further information on the PI technique.

Internal Rate of Return
The IRR is also a sophisticated, useful tool for assessing financial feasibility and decision-making in capital budgeting. The IRR is especially a useful valuation measure with the analysis of individual capital budgeting projects, but less for those which are mutually exclusive. In the proposed business model, projects are presumably not mutually exclusive. Therefore, the IRR is included in the conceptual model. The contents of the IRR techniques are described in Section 4.2.3.

Modified Internal Rate of Return
The MIRR shares the advantages with the IRR. In addition to the IRR, it delineates profit better, because of two important reasons: (1) reinvestment of cash flows at the cost of capital is practically possible (instead of at the IRR), and (2) multiple rates of return do not exist in case of the MIRR (which is sometimes the case in IRR computations). Despite the advantages the MIRR offers, the MIRR will not be used in the conceptual model. Dura Vermeer indicated a preferred use of the IRR, as this metric is commonly used within the company and at clients. The preference for using the IRR is deemed more important than scientific arguments for using the MIRR, leading to the choice to use the IRR instead of the MIRR.

Advantages and disadvantages of the various techniques justified the incorporation of the NPV, PI and the IRR in the conceptual model. Thereby, the selection of these metrics also fulfils the theoretical advice to use at least two or three methods for evaluating projects on their financial feasibility.

4.2.1 Net Present Value (NPV)
The NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. It is the result of calculations used to find today's value of a future stream of payments and therefore accounts for the time value of money (Leybag, 2018). The basic premise of present values is that the stream of future cash flows must be discounted back to the current time using the firm's cost of capital as the discount rate (Alhabeeb, 2016). Often the WACC is used as discount rate, but in some cases a risk-adjusted discount rate is used instead. The use of a discount rate also entails a drawback of the NPV method: the discount rate is subject to change, but the NPV method uses a set discount rate for the entire period the NPV is calculated for. Further drawbacks of the NPV are its expression in terms of money instead of a percentage (it does not give a view on the return of a project) and the fact that it does not factor in the overall magnitude of the project (which can lead to a biased view on the profitability of a project). Both drawbacks would be solved by computing the IRR (for a percentage) and the PI (for magnitude) in addition to the NPV.

If subtracting the initial cost of the investment from the sum of the cash flows in the present day is positive, then the investment is worthwhile (Fernando, 2021c). The basic formula to calculate a project's NPV is depicted in Equation 2.

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \tag{1}$$

Where:
- C_t = Net cash in- or outflow during a single period t;
- r = Annual discount rate;
- t = Time period;
- n = Number of time periods.

4.2.2 Profitability Index (PI)

The PI describes an index between the costs and benefits of a proposed project. The PI is also helpful in ranking various projects, since it let investors quantify the value created per each investment unit (Chen, 2020). The PI is computed using the ratio in Equation 3.

$$PI = \frac{PV\ of\ future\ cash\ flows}{Initial\ investment} \tag{2}$$

A profitability index of 1.0 is logically the lowest acceptable measure on the index, as any value lower than that number would indicate that the project's present value is less than the initial investment. As the value of the profitability index increases, so does the financial attractiveness of the proposed project. The present value of future cash flows requires the implementation of the time value of money calculations. Cash flows should be discounted in the same manner as needed for the NPV method.

When using the profitability index to compare the desirability of projects, it is essential to consider how the technique disregards project size. Therefore, projects with larger cash inflows may result in lower profitability index calculations, because their profit margins are not as high. This is also the technique's primary limitation, as it reduces a project to a simple number when the success or failure of an investment or expansion relies on many factors and can be undermined by unforeseen events. Hence, the PI must be used as a tool in conjunction with other types of analysis to make a well-informed decision (Hayes, 2020a). The primary limitation is tackled in this research by also computing the NPV and the IRR.

4.2.3 Internal Rate of Return (IRR)

The IRR is a metric used in financial analysis to estimate the profitability of potential investments (Alhabeeb, 2016). The IRR is the discount rate that makes the NPV of all cash flows equal to zero in a discounted cash flow analysis. The formula for the IRR is shown in Equation 4.

$$0 = NPV = \sum_{t=0}^{n} \frac{C_t}{(1 + IRR)^t} \tag{3}$$

Where:

- C_t = Net cash inflow during the interval (t-1,t];
- IRR = The internal rate of return;
- t = Time period;
- n = The number of time periods.

The IRR allows investments to be analysed for profitability by calculating the expected growth rate of an investment's returns and is expressed as a percentage (Jassy, 2021). Generally speaking, the higher an IRR the more desirable an investment is. IRR is uniform for investments of varying types and, as such, ranks multiple prospective projects on a relatively even basis. Most IRR analyses are done in conjunction with a view of a company's WACC (or risk-adjusted discount rate) and NPV calculations. In theory, any project with an IRR greater than its cost of capital are profitable (Fernando, 2021b).

The IRR also has some limitations. The IRR itself is only a single estimated figure that provides an annual return value based on estimates. Since estimates in IRR and NPV can differ from actual results, most analysts will choose to combine IRR analysis with scenario analysis. In some cases, issues can also arise when using IRR to compare projects of different lengths. Furthermore, it is possible to find multiple solutions for the IRR for the same project, in particular if the trailing cash flows fluctuate between positive and negative cash flows (Fernando, 2021b). Lastly, the IRR does not give a true sense of the value that a project will add to a firm: it simply provides a benchmark figure for what projects should be accepted based on the firm's cost of capital.

4.3 Modelling financial metrics

This section focuses on the way financial metrics are modelled to answer part b of the second research question. The main part of this section is a roadmap, which is an essential element of the conceptual model.

The roadmap provides a stepwise and software-independent description for modelling the NPV, PI and IRR. Thereby, it enables a transition from the conceptual model towards a calculation model.

Before presenting the roadmap, it is important to notice that models to assess financial feasibility can serve different purposes at different points in the project. These might include (Fairhurst, 2012):
- What are the key sources of risk that the project needs to manage?
- How can the project's benefits be optimised?
- Should the project be authorised to proceed beyond the concept phase?
- Which option or combination of options should be adopted for the project?
- Should the project be authorised to proceed to full implementation?

To make good judgements about what is relevant to the model and the level of detail that is appropriate, the modeller needs to understand the decisions to be supported. Models tend to require more detail as the modelling purpose goes further down the list above. Increasing the level of detail is, therefore, a natural process as different decisions are taken during the course of a project. A conceptual model enables the transition towards a calculation model. Therefore, the conceptual model has to be as extensive as possible and provide a step-by-step plan that incorporates of a wide range of levels of detail in an eventual calculation model.

Various sources shed light on the steps towards a functional model to assess the financial feasibility of a project (CFI, 2021; Fairhurst, 2012; Seth, 2021; Gaur, 2019; Schneider, Mozgova, & Lachmayer, 2020; Van Ostaeyen, 2014). In total, 19 steps are included in the roadmap. These steps can be subdivided into preparatory steps (steps 1 to 5), modelling steps (steps 6 to 14) and finalizing steps (15 to 18). The last step (step 19) entails the final decision and determines whether the model can be archived or the next iteration of modelling has to be made from step 4 onwards. The next (sub) sections each elaborate on one of the steps.

4.3.1 Step 1: Identify the decision(s) to be supported by the model

The first step answers the questions above of Fairhurst (2012). Answering these questions determines the purpose of the model and the decision(s) supported by it. An example of a decision is whether the project can proceed beyond the concept phase or even to full implementation. The goal of the model should be clear after this step. This also determines the amount of detail included in the model. For example, the goal of the proof of concept in this report is to validate the conceptual model. Such a goal asks for a model with less detail than for example a model that is used to assess whether a project can proceed to full implementation.

4.3.2 Step 2: Identify the users of the model

This is also an important preparatory step for an eventual calculation model, because it complements and further explains the goal of the model. For example, if the model is only used by Dura Vermeer to assess financial feasibility from the provider's side, the model has to be composed from the viewpoint of Dura Vermeer. On the contrary, the model could also be set up from the client's perspective to show the added value of the business model from their viewpoint.

4.3.3 Step 3: Decide what software will be used for the model

Fairhurst (2012) mentions in her book that many tools exist for computing the NPV. Excel is most commonly used for this type of analysis. Also for the IRR, various tools exist. In general, calculating the IRR is done in three ways:
1. Using a function to automatically determine the IRR in Excel or any other spreadsheet programme;
2. Using a financial calculator;
3. Using an iterative process where the analyst tries different discount rates until the NPV equals zero.

The conceptual model in this report leads to a calculation model too complicated to use a financial calculator. Therefore, the use of Excel or any other spreadsheet programme prevails over a financial calculator. Within the eventual model, it is recommended to use both a build-in function and an iterative process to calculate the IRR. This reduces the likelihood of unrecognized errors in the model.

4.3.4 Step 4: Determine whether taxation should be included or excluded

Costs and cash-related benefits both affect a company's liabilities for corporation tax. Since tax payments or credits have an impact on cash flows, they are often relevant to the purposes of modelling financial metrics. Corporation tax may affect the modelling process in two ways (Fairhurst, 2012):

- Effect on the discount rate calculation, and;
- Effect on relevant cash flows.

As corporation tax can affect the modelling process, it has to be considered whether taxes are included or excluded in an eventual calculation model. Including the effects of taxation makes an NPV model larger and more complex. Since there are advantages to keeping models as simple as necessary, including or excluding taxation should be considered carefully. If NPV models are used to compare project options for which taxation effects are proportional to the relevant costs and benefits, taxation may make insufficient difference to the comparisons being made for it to be included.

4.3.5 Step 5: Estimating all variables and parameters relevant to the model

Chapter 5 elaborates on the variables/parameters (e.g. categories of costs, benefits, etc.) relevant to the model. This chapter is useful to use as a starting point for the fifth step. For the determination of projected costs and benefits over time in general, various techniques and sources of data are available to estimate values for variables and parameters relevant to the model. Especially the estimation of costs is important for the model, as in that area presumably the most assumptions are made. All cost estimations are a reflection of the quality of the input data (Kambanou & Lindahl, 2016). The following sources can be used to gather input data for estimation of variables and factors (Huang, Newnes, & Parry, 2012; Van Ostaeyen, 2014):

- Historical data:
  This source of data is available for input variables included in the initial investment. However, normally Dura Vermeer is not responsible for maintenance and other costs relevant after the design and installation phase. Estimates for the use phase can also be based on historical data, but have to be collected from installers (or other subcontractors) specialized.
- Measurements:
  This source of information is not available (yet) for Dura Vermeer, as for example maintenance should first be offered before measurements can be executed.
- Internal experts' estimates:
  Dura Vermeer has several experts employed able to predict a large proportion of costs included in a PaaS model. They can also predict some of the risks and uncertainties of the proposition.
- External experts' estimates:
  Not all parameters can be estimated based on the experience of internal experts, since the PaaS model is new for Dura Vermeer. Consequently, several factors/variables have never been faced by Dura Vermeer. Information and estimations might then be retrieved from external experts' estimates.
- Financial data:
  Some specific financial data is required to derive estimates for certain input parameters, such as the labour cost rate and the WACC or risk-adjusted discount rate. Mostly, these parameters can be determined in consultation with a company's finance department and depend on the quality of the accounting systems used.

4.3.6 Step 6: Structure the relevant costs and benefits

In this step, all future cash flows (based on the previous step) should be arranged corresponding to each year of receipt. Some are repeated every year (for example maintenance costs), whereas others take place only one or two times during the lifetime of the project (for example replacement costs).

This step delivers the calculation model's first rough design. Therefore, some special considerations have to be made for modelling the NPV and IRR specifically. Although the NPV can be calculated manually, most NPV forecasts are made by developing a model built using a spreadsheet. The conventional design is to use a table with columns for the different time periods and rows for the relevant costs and benefits. Calculations are then aligned under the table. As displayed in the Figure 4.1, a cumulative NPV can be included as well. The inclusion of a cumulative NPV is not essential, but has two advantages. First, it provides a check to prevent spreadsheet design errors. In this case, the end cumulative NPV matches the primary calculation.

Second, it provides an estimate of the payback period, i.e. the time by which the cumulative present value of benefits exceeds that of costs. In this case, the payback period is approximately a little over four years. Figure 4.1 shows an example of a simple spreadsheet for an NPV calculation (Fairhurst, 2012).

Estimates		Costs and benefits broken down by year (£k)					
	Value (£k)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Delivery cost	2,500	1,250	1,250	0	0	0	2,500
Net benefits	3,500	0	500	1,000	1,000	1,000	3,500
NPV calculation		Year 1	Year 2	Year 3	Year 4	Year 5	Total
Cash flow: Benefits - Cost (£k)		-1,250	-750	1,000	1,000	1,000	1,000
Discount Rate	4%						
Mid-year discount factor		0.9806	0.9429	0.9066	0.8717	0.8382	
Cash flow Present Value (£k)		-1,226	-707	907	872	838	684
Cumulative NPV (£k)		-1,226	-1,933	-1,026	-155	684	

Figure 4.1 - Example of a simple model/spreadsheet for an NPV calculation (Fairhurst, 2012)

Also for the IRR, some special considerations have to be taken into account. Due to the characteristics of the IRR, trial-and-error is needed to arrive at the correct IRR (possibly along with the use of a built-in function in the software used for the model). Therefore, it is useful to include the NPV calculations twice in the model. This way, it is possible to arrive at the IRR with trial-and-error without adjusting the original NPV. Hereby, the model is less prone to errors and more clear.

4.3.7 Step 7: Build inputs and record associated assumptions

The previous two steps enable the building of inputs for the model. Because the initial investment is paid for upfront, this is the first cash flow included in the eventual calculation; no elapsed time needs to be accounted for (Fernando, 2021c). It is important to record all the associated assumptions along with building the inputs for the model. Experts have to validate the model by considering the assumptions. Besides, the assumptions are important for the presentation of results to clients and/or senior managers. A few other recommendations help in improving the transparency of the model and avoiding errors. They are summarized in the list below (Fairhurst, 2012):

- Colour code inputs, calculations and results, and separate where possible;
- Use each column for the same purpose;
- Only enter data once e.g. avoid duplicating numbers by copying formulas;
- Make the model easy to comprehend from left to right and top to bottom;
- Include error checks, ideally with conditional formatting to highlight errors.

4.3.8 Step 8: Determine free cash flows

In this step, the free cash flows per period are calculated. This step is rather straightforward and is simply done by summing all individual cash inflows and outflows of each period to arrive at the total free cash flow of that accompanying period.

4.3.9 Step 9: Discount the free cash flows with the appropriate discount rate

In this step, the free cash flows are discounted with the appropriate discount rate. Determining the appropriate discount rate is probably one of the most difficult steps in which numerous choices and assumptions are made. Therefore, Chapter 6 describes in more detail how the appropriate discount rate is determined. Cash flows other than the initial investment are all in the future, so they need to be adjusted for the time value of money at the appropriate discount rate (determined in step 5). It is assumed that the yearly cash flows are earned at the end of the year, with the first payment arriving exactly one year after the initial investment (if the client pays the fee monthly instead of yearly, it is better to discount midyear instead of at the end of the year). Discounting all free cash flows finalizes this step.

4.3.10 Step 10: Finalize NPV calculations and compare output with the decision rule

In this step, the calculations of the NPV are finalized. The NPV is now easily determined by summing all discounted cash flows, which were determined in the previous step. The result of that summation can then be compared to the decision rule. Theoretically, any project with an NPV larger than zero should be accepted. On the contrary, any project with an NPV lower than zero should be rejected. Table 4.2 summarizes the actions that, in theory, should be taken based on the result of NPV calculations.

Table 4.2 - Decision rule based on the value of the calculated NPV

If...	this means that...	and the company...
NPV > 0	the investment is expected to increase shareholder wealth	should accept the project.
NPV < 0	the investment is expected to decrease shareholder wealth	should reject the project.
NPV = 0	the investment is expected not to change shareholder wealth	should be indifferent between accepting or rejecting the project.

However, from a financial modelling perspective, the decision-making process is more complicated than a deal-or-no-deal situation. It depends on the quantification of uncertainty to assess whether the project should go ahead (Fairhurst, 2012). The quantification of uncertainty determines how sensitive the model is to changes in inputs and gain a better perspective on whether a project should be accepted. The quantification of uncertainty is included in this roadmap in the 13^{th} step.

4.3.11 Step 11: Finalize PI calculations and compare output with the decision rule

This step finalizes the calculations of the PI. By construction, if the NPV is zero, PI is one (Peterson & Fabozzi, 2002). The PI is a variation of the NPV and makes use of the same partial results.

The decision rule for the PI is usually in accordance with the decision rule for the NPV. Rejecting or accepting investments having PI's greater or less than 1.0 is consistent with rejecting or accepting investments whose NPV is greater or less than 0. However, in ranking projects, the PI might rank projects differently than the NPV. This can happen when projects with different amounts of initial investment are ranked. In Table 4.3 the theoretical decision rule for the PI is explained.

Table 4.3 - Decision rule based on the value of the calculated PI

If...	this means that...	and the company...
PI > 1	the investment returns more than €1 in present value for every €1 invested	should accept the project.
PI < 1	the investment returns less than €1 in present value for every €1 invested	should reject the project.
PI = 1	the investment returns €1 in present value for every €1 invested	should be indifferent between accepting or rejecting the project.

4.3.12 Step 12: Finalize IRR calculations and compare with the decision rule

Calculation of the IRR is less straightforward than the determination of the NPV and PI. The IRR is the discount rate that makes the NPV (approximately) zero. It is calculated numerically through trial-and-error or by the use of some software system (Vaidya, 2020). It is useful to include the NPV calculations twice in the model, as it enables experimenting with the IRR without adjusting the original NPV calculations and erasing those results (see also step 6).

The decision rule for the IRR is to invest in a project if it provides a return greater than the cost of capital (or any other appropriate discount rate). In other words, the IRR is compared with the risk factor (Fairhurst, 2012). If the IRR is higher than the discount rate, the returns from the investment are high enough to justify the risk of the investment, and vice versa. However, two things should be taken in mind when interpreting the results of IRR calculations (Peterson & Fabozzi, 2002). First of all, the IRR may give a different decision than the NPV, because the NPV metrics assumes that cash flows are reinvested at the cost of capital, whereas the IRR assumes that cash flows are reinvested at the IRR. Secondly, when capital rationing is needed, selecting investments based on the IRR ranking is not consistent with maximizing wealth. The source of this problem is that the IRR is a percentage and not a currency amount. Therefore, the IRR has to be considered in combination with the decision rules of the NPV and PI. Table 4.4 below gives a summarization of the decision rule for the IRR.

Table 4.4 - Decision rule based on the value of the calculated IRR

If...	this means that...	and the company...
IRR > discount rate	the investment is expected to return more than required	should accept the project.
IRR < discount rate	the investment is expected to return less than required	should reject the project.
IRR = discount rate	the investment is expected to return what is required	should be indifferent between accepting or rejecting the project.

4.3.13 Step 13: Quantifying uncertainty

It is important to consider the uncertainty incorporated in the model before building the outputs of the model. A model is only as good as the assumptions made in determining its inputs (garbage in is garbage out). Therefore, all financial models should be subjected to analyses to quantify uncertainty (Fairhurst, 2012). Three types of analysis are suitable to quantify uncertainty: sensitivity analysis, scenario analysis and Monte Carlo simulation. Conducting these analyses involves several actions and is an extensive and complex process. Therefore, their contents are discussed in Section 6.3.

4.3.14 Step 14: Build outputs: summaries, charts and reports

Building outputs and drafting summaries, charts and reports is also an important step in the process of modelling financial metrics. It should be carefully thought through what information is presented in the outputs. If the results of the model are used for stakeholder communication, it is important to present the underlying assumptions as well in addition to the calculated figures. This allows for a full picture of the projection. Senior partners and management of a company are usually more interested in the underlying assumptions and results from uncertainty analyses than in the direct results of the model's calculations. This is important to keep in mind when building the model's outputs.

4.3.15 Step 15: Peer review of the draft model

Up until the previous step, the steps were all more or less directly coupled to the development of the model and its results. It is also important to validate the contents of the model. This is done in the 15th step. Validation of the model is usually performed by means of (a) peer review(s). Various persons can be approached to peer review the (draft) model (for example management, colleagues from the financial department, calculators or other relevant experts).

4.3.16 Step 16: Update the model in response to peer review

Most likely, results from the peer review(s) in the previous step will present some flaws in the model or appoint improvements. In this step, the model should be updated in response to the results of the peer review(s) if and where it is necessary.

4.3.17 Step 17: Take relevant decision(s) and review other insights identified by modelling

Now that the model is revised and (possibly further) improved, the relevant decisions determined in the first step can be taken and other insights identified by the model can be reviewed. This step is a relatively short one and is more or less a wrap up of all steps up until this point. It concludes the current version of the model.

4.3.18 Step 18: Identify decisions (if any) to be supported by the next iteration of modelling

As mentioned before, a model has a certain goal that determines the details incorporated in the model. A model that is built for deciding if a project can move to the concept phase needs fewer details than a model that should decide whether a project can proceed to full implementation. Depending on the decisions made by the current version of the model, decisions (if any) can be identified to take in the next iteration of modelling. For example, if the current model's goal was to decide if the project can move to the concept phase, the next iteration might provide a decision on whether the project can proceed to full implementation.

4.3.19 Step 19: Repass the process from point 4 or archive the model as appropriate

The last step of the roadmap finalizes the current version of the model. If new decisions are identified in the previous step, the presented roadmap has to be repeated from step 4 onwards. If the model does not need a next iteration, the model is appropriate and can be archived. The way a model is or can be archived is company-dependent and should be done in a way that is most useful for the company. Thus, this depends on the systems Dura Vermeer uses for archiving these kinds of files.

4.4 Conclusion

This last section concludes the fourth chapter and summarizes the most important findings. First of all, in Section 4.2 six methods for assessing the financial feasibility of a PaaS proposition were considered for inclusion in the conceptual model: (i) Payback Period, (ii) Discounted Payback Period, (iii) Net Present Value, (iv) Profitability Index, (v) Internal Rate of Return and (vi) Modified Internal Rate of Return. Based on their advantages/disadvantages and the recommendation to appoint at least two or three metrics to assess financial feasibility, the NPV, PI and IRR were selected as the most appropriate techniques to incorporate in the conceptual model. All three take the time-value of money into account. Furthermore, the NPV and IRR are both considered to be the most sophisticated tools to use for capital budgeting. The PI was additionally chosen, as it enables factoring in the overall magnitude of projects.

Section 4.3 extensively described a roadmap to include as an essential part of the conceptual model. The roadmap enables the transition of the conceptual model towards a calculation model. It consists of 19 steps, which together gives a clear outline for modelling the three chosen metrics to assess financial feasibility. The roadmap is iterative: step 19 returns the modeller to step 4 for subsequent project stages in which higher levels of detail are needed. The practical application of the model is shown for an example project in the eight chapter of this research. With the development of an extensive roadmap, the second research question is answered.

5

RESEARCH QUESTION 2: VARIABLES INFLUENCING FINANCIAL FEASIBILITY

Several factors and variables contribute to and affect the financial feasibility of a PaaS proposition. Determining factors and variables is required, since they serve as important input to the conceptual model and the roadmap. With the categories of factors and variables at hand, only their tangible values have to be determined in step 5 of the roadmap. Life Cycle Costs (LCC) are considered to determine total costs and thereby financial feasibility. LCC provides a structured approach to address all the different costs and revenues of a project over a certain study period. All the potential costs are adjusted to reflect the time value of money (Marszal & Heiselberg, 2011). This chapter investigates the variables and parameters encountered specifically in propositions for sustainability measures. Literature in Section 5.1 identifies the variables and parameters that contribute to a PaaS proposition in general. Section 5.2 complements literature by comparing the general variables/parameters to those of various sustainability measures. After that, Section 5.3 validates Section 5.1 and 5.2 by analysing two cases: 'Façades-as-a-Service' and 'Housing-as-a-Service'. These cases are closely related to the field of sustainability measures. Lastly, Section 5.3 concludes this chapter and gives the final overview of variables/parameters.

5.1 Literature: input variables and parameters

Literature sheds light on various categories of costs and benefits involved in a PaaS proposition. These general costs and benefits categories are described in this section.

Analysis of the financial characteristics and variables of a PaaS model takes place from a company perspective of from a 'business sector' perspective. The company perspective is the most interesting considering the demarcation of this research. Within the company perspective, the object of analysis is the organisation that introduces the PaaS system (in this case Dura Vermeer). The company perspective asks for a logical analysis of all costs and revenues (Goedkoop, Van Halen, Te Riele, & Rommens, 1999).

First of all, the main characteristics of the PaaS system have to be considered, because these characteristics affect the general layout of revenue streams and cost structure. Revenue streams and the cost structure differ from a traditional business model. The use-oriented system has tangible value for the user, since various costs and activities are shifted to the provider. This has some implications for the provider. The system may provide higher revenues per product and attract new customer segments, but the cash flows are changed and the highest profits are made towards the end of the product's lifetime (Mont, Dalhammar, & Jacobsson, 2006). Since the provider remains the owner of the product, the need for capital is high, which significantly affects the cost structure. Barriers to attracting new clients are low however, due to low initial investment by the client, which has effect on the revenue stream (Tukker, 2004). The need for capital can be lowered by introducing a deposition fee at the beginning of the leasing period (Mont, Dalhammar, & Jacobsson, 2006). The introduction of a deposition fee affects the attraction of customers. Therefore, it is possible that a deposition fee induces indirect costs. In the model however, the deposition fee is included as a revenue stream, as its effect on the attraction of new clients is only indirect.

Secondly, the yearly rate of inflation, the functional unit (e.g. 100 product or service units sold) and the lifetime of products affect both the revenue streams and cost structure (Azarenko, Roy, Shehab, & Tiwari, 2009; Liu, O'Rear, Tyner, & Pekny, 2014). The yearly rate of inflation is included in a model by adding a percentage that annually increases the determined revenues and costs. This is not necessary for discounted cash flows, since the discount rate automatically takes inflation into account (i.e. inflation is incorporated in the risk-free rate). The functional unit affects magnitude of the revenue streams and the cost structure. The lifetime of products has effect on the proposition, as it can be extended by improving maintenance. This will increase maintenance and/or reconditioning costs, but on the other side might lead to lower life cycle costs due to an extended lifetime.

Concluding, the factors/variables influencing a PaaS proposition in general (both revenues and costs) are the inflation rate, functional unit, the lifetime of individual products within the proposition and the life span of the offering.

5.1.1 Variables influencing revenue streams

By adopting the PaaS model, revenue streams change significantly. Product manufacturers under the traditional model generate money at the point of sale, whereas service providers generate income monthly or yearly. This means, although investment patterns can be similar, revenue patterns and total income differs (Goedkoop, Van Halen, Te Riele, & Rommens, 1999). Furthermore, the pricing of the offering is very important. Pricing strategy is founded on three key elements: cost, competition and value to the customer (Dimache & Roche, 2015). The latter two are hard to determine, because they are more prone to subjectivity than the estimation of cost. Especially the value to the customer is difficult to establish, since customers value the product-services mix differently as they commonly have different preferences for additional services. All revenues in the product life chain should be included (Goedkoop, Van Halen, Te Riele, & Rommens, 1999). Lastly, also subsidies and tax credits should be taken into account as positive cash flows. Ownership of the products remains at Dura Vermeer. Therefore, if the acquisition of certain products yields subsidies or tax credits, these will benefit Dura Vermeer.

The general remarks in the previous paragraph are supplemented with variables identified in various articles. The following variables are included as additional inputs for revenue streams in the conceptual model and are displayed in Table 5.2 in Section 5.1.3 (Dimache & Roche, 2015; Goedkoop, Van Halen, Te Riele, & Rommens, 1999; Mont, Dalhammar, & Jacobsson, 2006): deposition fee, harvest/salvation value, monthly/yearly fee (income from (standard) service contract), subsidies and tax credits.

5.1.2 Variables influencing cost structure

The basic construct in LCC for cost estimation is the Product Life Cycle (PLC). The PLC spans chronologically all activities throughout a product's physical life: from its conception until its disposal into waste streams. It consists of four phases: design, production, use and End-Of-Life. Typically in an LCC analysis, the PLC is decomposed into a Cost Breakdown Structure (Van Ostaeyen, 2014). Figure 5.1 gives an example of such a breakdown structure. It enables the identification of the variables directly coupled to the life cycle of a product influencing the cost structure of the PaaS proposition in this research. Costs not directly coupled to the PLC, for example marketing costs, are excluded.

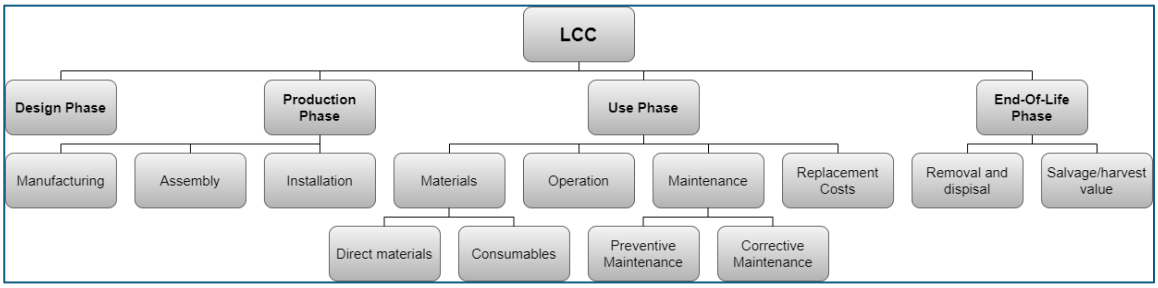

Figure 5.1 - Generic Life Cycle Cost Breakdown Structure

A thorough cost estimation process upfront is important, as costs can be controlled when committed, but not minimised afterwards (Dimache & Roche, 2015). A critical design decision is the choice of realising either (a) products with reliability and long life (but with expensive resource usage and maintenance costs) or (b) products with moderate reliability and life (but with less resource usage and maintenance costs) (Kimura, Matoba, & Mitsui, 2007).

The identified variables are included in Table 5.1 with some additional remarks where needed (Mont, Dalhammar, & Jacobsson, 2006; Liu, O'Rear, Tyner, & Pekny, 2014; Marszal & Heiselberg, 2011; Goedkoop, Van Halen, Te Riele, & Rommens, 1999; Dimache & Roche, 2015; Gustafsson, Myhren, Dotzauer, & Gustafsson, 2019; Kyriaki, Konstantinidou, Giama, & Papadopoulos, 2017). The table also includes input variables that are not directly coupled to the product's life cycle, for example the marketing costs.

Table 5.1 - Variables influencing the cost structure, including some specific remarks (where needed)

Variable	Remarks
Development costs (design phase)	-
Production/manufacturing costs	Production and manufacturing costs include costs of materials, process of producing, assembly and labour costs.
Installation costs	-
Transportation costs	These are higher compared to the traditional model, because with a PSS the organisation is also responsible for delivering spare parts whenever they are needed.
Operation and maintenance (O&M) costs	The costs associated with maintenance tasks can be quite high: between 10% and 40% of the total operating expenditure. As a result, the area of maintenance costs needs a lot of attention due to its potential in extending the life of a system, maintaining reliability, reducing the consequences of failure and, in fact, reducing the maintenance cost. Maintenance can be either preventive of corrective. Also the labour costs of inspection should be taken into account.
Replacement costs	The LCC is calculated over the lifetime of the system, but the system may include units with different lifetimes. Replacement of parts with a shorter lifetime than the life span of the project have to be considered.
Disassembly and reconditioning after contract (End-Of-Life treatment)	-
Marketing costs	Due to a (partial) transition to a PaaS system, marketing costs are presumably needed to attract (new) customers.
Cost for information system	It is useful to develop an information system for an efficient PaaS scheme, which would help producers and retailers create a clear picture of the amount of installed products (as a service) and the remaining lifetimes of those products (and their condition). This also leads to clear understanding of what parts need to be supplied and to what location.

5.1.3 Summary of general variables influencing financial feasibility

Several variables are identified in the previous sections that affect the financial feasibility of a PaaS proposition in general (based on literature). Table 5.2 summarizes and displays all identified variables.

Table 5.2 - Summary of variables influencing the financial feasibility of a PaaS proposition in general

Influencing both	Influencing revenue streams	Influencing cost structure
Inflation rate	Deposition fee	Development costs
Functional unit	Monthly/yearly fee	Production/manufacturing costs
Lifetime individual products	Harvest/salvation value	Installation costs
Lifespan of the offering	Subsidies	Transportation costs
	Tax credits	O&M costs
		Replacement costs
		End-Of-Life treatment
		Marketing costs
		Cost for information system

5.2 Identification of financial variables based on sustainability measures

This section complements the variables/parameters identified in literature by investigating the LCC of sustainability measures. First, potential sustainability measures have to be identified to enable the comparison with literature. Various documents and (scientific) articles were studied to compile an extensive list of sustainability measures (Carpino, Bruno, & Arcuri, 2020; Coimbra & Almeida, 2013; Dineen & Ó Gallachóir, 2017; Dura Vermeer, 2020; Gemeente Leusden, 2018; Rijksoverheid, sd; Roskam, 2015). Only sustainability measures are considered that Dura Vermeer applies in their renovation projects.

Table 5.3 displays the sustainability measures. The third column in the table shows in which section the LCC of that particular sustainability measure is explored. The LCC of draught-proofing and airtightness, (connection to) heat network, heating (e.g. radiators and floor heating) and passive solar energy are not considered. Draught-proofing and airtightness are usually improved by relatively small interventions. Therefore, they are irrelevant to offer as a service. The (connection to a) heat network cannot be offered as a service, because it is the heat network operator's responsibility. Heating (for example, radiators and floor heating) is not considered, as it is often already present in dwellings. Passive solar energy is achieved by for example placement of trees, blinds or a greenhouse. Measures for passive solar energy are all products that are illogical to offer as a service. Therefore, their LCCs are not considered.

Table 5.3 – Possible sustainability measures

Category	Measure	Section
Building envelope	Façade insulation	5.2.1
	Floor insulation	5.2.1
	Roof insulation	5.2.1
	Glass insulation	5.2.2
	Draught-proofing and airtightness	-
HVAC (heating, ventilation and air conditioning)	Air-to-water heat pump	5.2.3
	Water-to-water heat pump	5.2.3
	Hybrid heat pump	5.2.3
	Heat network	-
	Heating	-
	Ventilation	5.2.4
Other renewable energy sources	PV panels	5.2.5
	Solar boiler	5.2.6
	Passive solar energy	-

5.2.1 LCC façade, floor and roof insulation

Insulation is material used to reduce heat loss or heat gain by providing a barrier between the inside of a house and the temperature outside. The LCC of insulation is rather straightforward. Mainly the initial costs, maintenance costs and demolition costs are considered in LCC calculations for insulation. The initial cost for insulation includes all material costs, labour costs and equipment/installation costs. The largest contributor in initial costs is the labour cost (around 60% of initial costs). Material costs take around 30% and machine costs 10% of the total initial costs (Isolatieprijs, 2021). The maintenance of insulation is dependent on chosen materials. Different materials have different maintenance requirements. Also the maintenance interval is different and depends on the materials used. Apart from that, demolition costs must be considered as well. Irrespective of the type of material used, the initial costs contribute to the highest proportion of the LCC of insulation. The maintenance costs vary from 13% to 29% and demolition range from 13% to 25% of total Life Cycle Costs (Illankoon, Tam, & Le, 2018). The lifetime of insulation is estimated to be between 30 and 50 years before it needs replacement (Petrović, Zhang, Eriksson, & Wallhagen, 2021; Kumar, et al., 2020). To conclude, the study of the LCC of insulation shed light on the distribution of costs and its range of lifetime, but did not bring new variables forward that have to be included in the eventual model.

5.2.2 LCC glass insulation

Glass insulation consists of two or more glass window panels separated by a vacuum or gas-filled space to reduce heat transfer. Variables included in the LCC of glass insulation are similar to insulation. The initial investment costs and operating and maintenance (O&M) costs are mainly considered in LCC calculations of glass insulation. The initial investment costs consist of the glass purchase cost, labour cost and transportation fees. The operating and maintenance costs include repair and replacement costs (Lee, Hong, Lee, & Jeong, 2012). The life span of glass is dependent on the type of glass and differs significantly between various sources. It can vary between 15 and 50 years (Kime & Hoskara, 2019; Lee, Hong, Lee, & Jeong, 2012; Petrović, Zhang, Eriksson, & Wallhagen, 2021). The maintenance costs of glass insulation are relatively low compared to the initial investment and can be lower than 5% of the total LCC (Kime & Hoskara, 2019). LCC analyses of various sources did not bring forward new variables to include in the conceptual model.

5.2.3 LCC heat pump

A heat pump is used to warm (and sometimes also cool) buildings by transferring thermal energy from a cooler space to a warmer space (or vice versa) using the refrigeration cycle. Categories within the LCC of a heat pump are again comparable to the previous measures. The costs are categorized into the initial investment cost (cost of heat pump and back-up heater), installation costs, annual O&M costs, reinvestment based on replacement and asset preservation costs of the heating and cooling system, and residual/harvest value at the end of the project's life span (Doseva & Chakyrova, 2020; Gustafsson, Myhren, Dotzauer, & Gustafsson, 2019; Ates, 2015). Various types of heat pumps exist (e.g. hybrid systems, ground-source heat pumps, air-to-water heat pumps, exhaust air heat pumps and air-to-air heat pumps), making it difficult to determine general cost distributions within the LCC of heat pumps. However, although exact percentages are unknown, the upfront costs together with the installation costs contribute the most to the LCC of heat pumps (DelPiano, 2020). Also the residual/harvest value has an impact on the LCC, but is dependent on the chosen type of heat pump and life span of the project. For example, the residual/harvest value of an exhaust air heat pump can be up to 75% of the initial investment after 25 years (assuming proper maintenance), whereas the residual/harvest value of air-to-air heat pumps can be as low as 10% of the initial investment after 25 years (Paiho, Pulakka, & Knuuti, 2017). Assumed lifetimes can vary between 20 and 30 years for heat pumps (Doseva & Chakyrova, 2020; Kegel, Sunye, & Tamasauskas, 2012). New variables influencing the financial feasibility of a PaaS proposition were not identified based on the study of the LCCs of various types of heat pumps.

5.2.4 LCC ventilation

Ventilation is mainly used to improve comfort for residents. It is also used for increasing sustainability, if for example heat recovery is applied. Information on the LCC of ventilation systems was minimal. Johansson (2007) distinguishes ventilation systems into two types: ventilation systems with variable airflow rates (VAV) and ventilation systems with constant airflow rates (CAV). The LCC of ventilation systems, irrespective of the type of ventilation system, is mainly determined by their initial costs, maintenance costs and repair costs. A VAV system is more sustainable in energy usage, but have higher installation and maintenance costs than CAV systems. The maintenance costs of a CAV system is around 25% of the initial investment, whereas the maintenance costs of VAV systems can be up to 40% of the initial investment. For both, a lifetime of 40 years is normal (Johansson, 2007). Again, the LCC of ventilation systems did not reveal new variables/parameters.

5.2.5 LCC PV panels

PV (photo-voltaic) or solar panels use sunlight as a source of energy to generate electricity. The placement of PV panels is popular due to its low payback time (nowadays around seven or eight years). Investment costs take up the largest part of the LCC of PV panels with around 70% for a 20-year project life span (Abu-Rumman, Muslih, & Barghash, 2017). The initial investment costs include the development costs, material costs and installation costs. Maintenance costs are taking another significant part of the total LCC for PV panels with around 27%. Maintenance includes cleaning and repairing. Replacement costs are also of importance, because PV installations usually consist of various parts with shorter lifetimes than the lifetime of the whole system (Fan, 2014; Taylor, 2011). Lastly, also dismantling and disposal costs should be considered within the LCC calculations of PV panels. However, information on these areas is lacking, which makes it hard to accurately determine these costs (Toosi, Balador, Gjerde, & Vakili-Adrebili, 2018). Although certain elements have shorter lifetimes, the lifetime of a complete PV system is around 20 to 25 years (Abu-

Rumman, Muslih, & Barghash, 2017; Taylor, 2011). The LCC analyses of various articles did not indicate new variables/parameters.

5.2.6 LCC solar boiler

Solar boilers have similar functioning as PV panels, but instead use the energy of sunlight to heat water. Solar boilers are often applied in combination with PV panels, but also function as a stand-alone sustainability measure. The main costs considered for the LCC of solar boilers are the initial investment, maintenance costs and salvage/harvest value. With regular maintenance, it is estimated that the maintenance costs are around 10% of the initial investment (Botsaris, Angelakoglou, Gaidajis, & Tsanakas, 2011). However, it is also possible to increase maintenance costs to 25% of the initial investment, but thereby increasing the lifetime of the system by around 10 years (Košičan, Picazo, Vilčeková, & Košičanová, 2021; Kumar, et al., 2020). It is unclear what the exact effect is of the increase in lifetime on the LCC of solar boilers. The lifetime of a solar boiler (complete system) varies between 20 and 30 years depending on the intensity of maintenance (Botsaris, Angelakoglou, Gaidajis, & Tsanakas, 2011; Košičan, Picazo, Vilčeková, & Košičanová, 2021). The LCC of a solar boiler system is, once again, rather straightforward and did not highlight any other variables or parameters influencing the financial feasibility of a PaaS model.

5.3 Validation by analysing two examples: FaaS and HaaS

Two cases were analysed to validate the results so far. The cases are useful to compare the current results with, as both are closely related to the PaaS proposition of this research and are both already applied in practice. The first case is Façades-as-a-Service. Section 5.3.1 elaborates on the FaaS project. The second case is Housing-as-a-Service. The analysis of this case is described in Section 5.3.2.

5.3.1 Façades-as-a-Service

In the 'Façades-as-a-Service' proposition, integrated façades are offered as a service. Integrated façades are complex building assemblies in which a large part of the building's service and climate-control systems are contained within the modular construction of the building's envelope (Azcárate-Aguerre, Den Heijer, & Klein, 2018). Façades-as-a-Service is a collaboration between three Dutch façades builders initiated by an area developer that was willing to accept a pilot project. As with the PaaS proposition of this research, the ownership of the façade(s) remains at the three façade builders. This stimulates the development of sustainable and future-proof façades and incentivise taking into account technological innovation and adaptability in the design phase (Coalition Circular Accounting, 2020).

One important step was the assessment of the business case before actually testing the proposition in practice. The financial side of the business case consists of the calculations of the cash flows. Based on the cash flows, funding was attracted for the project (Coalition Circular Accounting, 2020). Incoming cash flows are relatively straightforward; they exist of the periodical fees and the harvest value at the end of the project's lifetime (ABN AMRO, 2020; Coalition Circular Accounting, 2020).

Outgoing cash flows of FaaS are the initial investment costs (e.g. material costs, installation costs), maintenance costs, replacement costs for parts with a shorter lifetime than the project's life span and financing costs (ABN AMRO, 2020; Azcárate-Aguerre, et al., 2018; Coalition Circular Accounting, 2020; Van Winden, 2016). The financing costs for the project are not yet included in Table 5.2 and have to be included in the table. Other variables are all validated by the financial side of the business case for FaaS. The overall costs were 22% higher than with a traditional model. However, this seems to be within an acceptable range, as the FaaS offering has benefits (services) to potential clients that a traditional model does not have.

The last factor influencing the feasibility of the FaaS project was the life span of the project. The life span of the project affects the replacement costs, because one year difference in the life span can have a significant impact on replacements costs and therefore on the feasibility of the business case (Van Winden, 2016). Furthermore, the time factor also interacts with the harvest value. The harvest value has limited impact over 30 years with a discounted cash flow analysis, but more with a contract for 10 years (Coalition Circular Accounting, 2020).

Concluding, the case of FaaS indicated one new financial variable/parameter: financing costs. Other factors were all validated by the FaaS project. Furthermore, the FaaS proposition showed one important remark: total/final costs might be slightly higher for clients of a PaaS proposition, but these are presumably balanced against the value of the services offered along with the proposition.

5.3.2 Housing-as-a-Service

The second proposition considered for validation is 'Housing-as-a-Service'. One Dutch contractor is currently leasing houses to housing corporations. This helps corporations in expanding their housing stock, which is currently strongly needed in the Netherlands. It also fits within the circular train of thought, as the ownership of the houses remains at the contractor, for who the raw materials at the end of the lifecycle are more useful than for the housing corporation. The leased houses are owned by a joint venture, financed by a large Dutch bank. The joint venture started recently with the construction of 10 houses under this leasing structure (Doodeman, 2021).

The cash inflows are comparable to that of the FaaS-model and consist of the yearly lease payments by the client and the harvest value. The outgoing cashflows are somewhat more extensive than in the FaaS proposition. The cost categories are divided amongst various life cycle stages. Table 5.4 displays an organized overview of all cash outflows of the HaaS project (Petrović, Zhang, Eriksson, & Wallhagen, 2021). Indirect costs, such as marketing costs, were not revealed in the case study. The life span of the project is not included as well. The life span of the project is 10 years at maximum (Pots, 2021), but the life span's influence on the HaaS project is unclear.

Table 5.4 - Overview of categories of cash outflows of the HaaS project

Life cycle stage	Cost categories
Pre-construction stage	Costs of purchase/rent the land
	Development costs
Production stage	Raw material supply
	Transport
	Manufacturing
Construction process stage	Transport to the building site
	Installation into building
Use stage	Maintenance
	Repair
	Replacement
	Refurbishment
End-Of-Life stage	Deconstruction/demolition
	Transport
	Waste processing
	Disposal

The case of HaaS did not reveal new variables/parameters. However, the distribution of variables and factors along the life cycle stages of the project makes the table more clear. Therefore, rearranging Table 5.2 in Section 5.1.3 into life cycle stages makes it more comprehensible.

The total costs of house leasing are higher than if housing corporations build houses on their own. This is a disadvantage, since housing corporations are currently able to secure loans with lower financing costs than the leasing company (Pots, 2021). However, higher total costs can still be balanced against additional services offered in the proposition, for example adding an energy plan and mobility (such as, electric shared cars, scooters or carrier bikes) to the proposition (Wocozon, 2021). The quality of preventative maintenance is also variable at the client's wish (Parker, 2021).

Concluding, the case of HaaS validated the identified variables and parameters, as it did not bring new variables/parameters forward. The HaaS project, however, did show that Table 5.2 can be improved in its clarity if categories of revenues and costs are rearranged into life cycle stages (see Table 5.5). Furthermore, as well as the FaaS proposition, the business model yields higher total (life cycle) costs than the traditional business model. However, additional services offered in the new business model can potentially balance against the higher costs of the model.

5.4 Conclusion

This chapter identified variables/parameters affecting the financial feasibility of a PaaS proposition. Identification of variables/parameters is important input for the fifth step of the roadmap. Section 5.2 compared the results of literature (Section 5.1) by assessing the LCC of various sustainability measures. The section did not indicate new insights in variables and parameters. Table 5.5 shows (although complemented with additional results) the results of literature and Section 5.2. Lastly, two cases, 'Façades-as-a-Service' and 'Housing-as-a-Service', were studied in Section 5.3 to validate the results of literature and Section 5.2. The main results of Section 5.3 were the inclusion of 'financial costs' (the compensation investors demand for risk) and the suggestion to categorise variables/parameters in life cycle stages. The results of literature and Section 5.2 were validated by the two case studies. The cases also indicated an increase in total costs of the PaaS model compared to traditional business models. However, the convenience of services offers additional value to clients that balances against the increase in total costs. The adjustments suggested by Section 5.3 are covered in Table 5.5. The table is also the main conclusion of this chapter.

Table 5.5 - Final overview of factors/variables influencing financial feasibility of a PaaS model categorised in life cycle stages

Life cycle stage	General	Revenue streams	Cost structure
Entire life cycle	Functional unit	Tax credits	Marketing costs
	Lifetime products	Subsidies	Information system
	Life span offering		Financing costs
Design phase		Deposition fee	Development costs
Production phase			Material costs
			Manufacturing costs
			Transportation costs
			Installation costs
Use phase		Monthly/yearly fee	O&M costs
			Replacement costs
			Refurbishment costs
			Transportation costs
End-Of-Life phase		Harvest value	Deconstruction costs
			Transportation costs
			Waste processing
			Disposal costs

6

RESEARCH QUESTION 3: INCORPORATING RISK AND UNCERTAINTY

In the sixth chapter of this research, the third research question is answered: "How can risk and uncertainty be quantified and incorporated in the conceptual model?" The quantification and incorporation of risks and uncertainty in models to assess financial feasibility is an important consideration. It is probably one of the more difficult subjects of capital budgeting. Chapter 4 described how financial metrics can be modelled. The results of such a model are, however, static and do not allow for informed decision-making about the continuation of proposed projects. To allow informed decision-making, decision-makers should also examine involved risk and uncertainty to know under what conditions they are accepting (or rejecting) a considered project. To answer the third research question, this chapter is divided into four sections. First of all, literature in Section 6.1 elaborates on the difference between risk and uncertainty, and presents literature on their incorporation in the conceptual model. Secondly, Section 6.2 describes various ways of incorporating risk specifically in the conceptual model. After that, Section 6.3 elaborates on the quantification of uncertainty. Lastly, Section 6.4 summarizes the most important findings.

6.1 Literature: risk and uncertainty

Cash flows determined with general capital budgeting techniques are estimates, which means they are uncertain. Therefore, financial managers have to incorporate risk into the analysis of projects to identify which ones maximize owners' wealth.

6.1.1 Risk and uncertainty in general

Risk and uncertainty are important considerations in capital budgeting. First, the distinction between both terms has to be made to enable inclusion in the conceptual model. In general, risk is referred to as a situation where the cash flow of an investment proposal has a probability distribution (although this distribution is not necessarily known) (Pandey, 2018). In principle, risk is estimated and expressed in a variable/parameter. Therefore, it is possible to mitigate risk. Risk in the PaaS model differs from risk encountered in traditional business models. In traditional business models, the product is sold once. This leads to a risk of completely losing the revenue of a product, but the chance for this loss is not as frequent as for a PSS. In a PSS, the revenue streams are smaller than in traditional models, but they occur multiple times (monthly or yearly). Thus, the risk of losing revenue has a smaller impact, but the chance is more frequent than in a traditional model (Schneider, Mozgova, & Lachmayer, 2020).

Uncertainty occurs when no information is available to formulate a probability distribution (Pandey, 2018). Whereas risk is incorporated within the model, uncertainty is assessed over the model. It cannot be estimated (although it can be quantified) and cannot be expressed in a variable/parameter. Most of the uncertainty is centred around the use stage and has to do with service, maintenance and repairs (Kambanou & Lindahl, 2016). Uncertainty may result from economic conditions, market conditions, taxes, interest rates and international conditions. For an evaluation of any investment to be meaningful, the risk/uncertainty that its cash flows will differ from what is expected has to be evaluated (Peterson & Fabozzi, 2002).

6.1.2 Incorporation of risk

Risk estimation has a central place in capital budgeting and assessing a project's financial feasibility. Risk theory advocates that the change in market risk of a company by adding a project to the firm's portfolio is more important to consider than a project's stand-alone risk. When owners demand compensation for risk, they are requiring compensation for market risk; the risk they cannot get rid of by diversifying. If the firm's owners hold diversified investments, it is the market risk that is relevant to the firm's decision-making. Even though it is generally believed that the market risk is the most relevant to analyse, stand-alone risk should not be ignored and is often used by companies to determine a project's level of risk for several reasons. First of all, it is far more straightforward to determine a project's stand-alone risk than market risk (Brigham & Daves, 2007). Secondly, if decisions are made for smaller and more closely held firms with less diversified portfolios, the stand-alone risk gives a good idea of the market risk. Lastly, also for larger companies, stand-alone risk is useful to consider, as stand-alone risk is often highly correlated with market risk (Peterson & Fabozzi, 2002).

In capital budgeting, risks are often incorporated within the discount rate applied in budgeting techniques (Hofstrand, 2013). The discount rate determines the present value of future cash flows in a DCF analysis and expresses the time value of money. This establishes if the future cash flows from a project or investment exceed the capital outlay needed (Majaski, 2020). Many companies calculate their weighted-average cost of capital (the WACC) and use it as their discount rate. In that case, the market risk of the company's project portfolio is considered and used in capital budgeting methods. In situations where the new project is considerably more or less risky than the company's normal operation, it might be necessary to adjust the discount rate (Alhabeeb, 2016). Adding a risk premium to the cost of capital and using the sum as the discount rate takes into consideration the risk of investing (Majaski, 2020). In that case, stand-alone project risks are considered. Alternatively, the capital asset pricing model (CAPM) can be used to find an appropriate discount rate (Chittenden & Derregia, 2015). It is also possible to adjust for risk within the cash flows itself. Often Certainty Equivalents are used to adjust within cash flows. These techniques are all also described in the following paragraphs.

Weighted-Average Cost of Capital

If a business is assessing the viability of a potential project, they may use the WACC as starting point to compute a risk-adjusted discount rate. The WACC is the average cost the company pays for capital from debt or equity (Hayes, 2021a). Therefore, it is a calculation of a firm's cost of capital in which each category of capital is proportionately weighted. All sources of capital (including common stock, preferred stock, bonds, and any other long-term debt) are included in a WACC calculation (Hargrave, 2021). It reflects the company's exposure to market risk and therefore the average riskiness of the firm's activities (Ruegg & Marshall, 1990). The WACC is calculated by using Equation 1.

$$WACC = \left(\frac{E}{V} * Re\right) + \left(\frac{D}{V} * Rd * (1 - Tc)\right) \qquad (4)$$

Where:

- E = Market value of the firm's equity;
- D = Market value of the firm's debt;
- $V = E + D$;
- Re = Cost of equity;
- Rd = Cost of debt;
- Tc = Corporate tax rate.

The cost of equity (Re) can be tricky to calculate, since the cost of share capital does not technically have an explicit value. Equity has no concrete price that the company has to pay. Yet, that does not mean there is no cost of equity. Since shareholders will expect to receive a certain return on their investments in a company, the equity holders' required rate of return is a cost from the company's perspective: if the company fails to deliver this expected return, shareholders will simply sell off their shares, which leads to a decrease in share price and the company's value. The cost of equity, then, is essentially the compensation the market or shareholders demand in exchange for owning the asset and bearing the risk of ownership. The cost of equity can be calculated with the dividend capitalization model if a company pays dividend or otherwise with the capital asset pricing model (CAPM). The latter is, however, more complicated (Kenton, 2021b).

Calculating the cost of debt (Rd), on the other hand, is a relatively straightforward process. To determine the cost of debt, the market rate that a company currently pays on its debt is used. If the company is paying a rate other than the market rate, an appropriate market rate is estimated and substituted into the calculations instead (Hargrave, 2021).

A big limitation is that the WACC formula seems easier to calculate than it really is. Because certain elements of the formula (for example, the cost of equity) are not consistent values, various parties may report them differently (Hargrave, 2021). The actual estimation of the cost of capital for a firm requires a bit of educated guesswork, and lots of reasonable assumptions (Fabozzi & Peterson, 2003).

Risk-adjusted discount rate

One way of incorporating risk in capital budgeting analyses is by adjusting the discount rate. There are several ways to incorporate risk into the discount rate, but in any case, the greater the perceived risk, the higher the discount rate adjustment (Gorton, 2020). Based on literature, three techniques are considered to include in the conceptual model.

The first way of adjusting the discount rate for risk uses the WACC as a starting point. This method is commonly used by firms to adjust their discount rates to reflect risk. The project cost of capital depends on the use to which that capital is put. Therefore, it depends on the risk of the project and not on the risk of the company (Taheri, Irannajad, & Ataee-pour, 2009). It also depends on the specific capital distribution (equitey/debt) of the project. Projects involving contractual or legal obligations may be low risk and require a discount rate below the WACC. Ongoing projects involving existing business operations may require the firm's WACC as discount rate. Investments into new products and markets may require a risk premium of five to ten percent above the firm's WACC to account for the uncertainty of customer and competitor reaction, learning curve effects, advertising expenses, price levels, and so on (Parry & Firer, 1990). Table 6.1 and 6.2 show how the discount rate can be adjusted with the WACC as a starting point. In general, estimating project risk, and therefore also the risk-adjusted discount rate, is never going to be an exact science and is prone to a certain amount of subjectivity.

Table 6.1 - The premium/discount approach to estimate the cost of capital for projects (Anderson, Byers, & Groth, 2000)

Project category	Discount rate
For expansion of scale of a project, for the same product line, same risk of sale, etc. The added capacity is not expected to adversely affect market prices.	WACC
Cost reduction project to reduce (variable) costs. The project reduces the firm's operating risk.	WACC – discount
Unknown product acceptance, uncertain incremental markets, known technology.	WACC + premium for market risk
Unknown product acceptance, uncertain incremental markets, unknown technology.	WACC + premium for market risk + technology risk
Foreign investment	WACC used for domestic projects + premium political risk

Table 6.2 - Suggested discount or additional premium for project categories (Taheri, Irannajad, & Ataee-pour, 2009)

Project category	Premium/discount
Improvement, known technology	-5%
Expansion of existing business	0%
New product	10%
Speculative venture	15%

A second method to adjust for risk in the discount rate is to add a risk premium to the risk-free rate (Schmidt, 2014). To mitigate personal judgement from the process of determining the discount rate, the discount rate can be adjusted by using CAPM (Baker & English, 2011). Although this method is more objective, it is hard to arrive at the correct risk premium by applying CAPM. It is comparable to determining the cost of equity in WACC calculations. In this case, however, the equity beta is substituted with the project beta. Riskier projects will result in taking the project beta upwards, which results in a higher discount rate (Parasuraman, 2002). The difficulty here is that it is hard to get project-wise betas. One way to arrive at a project-specific beta is by applying the pure-play method. In other words, a list of publicly traded companies is used that reasonably resembles the project for which the beta is estimated.

The third and last method is, in theory, relatively simple and straightforward. Determination of several parameters in previous methods, for example the beta, are based on results of the past. Because what happened in the past is not a guarantee of what will happen in the future, it is often useful to look at expected returns going forward. Another approach is to simply ask investors what they expect for the project specifically (Schmidt, 2014).

The methods for adjusting for risk in the discount rate have several limitations. In using a constant risk-adjusted discount rate, it is assumed that the risk of achieving future expected cash flows remains the same over the life of the project. This may not be realistic, particularly if the project involves the introduction of a new product. In that case, the major risks may occur during the early years while the product is developed, marketed and promoted. The risk-adjusted discount rate should, therefore, decrease over time rather than remain constant (Parry & Firer, 1990). However, this is less of a problem with PaaS propositions, since the nature of PaaS models causes risks to be bigger in later years of the proposition compared to traditional business models.

Another weakness is that the risk-adjusted discount rate does not tell decision-makers which risks they are taking. Theoretically, a risk-free rate should be used to discount for the time value of money; adjustments for any risks should be made separately. Furthermore, a point rarely made in literature is that for cost streams the discount rate should be lowered instead of increased to make the project less desirable. Raising the discount rate for uncertain cost streams will bias decision-makers toward projects with a greater risk of higher than anticipated costs (Ruegg & Marshall, 1990). Modellers applying the conceptual model of this report may, therefore, choose to incorporate a higher level of detail in an eventual calculation model by applying different discount rates for cash inflows and outflows and in general for cash flows with different levels of risk.

Lastly, as already mentioned, an important limitation is the fact that there is no good way of specifying exactly how much higher or lower these discount rates should be. Given the present state of the art, risk adjustments are necessarily judgemental and somewhat arbitrary (Brigham & Daves, 2007). No matter which approach is taken, the determination of an appropriate discount rate will always be prone to a certain level of subjectivity.

Certainty Equivalents (CE)

The most common method for incorporating risks in cash flows is the Certainty Equivalents technique. Two approaches are used to derive CEs.

The first derivation of CEs is based on risk attitude. In this method, CEs are determined with the value for which the decision-maker is indifferent between a certain sure payment and the expected value of uncertain return. The degree of risk adjustment is decided by management for each time period. The method also disaggregates the discounting for time and the adjusting for risk (Parry & Firer, 1990). All cash flows are multiplied with their certainty-coefficient and then discounted with the risk-free rate of return to account for the time value of money.

The second approach is based on risk exposure. This approach seems particularly appropriate for private firms that have historical records of business performance for different types of investments (Ruegg & Marshall, 1990). The second approach is, therefore, less subjective than the first, because the first is based on the decision-maker’s notion of the level of investment risk. This approach is currently not applicable for Dura Vermeer, as historical records are lacking for the PaaS model.

One advantage of the CE technique is that it can account for risk by including both the decision-maker’s risk attitude and assessment of risk exposure. Another advantage is that it separates discounting that accounts for the time value of money from adjustments for risk. Both are combined in techniques for adjusting the discount rate. Thus, the CE allows for differential risk ‘weighting’ over time. This is probably more appropriate than the increasingly heavy discounting for risk over time implicit in techniques for adjusting the discount rate (Ruegg & Marshall, 1990).

Despite its advantages, the use of CEs raises implementation problems. Decision-makers may find it easier to subjectively raise the discount rate for a risky project rather than specifying CEs for each year (Parry & Firer, 1990). A further limitation is that it is 'data hungry', and the procedure for 'feeding' it is to a large extent subjective. Another limitation is the lack of theory for establishing a CE that combines risk attitude and risk exposure (Ruegg & Marshall, 1990). Lastly, the NPV assumes that the cash flows are reinvested at the WACC (or appropriate discount rate). However, with CE, the risk-free rate is used as the discount rate, potentially creating problems similar to those associated with the NPV, as it is thereby assumed that cashflows are reinvested at the risk-free rate instead of the WACC or risk-adjusted discount rate (Nippani, 2017).

6.1.3 Incorporation of uncertainty

Cash flows included in an eventual calculation model also include a certain amount of uncertainty. As a result of the diversity of the causes of uncertainty, the methods of quantifying are various as well (Kreye, Goh, & Newnes, 2009). Three techniques are considered for the conceptual model to quantify uncertainty: sensitivity analysis, scenario analysis and Monte Carlo simulation.

Sensitivity analysis

One way of dealing with uncertainty is by conducting a sensitivity analysis. Sensitivity analysis is a technique that indicates how much the results will change in response to a given change in an input variable, other things held constant (Brigham & Daves, 2007). Thereby, it also enables identification of critical variables to the project (Parry & Firer, 1990). It allows management to make more informed decisions and create a view on the room available for judgemental error (Arnold, 2005).

The use of sensitivity analysis has several advantages. First, it shows the significance of a single input variable in determining project outcomes. Second, it recognizes the uncertainty associated with the input. Third, it gives information about the range of output variability. And fourth, it does all of these when there is little information, resources, or time to use more sophisticated techniques (Ruegg & Marshall, 1990). Together, these advantages lead to an indication where further investigation might be worthwhile. The collection of data can be time consuming and expensive. If the sensitivity analysis points to some variables being more crucial than others, then search time and money can be concentrated (Pandey, 2018). Besides, during the implementation phase of the investment process, the original sensitivity analysis can be used to highlight those factors that have the greatest impact on the financial metrics. These parameters can be monitored for deviation from projected values. The management team can draw on contingency plans if the key parameters differ significantly from the estimates (Arnold, 2005).

Unfortunately, sensitivity analysis also has its disadvantages and limitations. A major disadvantage is that it gives no explicit probability measure of risk exposure. It does also not include explicit treatment of risk attitude (Ruegg & Marshall, 1990). This might create a biased view, since the probability that one variable deviates for example 10 percent from its expected value might be significantly higher than another variable deviating 10 percent. Another drawback is that each variable is changed in isolation, while all other factors remain constant (Arnold, 2005). This is a problem when in reality multiple factors can change simultaneously; factors are possibly correlated with each other and enhance/weaken each other. Using other techniques in addition to sensitivity analysis (for example scenario analysis and Monte Carlo simulation) will for a large part cope with the disadvantages and limitations.

Scenario analysis

Scenario analysis also looks at the range of likely values of key variables, in addition to measuring the sensitivity of changes in those variables. Thereby, it is a useful extension to sensitivity analysis. In a scenario analysis, the financial analyst(s) start(s) with the base case of the model, in which the most likely set of values for the input variables are incorporated. Then, experts within the company (for example marketing, engineering, and other operating managers) are asked to specify a worst-case scenario (low unit sales, low sales price, high variable costs, and so on) and a best-case scenario. If no exact probabilities are known, usually the best- and worst-case scenarios are set with a probability of 25 percent of conditions being that good/bad and a 50 percent probability is assigned to the base-case conditions (Brigham & Daves, 2007). Assigning these probabilities to the outcomes allows for the calculation of an expected result of each financial metric and its associated standard deviation (Parry & Firer, 1990). In addition, the coefficient of variation can be calculated. The coefficient of variation represents the ratio of the standard deviation to the mean. It is useful to compare projects with different magnitudes. The variability in outcomes under the three different scenarios helps the management to assess the uncertainty a project carries.

It is also possible to include scenarios in the analysis that change some factors positively and some negatively, although it is harder to assign probabilities to these scenarios. Therefore, these scenarios (other than the base-case and worst/best case) should not be included in calculations for expected results, standard deviation and coefficient of variation. They would, however, still give a useful overview of the performance of the project under the scenario's conditions.

The biggest limitation of scenario analysis is that it only considers a few discrete outcomes, even though there is an infinite number of possibilities. Thereby, it still does not provide a complete quantification of uncertainty.

Monte Carlo simulation

The fact that only a few discrete outcomes are produced limits the value of scenario analysis. Monte Carlo simulation is a more rigorous method of assessing a project's uncertainty. It ties together sensitivities and input variable probability distributions (Parry & Firer, 1990). The basis of a Monte Carlo simulation is that the probability of varying outcomes cannot be determined, because of random variable interference. A Monte Carlo simulation takes the variables that have uncertainty and assigns them random values from a probability distribution. The eventual calculation model is then run and a result is provided. This process is repeated several times, while assigning the variables in question with many different values. Once the simulation is complete, the results are averaged together to provide an estimate and the possibility to derive distributions rather than just point estimates (Kenton, 2021e). Although the output of a Monte Carlo simulation depends on its design. Most useful for this report is a histogram of each financial metric, together with an expected value (average) of each financial metric and their volatilities. The histogram provides information not visible from the static discounted cash flow analysis. It allows, for example, for an estimate of the probability that a project has an NPV greater than zero (or any other value). This has significant additional value to solely conducting a sensitivity and scenario analysis.

Despite its major advantages, the Monte Carlo simulation also has some drawbacks. First of all, the eventual calculation model becomes quite complex to use. However, while Monte Carlo simulation is considerably more complex than scenario analysis, simulation software packages make this process more manageable (Brigham & Daves, 2007). Secondly, the probability distribution of outcomes does not indicate whether the project should be accepted. The output of the Monte Carlo simulation enables comparison of an average outcome with the decision rule, but the quantified uncertainty still needs judgement. Therefore, it is still prone to subjectivity.

6.2 Incorporating risk

Literature extensively described some basic constructs about risk and the difference with uncertainty. This section describes how risks can be incorporated in the conceptual model and eventually in a calculation model.

Risks can be incorporated in two ways in capital budgeting models. Firstly, the discount rate can account for risks by adjusting it to higher values for higher project-specific risk or vice versa. Secondly, risks can be incorporated within the cash flows. The most common method to adjust for risk in cash flows is the Certainty Equivalent technique. Both techniques are compared to each other in Section 6.2.1. Only the first method, adjusting the discount rate, is used in this report. Various methods adjust for risk in the discount rate; none of them is theoretically preferred. Section 6.2.3 elaborates on these techniques. In total three techniques are described. One of the techniques has the WACC as starting point. Because it is complex to arrive at a company's WACC, a separate section upfront is dedicated to the way Dura Vermeer can arrive at its WACC. Section 6.2.2 elaborates on the WACC.

6.2.1 Risk-adjusted discount rate versus certainty equivalents

Literature in Section 6.1.2 described the theory on risk-adjusted discount rates and certainty equivalents. This section compares both ways of incorporating risk and ultimately selects the most appropriate approach for the conceptual model. In theory, both methods would produce identical results if managers were able to estimate accurate values for the inputs of both methods. In practice, their popularity among firms differs, because of various characteristics of the methods. The methods for incorporating risk by adjusting the discount rate are by far the most appealing methods and most popular in practice (Baker & English, 2011). Several reasons contribute to that popularity.

First of all, the risk-adjusted discount rate method is easier to use in practice, because the discount rate for average-risk projects (the firm's corporate cost of capital) can be estimated from observable market data. Market data are not available to help managers estimate certainty equivalent cash flows. There is no practical way to estimate certainty equivalents. To further complicate matters, certainty equivalents should reflect shareholders' estimations rather than those of management. Therefore, the certainty equivalent method is not used often in corporate decision-making (Brigham & Ehrhardt, 2008).

Secondly, some financial theorists have suggested that the certainty equivalent approach is theoretically superior. However, other theorists have shown that if risk increases with time, then using a risk-adjusted discount rate is a valid procedure. By compounding the risk premium over time, the risk-adjusted discount rate method automatically assigns more risk to cash flows that occur in the distant future. Since the CE method assigns risk to each cash flow individually, it does not impose any assumptions regarding the relationship between risk and time (Brigham & Ehrhardt, 2008). As risks in a PaaS model shift more towards later years of a proposition, a risk-adjusted discount rate is preferred.

For these reasons, the risk-adjusted discount rate is included in the conceptual model to incorporate risk in the decision-making process of implementing potential PaaS propositions.

6.2.2 Weighted Average Cost of Capital

Corporations often use the WACC as discount rate for financial decisions, as the WACC represents the overall required rate of return for the firm. However, for projects with different risk exposures, the WACC is not the most appropriate discount rate, as it does not incorporate project-specific risk. Nevertheless, it can serve as a good starting point in determining the appropriate discount rate.

The WACC is calculated after tax and sets a discount rate at a nominal rate, i.e. including the effects of inflation. A large part of the input parameters can be determined in consultation with a company's finance department and depend on the quality of the accounting system (Van Ostaeyen, 2014). For a clear overview, the equation to calculate the WACC (already shared in literature) is once more displayed in Equation 5.

$$WACC = \left(\frac{E}{V} * \ Re\right) + \left(\frac{D}{V} * Rd * (1 - Tc)\right) \qquad (5)$$

Although the equation in itself is easy to compute, it is difficult to arrive at the values of certain elements of the formula. Table 6.3 gives a brief description of the elements incorporated in the formula above and the way Dura Vermeer specifically can arrive at their values.

Table 6.3 - Description of input parameters for WACC calculation and their values

Parameters	Description and value determination
E	This is the market value of Dura Vermeer's equity. This value is presumably easy to determine and is simply requested at the financial department of Dura Vermeer.
D	*D* reflects the market value of Dura Vermeer's debt. Financial data of the financial department of Dura Vermeer can presumably provide the value of this parameter.
V = E + D	This is simply the total market value of the firm by adding Dura Vermeer's equity and debt.
Re	This input parameter is the cost of equity for Dura Vermeer. This is the most difficult value to determine in a WACC calculation, since the cost of share capital does not technically have an explicit value. It represents the compensation that the market or shareholders demand in exchange for owning the asset and bearing the risk of ownership. It can be determined in two ways: 1 With the dividend capitalization model, but it requires that a company pays dividends. As Dura Vermeer is privately owned, Dura Vermeer does not pay dividends. Therefore, the first method is not suitable to arrive at the cost of equity. 2 With the capital asset pricing model (CAPM), which is more complicated, but can always be used for WACC calculations. Because of its complexity, the CAPM model is more extensively discussed below.
Rd	*Rd* is the cost of debt for Dura Vermeer. To determine the cost of debt, the effective interest rate that Dura Vermeer is currently paying on its debt is used. There are two main ways to calculate the cost of debt, depending on the information available. Below, these methods are described in more detail.
Tc	*Tc* is the corporate tax rate of Dura Vermeer. The financial department can probably clarify the value of this parameter. General corporate income tax is established at 25% in the Netherlands for taxable amounts above €245,000 (which is the case for Dura Vermeer). An exception accounts for activities covered in the innovation box, for which a reduced rate of 9% applies (Dutch Ministry of Finance, 2021). Therefore, 25% can be used as an estimation for the corporate tax rate, but an exact value should be requested at the financial department.

Determination of cost of equity: Capital Asset Pricing Model (CAPM)

Literature shows that the CAPM is the main method used by firms to determine the cost of equity, since a better method is not yet available (Taheri, Irannajad, & Ataee-pour, 2009). The formula for computing the cost of equity with CAPM is relatively easy to understand, but arriving at the correct input parameters is difficult. The basic CAPM formula for the cost of equity is shown in Equation 6 (Kenton, 2021a).

$$Re = Rf + \beta * (Rm - Rf) \tag{6}$$

Where:

- Re = Cost of equity;
- Rf = Risk-free rate of return;
- β = Beta (sensitivity of expected return of Dura Vermeer to the market return);
- Rm = Market rate of return.

Below, each input parameter is individually discussed.

Risk-free rate of return

A good proxy of the risk-free rate of return is a government bond with the same valuta as used by the company. For euros, often the yield of a German government bond is used to arrive at the risk-free rate of return. The maturity of the bond has to be the same as the lifetime of the project under consideration.

Beta

Beta is the measure of the volatility, or market/systemic risk, of a company compared to the market as a whole (Kenton, 2021d). Normally, a regression equation is used based on historical stock-return data to arrive at the beta of a listed company. Dura Vermeer is, however, privately owned. Therefore, it is not possible to estimate the stock beta by a regression equation. To estimate the beta of a private company, there are two primary approaches (Mirzayev, 2019). The beta can be obtained by the pure-play method or one can find the beta of the company's earnings and adjust it. The first is the easiest to execute. Therefore, this method is used to arrive at Dura Vermeer's beta.

The following steps calculate the beta for Dura Vermeer with the pure-play method (Mirzayev, 2019):

1. First, the beta of publicly traded companies that generate income from similar operations as Dura Vermeer has to be found. Based on their betas, a proxy is made for the industry average levered beta. The following companies are publicly traded and comparable to Dura Vermeer:
   - BAM Groep: A Dutch contractor, which is the largest construction company based on their revenue in the Netherlands.
   - Boskalis Westminster: A Dutch dredging and heavy-lift company that operates for a large part in the Dutch construction sector.
   - Heijmans: Also a large Dutch contractor, that is very comparable to BAM Groep and Dura Vermeer.

   Initially, the selection of company's was broader. However, various firms were eventually excluded from the list, as only the listed companies above can be reliably included in the pure-play method. In later stages, it is possible to investigate whether other companies can be included as well, as the current selection is very minimal for the pure-play method.
2. Secondly, the debt-to-equity and tax ratios of the comparable companies are used to unlever the betas. Equation 7 determines the unlevered betas of the companies.

$$Unlevered\ Beta = \frac{Levered\ Beta}{1 + (1 - Tax\ Rate) * Debt\ to\ Equity\ Ratio} \tag{7}$$

3. The third step calculates the average of the unlevered betas of the comparable companies. This beta represents the unlevered industry beta.
4. Lastly, the average unlevered beta has to be re-levered to arrive at the levered beta by using the debt-to-equity and tax ratio of Dura Vermeer. Equation 8 shows how the levered beta is computed. For clarity: the tax rate and debt-to-equity ratio in the formula below should be the specific ratios of Dura Vermeer.

$$\beta = Average\ Unlevered\ Beta * (1 + (1 - Tax\ Rate) * Debt\ to\ Equity\ Ratio) \tag{8}$$

The method above provides a relatively accurate proxy for the beta of a private company, in this case Dura Vermeer. However, the method also has certain pitfalls. Most important is its neglect of the difference between the size of the private company and that of the publicly traded companies. With the method above, it is assumed that all companies have more or less similar scales.

Market rate of return

The market rate of return is what investors expect the market to return. By subtracting the risk-free rate from this market rate of return (in Equation 6 denoted as $(Rm - Rf)$), the equity market risk premium is calculated. This value is online available. For example, KPMG recommends an equity market risk premium of 5.5% for the Netherlands as of 30 June 2021 (KPMG, 2021). Note that this value is the market risk premium and not the market rate of return. This value is, therefore, included for the entire last part in Equation 6. This value is the last value needed for the CAPM formula.

Determination of cost of debt

As described in Table 6.1, two main ways can determine the cost of debt. The first way of determining the cost of debt is by computing the formula depicted in Equation 9 (Hayes, 2021d).

$$Rd = (Risk\ Free\ Rate + Credit\ Spread) * (1 - Tax\ Rate) \tag{9}$$

The tax rate is already determined for the WACC calculation. For the risk-free rate, the yield of a German government bond is used with the same maturity as the lifetime of the considered project. The credit spread in general is the difference between the yield of two different debt instruments with the same maturity but different credit ratings. Dura Vermeer's credit spread is the difference between the corporate bond yield (which is determined based on its credit rating, available at the financial department) and the yield of the German government bond. Again, it is important that the maturity of both is the same. Embedding these values in Equation 9 determines Dura Vermeer's cost of debt.

Alternatively, Dura Vermeer's cost of debt is determined by the total amount of interest paid on each of Dura Vermeer's debts for the year (Hayes, 2021d). The interest rate that Dura Vermeer pays on its debts is inclusive of both the risk-free rate of return and the credit spread, because lenders take both into account when initially determining an interest rate. Once the total interest paid for the year is determined, it should be divided by the total of all debts. Hereby, the average interest rate on all Dura Vermeer's debts is determined. However, this value is the before-tax cost of debt. To arrive at the after-tax cost of debt, the average interest rate is multiplied (similar as in Equation 9) by: (1 – tax rate).

6.2.3 Adjusting for risk in the discount rate

Firms often use their WACC (see Section 6.2.2) as discount rate in their capital budgeting models. Capital budgeting literature suggests, however, that the WACC is only appropriate as discount rate if the considered project has the same level of risk as the average project of the company. If the considered project includes higher or lower levels of risk, the WACC is not appropriate anymore to apply as discount rate, as it only includes a company's market risk in the model. One way to incorporate stand-alone risk of projects is to adjust the discount rate. The use of a risk-adjusted discount rate is based on the concept that investors demand higher returns from risky projects. Several ways can adjust for project-specific risk in the discount rate. Theoretically, none of them is preferred to others. Most managers use subjective risk assessments in adjusting their discount rate (Payne, Heath, & Gale, 1999). This section describes three methods to adjust the discount rate and the way they can be applied by Dura Vermeer in a model to assess financial feasibility. Literature also suggests to use more than one approach (Taheri, Irannajad, & Ataee-pour, 2009).

Adjusting with WACC as starting point

Literature provided a general description of this method based on literature. Moreover, Section 6.2.1 already described how the WACC can be computed. From this point, it is possible to adjust for risk by adding or subtracting a certain percentage from the WACC. Table 6.4 (also displayed in the literature section) shows the suggested adjustments for several project categories.

Table 6.4 - Suggested discount or additional premium for project categories (Taheri, Irannajad, & Ataee-pour, 2009)

Project category	Premium/discount
Improvement, known technology	-5%
Expansion of existing business	0%
New product	10%
Speculative venture	15%

The proposed PaaS model in this research is categorized in 'unknown product acceptance, uncertain incremental markets, known technology', since it is a new business model. Dura Vermeer is familiar with all (potential) products included in the proposition. As it is not a completely new product, this report suggests using a premium between 0% and 10%. To be more specific, this research suggests using a premium of 5% or 7.5% above the WACC, because on the one hand the proposed business model is not a totally new product, but on the other hand is not exactly an expansion of existing business either. Both can be included in the conceptual model (and eventually in a calculation model) to assess financial feasibility. Eventually, the premium can be reduced to 0% if Dura Vermeer is completely familiar with its new business model.

Adjusting by adding a risk premium to the risk-free rate

Literature described the basic constructs for adjusting the discount rate by adding a risk premium to the risk-free rate. Using the pure-play method and Equation 10 below enables calculating a risk-adjusted discount rate by adding a risk premium to the risk-free rate.

$$Discount\ rate = Rf + \beta_{project} * (Rm - Rf) \quad (10)$$

Where:
- *Rf* = Risk-free rate of return;
- $B_{project}$ = Beta specifically determined for the considered project;
- *Rm* = Market rate of return (the same as determined in Section 6.2.1).

The problem is that it is currently not possible to derive the project-specific beta from pure play companies, because currently no companies are publicly listed that solely provide Products-as-a-Service (at least as far as the knowledge of the researcher goes). Therefore, it is not possible to apply this method (yet) to determine an appropriate discount rate for a PaaS-proposition.

Investors' expectations

The last method to adjust the discount rate for risk is by investors' expectations. The previous methods are all based on results in the past. Results achieved in the past are, however, not a guarantee for future results. Therefore, an additional approach is to identify investors' expectations of the project under consideration. This method can be applied in conjunction with the first method. For the proof of concept in this report, this method is less useful, since an example project is used in which investors are not involved.

6.3 Quantifying uncertainty

The previous section elaborated on the incorporation of risks in a model to assess a project's financial feasibility. Cash flows in a model also include uncertainty. Blindly accepting the output of a model is a dangerous business, since it does not give a clear view on the uncertainty included in the output (Fairhurst, 2012). Quantification of uncertainty helps to determine the sensitivity of a model to changes in inputs. Thereby, it creates a better perspective on whether or not the proposed project should be accepted. Three techniques are considered for the quantification of uncertainty. This report advises that they are all conducted in order to get a thorough view on the uncertainties included in a future PaaS proposition. Literature already described the general contents of sensitivity analysis, scenario analysis and Monte Carlo simulation. It also provided their advantages and limitations. The following sections (6.3.1, 6.3.2 and 6.3.3) all describe the practical application of these techniques. They provide roadmaps to eventually conduct the analyses and simulations.

6.3.1 Sensitivity analysis

Literature extensively described the theoretical contents of sensitivity analysis. The advantages and limitations of this kind of analysis were also depicted. Despite the mentioned drawbacks of the technique, this research advises conducting a sensitivity analysis nonetheless. The major advantage of identifying critical variables of the project (which comes more clearly forward in this technique than in others) mainly contributes to this advice. The remainder of this section provides an extension to the 13th step of the roadmap presented in Chapter 4. It describes the practical application of sensitivity analysis for the conceptual model.

The following steps have to be followed to correctly assess uncertainty by means of sensitivity analysis (Brigham & Daves, 2007; Pandey, 2018):

1. Identification of (key) variables, which have an influence on the project's financial metrics.
   The first step is the most important step in finding reliable results with a sensitivity analysis. The list of variables in Section 5.4 (Table 5.5) is useful for an estimation of the most important variables. More key drivers do not necessarily improve valuation. Only those variables that carry significant explanatory power for the financial performance of the project should be assessed as key drivers. A rough estimation states that the number of key drivers should not exceed ten variables (assuming standard complexity of the financial model) (Janiszewski, 2011). Literature shows that at least the life span of the offering and the discount rate have to be included in a sensitivity analysis (Schneider, Mozgova, & Lachmayer, 2020; Peterson & Fabozzi, 2002; Schmidt, 2014). In consultation with experts at Dura Vermeer, these two

variables can be supplemented with additional variables that are likely to have a significant impact on the financial feasibility.

2 Adjusting identified variables.
   The key variables to the project should now be changed by several percentage points above and below the expected value. All other variables have to be held constant. To create a thorough view of the impact variables have on financial feasibility, this research suggests to adjust selected variables with at least 10 and 20 percent above and below their expected values.
3 Analysis of the impact of changes in variables.
   In the last step, the set of results of financial metrics is plotted to show the sensitivity of the results to changes in each key variable. Graphs should be used to plot the financial metrics to the percentage change in the key variables (see the proof of concept in Chapter 8 for a practical example). The steeper the line, the more sensitive the results are to that variable. If two projects are compared, the one with the steeper sensitivity lines is riskier: for that project a relatively small error in estimating a variable would produce a larger error in the project's expected results.

Various software programmes (such as Excel) include tools (or plugins) to assist in performing sensitivity analysis. Based on the software programme chosen to transit from the conceptual model towards a calculation model, it is worthwhile to investigate whether helpful tools assist in executing sensitivity analysis.

6.3.2 Scenario analysis

Literature described the general background and theory about scenario analysis. It also described briefly the advantages and disadvantages of the application of scenario analysis. This research advises applying scenario analysis to quantify uncertainty, since it offers useful additional insights compared to sensitivity analysis. Scenario analysis also looks at the range of likely values of variables in addition to measuring the sensitivity of changes in key variables. This section describes steps to apply scenario analysis to quantify uncertainty in the model. Thereby, it serves as an extension to the 13^{th} step of the roadmap presented in the fourth chapter.

The following outline of steps can be used to perform scenario analysis to quantify uncertainty:

1 Determining base case
   The first step in a scenario analysis is determining the base case. The expected values of each input variable are included in the eventual calculation model and the results for this case are calculated. As exact probabilities are unknown, this research suggests assigning a probability of 50 percent to this case (based on literature).
2 Determining worst- and best-case scenarios
   Various internal experts (management, financial/sales department, calculators, etc.) can be consulted to determine these scenarios. Establishing the scenarios should be done together, since that allows for less bias in ascertaining the scenarios. Results are then calculated for both scenarios. Again, as the exact probabilities of the scenarios are unknown, this research suggests assigning a probability of 25% to each of these two scenarios.
3 Optional: determining alternative scenarios
   The team of internal experts might also establish some additional scenarios that they foresee as a possibility in the future. These might deviate from the three scenarios thus far and change some input variables positively and others negatively. These scenarios should not be considered for quantifying uncertainty, but they shed light on the financial feasibility of the PaaS proposition under specific conditions.
4 Quantifying uncertainty
   Uncertainty is quantified by calculating expected outcomes of the financial metrics (NPV, PI and IRR), standard deviation and coefficient of variation. The equations below (11, 12 and 13) show how these values are calculated. Each formula has to be calculated three times: for the NPV, PI and IRR.

$$\text{Expected outcome financial metric} = \sum_{i=1}^{I} P(X_i) * X_i \quad (11)$$

Where:
- i = Scenario i;
- I = Total scenarios considered for uncertainty (at least three (worst-, best- and base-case), but could be more if it is possible to determine probabilities for those scenarios).
- $P(X_i)$ = The probability of scenario i (0.25 for worst- and best case, and 0.50 for base-case);
- X_i = Output of scenario i.

$$\text{Standard deviation financial metric} = \sqrt{\sum_{i=1}^{I} P(X_i) * (X_i - \text{Expected outcome})^2} \quad (12)$$

Where:
- i = Scenario i;
- I = Total scenarios considered for uncertainty (at least three (worst-, best- and base-case), but could be more if it is possible to determine probabilities for those scenarios).
- $P(X_i)$ = The probability of scenario i (0.25 for worst- and best case, and 0.50 for base-case);
- X_i = Output of scenario i;
- Expected outcome = The result of Equation 11 for the specific financial metric.

$$\text{Coefficient of variation financial metric} = \frac{\text{Standard deviation}}{\text{Expected outcome}} \quad (13)$$

Where:
- Standard deviation: The result of Equation 12 for the specific financial metric;
- Expected outcome: The result of Equation 11 for the specific financial metric.

6.3.3 Monte Carlo Simulation

The background and theory of Monte Carlo simulation are briefly discussed in the literature. This section elaborates on the practical application of Monte Carlo simulation to incorporate it in the conceptual model. Monte Carlo simulation is a useful extension to sensitivity and scenario analysis. It ties together sensitivities and input variable probability distributions. Unlike the outputs produced by the scenario analysis, Monte Carlo simulation delivers continuous outcomes. Therefore, this report advises incorporating Monte Carlo simulation in the conceptual model. The description for the practical application of Monte Carlo simulation serves as an extension to the 13th step of the roadmap presented in Chapter 4.

During the eventual transition from the conceptual model to the calculation model, it should be checked if software packages or plugins are available to assist in conducting the Monte Carlo simulation. The following general steps can be followed to conduct a Monte Carlo simulation:

1. Identify variables influencing cash in- and outflows
   This step has already been finished (in previous sections of this report) and does not need further consideration.
2. Optional: Determine correlation between variables
   Although not necessary, the determination of correlation between variables increases the level of detail in the Monte Carlo simulation. Correlating inputs is a modelling technique that adjusts the simulation process to reflect the implications of covariance. This step can be considered in future projects, when distributions of variables are known. Correlations can be determined in consultation with experts (the same experts as involved with the sensitivity and scenario analysis). An example of correlation is the negative correlation between maintenance costs and replacement costs (with higher levels of maintenance, it is expected that the lifetime of individual products is increased and therefore the frequency of replacement costs decreases).

3 Estimation of probability distributions for each variable
The exact distributions of variables are hard to determine; even if in a few years historical data is available. Nonetheless, it is possible to assign probability distributions to each variable if exact probability functions are unknown. The triangular distribution can be used for each individual input variable. It is based on a knowledge of the minimum and maximum values and an 'inspired guess' as the modal value. The triangular distribution is often used in business decision making, particularly in simulations. Internal experts can help in determining the expected values of variables and estimates of their minimum and maximum values. This research advices using this distribution for the input variables in the Monte Carlo simulation.
4 Conduct Monte Carlo simulation
The fourth step is developing a computer programme that randomly selects one value from the probability distribution for each variable and uses these values to calculate the financial metrics. This step remains quite abstract for now, as a software programme has to be selected to be more specific about this step. Many software programmes have plugins or tools available to assist in this kind of simulation.
5 Analyse and discuss outcomes
As mentioned in literature, the outputs of a Monte Carlo simulation are a histogram of the financial metric, together with an expected value (average) of each financial metric along and their volatilities. The resultant statistics of Monte Carlo simulation are a more accurate mirror of the project's 'randomness' than the variance observed under the scenario-based approach. Based on these results, informed decision-making is enabled for continuing the proposed PaaS model.

6.4 Conclusion

This chapter has provided an answer to the third research question of this research. It described the way risk and uncertainty are included in the conceptual model and eventually in a calculation model. Literature discussed the differences between risk and uncertainty. This distinction is important, since risk and uncertainty are differently incorporated in the conceptual model. In general, risks are incorporated within the model, whereas uncertainty is assessed over the model. Where risk is expressed in a variable/parameter and possible to mitigate, uncertainty cannot be expressed in a variable/parameter (although it is possible to quantify risk).

Risks are incorporated by adjusting the discount rate or by adjusting the cash flows. Adjusting the cash flows is, however, more complex to apply and considering the nature of the PaaS model (a shift of risk towards later years of a project) presumably not totally sound. Therefore, this report advised to adjust the discount rate to incorporate risk (a risk-adjusted discount rate). Two approaches can determine a risk-adjusted discount rate:

1 Adjusting with the WACC as starting point:
This method adds a risk premium of several percentage points to the WACC. The proposed business model is not a completely new product, but not an extension of existing business either. Thereby, the PaaS model is not part of one particular pre-specified project category for which risk premiums are suggested by literature. Therefore, the report advised to add a 5% to 7.5% risk premium to the WACC to determine the risk-adjusted discount rate.
2 Adjusting based on investors' expectations:
An alternative approach is to simply ask investors about their expectations for the project. Their suggested rate of return is then used as risk-adjusted discount rate.

This chapter also elaborated on the quantification of uncertainty. This is an important consideration for the decision-making process. In total, three techniques assist in quantifying uncertainty:

1 Sensitivity analysis:
This method gives a clear view of the sensitivity of input variables/parameters on a project's financial feasibility.
2 Scenario analysis:
This techniques shows a project's performance under the conditions of certain scenarios. Every project is at least tested on a worst-, base- and best-case scenario.

3 Monte Carlo simulation:
This approach ties together sensitivities and input variable probability distributions. Thereby, it complements both the sensitivity analysis and scenario analysis by providing continuous statistics instead of discrete statistics.

All three techniques provide different forms of information about uncertainty. Therefore, this report recommended all methods for the quantification of uncertainty. Section 6.3 described every technique extensively. It also provided roadmaps for the practical incorporation in eventual calculation models.

7

RESEARCH QUESTION 4: DEVELOPMENT OF CONCEPTUAL MODEL

The seventh chapter of this report elaborates on the fourth research question of this research: "How can the financial metrics and risk/uncertainty be combined in a product-independent conceptual model for the PaaS model applied to sustainability measures?" The central goal of this chapter is to capture the results of Chapters 4, 5 and 6 into one conceptual model. This gives a clear outline of the way the financial feasibility of the proposed PaaS model can be assessed/modelled.

Literature in Section 7.1 provides a clear definition for a conceptual model. For this research specifically, a conceptual model is used as a non-software specific description of a computer calculation model. As mentioned in literature, a conceptual model can be represented in various ways. In this research, the framework of Robinson (2013) is used for a textual representation of the model. The results of each step included in the framework are described in distinct sections (although the first two steps are combined): (1) Understanding the problem situation (Section 7.2); (2) Determining the modelling and general project objectives (Section 7.2); (3) Identifying the model outputs (responses) (Section 7.3); (4) Identify the model inputs (experimental factors) (Section 7.4); and (5) Determining the model content (scope and level of detail), identifying any assumptions and simplifications (Section 7.5). Section 7.6 complements the textual representation of the conceptual model with visualisations for clarity. Lastly, Section 7.7 concludes and summarizes this chapter.

7.1 Literature: development of conceptual model

Various definitions for a conceptual model exist. In general, a conceptual model is defined as "an abstract representation of something generalized from particular instances" (Liu, Yu, Zhang, & Nie, 2011). For this research specifically, a conceptual model is used as a non-software specific description of a computer calculation model (Robinson, Arbez, Birta, Tolk, & Wagner, 2015). From a modeller's perspective, a conceptual model gives a structure that is easier to implement (Lovric, Kaymak, & Spronk, 2008). A documented conceptual model is for communication and is the basis for guiding all activities in computer model development and use (Robinson, Arbez, Birta, Tolk, & Wagner, 2015). The conceptual model has to be independent of any particular computer language or software implementation, but should be precise enough to be equivalently implemented in different implementation frameworks (Schellinck, 2021). It is probably the most important aspect of any modelling study. Get the conceptual model right and the rest of the modelling work will be more straightforward, providing the right information in the right time scale (Robinson, 2011). For this research, a conceptual model is also needed because the product (a sustainability measure or a combination of sustainability measures) is not known yet.

Conceptual models can be represented in various ways. The most popular are textual and pictorial representations. The main objectives of the textual representation are to describe the content of each conceptual model component (Onggo, 2010). This research uses the framework presented in Robinson (2013) to develop the conceptual model. Although Robinson (2008) already described and adopted parts of the framework, Robinson (2013) provided the clearest description of the framework. The framework provides in total five activities that deliver a textual representation of the model: (1) Understanding the problem situation; (2) Determining the modelling and general project objectives; (3) Identifying the model outputs (responses); (4) Identify the model inputs (experimental factors); and (5) Determining the model content (scope and level of detail), identifying any assumptions and simplifications. The objectives of pictorial representation are then to elicit visual imagery to support the textual representation (Onggo, 2010). For instance, process flow diagrams are useful for communicating the conceptual model (Robinson, 2013).

7.2 Objectives

The first two steps in the framework of Robinson (2013) are closely related and written up in the same text box. Starting with an understanding of the problem situation, a set of modelling and general project objectives are determined. These objectives drive the further derivation of the conceptual model. The organizational aim determines the model objectives. Once these are determined, it is possible to identify how modelling contribute to these. The modeller should also clarify the nature of the model and its use, since this has an impact on the conceptual model design (Robinson, 2008). The text box fulfils the first two steps: understanding the problem situation and determining the modelling and general project objectives.

Understanding the model's problem situation and objectives

Organizational Aim

The overall aim is to achieve financial feasibility in a new business model: sustainability measures offered as a service (i.e. the PaaS model). Currently, Dura Vermeer has no clear vision of the financial feasibility of this new business model and no tools to assess its financial feasibility.

Modelling Objectives

- To determine the financial feasibility of sustainability measures offered as a service.
- To identify the most significant factors influencing financial feasibility (the most sensitive).
- To assess the performance of the proposition in certain scenarios.
- To get a rough estimate of the probabilities of outcomes.

General Project Objectives

- Time-scale
  The first design of the calculation model will be drafted in three weeks, for further detailing no specific time-scale is defined.
- Flexibility
  The model should provide enough flexibility to allow improvements in detailing the model in later stages.
- Visual display
  A simple and organized design should be adopted, that clearly outlines the input variables and the outputs/results (for assessing financial feasibility).
- Ease-of-use
  It has to be easy to understand and interpret the model. This is achieved by designing a model in which the intended user only has to change input variables.

7.3 Outputs

In the third step of the framework, the outputs (often called responses) of the model have to be determined. They are useful to know prior to thinking about the content of the model. The objectives are central in determining the outputs. The outputs have to indicate whether the modelling objectives are achieved and if not, why the objectives are not achieved. Once the required responses are identified, consideration should also be given to how the information is reported. Options are for example numerical data (e.g. mean, maximum, minimum, standard deviations) or graphical reports (e.g. time-series, bar charts, Gantt charts, pie charts) (Robinson, 2008).

Outputs (responses)

- NPV (for various scenarios): Expressed in €. The decision rule in Section 4.2.1.10 helps interpreting this output.
- PI (for various scenarios): Expressed in a numerical ratio. The decision rule in Section 4.2.1.11 helps interpreting this output.
- IRR (for various scenarios): Expressed in a percentage. The decision rule in Section 4.2.1.12 helps interpreting this output.
- Sensitivity of the previous outputs for determined key variables. Graphs should be used to plot the financial metrics to the percentage change in the key variables. The steeper the line, the more sensitive the results are to that variable.
- Expected outcome of financial metrics expressed the same as the financial metric.
- Standard deviation of financial metrics expressed the same as the financial metric.
- Coefficient of variation of financial metrics. Expressed as a numerical ratio of the standard deviation to the mean.
- Histogram of each financial metric (depicting probabilities of outcomes), together with an expected value (average) of each financial metrics and with their volatilities (result of Monte Carlo simulation).

7.4 Inputs (experimental and other factors)

The fourth step of the framework identifies the inputs of the model. The inputs are divided into experimental factors and other input factors. Experimental factors (variables) are the model data that can be changed to achieve the modelling objectives. Other factors (parameters) are, in principle, a given to the model and not to be changed to achieve the modelling objectives (although this does not mean that their sensitivity cannot be assessed in a sensitivity analysis). All factors are outlined in the text box.

Experimental factors (variables)

- Functional unit
- Marketing costs
- Deposition fee
- Material costs
- Transportation costs
- Monthly/yearly fee
- Refurbishment costs
- Life span offering
- Information system
- Development costs
- Manufacturing costs
- Installation costs
- O&M costs

Other factors (parameters)

- Discount rate
    - Market value equity
    - Market value debt
    - Cost of equity
    - Cost of debt
    - Corporate tax rate
    - Risk adjustment
- Disposal costs
- Inflation rate
- Lifetime products
- Financing costs
- Tax credits
- Subsidies
- Replacement costs
- Deconstruction costs
- Waste processing

7.5 Contents

In the last step of the framework, the contents of the model are determined. Model content consists of two elements. The scope is the boundary of the model in terms of its breadth. The level of detail is the boundary of the model in terms of the depth of detail modelled for each component within the scope. Throughout the process of developing the conceptual model, various assumptions and simplifications are made (Robinson, 2008). These should be explicitly recorded alongside the detail of the conceptual model. Assumptions and simplifications are quite distinct concepts (Robinson, 2013):

- Assumptions are made when there are uncertainties or beliefs about the real world being modelled.
- Simplifications are incorporated in the model to enable more rapid model development and use, and to improve transparency.

Determination of the scope and level of detail of the calculation model resulting from this report is different than the way the scope and level of detail are determined for a regular simulation model. In regular simulation models, they are determined by including or excluding certain attributes and inputs (for example, for a car manufacturer the arrival pattern of engines can be included or excluded; by excluding, it is assumed that an engine block is always available). This is different for the calculation model, because it is relatively simple to incorporate all facets for calculations. The difficulty is determining accurate values for all input variables. The assumptions made in determining the accurate values and adopting certain techniques eventually defines the scope and level of detail of the model. The contents of the conceptual model are, therefore, determined by its objectives (Section 7.1). The assumptions and simplifications are presented in the text box below. The list of assumptions and simplifications also depends on the development of the calculation model and decisions made in that process. Therefore, the list has to be extended during the development of the calculation model and determination of input variables' values (and assumptions and simplifications made in determining the values).

Assumptions

- Assumptions made with the NPV:
  - Reinvestment at the cost of capital (or risk-adjusted discount rate).
  - Projects are mutually exclusive.
  - Independent projects have independent cash flows.
- Assumption made with the IRR: Reinvestment at IRR instead of the cost of capital (or risk-adjusted discount rate).
- Assumptions made with the WACC:
  - The risk-free rate of return is the yield of a German bond with the same maturity as the project's life span.
  - The correct value for the beta is derived from companies publicly traded and operating in the same sector as Dura Vermeer (pure-play method). This method also assumes that those companies have more or less similar scales as Dura Vermeer.
- Adjusting the discount rate with the WACC as starting point assumes set adjustments (percentage points) for various categories of project types.
- Yearly cash flows are earned at the end of the year, with the first payment arriving exactly one year after the initial investment.
- Assumptions made in Monte Carlo simulation:
  - Considered risk is in isolation of other projects (in reality, risks are often correlated among various projects).
  - Probability distributions of the values of input variables are all triangular.

Simplifications

- Simplifications in NPV calculations:
  - Uses a set discount rate for the entire life span of the project (in reality, the discount rate is subject to change).
  - Uses the same discount rate for cash inflows and cash outflows. This simplification can be adjusted in later versions of an eventual calculation model.
- Adjustments with the WACC as starting point to arrive at a risk-adjusted discount rate are all fixed and determined per category of project type (already mentioned as an assumption, but also accounts as a simplification).
- For sensitivity analysis, ten key drivers are selected at most (although more factors have an impact on the final results of the model).
- For scenario analysis, only three scenarios are considered for quantifying uncertainty.
- In Monte Carlo simulation: At least for the proof of concept and subsequent simpler versions of the calculation model, correlation between input variables is excluded from the simulation.

7.6 Visualisations

The last section visualizes the textual representation of the conceptual model. Figure 7.1 displays the conceptual model and shows the process of modelling financial feasibility. The texts in the rectangles refer to particular sections in this report to find detailed information. Figure 7.2 (after Section 7.7) complements the conceptual model by presenting the roadmap of consequent activities to transit from the conceptual model towards a calculation model. Similar to Figure 7.1, each rectangle refers to a specific section for a detailed description of that activity. Together, both figures also summarize and conclude of Chapter 7.

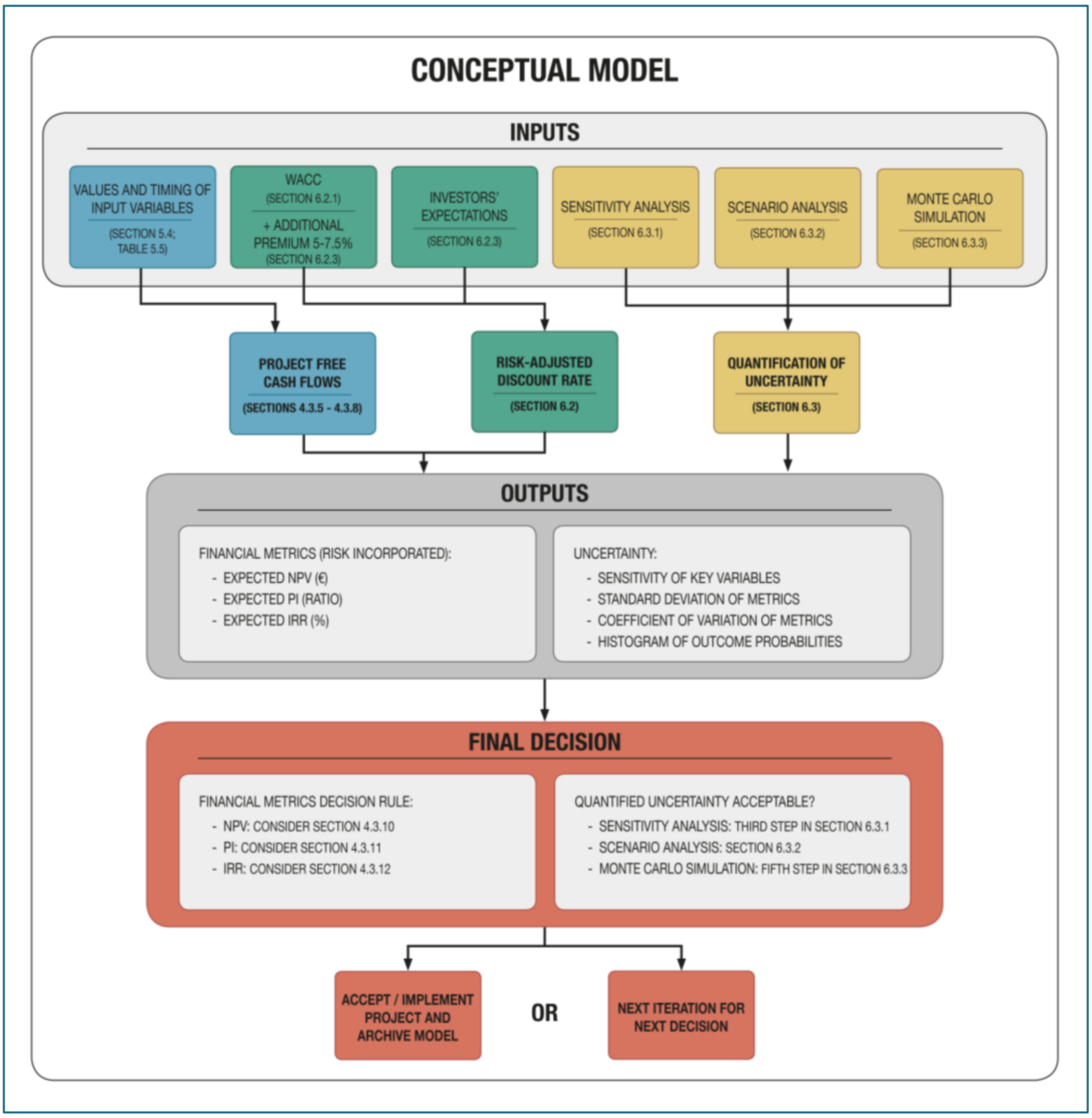

Figure 7.1 - Conceptual model of financial feasibility the of PaaS proposition

7.7 Conclusion

This chapter elaborated on the fourth research question of this research. The goal of the fourth research question was to combine the answers of the previous research questions and develop a conceptual model to assess the financial feasibility of future PaaS propositions. The development of the conceptual model was also the main goal of the research. The five steps of Robinson (2013) provides the textual representation of the model. The organizational aim, modelling objectives and general project objectives led to the understanding of the model's problem situation. The description of outputs, (experimental) factors, assumptions and simplifications complemented the textual representation of the conceptual model. The textual representation is visualized in Figure 7.1. The conceptual model links all contents to assess financial feasibility to each other. The conceptual model is accompanied with a roadmap. The roadmap enables and assists in the practical transition from the conceptual model towards a calculation model. In total, it entails 19 iterative steps with some extensions and references to sections in this report where extensive information is found for that step. The roadmap is displayed in Figure 7.2.

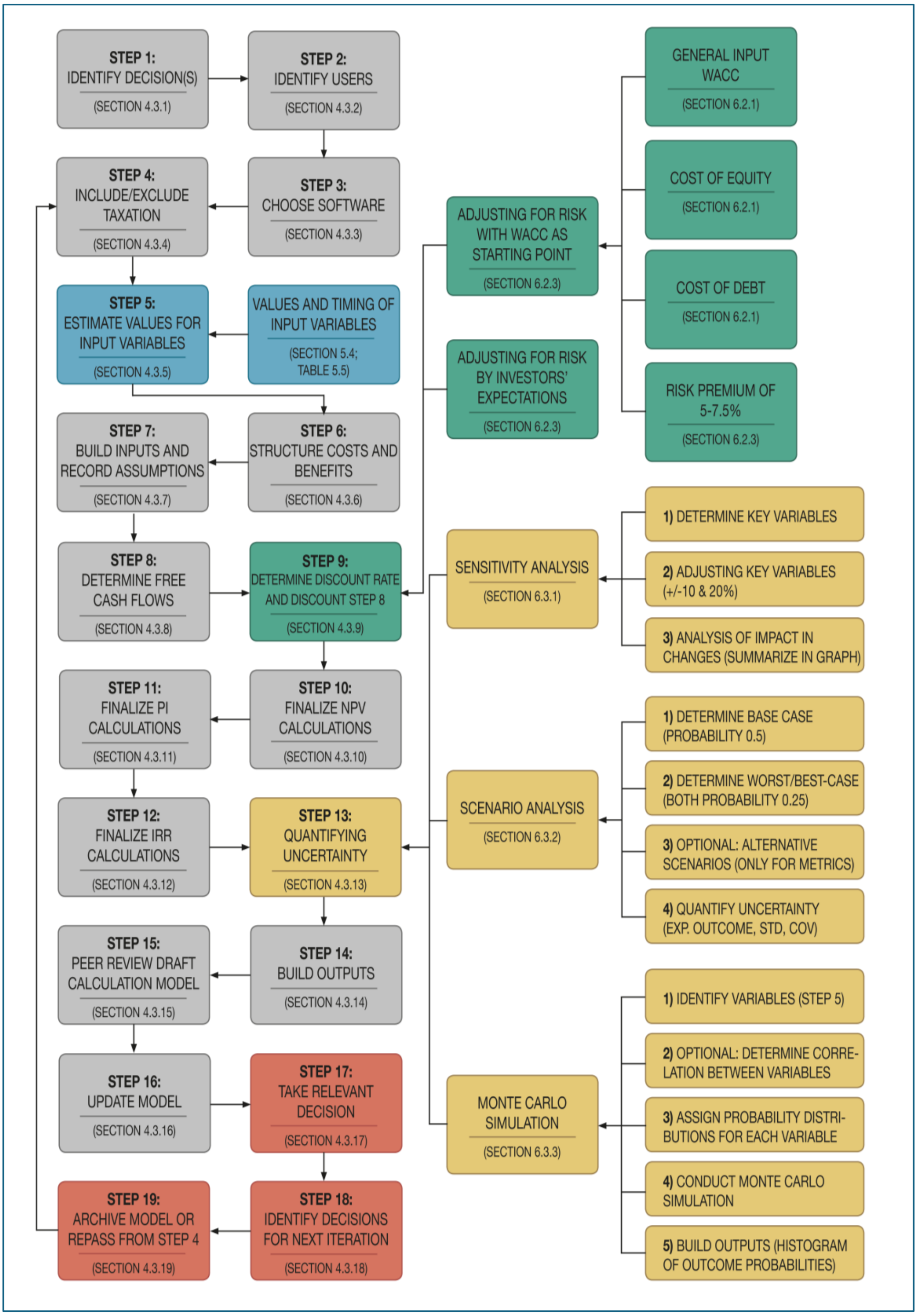

Figure 7.2 - Addition to conceptual model: roadmap to model financial feasibility. The roadmap enables the transition from the conceptual model to a calculation model (e.g. the proof of concept in the next chapter).

8

RESEARCH QUESTION 9: PROOF OF CONCEPT

The eight chapter answers the fifth and last research question of this report. The last research question validates the conceptual model: "Does a proof of concept confirm the usefulness of the conceptual model?" This research question is answered by walking through the roadmap presented along with the conceptual model. The project used for the proof of concept is the renovation project in Winschoterdiep (Groningen). The project entails a renovation of an old, five stories high warehouse built in 1916, which was later on transformed into student housing. In total, 39 apartments are included in the building. Housing corporation Lefier is the owner of the building and is letting the apartments to students. Dura Vermeer is renovating the building. An important part of the renovation project is increasing the sustainability of the building. The project is already in an advanced stadium of the preparation of the project. Therefore, this project is suitable for the proof of concept of this research, since input variables and parameters are for a large part already determined (not all variables/parameters, as a more traditional business model is applied in this project). It is, thus, less time-consuming to use this project than renovation projects situated in earlier stages.

The upcoming sections in this chapter each elaborate on one step of the roadmap. Walking through these steps develops a calculation model for the proof of concept in which the financial feasibility is being assessed of the example project. This validates the conceptual model. Furthermore, each step also elaborates on the useful insights one might get from the calculation model. A manual for the Excel model itself is presented in Appendix II or in the Excel file.

8.1 Step 1: Identify the decision(s) to be supported by the model

The first step of the model focuses on the purpose of the calculation model to be developed. This also affects the amount of detail that has to be included in the model. The proof of concept delivers the first version of the calculation model. Therefore, it is the most important iteration in transforming the conceptual model towards a calculation model. In the textbox below, the decision that specifically the proof of concept has to support is defined.

Decision to be supported by proof of concept

The proof of concept has to validate the conceptual model presented in the previous chapter. It should indicate whether the steps presented in Figure 7.2 are sufficient to transit from the conceptual model towards a calculation model.

8.2 Step 2: Identify the users of the model

In the second step, the users of the model are identified. The textbox below elaborates on the eventual user of the calculation model.

User(s) of the model

In the case of the proof of concept, the sole user of the calculation model is Dura Vermeer, as this version of the model is only used to validate the results of this research. Thus, financial feasibility is assessed from the provider's side of the PaaS model.

8.3 Step 3: Decide what software will be used for the model

Step 3 elaborates on the software to be used for the calculation model. Various programmes are available for capital budgeting. For the proof of concept, Excel will be used as software programme. The list below substantiates the use of Excel:

- The researcher of this report is acquainted with the software;
- Excel is accessible software for Dura Vermeer and most of its employees are relatively acquainted with it;
- Various sources used for this research described the way capital budgeting can be modelled in practice in Excel;
- Excel offers extensive functions and possibilities for capital budgeting;
- Excel is 'easy to read': it is relatively easy to walk through the model if certain results are incomprehensible;
- Various extensions for Excel are freely accessible to assist in advanced activities, such as sensitivity analysis and Monte Carlo simulation.

8.4 Step 4: Determine whether taxation should be included or excluded

Internal experts indicated that it would be easiest to include taxes in the proof of concept, as these were already accounted for in budget plans made for the project (at least for this particular project). Therefore, taxation is included in the model.

8.5 Step 5: Determine estimations for all variables and factors relevant to the model

The fifth step identifies input variables and parameters for the calculation model. Input to the model is divided into two categories: project-specific input and estimates from the financial department to determine Dura Vermeer's WACC. Only limited time was available for the proof of concept. Therefore, only two sources of information were accessed to gather input data: internal experts' estimates and financial data available at the financial department of Dura Vermeer. In total three internal experts were consulted to estimate values for the input variables and parameters. Table A.1 in Appendix I shows all established values for financial inputs to determine Dura Vermeer's WACC. Table A.2 in Appendix I displays all estimates for the project-specific variables/parameters. Table A.2 is combined with the sixth step for clarity. The categories of input variables/parameters are based on the categories determined in Table 5.5 in Chapter 5. Sources used for cost estimations not provided by internal experts or the financial department are provided in the remarks.

One additional remark has to be made for the end-of-life costs of the proposition. Internal experts indicated that they would not incorporate end-of-life costs of products in the proposition. Therefore, the client pays the yearly fee needed to redeem the proposition of Dura Vermeer. The potential value of products at the end of the offering's life span, thus, benefits the client, as the ownership of the products is transferred from Dura Vermeer to the client at that moment.

8.6 Step 6: Structure the relevant costs and benefits

In this step, all future cash flows (based on the previous step) are arranged corresponding to each year of receipt. The third column ('Year') in Table A.2 (Appendix I) displays the year of receipt of every category. The initial year of this project is 2022 (for simplicity). Yearly costs arrive from year one onwards (in other words, 2023). The special considerations in Section 4.3.6 are all taken into account in the design of the calculation model (i.e. inclusion of the cumulative NPV and IRR calculation with trial-and-error and build-in function).

8.7 Step 7: Build inputs and record associated assumptions

With all inputs determined in the previous two steps, it is possible to build the inputs of the calculation model in Excel. The assumptions made for these inputs are all documented in Tables A.1 and A.2 in Appendix I. Also, the recommendations described in Section 4.3.7 are taken into account (e.g. colour coding and inserting input only once), resulting in the input spreadsheet as displayed in Figure 8.1. The elaborate description of the way these recommendations are incorporated in the model is described in the manual provided in Appendix II and the Excel file. The inputs are built in a way that is easy for future users of the model to insert inputs into the model.

	Live case					
	Input variable	**Specification**	**Details**	**Costs**	**Year(s) (separate with comma or "Yearly")**	**Jaren ingevoerd**
Entire life cycle	*Tax credits*			€ -		0
				€ -		0
		Total		€ -		
	Subsidies (per unit)			€ -		0
				€ -		0
		Total		€ -		
	Marketing costs			€ -		0
				€ -		0
		Total		€ -		
	Information system			€ -		0
				€ -		0
		Total		€ -		
	Input variable	**Specification**	**Details**	**Quantification**	**Year (if multiple, separate with comma)**	**Jaren ingevoerd**
Design phase	*Deposition fee (per unit)*	Fee		€ 2,000.00	2022	1
		Payback		€ -2,000.00	2037	1
		Total		€ -		
	Development costs	Deel 1	Voorbereidingskosten	€ 45,436.28		
		Deel 2	Voorbereidingskosten	€ 30,547.00		
				€ -		
		Total		€ -75,983.28	2022	1

Figure 8.1 - Overview of input worksheet in the Excel model (all cost and benefit categories)

8.8 Step 8: Determine free cash flows

In this step, the free cash flows per period are calculated. Figure 8.2 shows the summation of all values per period to arrive at the net cash flows. Figure 8.2 is the main part of the discounted cash flow model. It provides a clear representation of all cash flows included in the entire lifespan of the project.

Discounted cash flow model		
Lifetime	15	15
Discount rate	12.40%	
Functional unit	39	
Startup year	2022	
Scenario	Scenario 1 - Base Case	

	Indv. Value	Total project	2022 0	2023 1	2024 2	2025 3	2026 4	2027 5	2028 6	2029 7	2030 8
Entire life cycle											
Tax credits	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Subsidies	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Marketing cost	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Information system	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Design phase											
Deposition fee	€ 2,000.00	€ -	€ 78,000.00	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Development cost	€ -75,983.28	€ -75,983.28	€ -75,983.28	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Production phase											
Material costs	€ -22,035.02	€ -859,365.86	€ -859,365.86	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Manufacturing costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Installation costs	€ -7,816.74	€ -304,853.00	€ -304,853.00	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Use phase											
Yearly fee	€ 73,500.00	€ 2,866,500.00	€ -	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00
O&M costs	€ -3,539.04	€ -138,022.50	€ -	€ -9,001.50	€ -9,001.50	€ -9,501.50	€ -9,001.50	€ -9,001.50	€ -9,501.50	€ -9,001.50	€ -9,001.50
Replacement costs	€ -1,820.51	€ -71,000.00	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Refurbishment costs	€ -844.77	€ -32,946.00	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
End-Of-Life phase											
Harvest value	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Deconstruction costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Waste processing	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Disposal costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Net cash flows			€ -1,162,202.14	€ 182,098.50	€ 182,098.50	€ 181,598.50	€ 182,098.50	€ 182,098.50	€ 181,598.50	€ 182,098.50	€ 182,098.50
Discount factor			1	0.88968	0.79153	0.70420	0.62652	0.55740	0.49590	0.44120	0.39252
PV cash flows			**-€ 1,162,202.14**	**€ 162,009.09**	**€ 144,135.98**	**€ 127,882.56**	**€ 114,087.61**	**€ 101,501.27**	**€ 90,055.53**	**€ 80,341.06**	**€ 71,477.70**

Figure 8.2 - Worksheet of the discounted cash flow model and summation of values to arrive at the free cash flows

8.9 Step 9: Discount the free cash flows with the appropriate discount rate

With the WACC (7.4%) and the risk-adjusted discount rate (12.4%) already determined in previous steps, this step is quickly completed. The free cash flows are assumed to be earned end-of-year. The cash flows are then discounted by multiplying the free cash flows with the discount factor of that year. The formula for the discount factor is given in Equation 14.

$$Discount\ factor\ year\ t = \frac{1}{(1 + risk\ adjusted\ discount\ rate)^t} \quad (14)$$

8.10 Step 10: Finalize NPV calculations and consider the decision rule

This step finalizes the calculations of the NPV. After previous steps, the NPV is computed by summing all discounted cash flows. Excel also has a built-in function to determine the NPV. This function is also included to double-check the correctness of the NPV arrived at manually. Both values corresponded, which validates the correctness of the calculation. Table 8.1 displays the results of calculating the financial metrics (including the NPV).

Table 8.1 - Results of the model

Financial metric	Result
NPV	€32,387.36
IRR	12.94%
PI	1.028

The decision rule (Section 4.3.10) is considered to interpret the results of the calculations. Theoretically any project can be accepted with an NPV larger than zero. The project can, therefore, be accepted if the client of this project is willing to pay the yearly fee, as the NPV is €32,387.36. This means that the expected value of future cash flows is €34,387.36 more worth than the initial investment of €1,162,202. Note that the NPV already takes the time-value of money and risks into account. However, it is still important to consider the uncertainty under which the decision is made. Therefore, the analyses in the 13th step have to be considered as well.

8.11 Step 11: Finalize PI calculations and consider the decision rule

Step 11 finalizes the calculations of the PI. Calculations for the PI use for a large part the same concepts as the NPV. Table 8.1 shows that this calculation leads to a value of 1.028. This means that every euro invested in the project generates €0.028 in additional value. Projects with a PI bigger than one should be accepted. In theory, the proposed project can, therefore, be accepted. This is in line with the decision rule in Section 4.3.11 and the decision made in step 10 (the PI produces the same decision as step 10, as long as it is not necessary to choose among projects). However, before making a decision, it is important to consider involved uncertainty.

8.12 Step 12: Finalize IRR calculations and consider the decision rule

The last financial metric to be considered is the IRR. Step 12 calculates the IRR and considers the corresponding decision rule. Similar to the NPV calculations, the IRR is calculated in two different ways: manually and with the built-in function of Excel (as a double check). For the project of Winschoterdiep, an IRR of 12.937% sets the NPV to approximately zero. That is equal to earning a 12.937% compound annual growth rate. The built-in function of Excel computed the same value and thus verified the manually derived number. Technically, the value determined with trial-and-error could be removed from the model. However, it was decided to maintain the trial-and-error function as verification in case the model is adjusted in later versions.

The decision rule for the IRR in Section 4.3.12 can now be considered. A company should invest in a project if it provides a return greater than the cost of capital, or in this case the risk-adjusted discount rate. The IRR (12.937%) is higher than the established risk-adjusted discount rate of 12.40%. This means that the returns from the investment are high enough to justify the risk of the investment in theory. Again, the decision should also take uncertainty into account.

8.13 Step 13: Quantifying uncertainty

The 13th step focuses on the quantification and analysis of uncertainty. The model is only as good as the assumptions made in determining the input; garbage in is garbage out. An analysis of uncertainty helps in determining what parts of the model need further attention. As described in Section 6.3, this report suggests conducting a sensitivity analysis, scenario analysis and Monte Carlo simulation. The following (sub) sections describe the application of these techniques in the Excel model and what is concluded from the quantified uncertainty. Detailed output is also presented in Appendix IV.

8.13.1 Sensitivity analysis

Sensitivity analysis is the first method to quantify uncertainty. The first step in the sensitivity analysis is the selection of key variables. Literature already mentioned that at least the WACC and the lifetime/lifespan of the project have to be considered in a sensitivity analysis, since these factors potentially have a significant impact on financial feasibility. In addition to these two factors, it was decided in consultation with internal experts to include all categories of costs and benefits in the analysis. Instead of assessing individual costs/benefits, the sensitivity of entire categories was assessed (e.g. material costs in total instead of just the cost of the heating pump). The magnitude of the yearly fee was the main reason to incorporate entire categories. It would be meaningless to include individual costs and benefits, as their impacts on the outputs of the model are insignificant compared to the impact of the yearly fee.

The second step adjusts the identified variables and parameters with predetermined percentage points above and below their original value to assess their effect on the results. Data tables in Excel adjust the original values and calculate new outputs without actually adjusting the original values in the file.

The last step analyses the impact of changes in the variables/parameters. It is useful to visualize this in graphs. In total three graphs are needed; one for each financial metric. The horizontal axis shows the deviation/adjustments above and below the original value. The vertical axis represents the corresponding values of the financial metrics. Figure 8.3 displays the graph for the NPV. The other graphs are presented in Appendix IV. The figures show the usefulness of a sensitivity analysis, as various conclusions can be quickly drawn. The lines intersect at 0%, as this point just represents the base case (without any adjustments). The steeper the line, the more sensitive the results are to that variable. To that extent, the most important variables/parameters to the financial feasibility of the project of Winschoterdiep are the yearly fee, the material costs and the WACC (although the yearly fee positively affects the results if increased, whereas the material costs and the WACC negatively affect results if they are increased). This implies that the WACC and

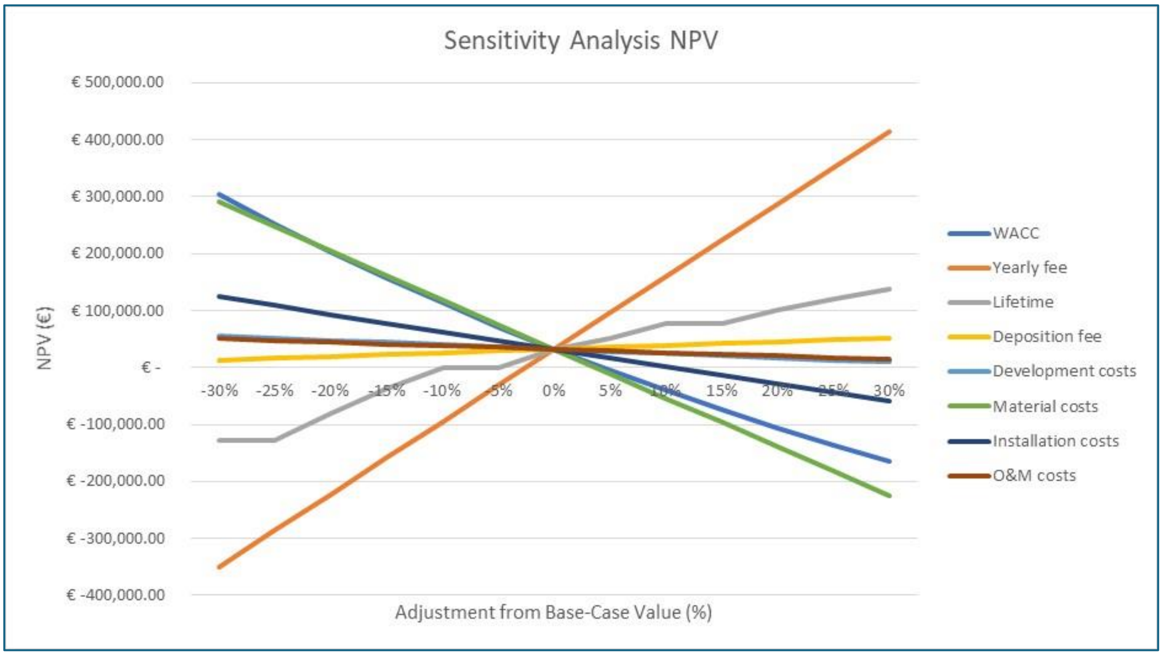

Figure 8.3 - Sensitivity of the NPV to input variables and parameters

material costs have to be determined with the highest accuracy possible to get reliable results about the financial feasibility. It also indicates that material costs might be the first category to consider for cost reductions. Lastly, it implies that attention has to be paid in establishing the yearly fee, as just a €100 increase in yearly fee per unit could absorb significantly more uncertainty and thereby significantly mitigate risks.

8.13.2 Scenario analysis

The second part of quantifying uncertainty is performing a scenario analysis. The roadmap described in Section 6.3.2 conducts the scenario analysis. First of all, the base case is determined. This is already determined in previous steps by establishing the most likely values of each input variable/parameter. As exact probabilities for scenarios are unknown, a probability of 0.5 is used, as suggested in Section 6.3.2.

Next, the worst- and best-case scenarios are determined. Internal experts established worst- and best-case values for all input variables/parameters. Some of these values were already determined in the internal budget plans of the project. For other costs and benefits, the experts indicated that a 3% margin above and below the most likely value would be an appropriate estimation of the worst- and best-case values. The suggested probability of 0.25 is used for both scenarios, since exact probabilities are unknown.

The third step is optional and can be used to identify additional scenarios. In consultation with the experts, it was decided that additional scenarios were not necessary for the proof of concept.

Lastly, equations 11, 12 and 13 quantified the results of the scenario analysis. The results are displayed in Table 8.2. The expected values provide additional weight to the results of the base case. In this case, the expected values are slightly higher than the results calculated for just the base case. This means that the project will rather turn out more positive than negative compared to the base case. At the same time, the standard deviation is relatively high. This should be taken into account, as it shows that the expected values incorporate some uncertainty. The worst- and best-case scenarios are, thus, considerably deviant from the expected value. Lastly, the coefficients of variation are not that relevant for these results. The coefficient of variation is a measure to compare projects to each other, since it accounts for the magnitude of projects. However, it is not possible to derive anything from the sole measure.

Table 8.2 - Result of scenario analysis for every financial metric

Results of scenario analysis	
Expected NPV	€36,010.18
Standard deviation NPV	€71,217.65
Coefficient of variation NPV	1.98
Expected IRR	13.03%
Standard deviation IRR	1.21%
Coefficient of variation IRR	0.09
Expected PI	1.04
Standard deviation PI	0.06
Coefficient of variation PI	0.06

8.13.3 Monte Carlo simulation

The last method for the quantification of uncertainty is a Monte Carlo simulation. The roadmap presented in Section 6.3.3 guides the Monte Carlo simulation. In general, the first step identifies all input variables and parameters affecting the cash flows. This is already completed in previous steps (mainly in the fifth step).

Secondly, optionally correlation between variables are included in the Monte Carlo simulation. This step is not explicitly necessary, although it increases the level of detail of the simulation. It is opted to exclude correlations from the proof of concept, as it is too time-consuming and historical data is lacking.

In the third step, the probability distributions for the input variable are determined. The exact distributions of variables are unknown. Therefore, a triangular distribution is used (Section 6.3.3). In consultation with the internal experts it was decided to use 3% above and below the most likely values for the distributions of each variable. Hereby, it was possible to save some time and quickly arrive at relatively accurate results.

In the fourth step, the Monte Carlo simulation is conducted based on the inserted input data. Excel can perform a Monte Carlo simulation by inserting a data table for each financial metric. In total, the simulation used 5,000 trials to arrive at the output data of the Monte Carlo simulation.

The last step in a Monte Carlo simulation is the analysis and discussion of outcomes. Unfortunately, for this proof of concept, time was too limited to internally discuss the outcomes with various experts. A brief analysis of the results and most striking results are, therefore, discussed by the researcher. In Figure 8.3 (further results are presented in Appendix IV), two graphs of the outputs of the Monte Carlo simulation are presented (the PI is cut from the figure for clarity; outputs are also presented and displayed in step 14 in the next section). The results are mostly in line with the results of the scenario analysis. However, the range of values is quite large: for example, the range of the NPV was €388,462.75 (with a minimum value of minus €185,036.40 and a maximum value of €203,426.35). This wide range of values presumably results from the number of variables that can vary in the Monte Carlo simulation. Furthermore, the figures show that the vast majority of outcomes are above the hurdle rate (above zero for the NPV and above the discount rate for the IRR). This shows that, most likely, the project is financially feasible. However, the graphs are skewed to the right. Therefore, the accent of possible results are in the positive area, but it also means that the downside risk is greater than the upside potential. The downside risk is considerable, since the negative side has relatively large extremes. Often downside risk is specifically considered in portfolio performance, since upward extremes are not actually a risk for an investor (in this case Dura Vermeer or external financier). Downside risk is, however, important to consider, as it depicts the probability of losses. The Sortino rate is a way to consider the standard deviation of the downside risk, rather than that of the entire risk.

As mentioned, the graphs of both metrics are skewed to the right (the IRR is even more skewed). The researcher expects that this results from the specific outline of cash flows for this model (with large undiscounted costs during the start-up and only one category of benefits every year, which is being discounted) together with the risk-adjusted discount rate (which partly cancels the skewness of the NPV). Argumentation for these beliefs is more extensively provided in Appendix V.

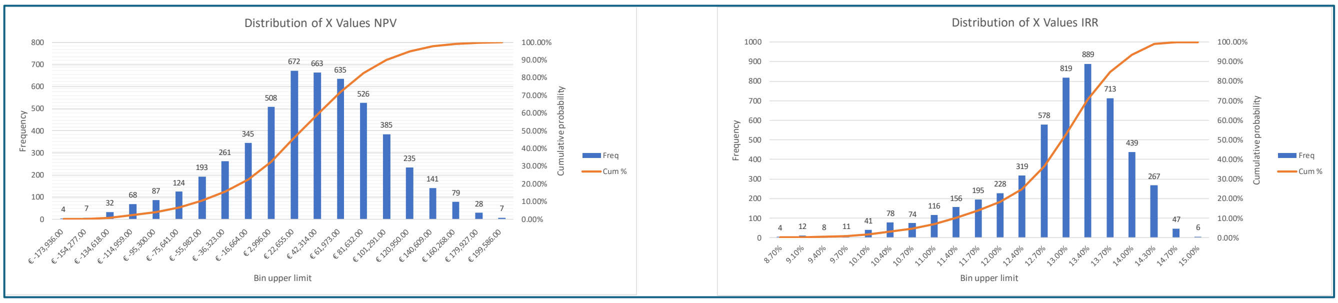

Figure 8.3 - Resulting graphs of the Monte Carlo simulation. The left graph shows the distribution of NPV values, the right graph the distribution of IRR values. The line in both graphs represents the cumulative distribution.

8.14 Step 14: Building outputs: summaries, charts and reports

This step focuses on a clear presentation of the outputs. The goal of building clear outputs is to enable management and decision-makers to quickly create a view on the results of the financial feasibility of a considered project (in this case Winschoterdiep). Figure 8.4 displays a screenshot of the summary of outputs in the Excel model. Detailed results are presented in Appendix IV. A brief report has to be written by the modeller in addition to the overview of results, in which the concepts of the graphs are explained (what the reader/viewer can learn from the results/graphs) and any striking outputs are described. Such a report is not written for the proof of concept, as description and interpretation of results are already presented in corresponding steps. Therefore, this step does not provide a detailed interpretation of the results, but only shows the usefulness of a summary of outputs in the calculation model. Figure 8.4 shows the overview of results that management can use for interpretation.

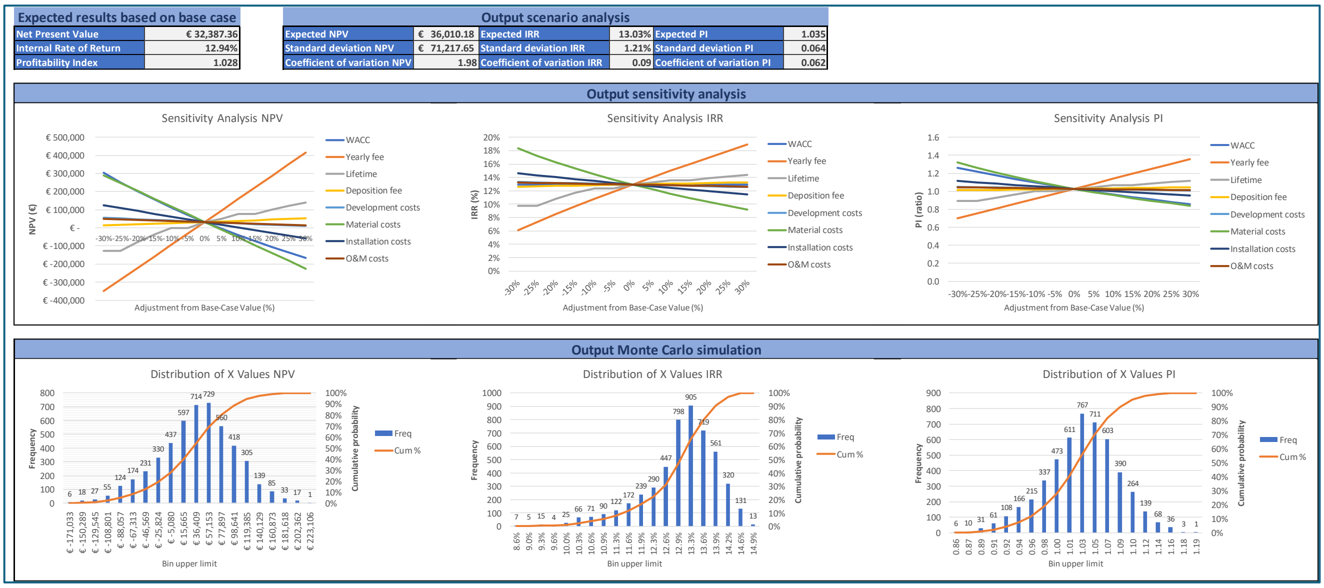

Figure 8.4 - Summary of outputs for the financial feasibility of Winschoterdiep

8.15 Step 15: Peer review of the draft model

The previous step completed the development of a first version of a calculation model to assess financial feasibility. The last steps on finalize the model. For the proof of concept, a peer review and validation of the model is performed by the modeller, two external experts (both have expertise with modelling in Excel) and indirectly the supervisors of this thesis (as they provide feedback on the results/report). The external experts mainly focused on the model itself. They did not encounter mistakes or irregularities in the model. In the paragraph below, some additional remarks are made by the modeller.

The summary of outputs enables quick validation of the model, as any mistakes or errors in the model will presumably result in weird results that do not stroke with the looks of the output. First of all, the means of financial metrics determined with the base case, scenario analysis and Monte Carlo simulation are relatively similar to each other, which confirms correctness of the model. Only minor differences are shown in the outputs of the mean, presumably resulting from (1) unsymmetric worst- and best-case scenario compared to the base-case in the scenario analysis (therefore differs from the expected results based on the base case) and (2) inclusion of the risk-adjusted discount rate and lifespan of the project as variables in the Monte Carlo simulation (both constant in the scenario analysis).

The sensitivity analysis does not show any outputs indicating an error in the model as well. All financial metrics are most sensitive to changes in the yearly fee and material costs. This output was expected, since the yearly fee is the only significant category of benefits in the model (the deposition fee is only minor compared to the magnitude of cost categories) and the material costs are the largest category of costs. The graphs of the NPV and PI show that the WACC also has a relatively high impact on the outputs of the model, which was expected upfront as this variable has a significant impact on the only benefits included in the model (as also explained in step 13). The WACC is a horizontal line in the graph of the IRR, which is also correct as the IRR does not depend on the WACC. Keep in mind that calculations for the IRR are in itself independent from the WACC. However, this does not account for the decision rule, as a higher IRR is needed if the WACC increases.

Lastly, it stood out that the graphs of the Monte Carlo simulation were all skewed to the right, although the IRR was more extremely skewed than other metrics. Section 8.13.3 and Appendix V elaborate on the underlying arguments for this occurrence. To that extent, the summary of outputs does not indicate any major flaws in the model and therefore validates the model.

For the proof of concept, the peer review entailed a review of both the model itself and the input. In the future, it is not necessarily needed to review the model itself. A peer review of the model itself is only needed if the model is significantly changed or supplemented. In any other case, the peer review should mainly focus on the input for the model.

8.16 Step 16: Update the model in response to peer review

The previous step did not point to any major flaws or inaccuracies in the model. Therefore, it is not necessary for this version of the model (for the proof of concept) to update the model. For later versions of the model, this step involves a more time-consuming process based on the peer review in the fifteenth step.

8.17 Step 17: Take relevant decision(s) and review other insights identified by modelling

The proof of concept had to validate the conceptual model presented in Chapter 7. Step 15 already indicated that the proof of concept was sufficient to validate the conceptual model. In other words, the steps included in the roadmap of the conceptual model are extensive enough to deliver a sufficient calculation model. A further decision to be made is whether the calculation model developed for this proof of concept is sufficiently extensive to use as an outline for follow-up versions (for example to assess whether a proposed PaaS model can proceed from the concept phase onward). The version developed for the proof of concept is sufficiently extensive (it enabled decision-making for an example project), although improvements are conceivable to improve the ease of use (see Section 9.4).

8.18 Step 18: Identify decisions to be supported by the next iteration of modelling

The proof of concept was developed for the validation of the conceptual model. As the conceptual model was validated, it can be used along with the roadmap to assess the financial feasibility of projects that are actually under consideration (e.g. in the concept or implementation phase). The decision supported by the next iteration is described in the text box below.

Decision to be supported by the next iteration

In the next iteration of the model, an actual project might be considered for implementation. The first step will be the concept phase, to get a quick overview of the considered project's is financial feasibility. The decision to be supported in the next iteration is, therefore, whether a considered project can move on to the implementation phase, in which the financial feasibility of the project is considered with an even higher level of detail.

8.19 Step 19: Repass the process from point 4 or archive the model as appropriate

The previous step identified the decision that is to be supported by the next iteration of modelling. This means that the presented roadmap has to be repeated from step 4 onwards. Currently, however, no project is actually under consideration in which sustainability measures will be offered as a service. Therefore, the model developed in this proof of concept has to be temporarily archived along with this report, so it is easily accessed when future projects are being considered. Step 19 is the last step of the roadmap and, therefore, the last step of the proof of concept.

8.20 Conclusion

This chapter presented a proof of concept to validate the conceptual model developed in Chapter 7. The renovation project in Winschoterdiep was selected as example to assess the financial feasibility. Following, the nineteen-step roadmap was walked through to show the usefulness of the conceptual model. The proof of concept was a success and provided useful business insights as explained gradually throughout the chapter. Useful (business) insights of the proof of concept were:

- The means of financial metrics determined with the base case, scenario analysis and Monte Carlo simulation are relatively similar to each other; around:
    - NPV = €30,000 (which means that the expected future cash flows are €30,000 more worth than the initial investment);
    - IRR = 13% (which is higher than the risk-adjusted discount rate and therefore justifies the risk of the investment);
    - PI = 1,033 (which means that every euro invested in the project generates €0,033 in additional value).
- The risk-adjusted discount rate is 12,40% (including a risk premium of 5%, as advised by literature, since the PaaS proposition is a combination of an expansion of existing business and a new product);
- The yearly fee, material costs and WACC are the most important factors (the model is the most sensitive for these variables/parameters) and should, therefore, be determined with high accuracy;
- Resulting graphs of the Monte Carlo simulation are skewed to the right, meaning that the downside risk is greater than the upside potential.

Dura Vermeer is currently unfamiliar with the PaaS model. The financial calculation model developed in this chapter as proof of concept provided clear insights to Dura Vermeer. The calculation model provided the opportunity to look at the financial feasibility in one glance, along with the uncertainties incorporated in the financial feasibility. In addition, the sensitivity analysis, various scenarios in the scenario analysis and the Monte Carlo simulation clearly represent the directing elements of the model and show how important it is to take a good look at those elements.

9

RECOMMENDATIONS AND LIMITATIONS

The previous chapter answered the last research question. Before concluding the research in the next chapter, this chapter appoints some recommendations and limitations that have to be taken into account. Each section below depicts the recommendations and limitations of one individual chapter of the research. The seventh chapter, in which the conceptual model was developed, did not bring forward any recommendations or limitations. Therefore, no section is dedicated to this chapter.

9.1 Chapter 4: Modelling financial metrics

This first section presents recommendations and limitations of the fourth chapter, in which appropriate financial metrics were chosen and a roadmap was presented for the modelling of financial metrics. By relying on the NPV and the IRR in the model to assess financial feasibility, the model automatically incorporates some serious limitations caused by the assumptions made by adopting those techniques. The following limitations have to be considered with the NPV (and the PI, as it is a variation of the NPV):

1. As regards the modelling of the NPV, projects are assumed to be mutually exclusive, but this is seldom the case in modern day's giant organizations, where projects are often interrelated and rejecting a project solely based on NPV can result in sunk cost from a related project.
2. A further assumption is that independent projects have independent cash flows, but although the project may look independent, in reality it is not: for example, the brand awareness of a project can be closely associated with the spending on sales promotions and product-specific advertising (Collis, 2018).
3. Modelling of the NPV aggregates several estimates into one catchy figure. While this increases understandability and keeps things comparable and manageable, the information on the duration of the repayment of initial investment is lost.
4. A limitation is that modelling the NPV usually assumes that cash flows occur at the end of a period, whereas in reality they will probably occur unevenly throughout the year (or month in a model with a higher level of detail), with a large portion of costs spent closer to the beginning of a period.

Incorporation of the IRR in a model for assessing financial feasibility automatically introduces limitations to the model as well:

1. An important assumption that is automatically made by calculating the IRR is that all positive cash flows of a project will be reinvested at the same rate as the IRR, instead of the company's cost of capital. Therefore, the IRR may not accurately reflect the profitability and costs of a project.
2. Although the IRR is expressed as a percentage that normalizes returns and is easy to understand, it does not necessarily rank projects in the correct order considering the added wealth a project offers. Therefore, it is usually better to pick the project with the highest NPV and not necessarily the highest IRR, as financial performance is measured in valuta (Jassy, 2021).

Chapter 4 also presented a roadmap for the modelling of financial metrics. The adoption of that roadmap also entails some limitations. First of all, no model is ever a perfect representation of reality, and the presented roadmap will not deliver a model that is an exception to that point. To that extent, the following points are worth remembering:

- Since capital budgeting models are reliant on estimates, perfect accuracy is an unrealistic expectation;
- Any financial model is developed in the context of a framework of simplifying assumptions. As more detail is added, the implications of the associated assumptions and constraints may go unrecognised;

- The discount rate underpinning any capital budgeting model is itself often derived from a separate model and is thus a model within a model.

Thus, while the model and approach for the model are financially sound from a theory point of view, the calculations are only as good as the data driving it. It is therefore recommended to use the projections and assumptions with the maximum possible accuracy, for items of the investment amount, acquisition and disposition costs, all tax implications, the actual scope and timing of cash flows (Seth, 2021).

9.2 Chapter 5: Variables influencing financial feasibility

In this section, recommendations and limitations brought forward by Chapter 5 are depicted. Chapter 5 answered the second research question and identified variables and parameters influencing the financial feasibility of a PaaS proposition. First of all, the services added to a PaaS offering affect the revenue streams and cost structure in general. In addition, the added services also affect the general performance of the PaaS proposition, as merely adding simple services to a current product offering is shown to be negatively associated with financial performance (Parida, Sjödin, Wincent, & Kohtamäki, 2014). For use-oriented models, several services offered in the contract packages could be built according to the customers' demands and financial abilities: maintenance type (preventive, intelligent), tools/consumables management, consultancy and advice on the most efficient machine utilisation mode, machining process optimisation (Azarenko, Roy, Shehab, & Tiwari, 2009). As merely adding simple services negatively affects the performance of a proposition, it is recommended to pay attention to the services added to the proposition.

Secondly, various sources for the estimation of variables and parameters were considered. Currently, Dura Vermeer will presumably mainly use internal experts, external experts and data from the financial department for the estimation of variables and parameters. In future years, an additional source might become available, which could improve the accuracy of the estimations: measurements (Van Ostaeyen, 2014). Chances are that the PaaS model has to be supported with an information system. This system might also provide techniques to keep track of measurements, which can be used to further develop offered products or finetune services offered in the model. This accounts for measurements on exact initial investment costs, but, for example, also the failure rate or replacement time that certain parts/elements have on average to get a more precise estimation for maintenance.

9.3 Chapter 6: Incorporating risk and uncertainty

The incorporation of risk and uncertainty in the conceptual model also entails some recommendations and limitations. This section elaborates on those recommendations and limitations.

First of all, it is recommended to think about the discount rate for cash outflows if the level of detail of the model is increased. The more uncertain an outflow, the lower the appropriate discount rate. At first, this seems counter-intuitive. It is a point often overlooked. The more uncertain the magnitude and/or timing of cash outflows, the more difficult it is to justify a project. One should reflect uncertainty about the actual dollars required to undertake a project in the analysis. The riskier the outflows, the greater they should be weighted negatively in the NPV (Anderson, Byers, & Groth, 2000). However, in a PaaS proposition the revenues all come in later years, whereas the accent of cash outflows is in the first years (and less discounted). Therefore, this method could also feel like double punishment for risky cash flows. This trade-off might be considered if the level of detail is being increased.

Secondly, if cash flows have different risk levels within a period or across periods, different discount rates for different cash flows can be used. An implicit relationship exists if one uses a single hurdle or discount rate across time. The use of the same discount rate in different future periods assumes an increased risk of cash flows in successive periods. This follows since discounting is non-linear. The higher the rate and/or the longer the time, the greater the non-linearity (Anderson, Byers, & Groth, 2000). This is a limitation when it is not necessarily the case that risk increases non-linear across time.

9.4 Chapter 8: Proof of concept

The last recommendations and limitations are for the proof of concept in the eighth chapter. First of all, some general recommendations are appointed. For the proof of concept, a single project was used. In the later stages of the new business model, it is also possible to opt for categories of housing instead of a single project. This way, the functional unit is not determined for one project, but for an entire category of types of housing for which Dura Vermeer can offer sustainability measures as a service. Furthermore, it is also useful to test a second project in a proof of concept for further validation. For example, a project with a different outline of revenues and costs or a project that is not yet in its preparatory phase to get a view on the accuracy of cost estimations.

Secondly, a recommendation is put forward that specifically improves the seventh step in the proof of concept. Currently, it is necessary for the calculation model to insert values for input variables in multiple worksheets. The building of inputs in the Excel model can be further improved by creating a worksheet in which all inputs can be inserted and are directly linked to all other worksheets. This makes it easier and more clear for modellers or future users of the model to use the model.

Lastly, a recommendation is appointed for the 13th step of the proof of concept; more specifically, for the scenario analysis. Scenario analysis could be significantly improved by writing a so-called ‘macro’, which automates the process of scenario analysis.

10

CONCLUSION

The last chapter of this research concludes this report. The Dutch existing housing stock should be completely energy neutral in 2050. Around 7 million houses have to be renovated to more sustainable conditions to achieve this goal. This number asks for a quick commence of the energy transition, but also provides an opportunity for Dura Vermeer to safeguard an important position in the future market of the energy transition. One possible way of safeguarding this position is by reacting to the bottlenecks that currently withhold the energy transition from further progress. Several bottlenecks currently contribute towards stagnation in the energy transition of the existing housing stock. Against this backdrop, this study developed and validated a conceptual model to assess the financial feasibility of the PaaS model; a promising model that relieves part of the encountered bottlenecks. In total, five research questions were composed and answered to deliver and validate the conceptual model.

Capital budgeting techniques have to be used to assess a PaaS proposition's financial feasibility. Various techniques can assess financial feasibility, but it is useful to include only two or three in the conceptual model. Therefore, part of the first chapter focused on selecting appropriate financial metrics (or capital budgeting techniques) to incorporate in the conceptual model. In total, six financial metrics were considered. Numerous advantages and disadvantages justified a choice for the incorporation of the NPV, PI and IRR in the conceptual model. Most importantly, all three take the time-value of money into account by discounting future cash flows. The NPV is an important method to project future cash flows within LCC, which is often used for cost estimation in a PaaS model. The PI enables factoring in the overall magnitude of projects, which provides additional value to the NPV. The IRR is useful as some managers desire a rate of return instead of (or in addition to) a value amount (NPV) and/or a factor (PI). Given their advantages, these financial metrics together deliver a clear and extensive view of the financial feasibility of sustainability measures offered as a service. Dura Vermeer is currently unfamiliar with the offering of services. Offering services introduces new cost and benefit categories. Therefore, it was important to provide a clear description of the way the financial metrics can assess financial feasibility in the conceptual model. A roadmap of 19 steps was developed to model the financial metrics. The roadmap is iterative: the last step returns the modeller to step 4 for subsequent project stages in which higher levels of detail in the model are needed. It served as important input to the conceptual model. The roadmap enables the practical transition from the conceptual model towards a calculation model.

Three steps of the roadmap, and thereby the conceptual model, needed elaboration before the actual roadmap could be developed. The first was the fifth step, in which values for the input variables and parameters of the conceptual model are estimated. Chapter 5 discussed the details of this elaboration. Literature, the LCCs of various sustainability measures and two case studies ('Façades-as-a-Service' and 'Housing-as-a-Service') composed an extensive list of variables and parameters that influence a PaaS proposition's financial feasibility. The variables/parameters were categorised into the lifecycle stages in which they (can) occur. Table 10.1 displays the identified variables and parameters categorised in lifecycle stages.

Table 10.1 - Final overview of factors/variables influencing financial feasibility of a PaaS model categorised in life cycle stages

Life cycle stage	General	Revenue streams	Cost structure
Entire life cycle	Functional unit	Tax credits	Marketing costs
	Lifetime products	Subsidies	Information system
	Life span offering		Financing costs
Design phase		Deposition fee	Development costs
Production phase			Material costs
			Manufacturing costs
			Transportation costs
			Installation costs
Use phase		Monthly/yearly fee	O&M costs
			Replacement costs
			Refurbishment costs
			Transportation costs
End-Of-Life phase		Harvest value	Deconstruction costs
			Transportation costs
			Waste processing
			Disposal costs

The remaining extensions of steps in the roadmap were both discussed in Chapter 6: incorporation of risk (extension to the ninth step) and the quantification of uncertainty (extension to the 13th step). In general, risk can be incorporated in a model in two ways: adjusting the discount rate (by a risk-adjusted discount rate) and adjusting the cash flows (by Certainty Equivalents). Adjusting for risk by a risk-adjusted discount rate is the most easiest and theoretically more sound for a PaaS proposition. Therefore, the report advised to apply a risk-adjusted discount rate for the incorporation of risk. A risk-adjusted discount rate is determined in two ways:

1 Risk-adjusted discount rate with the WACC as starting point: For this method, first the WACC has to be computed. Next, a risk premium (project-specific risk) is added to the WACC (reflection of the overall risk of the company) to reflect the risk incorporated in the project. The proposed business model is not a completely new product, but not an extension of existing business either. Thereby, the PaaS model is not part of one particular pre-specified project category for which risk premiums are suggested by literature. Therefore, the report advised to add a 5% to 7.5% risk premium to the WACC to determine the risk-adjusted discount rate.

2 Risk-adjusted discount rate based on investors' expectations: Investors can be consulted for their expectations of the returns of a considered project. This is then used as a risk-adjusted discount rate within the model.

Both methods were included in the conceptual model. Chapter 6 also extensively described the 13th step: the quantification of uncertainty. The quantification of uncertainty is important for the decision-making process. In total, three techniques quantify uncertainty:

1 **Sensitivity analysis** gives a clear view of input variables that have the most influence on a project's financial feasibility.

2 **Scenario analysis** enables a clear view of the project's performance under certain conditions.

3 **Monte Carlo simulation** ties together sensitivities and input variable probability distributions (estimations). Thereby, it complements the scenario analysis on its main weakness by providing continuous statistics instead of solely discrete statistics.

All three techniques provide different forms of information about uncertainty. Therefore, the research recommended including all techniques in the conceptual model for the quantification of uncertainty.

With the first three research questions being answered and all extensions of steps of the roadmap described, it was possible to develop the conceptual model. The development of a conceptual model was the main goal of this research. The textual representation of the conceptual model was developed in five steps. The description of the organizational aim, modelling objectives, general project objectives, outputs, (experimental) factors, assumptions and simplifications together provided the textual representation.

Visualizations of the textual representations were also used for clarity. As the conceptual model is the most important result of this research, the visualization of the conceptual model is presented once more in Figure 10.1 below. The research also presented a roadmap in addition to the conceptual model. The roadmap is used for the practical elaboration of the conceptual model. The conceptual model links all discussed contents and shows how they are related to each other. Next, the roadmap can be used for the transition to a calculation model.

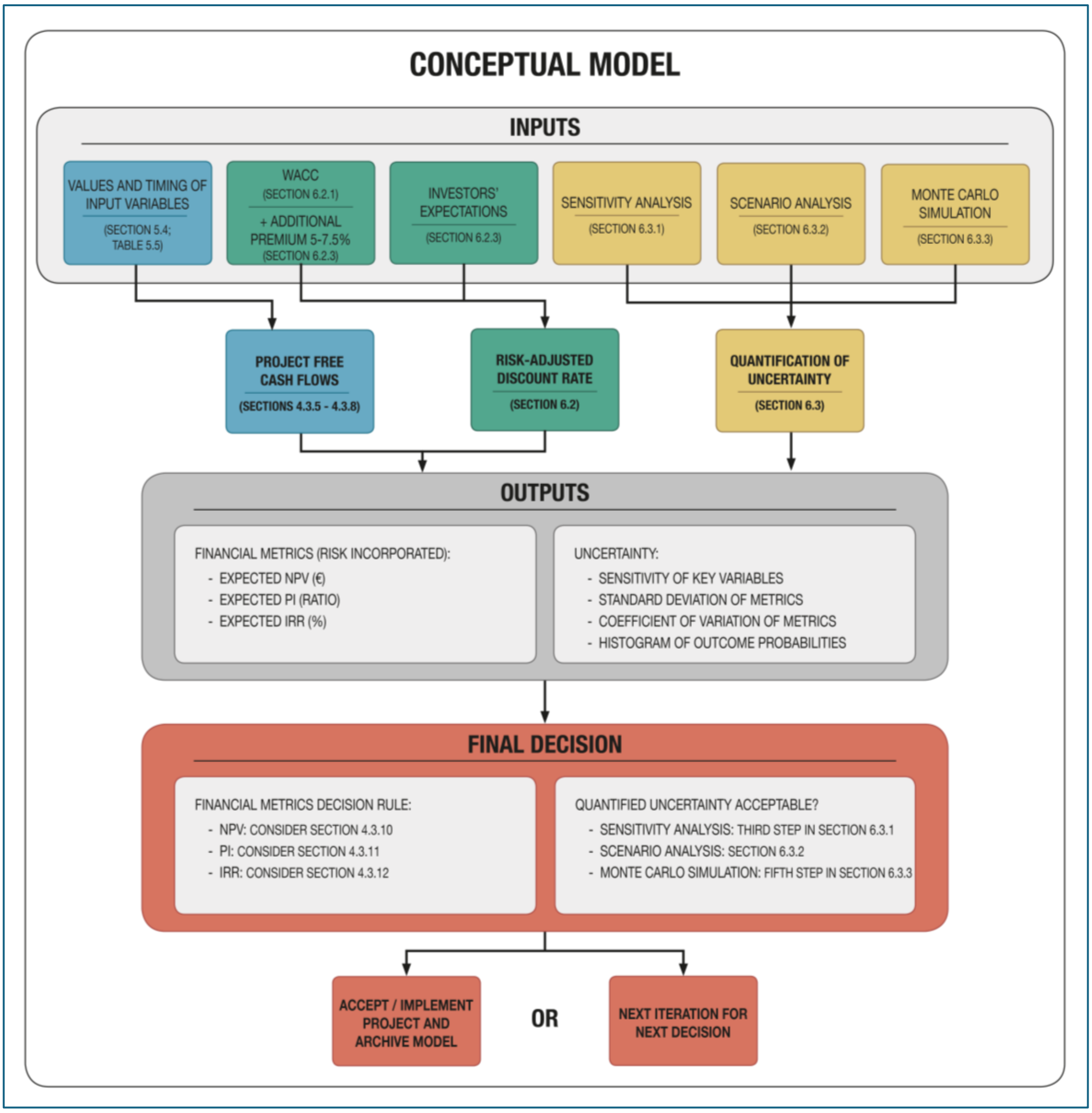

Figure 10.2 - Conceptual model of financial feasibility of PaaS proposition

Lastly, as validation of the conceptual model, a proof of concept walked through the 19 steps of the roadmap. The financial feasibility of the project of Winschoterdiep was assessed. The proof of concept was a success and provided useful business insights:

- The means of financial metrics determined with the base case, scenario analysis and Monte Carlo simulation are relatively similar to each other; around:
  - NPV = €30,000 (which means that the expected future cash flows are €30,000 more worth than the initial investment);
  - IRR = 13% (which is higher than the risk-adjusted discount rate and therefore justifies the risk of the investment);
  - PI = 1,033 (which means that every euro invested in the project generates €0,033 in additional value).

- The risk-adjusted discount rate is 12,40% (including a risk premium of 5%, as advised by literature, since the PaaS proposition is a combination of an expansion of existing business and a new product);
- The yearly fee, material costs and WACC are the most important factors (the model is the most sensitive for these variables/parameters) and should, therefore, be determined with high accuracy;
- Resulting graphs of the Monte Carlo simulation are skewed to the right, meaning that the downside risk is greater than the upside potential.

The proof of concept validated the conceptual model on several fronts. First of all, the proof of concept provided useful business insights (as explained) and the opportunity to look at the financial feasibility in one glance. Secondly, the summary of outputs did not point towards any mistakes or errors in the model, as the means determined with the base case, scenario analysis and Monte Carlo simulation were relatively similar to each other. Lastly, the results of the sensitivity analysis did not show any outputs indicating an mistake or error in the model. All financial metrics were most sensitive to changes in the yearly fee, material costs and the WACC. These outputs were expected upfront. Thereby, the proof of concept validated the conceptual model.

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Appendices

APPENDIX: SPECIFICATION OF INPUT VARIABLES AND PARAMETERS

Table A.1 - Determination of values for input variables/parameters for calculation of the WACC

Category	Specification	Value	Remarks
Unlevered industry beta	BAM Groep – Levered beta	2.42	(Yahoo Finance, 2021a)
	BAM Groep – Tax rate	25%	Estimation
	BAM Groep – Debt/equity ratio	1.5915	(The Wall Street Journal, 2021a)
	Boskalis Westminster – Levered beta	1.16	(Yahoo Finance, 2021b)
	Boskalis Westminster – Tax rate	25%	Estimation
	Boskalis Westminster – Debt/equity ratio	0.2220	(The Wall Street Journal, 2021b)
	Heijmans – Levered beta	1.42	(Yahoo Finance, 2021c)
	Heijmans – Tax rate	25%	Estimation
	Heijmans – Debt/equity ratio	0.6090	(The Wall Street Journal, 2021c)
Capital structure DV	Debt to total capitalization	70%	Estimate of average, as it usually fluctuates around this value.
	Equity to total capitalization	30%	Estimate of average, as it usually fluctuates around this value.
Cost of equity	Risk-free rate	0.06%	German bond yield for 15 years (World Government Bonds, 2021).
	Equity market risk premium	5.50%	(KPMG, 2021)
Cost of debt	Corporate bond yield	5.21%	Derived from credit spread based on DV's credit rating (Damodaran, 2020).
	Corporate tax rate	25%	
WACC calculation	Additional risk premium	5%	Determined in Section 6.3.2.

Table A.2 - Determination of values for input variables/parameters specific to the project

Category	Specification	Year	Value	Remarks
Entire life cycle				
Functional unit	-	-	39 units	As described in the introduction of this chapter.
Life span offering	-	-	15 years	After 15 years, some replacement costs will increase.
Design phase				
Fee per unit	-	2022	€2,000	An estimate of what housing corporations might be willing to pay and helps Dura Vermeer in financing the project.
Development costs	-	2022	(€75,983.28)	Preparation costs of the project.
Production phase				
Material costs per unit	Insulating ground floor	2022	(€860.77)	Executed by subcontractor, thus only included as material costs.

	Glass insulation	2022	(€4,325.74)	Part of installation costs included here, as it is partly executed by subcontractor.
	Insulating façades (covering walls)	2022	(€6,264.49)	Largely executed by subcontractor, thus only included as material costs.
	Central heating boilers	2022	(€533.69)	Executed by subcontractor. Two boilers collectively included in the building.
	Heat pump	2022	(€1,491.03)	One collectively placed by subcontractor.
	Radiators	2022	(€2,872.44)	-
	WTW	2022	(€3,525.46)	For large part executed by subcontractors.
	PV-panels	2022	(€793.82)	In total 81 collective panels.
	Viega installation	2022	(€1,367.59)	-
Installation costs per unit	Preparatory coverings	2022	(€214.23)	
	General construction site costs	2022	(€4,747.90)	In Dutch, 'algemene bouwplaatskosten (ABK)'.
	Provision for glass insulation	2022	(€288.51)	-
	Adjustments for WTW	2022	(€1,010.97)	-
	General adjustments for installations	2022	(€1,146.36)	-
	Adjustments for PV-panels	2022	(€122.05)	Total costs divided over 39 apartments.
	Restoration and cleaning	2022	(€286.72)	Costs after installing the sustainability measures.
Use phase				
Fee per unit	-	Yearly	€4,900	Determined based on total costs expenditures (in order to make the financial metrics positive).
O&M costs per unit	Central heating boilers	Yearly	(€80.10)	(Remeha, 2021)
	Heat pump	Yearly	(€12.82)	
	WTW	Yearly	(€120)	Monthly €10 per unit.
	PV-panels	Yearly	(€17.88)	Exists of cleaning costs per panel and general costs for the entire installation.
	Viega installation	Once per three years	(€12.82)	
Replacement costs per unit	Thermic buffer heat pump	2038	(€89.74)	Total costs divided over 39 units (CE Delft, 2021).
	WTW	2038	(€1,700)	
	PV-panels	2038	(€30.77)	Costs of replacing the inverter.
Refurbishment costs per unit	Paintwork window frames	2032, 2042	(€422.38)	

II

APPENDIX: MANUAL EXCEL-FILE/MODEL

General

This Excel-file represents a calculation model of the financial feasibility of sustainability measures offered as a service ('Products-as-a-Service' business model). The first version of the model in this Excel-file was established as part of a graduation thesis. The report of that thesis can also be used as extended manual for this Excel-file. Financial feasibility is assessed by means of a discounted cash flow model. This implies that all future cash flows are discounted with a discount rate. The contents and principles of a discounted cash flow model are more extensively described in the according report. In this worksheet, the practical manual of this calculation model is presented. Below, a legend is presented for cells and worksheets of this Excel-file (Figure A.1).

Cell	*Input cell in which values or descriptions can be inserted.*
Cell	*Input cell coupled to darker input cell (automatically copies the needed information).*
Cell	*Cell with a predetermined value (no adjustments necesarry).*
Cell	*Output cell or cell with important calculation.*
Worksheet	*Manual worksheet (current worksheet with all information about the file/model).*
Worksheet	*Worksheet in which no inputs have to be inserted.*

Figure 2 - Legend of the Excel-file

Cashflow specification

This is the most important input sheet of this calculation model. The project-specific cashflows are inserted here. This is also the sheet where the specific values of scenarios are inserted. First of all, the live case is the current scenario selected in the 'DCF'-worksheet (see below). Here, the description (specification and details) can be inserted of various costs and benefits categories. The values of those categories and years are automatically copied in the live case based on the selected case in the 'DCF'-sheet (the 'live case'). In the other scenarios, starting with scenario 1 (the base case) in column I, the values of the categories of costs and benefits can be inserted that belong specifically to that scenario. For the quantification of uncertainty, it is important to enter at least a worst and best case scenario next to the base case. It is also possible to include a fourth and fifth scenario, based on specific circumstances that modellers want to assess the financial feasibility of. Inserted values are automatically copied to the live case and collected in the 'DCF'-sheet in the years entered for that specific category, and if necessary multiplied with the functional unit (amount of houses included in the renovation project). To summarize, the darker orange cells are input cells, lighter orange are input cells that are automatically filled by other input cells and grey cells are predetermined cells (the latter two do not have to be changed).

WACC (Weighted Average Cost of Capital)

The risk-adjusted discount rate is determined in the 'WACC'-tab. Several values have to be inserted in this worksheet to calculate the appropriate risk-adjusted discount rate. First of all, an industry unlevered beta has to be determined with the pure play method. Under 'Comparable Companies Unlevered Beta', data of publicly traded companies similar to Dura Vermeer can be inserted: their beta, their debt and equity percentage of their total capital and their tax rate (for Dutch companies, most likely around 25%). The unlevered beta is automatically computed in the sheet if this data is inserted. Under 'WACC Calculation', specific input variables/parameters have to be inserted specifically for Dura Vermeer. The financial department can be consulted to determine most values of the input variables/parameters incorporated in this worksheet. The percentage of debt and equity of the total capital value of Dura Vermeer is needed to determine the debt/equity ratio. For the cost of equity, the risk-free rate (German bond yield with same maturity as the lifespan of the considered project) and the equity market risk premium (source from according report can be used for this value) are needed to automatically determine the cost of equity. Next, for the cost of debt, the corporate bond yield has to be inserted along with the corporate tax rate (most likely around 25%). The credit spread (the difference between the corporate bond yield and the risk-free rate of return) is then automatically determined. If the modeller is unable to determine the corporate bond yield, Dura Vermeer's credit rating can be used to determine the credit spread from the table next to the WACC calculation. The after-tax cost of debt is automatically calculated by inserting these values. The last value that has to be inserted is the risk premium. An appropriate value for the risk premium can be determined based on the according report (Section 6.2.3). After inserting all input variables/parameters needed for the discount rate, the discount rate is computed in the worksheet and copied to the 'DCF'-sheet. Again, the orange cells are the input cells in this worksheet and are the only cells that have to be adjusted to calculate the appropriate risk-adjusted discount rate.

DCF (Discounted Cashflow)

The last input variables/parameters needed for and calculation of financial metrics are included in the 'DCF'-worksheet. The sheet automatically adjusts its outline based on the input variables. Also the 'live scenario' is selected in this worksheet and automatically updated in the sheet if adjusted. The last column of the sheet displays if the total sum of the row is corresponding with the total costs of that category as determined in the 'Cashflow specification'-sheet. If they are corresponding, the cell is green. If not, the cell is red. This does not necessarily mean that a mistake is made; it can also mean that a year is entered in the 'Cashflow specification'-sheet that is beyond the lifespan of the project and therefore not included in the calculation of this worksheet. The final calculations of financial metrics takes place below the outline of costs and benefits. All outputs of financial metrics are automatically computed, except for the manual IRR determination. The value of this cell should be determined by trail-and-error. Control cell C52 has to be approximately zero for the manually determined IRR to be correct. Of course, simply the percentage of the IRR determined by Excel's built-in function can be inserted to double check whether the control cell is indeed approximately zero. Calculations of the NPV and IRR are included twice as a double check (blue is manually inserted, whereas the grey cells are computed with a built-in function of Excel).

Sensitivity analysis

The sensitivity analysis worksheet is the first sheet focused on quantifying uncertainty. After determination of key variables, the data tables (or 'Gegevenstabellen') can be filled in in this tab. Sensitivity of a variable can be inserted in the model by multiplying the relevant variable in the output sheet with the zero in the left upper corner of the table in which the sensitivity output is placed. If it is a single value like the WACC, it can be simply done by multiplying that value in the output sheet with (1+'cell in table upper left corner'). For cost categories, for example maintenance cost or yearly fee, the entire row in the output sheet must be multiplied with that same value (and secured with the $-sign). Examples are given in the 'Voorbeeld_DCFModel'-file to concretise this description. Next, a data table (or in Dutch 'gegevenstabel') has to be set up. A data table has to be inserted three times per variable/parameter (once for every metric). Data tables can be created in the 'Gegevens/Data' tab above and then select 'Gegevenstabel/Data Table' under 'Wat-als-analyse/What-if-analysis'. The two columns for the specific metric has to be selected, including the header in which the output of the metric for the base case is given. Then, the data table can be inserted. In the column cell (the bottom of the two options), the 0 at the left upper cell should be selected. The output of the sensitivity analysis is automatically inserted in the graphs. The steeper the line, the more sensitive the output of a financial metric is to that input variable/parameter.

Important notes: For a correct sensitivity analysis, the base case scenario should be active in the 'DCF'-worksheet. Furthermore, if the lifetime/lifespan of the project is included in the sensitivity analysis, the extension to the formula as described above should be inserted along with the 'AFRONDEN' or 'ROUND' function in order to get realistic values conform the model (the file only works with whole numbers as years). Lastly, data tables are not automatically calculated with the default settings of this file. Therefore, if new data tables are inserted or adjustments in inputs are made, it is necessary to recalculate the data tables by clicking 'Blad berekenen' or 'Calculate sheet' in the tab 'Formules/Formulas' above with the 'Sensitivity analysis'-worksheet opened.

Scenario analysis

The second analysis for quantifying uncertainty is performed in this worksheet. A scenario analysis is automatically performed by manually inserting the outputs of the financial metrics in this sheet. Firstly, the correct scenario has to be selected in the 'DCF'-worksheet. Next, the outputs of the financial metrics have to be inserted in the according orange input cells. Lastly, the probability of every scenario has to be entered. It is suggested to use a probability of 0.5 for the base case scenario, and 0.25 for both the worst-case and best-case scenario, if exact probabilities of scenarios are unknown. Based on the outputs of the individual scenarios, the expected values, standard deviations and coefficients of variation are automatically computed for each financial metric.

Monte Carlo simulation

This sheet finalizes the quantification of uncertainty. For this sheet, it is most important to establish the minimum and maximum values of all input variables/parameters. The most likely values of the input is automatically displayed and collected from the base case in the 'Cashflow specification'-worksheet. The darker orange input cells have to be filled in to establish the expected extreme values. It is not necessary to adjust any other cell in this sheet than determining the extreme values (also the lighter orange cells are coupled to input cells located elsewhere and do not have to be adjusted).

Important notes: Make sure that the base case scenario is selected in the 'DCF'-sheet. Furthermore, similar to the 'Sensitivity analysis'-worksheet, the Monte Carlo simulation mainly exists of data tables that are not automatically updated. Therefore, if input variables are adjusted, new data tables have to be established by clicking 'Blad berekenen' or 'Calculate sheet' in the tab 'Formules/Formulas' above with the 'Monte Carlo simulation'-worksheet opened. This might take a while, as the Monte Carlo simulation uses 5000 runs to determine the outputs.

Summary of outputs

The last sheet is the summary of outputs. This sheet is automatically composed through the inputs of other sheets and is simply a summarization of all results and outputs thusfar. This sheet is a clear overview of all important output values and graphs that can be presented to management and decision-makers. No adjustments have to be made in this worksheet.

III

APPENDIX: ADDITIONAL FIGURES OF THE EXCEL-MODEL

WACC Calculator		
WACC Calculation		Remarks
Capital Structure		
Debt to Total Capitalization	70.00%	Date:
Equity to Total Capitalization	30.00%	Date:
Debt/Equity ratio	233.33%	
Cost of Equity		
Risk Free Rate	0.06%	German bond yield 15 yrs; date: 30-09-21
Equity market risk premium	5.50%	
Levered Beta	2.82	
Cost of Equity	15.55%	
Cost of Debt		
Risk Free Rate	0.06%	Coupled with rate above
Corporate bond yield (based on credit rating)	5.21%	
Credit spread	5.15%	
Tax Rate	25.00%	
After-Tax Cost of Debt	3.91%	
WACC	7.40%	
Risk premium	5.00%	Determined in Section 7.2.2.1
Risk-adjusted discount rate	**12.40%**	

Comparable Companies Unlevered Beta						
Company	Levered Beta	Debt	Equity	Debt/Equity	Tax Rate	Unlevered Beta
BAM Group	2.42	61.41%	38.59%	159.15%	25.00%	1.10
Boskalis Westminster	1.16	18.17%	81.83%	22.20%	25.00%	0.99
Heijmans	1.42	37.85%	62.15%	60.90%	25.00%	0.97
Median	1.67	-	-	80.75%	-	1.02

Figure A.2 - Overview of input (and output) worksheet for determination of the WACC (and risk-adjusted discount rate)

Discounted cash flow model

Lifetime	15	15
Discount rate	12.40%	
Functional unit	39	
Startup year	2022	
Scenario	Scenario 1 - Base Case	

	Indv. Value	Total project	2022 0	2023 1	2024 2	2025 3
Entire life cycle						
Tax credits	€ -	€ -	€ -	€ -	€ -	€ -
Subsidies	€ -	€ -	€ -	€ -	€ -	€ -
Marketing cost	€ -	€ -	€ -	€ -	€ -	€ -
Information system	€ -	€ -	€ -	€ -	€ -	€ -
Design phase						
Deposition fee	€ 2,000.00	€ -	€ 78,000.00	€ -	€ -	€ -
Development cost	€ -75,983.28	€ -75,983.28	€ -75,983.28	€ -	€ -	€ -
Production phase						
Material costs	€ -22,035.02	€ -859,365.86	€ -859,365.86	€ -	€ -	€ -
Manufacturing costs	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -
Installation costs	€ -7,816.74	€ -304,853.00	€ -304,853.00	€ -	€ -	€ -
Use phase						
Yearly fee	€ 73,500.00	€ 2,866,500.00	€ -	€ 191,100.00	€ 191,100.00	€ 191,100.00
O&M costs	€ -3,539.04	€ -138,022.50	€ -	€ -9,001.50	€ -9,001.50	€ -9,501.50
Replacement costs	€ -1,820.51	€ -71,000.00	€ -	€ -	€ -	€ -
Refurbishment costs	€ -844.77	€ -32,946.00	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -
End-Of-Life phase						
Harvest value	€ -	€ -	€ -	€ -	€ -	€ -
Deconstruction costs	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -
Waste processing	€ -	€ -	€ -	€ -	€ -	€ -
Disposal costs	€ -	€ -	€ -	€ -	€ -	€ -
Net cash flows			€ -1,162,202.14	€ 182,098.50	€ 182,098.50	€ 181,598.50
Discount factor			1	0.88968	0.79153	0.70420
PV cash flows			**-€ 1,162,202.14**	**€ 162,009.09**	**€ 144,135.98**	**€ 127,882.56**
Extra row for IRR			*-€ 1,162,202.14*	*€ 161,238.58*	*€ 142,768.23*	*€ 126,066.60*
Cumulative row for IRR			*-€ 1,162,202.14*	*€ -1,000,963.56*	*€ -858,195.33*	*€ -732,128.73*
Cumulative NPV			**-€ 1,162,202.14**	*€ -1,000,193.05*	*€ -856,057.06*	*€ -728,174.50*

	2026 4	2027 5	2028 6	2029 7	2030 8	2031 9	2032 10
Entire life cycle							
Tax credits	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Subsidies	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Marketing cost	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Information system	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Design phase							
Deposition fee	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Development cost	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Production phase							
Material costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Manufacturing costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Installation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Use phase							
Yearly fee	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00	€ 191,100.00
O&M costs	€ -9,001.50	€ -9,001.50	€ -9,501.50	€ -9,001.50	€ -9,001.50	€ -9,501.50	€ -9,001.50
Replacement costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Refurbishment costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -16,473.00
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
End-Of-Life phase							
Harvest value	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Deconstruction costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Transportation costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Waste processing	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Disposal costs	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Net cash flows	€ 182,098.50	€ 182,098.50	€ 181,598.50	€ 182,098.50	€ 182,098.50	€ 181,598.50	€ 165,625.50
Discount factor	0.62652	0.55740	0.49590	0.44120	0.39252	0.34922	0.31069
PV cash flows	**€ 114,087.61**	**€ 101,501.27**	**€ 90,055.53**	**€ 80,341.06**	**€ 71,477.70**	**€ 63,417.55**	**€ 51,458.54**
Extra row for IRR	*€ 111,932.64*	*€ 99,110.43*	*€ 87,516.08*	*€ 77,704.21*	*€ 68,802.97*	*€ 60,754.11*	*€ 49,062.90*
Cumulative row for IRR	*€ -620,196.08*	*€ -521,085.65*	*€ -433,569.57*	*€ -355,865.36*	*€ -287,062.40*	*€ -226,308.29*	*€ -177,245.39*
Cumulative NPV	*€ -614,086.90*	*€ -512,585.62*	*€ -422,530.09*	*€ -342,189.04*	*€ -270,711.34*	*€ -207,293.79*	*€ -155,835.25*

NPV (manual)	€ 32,387.36	
NPV (excel)	€ 32,387.36	Controlecel
IRR (manual)	12.94%	€ 1.56
IRR (excel)	12.94%	Controlecel
PI	1.028	

Figure A.3 - Overview of finalized calculations of financial metrics

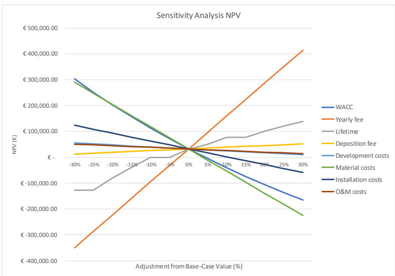
WACC

Adjustment NPV	NPV	Adjustment IRR	IRR	Adjustment PI	PI
0	€ 32,387.36		12.94%		1.028
-30%	€ 302,969.38	-30%	12.94%	-30%	1.261
-25%	€ 251,465.44	-25%	12.94%	-25%	1.216
-20%	€ 202,760.85	-20%	12.94%	-20%	1.174
-15%	€ 156,667.71	-15%	12.94%	-15%	1.135
-10%	€ 113,012.57	-10%	12.94%	-10%	1.097
-5%	€ 71,635.17	-5%	12.94%	-5%	1.062
0%	€ 32,387.36	0%	12.94%	0%	1.028
5%	€ -4,867.90	5%	12.94%	5%	0.996
10%	€ -40,257.51	10%	12.94%	10%	0.965
15%	€ -73,899.02	15%	12.94%	15%	0.936
20%	€ -105,901.44	20%	12.94%	20%	0.909
25%	€ -136,365.87	25%	12.94%	25%	0.883
30%	€ -165,386.18	30%	12.94%	30%	0.858

Yearly fee

Adjustment NPV	NPV	Adjustment IRR	IRR	Adjustment PI	PI
0	€ 32,387.36		12.94%		1.028
-30%	€ -349,878.66	-30%	6.09%	-30%	0.699
-25%	€ -286,167.66	-25%	7.32%	-25%	0.754
-20%	€ -222,456.65	-20%	8.52%	-20%	0.809
-15%	€ -158,745.65	-15%	9.67%	-15%	0.863
-10%	€ -95,034.64	-10%	10.79%	-10%	0.918
-5%	€ -31,323.64	-5%	11.87%	-5%	0.973
0%	€ 32,387.36	0%	12.94%	0%	1.028
5%	€ 96,098.37	5%	13.98%	5%	1.083
10%	€ 159,809.37	10%	15.00%	10%	1.138
15%	€ 223,520.38	15%	16.00%	15%	1.192
20%	€ 287,231.38	20%	16.99%	20%	1.247
25%	€ 350,942.39	25%	17.96%	25%	1.302
30%	€ 414,653.39	30%	18.92%	30%	1.357

	NPV	IRR	PI
Minimum	€ -349,878.66	6.09%	0.699
Maximum	€ 414,653.39	18.92%	1.357



Lifetime

Adjustment NPV	NPV	Adjustment IRR	IRR	Adjustment PI	PI
0	€ 32,387.36		12.94%		1.028
-30%	€ -127,060.75	-30%	9.73%	-30%	0.891
-25%	€ -127,060.75	-25%	9.73%	-25%	0.891
-20%	€ -80,023.21	-20%	10.83%	-20%	0.931
-15%	€ -38,065.54	-15%	11.70%	-15%	0.967
-10%	€ -736.70	-10%	12.39%	-10%	0.999
-5%	€ -736.70	-5%	12.39%	-5%	0.999

Deposition fee

Adjustment NPV	NPV	Adjustment IRR	IRR	Adjustment PI	PI
0	€ 32,387.36		12.94%		1.028
-30%	€ 13,039.75	-30%	12.61%	-30%	1.011
-25%	€ 16,264.36	-25%	12.66%	-25%	1.014
-20%	€ 19,488.96	-20%	12.72%	-20%	1.017
-15%	€ 22,713.56	-15%	12.77%	-15%	1.019
-10%	€ 25,938.16	-10%	12.83%	-10%	1.022
-5%	€ 29,162.76	-5%	12.88%	-5%	1.025

Figure A.4 - Worksheet of the sensitivity analysis in Excel

Trials NPV	NPV	Trials IRR	IRR	Trials PI	PI
1	€ 54,519.54	1	12.58%	1	1.047
2	€ 58,309.09	2	10.05%	2	1.027
3	€ 84,994.15	3	13.33%	3	1.079
4	€ 87,644.97	4	13.07%	4	1.004
5	€ -130,720.88	5	13.27%	5	0.983
6	€ 42,121.62	6	11.94%	6	1.059
7	€ -45,151.09	7	13.89%	7	0.997
8	€ -171.79	8	13.19%	8	0.996
9	€ 98,311.18	9	13.47%	9	1.045
10	€ 23,946.76	10	13.55%	10	1.038
11	€ 34,135.07	11	12.51%	11	1.048
12	€ 18,863.64	12	13.50%	12	1.017
13	€ 8,301.70	13	12.15%	13	1.053
14	€ -40,475.20	14	12.33%	14	1.025
15	€ 78,280.36	15	13.62%	15	0.985
16	€ -30,696.65	16	12.96%	16	1.095
17	€ 57,392.04	17	11.07%	17	0.930
18	€ -168,509.66	18	12.86%	18	1.021
19	€ -8,187.29	19	13.64%	19	1.040
20	€ 34,085.53	20	11.73%	20	1.033
21	€ 6,592.01	21	12.56%	21	0.963
22	€ 54,431.59	22	12.80%	22	1.061
23	€ -32,536.84	23	13.57%	23	0.922
24	€ -41,880.53	24	12.91%	24	1.016
25	€ -39,030.92	25	10.24%	25	0.920
26	€ 43,465.49	26	12.31%	26	1.057
27	€ 9,001.92	27	13.21%	27	1.033

NPV			
Mean	€ 26,329.47	Range	€ 412,091.62
Min	€ -197,064.61	Bins	20
Max	€ 215,027.01		
Count	5000		
Bin width	€ 20,604.60		

LL	UL	UL round	Freq	Cum Freq	Freq %	Cum %
€ -197,064.61	€ -176,460.02	€ -176,461.00	6	6	0.0012	0.0012
€ -176,460.01	€ -155,855.42	€ -155,856.00	14	20	0.0028	0.004
€ -155,855.41	€ -135,250.82	€ -135,251.00	32	52	0.0064	0.0104
€ -135,250.81	€ -114,646.22	€ -114,647.00	64	116	0.0128	0.0232
€ -114,646.21	€ -94,041.62	€ -94,042.00	82	198	0.0164	0.0396
€ -94,041.61	€ -73,437.02	€ -73,438.00	150	348	0.03	0.0696
€ -73,437.01	€ -52,832.42	€ -52,833.00	201	549	0.0402	0.1098
€ -52,832.41	€ -32,227.82	€ -32,228.00	257	806	0.0514	0.1612
€ -32,227.81	€ -11,623.22	€ -11,624.00	397	1203	0.0794	0.2406
€ -11,623.21	€ 8,981.38	€ 8,982.00	547	1750	0.1094	0.35
€ 8,981.39	€ 29,585.98	€ 29,586.00	706	2456	0.1412	0.4912
€ 29,585.99	€ 50,190.58	€ 50,191.00	713	3169	0.1426	0.6338
€ 50,190.59	€ 70,795.18	€ 70,796.00	668	3837	0.1336	0.7674
€ 70,795.19	€ 91,399.78	€ 91,400.00	496	4333	0.0992	0.8666
€ 91,399.79	€ 112,004.38	€ 112,005.00	315	4648	0.063	0.9296
€ 112,004.39	€ 132,608.98	€ 132,609.00	210	4858	0.042	0.9716
€ 132,608.99	€ 153,213.58	€ 153,214.00	83	4941	0.0166	0.9882
€ 153,213.59	€ 173,818.18	€ 173,819.00	36	4977	0.0072	0.9954
€ 173,818.19	€ 194,422.78	€ 194,423.00	17	4994	0.0034	0.9988
€ 194,422.79	€ 215,027.38	€ 215,028.00	6	5000	0.0012	1
€ 215,027.39			0			

Figure A.5 - Screenshot of the Monte Carlo simulation for Winschoterdiep

	Total costs per phase (not discounted)					Output						Probability
Scenario	*Entire life cycle*	*Design phase*	*Production phase*	*Use phase*	*End-Of-Life phase*	*NPV*	*Manual NPV*	*IRR*	*Manual IRR*	*PI*	*Manual PI*	
Scenario 1 - Base Case	€ -	€ -75,983.28	€ -1,164,218.86	€ 2,624,531.50	€ -	€ 32,387.36	€ 32,387.36	12.94%	12.94%	1.03	1.03	0.5
Scenario 2 - Best case	€ -	€ -73,703.78	€ -1,106,011.14	€ 2,729,647.38	€ -		€ 140,219.56		14.82%		1.13	0.25
Scenario 3 - Worst case	€ -	€ -78,262.78	€ -1,195,226.47	€ 2,490,925.62	€ -		€ -60,953.58		11.40%		0.95	0.25
Scenario 4 - [Scenario Name]	€ -	€ -	€ -	€ -	€ -							
Scenario 5 - [Scenario Name]	€ -	€ -	€ -	€ -	€ -							

Results

Expected NPV	€ 36,010.18
Standard deviation NPV	€ 71,217.65
Coefficient of variation NPV	1.98
Expected IRR	13.03%
Standard deviation IRR	1.21%
Coefficient of variation IRR	0.09
Expected PI	1.04
Standard deviation PI	0.06
Coefficient of variation PI	0.06

Figure A.6 - 'Scenario analysis'-worksheet in the Excel-file filled in for Winschoterdiep

Monte Carlo simulation

General input		General input MC simulation				
		Low	Most likely	High	P(X)	x
Lifetime	18	10	15	20	0.903568871	18
Discount rate	12.47%	11.40%	12.40%	13.40%	0.566166689	12.47%
Functional unit	39					

DCF input							MC simulation input				
	Input variable	Specification	Details	Costs	Year(s) (separate with comma or "Yearly")	Jaren ingevoerd	Low	Most likely	High	P(X)	x
Entire life cycle	*Tax credits*			€ -		0		€ -		0.407	€ -
				€ -		0		€ -		0.217	€ -
		Total		€ -							
	Subsidies (per unit)			€ -		0		€ -		0.569	€ -
				€ -		0		€ -		0.171	€ -
		Total		€ -							
	Marketing costs			€ -		0		€ -		0.725	€ -
				€ -		0		€ -		0.213	€ -
		Total		€ -							
	Information system			€ -		0		€ -		0.198	€ -
				€ -		0		€ -		0.370	€ -
		Total		€ -							
	Input variable	Specification	Details	Quantification	Year (if multiple, separate with comma)	Jaren ingevoerd	Low	Most likely	High	P(X)	x
Design phase	*Deposition fee (per unit)*	Fee		€ 2,006.02	2022	1	€ 1,940.00	€ 2,000.00	€ 2,060.00	0.595	€ 2,006.02
		Payback		€ -2,006.02	2037	1					
		Total		€ -							
	Development costs	Deel 1	Voorbereidingskosten	€ 45,133.42			€ 44,073.19	€ 45,436.28	€ 46,799.37	0.302	€ 45,133.42
		Deel 2	Voorbereidingskosten	€ 30,740.21			€ 29,630.59	€ 30,547.00	€ 31,463.41	0.689	€ 30,740.21
				€ -				€ -		0.767	€ -
		Total		€ -75,873.62	2022	1					

Figure A.7 - Fragment of the 'Monte Carlo simulation'-worksheet where the probability distributions are inserted

IV

APPENDIX: OUTPUTS WINSCHOTERDIEP

Table A.3 - Expected results based on base case

Financial metric	Output
Net Present Value	€32,387.36
Internal Rate of Return	12.94%
Profitability Index	1.028

Table A.4 - Output scenario analysis

Net Present Value		Internal Rate of Return		Profitability Index	
Expected NPV	€36,010.18	Expected IRR	13.03%	Expected PI	1.04
Standard deviation NPV	€71,217.65	Standard deviation IRR	1.21%	Standard deviation PI	0.06
Coefficient of variation NPV	1.98	Coefficient of variation IRR	0.09	Coefficient of variation PI	0.06

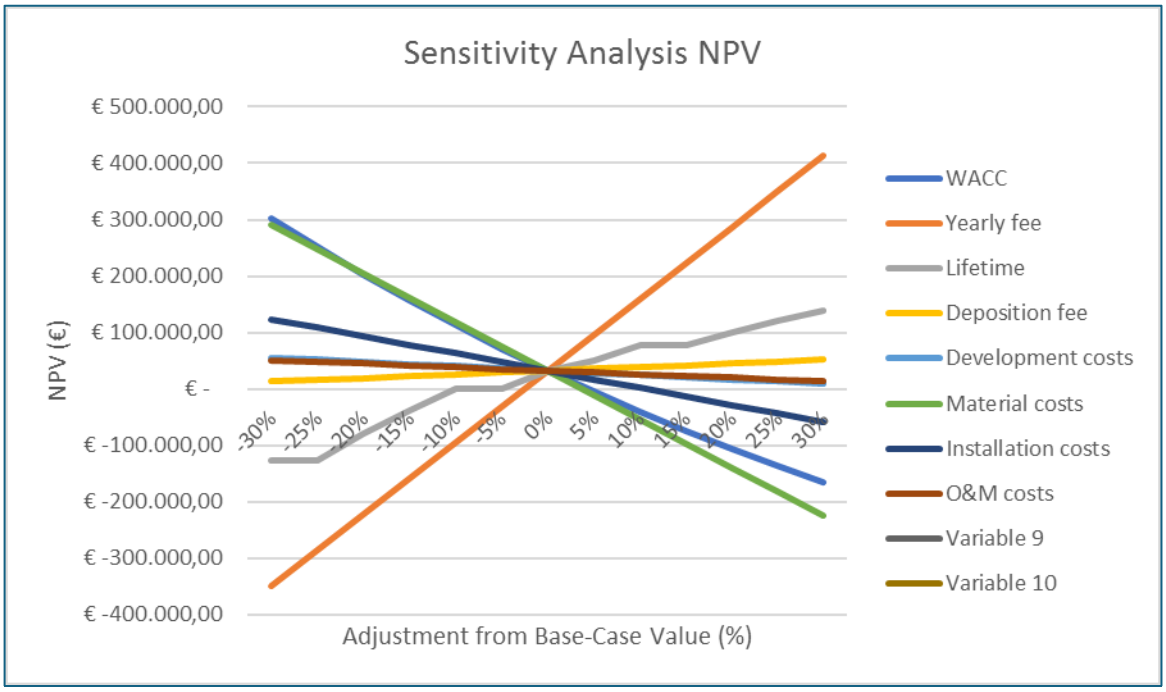


Figure A.8 - Sensitivity of NPV to various input variables/parameters

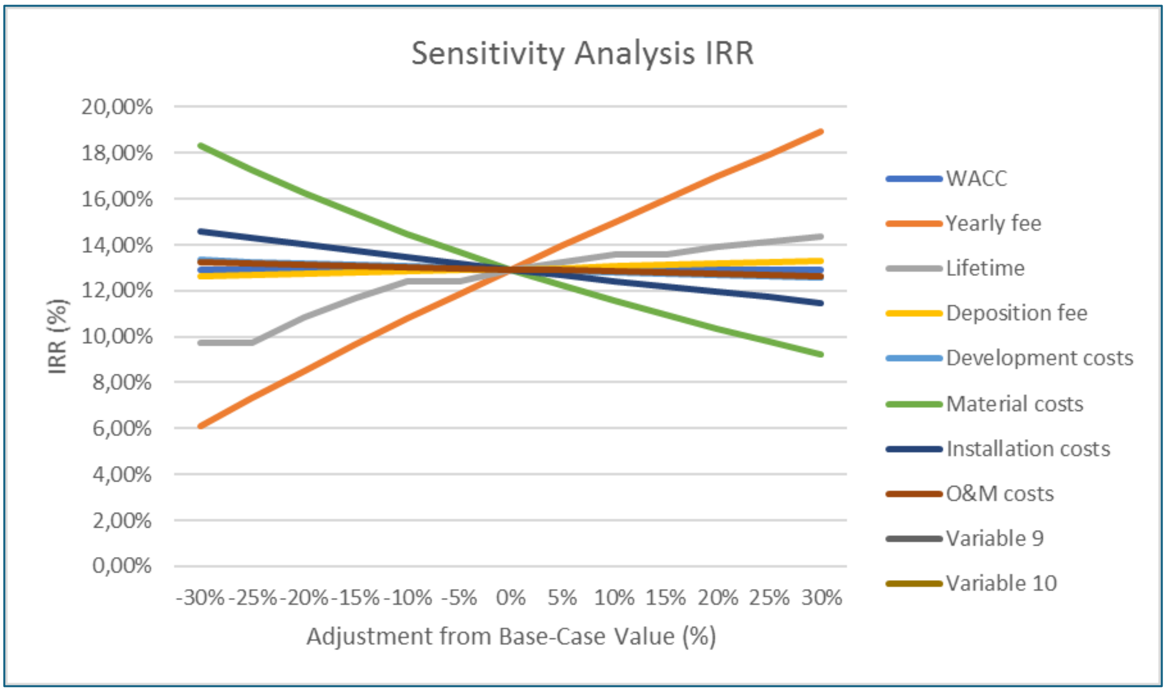


Figure A.9 - Sensitivity of IRR to various input variables/parameters

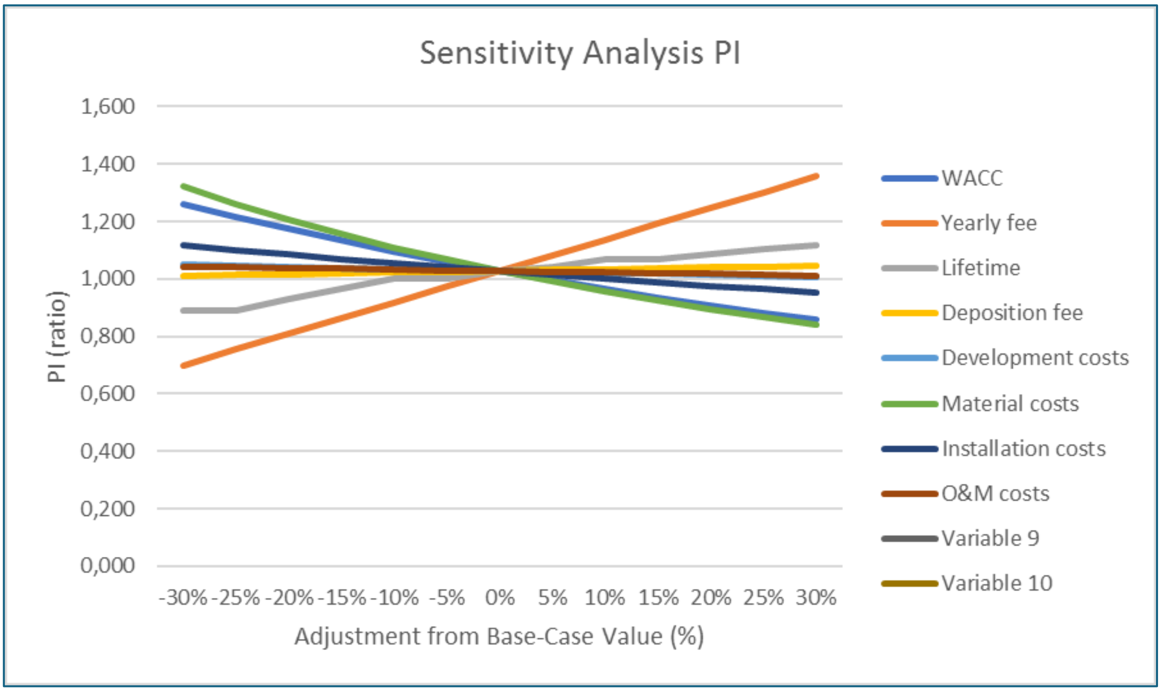


Figure A.10 - Sensitivity of PI to various input variables/parameters

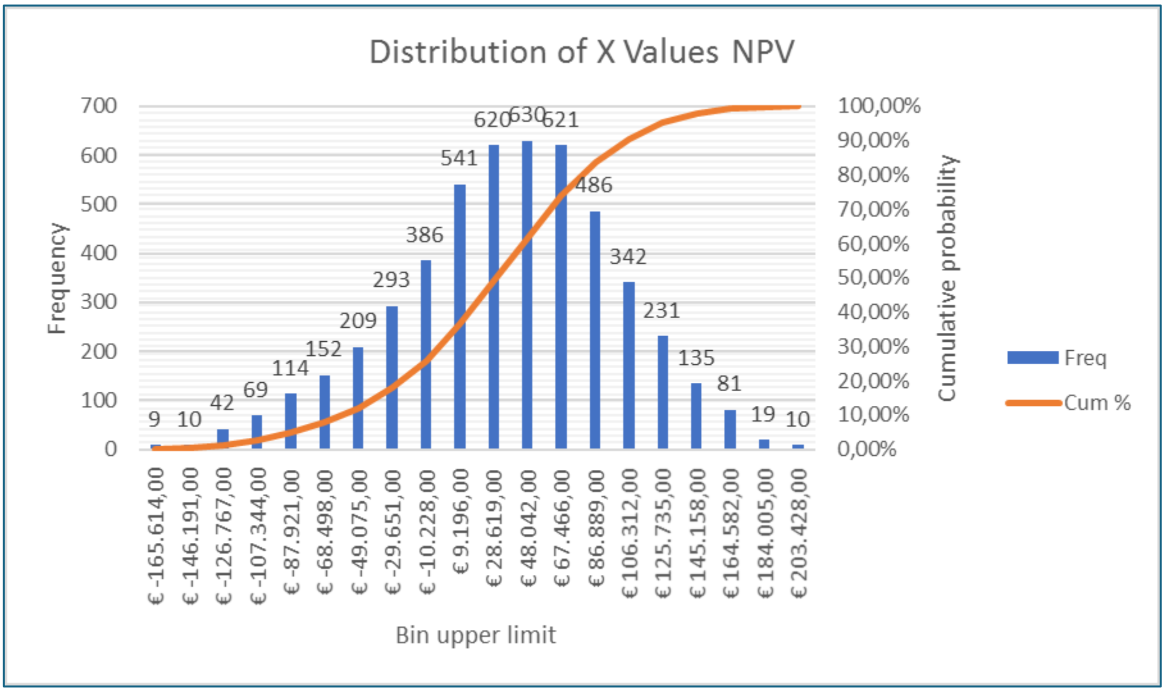


Figure A.11 - Output of Monte Carlo simulation for the NPV

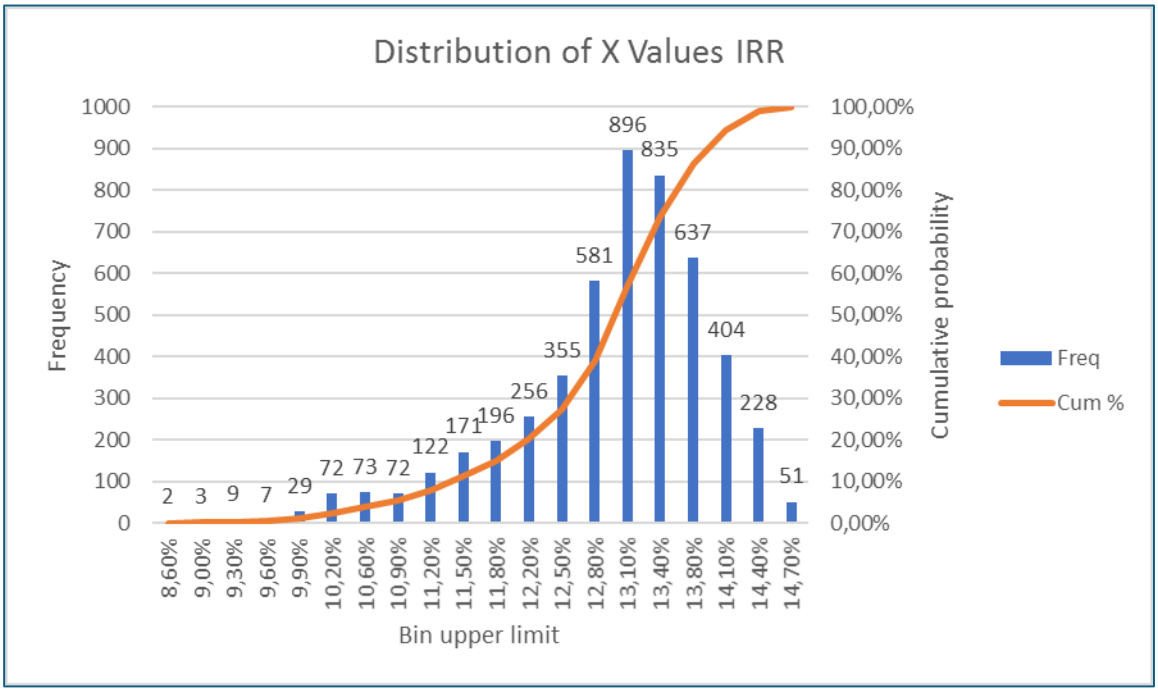


Figure A.12 - Output of Monte Carlo simulation for the IRR

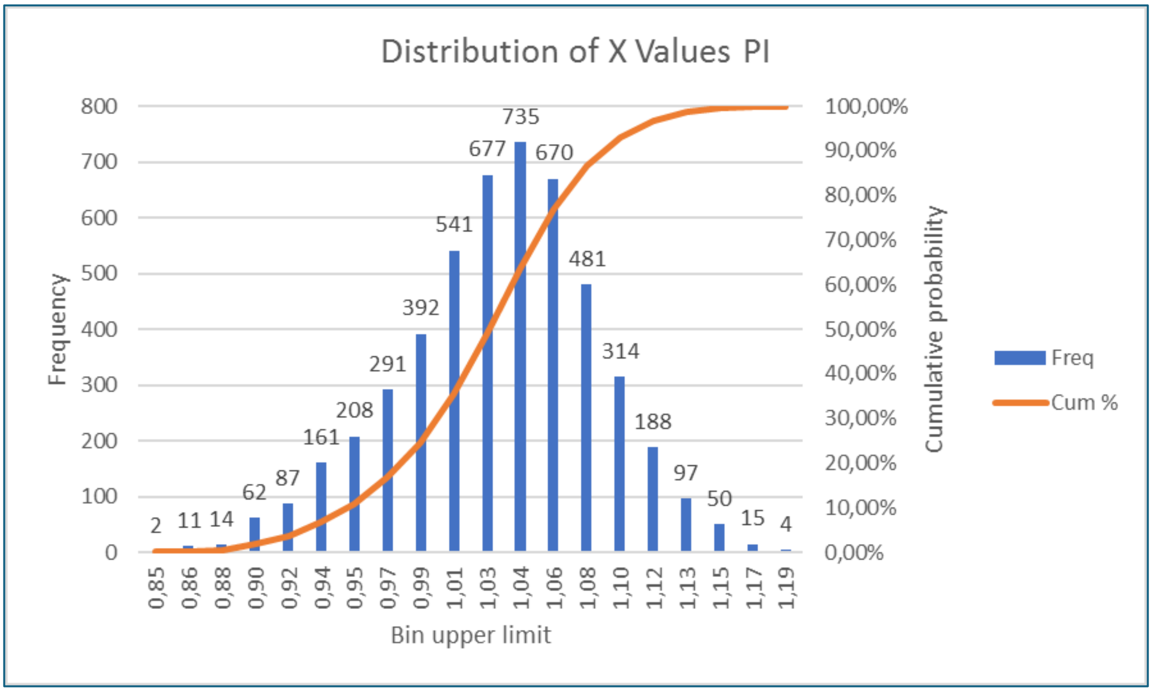
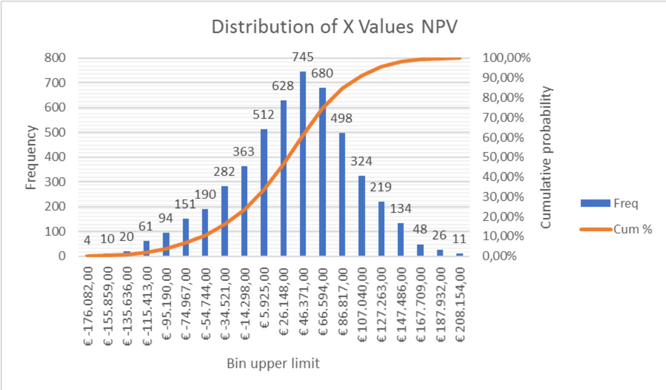


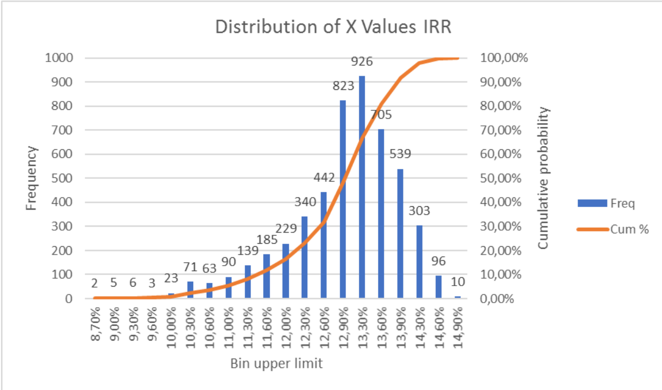
Figure A.13 - Output of Monte Carlo simulation for the PI

V

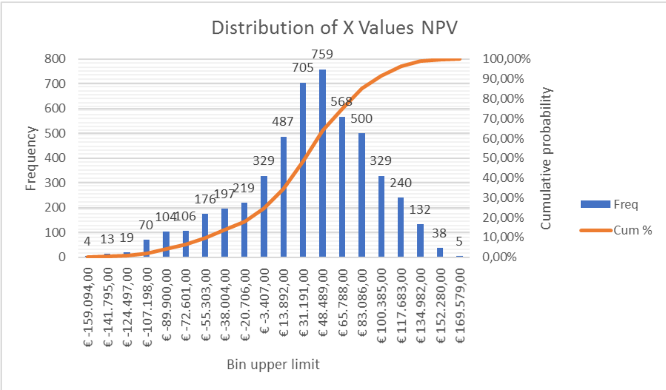
APPENDIX: DISCUSSION OF RESULTANT STATISTICS MC SIMULATION

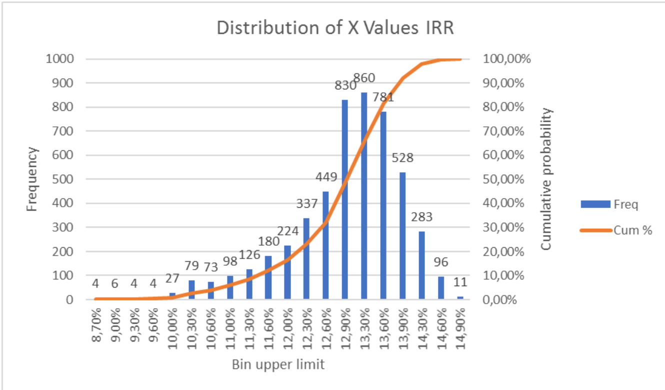
All variables triangular





Risk-adjusted discount rate constant, all other variables triangular





The extreme values of the output of financial metrics take place when costs are high and benefits low (worst-case scenarios) or when costs are low and benefits are high (best-case scenarios). However, in a discounted cash flow model the future benefits are discounted, resulting for this specific model (with almost all costs in the beginning – i.e. not discounted, and all benefits in future years – i.e. discounted) in the most beneficial cases being relatively less favourable than the worst cases being unfavourable. This explains a skewness of both graphs to the right (less extremely positive cases than negative).

The graph of the NPV is, however, less skewed to the right than the IRR. This seems to be caused by the risk-adjusted discount rate. When the risk-adjusted discount rate is inserted as a constant instead of a triangular distributed input variable, the NPV indeed skews further to the right (see images above). This suggests that the underlying data is indeed skewed to the right, but that the risk-adjusted discount rate functions as counterpart. This shift does not take place in the graph of the IRR, as the IRR is not dependent on the risk-adjusted discount rate. Furthermore, the shift of the NPV graph more to the middle because of the risk-adjusted discount rate is not that strange either. A lower risk-adjusted discount rate results in benefits becoming more important. Therefore, it is easier to find higher values in the Monte Carlo simulation for the NPV in comparison to the IRR. Besides, the risk-adjusted discount rate results in more extreme values in any event, because it simply adds an additional variable in the calculations that can vary. In general, the larger range of outputs in the NPV is also resulting from including the risk-adjusted discount rate. If in a unfavourable scenario the risk-adjusted discount rate is high in addition, the negative value of this scenario would be even more negative. Vice versa, if in a favourable scenario a lower risk-adjusted discount rate is assigned in addition, the output of this scenario would be even more positive than it already was. As the IRR is independent from the risk-adjusted discount rate, this point does not account for the IRR. Lastly, the risk-adjusted discount rate weighs heavily on the distribution of the NPV (see also the sensitivity analysis), which is why this distribution is more shaped to a distribution that is logical for the risk-adjusted discount rate.