Quantifying key risks and modelling investment opportunities at Company X

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Joost Postma
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Author
Joost Postma
MSc Financial Engineering and Management

Company X
[redacted]

University of Twente
Drienerlolaan 5
7522 NB, Enschede
Netherlands

Supervisors Company X
Supervisor 1
Controller
Supervisor 2
Director

Supervisors University of Twente
Dr. B. Roorda
BMS, FE
Dr. R.A.M.G. Joosten
BMS, FE

Preface

This report is my master's graduation thesis carried out at Company X. It marks the end of my master Financial Engineering and Management at the University of Twente and therefore, my time as a student at the University of Twente. In the process of completing my master's degree, I have learned a lot, met many interesting and kind people, and had a lot of great experiences. For this, I am grateful.

I would like to take the opportunity to express my gratitude to Company X, where I was given the chance to conduct this research and to help improve their risk management policy. The people at Company X were very kind, insightful, and they were always ready to help or have a quick chat. I would especially like to thank my supervisors at the company, who have helped me many times with their guidance and useful feedback. I would also like to thank all other colleagues for creating a pleasant working experience. I am looking forward to continuing working at Company X and keep learning more about the world of real estate investing.

In addition, I would like to thank my first supervisor of the University of Twente, Berend Roorda, for his time, useful feedback, and insightful advice. Berend always made enough time for all my questions and helped me maintain focus on what is important and what is not. I would also like to thank my second supervisor, Reinoud Joosten, for taking the time to help me improve my thesis and for his feedback. Next to this, I would like to thank my fellow students at the University of Twente, with a special thanks to Benjamin and Frits, for making it such a great experience.

Lastly, I would like to thank my parents and my girlfriend, for supporting me during this research and for always being there to listen and give advice. I hope you enjoy reading this thesis, I have surely enjoyed writing it.

Management Summary

This research has been carried out at Company X, a Dutch company primarily focused on real estate development and investment. Company X invest in real estate and (re)develop their bought real estate assets. The objective of this research is to quantify the key risks faced by Company X in their operations. The current risk management policy of Company X consists of mostly intuition, where investment decisions are made based on their experiences, the known (quantitative and qualitative) facts about the project, and their estimations based on intuition and the current state of the market. Although there certainly are quantitative aspects to this approach, Company X desires more insight into the possible outcomes of an investment, the likelihood of certain key risks occurring, and the impact of these risks via a quantitative method to analyse the key risks. We have achieved this by creating a simulation model and a scenario analysis tool that enables Company X to quantify the probabilities and impacts of the key risks on their investments as well as the overall profitability in terms of the Key Performance Indicators (KPIs) of their investments.

In order to quantify the key risks faced by Company X, we created a Monte Carlo model and a scenario analysis tool. This is done by first identifying these risks, the current KPIs used to measure the potential performance of an investment, and the relevant variables and parameters used in determining these KPIs. We have identified the following key risks: *political risk, liquidity risk, valuation of investment property, credit risk, interest rate risk, development risk,* and *vacancy risk*. We have measured the impact of these using the NPV, and the KPIs currently used by Company X, which are the BAR, NAR, and both the unleveraged and leveraged IRR. After having identified the key risks and the relevant KPIs, we have reviewed the available literature to gain more insight and to determine which quantification methods and risk indicators to use in order to quantify the key risks.

The literature review led to the decision to create two methods of quantification for Company X, a Monte Carlo simulation and a scenario analysis tool. The Monte Carlo simulation model is useful for finding the likelihoods of the risks occurring and estimating the bounds between which each KPI and each relevant variable will lie. The scenario analysis tool is complementary to the Monte Carlo model in the sense that the model can be used to find the risks with the highest likelihood, after which the tool can be used to determine the impacts of the key risks occurring on the KPIs and the general profitability of an investment.

In order to measure the risks, certain indicators are used, namely the Value-at-Risk (VaR) and the volatility. These indicators can be measured for each simulated variable, as well as each KPI. We have used the VaR to determine the worst outcome per KPI or variable in α% of the scenarios, where α is the confidence level. We have also measured the volatility for each simulated variable and each KPI. The volatility helps Company X in determining the variables that have the biggest swings in value, indicating the overall risk level of these variables. These risk indicators, alongside other statistical values are used in determining the likelihood and impact of each key risk.

After having determined which quantification methods and risk indicators to use, we have designed and created the model and tool. The Monte Carlo model consists of a risk dashboard and the simulation of a large number of scenarios. The model simulates the scenarios by generating random values for all relevant variables using their respective distributions, it also incorporates the correlations between these variables using a Cholesky decomposition and quantile mapping. We then use the simulated values for the variables to determine the KPIs for each scenario. All these scenarios are then analysed and evaluated in the risk dashboard. The risk dashboard assists Company X in their decision-making process regarding new investments and projects, which it does by giving the user insight into the likelihood of each key risk occurring; the VaR and volatility of the KPIs and variables; and the overall profitability of the investment.

The scenario analysis tool complements the Monte Carlo model (including the dashboard) by further analysing the key risks that are most likely to occur. The stakeholders at Company X can fill in the values for each variable, alongside additional factors such as the complexity of the project, the quality level of the project and the amount of years the investment will stay in their portfolio. The stakeholders can alter the values corresponding to the key risk they want to analyse to determine the impact on the KPIs and overall profitability of the project. This tool assists Company X in their decision-making process by letting the stakeholders quickly find what happens when changes occur in the variables and parameters of an investment.

After having tested the Monte Carlo model on historical projects, it became clear that the model is able to identify which variables have the highest impact on the profitability of an investment, and which variables are mostly responsible for the highest risks. The model showed, for instance, that in the case of this project, the indexation had the highest probability of falling below its desired level, however, the highest impact on the profitability was caused by a rise in interest rates. This information can help Company X in making decisions regarding their investments, such as hedging for high interest rates by investing in interest-rate derivatives, which could (partially) remove the danger of interest rates increasing more rapidly than expected.

The main objective of this thesis is to quantify the key risks involved in Company X's operations. Which we achieved by creating a Monte Carlo model and a scenario analysis tool which enable Company X to estimate the likelihood of the key risks, the bounds in which the KPIs and relevant variables lie, and the impact of the key risks on the KPIs and overall profitability of a project or investment. The model and tool are complementary to the intuition and experience of Company X in their decision-making process, which was a personal goal during this research as well as a desire of Company X. During the research, it became apparent that the intuition and experience of the people at Company X is crucial in the success of Company X, which is why the model and tool allow for this intuition and experience to be, not only included, but necessary in the risk analyses of each project or investment.

List of Tables, Figures, and Formulas

List of abbreviations

BAR	Gross Initial Yield (Bruto Aanvangsrendement in Dutch)
DCF	Discounted Cash Flow
GBO	Useable Surface Area (Gebruiks Oppervlakte in Dutch)
GRR	Gross Revenues earned via Rent
IA	Investment Amount including purchasing costs
IRR	Internal Rate of Return
KPI	Key Performance Indicator
LTV	Loan-to-Value
MARR	Minimum Attractive Rate of Return
NAR	Net Initial Yield (Netto Aanvangsrendement in Dutch)
NPV	Net Present Value
NRR	Net Revenues earned via Rent
PDF	Probability Distribution Function
ROI	Return on Investment
VaR	Value-at-Risk
VAT	Value-added tax
WACC	Weighted Average Cost of Capital

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1 Introduction

Risk management has been utilized by businesses and entrepreneurs for a long time, it allows for insight into the possible losses and gains in term of revenue, as well as the likelihood of certain cost-inducing events occurring. In this research, we create a risk management model and tool using literature, expert opinions and programming in order to improve the risk management at Company X. We use risk indicators such as the volatility and the Value-at-Risk, and Key Performance Indicators (KPIs) such as the Net Present Value and the Internal Rate of Return to determine the likelihoods and impacts of key risks faced by the stakeholders at Company X.

The founder and former director of Company X always said that he does not make decisions based on how much revenue an investment can make, but based on how much could be lost when the investment fails. This way of thinking is very much in line with risk management, where it is important to understand what can be lost as a result of certain decisions. However, the reality is that it is often impossible to exactly calculate how much can be lost, which leads to the problem of uncertainty. This is where risk management comes in, since it offers tools and theories that help manage the uncertainty in investment decisions. This contributes to one of the main goals during this research, namely creating a model that can estimate the under- and upper limits of an investment in terms of revenue by using measures such as the Value-at-Risk. The next main goal is then to determine the impact of a key risk occurring by creating a tool that lets the stakeholders analyse scenarios in which these key risks occur. Achieving these goals help the stakeholders in their investment decisions by combining the current literature on risk management and the residential real estate market with the experience and intuition of the stakeholders at Company X.

This chapter serves as an introduction. First, we will give some background information on the company, then we will discuss the motivation for this research, and finally, we will give additional information on the stakeholders, the methodology, and the final deliverable.

1.1 Company background

Company X is a Dutch company, primarily focused on real estate development and investment. Company X invests in real estate, as well as the (re)development of real estate on bought land or of bought properties. Most real estate development projects are carried out in collaboration with Company Y, a large construction company in the Netherlands. Company X are the main shareholder and owner of Company Y.

In 2019, 75% of the investments of Company X comprised of residential real estate. The company mainly operates in the Netherlands and in Germany. Company X is a large company with a total portfolio value of roughly [redacted] euros and a Return on Investment of about [redacted] in 2019.

Company X is keen on developments in the housing market (both Dutch and international), and they are pursuing a goal of improving their risk management. Company X is currently revising their risk management policies and protocols, and need further quantification of the key risks they face in their operations, which is what motivated Company X to have a research conducted into this matter.

The main sources of income for Company X are project development and investments. Here, project developments comprise of purchasing land and then developing residences, apartment buildings, or offices for instance. These developments, when finished, generate a stream of income (mainly via rent). Investments are described by creating a portfolio consisting of real estate, like existing residences, apartment buildings, or offices for instance. These immediately become assets of Company X, and are then either renovated, rebuild, or added to the portfolio to generate a stream of income.

1.2 Motivation for research

During the first meeting with the stakeholders of the problem, it became apparent that the risk policy Company X usually carries out, stems from intuition, cash flow prognoses and market data. The company is aware of the risks involved in the area in which it operates, which is stated in their annual report, however, these risks are only described qualitatively.

Company X already split up the identified risks into four groups: Strategic risks, Financial risks, Operational risks, and Compliance risks. Company X worries that the risks in these groups are not yet analysed enough when making decisions about investments and developments. More about these risks, and how Company X currently deals with these risks can be found in Chapter 3.

So, to ensure a more in-depth analysis of the risks in a new project or investment, Company X has presented me with the assignment to quantify the most important risk measures, and to then create a model which quantifies these risks with the use of risk indicators and display them in a clear manner. This can be boiled down to the following action problem, as viewed by Company X:

"The risks involved in Company X's operations are not quantitatively analysed."

1.3 Problem context and the core problem

In order to establish a definite core problem to solve during my research, it is important to first identify the problems that are present in the organisation.

To determine what should be done to improve the risk management policy of Company X, a problem cluster is made, which is a network of problems and the relationships between them. The cluster consists of action problems, which are defined by Heerkens & van Winden (2012) as *"discrepancy between the norm and reality, as perceived by the problem owner"*. In this cluster a potential core problem can be identified by looking for the problems that do not have any clear cause (Heerkens & van Winden, 2012). However, in the case of Company X, there are no real problems in this part of their operations, however, there are opportunities for improvement.

So, instead of creating a problem cluster, we create an improvement cluster. Here the different areas of improvement will be stated and the causal relationships will be indicated through a network, similarly to a problem cluster. This will still identify the core of the cluster that is not directly solved by any other areas of improvement. This main point of improvement will then be regarded as the "core problem" of this research.

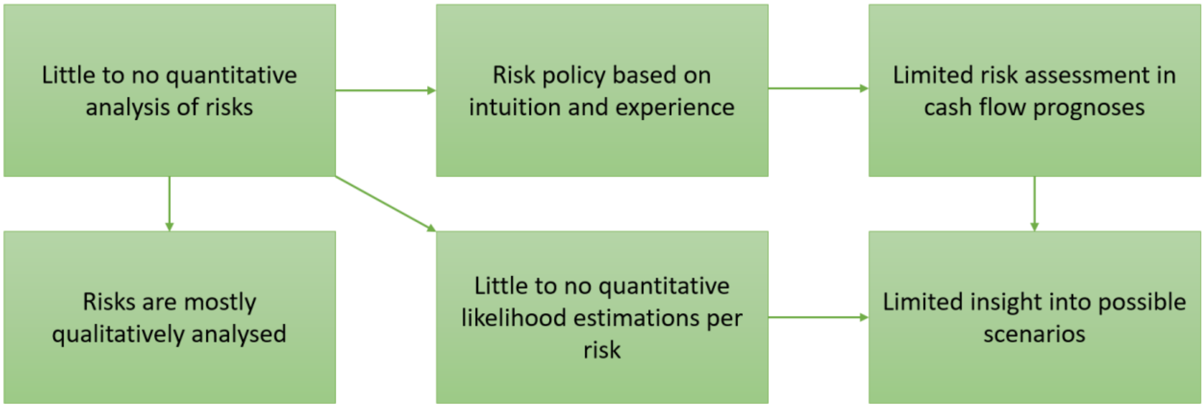


Figure 1 – Improvement cluster for the risk management policy of Company X.

So, as can be seen in Figure 1, there is a clear core problem that causes the points of improvement present at Company X, namely that there is little to no quantitative analysis of the risks. Company X does analyse the risks involved in their investments, however, this is done mostly via qualitative analysis and intuition. We further describe how Company X specifically handle these risks in Chapter 2.

This core problem causes three points of improvement, the first being that risks are mostly qualitatively analysed, which is not necessarily a problem. However, by only qualitative analysing the risks, Company X makes it hard to get clear, numerical insights into the different scenarios that can occur during projects and investments.

The next point of improvement is that there are little to no quantitative likelihood estimations per risk, which causes a degree of uncertainty about the likelihood of certain events occurring, which can lead to unreliability in reserving capital for potential costs. The final point of improvement is that the risk policy of Company X is mostly based on intuition and experience, which is certainly not something that should be regarded as a problem. Company X has made a lot of good decisions regarding their investments and development projects, indicated by their overall return on investment (ROI) over the years. So, it can be concluded that this intuition that is used, should not be discarded. However, there is an opportunity to improve by including quantitative risk analyses into this policy, ensuring that decisions are also motivated with the use of the available data.

The core problem then indirectly leads to a limited risk assessment per project, meaning that there is more information to be known about the potential risks of a project. The point of improvement to which the core problem and the other points of improvement ultimately lead is that there is limited insight into possible scenarios that can occur. The insight is said here to be limited, indicating that there is certainly awareness within Company X about the possible scenarios, however, there is no clear model that represents these scenarios with data and calculations. A quantitative analysis of the risks during a development or an investment can be of great help when making decisions and when predicting future cash flows since it can give insight into the outcomes corresponding with certain scenarios, and it can help Company X manage their allocation of funds in the cash flows to be prepared for the costs that can arise during certain scenarios. So, a quantitative analysis of risks can improve the risk management of Company X.

The reality is that Company X can improve their decision-making strategies by gaining insight into the potential impact of the risks present in their operations. The norm which Company X aims for, is to have a quantitative view of the most important risks possibly influencing the current and future cash flows of their projects. We measure the key risks in this model using the Key Performance Indicators

(KPIs) that the stakeholders currently use for assessing projects, namely the Internal Rate of Return (IRR), the Gross Initial Yield (Bruto Aanvangsrendement in Dutch, abbreviated as BAR), and the Net Initial Yield (Netto Aanvangsrendemen in Dutch, abbreviated as NAR). These KPIs are used by management to make decisions regarding investments and development projects. In addition to this, we measure the Net Present Value (NPV) per project per m² of useable surface area (GBO) in order to gain more insight into the cash flow of a project and whether it is profitable or not.

Company X uses these KPIs as thresholds for accepting projects, they first determine the minimal acceptable value, and then calculate the actual value to compare these with each other. The IRR is defined as the rate of return that lets the present worth of the cash flows be equal to zero (Hartman & Schafrick, 2004). The IRR is often used to make investment decisions, where it is compared with the discount rate of a project, which is often indicated as the minimum attractive rate of return (MARR). If the IRR is greater than the MARR, the project is justified (Hartman & Schafrick, 2004). Company X similarly use the IRR for the decision of accepting an investment project.

The BAR and NAR represent the quotient of the first year's gross and net income and value, and are calculated by dividing the (gross and net) revenues earned via rent by the investment costs (Nelisse et al., 2004). These two variables are used by Company X in their decision making as well. When deciding whether to invest in a new project or not, the BAR and NAR should be above a certain threshold. This threshold can differ per project, we use it in the final model to check whether projects are still justified when certain events (related to key risks) occur.

1.4 Stakeholders

In this section we describe the stakeholders of the core problem in this research. The stakeholders are the people that will be directly influenced by this research, as well as people that will directly influence the research. The stakeholders in this research are as follows.

- Controller.
- Asset managers.
- Chief Executive Officer.
- Chief Financial Officer.
- Creditors of Company X.
- Commercial director.
- Director of project development.
- Project development team.
- Supervisor from the university.

These stakeholders all influence this research, since they will provide the necessary resources, as well as their view on the current state of risk management and the risks deemed most important. Stakeholders that will be directly influenced by the outcome of this research, are the people that will account for the key risks in their own analyses, or calculations.

1.5 Problem-solving approach and research design

In this section we describe the research questions needed to solve the knowledge problems faced in this research, as well as the reason behind the questions. The research questions are listed per chapter in which they are answered. We give the sub-questions belonging to each research question as well.

1.5.1 Current situation

In Chapter 2, which describes the current situation, we provide an answer for the following research question and corresponding sub-questions.

1 What is the current situation?

a) Which risks are relevant to Company X?
b) What is the current risk management policy?
c) What are the main operations of Company X?
d) What are the most important risks to this research?

Investigating the processes and corresponding data at Company X is crucial to understand where the improvement is needed, and what is needed to achieve this improvement. Therefore, we start with answering the mentioned sub-questions, which give a clear view of the current situation at Company X. We first find and state all relevant risks, and investigate the current risk management policy. Then we narrow the scope of this research by deciding on which part of the operations of Company X we are going to focus, and which key risks we take into consideration for the final model.

1.5.2 Key risks and quantification methods

Chapter 3 contains literature research on the key risks and suitable quantification methods as well as an elaboration on which methods and measures we use to create the final risk management model. In this chapter we answer the following research question, along with the corresponding sub-questions.

2 How can the key risks be quantified and modelled?

a) What is mentioned in the literature about the key risks relevant for Company X?
b) What quantification methods are suited for Company X, and what are their strengths and weaknesses?
c) Which quantification methods will be used in creating the model and how can these methods quantify the key risks?
d) How can the final model be tested for reliability and validity?

We answer the main research question by first answering the four sub-questions. The answer to the main research question helps create the model, which leads to the solution of the main core problem.

Sub-question 2a provides more in-depth information about each key risk as described in the literature. We derive the literature about the key risks from international papers, books, and articles revolving mostly around the key risks in a real estate environment or a financial environment. This consists of a definition, information on how it is measured, factors that influence this risk, and how this risk can cause potentially positive and negative effects on the BAR, NAR, NPV and IRR (the main indicators to assess a project or investment).

Sub-question 2b covers quantification methods and theories that are applicable to real estate development and investment. This includes general information on each method, as well as how the method works, what data are needed, and the strengths and weaknesses of each method.

Sub-question 2c revolves around the decisions of which quantification method(s) to use in order to assess the key risks and how to use these methods. It may be the case that certain risks need to be quantified with a different method than other risks. Also, this sub-question covers the purpose of each quantification method, for instance, a scenario analysis can be used to determine the impact of certain risks, whereas a Monte Carlo simulation can be used to assess the likelihood of a risk.

Sub-question 2d provides information on how the available data can be tested for reliability and validity. This includes information on what reliability and validity entails, information on the different methods and strategies concerning the testing, and why this is important.

1.5.3 Model design

In Chapter 4 and Chapter 5 we provide the necessary information on how to design the model in order to obtain a clear overview of all risks. We design the final model in close contact with the stakeholders, especially the stakeholders who are going to use the model. We do this to ensure that the stakeholders can easily use the model to their advantage. The following sub-questions help in answering the research question.

3 How should the final model be designed?

a) How can the key risks be analysed and compared to each other?
b) How can Company X use the final model to assess potential risks?

Sub-question 3a gives insight into how the risks can actually be compared to each other and how these key risks can be analysed. We answer this by determining the output of the model, and how this output can be clearly stated and illustrated. The idea is to create a dashboard featuring all relevant variables, parameters, and outcomes corresponding to the relevant risks.

We will answer Sub-question 3b by explaining how the model and tool can be used to analyse the impact and likelihood of the key risks, as well as how the relevant variables are generated in the model and how these lead (in combination with the KPIs) to the quantification of the key risks.

1.5.4 Discussion

Chapter 6 consists of the validation of the model, as well as the effect the model potentially has on the investment/development decisions on Company X.

4 What effect does the model have on the investment/development decisions of Company X?

a) Is the final model reliable and valid in assessing the key risks?
b) How can the final model be implemented at Company X?

Sub-question 4a gives insight into the reliability and validity of the model by using the testing methods as found in Chapter 3. This entails testing the model on historical data, as well as assessing the accuracy of the model based on this historical data.

Sub-question 4b entails the future implementation phase, where it is described how the final model can be implemented at Company X, and how the stakeholders at Company X can be guided during this process. The limitations and possible future improvement of the tool and model are also discussed in this section.

1.6 Final deliverable and goal of this research

In order to let Company X gain more insight into their risk management and into the risks that occur with the start or purchase of a new project/asset, we provide them with a model that quantitatively displays the most important risks. This is done with the use of theories found in the literature, data obtained from stakeholders, and with the use of Excel and its build-in programming tool VBA (Visual Basic). We have chosen to use Excel and VBA since Company X currently makes almost all its estimations and calculations regarding investment decisions using Excel.

The idea is to design a model that needs input data from a new, current or old project in terms of cash flow statements and market data in order to calculate the key risks involved in an investment or project. To do this, we first describe the current situation regarding available data and Company X's risk management policy (which is done in Chapter 2), and then we find the suitable theories and methods to manipulate, process, and use the data, which is done in Chapter 3. After this, we design the model using Excel and its built-in programming language VBA, how this is done can be found in Chapter 4 and Chapter 5. This then results into an overview of the most important risks. To ensure reliability and validity of this final tool, we perform sensitivity analyses, as well as statistical tests, if needed and possible.

The tool also incorporates a learning effect, where more data gathered by future projects further enhances the validity of the risk assessment. This is because future projects give increasingly more insight into the different scenarios that can occur. When analysing these scenarios with the use of quantified risks, the analyses will become increasingly efficient in predicting the outcomes of future events.

Currently, Company X uses a buffer of capital in their cash flows to cover potential losses. This buffer is based on intuition and the known aspects of the project/investment, also, it is not clearly stated as one item in the prognoses, it is incorporated when estimating the variables in the cash flow by altering the estimations to more "safe" levels. This means that the estimated values of the variables are altered in such a way that they can cover disappointing scenarios, for instance, the building costs are expected to be roughly €3 million, so, to enable some setbacks to occur during the building process, the building costs in the cash flow are set to €3.1 million. This buffer covers the losses that are expected to occur, rather than extreme losses. To help improve the reliability of this buffer of capital, it is needed to support the intuition of Company X. We attempt this by delivering a model which quantifies the key risks, estimates the likelihood of these risks, and which can display the potential outcomes in terms of profits/losses of multiple scenarios.

The goal of this research is to provide a model which supports Company X in their decision making process regarding new investments via quantitative analyses of the key risks by determining the likelihoods and impacts on the KPIs (NPV, BAR, NAR, and IRR).

2 Current Situation

In this chapter, we describe the current situation by giving an overview of the current risks, analysing the already available data, and stating the current way of dealing with risks. By doing this, we answer the first research question: *"What is the current situation?"* In Section 2.1 we give an overview of the current risks; in Section 2.2 we discuss the available data and give an analysis of historical projects with regard to the key risks; in Section 2.3 we discuss the operations of Company X; and in Section 2.4 we select the most important risks to Company X.

2.1 Overview of the current risks

In order to understand the current position of Company X regarding their risk policy, it is important to first get an overview of the risks already identified.

Company X mentions most of their risks in their annual report. We have taken these risks as a starting point in defining the key risks. Company X divides their known risks over four types, as shown in Table 1.

Table 1 – Overview of risks per risk group.

Strategic risks	Financial risks	Operational risks	Compliance risks
Product risk	Liquidity risk	Vacancy risk	Reputational damage
Sensitivity to cyclical movements	Valuation of investment property	Data security	
Political risk	Credit risk		
	Interest rate risk		
	Development risk		

As can be seen in Table 1, the risks as viewed by Company X can be divided into four groups: *strategic*, *financial*, *operational*, and *compliance*. The *strategic risks* comprise of risks that can have an impact on the feasibility of Company X's strategic objectives (Company X, 2019). The *financial risks* are related to financing, the financial result, the financial stability of partners, and tax-related risks (Company X, 2019). The *operational risks* involve unexpected developments that can negatively impact internal processes, employees, clients, and systems (Company X, 2019). And finally, *Compliance risks* are all matters that could negatively impact the reputation of Company X (Company X, 2019).

Currently, most of these risks are dealt with by following intuition. However, there are some risks that are already somewhat quantified. Company X estimates their future cash flows for each project, incorporating the time in which the asset is kept in their portfolio to generate profit, also known as the exploitation phase. Before an asset can be exploited, it needs to be developed, which is done during the development phase, during this phase, Company X tracks and estimates the equity risk and profit risk, which they currently want to replace with the mentioned risks in Table 1. This is done in order to monitor how the projects are doing and to be able to recognize failing projects early.

We define equity risk as the amount of equity that can be lost, and profit risk as the amount of profit that can be lost. These are risks that mainly indicate the state of the current projects with regard to the phase in the construction process, and how much of the invested capital can still be lost. The risks decrease in value when the projects reach further phases. Although this is very useful for the company, this can be improved in my opinion. The impact on profit and equity should still definitely be considered as measures, however not as key risks.

In order to estimate the future worth of an asset, Company X assumes a life span of 10 years for each asset and they assume that the asset value increases with the Dutch inflation rate. The second assumption is questionable, since the purchasing power of consumers might not be strongly correlated to the value of houses in the Dutch market. More research into this should be done by conducting a market research. How this can be done will be further discussed in the Discussion chapter of the thesis.

The assets in the portfolio are funded with a mix of own capital and loans from banks. The mix is estimated by the stakeholders to, on average, be 40% own capital and 60% loans. This type of funding, like almost any type of funding, bears risks. These risks involve *product risk*, *liquidity risk*, and *political risk*. We give more information on these risks as well as the regulations and laws Company X deals with in Chapter 3.

In order to narrow the scope of this research, we focus on the Dutch assets and projects in the portfolio of Company X.

2.2 Available data and current risk management policy

Company X collects and uses data in order to make prognoses and to monitor projects and assets. The data useful for this research can mainly be found in the cash flow prognoses and the recalculations of projects. The cash flow prognoses give important data about the costs and revenues in total and per year, split up in different cost/profit items to ensure it is known what affects the cash flow and how. The data in these prognoses also contain assumptions, which include but are not limited to: yearly rent; indexation; future worth and lifespan of an asset; and vacancy rate.

2.2.1 Data identification and description of cash flows

The cash flow prognosis uses the available data and assumptions made as input for estimating the BAR, NAR, and IRR, and it also gives indications on the future costs and revenues per year, as well as return on equity, and loan payments.

The recalculation of projects consists of the factual data obtained after the project has finished. This mainly consists of data on how the assets were developed, including the actual costs and revenues, rent, and market value of the asset. With the data obtained from the recalculation, the prognosis made at the start of a project can be compared to the realised values of the KPIs. The predicted BAR, NAR, and IRR, as well as the costs, revenues and other data can be compared to their actual values, indicating whether the assumptions and predictions made were accurate or not, and whether the final result is acceptable or not. Whether this is possible during the time span of this research depends on the availability of these data and the amount of past projects and investments that have been recalculated. We use these data in Section 2.2.1 to analyse historic projects in order to get a view of the accuracy of Company X’s prognoses, and we use it in Chapter 6 to validate the final model.

Before the actual analysis can be done, it is important to determine how we calculate the key values in project valuation, the BAR, NAR, and IRR.

Gross Initial Yield (BAR)

We calculate the BAR in the same manner as described by Nelisse et al. (2004), namely by dividing the gross revenues earned via rent (GRR) by the investment amount including purchasing costs (IA), as depicted in Formula 1.

$$BAR = \frac{GRR}{IA}$$

Formula 1 – Calculation of BAR.

So, to calculate the BAR, we need to first determine the GRR and IA. The GRR is found by assuming a value for the monthly rent price per square meter useable surface, and then multiplying this with the total useable surface in square meters for the whole building. This gives the theoretical GRR per month, which when multiplied with 12, gives the yearly theoretical GRR. To find the GRR needed for the calculation of the BAR, we made an assumption regarding the vacancy rate of the building. The vacancy rate is the percentage of residences that are vacant, meaning that these residences will not earn any revenue for Company X. After multiplying the yearly theoretical GRR with 100% - vacancy rate, the GRR needed for the calculation of the BAR is calculated.

The IA is comprised of all purchasing costs and the final purchasing sum. Here the purchasing sum is the price of the investment, which is already known at the time of the prognosis. The purchasing costs comprise of the extra costs faced, such as taxation costs, acquisition costs, and the costs of upgrading the investment to the standards of Company X. These costs are mainly known at the time of prognosis, however, the purchasing costs can deviate from the prognosis when the costs of upgrading the investment turn out higher than expected due to miscalculations.

Net Initial Yield (NAR)
We calculate the NAR similarly to the BAR, namely by dividing the net revenues earned via rent (NRR) by the investment amount including purchasing costs (IA), as shown in Formula 2 (Nelisse et al., 2004).

$$NAR = \frac{NRR}{IA}$$

Formula 2 – Calculation of NAR.

The difference between the BAR and NAR is that we subtract the exploitation costs and the vacancy rate from the GRR. These exploitation costs consist of for example maintenance costs, contributions to the owners association, property tax levy (extra tax on the renting out of social housing) and management costs. The exploitation costs are mostly known when the prognosis is made. However, certain fluctuations can occur due to i.e. calamities raising the maintenance costs.

Internal Rate of Return (IRR)
We calculate the IRR in the same manner as described by Hartman & Schafrick (2004), namely as the rate of return that lets the present worth of the cash flows be equal to zero. To calculate the IRR, the total cash flow is determined first, after which we calculate IRR by determining for which rate of return the present worth of the total cash flow is equal to zero. The total cash flow consists of multiple streams of revenues and costs, where we calculate the total revenue (or costs) per time period. The time periods consist of one year each, and the total life span of each investment or project is assumed to be 10 years in the cash flow prognoses.

The first time period (year 0) consists of the private equity needed to fund the investment or project. This depends on the investment amount including purchasing costs (IA) and the amount of capital borrowed from the bank (debt). The ratio between equity and debt for the funding of an investment or project is called the Loan-to-Value (LTV). The LTV is known when the cash flow prognosis is made, and is of direct influence on the interest to be paid to the creditor (bank).

From year 1 to 9, the streams of revenue consist of multiple items, it starts with the net revenues earned via rent (NRR), calculated in the same manner as for the NAR. After this, we subtract the interest that needs to be paid in the specific period. The interest to be paid to the bank firstly depends on the interest rate, which consists of the risk-free rate and a spread determined by the bank and established in the contract. We use a fixed interest rate for the whole lifespan of the investment, which is the case for most investments since it is usually established in the contract with the creditor. The interest to be paid is also dependent on the amount of debt, which is decided by the IA and the LTV. The amount of debt to be paid in the beginning and the end of the period is then averaged and multiplied with the interest rate, which subsequently gives the interest to be paid. The interest rate is usually fixed during the lifespan of a project. Also, the cash flow consists of multiple additional costs per period, such as maintenance costs, service costs, renting costs, management costs, and other exploitation costs.

After having subtracted the interest from the NRR, it is time for the corporate tax and the Value-Added Tax (VAT). The corporate tax rate for Company X is currently equal to 25%, as dictated by the Dutch government. So, every period, Company X has to pay a corporate tax of 25% of the revenues earned before tax. The VAT over the investment in an asset, which is 21% of IA, is to be paid and the VAT over the additional expenses of Company X are written off.

After we have subtracted the taxes from the NRR as well, the final subtraction will be the repayments to the bank. These repayments are done every period and remain the same over every period. We calculate the repayments by multiplying the original amount borrowed by the bank (original debt) with a repayment percentage determined by Company X. This repayment percentage usually does not change, however, there are situations where Company X or the bank finds it obligatory to lower or raise this repayment percentage, i.e. when breaches of contract occur.

What remains of the NRR after the subtraction of the interest, the corporate tax, and the repayments, is what makes up the revenue stream of the corresponding period. In order to account for inflation and other increases, we have incorporated an index in the cash flow. For all revenue and cost streams, except tax, interest and repayments, the amount of the revenue/cost stream per period is multiplied with 100% + index (in %), which leads to a compounding effect. The value of the index is an assumption, usually based on the inflation rate in the Netherlands.

For the final period (year 10), there are additional revenues and costs next to the same stream of revenues and costs as in the previous periods (year 1 to 9). These additional revenues and costs consist of the revenue of selling the investment/project, and the final payment of the outstanding debt to the bank.

The revenue of the sold investment/project is dependent on the future market value, IA, and the tax rate of the asset, which is a percentage of the surplus in value of the asset at time *t* compared to the value at time 0. We have calculated the revenue of selling the asset using Formula 3.

$$Revenue\ of\ selling\ an\ asset = Market\ Value - (Market\ Value - IA) * Tax\ rate\ surplus$$

Formula 3 – Calculation of revenue of selling an asset.

Here the current market value of the asset is known before the prognosis is made, this is decided through taxation of the asset by a third party. We have estimated the growth of the market value of the asset intuitively, mostly by analysing the current housing market and market forecasts made by third parties. We then determine the future market value, as used in Formula 3, by factoring the current market value with the growth of the market value per year for 10 years.

The final payment of the outstanding debt to the bank is comprised by the amount of money that Company X still owns the bank. So, this is reliant on the LTV, the original amount of capital loaned from the bank, and the repayment percentage. Figure 2 shows the final cash flow, containing the initial investment, net earnings per year, selling price after tax, and the final payment of debt.

EQUITY RETURNS: LEVERAGED											
Equity contribution	-18.132.330										
Dividend Paid Out		316.970	364.334	412.878	462.640	513.655	565.961	619.597	674.603	731.020	788.891
Revenue from sales after taxes											60.254.440
Remaining debt after 10 years											-23.074.096
Cumulative Cash Flow	-18.132.330	316.970	364.334	412.878	462.640	513.655	565.961	619.597	674.603	731.020	37.969.235
IRR leveraged	**9,53%**										

Figure 2 – Cash flow of leveraged returns.

Company X uses the final cash flow as shown in Figure 2 to determine the leveraged IRR, which means the IRR of the total cash flow including taxes and financing costs. We determine the unleveraged IRR as well, which includes only the operational costs of an investment. This means that the unleveraged IRR is not influenced by potential financing risks, such as changes in interest rate. Company X mainly uses the leveraged IRR as an indicator of an assets' profitability, since this reflects the real world more accurately. Company X compares the leveraged IRR of an investment to their Minimum Acceptable Rate of Return (MARR), which is currently set to 8%. This means that the leveraged IRR of an investment should be at least 8% in order for an investment to be accepted. Company X determines the MARR via intuition, experience, and market research, where management decides which MARR to use according to their investment strategy.

The MARR can also be determined by setting it equal to the Weighted Average Cost of Capital (WACC), which can be calculated using the Cost of Equity and Cost of Debt needed to fund an investment (Sullivan, et al., 2013). However, Company X does not utilize this rate, they choose the MARR according to their strategy, as well as their intuition and experience derived from past investments.

Relevant variables

After we have determined how the most important performance indicators (BAR, NAR, and IRR) are calculated, we can identify the variables that influence these indicators. These variables, along with the indicators they influence, are shown in Table 2.

Table 2 – Overview of relevant variables in relation to the key performance indicators.

Variable	BAR	NAR	IRR
Rent	Yes	Yes	Yes
Vacancy rate	Yes	Yes	Yes
Purchasing costs	Yes	Yes	Yes
Exploitation costs	No	Yes	Yes
Loan-to-Value (LTV)	No	No	Yes
Interest rate	No	No	Yes
Repayment percentage	No	No	Yes
Index	No	No	Yes
Rise in market value	No	No	Yes
Complexity of project	Yes	Yes	Yes

All variables shown in Table 2 are subject to changes after the prognosis has been made, which makes these variables relevant to the possible riskiness of an investment or project. The variable on the bottom line of Table 2 covers the complexity of a project. This variable indicates whether a project is prone to errors during its development phase or during the refurbishment of an asset. We define errors as problems or calamities faced during building activities that lead to higher costs than expected, caused by, for example, the quality of land, the location, or unique building designs.

We describe how these variables are taken into account when quantifying the key risks in Chapter 4 and Chapter 5.

2.2.2 Current way of dealing with risks

Company X mainly deals with their risks via intuition and experience from past projects/investments. Company X makes use of the cash flow prognoses as described earlier as well as the recalculations of previous projects and investments to decide whether or not a project or investment should be accepted. This decision mainly relies on the values for the BAR, NAR, and IRR as well as the overall appeal of the project/investment regarding i.e. demographic aspects, market outlook, and the current state and diversification of their portfolio.

Company X acknowledges risks in larger projects and investments by qualitatively stating the risks and colour-coding these based on the severity of these risks as perceived by the stakeholders, where a severe risk is described as a risk with a large impact on the ROI or a risk with a very high likelihood of occurring. If Company X finds that a risk is particularly high, they will brainstorm about the worst-case scenario in terms of costs, for instance, a scenario in which certain permits may not be obtained. These scenarios are usually thought of and analysed during meetings between the stakeholders where they discuss whether or not to invest in a certain asset. The calculations done during this analysis are mostly done by hand and with intuition, where experience is the main driver of determining the worst-case scenarios. There is an upside and a downside to this, the upside is that experience and intuition are a very powerful way of estimating which possible scenarios there are, however, the downside is that it is more prone to small errors and it is not time-efficient.

Also, the real estate market is not an easy-to-predict market, especially during crisis times (van Dalen & de Vries, 2015). This is due to the non-efficiency of the real estate market caused by buyers and sellers not always having access to the most actual market information, which increases difficulty in the pricing of assets (van Dalen & de Vries, 2015). Also, due to the regulations in the housing market, as well as the limited amount of land available for housing, there is an inelastic supply which has a delayed reaction on the demand (van Dalen & de Vries, 2015). All this leads to a market that is hard to predict based on numbers alone, especially in times of crisis where housing prices differ a lot. Because of this relatively unpredictable market, it is important to incorporate the intuition and experience of the stakeholders at Company X in the final model. However, a model that can estimate and quantify the impact and likelihood of the key risks can certainly assist in the decision-making process of Company X.

Company X only determines the worst-case scenarios for projects and investments which show severe risks, meaning that there is a possibility that undervalued risks lead to high costs due to Company X not being prepared for them. This is also a reason for Company X to upgrade their risk management policy, quantifying all key risks for each project instead of only quantifying those that appear to be severe will lead to better protection against unforeseen costs, as well as a higher accuracy of the budget needed to cover potential losses.

The operational method Company X uses to cover for potential losses due to certain risks is incorporating a cost buffer in their cash flows, which consists of a certain amount of capital reserved per variable for covering losses due to risks. The accuracy of this unforeseen costs item is not yet at its desired level, as is shown in the analysis of historical projects. We attempt to improve this accuracy by quantifying the key risks and displaying them via the model as shown in Chapter 4.

2.2.3 Analysis of historical projects and investments

In this section, we make an analysis of historical projects and investments of Company X. In order to determine the current accuracy of the cash flow prognoses, we analyse 11 historical projects and investments by comparing the prognosis of these projects and investments with the realised results. To do this, we use the recalculation of each project or investment to collect the results, however, the recalculation reports do not contain data on all relevant variables, meaning that not all risks can be analysed. Also, due to confidentiality, we have replaced the names and locations of the projects by numbers (1 to 11). The following relevant variables and parameters can be compared with the use of the available data: *Purchase price; Unforeseen building costs; Purchasing costs; LTV; Income from rent.* Alongside these variables and parameters, we also compare the BAR per project, to get more insight into the overall expected and realised results.

In order to be able to compare the different projects and investments, we denote all relevant parameters and variables as a percentage. Also, next to the comparisons, we give the average discrepancies, these show which variables and parameters are on average the hardest to predict, and which are relatively easy to predict. Firstly, we create a graph of each found discrepancy as a percentage, which is shown in Figure 3.

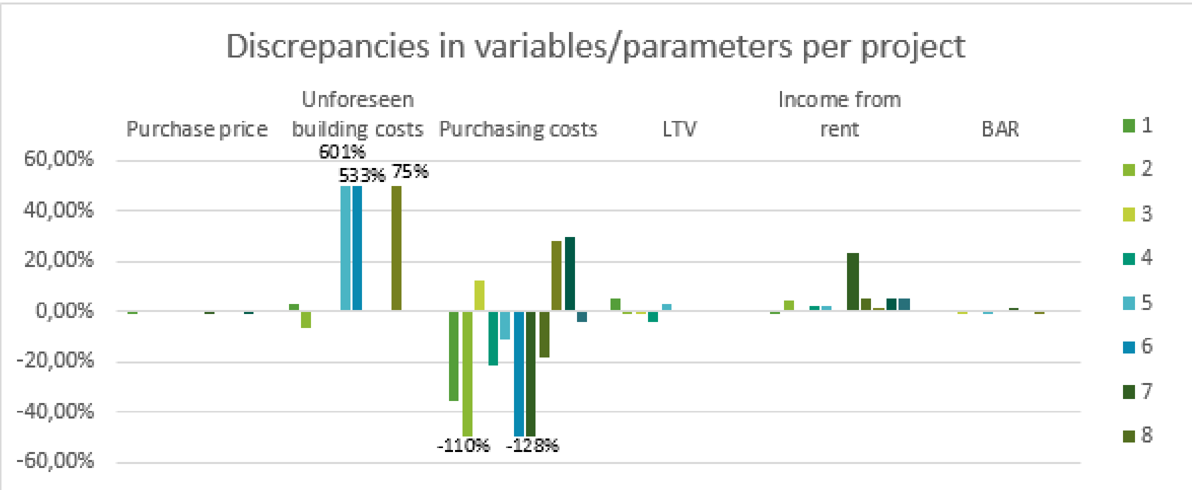


Figure 3 – Discrepancies in variables/parameters per project.

In Figure 3 , each colour represents a project, also, in order to maintain readability, we cap the extremely high percentages at 50%, their true percentage value is given above the corresponding bar in Figure 3. We have done this in order to keep the graph readable. The values we show in Figure 3 are relative values, meaning that it shows the difference between prognosis and reality as a percentage of the prognosis, the absolute discrepancies (in €) are shown in Table 3. So, as can be seen, there are multiple noteworthy discrepancies between prognosis and reality. Especially the *unforeseen building costs* and *purchasing costs* seem hard to predict, where the unforeseen building costs are usually higher than they appear to be, and where the purchasing costs appear to be lower than first expected. However, many of the other variables and parameters seem to be predicted with a high level of accuracy. In order to further analyse the differences between prognosis and reality, the average discrepancies per variable/parameter are determined, which we show in Table 3.

Table 3 – Average discrepancies per variable/parameter.

Variables/parameters	Average discrepancy (in €)	Average discrepancy (in %)
Purchase price	- € 262	0.12%
Unforeseen building costs	€ 244,298	241.01%
Purchasing costs	- € 213,092	- 28.06%
LTV	-	0.49%
Income from rent	€ 56,750	4.53%
BAR	-	0.20%

So, as can be seen in Table 3, the average discrepancies are in general not large, meaning that the prognosis appears to be accurate for most variables and parameters. However, there are two occurrences where this is not the case, the values for the predicted *unforeseen building costs* and *purchasing costs* items differ substantiality from the realised values. Especially the *unforeseen building costs* item is largely different from the expected value, namely 240% larger. As can be deducted from the graph in Figure 3, there are 3 instances where the *unforeseen building costs* are much higher than expected, meaning that in 3 of in total 11 projects and investments, a discrepancy in value of *unforeseen building costs* between prognosis and reality took place. This means that there certainly is room for improvement when it comes to predicting the *building costs* of projects, or upgrading costs of turn-key investments. However, when we look at the absolute differences in euros, as seen in Table 3, it becomes apparent that the predicted *purchasing costs* also differ notably from reality. Making scenario analyses using the final model could be of help in preparing for high *building costs* and *purchasing costs* by letting the stakeholders at Company X know what the impact of increased *building costs* and *purchasing costs* is.

The *purchasing costs* are being predicted with relatively low accuracy, resulting in an average discrepancy between prognosis and reality of -28%, meaning that the realised *purchasing costs* are on average 28% lower than the expected *purchasing costs*. Although this has a positive effect on the expected results and the KPIs, it is still undesirable to have large differences between prognosis and reality. This is because when the stakeholders at Company X create these prognoses, they reserve the capital needed to fund the project or investments, as well as for the payments that are needed, and the capital that is left can then be used to fund other projects and investments. So, when the amount of capital that is reserved for a certain project or investment is estimated to be larger than actually needed, fewer capital is left for other projects and investments, meaning that certain investment opportunities might be missed.

Also, 5 out of the 11 projects and investments have a higher difference between prognosis and reality than average, meaning that there is a high standard deviation, as well as a high degree of uncertainty in the estimates of the stakeholders at Company X. The final model will help the stakeholders at Company X with improving the accuracy of these estimations via the Monte Carlo simulation, which they can use to obtain the most likely values for the relevant variables and KPIs as well as an estimation of the likelihood that these values will go above desired levels according to its respective probability distribution, more information about how this is done can be found in Chapter 4.

Using Table 3 in combination with the graph in Figure 3, we also show that the other variables and parameters are well-estimated, since the averages of these are all within 1% except for the *Income from rent*, which is about 4.5% due to 1 outlier. Also, the BAR, which is an indication of yearly income, is estimated accurately, since the largest difference we observe between prognosis and reality is only 1.49%. This means that Company X is capable of closely estimating their cash flows, however, with the help of a model that quantifies the key risks, this accuracy can be improved even further, and furthermore, the impact of wrong estimations can be determined before they occur in reality.

2.3 Operations of Company X

To narrow the scope of this research, it is important that we first decide which part of the company's operations will be focused on. The alternatives here are to:

- Focus on the "turn-key" and project development investments;
- Focus on the project development phase;
- Focus on the decision regarding whether to keep or sell a developed project.

The first alternative is to focus on the "turn-key" asset and project development investments. Here, the turn-key asset investments are the investments in real estate that are purchased directly and then rented out in order to generate income. This is an interesting alternative due to the current state of the housing market, as well as the introduced rent ceiling in the Netherlands, which limits the maximum price of rent that can be asked by Company X for certain types of housing (such as social housing) and certain regions. Also, due to gentrification, a lot of housing prices in previously low-yielding regions are rising in value, meaning that "turn-key" investments currently hold lucrative potential. This alternative also considers the investments in project developments, where a decision should be made whether to develop a certain project, or not. This decision involves all future cash in- and outflows that can occur when developing a project, as well as possible fluctuations of the housing market, interest rate or inflation. It could be interesting to investigate this alternative in order to provide a decision-making tool for Company X to help with getting an overview of all potential worst-case scenarios, risks relative to revenue, and probabilities of certain events occurring. The project development investments in this alternative are also purchased turn-key, meaning that the plans, technical drawings, and sometimes permits are already made or bought by the selling party which delivers these in addition to the plot of ground on which the investment will be build. So, there is less of a building process as when a project is completely self-developed, such as in the second alternative, however, there is often an upgrading process, where the current plans are updated to fit the style of Company X. Also, this alternative focuses less on the process of building the asset and more on the cash flows of an asset.

The second alternative is to focus on the project development part of Company X. This option will most likely have the biggest impact, since the portfolio of Company X comprises mostly of self-developed real estate. However, the risks that are involved are hard to quantify, due to the complex and ever-changing properties of project development. There is no development process that is exactly the same, so, in order to quantify the risks, assumptions will be needed as well as subjective data collection methods, like surveys. This makes this alternative the hardest to realise.

The third alternative is to focus on the decision regarding whether to keep or sell a developed project. This decision is made at the end of the project development phase, where real estate is developed and a decision should be made whether to keep or sell this real estate. This decision relies on a lot of factors, including analyses of the market, demographics, cash flow projections, and risks. The risks involve, for example, liquidity risk, credit risk, interest rate risk, and vacancy risk. This alternative is interesting due to its importance to the company, since every asset in the portfolio has gone through this process, and every potential asset will need to go through this process.

In order to decide which part of the operations we will focus on, we approached several stakeholders. The stakeholders at Company X mentioned that to gain the biggest advantage, we should determine when certain risks occur, and how much of an impact these risks can have. The stakeholders and I were in agreement, that for this to be possible, it is necessary to focus on the investment phase of the operations. So, we will focus on the "turn-key" asset investments and project development investments.

We have chosen this part of the operations is chosen because when deciding whether to invest in a new asset or project, solid prognoses and analyses of both the new investment itself and the market are needed. Company X starts or buys several new projects and assets every year, so more insight into the present risks could help them make better choices regarding risky assets or improve the accuracy of the estimates regarding the future cash flows and BAR, NAR, and IRR. These insights will also be helpful when preparing offers for the assets or even the land on which a project will be carried out. Also, turn-key investments are better suited for a model, since cash flows have clear variables and parameters, and since it is much more predictable than a building process, which differs with each project. This, along with the preference of the stakeholders, led to the decision to focus on the turn-key asset investments and project development investments. The most important risks belonging to this phase of the operations are chosen, described, and motivated in Section 2.4.

2.4 Most important risks

In this section, we determine the key risks that will be modelled and analysed. This will be done in close collaboration with the stakeholders, they have given their expert opinion on each potential key risk, which led to the selection of seven final key risks. In order for a potential key risk to be modelled, it should first and foremost be a risk that is very relevant for Company X in terms of impact and likelihood. Also, Company X should be able to influence the key risk, meaning that Company X wants to be able to change their operations or undergo certain actions in order to mitigate the effects of a key risk.

As mentioned earlier, there are 4 groups of risks: *strategic*, *financial*, *operational*, and *compliance*, which contain a total of 11 risks which will be considered to be incorporated in the final model. In order to determine which of these 11 risks are not necessary to model, we have analysed each risk on its relevance to Company X, as well as its ability to be influenced. We carry out this analysis in collaboration with the stakeholders. The risks that will not be included in the final model are still of certain relevance to Company X, however, these risks are currently not in need of quantification. Table 4 shows the potential key risks divided per risk group.

Table 4 – Overview of potential key risks per risk group.

Strategic risks	Financial risks	Operational risks	Compliance risks
Product risk	Liquidity risk	Vacancy risk	Reputational damage
Sensitivity to cyclical movements	Valuation of investment property	Data security	
Political risk	Credit risk		
	Interest rate risk		
	Development risk		

The first risk is *product risk*, which involves the risk that the 'product features' of the real estate assets of Company X no longer match shareholders' wishes, meaning that the long-term funding could become inadequate (Company X, 2019). When this risk is high, it means that it is harder to obtain funding, due to the assets of Company X not being of a desired level of quality. Although this is an important risk to bear in mind, Company X believes that this risk is currently at the desired level, mainly due to the diversity of the portfolio, as well as the overall quality of the assets. Also, the funding of Company X's assets is based on long-term relationships with creditors as well as a significant amount of private equity, meaning that the likelihood of this risk becoming a problem is low. So, we do not incorporate *product risk* in the final model.

Sensitivity to cyclical movements is another risk from the *strategic* group. This risk involves the impact of fluctuations in the economic cycle to the results of Company X (Company X, 2019). Although this risk is certainly relevant for Company X, as well as impactful, it is seen as unnecessary to further quantify this risk. This is because the *financial* group of risks already cover fluctuations in market value of assets, interest rates, and other market instruments, meaning that an indication of the state of the market is already covered by the *financial* risks. Also, Company X believes that their sensitivity to cyclical movements is currently at their ambition, mainly since the portfolio of Company X is well-diversified and since Company X believes that operating in a competitive market always brings a certain sensitivity to cyclical movements of the market. So, we do not incorporate *sensitivity to cyclical movements* in the final model.

Political risk is the final risk from the *strategic* group, this risk occurs when changes in political policy or legislation have a direct effect on the result of Company X (Company X, 2019). This risk is of importance to Company X, especially due to the unpredictability of certain rules and legislations. Whilst many newly installed rules and policies are beneficial for the economy or nature, they can have negative effects on the results of Company X, for instance when permits cannot be obtained within the same time frame as usual, leading to longer lead times and more building costs. Also, Company X believes that they are not yet as prepared for regulatory changes as possible. A model which can estimate the impact of certain regulatory changes, as well as the likelihood would improve the ability of Company X to prepare for these situations, potentially saving costs. So, we incorporate *political risk* in the final model.

Liquidity risk is the first risk from the *financial* group. This risk involves the inability of Company X to pay for the funding obtained from creditors, for instance when Company X does not have the required equity to pay the bill of the bank that lent Company X the money needed for an investment. This risk is certainly relevant for Company X, since the impact of this risk is high. When Company X has trouble with paying the bills and fulfilling contractual obligations proposed by their creditors, it becomes harder for Company X to get funding, meaning it gets harder to make investments, also, the cyclical payments and loan premiums will become more expensive. Currently, Company X believes that their exposure to *liquidity risk* is well-managed and on a healthy level, the balance sheet ratios are good, and there is enough equity to guarantee constant availability of sufficient credit (Company X, 2019). However, due to the large impact of this risk when it occurs, Company X found that it was worthwhile to implement this risk into the final model, especially since the current COVID-19 pandemic has put strains on economies world-wide. So, we incorporate *liquidity risk* in the final model.

Valuation of investment property is the second risk of the *financial* group, which involves the fluctuations in asset value, mainly due to shifts in the market or over- or undervaluation. The value of

Company X’s assets is certainly relevant for Company X, as well as the likelihood of asset values dropping below desired levels. Assets that depreciate in value cause negative effects for the overall return of the portfolio, especially assets that were estimated to rise in value whilst they actually remain the same or even depreciate. Using a risk model that can determine the possible impact of fluctuations in asset value is very useful for dealing with these situations, Company X could then take this into account when determining a certain investment will be worthwhile or not, or maybe whether to keep or sell assets from their portfolio. So, we incorporate the risk *valuation of investment property* in the final model.

Credit risk entails the risk that market conditions cause solvency or continuity issues to arise at tenants, project developers, property managers or other suppliers (Company X, 2019). Due to the global COVID-19 pandemic and the current state of the economy, credit risk has become increasingly relevant. Although there are standardised processes within Company X that ensure that the creditworthiness of debtors is assessed properly, it is still beneficial for Company X to know what would happen if this risk were to occur, and how it can be dealt with. For example, if multiple tenants lose their jobs and thus face difficulties in paying rent and other expenses, Company X might see a dip in their results. In order to be prepared for these occasions, we incorporate *credit risk* in the final model.

Interest rate risk covers the risk that unfavourable interest rate changes negatively affect the results of Company X’s portfolio (Company X, 2019). We define the interest rate as the risk-free rate increased with a spread, which means that it is the amount of money to be paid as interest by Company X to their creditor. If the interest rates rise, Company X will be obliged to pay larger bills per period to their creditor, whereas rising interest rates will also affect the market, often causing lower prices of assets. When people find it harder to qualify for mortgages due to high interest rates, fewer people will be able to purchase housing. So, the effect of fluctuating interest rates is certainly relevant for Company X, since it affects the rent income, asset value, and the amount of money to be paid per period. This risk can be dealt with by assessing it with a risk model, where the impact of such fluctuations can be analysed beforehand, as well as the likelihood of certain shifts in interest rate. So, we incorporate *interest rate risk* in the final model.

Development risk is the fifth risk of the *financial* group, it involves the risk that the costs of developing assets, by either building, renovating, or upgrading to fit certain regulations and standards, turns out higher than expected. This risk is certainly relevant for Company X, since high development risk means that there is a larger chance that the development costs will turn out higher than expected, which negatively affects the return on that investment. Next to this, it is beneficial for Company X to know before developing a project what happens to the result when the development process takes a longer time, or costs more funding or equity. So, we incorporate *development risk* in the final model.

Vacancy risk is the first of the two risks belonging to the *operational* group. This risk covers the loss of income as the result of unplanned vacancy (Company X, 2019). Unplanned vacancy is of relevance to Company X, especially for the commercial sector, where it is not unlikely for an asset to be vacant for a period of multiple months. This, of course, has negative effects on the income via rent of Company X. However, it is not only commercial real estate that deals with vacancy, residential assets are also in risk of becoming vacant for a certain period of time. In order to determine the likelihood of vacancy, as well as the impact of a certain vacancy rate, it is important to model this risk. So, we incorporate *vacancy risk* in the final model.

The other risk belonging to the *operational* group is *data security*. This risk involves the risk of having confidential information end up in the wrong hands as a result of cybercrime or the failure of IT systems (Company X, 2019). This risk can be very impactful, however, Company X believe that raising awareness amongst employees and the numerous safety protocols are enough to keep this risk at their desired level. Also, it is very hard to model a risk such as *data security*, especially since the likelihood, as well as the potential impact of this risk is almost impossible to determine beforehand. So, we do not incorporate *data security* in the final model.

Reputational damage is the only risk belonging to the *compliance* group, and it is the final potential key risk. This risk covers the impact of unfavourable reporting on Company X in media or other channels, which damages the reputation of Company X (Company X, 2019). This risk can cause negative effects, since a bad reputation leads to trouble getting funding, as well as higher vacancy rates. However, according to Company X, the company policy in combination with the licenses and certifications owned by Company X is enough to have reduced this risk to an acceptably low level. Also, since it is not possible to model a lot of the factors that cause reputational damage, such as human error, we do not include *reputational damage* in the final model.

So, in total, we include seven out of the eleven potential key risks in the final model. These risks are further elaborated on in Chapter 3, and how these are incorporated in the final model be found in Chapters 4 and 5. An overview of the key risks is shown in Table 5.

Table 5 – Overview of the key risks.

Key risks
Political risk
Liquidity risk
Valuation of investment property
Credit risk
Interest rate risk
Development risk
Vacancy risk

3 Key risks and quantification methods

In this chapter we answer the main research question: *"How can the key risks be quantified and modelled?"* by answering the corresponding sub-questions using literature. In Section 3.1 we answer Sub-question 2a: *"What is mentioned in the literature about the key risks?"* This will help in finding relationships between the key risks and possible variables and parameters, it will also provide information on how these risks are usually managed and what influences them. In Section 3.2 we answer Sub-question 2b: *"What quantification methods are suited for Company X, and what are their strengths and weaknesses?"* which will provide relevant literature on possible methods of quantifying the key risks, as well as methods for modelling these risks. In Section 3.3 we elaborate on the chosen quantification and modelling methods that will be used in designing the final, answering Sub-question 2c: *"Which quantification methods will be used to create the model and how can these methods quantify the key risks?"* In Section 3.4 we give an answer to Sub-question 2d: *"How can the final model be tested for reliability and validity?"* which gives the necessary methods and techniques to ensure the reliability and validity of the final model. In this chapter we provide all necessary information and preparation to design the final model in Chapters 4 and 5.

3.1 Further explanation of key risks

In this section we provide information about the key risks identified in Chapter 2, including information on how the key risks are managed, what influences them, and how they affect the cash flow of real estate investment companies. We investigate the following key risks: Political risk, Liquidity risk, Valuation of investment property, Credit risk, Interest rate risk, Development risk, and Vacancy risk. In the final model, we quantify each key risk by letting them be represented by their relevant variables and parameters. So, for each key risk, we give and motivate the relevant variables and parameters, as well as the way in which these variables and parameters can indicate the level of risk. Many key risks in this model are affected by the interest rate, which we define as the risk-free rate increased with a certain spread, meaning that the interest rate is the amount of interest to be paid by Company X to their creditor(s). The interest rate used in the model and in calculations will also equal the risk-free rate increased with a spread, since this reflects the reality of real estate investments the best.

3.1.1 Political risk

The first risk we review is political risk. Political risk is described by Company X in their annual report as the risk of political policy or legislation directly influencing Company X's results in a negative manner (Company X, 2019). Examples of political risks are the impact of changing climate measures and issues with obtaining permits due to changes in legislation. Political risk is a rather abstract and broad concept, where many events can lead to a rise in political risk. A large political risk in this research is defined as an increased chance of a reduction in profit due to changes in political policy or legislation.

According to Lee (2001), political risks arise when worldwide, national, or local governments change certain rules and legislations under which businesses operate, often for reasons beneficial for regulating banking, improving the economic structure of a country, or for environmental reasons. This means that political risks arise when governmental institutions install these new rules or legislation causing businesses to be forced to adapt, often resulting in costs. These adaptations can affect the profitability, a business might, for example, be forced to improve their carbon footprint, causing an increase in costs and time. Another possible factor of adverse effects on the return of a business is due to penalties imposed by governments when breaking certain laws and regulation (Lee, 2001). These changes in rules and legislation are often based on environmental, social or economic reasons. These changes can be helpful in the long term, such as the Basel III accord aiming to enhance the safety and stability of the banking sector by introducing stricter definitions of capital (Shakdwipee & Mehta, 2017).

Lee (2001) also states that political risks are borne primarily by foreign investors, meaning that well-diversified international portfolios are often the most vulnerable to political risk. This is because political risks due to exchange rates, limits on the ownership of equity and debt, and differences in legislation are far more, if not exclusively, present in international portfolios. Also, regulations and legislature in the domestic market is shared with domestic competitors, meaning that companies with strictly domestic portfolios face the same difficulties in terms of political risk as their competitors.

Hainz and Kleimeier (2012) state that political risk is divided into three broad categories, namely: traditional political risk, regulatory risk, and quasi-commercial risk. Here traditional political risk covers risks related to expropriation, convertibility and transferability of money, and political violence (Hainz & Kleimeier, 2012). So, the severity of traditional political risk is dependent on the country in which operations are carried out. Since this research focuses on the Dutch portfolio of Company X, the country in which Company X operates is the Netherlands. According to Col and Errunza (2015), the risk of expropriation in the Netherlands is low compared to other countries, meaning that there is a low risk of measures taken by the Dutch government that will deprive Company X of its investments. Since Company X is a Dutch company and the focus is on their Dutch portfolio, there is no risk of problems regarding convertibility and transferability of money.

Regulatory risk is described by Hainz and Kleimeier (2012) as risks caused by regulatory changes, such as changes in investment laws or taxation, such as introduction of rent caps. These changes are often due to preceding events causing a need for intervention to protect the housing market from becoming inaccessible for certain income groups. Regulatory risks are very relevant for Company X, meaning that it is necessary for Company X to understand which scenarios can occur due to these risks and how the effects of these scenarios on the profitability of Company X can be constrained. Quasi-commercial risks arise when state-owned suppliers, customers or other involved parties become unable to fulfil contractual obligations (Hainz & Kleimeier, 2012). So, quasi-commercial risks can occur, for example, when the committee of a municipality involved in a project changes, resulting in possible reluctance towards the development of the project causing delays in the building process and thus a reduction in revenue earned via rent.

Political risk is most often measured with the International Country Risk Guide (ICRG) rating system. This rating system assigns risk points to a group of political risk components, which provides an assessment of the political stability of a country (Howell, 2011). The ratings given by the ICRG are dependent on the amount of points given per risk component, where there are a total of 100 points available over 12 political risk components (Howell, 2011). The amount of points scored by a country gives an indication of the political risk present in that country, where a low score means a high risk and vice versa.

In the final model, we will quantify political risk by letting it be represented by 4 relevant variables, as is shown in Figure 4. These variables are the duration of vacancy, the price of rent, the redemption percentage, and the Loan-to-Value (LTV) ratio. These are chosen since political risks often lead to higher redemption percentages and lower LTV ratios, since regulatory changes or environmental interventions can lead to lower trust of creditors, meaning that the creditors only give out smaller loans with larger yearly repayments. Also, political risk can often be noticed in the building process as a delay, where regulatory changes, especially due to environmental reasons, cause extra legislation or additional steps in the process. And finally, lower prices of rent are an indication of political risk, since local governments from cities or areas can introduce regulations based on the affordability of residences (such as rent caps), which lead to a forced decrease of price of rent. So, if political risks are high, this can often be noticed in the duration of vacancy, since it takes a longer time before the asset can be rented out, the price of rent, the LTV, and the redemption percentage.

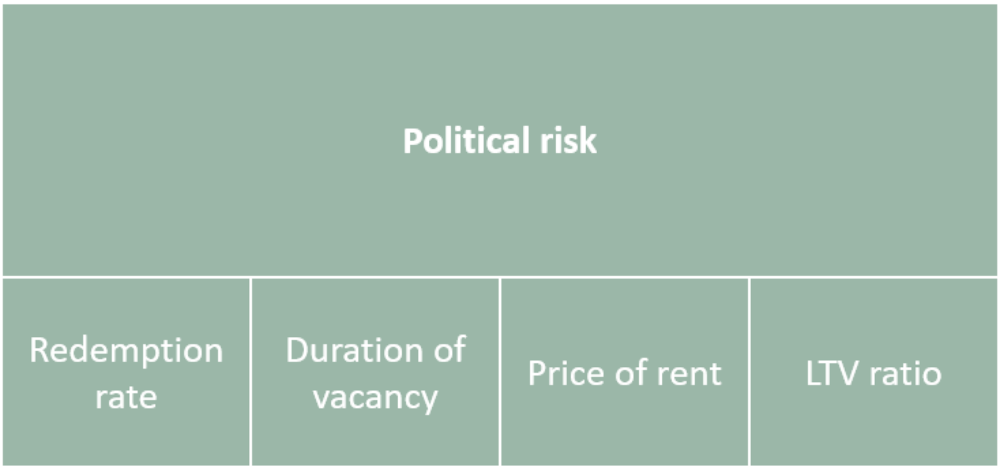


Figure 4 – Political risk and the variables that influence it.

3.1.2 Liquidity risk

The second risk we review is liquidity risk, which is described by Angbazo (1997) as the risk of not having a sufficient amount of cash or borrowing capacity to pay the required bills and other ongoing expenses, which means the company is forced to borrow emergency funds at excessive costs. So, liquidity risk is the risk of not having enough accessible funds to pay creditors, meaning that the company's overall position with regard to their creditors could deteriorate, leading to a situation where loans are harder to obtain, and premiums and cyclical payments become higher.

According to Zheng, et al. (2015), a market is liquid when a large quantity of assets can be sold quickly with limited impact on the price of the assets. So, an illiquid market is a market in which parties face difficulties when selling assets. The less liquid a market becomes, the longer it may take to sell the asset for its fair value, meaning asset owners might become interested in selling their assets for a lower price. Although it seems logical to determine the liquidity risk by using the time it takes to sell an asset, one should also consider the possibility that the price is set too low, meaning that the actual asset might not be as liquid as thought (Cheng, et al., 2013).

Liquidity risks can be affected by the liquidity of both the market and the asset, as well as the total liquid value of the assets that a company owns and the liabilities of a company. According to Brunnermeier & Pedersen (2009) market liquidity is the level of ease and speed with which assets can be traded and funding liquidity is the level of ease with which funding can be obtained from creditors.

The dangers of liquidity risk mainly involve not having a sufficient amount of income to pay the creditors, which can occur if, for example, Company X breaches the contract agreements made with the bank, leading to a situation where the bank demands the loan to be paid earlier whilst Company X cannot sell their assets quickly enough to generate the needed cash. However, Company X is a unique organisation in the sense that they are very liquid relative to their competitors, mainly due to the organisation being family-owned and thus having a lot of reserve resources in terms of liquid cash and assets. Since the real estate market is currently relatively liquid due to housing shortages, Company X currently has a low liquidity risk.

We represent liquidity risk by the variables interest rate, LTV ratio, and the redemption rate, as we show in Figure 5. A high liquidity risk leads to creditors (usually banks) to increase the LTV ratio and the redemption rate since they have a lessened trust in the ability of the organisation to repay the loan. This is often a result of increased interest rates, where the organisation has to pay a higher yearly fee to the creditor for actually getting the loan. Next to this, high interest rates causes lower asset values, since the purchasing power of potential buyers becomes lower, which leads to less liquidity of the real estate organisation since the selling of assets takes a longer time. So, a high liquidity risk is represented by a high interest rate in combination with a high LTV ratio and redemption rate.

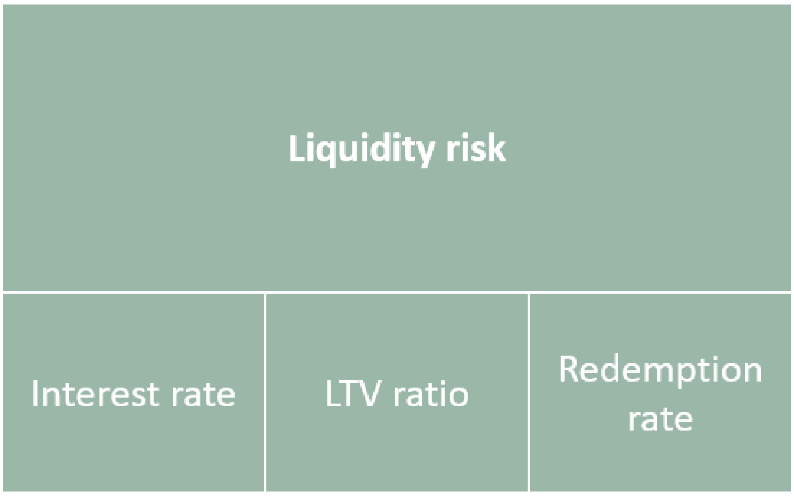


Figure 5 – Liquidity risk and the variables that influence it.

3.1.3 Valuation of investment property

The third risk is the risk of fluctuating asset values due to negative changes in housing prices or the over- or undervaluing of assets, which lead to negative effects on the profitability of investments and projects and/or misreported returns. According to the annual report of Company X, these situations lead to sales decisions that are based on incorrect data (Company X, 2019). According to Boelhouwer (2017), there are two types of explanations for an increase or decrease in house prices, namely speculative and fundamental.

As described by Boelhouwer (2017), changes in asset prices due to fundamental reasons are objective, these cover for instance the effects of fluctuations in wages, interest rates, and demographic developments. Changes due to speculative reasons are subjective, meaning that these changes are caused by people expecting certain events to happen in the future (Boelhouwer, 2017). An example of a speculative change in asset price is the increase of house prices due to house owners thinking that house prices will rise in the future. These speculative changes are the most important in terms of risk management, since these are more unpredictable and variable.

So, the risk of over- or undervaluing assets is especially large when large groups of people believe that certain events will occur that affect the price of the assets. This leads to a self-fulfilling prophecy where people can create a higher price by creating more demand. These kind of speculative “bubbles” will most likely deflate after some time, which leads to a market correction and thus a fair price of the assets (Boelhouwer, 2017).

According to Catte et al. (2004), the housing market has characteristics that set it apart from other markets, namely a prevalence of small investors; the absence of derivatives and short-selling; the heterogeneity and indivisibility of the traded asset, and a low transaction frequency. These characteristics cause the prices of the assets in the housing market to be driven by expectations with more ease than other asset markets (Catte et al., 2004). When the assets in the housing market become more and more popular due to low interest rates and high expectations, a bubble can occur which will influence the prices of the assets in the portfolio of Company X to such extent that the returns predicted are not representative for the actual returns. A price higher than expected might be positive for the return of the portfolio, however, if such a high price was expected, the extra cash flow could be used in other areas. A price lower than expected, logically, leads to lower returns, which has negative effects on the overall results.

We represent the valuation of investment property risk by multiple variables, namely interest rate, rise in market value, price of rent, vacancy rate, and the quality level of an asset, as we show in . As previously mentioned, the risk of over- or undervaluing asset value comes from the state of the market and the speculation of the potential buyers. High interest rates lead to lower market values of the assets of Company X, which is due to the lowered purchasing power of potential buyers causing the real estate market to become less liquid. However, the illiquidity in the buying market creates a spike of interest in the renting market, meaning that the people that would normally buy their residence, now prefer to rent a residence. This causes rent prices to increase and vacancy rates to decrease, meaning that more revenue will be earned via rent. The risk of over- or undervaluing property is also represented by the quality level of an asset, where high quality in combination with lower market value, as well as low quality in combination with high market value can lead to wrongfully estimated values for property.

So, high risk of over- or undervaluing property value can be determined if these described correlations are not present, for instance, when the interest rate is high in combination with an increasing market value, or when an asset with a standard quality level has the same market value as an asset with a high quality level. The risk level of valuation of investment property in the model can be determined by combining the levels of the interest rate and fluctuation in market value. Also, using the scenario analysis tool, Company X can determine what would happen to the market value, as well as the KPIs, when the quality level of an asset increases of decreases.

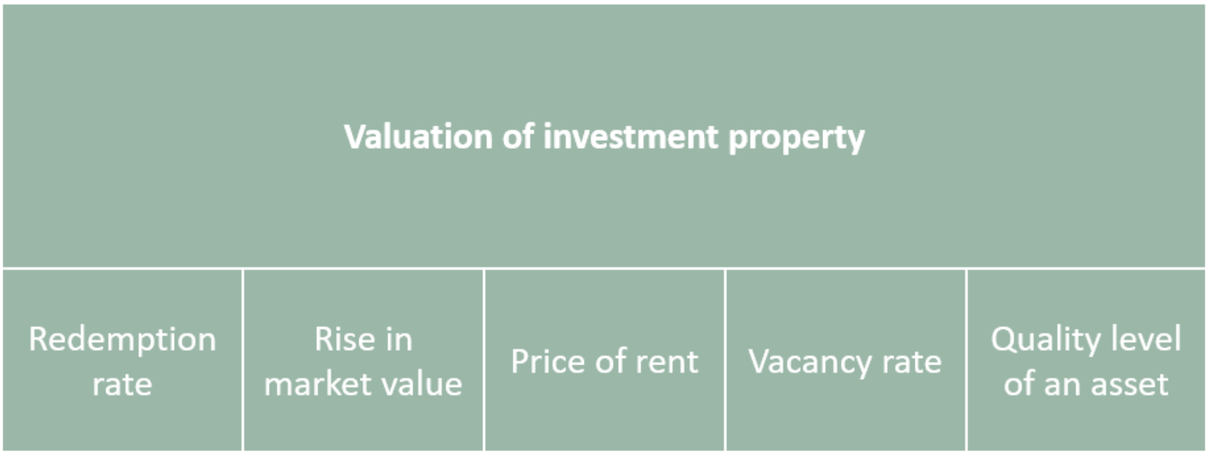


Figure 6 – Valuation of investment property risk and the variables that influence it.

3.1.4 Credit risk

We describe credit risk as solvency or continuity issues that arise at tenants, project developers, property managers, or other suppliers (Company X, 2019). So, the level of credit risk is mostly determined by the credit worthiness of the parties that owe debt to Company X. When payments from outgoing invoices are not received, this could negatively impact the revenue made by Company X. According to Crook, Edelman & Thomas (2007), credit scoring is essential in selecting tenants and other creditors, they do this by classifying creditors that are likely to repay and those that are unlikely to repay. This distinction can be made using consumer credit scoring, where the creditors are assessed based on capital levels and historical loan payment behaviour (Crook, Edelman, & Thomas, 2007). Another way of making this distinction is by setting certain requirements for potential tenants based on their income and age, in order to ensure that the future tenants have enough liquidity to pay their rent.

Companies can reduce credit risk with security deposits, prepaid rent requirements, and insurances and guarantees (Grenadier, 1996). So, companies can protect themselves from missing payments with the use of these measures. When credit risk is high and no measures are taken to circumvent these risks, the stream of revenue from companies can reduce, which leads to unbalanced cash flows and disappointing yields.

According to Hull (2012, pp. 534-536), certain clauses can be included in contracts to mitigate credit risk to a certain extent. The first clause is the ‘netting’ clause, which states that if a company (or party) defaults on one transaction, it must default on all outstanding transactions with the counterparty (Hull, 2012, pp. 534-536). This ensures that when the counterparty defaults, they cannot just default on the transactions that bear negative value for the company, but on all of the transactions.

The second clause is the ‘collateralization’ clause, which involves the inclusion of collateral in a contract where the counterparty must equal their cumulative collateral to the difference between the value of transactions to the company and a specified threshold level (Hull, 2012, pp. 534-536). This ensures that when the counterparty defaults, the company can seize the collateral, reducing the negative effects of a default.

The third and final clause discussed here is the ‘downgrade triggers’ clause. This measure can be included in the contract to mitigate credit risk by stating that if the credit rating of the counterparty falls below a certain level, the company has the option to close the transaction at market value (Hull, 2012, pp. 534-536). Although this enables a company to protect itself from transactions with counterparties that have bad credit ratings, it cannot fully protect them from big jumps in credit rating from the counterparty, like a jump from rating A to default (Hull, 2012, pp. 534-536).

The aforementioned clauses will not be used in the final model, since the model focuses on assets in the residential real estate, where the counterparty is most often comprised of multiple potential private home-renters/buyers. So, due to the fact that the counterparty is comprised of multiple separate parties, the risk of the whole counterparty defaulting can be neglected. In order to model credit risk, we represent it with the variables interest rate, price of rent, and the indexation, as is shown in Figure 7. The risk of renters and potential buyers not being able to fulfil payments to Company X is high when the interest rate and indexation is high, since high interest rates lead to less purchasing power of the buyers, meaning that the loans that they need in order to fulfil the payments to Company X become more expensive. Also, a high indexation is caused by higher inflation, meaning that people need to have more money in order to fulfil the payments for rent or a purchase. When high inflation is not complemented by an equal rise in wages, the purchasing power of the home-renters/buyers will decrease, increasing credit risk for Company X.

Also, when Company X increases their price of rent, revenues increase when renters can still fulfil their payments and when vacancy rates remain the same, however, due to increasing prices of rents, the chance of unfulfilled payments rise, meaning that the credit risk increases. So, a high credit risk is correlated with high interest rates, high indexation rates, and increased prices of rent.

Figure 7 – Credit risk and the variables that influence it.

3.1.5 Interest rate risk

Changes in interest rate influence the amount of debt that has to be paid to the bank by Company X, where an upward change of interest rate causes an increase in debt to be paid per period and a downward change causes a decrease in debt to be paid per period. We regard interest rate risk per project, and not for the final balance sheet, mainly because the final model is designed to assist in the decision-making process faced when investing in a certain new project or asset. Also, the interest rate, as used in this research, consists of the risk-free rate increased with a spread determined by the creditor of Company X.

According to Chaney & Hoesli (2010), interest rate risk describes the sensitivity of a certain asset to changes in the interest rate. The level of interest rate risk is often measured by the modified duration, which is an indication of the change in asset price due to changes in interest rate, here an interest rate sensitivity (duration) of i.e. 5% implies that the price of an asset will fall by 5% if the interest rate increases by 1% (Chaney & Hoesli, 2010). This relationship between interest rate and asset price will be taken into account in the final model by modelling correlation between both variables, more information about this and the other correlations in the final model can be found in Section 4.2.

In order to measure the interest rate risk of a company, the sensitivity of the portfolio (or single assets) to changes in interest rate should be determined. This can be done by, for instance, scenario analyses, Monte Carlo simulations or sensitivity tests. When an asset heavily fluctuates in value when the interest rate changes, it can be said that the asset has a high interest rate risk. Furthermore, Stevenson, et al. (2007) state that firms with a greater development focus are often more exposed to interest rate risk. This is mainly due to major developments taking a longer time, and often requiring more periodical payments, which puts the asset in development in danger of suffering more interest rate changes.

So, the main factors that influence interest rate risk are the assets or portfolio's sensitivity to changes in interest rate, and the time period in which the debts are to be paid to the bank. Financial institutions often hedge themselves against interest rate risk by ensuring that the duration of their assets equals the duration of their liabilities (Hull, 2012, pp. 143-144). A real estate investment company could use this strategy by setting the duration of their assets that will be kept in the portfolio equal to the assets that will be sold.

Interest rate risk is mostly defined by the correlation between the interest rate and the asset price, where the percentage change in asset price due to a 1% rise in interest rate can be defined as the modified duration of that asset (Chaney & Hoesli, 2010). However, in the case of Company X and real estate, the asset price is often no longer variable at the time of the cash flow calculations. Also, asset prices in real estate tend to be influenced by speculation (Boelhouwer, 2017), meaning that the price change of an asset caused by a change in interest rate cannot be compared to another asset in a different time period, since the speculative effects will be incomparable. So, in order to circumvent this problem, we define the modified duration by the change in value of an assets' NPV due to a 1% change in interest rate, as we show in Figure 8. This modified duration will represent the interest rate risk in the final model. If the modified duration is high, then the interest rate risk is high as well.

Figure 8 – Interest rate risk and the variables that influence it.

3.1.6 Development risk

According to Linjie (2010), development risk encompasses the possibility of losses due to real estate development, which is divided into three parts, environmental risks, enterprise risks, and project risks. Environmental risks include events occurring where extra costs need to be made due to environmental issues, such as costs due to delay caused by the nitrogen regulations in the Netherlands or extra costs due to mandatory upgrading of the energy label of an asset.

Enterprise risks cover the decision risks, which involve the risk of incorrect prognoses regarding costs and revenue, as well as the risk of the location being unpopular causing the revenue earned via rent to be lower. Project risks cover the risk of losing income due to complexities and issues during the project, which can be caused by very complexly designed assets which might cause unforeseen costs during the building phase. According to Linjie (2010), enterprise risks including decision risks have the largest impact, which is due to the large number of decisions and prognoses made before and during a project.

Development risks are hard to express by a single variable, most studies express it using qualitative labels from very low to very high. Linjie (2010) expresses development risk using a fuzzy evaluation model with qualitative labels and Ma & Meng (2009) express it using a neural network, where multiple real estate projects are scored on a scale ranging from very large development risk to very small development risk, which is then translated into a numeric score and modelled using training software.

So, development risks are often measured using mostly qualitative variables and parameters, such as complexity of a project. High development risk often leads to extra unforeseen costs, however, taking development risks can also be outweighed by the benefits obtained from a more complex design. This means that development risk should always be identified, however, like many other risks, a balance should be found by outweighing the benefits and possible losses.

We represent development risk by the variables complexity of building process, quality level of asset, and duration of vacancy, as Figure 9 shows. High development risk is often caused by a very complex building process, where the land plot on which the asset must be built is for example of poor quality, this means that more time and resources must be spent on preparing the ground and building the asset, which leads to a higher duration of vacancy and a higher cost of upgrading the asset to the standards of Company X. Also, when Company X wants to achieve a higher quality asset, they increase their development risk since a higher quality is almost always achieved via the spending of more resources and time, causing the duration of vacancy, as well as the cost of upgrading the asset to be higher. So, a high development risk is caused by high complexity of a building process and/or a high quality level of the asset. A high development risk is also represented by a high duration of vacancy and a high cost of upgrading the asset.

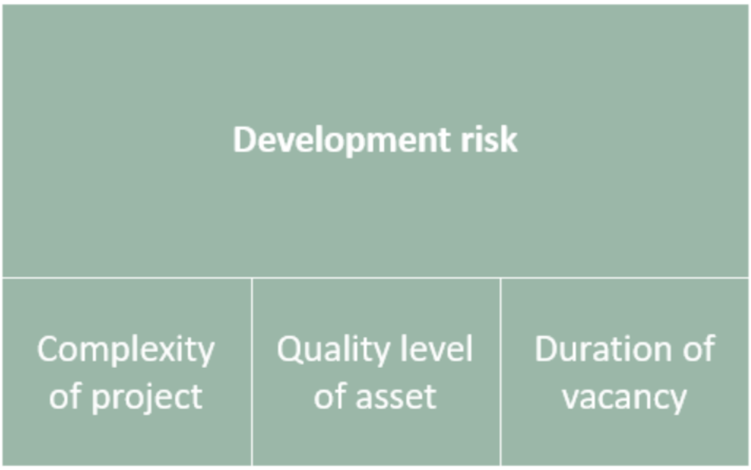


Figure 9 – Development risk and the variables that influence it.

3.1.7 Vacancy risk

Vacancy risk can be described as the probability of not receiving as much revenue from rent as thought due to failure to rent out one or more assets (Leskinen, et al., 2020). Vacancy risk is mostly measured using vacancy rates, which indicate the percentage of assets or parts of assets that are vacant during their corresponding lifespan. Igarashi (1991) showed that rent adjustments and vacancy rates are positively correlated in the long run, indicating that increases in rent lead to a higher vacancy rate. This is fairly logical, however, it shows that it is important to find balance in the amount of rent asked from creditors and the acceptable vacancy rate.
Rosen & Smith (1983) state that there is an optimal or natural vacancy rate, which differs per market and is equal to the *"rate at which there is no excess demand nor excess supply and hence the rate is at its long-run equilibrium"*. This rate can be hard to express and is usually determined by using optimization models and calculations of ask and demand in the market (Rosen & Smith, 1983).
Gabriel & Nothaft (1988) state that vacancy rate can be expressed as the product of the amount of time that a certain asset (or part of an asset) is vacant and the duration of that vacancy. This means that when accounting for vacancy risk, it is important to approximate the probability that an asset or part(s) of an asset will be vacant during a certain time span. If an investment does not account for the vacancy risk, there is a probability that the revenues from rent will be lower, which in turn will lead to lower profits and maybe even losses.

So, vacancy risk is very important to account for in correctly creating prognoses of the future cash flows of a certain asset. This risk is mostly influenced by the rent levels in the market, as well as the rent asked by the owner of the asset. High vacancy risk can occur in times of crisis and/or when the demand for housing is low. However, the housing market currently faces a shortage, where the current production of housing cannot keep up with the growing number of households in the Netherlands, meaning that vacancy rates will most likely be low in the coming time (Boelhouwer, 2020).

Vacancy risk is directly quantifiable by utilizing the variable vacancy rate, however, the vacancy rate is directly influenced by the variables price of rent and interest rate, which should be acknowledged. Low interest rates lead to higher asset values and more interest from the buyers on the market since buyers can obtain loans for a cheaper price, meaning that their purchasing power increases. This has a positive effect on the market value of the asset, however, due to the rising popularity of buying residences, there is less interest for renting residences, resulting in an increase in vacancy rate. Next to this, high prices of rent may also cause an increase in vacancy rate, if the price of rent is set too high by Company X in comparison to their competitors, the vacancy rate increases. So, we determine the level of vacancy risk by measuring the vacancy rate, as Figure 10 shows. We correlate the vacancy rate with the price of rent and therefore the interest rate as well. More information on these correlations and how they are modelled can be found in Section 4.2.

Figure 10 – Vacancy risk with the variable that influences it.

3.2 Quantification methods

In this section we provide information on the quantification methods used in the final model, which includes an explanation of how the methods are used and what risk indicators they measure. In this section we also discuss the applicability of these methods to this research, and we motivate the decision of incorporating these methods in the final model. We discuss the following quantification methods: Monte Carlo simulation and scenario analysis.

3.2.1 Monte Carlo simulation

The key risks we describe in Section 3.1 depend on multiple variables. These variables can take certain values, which either has a positive effect on the final result of a project or an investment or a negative effect, for instance, a high vacancy rate leads to lower rent income, negatively affecting the final result. The values of these variables indicate whether an investment or project has high or low risk levels and whether the impact of those risks are high or low. In order to determine which values these variables can take as well as the probability that these variables will take certain values, quantification methods are needed. The first quantification method we discuss in this section is the Monte Carlo simulation.

A Monte Carlo simulation uses random numbers based on a distribution to return a large number of possible outcomes, the range of values corresponding with these possible outcomes can then be used to obtain useful risk measures indicating the likelihood of a certain investment becoming profitable or not (Yeh & Lien, 2020). So, a Monte Carlo simulation can generate random values for the relevant variables, and then simultaneously use these variables to output the relevant performance indicators, which in this research are the NPV, BAR, NAR, and IRR. By generating a large number of possible scenarios, it becomes possible to estimate the likelihood of these performance indicators falling below the desired levels.

Monte Carlo simulations are not yet widely used in real estate investments, which is likely due to the mathematical and statistical dimension of this approach (Hoesli, et al., 2006). However, there are certain examples in the literature of Monte Carlo simulations being used to forecast future cash flows in order to improve the long-term decision making in real estate investments (Kelliher and Mahoney, 2000; Tucker, 2001; French and Gabrielli, 2004; Hoesli, Jani, & Bender, 2006). Forecasting future cash flows is often done in combination with elements from the Discounted Cash Flow (DCF) technique, where French and Gabrielli (2004) even used the Monte Carlo simulation technique to extend the DCF technique by incorporating uncertainty into the analysis in order to model a range of possible outcomes for investments in real estate.

According to Meins & Sager (2013), Monte Carlo simulations in combination with the DCF model can also be used to estimate the riskiness of investments by measuring the volatility of the returns and subsequently measuring the effect of each variable on the volatility of the returns by estimating the impact of changing the value of the relevant variables. So, it is possible to measure the level of certain risk indicators by using a Monte Carlo simulation to generate a large number of potential returns, the volatility of these returns is then used as an indicator of risk. If changing the value of a single variable substantially increases or decreases this volatility, it can be said that the impact on risk of that variable is high. More information about volatility as a risk measure can be found in Section 3.2.4.

We use the Monte Carlo simulation technique as a tool to find information about the likelihood of certain risks occurring and the impact of these risks on the key performance indicators (KPIs) of the investment. We do this by first generating random values for all relevant variables, and then calculating the values of the KPIs for each iteration. The values for the KPIs and relevant variables belonging to the key risks are then used to calculate averages, volatilities, the Value-at-Risks and the likelihood of obtaining less then desired results. We calculate these values for the standard KPIs in this research, namely the BAR, NAR, and IRR, however, in order to get an idea of the impact on the actual monetary results, the NPV (Net Present Value) is also calculated and processed. We determine the NPV via the DCF technique and it represents the difference between the present value of the cash inflows and cash outflows, which is used in a common rule-of-thumb that projects or investments with negative NPVs should be discarded (Ross, 1995). We do directly use this rule-of-thumb in the final model, mainly since Company X desires that the NPV lies above the break-even point, meaning that the NPV being positive is not enough justification to accept an investment. Also, the NPV only indicates the value of an investment in terms of money, whereas Company X also makes investment decisions based on, for example, political or demographic reasons. More information about how we design the final model and how it should be used can be found in Chapters 4 and 5.

We generate the random values of the relevant variables based on their respective distributions. Usually when performing Monte Carlo simulations, the normal distribution is used, however, in real estate the triangular distribution is a more appropriate approximation of the relevant variables (D’Arcy et al., 2005). Although it is mentioned by French & Gabrielli (2004) that the normal distribution is more statistically robust, the triangular distributions better represents the thought process of the appraisers in real estate (D’Arcy et al., 2005). This is the case because appraisers and other stakeholders in real estate are prone to think in worst-case and best-case scenarios, as well as a most likely scenario, this leads to a three-point (triangular) distribution (D’Arcy et al, 2005). Next to this, multiple studies have used the triangular distribution as well, such as Meins & Sager (2013); Kelliher & Mahoney (2000), and Hoesli, et al. (2006). Figure 11 shows a graph of the triangular distribution.

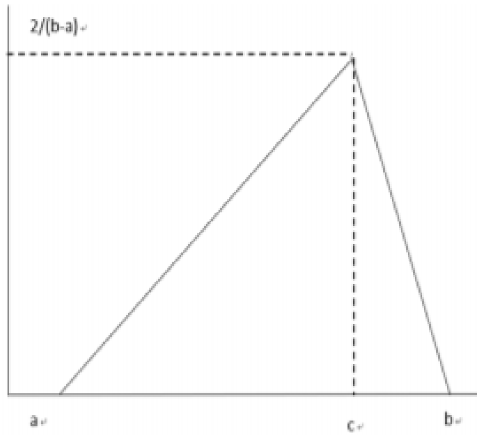


Figure 11 – Triangular distribution, derived from Zhai, Chen & Chen (2018).

The triangular distribution is a continuous probability distribution with a lower limit of a, a mode of c, and an upper limit of b, where a, b, and c can also be described as the minimum, maximum, and most probable value respectably (Zhai, Chen, & Chen, 2018). The limits a and b, as well as the mode c are depicted in Figure 11. The probability density function formula of the triangular distribution can be found in Formula 4.

$$f(x|a,b,c) = \begin{cases} \dfrac{2(x-a)}{(b-a)(c-a)} \\ \dfrac{2(b-x)}{(b-a)(b-c)} \end{cases}$$

Formula 4 – Probability density function of the triangular distribution, as retrieved from (Zhai, Chen, & Chen, 2018).

So, we use the triangular distribution to generate random values, however, there are relevant variables that do not dependent on the thought process within real estate, which are the indexation (which is mainly defined by the inflation rate), the interest rate, and the redemption rate. This means that these variables might follow a different distribution. Also, the triangular distribution uses built-in constraints for the randomly generated variables, meaning that a risk measure such as the Value-at-Risk (VaR) becomes obsolete. In order to let the model be able to generate outliers, which also reflects the real world more accurately, we introduce correlations between the variables. The correlation between certain variables causes a triangularly distributed variable to be able to increase or decrease over or under the limits based on the value of the other correlated variable(s). More information on how this correlation is achieved and what its effects are on the final model can be found in Section 4.2 and Section 4.3.

To determine which distribution fits the indexation, we analyse historical data and consult the literature. First, we determine the distribution of the indexation, for which the most recent inflation rate data is collected from the Dutch Central Bureau of Statistics (CBS) (CBS, 2021). In order to derive the distribution, we make a histogram of the historical inflation growth rates, which is shown in Figure 12.

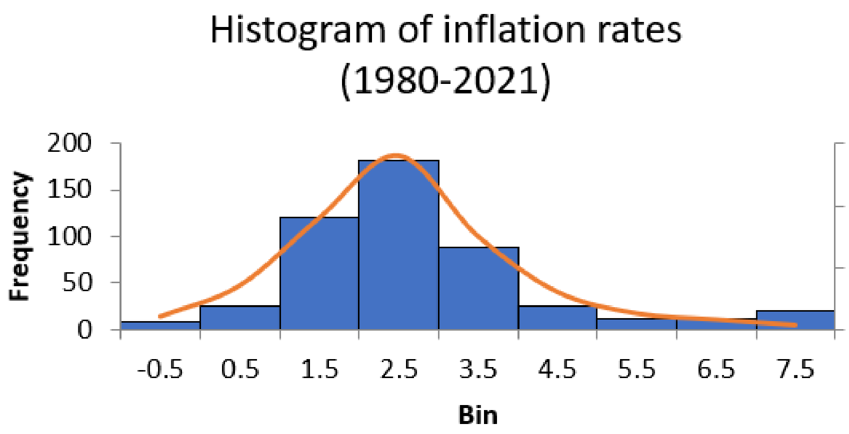


Figure 12 – Histogram of Dutch inflation rates from 1980-2021, derived from CBS (2019).

As can be seen in Figure 12, the histogram closely resembles a normal distribution which is slightly skewed to the right, indicating a lognormal distribution. One could argue that since lognormal distributions cannot take values below zero and that the inflation rate can drop below 0 in the Netherlands, as is shown in Figure 12, the normal distribution should be used instead (Hull, 2012, pp. 300-301). However, the indexation is not exactly the same as the inflation rate in the Netherlands, it is strongly correlated. Also, Company X never estimates the indexation to drop below zero, since costs and returns from rent are always assumed by Company X to scale up in the cash flow calculations over a time period of 10 years. So, to generate random values for the variable indexation, the lognormal distribution is used.

We generate the variables interest rate and redemption rate via a normal distribution in the final model. We have chosen the normal distribution in favour of the triangular distribution since these variables are, firstly, not only dependent on the thought processes of appraisers and secondly, the normal distribution is the most statistical robust in describing the nature of variables based on a certain mean and located in a certain expected range (French & Gabrielli, 2004). Also, modelling these variables according to the normal distribution allows for outliers to occur, which more closely resembles the actual interest rate and redemption rate. For example, the interest rate has seen a big drop in 2008 and a rapid rise around the year 2000, both changes in interest rate which would normally fall outside of the expected range. The redemption rate depends, amongst other factors, on the trust that a creditor has in Company X, which can also be very volatile in times where less revenue is made, which means that outliers should be a possibility in the final model. So, in order to generate values for the variables interest rate and redemption rate, we use the normal distribution.

In order to quantify the key risks of an investment or project, the stakeholders at Company X must set bounds for the value of the variables corresponding to each key risk. For instance, if the stakeholders want to assess the interest rate risk, they set the upper- and lower bounds of the interest rate as well as the current interest rate and desired interest rate, after which the Monte Carlo simulation will run and give an expected value and volatility of the interest rate, as well as the likelihood that the interest rate will drop below the desired level. Doing this for all variables corresponding to the key risks will allow the stakeholders to get an overview of which key risks are likely to become a problem and which are not. The key risks that are likely to become a problem can then be further assessed with the use of scenario analyses, which enables the stakeholders to determine the impact of the key risk on the KPIs. More information about scenario analyses can be found in Section 3.2.2.

3.2.2 Scenario analysis

The second quantification method discussed in this section is the scenario analysis, which is, as the name indicates, a method of analysing the potential future scenarios that can occur. Maack (2001) describes that scenario analysis focuses on the area of greatest uncertainty and that it systematically develops several plausible alternative future environments in which the operation might be implemented, and it then determines how these alternatives would affect the success of the operation. In this research, the different scenarios that are possible are changes in certain variables due to events occurring tied to the key risks, for example, a scenario could be that due to a decrease in expats the housing and rent prices do not grow as much as expected or even decrease.

These potential scenarios also have a potential effect on the profitability of an investment or a project, this effect is measured by determining the values for the KPIs (NPV, BAR, NAR, and IRR). So, a scenario analysis usually starts with stakeholders coming up with one or more scenarios, then determining which variables change in such a scenario and how these variables change, and then the KPIs are determined via the standard discounted cash flow method, however, with the values of the variables changed according to the scenario. According to Ens & Johnston (2020), scenario analyses examine plausible futures and forecasts situations that could happen, rather than situations that will happen, meaning it is important to know that scenario analyses are useful when there is uncertainty involved in a project or an investment.

We use the scenario analysis method by incorporating it in the risk quantification model, as designed in Chapter 4 and Chapter 5. This is done by installing a section where stakeholders can change the values for each variable manually, these changed variables are then processed using a button that is linked to a macro written in VBA (Excel). This macro calculates the new values for the KPIs using the changed values for the relevant variables and then it displays these values, as well as the changes compared to the old values, on the risk dashboard of the model. More information about the model and the risk dashboard can be found in Chapters 4 and 5.

This scenario analysis enables the stakeholders at Company X to be able to quickly go through several scenarios that might occur, such as best-case and worst-case scenarios, which helps Company X in their preparation. In this quantification method, all key risks can be evaluated and quantitatively analysed by the stakeholders at Company X. To do this, it is important that the scenarios are thoroughly thought out, and that all relevant variables corresponding to the risks are taken into consideration.

So, a major strength of this method is that it becomes possible to measure the impact of each key risk. However, the weakness is that this method is not able to estimate the likelihoods of each risk. This is why it is chosen to combine the scenario analysis method with the Monte Carlo simulation method.

We combine the scenario analysis method with the Monte Carlo simulation method by first letting the Monte Carlo simulation generate likelihoods for each possible key risk, then find those with the largest likelihoods and further analyse these with the outcomes generated in the simulation and a scenario analysis. We use the Monte Carlo simulation to find the key risks with the highest probability of occurring, as well as the probable values of the relevant variables and the KPIs, which is very useful. Next to this, the Monte Carlo simulation describes what is most likely to happen and what the best- and worst-case scenarios are, however, it cannot describe what happens when only two risks occur, or what happens to the KPIs when certain relevant variables increase and others decrease. This shortfall of the Monte Carlo simulation is covered by the scenario analysis method. So, the scenario analysis method helps the stakeholders to get a more in-depth view on what the impact is of the key risks.

3.3 Risk indicators

In this section we describe the risk indicators used in the Monte Carlo model, namely the Value-at-Risk (VaR) and the volatility. We explain and motivate these risk indicators in this section. The risk indicators are not the only output from the Monte Carlo model, where more statistical values and logical reasoning in combination with the risk indicators contribute to an overall quantification of the key risks and an overall result of the project or investment in turns of profitability and the likelihood of being profitable. We determine the risk indicators described here with the help of the quantification methods described in Section 3.2.

3.3.1 Value-at-Risk

The Value-at-Risk (VaR) measure is determined by finding the largest percentage loss with a given probability (confidence level) likely to be suffered on an investment, project or entire portfolio (Amédée-Manesme & Barthélémy, 2018). This means that finding the VaR is about determining the maximum amount of money lost (absolute) with a probability of $\alpha\%$. According to Amédée-Manesme & Barthélémy (2018), the VaR is the quantile of the projected distribution of losses over a certain time horizon, if α is taken to be the confidence level, the VaR then corresponds to the α^{th} quantile. So, the VaR indicates a certain worst-case scenario corresponding to a confidence level. The VaR thus serves as an indicator of the amount of budget needed to cover the biggest possible loss, which makes it viable as a risk management tool. This is also demonstrated by Basak & Shapiro (2001), who argue that the VaR can be used as a constraint, where management must exogenously specify a "floor" $\underline{W}$ as the threshold for accepting a certain investment or not. Here the term "floor" might be confusing, as the VaR is usually measured as an absolute value, meaning a large VaR means a large loss, so, the "floor" acts as a limit of what the absolute loss can rise to. In Figure 13 we show a histogram of a normally distributed variable including its VaR (with a confidence level of 95%), we have included this graph as an example.

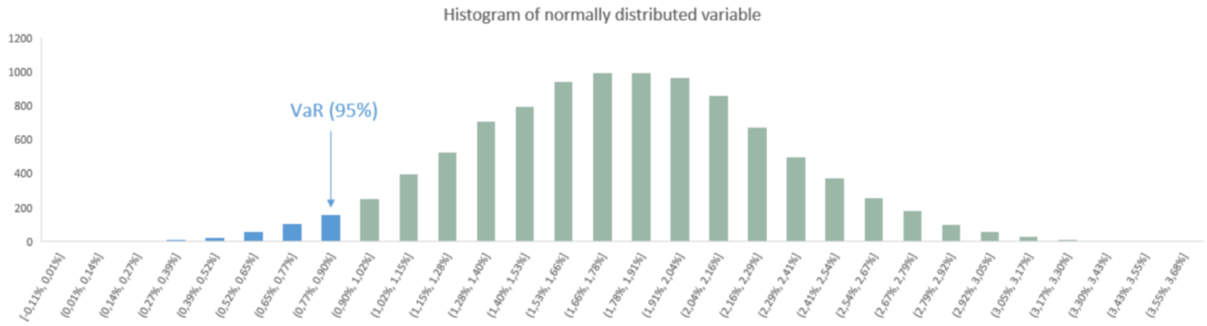


Figure 13 – Histogram of a normally distributed variable and its VaR.

As the name suggests, the VaR can very well be used as a measure of risk, meaning that a large VaR indicates a large (absolute) value of lost money, which indicates a higher risk. Adrian & Shin (2014) also mention the VaR as a risk measure, where they note that the VaR rule, which stipulates that the organisation maintains enough equity to cover its VaR, ensures that the probability of default of the organisation is kept constant. This means that a firm should cut back its asset exposure when the environment becomes more risky, thus bringing the VaR back in line with their equity, and vice versa (Adrian & Shin, 2014). The VaR rule is usually applied on portfolio level, however, it can also be used at project/investment level, namely by ensuring that the threshold, or the “floor” as described by Basak & Shapiro (2001), is correctly determined by management. Correctly determining this threshold means that the “floor” should not allow the total loss to become more than the equity needed (relative to the project/investment) with a confidence level of α%.

The VaR is very helpful in determining risk exposure and as a constraint, however, it is still a soft constraint, since the confidence level α% also indicates a probability of $(100 - \alpha)$% that the loss is higher than the VaR (Amédée-Manesme & Barthélémy, 2018). So, if the confidence level is equal to 99%, there is a 1% chance that the loss of the investment will become higher than the VaR. In order to be prepared for an event where the loss of the investment or project becomes higher than the VaR, the Expected Shortfall (ES) can be used.

The ES is also called the conditional Value-at-Risk (CVaR) and is derived from the VaR. It is more sensitive to the shape of the tail of the loss distribution, which is helpful when the losses in the $(100 - \alpha)$ percentile are relatively large (Amédée-Manesme & Barthélémy, 2018). The ES is calculated as the mean of the excess distribution of the losses beyond the VaR, so it can be seen as the capital charge that incorporates risks posed by extreme events (Saunders & Allen, 2010). So, the VaR shows the firm the highest possible loss corresponding with a certain confidence level α, whereas the ES shows the firm the average loss taken when the loss falls in the $(100 - \alpha)$ percentile (extreme events with a probability of $(100 - \alpha)$%). However, in this research, the variables and parameters used in finding the VaR and ES are generated via a Monte Carlo simulation where the distributions of returns do not have large tails, as is shown in Chapter 4, which leads to the ES not being as useful. Also, since the tool is made for Company X to use when making decisions, there should not be any redundant calculations. So, since the ES is redundant and since the stakeholders at Company X wish to keep the final model streamlined and clear, the ES will not be incorporated in the final model.

In order to calculate the VaR properly, we need potential outcomes in terms of KPIs. We have done this using a Monte Carlo simulation, as described in Section 3.2.1 and further modelled in Chapter 4. The Monte Carlo simulation generates 10.000 random outcomes, from which the VaR is calculated as previously explained. This enables the stakeholders at Company X to generate potential outcomes based on a certain distribution that approximates the reality the best, these potential outcomes are then analysed using the VaR method and assigned a certain confidence level α. This leads to a better understanding of what amount of money can be lost α% of the time. Next to the NPV of the investment/project, the BAR, NAR, and IRR are also analysed with the use of the VaR method, this results in a VaR as a percentage. The VaR is not usually displayed as a percentage, however, the calculations remain the same, as well as the advantages of the risk measures. Measuring the VaR using a Monte Carlo simulation has a drawback, namely that it tends to be slow because a company’s portfolio has to be revalued many times (Hull, 2012, pp. 471-494). However, this drawback is less impactful in this research since the model is designed for a single investment or project, however, it is certainly important to mention, especially with regard to future modifications of the model.

By utilizing the Monte Carlo simulation method and the VaR measure, it is possible for Company X to obtain an overall view of the riskiness of a certain investment or project. By setting constraints for the values of the VaR, the stakeholders can improve their knowledge when making decisions about these investments and projects. Also, when the VaR is especially high, more in-depth analyses can be made of the cause for this using the scenario analysis present in the model, which would allow Company X to take actions in circumventing large risks where needed.

3.3.2 Volatility

The second risk indicator is volatility, which indicates the amount of big swings in returns of a certain asset. The volatility is often measured as the standard deviation of the returns, where a high standard deviation means a high volatility, indicating that the returns of that asset are prone to increase or decrease with large swings. The volatility can be used as a risk measure, since potential for large swings (high volatility) gives a higher probability of potential losses. However, volatility is not necessarily something that should be avoided entirely, as demonstrated by Cannon, et al., (2006) in their research where they show that a 10% increase in volatility increased the returns by 2.48% annually in the U.S. metropolitan housing market.

Volatility is often hard to measure in real estate markets, mainly since it is influenced by multiple factors that are specific to certain locations and areas. This leads to the need for a distinction between two types of volatility, namely idiosyncratic and systematic volatility, which are defined as the degree of variation in a property's private value and common value respectively (He et al., 2018). As described by Miller & Pandher (2008), idiosyncratic volatility appears to serve as a reduced-form factor for fluctuations in housing supply-demand conditions unrelated to systematic economic drivers such as the stock market and national housing market. This means that when investing in an area, it is important to make distinctions between that specific area and the national housing market. This research focuses on systematic volatility, where the distributions used to generate the random values for all variables are based on the overall housing market and real estate developments. There is room in the final model for idiosyncratic aspects, since the input needed for the model is adjustable, meaning that the stakeholders at Company X can change certain aspects of a variable based on the location or another specific aspect of an asset.

Another distinction that should be made in determining volatility is between historical and implied volatility. Historical volatility is estimated by the sample standard deviation of returns over a historical period, meaning it is measured using returns that already happened (Engle, 2004). This provides information about the trends the volatility seem to follow, however, it is very dependent on the period chosen and it is really the volatility of a future period that should be considered the risk (Engle, 2004). In order to use volatility as a risk measure, the implied volatility should be considered. Implied volatility is the forecast of volatility in a market, where it is often suggested that implied volatility is the most efficient estimator of future realized volatility (Christensen and Prabhala, 1988; Jorion, 1995; Diavatopoulos et al., 2010). So, in order to assess the risk of a certain investment or project, the implied volatility should be used rather than historical volatility.

The final model will incorporate volatility as a risk measure by predicting the volatility of the investment or project based on the values of the NPV, BAR, NAR, and IRR generated via the Monte Carlo simulation. This means that the final model uses the volatility of the relevant variables as input, and the volatility of the calculated KPIs as output. The model will determine the standard deviation of these KPIs, as well as the standard deviations of all relevant variables corresponding to the key risks. This will give the stakeholders at Company X insight as to how much the KPIs can fluctuate in value and which key risks are the most volatile in terms of their relevant variables. It is important to keep in mind that high volatility does not necessarily means that the returns will be negatively affected, however, it does mean that the risk of a largely negative or positive return is higher. So, the final model will make this clear by comparing the return corresponding to the simulated volatility with a benchmark, which will indicate the whether an increase in volatility has had a negative impact on the returns or a positive impact. Also, in order to incorporate the idiosyncratic nature of volatility in real estate markets, it is important that the stakeholders at Company X can manually input the averages and upper- and lower limits of each relevant variable, since these will often vary per region. The riskiness of each key risk will be shown in the dashboard of the model dependent on the volatility of the corresponding relevant variables. Next to this there will be an indication of the riskiness of the entire project or investment based on the volatility of the KPIs. More information about how these risks are shown in the dashboard and how the final model is designed can be found in Chapter 4 and Chapter 5.

3.4 Method of testing the accuracy of the final model

Before the model is designed, it is important to first understand how to test the accuracy of the model. In this section we explain this, whereas we test the model in Chapter 6.

The final model is able to perform scenario analyses, as well as simulations in order to estimate the impact and likelihood of the key risks, which is very useful. However, it is only useful if the model is reliable, meaning that the model should be able to deliver measures of impact and likelihood without fail and with accuracy. In order to determine whether model can be trusted, we use the back testing method.

Back testing can be seen as a reality check, it involves testing how well the estimates made by a model would have performed in the past (Hull, 2012, pp. 471-494). The back testing of the model in this research is done by using the model to estimate the impact and likelihood of the key risks for a selected group of historical projects and investments of Company X. According to Christoffersen (1998, as cited in Campbell, 2005), the back testing of the VaR can be reduced to determining whether the estimations of past data satisfies two properties, namely the *unconditional coverage property*, and the *independence property*.

We back test the final model by letting the Monte Carlo model generate 10.000 scenarios based on the distributions of the relevant variables and based on the default under- and upper limits, expected values, and threshold values. The Monte Carlo model provides several values in terms of KPIs, risk indicators, and other statistical values. From all these values, we use the VaR of the modelled BAR in combination with the realised BAR in order to determine whether the Monte Carlo model has been successful in estimating the value of the BAR. Only the BAR is analysed in the back testing of the model since this is the only KPI that has been consistently documented for all projects. This does limit the back testing, since a thorough back test requires the testing of all KPIs and variables. In order for this to happen, more data in terms of KPIs needs to be documented in the future. Currently, the data to determine the realised values of the KPIs is available, however, it is still very raw and scattered, meaning that determining all the realised values of the KPIs would be outside of the scope of this research in terms of available time. However, the realised values for the BAR still indicate the level of reliability of the model, especially when keeping in mind the two properties used in the back testing of the VaR, namely the *unconditional coverage property*, and the *independence* property.

The *unconditional coverage property* means that the probability of obtaining a result in excess of the VaR, should always correspond with its confidence level (Campbell, 2005). If results in excess of the VaR occur more often than the model predicts, then the model understates the actual level of risk, if it is the other way around, the model is too conservative (Campbell, 2005). So, if the estimated results in terms of the BAR of the selected historical projects and investments of Company X are within limits of the VaR corresponding with the model in $(100 - \alpha)\%$ of the tested cases, the model satisfies this property.

The *independence property* places a restriction on the ways in which results in excess of the VaR occur, namely by stating that any two excess results must be independent from each other (Campbell, 2005). This means that the results that are in excess of the VaR according to the model, should be independent, meaning that they do not influence each other. This property is hard to test for, since there are not a lot of historical projects and investments with enough data available, which means that according to the *unconditional coverage property*, there should be at most 1 excess result if the confidence level of the VaR is equal to 99%. If there is only 1 result, it is not possible to determine whether the model satisfies the *independence property*. Also, in reality, the *independence property* is not always satisfied, excess results tend to 'bunch' together and form clusters. These clusters often occur due to the correlations between projects, for instance when there is an economic crisis, where excess results occur much more frequently than during normal times. So, when testing for the *independence property*, it is important to sample projects and assets over multiple time periods. Also, if the *independence property* is not satisfied, this does not automatically disregards the entire model due to this 'bunching'-property of projects and assets.

Despite this lack of historical data, it is still very much worthwhile to back test the final model by using the available data. In this research, we back test by first collecting the estimated variables corresponding with the key risks from each project or investment, we then use these variables as the first part of input for the model. The second part of input involves assumptions about the ranges between which the variables will stay in the lifetime of a project or investment, as well as the average value. We determine this second part of input in the same manner for each historical project or investment, namely by using percentages as limits, meaning that each project or investment will have the same relative limits. For instance, if the vacancy rate is estimated to decrease with at most 50% and increase with at most 50%, and if project A has an estimated vacancy rate of 2%, and project B has an estimated vacancy rate of 3%, project A will have an under- and upper limit of 1% and 3%, whereas project B will have an under- and upper limit of 1.5% and 4.5%.

After having collected and generated the needed input, the model will run the simulation and then determine the KPIs for each observation. From these values we collect the BAR-values for each project, which we then use to determine the VaR corresponding to the BAR of each project. We then compare the realised BAR of each project or investment is with the simulated values of the VaR of each projects' BAR, in order to determine whether the realised result is in excess of the VaR or not. After this is done for each investment or project, we determine the total amount of excess results, and then determine whether the model is accurate or not. More information about this, as well as the results can be found in Chapter 6.

4 Design of the Monte Carlo model

In this chapter we answer the first part of the main research question: "How should the final model be designed?" by answering the corresponding sub-questions using the Monte Carlo model, and literature. Section 4.1 explains how the needed variables and parameters generated with a Monte Carlo simulation per distribution, as well as how the KPIs are then calculated. The Monte Carlo model uses three distributions in generating the relevant variables, namely the triangular distribution, the normal distribution, and the lognormal distribution. Section 4.2 explains how the relevant variables are correlated, and Section 4.3 explains how these correlations are modelled. Section 4.4 explains how the risk dashboard is designed and how the statistical measures and risk indicators are determined and used for each relevant variable, KPI, and key risk. Section 4.4 also shows how the key risks are quantified and how this is visualised in the dashboard.

The Monte Carlo models' main purpose is to assist Company X in estimating the likelihood of each key risk occurring and to estimate the limits in which the values of the KPIs and relevant variables will lie. We do this by using a Monte Carlo simulation where Company X can set the under- and upper limits of the relevant variables to match their intuition and market analyses, which we then use in combination with each variables' respective distribution to generate a series of random scenarios. These random scenarios consist of randomly generated values for each variable, including correlations between the variables, and the calculated values of the KPIs. We then use the outcomes of these scenarios to identify the risk indicators volatility, Value-at-Risk (VaR), and probability of success. These risk indicators are used to form a general risk assessment which indicates the level of riskiness per key risk using a colour code ranging from red (large risk) to green (little to no risk). Then we use the values for the VaR to assess the investment based on the range of values the KPIs can take, which indicates the worst-case scenario for an investment. A more elaborate explanation about how the Monte Carlo model is designed, how it works, and when it should be used is given in this chapter.

4.1 Generating scenarios

In this section we elaborate on the generation of scenarios for the Monte Carlo model. In order to analyse risks and predict future cash flows, it is important to first obtain enough input parameters and variables. We can do this by using real-world data and with simulated values, in this model we use the latter. We build the model using the built-in programming language of Excel, named VBA. VBA allows for the simulation of a large amount of scenarios in a relatively short time, as well as the needed calculations to obtain the KPI values. We then use the simulated scenarios to determine certain statistical values, as well as likelihoods of the key risks and other relevant risk indicators, more information on how this is done can be found in Section 4.4.

The Monte Carlo model generates 6 different variables, namely: the indexation, rise in market value, price of rent, vacancy rate, interest rate, and redemption rate. We then use these variables to calculate the values of the KPIs in each iteration. We have chosen to exclude certain variables from the Monte Carlo model which are used in the scenario analysis tool, these are the duration of vacancy, the complexity of a project, the quality level of a project, the LTV ratio, and the number of years in the portfolio. The variables complexity and quality level of a project and the number of years in the portfolio are excluded because the values of these variables are based on the choice of Company X, and thus fixed when entering the exploitation phase. The variable LTV ratio is excluded because the LTV ratio is often pre-determined by the creditor and Company X, randomly generating values for this ratio would not be logical, since it does not directly follow a certain distribution. The LTV ratio is mostly based on several market factors and the relationship between Company X and the creditor(s), which cannot be simulated. The duration of vacancy is not incorporated in the Monte Carlo simulation because it is often caused by a delay in the building process, however, the building process itself cannot easily be simulated, since delays are mostly due to human error. Also, the building process differs for each project or investment, meaning that accepting a common distribution for this variable would not make sense.

When simulating investments and projects, it is important to use the correct distribution per variable, this leads to a better depiction of reality and thus more accurate results. As explained in Section 3.2, there are 3 different distributions used in generating the needed output, which does complicate the model. However, in favour of accuracy, the most fitting distribution is chosen per variable, instead of a single distribution for all variables. The variables rise in market value, price of rent, and vacancy rate all follow the triangular distribution, meaning that they are generated between two given limits and most observations will lie around the given mean. The variables interest rate and redemption rate both follow the normal distribution, meaning that the observations for these variables display a bell-curve, where most observations lie around the mean. The variable indexation is generated via the lognormal distribution, which implies that the natural logarithm of the indexation is normally distributed (Hull, 2012, pp. 292-293). The lognormal distribution resembles a normal distribution which is skewed to the right, meaning that there are more outliers above the mean than below the mean. The lognormal distribution also implies that the indexation cannot take a value below 0, which is logical for this research, since the indexation is never estimated to drop below 0.

4.1.1 Variables generated with the triangular distribution

In order to generate the variables that follow a triangular distribution, we first need some parameters. These parameters are the under- and upper limit and mean of each variable, which are to be given by the stakeholders at Company X. We base the default values for the variables on the currently estimated value of the variable as stated in the current cash flow prognosis, where the under- and upper limit are set to respectively 75% and 125% of this mean for the rise in market value and vacancy rate, and - €1 and + €1 for the price of rent. The parameters are to be estimated by the stakeholders at Company X in order to incorporate their own intuition and experience, which in combination with the identified distribution leads to a combination of experience and theory in generating variables.

We model the triangular distribution by letting the code distinguish two cases, one where a variable is generated below the mean and one where a variable is generated above the mean. We do this by generating a uniform random number between 0 and 1, which we then use to determine which of the two cases will be executed. When the generated random number is smaller than the difference between the mean and the under limit divided by the difference between the mean and the upper limit, there will be a value generated between the under limit and the mean, if the generated random number is bigger, a value will be generated between the mean and the upper limit. After this, we use the triangular distribution in the model to perform the calculations as shown in Formula 5 to generate a random value for the variable.

$$f(x|a,b,c) = \begin{cases} a + \sqrt{x(b-a)(c-a)} & if\ x < (b-a)/(c-a) \\ c - \sqrt{(1-x)(c-b)(c-a)} & otherwise \end{cases}$$

Formula 5 – PDF of the triangular distribution used in the Monte Carlo model.

Where $f(x|a,b,c)$ equals the value for the random variable, x equals the randomly generated uniform number, and a, b and c equal the under limit, mean, and upper limit respectively. In the final model, we generate the triangularly distributed variables that are correlated with differently distributed variables by first generating a standard normally distributed number, then correlating this number with the other variable using the Cholesky decomposition, and then mapping this number on the triangular distribution using quantile mapping and the probability distribution function (PDF) as shown in Formula 5. A more detailed elaboration on how and why this is done can be found in Section 4.2. Further explanation on the triangular distribution regarding its PDF can be found in Appendix A.

4.1.2 Variables generated with the normal distribution

The parameters needed to generate the variables that follow the normal distribution are the mean and the standard deviation. The mean is to be given by the stakeholders at Company X, where they fill in their expected value of the variable based on their intuition, experience, and further research. The standard deviation is indirectly given by the stakeholders at Company X, namely by letting the standard deviation equal 50% of the average difference taken from the difference between the under limit and the mean, and the upper limit and the mean. This way of determining the standard deviation is done in order to keep the model user-friendly and in collaboration with Company X. Since many of the potential users want to keep the relevant variables in the same formatting in terms of parameters. Also, it helps the stakeholders at Company X to apply the same kind of reasoning and logic to each relevant variable when preparing the model.

We model the normal distribution by first determining the parameters and then using VBA's own function that generates a value from the normal distribution using its probability distribution function based on the parameters and a random generated number between 0 and 1. How this function generates values for the variables based on the normal distribution is shown in Formula 6.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

Formula 6 – PDF of the normal distribution.

Where $f(x)$ is equal to the randomly generated value for the relevant normally distributed variable, σ is the standard deviation, μ is the mean, and x is the random number between 0 and 1, which gets randomized with every iteration. More elaboration on how the PDF can be used to generate random values following the normal distribution can be found in Appendix A.

4.1.3 Variable generated with the lognormal distribution

In order to generate random values according to the lognormal distribution, we need to determine the following parameters: mean and standard deviation. The lognormal distribution means that the logarithmic value of a certain variable follows the normal distribution. The parameters relevant to the lognormal distribution are needed to find the input values for the built-in function that delivers random values according to the lognormal distribution, which are the lognormal mean and standard deviation. We determine these with the functions shown in Formula 7 and Formula 8.

$$SD(X) = \ln\left(1 + \left(\frac{\sigma^2}{\mu^2}\right)\right)$$

Formula 7 – Function of the standard deviation of the lognormal distribution.

$$E(X) = \ln(\mu) - \frac{SD(X)^2}{2}$$

Formula 8 – Function of the mean of the lognormal distribution.

Where $SD(X)$ and $E(X)$ are the standard deviation and mean of variable X respectively, σ is the normal standard deviation as determined by the input values in the model, and μ is the normal mean as determined by the input values of the model. After we determined the needed parameters, we can simulate the scenarios. The build-in function does this according to the lognormal distribution as shown in Formula 9.

$$f(x) = \frac{1}{x\sqrt{2\pi SD(X)^2}} \exp\left(-\frac{(ln\, x - E(X))^2}{2\sigma^2}\right)$$

Formula 9 – PDF of the lognormal distribution.

Where $f(x)$ is equal to the randomly generated value for the log normally distributed variable, x is a randomly generated number between 0 and 1, $SD(X)$ is the standard deviation, and $E(X)$ is the mean. The PDF of the lognormal distribution is further elaborated on in Appendix A.

4.1.4 Calculation of the KPIs

After we generate random values for the relevant variables, the new values for the KPIs can be determined for every iteration. We then use these values to quantify the key risks and to get an overview of the possible outcomes of the project or investment. Because of the many iterations in combination with 6 different variables and 5 KPIs, the run time of the Monte Carlo model is quite long, about 5 minutes, however, the simulation does not have to run multiple times in order to obtain the required output, so 5 minutes is certainly manageable. The run time can be shortened by reducing the amount of iterations in the model, or by deselecting certain variables. The amount of iterations can be set to any number between 1.000 and 10.000, these limits are set since the results should still be relevant whilst the run time must not become extraordinarily high. The variables that we simulate can be deselected when desired, meaning that deselected variables will be set to their default value for each iteration, reducing the run time, but also limiting the effectiveness of the model. So, when using the model, it is advised to keep the amount of iterations on 10.000 and to select all variables, however, when the stakeholders at Company X are certain about a certain variable, or have limited available time, it is possible to alter these settings.

The first KPI that the model calculates is the Net Present Value (NPV), which indicates the profitability of a project or investment. We decided to calculate the NPV per m² of useable surface area (GBO), since this is a preference of Company X and since this makes it easier to compare multiple projects with different scales. In order to be able to calculate the value of this KPI, we first have to simulate the flow of revenues for each iteration. Due to the simulation of the relevant variables, the cash flows are altered for each iteration, allowing for a different NPV with each different iteration. We calculate the NPV by using the Minimum Acceptable Rate of Return (MARR) and the cash flow for each iteration in the equation as shown in Formula 10.

$$NPV = R_0 + \sum_{1}^{n} \frac{R_n}{(1+i)^n}$$

Formula 10 – Calculation of NPV.

Where R_n is the cash inflow – outflow (revenue) per time period n and i is the MARR as determined by Company X (equal to 8%). Company X defines the MARR as their estimation of the Weighted Average Cost of Capital (WACC). The WACC is the weighted average of the Cost of Debt and the Cost of Equity (Sullivan, et al., 2013). The Cost of Debt is equal to the interest rate (risk-free rate increased with a credit spread) multiplied by (1 – Corporate Tax Rate), it indicates the effective after-tax interest rate that Company X pays on its loans (Sullivan, et al., 2013). The Cost of Equity is equal to the risk-free rate increased with the market risk premium multiplied by the assets' beta coefficient, it indicates the required return on an investment (Sullivan, et al., 2013). The WACC can then be determined by using the LTV ratio as the weights, and calculating the weighted average between the Cost of Debt and the Cost of Equity (Sullivan, et al., 2013). The WACC indicates the minimum rate of return needed for the investment to create value, which is why it is often used as the MARR.

In this research, we calculate the NPV including financial costs such as tax and interest payments (Cost of Debt). Although the MARR is estimated by Company X, the model enables it to still be influenced by the LTV ratio and the interest rate. We have incorporated the calculation for the WACC in the model to determine the MARR for each iteration, since a different interest rate or LTV would certainly influence the WACC and should thus influence the estimation of the MARR. We do this by assuming the Cost of Equity to remain equal to the value estimated by Company X, whilst letting the Cost of Debt be dependent on the simulated value of the interest rate. These values are then used to determine the WACC according to the given LTV ratio.

We use Formula 10 for all iterations in the simulation to determine the NPV corresponding with each iteration. We then use these values for the NPVs to determine the average, minimum and maximum NPV, as well as risk indicators such as the volatility, probability of remaining above the under limit, and the Value-at-Risk (VaR). More information about what these values mean and how they are used can be found in Section 4.4.

The second and third KPIs calculated by the model are the BAR and the NAR, which indicate the gross initial yield and net initial yield respectively. The difference between these two KPIs is that the NAR also incorporates the exploitation costs and the vacancy rate. Formula 11 and Formula 12 give the equations used for the BAR and NAR respectively.

$$BAR = \frac{GRR}{IA}$$

Formula 11 – Calculation of BAR, as retrieved from Nelisse et al. (2004).

$$NAR = \frac{NRR}{IA}$$

Formula 12 - Calculation of NAR, as retrieved from Nelisse et al. (2004).

Where the GRR is the gross revenue earned via rent, and the NRR is the net revenue earned via rent, where the NRR is equal to the GRR minus the exploitation costs and costs due to vacancy. The IA is the investment amount including purchasing costs. The values for the BAR and NAR are determined per iteration and also used to determine certain statistical values and risk indicators.

The final two KPIs calculated by the Monte Carlo model are the leveraged and unleveraged internal rate of return (IRR), which, similarly to the NPV, gives an indication of the profitability of the project or investment. The IRR equals the rate of return that lets the present worth of the cash flows be equal to zero (Hartman & Schafrick, 2004). A high IRR means that the project or investment will be profitable. The leveraged IRR differs from the unleveraged IRR in the sense that the leveraged IRR includes the amount of money loaned in order to make the investment, as well as the redemption rate and the interest rate paid to the creditor per time period. The unleveraged IRR disregards the loans and assumes that the total initial investment is paid from private equity, which is useful when comparing several projects with different LTV ratios.

We determine the IRR in the model by finding the rate of return needed to let the NPV be equal to 0, which is done using the IRR function of Excel, which uses Formula 13 to achieve this.

$$NPV = R_0 + \sum_{1}^{n} \frac{R_n}{(1 + IRR)^n} = 0$$

Formula 13 – Calculation of the IRR.

The IRR can also be determined via interpolation, where the NPV is calculated with two different rates of return, one causing it to become negative and the other to become positive, after the NPVs for each interest rate is determined, linear algebra is used to determine which rate would cause the NPV to equal 0 (Sullivan, et al., 2013). The leveraged and unleveraged IRR are determined per iteration, after which statistical values and risk indicators are determined for these KPIs as well.

The IRR has a very similar role as the NPV in the decision-making process of Company X, they both indicate the profitability of an investment. However, a key difference is that the IRR cannot handle cash flows where revenues per period alternate between a positive number and a negative number, since this causes the IRR to have multiple possible outcomes (not unique). That is why we decided to include the NPV in the model, which is able to handle these alternating revenues, and can thus consistently give an indication of the profitability of these types of cash flows.

4.2 Correlation between variables

In the Monte Carlo model, the simulated variables influence each other similarly to the real world, this influence is called correlation. If variables are correlated, it means that if one variable moves in a certain direction, the other variable will move in the same direction if positively correlated and in the opposite direction if negatively correlated. If two variables have a perfect correlation, a 10% move in the first variable will result in a 10% move in the other variable, which we denote as a correlation coefficient of +1 or -1. (D'Arcy et al., 2005). This correlation coefficient is usually determined using historical data, however, since it is hard to find the historical data of variables such as vacancy rates and redemption rates and because the available historical data from the other variables is limited, we have chosen to estimate the correlation coefficients between variables using expert opinion and reasoning. Table 6 shows the correlations in the final model, as well as their respective correlation coefficients, between the relevant variables identified in Chapter 2 and elaborated on in Chapter 3.

Table 6 – Overview of all correlations present in the final model.

	Interest rate	*Indexation*	*Rise in market value*	*Redemption rate*	*Price of rent*	*Vacancy rate*
Interest rate		-0.70*	-0.50*	0.20*	0.50*	0.12
Indexation	-0.70*		0.27	-0.09	-0.26	-0.06
Rise in market value	-0.50*	0.27		-0.17	-0.41	-0.06
Redemption rate	0.20*	-0.09	-0.17		0.14	0.05
Price of rent	0.50*	-0.26	-0.41	0.14		0.50*
Vacancy rate	0.12	-0.06	-0.06	0.05	0.50*	

As can be seen in Table 6, we simulate almost all variables in the Monte Carlo model with either direct or indirect correlations. The direct correlations are indicated in Table 6 with an asterisk, these correlations are called direct correlations since they are programmed in the Monte Carlo model to influence each other based on a certain randomly generated value. The indirect correlations are the second-order correlations not directly programmed in the Monte Carlo model but still present in the generated values due to the correlation of each variable with one common variable, namely interest rate. The vacancy rate is only slightly indirectly correlated with the other variables, mainly due to its only direct correlation being with the price of rent, however there is some degree of correlation due to the direct correlation of the price of rent with the interest rate. The other variables do have significant indirect correlations with each other, for instance the rise in market value and the indexation, where a high indexation leads to a weak to moderate increase in rise in market value, which is due to a low interest rate causing the indexation to increase. The presence of indirect correlations causes the Monte Carlo model to represent the residential real estate market in a more realistic way.

The first direct correlation in the model is the correlation between the interest rate and the indexation, which we negatively correlate with a correlation coefficient of -0.7 in the Monte Carlo model, which indicates a strong negative correlation. The correlation between the interest rate and the indexation is based on the Fisher effect, which is first put forward by Fisher (1930) and postulates that the nominal interest rate is equal to the sum of the real interest rate and the expected inflation rate (Cooray, 2002). Fisher (1930) stated that there is a one-on-one relationship between the interest rate and the inflation rate in a world of perfect foresight, whereas many other papers have not been able to either prove or disprove this (Cooray, 2002). Westerlund (2008) stated that the real correlation coefficient between interest rate and indexation is not -1 as Fisher (1930) implies, however, it is high, namely an average of -0.71 based on historical data of multiple countries. In this research, the inflation rate indicates the movements of the indexation, meaning that the interest rate and the indexation are also correlated. We set the correlation coefficient between the interest rate and the indexation to -0.7, based on the findings of Westerlund (2008), Cooray (2002), and Fisher (1930).

The second direct correlation in the model is between the interest rate and the rise in market value, which are moderately negatively correlated with a correlation coefficient of -0.5. This means that when the interest rate goes up, the rise in market value decreases and vice versa. A correlation coefficient of -0.5 is chosen because, according to the stakeholders at Company X, a rising interest rate does not always induce a similar decrease of market value. In certain situations the residences are not as influenced as expected, due to, for instance, a housing shortage.

The next direct correlation in the model is between the interest rate and the redemption rate, which we weakly positively correlate with a correlation coefficient of 0.2. This means that when the interest rate increases, the redemption rate increases as well. It is chosen to model a weak correlation between these variables because when interest rates increase, Company X has to pay more to obtain loans from creditors, which could lead the creditors to increase the redemption percentage due to a decreased trust in Company X paying back the loans. However, since Company X is a unique company with a relatively very high level of liquidity, there are little scenarios in which the trust of Company X’s creditors is lost. So, in order to maintain the correlation between the interest rate and the redemption rate whilst keeping in mind the liquidity of Company X, we have chosen the correlation coefficient to equal 0.2.

The variables interest rate and price of rent are also directly correlated in the model, with a correlation coefficient of 0.5, meaning that it is moderately positively correlated. A correlation of 0.5 indicates that when the interest rate increases, the price of rent increases as well. This is done because when, in reality, the interest rates go up, potential buyers lose purchasing power since they will have to pay more for loans and mortgages. This effect decreases the demand for the purchasing of residences, and thus, since people have to live somewhere, it increases the demand for renting residences. Due to this increase in demand for renting residences, the price of rent increases. We have chosen a moderate positive correlation to illustrate this effect, because although the price of rent often increases, the amount with which it increases is not one-on-one with the increase of interest rate due to the portion of people that are still able to obtain loans and mortgages to purchase residences. Also, even though demand for renting residences grows, the prices of rent can still stagnate due to rent caps and other governmental interventions to keep prices of rent at the same level.

The correlation between the price of rent and the vacancy rate is the final direct correlation discussed in this section. We have moderately positively correlated these variables with a coefficient of 0.5, meaning that when the price of rent increases, the vacancy rate increases as well. This is because increasing the price of rent leads to higher costs of living for tenants, which can cause certain tenants to be unable to afford living in an asset of Company X, which increases the vacancy rate. A moderate positive correlation is chosen since the price of rent certainly influences the vacancy rate, however, due to high demand of housing, vacancy rates might still be low, even when the prices of rent increase. Also, when competitors increases their prices of rent simultaneously with Company X, the vacancy rate will not increase as much.

4.3 Modelling the correlations between the variables

As mentioned in Section 4.2, almost all the variables are correlated with each other, either directly or indirectly. These correlations help the model better reflect reality, by letting the values of the different variables influence each other. We have modelled the correlations in the Monte Carlo model by combining two methods found in the literature, quantile mapping, and a method based on the Cholesky transformation, which is normally used as an optimization technique in linear algebra (Tiwari & Chong, 2020). The Cholesky decomposition used in this model can only be used for values that follow a (standard) normal distribution, which means another method is needed to ensure that the variables following other distributions should be (temporarily) transformed. We do this by using quantile mapping, which consists of mapping a certain distribution on another distribution on a percentile-to-percentile basis (Hull, 2018, pp. 252-260).

In this model, we use quantile mapping to keep the different distributions in the model, whilst still incorporating correlation between the different variables. We achieve this by first simulating random values for a certain variable based on the standard normal distribution without any correlation. We then correlate these randomly generated values using a method based on the Cholesky transformation. We then use the Cholesky transformation to calculate the correlated value of a certain variable dependent on a known value of the other variable. This combination of the Cholesky transformation and quantile mapping is done for all direct correlations between all variables, except for the direct correlation between the interest rate and the redemption rate, since these are both already normally distributed and can thus be correlated without quantile mapping.

In this model, almost every correlation is based on the interest rate, causing many of the variables to be indirectly correlated with each other. In the model itself, we determine the correlated variables ϵ_1 and ϵ_2 by first simulating 2 independent samples x_1 and x_2 from the normal distribution, as shown in Hull (2012, pp. 446-452). After simulating the independent samples, we determine the correlated values for the variables using the Cholesky decomposition derived from Hull (2012, pp. 446-452), as shown in Formula 14.

$$\epsilon_1 = d_1$$
$$\epsilon_2 = \rho d_1 + d_2\sqrt{1-\rho^2}$$

Formula 14 – Cholesky decomposition to determine correlated differences per variable.

Where ρ is the correlation coefficient, which differ per correlation as shown in Table 6, and ϵ_i is the correlated value of variable i. The correlated values of each variable are currently all following a normal distribution, which is fine for the variables interest rate and redemption rate, since these variables originally follow the normal distribution. However, the variable indexation originally follows the lognormal distribution, and the other variables originally follow a triangular distribution, so, the randomly generated values according to the normal distribution should be projected onto their original distributions using quantile mapping.

After having modelled the correlations between the normally distributed variables, the correlations between differently distributed variables must be modelled, which we do using quantile mapping. The first step in mapping the values from the normal distribution to another distribution is to determine in which percentile the correlated value of the variable lies. We do this by utilizing the standard normal table. First the Z-score is determined for each variable, which gives an indication of how far the simulated value is from the mean.

After finding the Z-score, we match it with the corresponding percentile point of the standard normal distribution. This percentile point can then be used to map the values of the variables from the standard normal distribution to another distribution. This is done using a Guassian copula, where the

jth percentile point of a set of generated values of variable U_i following the normal distribution is mapped into the jth percentile point of the set of generated values of variable V_i, which follow the original distribution of the corresponding variable (Hull, 2018, pp. 252-260).

So, if a simulated variable originally following the triangular distribution lies in the 5th percentile of the standard normal distribution, we map it into the 5th percentile of the corresponding triangular distribution. Which values the variables finally take is dependent on the parameters of the respective distributions and the percentile points of the correlated values following the standard normal distribution. These final values of the variables are the values that will be used in the Monte Carlo model to determine the KPIs, the statistical measures, and the risk indicators.

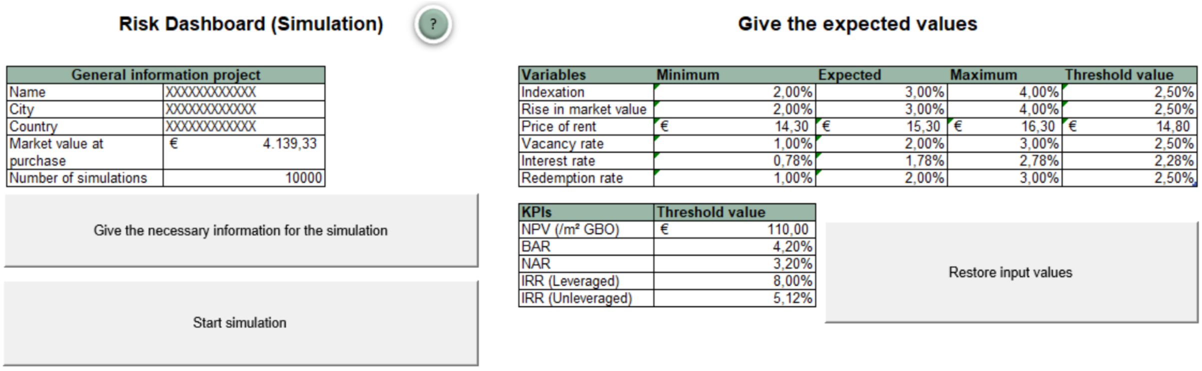
There is one downside in using quantile mapping to incorporate correlation between the variables, namely that the correlation coefficients used as input decrease in the final values of the variables after the mapping has occurred. This is due to the fact that when a variable is mapped from the standard normal distribution to the triangular distribution, the jump in value is relatively different to the jump in value when a variable is mapped into another distribution. We have decided to keep this decrease in correlation coefficient, mainly since the correlation is still very much present and since it is crucial for the nature of this model to maintain the original distributions of all variables.

4.4 Risk dashboard

In this section we explain how the risk dashboard shows the results of the Monte Carlo model, as well as how it can be used to analyse the likelihood of the key risks and how to analyse the relevant variables and KPIs, and how the stakeholders at Company X can use the model in their decision-making process.

4.4.1 Input tables

The first part of the risk dashboard contains some general information and it is the place for the stakeholders at Company X to input the needed under- and upper limits, expected values and other information. Figure 14 shows a screenshot of this part of the risk dashboard.



Risk Dashboard (Simulation) ?

General information project	
Name	XXXXXXXXXXXX
City	XXXXXXXXXXXX
Country	XXXXXXXXXXXX
Market value at purchase	€ 4.139,33
Number of simulations	10000

Give the necessary information for the simulation

Start simulation

Give the expected values

Variables	Minimum	Expected	Maximum	Threshold value
Indexation	2,00%	3,00%	4,00%	2,50%
Rise in market value	2,00%	3,00%	4,00%	2,50%
Price of rent	€ 14,30	€ 15,30	€ 16,30	€ 14,80
Vacancy rate	1,00%	2,00%	3,00%	2,50%
Interest rate	0,78%	1,78%	2,78%	2,28%
Redemption rate	1,00%	2,00%	3,00%	2,50%

KPIs	Threshold value
NPV (/m² GBO)	€ 110,00
BAR	4,20%
NAR	3,20%
IRR (Leveraged)	8,00%
IRR (Unleveraged)	5,12%

Restore input values

Figure 14 – Screenshot of input tables and general information.

As can be seen in Figure 14, the first table to the left contains some information on the project or investment, namely the name of the project, city, country, market value at purchase, and the number of simulations. Below this table there are buttons, the first button shows a pop-up screen when selected where the needed variables and the amount of simulations can be altered, which is shown in Figure 15.

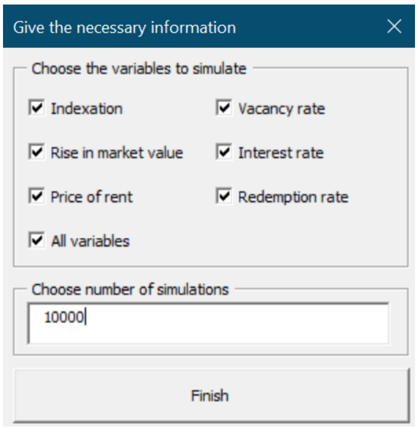


Figure 15 – The pop-up screen containing the variables that will be simulated and the amount of simulations.

As is shown in Figure 15, the pop-up screen which shows itself when the "Give the necessary information for the simulation"-button is pressed, lets the stakeholders at Company X decide which variables to simulate, and how many simulations to run. We have done this in order to let Company X decide whether they want to have a relatively fast simulation with less simulations and less variables or a more accurate simulation with all variables and 10.000 simulations.

The "Start simulation"-button starts the simulation and the most right "Restore input values"-button resets the tables to their default values. The upper-right table in Figure 14 shows the variables that can be simulated and their respective under limit, expected value, upper limit, and threshold value. The under- and upper limit indicate the values between the variable is expected to lie, whereas the expected value indicates the most probable value which a variable will assume (or mean in the case of a normal or lognormal distribution). The threshold value indicates the critical level at which a variable is regarded to become 'problematic', meaning that the risk it then bears is higher than Company X accepts. We use these values when the simulation starts for generating the random values for the variables.

The lower-right table gives the KPIs and their threshold values, which are again the critical levels at which a KPI is regarded to have a higher risk than accepted by Company X. We use these threshold values to determine the probability of success of each KPI, which is one of the risk indicators, more information about this is given in Section 4.4.2.

4.4.2 Risks per KPI

In the second part of the risk dashboard, the analysis of the results begins. This part of the risk dashboard displays the means, minimum values, maximum values, and risk indicators of the KPIs, where the risk indicators include the volatility, the probability of success, and the VaR. In order to show how the model works, the default values shown in Figure 14 have been used to perform 10.000 simulations. This led to the results shown in Figure 16.

KPIs ?

Results	NPV (/m² GBO)	BAR	NAR	IRR (Leveraged)	IRR (Unleveraged)
Average	€ 228	4,48%	3,48%	9,57%	6,84%
Volatility (absolute)	€ 150,86	0,12%	0,12%	1,03%	0,45%
Volatility (relative)	66,17%	2,67%	3,37%	10,74%	6,63%
Minimum	€ -188	4,19%	3,19%	6,62%	5,70%
Maximum	€ 1.001	4,76%	3,76%	14,83%	9,27%
Probability of success	76,89%	99,88%	99,95%	93,61%	100,00%
Risk level					

Value-at-Risk	NPV (/m² GBO)	BAR	NAR	IRR (Leveraged)	IRR (Unleveraged)
Confidence level	95%	95%	95%	95%	95%
VaR	€ -14,69	4,28%	3,28%	7,89%	6,11%
VaR (%)	-6,44%	95,56%	94,39%	82,50%	89,21%

Figure 16 – Screenshot of tables containing the results of the simulation per KPI.

The first table, as seen in Figure 16, shows the mean, minimum value, and maximum value of all KPIs, as well as the risk indicators volatility and probability of success. In this example, the volatility of the NPV is relatively high, which indicates an increased risk of getting a different result than expected. Also, the probability of success for the NPV is moderate. In this case, about 25% of the simulated scenarios demonstrated an NPV below the threshold value, meaning that there is an increased risk of Company X not meeting their own requirements for the NPV. Also, the VaR of the NPV is negative, indicating that there are certainly situations where the revenues made from the investment are lower than the threshold set by Company X. The VaR of the leveraged IRR shows this as well, since the VaR is lower than the MARR of 8%. However, most variables show low levels of risks, which indicates a relatively sound investment.

The second table in Figure 16 shows the values for the VaR of each KPI, alongside the selected confidence level. The confidence level is currently set at 95%, however, this can be changed by the stakeholders at Company X. The relative VaR (in %) of the BAR, for instance, is about 96%. This indicates that in 95% of all simulated scenarios, the lowest value for the BAR is about 96% of the mean BAR. The VaR is also given absolutely, meaning that in this case, the BAR never drops below about 4.28% in 95% of the simulated scenarios. The VaR alongside the other risk indicators are also visualised using bar charts, a screenshot of these bar charts can be seen in Figure 17.

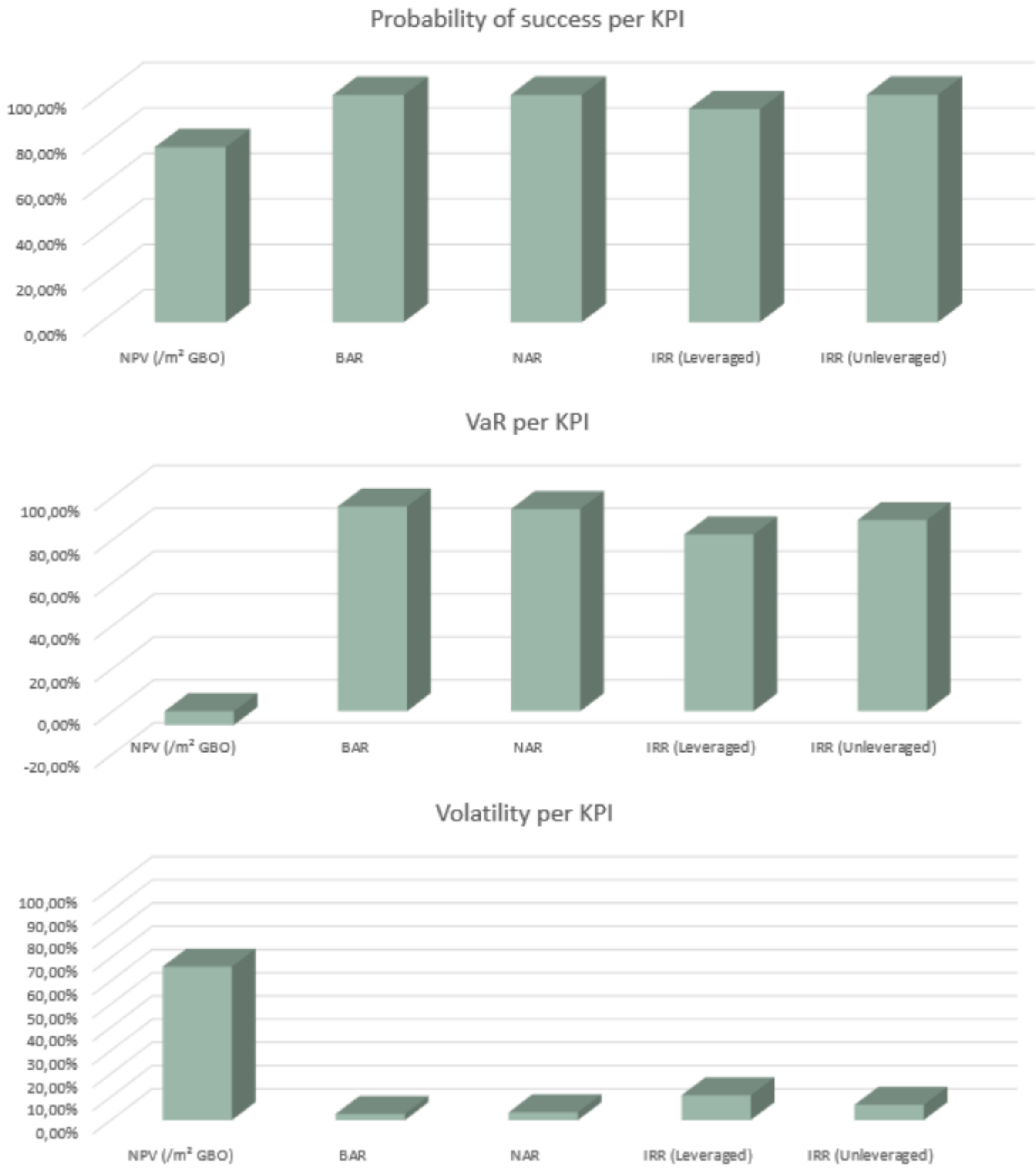


Figure 17 – Screenshot of the bar charts depicting the risk indicators per KPI.

4.4.3 Risks per variable

The next part of the risk dashboard contains the analysis of the simulation results with regard to the variables. We have divided this part into 2 sub-sections, the first consisting of the probability of success and the volatility per variable, shown in Figure 18, and the second consisting of a more in-depth analysis per variable, shown in Figure 19.

Figure 18 – Screenshot of the first section containing results of the simulation per variable.

As can be seen in Figure 18, the first section on the top-left gives an overview of the volatility and probability of success per variable. The top table gives the probability of success per variable, as well as the risk level. We have based the risk level on the probability of success, where a green colour means that there is little risk, an orange colour means that there is a moderate level of risk, and a red colour means that there is a high level of risk. The bottom table shows the volatility per table, as well as the average value of each variable, in order to indicate the bandwidth per variable after 10.000 simulations. We visualise these risk indicators using bar charts and a pie chart, which is done to visualise the levels of risk per variable relative to each other, which helps in pinpointing ‘problematic’ values.

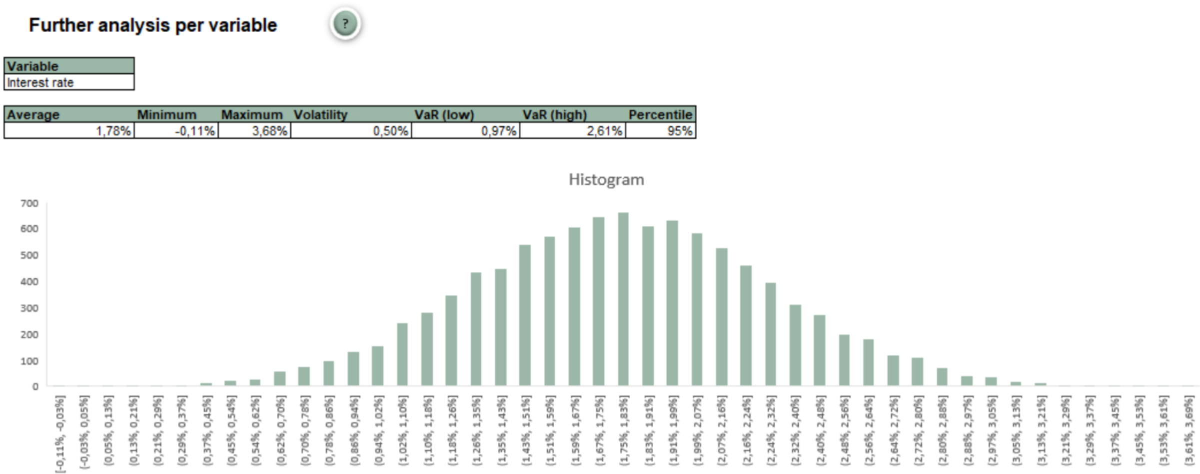
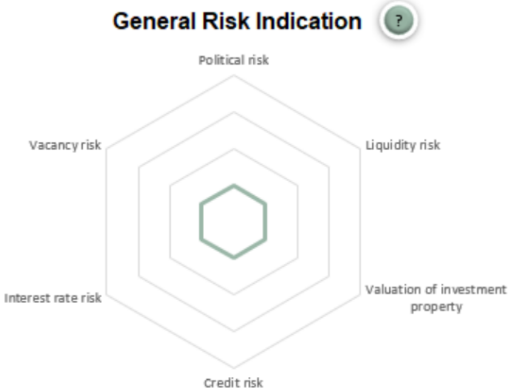


Figure 19 – Screenshot of the second section containing the results of the simulation per variable.

Figure 19 shows the second section of the simulation results per variable, which is a more in-depth analysis per variable. As you can see in the cell just below the title, the stakeholders must select the variable they want to analyse, which can be chosen from a drop-down menu. Per chosen variable, we give the mean, minimum value, maximum value, volatility, and VaR, as well as a histogram. We have incorporated this section in order to avoid having to show large tables and many histograms which would make the model less clear.

4.4.4 General risk indication

The fourth part of the risk dashboard consists of a general risk assessment, where the risk levels of the key risks are given based on the values of the relevant variables. In this section we give more elaboration on what these risk levels entail and on how they are calculated. Figure 20 shows a graph and table depicting the key risks and their risk levels.



Risk	Risk level
Political risk	1
Liquidity risk	1
Valuation of inves	1
Credit risk	1
Interest rate risk	1
Vacancy risk	1

Figure 20 – Screenshot of the general assessment of key risks.

As can be seen in Figure 20, we give a graph depicting each modelled key risk and their risk levels. The risk levels in this example are all 1 (green), indicating that the project has a low risk level. Other possible risk levels in this assessment are 2 (yellow) indicating a modest level of risk, 3 (orange) indicating a high risk level, and 4 (red) indicating a very high level of risk.

We determine the political risk with the relevant variables price of rent and redemption rate. We have chosen these variables because political risks are caused by, for instance, regulatory changes or inventions by the government which lead to a lower level of trust from the creditors of Company X. This then results in smaller loans with larger yearly payments (larger redemption rates). Also, introductions of rent caps and other interventions by governments in order to guarantee affordability of residences leads to a forced decrease in prices of rent (as is the case with social housing). So, in order to quantify political risk, we take the average of the probabilities of success from both the price of rent and the redemption rate, this percentage then indicates the political risk level of the project.

We determine the liquidity risk level with the relevant variables interest rate and redemption rate. We have chosen these variables because high liquidity risks are often due to high redemption rates, meaning that the debtor has to pay a larger amount of money in order to obtain loans. Also, high interest rates cause lower asset values, which then leads to less liquidity of Company X since selling assets takes a longer time. So, in order to quantify liquidity risk, we take the average of the probabilities of success from both the interest rate and the redemption rate, this percentage then indicates the liquidity risk level of the project.

We determine the risk level of over- or undervaluing property with the variables interest rate and rise in market value. A property has not been valuated correctly if the market value of the property rises whilst the interest rate rises as well. This is because an increased interest rate normally causes lower market values of assets, since there is less purchasing power due to higher loans and mortgages, which then causes the people to be less eager to purchase a residence. However, there are situations where both interest rates and market values rise, for instance when there is a housing shortage. Such situations could be due to 'bubbles' in the market where people systematically over-valuate property due to various reasons (like a shortage). In order to obtain an indication of the risk level of over- or undervaluing property, the Monte Carlo model counts the amount of simulated scenarios where the interest rate is higher than the 75th percentile and the rise in market value is higher than the 75th

percentile, as well as the scenarios where the interest rate is lower than the 25th percentile and the rise in market value is lower than the 25th percentile. This method indicates the amount of times that there is no logical correlation occurring between the interest rate and the rise in market value, which divided by the number of simulations gives a percentage which indicates the risk level of over- or undervaluing property.

We determine the credit risk level by the interest rate, indexation, and price of rent. This is because the risk of tenants or other debtors not being able to fulfil payments to Company X is high when the interest rate is high in combination with a high indexation. When the interest rates are high, it becomes harder for potential tenants and other debtors to obtain loans, which some debtors might need to fulfil payments. Also, a high indexation is often caused by high inflation rates, which potentially decreases the purchasing power of the debtors, since high inflation rates lead to the expenses of debtors to become more expensive. Credit risk also increases when Company X increase their price of rent, meaning that certain tenants might no longer be able to fulfil payments. So, we quantify credit risk in the Monte Carlo model by counting the simulated scenarios where either the price of rent is above the 75th percentile or both the interest rate and indexation are above the 75th percentile. We then count the number of times this occurs in the simulation and divide it by the total amount of simulations, which gives an indication of the credit risk level.

We determine the interest rate risk level with the modified duration of a project. As previously stated, the modified duration can be defined as the correlation between interest rate and asset price, where the percentage change in asset price due to a 1% rise in interest rate can be defined as the modified duration of that asset (Chaney & Hoesli, 2010). However the asset price is often not a variable during the time of risk assessment. So, instead of the asset price, we denote the modified duration with the change in NPV due to a 1% rise in interest rate. We then determine the level of interest rate risk with the value of the modified duration, if the modified duration is below 2%, the risk level is 1, if it is between 2% and 3% the risk level is 2, if it is between 3% and 4% the risk level is 3, if it is higher than 4%, the risk level is 4. In this research, we define the 1% rise in interest rate as 1% of the current interest rate, not an absolute 1% increase.

We determine the vacancy risk level with the vacancy rate. The vacancy rate is influenced by other variables in the model, such as the price of rent and the interest rate. However, the level of vacancy risk can be determined by measuring the probability of success of the vacancy rate, or in other words, the percentage of all simulated scenarios where the vacancy rate was below the threshold value. If this probability of success of the vacancy rate is above 80%, the risk level is 1, if it is between 70% and 80%, the risk level is 2, if it is between 50% and 70%, the risk level is 3, if it is below 50%, the risk level is 4.

After all key risks in the Monte Carlo model have been quantified, the graph shown in Figure 20 gives an overview. When certain key risks exhibit a risk level of more than 1, Company X should undertake extra steps in determining where the risk comes from and how to handle that risk. A step that Company X can take when certain key risk levels are high is performing scenario analyses using the scenario analysis tool, with this tool Company X can swiftly and easily change multiple variables in order to determine what would happen to the KPIs of the project or asset if certain variables are changed. This could help in a situation in which, for instance, the vacancy risk is high, then Company X can decrease the price of rent to various values in the scenario analysis tool.

4.4.5 Analysis of worst-case scenario per KPI

In order to give the stakeholders at Company X a view into which variables cause problems per project or investment, we devote a part of the risk dashboard to analysing the worst-case scenarios of each KPI, as well as the total investment. In this model, we define the worst-case scenario as all simulated scenarios in which the relevant KPI is below the VaR (with a confidence level of 95%), which essentially means that the 5% worst outcomes are analysed in this section of the risk dashboard. We do this by grouping all generated values for each variable corresponding with the 5% worst outcomes per KPI. After this is done, we give the average value per variable within these worst-case outcomes as well as the expected value per variable, indicating which variable has been the most ‘troublesome’. Figure 21 shows an overview of these worst-case scenario analyses.

Analysis of worst-case scenario's

NPV

Variables	Average worst case	Expected value
Indexation	2,10%	3,00%
Rise in market value	2,24%	3,00%
Price of rent	€ 15,34	€ 15,30
Vacancy rate	2,00%	2,00%
Interest rate	2,57%	1,78%
Redemption rate	2,45%	2,00%
NPV	€ -56,13	€ 228

BAR

Variables	Average worst case	Expected value
Indexation	3,33%	3,00%
Rise in market value	3,14%	3,00%
Price of rent	€ 14,51	€ 15,30
Vacancy rate	1,64%	2,00%
Interest rate	1,47%	1,78%
Redemption rate	1,88%	2,00%
BAR	4,24%	4,48%

NAR

Variables	Average worst case	Expected value
Indexation	3,33%	3,00%
Rise in market value	3,14%	3,00%
Price of rent	€ 14,51	€ 15,30
Vacancy rate	1,64%	2,00%
Interest rate	1,47%	1,78%
Redemption rate	1,88%	2,00%
NAR	3,25%	3,48%

IRR (Leveraged)

Variables	Average worst case	Expected value
Indexation	2,10%	3,00%
Rise in market value	2,24%	3,00%
Price of rent	€ 15,34	€ 15,30
Vacancy rate	2,01%	2,00%
Interest rate	2,57%	1,78%
Redemption rate	2,44%	2,00%
IRR (Leveraged)	7,60%	9,57%

IRR (Unleveraged)

Variables	Average worst case	Expected value
Indexation	2,19%	3,00%
Rise in market value	2,20%	3,00%
Price of rent	€ 15,16	€ 15,30
Vacancy rate	1,93%	2,00%
Interest rate	2,25%	1,78%
Redemption rate	2,24%	2,00%
IRR (Unleveraged)	5,99%	6,84%

Total

Variables	Average worst case	Expected value
Indexation	2,61%	3,00%
Rise in market value	2,59%	3,00%
Price of rent	€ 14,97	€ 15,30
Vacancy rate	1,84%	2,00%
Interest rate	2,07%	1,78%
Redemption rate	2,18%	2,00%

Figure 21 – Screenshot of the analysis of the worst-case scenarios.

As can be seen in Figure 21, each table indicates the worst-case scenario of a certain KPI or for the total investment. For example, if the stakeholders at Company X are interested in what actions they should undertake to decrease their risk exposure, they can use these tables to determine which variables are causing certain KPIs to drop below the desired limits. If they see that the leveraged IRR has a very low VaR, indicating problematic worst-case scenarios, they can determine that this is often due to a combination of a high interest rate and a low indexation and rise in market value. So, in order to decrease their risk exposure, they can, for example, reconsider the price they are willing to pay for the investment, the price of rent they should ask from the tenants, or the parameters for loaning the funds from their creditor. This final part of the risk dashboard, alongside the other elements of the risk dashboard, can help Company X in their decision-making process surrounding a potential investment, it gives insight into the relevant risks, potential scenarios, and the bounds in which the values of the KPIs will likely fall.

5 Design of the scenario analysis tool

In this chapter we answer the second part of the main research question: “How should the final model be designed?” by answering the corresponding sub-questions using the scenario analysis tool and literature. In Section 5.1 we explain how the scenario analysis tool is made and how it can be used to analyse the impact of changing relevant variables and parameters on the KPIs. In Section 5.2 we describe how the scenario analysis tool can be used to estimate the impact of the changes in relevant variables to the KPIs, which is helpful in assessing the key risks.

The scenario analysis tools’ main purpose is to help Company X estimate the impact of certain key risks on the return of an investment. The scenario analysis tool uses the discounted cash flow (DCF) technique in combination with the alteration of the values of the relevant variables to determine the values for the KPIs and the future value of an investment. The scenario analysis tool allows Company X to alter all 11 relevant variables, giving them the possibility of running countless scenarios related to the key risks. When Company X has filled in the values for each variable corresponding with the chosen scenario, the tool will calculate the values for the KPIs and the future value of the asset, which we then analyse with the use of threshold values and colour codes. When a certain KPI is under the desired threshold value, the colour code will indicate this by giving it a red colour, meaning that the scenario in question will have a large negative impact on the investment. In this chapter we give a more elaborate explanation about how this works and when the tool is effective.

5.1 Explanation of the scenario analysis tool

In this section we give an elaborate description of how the scenario analysis tool is designed, how it works, and what its added value to Company X is. First, a detailed description is given about how the scenario analysis tool works, and how it is made. In this section we also give scenarios in which the tool can be used, and how it then can be used.

As mentioned earlier, the final model is comprised of two parts, a scenario analysis tool and a Monte Carlo model. We have created the scenario analysis tool to enable the stakeholders at Company X to determine the impact of the key risks by letting them alter the values of the relevant variables corresponding with the key risks and then providing the stakeholders with the new values of the KPIs and a risk indication.

5.1.1 Limits and current values

The first part of the scenario analysis tool consists of two tables where the under limits and current values should be given, as well as three buttons, one for calculating the results, one for restoring the original values, and one for a pop-up window with information about the tool. The first part is shown in Figure 22.

Scenario analysis ?

Underlimits				IRR	
NPV		BAR	NAR	Leveraged	Unleveraged
€	165	3,36%	2,61%	8,00%	5,12%

Current Values				IRR	
NPV		BAR	NAR	Leveraged	Unleveraged
€	220	4,47%	3,47%	9,53%	6,82%

Calculate

Restore Original Values

Figure 22 – Input values of the scenario analysis tool.

Figure 22 shows the first part of the scenario analysis tool, the upper table contains default values for the under limits of the KPIs, which can be altered by the stakeholders at Company X to be equal to any value below the current values for the KPIs shown in the lower table. When the results of the scenario analysis indicate a value for one or more of the KPIs which is lower than its under limit, the tool will indicate this by colouring it red. When a certain KPI or multiple KPIs becomes red, the stakeholders can determine that the altered values of the risk variables will lead to worse than desired results. We set the default values for the under limits to 75% of the current values, which are determined by the original cash flow calculations made by the stakeholders.

The KPIs that we incorporate in this tool are the Net Present Value (NPV), the Gross Initial Yield (BAR), the Net Initial Yield (NAR), and the leveraged and unleveraged Internal Rate of Return (IRR). The NPV indicates the difference between the present value of the cash inflows and the cash outflows (Ross, 1995). So, the NPV can be used to check whether there is more cash coming in then cash coming out. We determine these cash flows using the discounted cash flow (DCF) method and incorporate both the operational and financial streams of revenue.

The BAR and NAR both indicate the quotient of the first year's gross and net income and value, and are calculated by dividing the (gross and net) revenues earned via rent by the investment costs (Nelisse et al., 2004). So, the BAR and NAR can be used to determine whether a project is generating enough yearly income via rent or not.

The IRR indicates the rate of return at which the NPV of the project or investment is equal to 0, so, in the case of Company X, when this rate would be equal to the IRR, the NPV would be 0, and when the IRR is lower than this rate of return, the NPV would become negative, meaning that the project or investment is not lucrative. There are two types of IRRs measured, namely the leveraged and unleveraged IRR. The difference between these two is that the unleveraged IRR is determined from the cash flow when no loans are taken and all funding is done privately, in other words, when the Loan-to-Value (LTV) ratio is equal to 0%. Adding the unleveraged IRR to the scenario analysis tool allows Company X to compare projects and investments to each other, even when these have different LTV ratios.

The three buttons shown in Figure 22 are the 'Help'-button, denoted by the question mark, the 'Calculate'-button, and the 'Restore original values'-button. The 'Help'-button gives extra information about the tables and the buttons, namely where to fill in which values and how to obtain and interpret results. Appendix B shows the pop-up window that appears when this button has been pressed, this text is in Dutch since the operational model for Company X will also be in Dutch (preference of the stakeholders). No further clarification of the text within these pop-up windows is given since these windows solely contain text that clarifies how the tool works, which is already done in this chapter.

The 'Calculate'-button will prompt the VBA code behind it to start and perform the calculations within the cash flow sheet according to the DCF method as well as general calculations to determine the new values for the KPIs. The 'Restore values'-button prompts the VBA code behind it to set the values within all tables to their default values.

5.1.2 Altering the variables corresponding to the key risks

The second part of the scenario analysis tool consists of a single table which holds the relevant variables related to the key risks, as well as the default values of these variables. These values are to be changed by the stakeholders at Company X in order to create scenarios, examples of certain scenarios that can be analysed are given in Section 5.2. The stakeholders at Company X can revert the values of the variables to their default values by pressing the 'Restore original values'-button. Figure 23 shows this part of the scenario analysis tool.

Variables	Value
Indexation	3,00%
Rise in Market Value	3,00%
Price of Rent (/m² GBO /mnd)	€ 15,30
Vacancy Rate	2,00%
Duration of Vacancy (months)	0
Interest Rate	1,78%
Complexity of Project	Normaal
Quality Level of Project	Basis
LTV	61,40%
Redemption Rate	2,00%
Number of Years in Portfolio	10

Figure 23 – Variables corresponding to the key risks.

So, as can be seen in Figure 23, there are 11 variables corresponding to the key risks. We set each variable in this table to a certain default value, which we derive from the original cash flow calculations and estimations made by the stakeholders of Company X. The stakeholders can alter these default values based on the scenario they want to run, when the stakeholders then press the 'Calculate'-button, the VBA code behind it will calculate the KPIs corresponding to those altered values.

Most of the variables that can we alter are directly changed in the cash flow calculations, enabling the DCF method to take the changes into account, however, the variables duration of total vacancy; the complexity of a project; the quality level of a project; and the amount of years in portfolio requires some more intricate programming and calculations, which we explain in this section as well.

The first variable we use in calculating the development of costs and profits is the indexation, which is mainly linked to the inflation rate. This variable determines the future value of the money gained and spent. The second variable is the rise in market value of the project or investment. This variable is very important in calculating future selling prices, meaning it heavily influences the NPV and the leveraged and unleveraged IRR. The third variable is the price of rent that residents pay each month, this price is the price per square meter of useable surface area. This variable decides the biggest part of the yearly cash flow coming in, when the price of rent is high, the yearly income will be high as well, and this leads to a better NPV and IRR. The price of rent also directly influences the BAR and the NAR, since these KPIs indicate the first year gross and net returns from rent divided by the investment costs.

The next variable is the vacancy rate, which is the percentage of residences that will remain vacant over the lifespan of the project or investment. Higher vacancy rates lead to less income from rent, and thus a lower value for all KPIs. The fifth variable is also linked to vacancy, this is the duration of total vacancy in months. This variable is mainly important when dealing with commercial projects or investments, where it takes time for Company X to find an interested tenant for the property. When the duration of total vacancy becomes more than 0, the amount of months that are normally used for generating income via rent is decreased, meaning that the NPV and the IRR decrease as well. We have programmed the duration of total vacancy in such a way that when the variable is changed from its default value of 0 to a certain amount of months, the VBA code changes the cash flows to reflect that in, for example, months 0 to 7 no returns are gained from rent.

The sixth variable is the interest rate, which indicates the amount of interest to be paid each year. We define the interest rate here as the risk-free rate increased with a credit spread. This variable has an effect on the amount of demand for the projects and investments of Company X, as well as the prices of rent and property value. This is because rising interest rates cause potential buyers to have a lower budget, meaning that there will be less demand for high-priced properties and thus a decrease in property prices follows due to this decrease in demand. The interest rate is also of influence to the cash flow of an investment, where higher interest rates cause higher financial costs for Company X, meaning that the revenue made per period will become lower. Changes in interest rate can thus cause changes in the leveraged IRR and the NPV (which both incorporate financial costs), where an increasing interest rate causes decreasing values for the leveraged IRR and the NPV. The unleveraged IRR is not sensitive to changes in interest rate, since it only accounts for operational revenue streams, not financial.

The next two variables share certain characteristics, these are the complexity of a project and the quality level of a project. These two variables respectively indicate the complexity of the building process of a project and the level of added quality that Company X wants to achieve with a certain project or investment. When a project has certain time-consuming building aspects due to, for example, intricate and unique designs of the property, the real building time will be longer than the expected building time, causing higher costs due to cost indices and less income due to the longer time it takes before the property can be rented out. So, a higher complexity, in this case, we model by letting the VBA code increase the duration of vacancy, which is noticeable in the leveraged and unleveraged IRR, as well as the NPV. The complexity in this tool can be assigned the values: 'normal', 'high', 'very high', and 'unique'. Setting the complexity to 'normal' causes no changes, setting it to 'high' causes a 3-month increase of vacancy, setting it to 'very high' causes a 6-month increase of vacancy, and setting it to 'unique' causes a 12-month increase of vacancy. These increases were discussed with the stakeholders at Company X.

The quality level of a project indicates the amount of resources are needed in addition to the standard resources in order to achieve a higher than usual level of quality. A higher level of quality leads to an increase in costs caused by upgrading the standard building procedures to a higher level, as well as an increase in rent price, causing higher yearly returns from rent. So, a higher level of quality leads to higher costs, but also a higher yearly return, meaning that a higher level of quality not always leads to higher or lower values for the KPIs, this depends on the initial costs of building and the initial price of rent. The quality level of a project can be assigned the values: 'normal', 'high' or 'luxury', where a normal quality level does not change anything, a 'high' level of quality leads to a 5% increase in upgrading costs of building procedures and a 2.5% increase of rent price, and a 'luxury' level of quality leads to a 10% increase in upgrading costs of building procedures and a 5% increase of rent price.

The next variables are the redemption percentage and the LTV (Loan-to-Value) ratio. The redemption percentage indicates the percentage of the total loan that needs to be paid back to the creditor each year, so, a rise in redemption percentage causes Company X to be prepared to pay a larger amount of money each year in order to fulfil the demands of the creditor, decreasing the yearly revenue made. However, a rise in redemption percentage also decreases the amount of money to be paid back at the end of the loan period, having a positive effect on the NPV and IRR. It is desirable for Company X to keep the redemption percentage relatively low, since this reserves more equity to invest in other projects or assets. Also, increasing the redemption percentage has an overall negative impact on the values of the NPV and the leveraged IRR.

The LTV ratio determines the amount of money loaned from creditors in order to be able to make the investment. The higher that the LTV ratio is, the more leverage is obtained via loans, which means that less private equity is needed to make the investment. This is positive for the leveraged IRR, since the amount of private equity invested in the first year relatively has a higher present value than the amount of equity to be paid back to the creditor in the final year. However, it can be risky to take high loans, especially for the creditors, since this increases the amount of money to be paid back each year, as well as the final repayment that must be made in the final year. So, if Company X runs into trouble and is not able to fulfil the demands of the bank, this negatively impacts their reputation with other creditors and it can also lead to fines or, in the worst case, even seizures of assets or bankruptcy.

The final variable in the scenario analysis tool is amount of years that the investment or project is kept in the portfolio of Company X. When the duration of a certain investment or project decreases, less returns are gained from rent and a higher amount of equity needs to be paid back in the final year, which all leads to a poorer NPV. However, sometimes it is less risky to decrease the amount of years in the portfolio, especially when the market is expected to become increasingly volatile and when it is expected that a crisis is coming. These kinds of situations can have very negative effects on the value of the property, causing even lower results. So, this tool helps Company X to find a balance in the amount of years that a property should remain in their portfolio. We alter this variable in the cash flow by letting the VBA code erase the years that are not relevant, for example years 9 and 10 when the number of years in the portfolio is set to 8, and then determining the new payback sum to the creditors, as well as the new revenue from selling the property in that year.

5.1.3 Results of the scenario analysis tool

In the final part of the scenario analysis tool we show the results of the scenario analysis tool. The results consist of a table with the values of the relevant KPIs, as well as the absolute and relative changes, and a table with the values of certain general results, alongside the absolute and relative changes of the general results. These tables indicate the level of risk, as well as the impact of the scenario that is analysed. When the stakeholders at Company X have pressed the ‘calculate’-button, these tables will showcase the new values, changes compared to the default scenario, and an indication of the amount of risk. When the KPI levels drop below their respective under limit (as mentioned in the first part of the scenario analysis tool), they will indicate this with a colour code.

KPI	Value	Change Absolute	Relative
BAR	4,47%	0,00%	0,00%
NAR	3,47%	0,00%	0,00%
IRR (Leveraged)	9,53%	0,00%	0,00%
IRR (Unleveraged)	6,82%	0,00%	0,00%
NPV	€ 220	€ 0	0,00%

General	Value	Change Absolute	Relative
Purchasing sum	€ 4.103,69	€ 0,00	0,00%
Market value at purchase	€ 4.139,33	€ 0,00	0,00%
Resale value when sold	€ 5.562,92	€ 0,00	0,00%

Figure 24 – KPIs and results of scenario analysis tool.

The first table shown in Figure 24 shows the KPIs that are most relevant to Company X, these are the BAR, NAR, IRR (leveraged and unleveraged), and the NPV. We give the new values and changes in value for these KPIs, both in absolute difference and relative difference. The relative differences are added to be able to compare all KPIs with each other. The values for the BAR and NAR are dependent on the returns gained via rent and the purchasing sum and costs, so, if these values drop below the desired levels, it can be an indication that either the rent is too low, or the sum for which the project or investment is purchased is too high. The values for the IRR (leveraged and unleveraged) and the NPV are determined by most variables, which all come together in the cash flow. The values are determined via the DCF-method and indicate the overall profitability of a project or investment. The idea behind this table is to check how the project or investment performs under a certain scenario (as designed by the stakeholders at Company X by inputting altered values for the variables). This helps the stakeholders at Company X with making decisions about certain projects and investments, like the minimal purchasing sum to accept, the price of rent to ask from tenants, or to determine how long a certain project or investment should be kept in the portfolio.

The second table holds general information about the project, namely the purchasing sum including purchasing costs, the market value at purchase, and the resale value when sold. The market value at purchase is a fixed parameter, since we pre-determine it by the current state of the market, so, no changes in value will occur for this parameter. The purchasing sum is usually also pre-determined, however, it may be the case that due to scenario analyses, we determine that the purchasing sum is too high. When the purchasing sum is deemed to high Company X can change this parameter too alter the cash flow and then determine the new KPIs, analysing whether the newly altered purchasing sum allows Company X to make the project or investment sufficiently profitable. However, purchasing sums cannot always be simply altered, since this is the price to be paid to the seller of the project or investment, meaning that they should be in accord with Company X paying a lower purchasing sum. So, this parameter helps in preparing for price negotiations with the selling party.

The resale value when the project or investment is sold does change when certain scenarios are created with the tool. The resale value depends on the cash flow and the change in market value, so, when the market is expected to change in favour of Company X, this can be taken into account when creating scenarios and deciding on whether or not to invest in a new project or asset. For these parameters, we measure the changes in an absolute manner, and a relative manner.

We incorporate additional cash flows, as well as a graph showing the paid out dividend per period, in the scenario analysis tool in order to provide visualisation for each project, as well as changes in cash flows. Figure 25 shows this visualisation.

EQUITY RETURNS: LEVERAGED											
Equity Contribution	-18.132.330										
Dividend Paid Out		315.909	363.241	411.752	461.480	512.460	564.731	618.330	673.298	729.676	787.507
Revenue from Sales After Taxes											60.254.440
Remaining Debt After 10 Years											-23.074.096
Remaining Balance Sheet Items											0
Cumulative Cash Flow	-18.132.330	315.909	363.241	411.752	461.480	512.460	564.731	618.330	673.298	729.676	37.967.851

PROPERTY-LEVEL RETURNS: UNLEVERAGED											
Market Value	-47.382.942										
Operational Result		1.809.392	1.864.005	1.920.263	1.978.216	2.037.915	2.099.411	2.162.759	2.228.015	2.295.237	2.364.482
Sales Revenue Before Taxes											63.678.712
Cumulative Unleveraged Cash Flow	-47.382.942	1.809.392	1.864.005	1.920.263	1.978.216	2.037.915	2.099.411	2.162.759	2.228.015	2.295.237	66.043.194

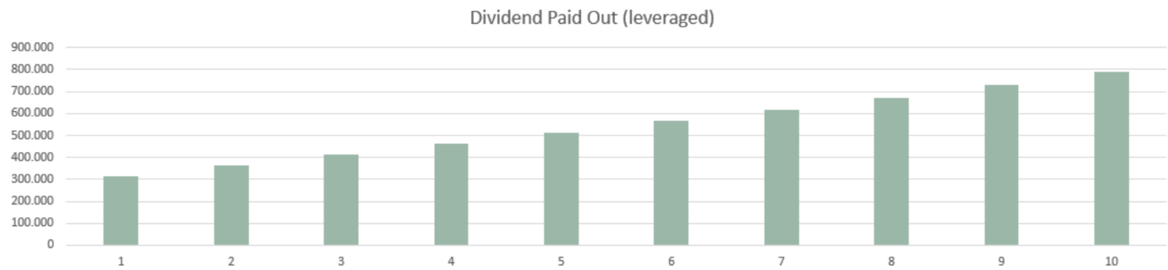


Figure 25 – Visualisation of cash flow.

So, as can be seen in Figure 25, we give two cash flows, the upper cash flow shows the leveraged returns and the lower cash flow shows the unleveraged returns. The key difference between these two is that the above cash flow also accounts for the loaned equity needed in order to fund the investment or project, meaning that the amount of own equity needed is lower, as well as the overall returns. Also, the leveraged cash flow shows the amount of money that Company X needs to pay back to their creditor at the end of the lifespan of the project or investment. We add the unleveraged cash flow in order to enable Company X to compare the cash flows with other investments or projects that have a different Loan-to-Value ratio. The graph shows the yearly returns earned via dividend from the property, this visualises the indexation of the project or investment, where a steep slope indicates a high indexation and vice versa.

5.1.4 Sensitivity analysis of the NPV

In order to aid the stakeholders of Company X in deciding which MARR to use in assessing an investment, we have made a sensitivity analysis of the NPV. We have done this by letting the code calculate several values of the NPV corresponding with several values of the MARR. In order to give an understanding of how such a sensitivity analysis can be used, we show the results from a test run with a MARR ranging from 7% to 9% with steps of 0.25% in Figure 26.

Sensitivity Analysis NPV

MARR	NPV	
7,00%	€	383,05
7,25%	€	340,75
7,50%	€	299,50
7,75%	€	259,25
8,00%	€	220,00
8,25%	€	181,71
8,50%	€	144,35
8,75%	€	107,90
9,00%	€	72,34

Figure 26 – Sensitivity analysis of the NPV.

The test run of the sensitivity analysis resulted in multiple values for the NPV, where a higher MARR results in a lower NPV. This is logical, since the made revenue stays the same and the MARR becomes higher, causing the amount of profit made relative to the desired profit (which is what the MARR indicates) to be lower. Company X can use this sensitivity analysis by filling in which potential MARR values they want to analyse. This analysis can then be used to find the optimal MARR regarding the strategy of Company X.

5.2 Assessment of key risks via scenario analysis

The key risks can be quantified using the scenario analysis tool, the Monte Carlo model, or both. In this section we elaborate on the quantification of key risks using the scenario analysis tool. The main difference between quantifying the key risks using the scenario analysis tool and the Monte Carlo model, is that the scenario analysis tool can determine the impact of a certain key risk based on the relevant variables, whereas the Monte Carlo model mainly determines the likelihood of a certain key risk. The impact of all 7 key risks can be measured by the scenario analysis tool, examples of how this can be done for each key risk is explained in this section, as well as how the scenario analysis tool can be used in combination with the Monte Carlo model.

5.2.1 Assessment of impact per key risk

Each key risk in this research can be assessed in terms of impact using the scenario analysis tool. This can be done by assigning certain values to the relevant variables corresponding to the key risk, which are then used in determining the altered values for the KPIs, as well as some general information. How these scenarios can be processed by the scenario analysis tool is explained here, as well as some examples of scenarios.

Political risk

This risk involves the impact of regulatory changes and (local) government interventions on the return of a certain project or investment. In the scenario analysis tool, the impact of this risk can be measured by altering the following relevant variables: duration of vacancy, price of rent, redemption rate, and the LTV ratio. If the stakeholders at Company X want to measure the impact of political risk, they should firstly determine the scenario in which such a political risk occurs. The scenario for political risk begins with, for instance, an intervention of the government on certain building procedures. To measure the impact of this intervention, Company X can increase the duration of vacancy, which then leads to altered values for the KPIs. Another example is the introduction of rent caps in certain cities or areas to accommodate for the lower-income class, which leads to a lower price of rent. These sort of scenarios can be analysed with the tool, which allows Company X to determine how certain political risks can impact their revenues and cash flows.

Liquidity risk
Liquidity risk involves the impact of not having enough liquid assets to fulfil the requirements of Company Xs' creditor(s). The impact of this risk is caused by changes in the following variables: interest rate, LTV ratio, and redemption rate. Liquidity risks are often present due to events tied to other risks occurring, since this risk is closely tied to the trust of the creditor(s) in Company X and the amount of liquid assets that Company X has. So, a scenario could be that due to missed payments of Company X to their creditor for a certain loan, the creditor decides to increase the redemption rate and decrease the LTV ratio, since they are no longer willing to loan out the original sum of money and to accept the current repayment schedule. The effect on the increased redemption rate and decreased LTV ratio on the KPIs shows the impact of this risk. Another scenario of high liquidity risk is an increased interest rate, where Company X must pay more in order to obtain their funding, which leads to less revenue.

Valuation of investment property
The impact of this risk is caused by the over- or undervaluation of assets, leading to misinformation and poor prognoses of the returns. The impact of this risk can be measured by altering the following variables: interest rate, rise in market value, and the quality level of an asset. Normally, a decreased interest rate causes the market value of assets to rise, since the purchasing power of people has increased due to mortgage loans getting less expensive. If a decreased interest rate does not actually cause the market value of assets to rise, there is an impact on the expected revenue of selling the asset. This impact can be measured by comparing the values for the KPIs of the scenario where a decreased interest rate does cause the market value of the asset to rise with the KPIs of the scenario where a decreased interest rate does not cause the market value of the asset to rise. Also, when a bubble occurs, and the market value of assets are relatively high, there is a risk that this bubble bursts, immediately dropping the market value of the asset. The impact of such an event can be estimated by lowering the rise in market value in the scenario analysis tool. And finally, a wrong estimation of the asset value can also be due to the quality level of a project being higher or lower than expected, to measure the impact of this scenario, the stakeholders can alter the quality level of the project and check what happens to the values of the KPIs.

Credit risk
This risks' impact comes from the debtors of Company X not having enough liquidity to fulfil the required payments (such as rent from tenants). This risk is often caused by high interest rates in combination with an increased indexation (caused by an increased inflation) and by increases in price of rent. However, these variables indicate the likelihood of credit risk, the actual impact of credit risk can be measured by also accounting for the missed payments, which can be done by increasing the vacancy rate of the project or asset. So, in order to determine the impact of credit risk, the vacancy rate should be increased in combination with an increase in interest rate, indexation, and price of rent. The effect of these increases on the values of the KPIs is the impact of credit risk.

Interest rate risk
Interest rate risk is the risk of the interest rate becoming higher and thus causing loans taken from creditors to become more expensive. The impact of this risk can be measured with the interest rate variable, namely by determining the modified duration. The modified duration, as previously mentioned, is the change in asset value caused by a 1% increase of the interest rate. However, since the current asset value is usually not variable at the time of analysing the different scenarios, the modified duration in this research is defined as the change in NPV caused by a 1% increase of the interest rate. The impact of this risk can be measured by simply altering the variable interest rate by increasing it with 1%, and then determining the new value for the NPV by checking the results table in the scenario analysis tool.

Development risk
This is the risk of costs and delay due to the building process of a project or asset. The impact of this risk can be measured by altering the duration of vacancy, complexity of a project, and/or the quality of a project. A scenario where the development risk is high is, for instance, when the ground on which the asset must be build is polluted, causing the complexity of the building process to go up since there is more time and money needed due to remediation of the ground, which leads to the cost of upgrading the asset and the duration of vacancy to increase. Also, high development risk can be caused by the request of management to increase the quality level of the asset, which does lead to more appeal and higher prices of rent, but also increases the duration of vacancy and the building costs. The impact that these increased variables have on the value of the KPIs can be seen as the impact of development risk.

Vacancy risk
Vacancy risk is the risk of Company X not being able to find tenants for their assets. This risk is increased if, for example, interest rates are low, causing potential tenants to be more interested in purchasing their own residences (due to low mortgages and more purchasing power) than in renting a residence. The impact of this risk can be directly measured by simply increasing the vacancy rate in the scenario analysis tool and then checking the results table to determine the change in value of the KPIs.

5.2.2 Combination with the Monte Carlo model
When Company X will be faced with an investment decision, they analyse which risks there are and how these can affect the potential asset. The Monte Carlo model and scenario analysis tool are aimed at helping Company X with these analyses. In this section, we discuss the way in which the model and the tool work together in analysing the potential risks Company X face.

When analysing risks, the stakeholders at Company X should first determine how likely it is that certain key risks occur and what can be lost when the asset is taken into the portfolio. This can be done with the Monte Carlo model. The Monte Carlo model should be used first and it gives Company X the risk levels per key risk, as well as indications of the amount of risk per KPI and relevant variable, more information on how this works can be found in Chapter 4. After the Monte Carlo model has been used, the likelihood of potential risks has been identified, which enables Company X to prepare for these risks and perhaps undertake action to reduce this likelihood. However, this is not the only analysis that should be made. In order to understand more about what will happen when a certain risk does occur, it is important to use the scenario analysis tool as well.

The scenario analysis tool should be used after using the Monte Carlo model, and it will serve as a way of calculating what will happen to the profitability and the KPIs of the asset when a scenario linked to a certain risk occurs. Company X can determine themselves how severely the risk will then alter the values of the relevant variables, and they will then be able to see what will happen to the value of the asset and other KPIs. For instance, if the Monte Carlo model has determined that there is a relatively high credit risk, the stakeholders at Company X can use the scenario analysis tool to determine what would happen to the KPIs and the overall investment if the vacancy rate, price of rent, interest rate and the indexation are relatively high. This will indicate what impact a high credit risk can potentially have, and thus prepare Company X for the worst-case scenario. If the amount of profit lost is manageable, an investment could still be worth it, however, if the likelihood of certain risks in combination with the impact is high, the investment might not be worthwhile anymore.

The Monte Carlo model can also be used to determine the likely under- and upper limits of revenue per project, this can be done with the Value-at-Risk (VaR). The VaR is used multiple times in the Monte Carlo model, namely for each relevant variable and each KPI, including the NPV. The VaR for the NPV is especially helpful in determining whether an asset will likely yield a profit or a loss, when the NPV is positive, the asset will yield a profit, when it's negative, the asset will yield a loss. So, when the VaR (with a 99% confidence level) of the NPV is positive, it can be assumed that in 99% of the cases, the asset will yield a profit. This makes the VaR a very valuable part of the risk analysis, especially for the NPV.

6 Validation of the model

This chapter acts as a conclusive chapter where we back test the model on several historical projects in Section 6.1, we explain and elaborate on the limitations of the model in Section 6.2, and give an explanation of how the model and tool can be implemented at Company X in Section 6.3. In this chapter we also explain how the model can be further validated in the future, and what other improvements can be made later on. We also briefly explain how the final product of this research can be of help in the future operations of Company X. In this chapter we answer the fourth and final research question: *"What effect does the model have on the investment/development decision of Company X?"*

6.1 Testing of the model on historical projects

As previously mentioned in Section 3.4, it is important for the validation of a model to test its accuracy using historical data. We do this by back testing the model on several historical projects, however, due to a lack of available data, only a limited amount of projects can be used to back test the model. Also, the only shared KPI available from these historical projects is the BAR, meaning the back testing can only be done on this particular KPI. Even though these restrictions make validating the model a lot harder, we still attempt to back test the model. Also, in order to properly validate the model after this research, more back testing should be done in the future. How this future back testing will be done and what is needed to accomplish the validation of the model is also described in this section.

There are 6 historical projects that had enough data available for the back testing of the model, the names and exact locations of these projects will not be shown due to confidentiality agreements. In order to be able to compare the projects, the 6 projects are all located in the Netherlands, they are all measured and analysed with the same variables, parameters, and definitions, and they all belong to residential real estate. We analyse these projects using the Monte Carlo model, which delivers an estimated BAR for each project. After identifying the simulated BAR, we compare it to the realised BAR, if these are relatively close for all projects, it can be said that there is an indication that the model is accurate. In order to fully validate the model, more back testing is needed, which will be done in the future.

In the back testing of the model, we first need to ensure that the required data is loaded into the model. How this is done, as well as the steps that follow are explained here using one of the historical projects as an example. The first step of the back testing is simply adding the model sheets and the macro's that run the calculations to the existing cash flow prognosis files of the historical projects. After which the next step is to fill in the expected value per variable, the limits to the values of the variables and the threshold values per variable and KPI, as can be seen in Figure 27.

Variabelen	Minimum		Verwacht		Maximum		Grenswaarde	
Indexatie		0,50%		1,50%		2,50%		1,00%
Marktwaardestijging		0,00%		1,00%		2,00%		0,50%
Huurprijs	€	7,13	€	8,13	€	9,13	€	7,63
Frictieleegstand		1,00%		2,00%		3,00%		2,50%
Interest rate		0,50%		1,50%		2,50%		2,00%
Aflossingspercentage		1,00%		2,00%		3,00%		2,50%

KPIs	Ondergrens	
NPV (/m² GBO)	€	305,39
BAR		3,35%
NAR		3,87%
IRR (Leveraged)		7,03%
IRR (Unleveraged)		4,25%

Herstel invoerwaarden

Figure 27 – Limits and threshold values of historical project 1.

We set the expected values, limits and threshold values of each historical project to a certain default, which is shown in Figure 27. The expected value of each variable is set to the values given in the original prognosis made by the stakeholders at Company X, since this indicates their intuition at that time. We set the upper- and under limit of each variable to respectively 1% less and 1% more than the mean (in absolute terms) or to €1 less and €1 more than the mean in the case of the price of rent. We chose these limits for its simplicity and since it indicates that Company X is confident in its prognosis. The threshold values for the variables do not necessarily play a role in determining the actual value for the BAR, however, it is part of the model, and we set these to the values between the minimum value and the mean per variable. The threshold values for the KPIs also do not necessarily play a role in determining the actual value for the BAR, however, it is part of the model, which we set to half of the prognosis for the NPV, and 75% of the prognosis for the BAR, NAR, and the IRR (both leveraged and unleveraged). We do this because the NPV is in general more volatile than the BAR, NAR, and IRR.

After having set the correct parameters for the model, the simulation can start. It will run 10.000 iterations and thus create 10.000 different scenarios based on the given parameters and the distributions of the variables. Each scenario generates a BAR, which can then be illustrated in a histogram as shown in Figure 28.

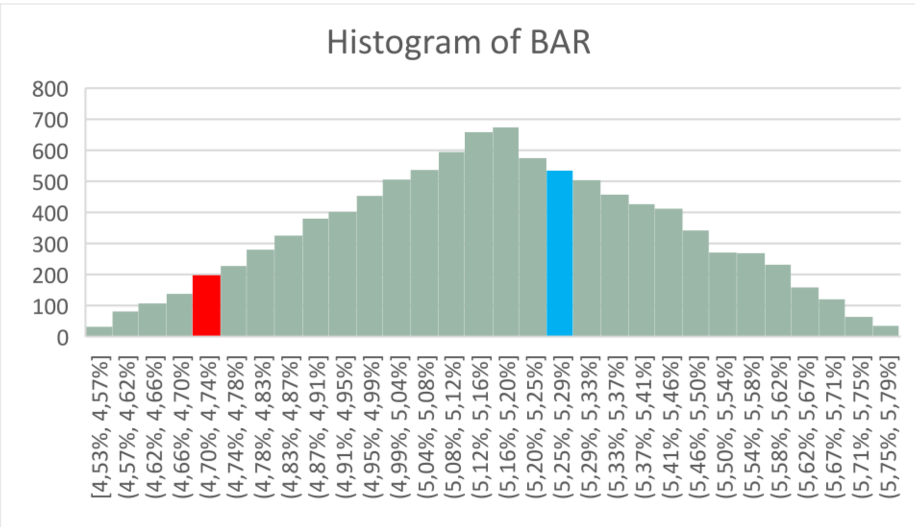


Figure 28 – Histogram of BAR outcomes of project 1.

Figure 28 shows a histogram of all BARs corresponding to all scenarios simulated by the model. As can be seen, the BARs follow a triangular distribution, due to the relevant variables in calculating the BAR being distributed triangularly. Also, we highlighted two bars of the histogram, the red bar indicates the interval in which the VaR of the BAR lies, and the blue bar indicates the interval in which the realised BAR lies. In the case of project 1, the realised BAR is a little higher than the expected (simulated) value of the BAR, however, it is very close. Also, the realised value of the BAR is well above the VaR, indicating that the model has successfully estimated the range in which the BAR will lie. This is done for every other possible historical project as well, resulting in the outcomes shown in Figure 29.

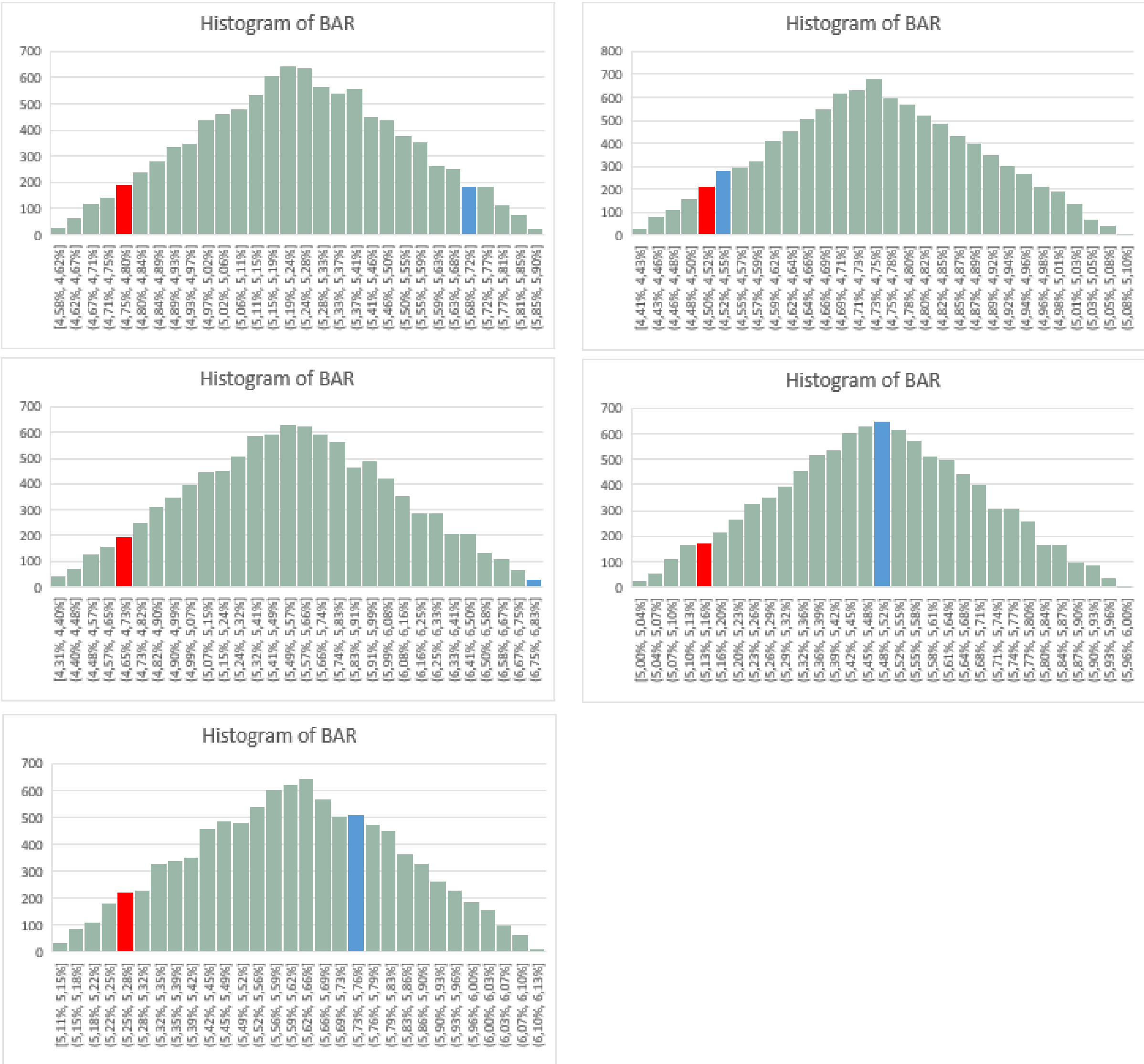


Figure 29 – Histograms of the BAR outcomes for all analysed historical projects.

The graphs in Figure 29 show all histograms of the BAR outcomes for all analysed historical projects, alongside their respective realised BARs and the VaR of the BAR per project. The first noteworthy observation from these histograms is that the volatility of generated BARs are relatively small, most likely due to the rather small bounds given in the parameter selection. The histograms show that all realised BAR values are above the VaR given by the model, indicating that the VaR, alongside the estimations for the BAR are estimated accurately. Also, all realised BARs are within the bounds estimated by the model, except for the realised BAR of Project 4 which was an absolute 0.2% higher than the highest simulated BAR. This indicates that the model is capable of giving a fair estimation of the bounds which the BAR of a project can take, especially when it comes to the VaR of the BAR. The one outlier in Project 4 is still close to the estimated values of the BAR in absolute terms, and is thus still within reasonable bounds.

In conclusion, the analysed historical projects have shown that the model created during this research would have been accurate in predicting the bounds in which the BAR will most likely lie, indicating a certain degree of validity within the model. However, the model is still not validated since this requires more historical data, as well as more analyses for each variable and KPI. How this can be done in the future is explained in Section 6.2.

6.2 Limitations of the model

The first limitation of the model is that the current way of modelling correlation between the variables is done on a one-on-one basis, meaning that a variable is correlated directly with only one other variable. This is not necessarily a problem since the indirect correlations caused by this way of modelling still depict the real-world correlations between all variables. However, it would be more elegant to expand on the Cholesky transformation used in modelling the correlations in order to let each variable be directly correlated with all relevant variables, thus creating a direct correlation matrix in which it is possible to directly insert correlation coefficients. Also, the quantile mapping done to maintain the correct distributions per variable causes the inserted correlation coefficients to become slightly different, whether the correlations are all modelled directly or indirectly. So, due to time restrictions and the necessary quantile mapping we have chosen to model the correlations using the methods described in Chapter 4.

In the future, Company X can improve the correlations between the variables by closely monitoring the values of all variables, and then using this data to estimate the correlation coefficients. These correlation coefficients can then be used to create a correlation matrix, which can then be implemented into the model using the Cholesky decomposition alongside quantile mapping to maintain the proper distributions per variable. This will cause the model to slightly improve and thus represent the real world more accurately.

The second limitation is that the model can become less accurate during times of crises, because during these times the market is very volatile, causing the relevant variables to become harder to predict and behave more unexpectedly. This is a limitation that is unfortunately very hard to overcome or improve, since the very nature of markets in a time of crisis is that it becomes harder to predict. However, the stakeholders at Company X can still use the scenario analysis tool in order to determine the effects of certain changes or events occurring. It is very important, especially in times of crises, to get an idea of what will happen to the profitability or the KPIs of an investment when big changes in the market occur. So, even though the simulation model will be less accurate during these times, the scenario analysis tool can still be used in the decision-making process.

The third limitation is that the risks involved in the building process of a project are not incorporated in the simulation model, meaning that the model does not account for the cost-inducing events tied to the building process. However, the scenario analysis tool does account for these costs, and the tool can thus be used to complement the model, especially when it comes to these building costs. The fact that the model does not incorporate building costs is due to it being a very hard to model variable, since every project is unique and the risks involved in the building process almost never occur at the same moments and with the same magnitude. So, realistically simulating such a risk is almost impossible, which is why it is incorporated in the scenario analysis tool, enabling the stakeholders at Company X to still be able to estimate the impact of these risks.

The fourth and final limitation is that the simulation model is not yet correctly validated, due to a lack of historical data. The current method of validation involves back testing the BAR of 6 historical projects, which did indicate that the model was fairly accurate for these 6 projects, however, only 6 projects and back testing on only one of the KPIs is not enough to validate the model entirely. Also, the distributions of the variables should be validated over time, even though expert opinion and literature is used to support these distributions, it is always good to determine whether the real world data behave in the same manner as the assumed distribution dictates.

Company X can still validate the model in the future, however, to do this they are required to collect enough data and to back test the model for each investment. Company X can do this by storing their prognosis for each investment, including the estimated values for all variables and KPIs. After the project is finished, they can then make an overview of the realised values of each variable and KPI, which can then be compared to the histograms of the variables and KPIs generated by the model using the estimated values. Also, Company X should keep track of the values of the variables over certain time periods and then, in the future, create a histogram for the values to validate whether the variables follow the correct distribution. If the histogram of the real world data of, for instance, the vacancy rate resembles a triangular distribution, this indicates that the distribution chosen in the model is correct. If this validation is done for each project over time, the model will become increasingly more valid. If Company X spots a pattern of wrong estimations, the model can be reviewed and altered if needed. This process of validation will ensure that the model will become more accurate and it will also identify possible improvement points.

6.3 Implementing the model and tool at Company X

In this section we cover how the model and scenario analysis tool can be implemented at Company X. As mentioned before, the model and tool are both excel (and VBA)-based tools, meaning that they can be added as sheets to the existing prognosis files that Company X already uses in their decision-making process. So, when the model and tool are implemented at Company X, it can be done with relative ease. There is however one key attribute that the files should share, namely that the prognosis files that Company X uses should all be the standardized in terms of used variables and parameters and the places that these variables and parameters will have in the file. Currently, the files do all share the same variables and parameters, however, they do not always remain in the same place for each project. Company X can alter this by creating a standardized excel file for creating prognoses, where the places are fixed and cannot be changed, which can be done by making it a semi-protected file. The model and tool can then be added to this semi-protected file, which creates a new standardized prognosis model and tool.

We placed buttons in both the model and tool in the shape of question marks, these can be clicked when a certain section of the model or tool is unclear. If these buttons are clicked, a screen pops up showing elaboration on each button, table, graph or visualization in that section. We did this in order to make the model as clear as possible. The model and tool are mainly going to be used by the asset managers, project development team, and the directors. The asset managers can use the model and tool to get an idea of how a certain investment will evolve and what its profitability will be, the project development team can use the model and tool to get an idea of what impact certain cost-inducing events will have and how likely this is, and the directors can use the output from the model and tool to assist them in their decision-making process, by for example checking if the investment can withstand an interest rate drop or whether it can handle certain risks in general.

After the implementation of this model and tool, the risks that Company X faces in their operations are put into a new quantified perspective. The stakeholders at Company X can use the model and tool to not only identify which risks could become prevalent in an investment but also what impact these risks can have, and in which bounds the KPIs of each investment will most likely lie, indicating the profitability of an investment. This quantitative analysis of the possible risks in each investment will give Company X the tools to further expand their intuition for each investment, and it is a helpful addition to the decision-making process of Company X regarding new investments. Also, we kept the stakeholders informed about the model and tool during its development, and after its finalisation we asked them for their feedback. This feedback helped conclude that the model and tool are indeed effective in quantifying the potential risks and it will be very helpful in estimating potential revenues and profitability, alongside the potential dangers of certain investments. The feedback also consisted of some additions to the model, namely the ‘help’-buttons and the values of the correlation coefficients. So, in conclusion, the model and tool are well-received, and will hopefully become an important part of the decision-making process of Company X.

7 Conclusion

We began this research with the objective to quantify the key risks faced by Company X in their operations. Currently, the risk management policy of Company X consists of mostly intuition, where investment decisions are made based on experience, the known (quantitative and qualitative) facts about the project, and estimations based on intuition and the current state of the market. Although there certainly are quantitative aspects to this approach, Company X desires more insight into the possible outcomes of an investment, the likelihood of certain key risks occurring, and the impacts of these via a quantitative method. This insight will improve the risk-awareness of Company X, and it will enable them to be better prepared.

In order to quantify the key risks faced by Company X, we created a Monte Carlo model and a scenario analysis tool. We have done this by first identifying the key risks, the current KPIs used to measure the potential performance of an investment, and the relevant variables and parameters used in determining these KPIs. We have identified the following key risks: *political risk, liquidity risk, valuation of investment property, credit risk, interest rate risk, development risk,* and *vacancy risk*. We measured the impact of these risks on the potential performance of an investment using the NPV, and the KPIs currently used by Company X, the BAR, NAR, and both the unleveraged and leveraged IRR. This answers the first main research question: *"What is the current situation?"* After having identified the key risks and the relevant KPIs, we reviewed the current literature to gain more insight into the key risks and to determine which quantification methods and risk indicators to use in quantifying these key risks.

The literature review led to the decision to create two methods of quantification for Company X, a Monte Carlo simulation and a scenario analysis tool. The Monte Carlo simulation model is useful for finding the likelihoods of the key risks occurring and estimating the bounds between which each KPI and each relevant variable will lie. The scenario analysis tool is complementary to the Monte Carlo model in the sense that the model can be used to find the risks with the highest likelihood, after which the tool can be used to determine the impact of those risks occurring on the KPIs and the general profitability of an investment. The insight into the key risks and the selection of fitting quantification methods done in Chapter 3 answer the second research question: *"How can the key risks be quantified and modelled?"*

In order to measure the risks, we used certain indicators, namely the Value-at-Risk (VaR) and the volatility. These indicators can be measured for each relevant variable, as well as each KPI. The VaR is used to determine the worst outcome per KPI or variable in α% of the scenarios, where α is the confidence level. So, the VaR can be used as an indicator of the amount of resources needed to cover the biggest possible loss with a probability of α%. The VaR lets Company X focus on the most realistic outcomes by negating the "worst-case" scenarios that will almost never happen, which helps Company X in finding their most suitable buffer of capital for each investment. We also measured the volatility for each relevant variable and each KPI. The volatility helps Company X in determining the variables that have the biggest swings in value, indicating the overall risk level of these variables. When variables are very volatile, the KPIs become increasingly volatile as well, leading to a situation where it becomes more likely that an investment will be either very profitable or that an investment will cause a loss. These risk indicators, alongside other statistical values are used in determining the likelihood of each key risk.

After having determined which quantification methods and risk indicators to use, we designed and created the model and tool. The Monte Carlo model consists of a risk dashboard and the simulation of a large number of scenarios. The created model simulates the scenarios by generating random values for all relevant variables using their respective distribution, we also incorporated the correlations between these variables using a Cholesky decomposition and quantile mapping. The simulated values for the variables are then used to determine the KPIs for each scenario. All these scenarios are then analysed in the risk dashboard. The risk dashboard consists of five parts, with the first being the input section. In the input section, the stakeholders have to fill in their expected value for each variable, as well as the estimated limits and threshold values. We then used these limits and expected values in combination with the respective distributions to generate the random values, whereas the threshold value is used to determine the probability of success for each variable. The stakeholders should then fill in the threshold values for each KPI, as well as the amount of simulations to run and the variables to simulate. After the input section has been filled out, the simulation can be started.

After the simulation has finished, the other parts of the risk dashboard show the results, where each KPI and variable is analysed by determining their average value, volatility, minimum value, maximum value, probability of success, and VaR. We then used these measures to determine the risk levels of each key risk, indicating the likelihood of each key risk occurring. In order to let the stakeholders at Company X be able to identify the most troublesome variables per KPI, as well as in total, we added an analysis of the worst-case scenarios in the risk dashboard. The worst-case scenarios are defined here as the worst 5% of all scenarios.

The scenario analysis tool complements the Monte Carlo model by further analysing the key risks that are most likely to occur. The stakeholders at Company X can fill in the values for each variable, alongside additional factors such as the complexity of the project, the quality level of the project and the amount of years the investment will stay in their portfolio. The stakeholders can alter the values corresponding to the key risk they want to analyse, for example, when the credit risk is high, they can increase the interest rate, indexation rate, and the price of rent accordingly to determine the impact of high credit risk on the KPIs and overall profitability of the project. The capabilities of the model and tool as described in Chapter 4 and Chapter 5 give an answer to the third research question: *"How should the final model be designed?"*

After having tested the Monte Carlo model on historical projects, it became clear that the model is able to identify which variables have the highest impact on the profitability of an investment, and which variables are mostly responsible for the highest risks. However, further validation is still needed due to a lack of historical data, which is a limitation of this research. The model showed, for instance, that in the case of this project, the indexation had the highest probability of falling below its desired level, however, the highest impact on the profitability was caused by a rise in interest rates. This information can help Company X in making decisions regarding their investments, such as hedging for high interest rates by investing in interest-rate derivatives, which could (partially) remove the danger of interest rates increasing more rapidly than expected. The implementation of the model and tool at Company X can be achieved by adding the sheets containing the scenario analysis tool, the Monte Carlo model dashboard, and the iterations made by the model to the existing cash flow prognosis file. This, alongside the 'help'-buttons placed in these sheets, will make it very much possible to implement at Company X. How the model and tool can affect the decision-making processes at Company X gives an answer to the fourth and final research question: *"What effect does the model have on the investment/development decisions of Company X?"*

The main objective was to quantify the key risks involved in Company X's operations. Which is achieved by creating a Monte Carlo model and a scenario analysis tool which enable Company X to estimate the likelihood of the key risks, the bounds in which the KPIs and relevant variables lie, and the impact of the key risks on the KPIs and overall profitability of a project or investment. The model and tool are complementary to the intuition and experience of Company X in their decision-making process, which was a personal goal during this research as well as a desire of Company X. This research has given a solution to the main research problem: *"The risks involved in Company X's* *operations are not quantitatively analysed"* by creating this model and tool. During the research, it became apparent that the intuition and experience of the people at Company X is crucial in the success of Company X, which is why the model and tool allow for this intuition and experience to be, not only included, but necessary in the risk analyses of each project or investment.

7.1 Discussion

In this section the results of this research are discussed, as well as the contributions to theory and practice. The result is the creation of a Monte Carlo model and scenario analysis tool which aids the stakeholders at Company X in their decision-making process regarding new investments and projects. Although the model can currently not be completely validated, the results of the preliminary validation were promising. Also, both the model and tool are completely functional and are highly customizable in terms of input, which makes it suitable for many different types of investments and projects. The model and tool, as well as the research done, all contribute to practice in the sense that Company X can use the model and the tool to determine the likelihood and impact of the key risks. Company X can use the research in terms of literature as a source of information regarding the key risks, as well as the relevant variables and measures that can indicate the level of each of these risks.

This research contributes to the current theory by firstly adding additional insights into the modelling of Monte Carlo simulations and the use of these simulations, as well as scenario analyses and the VaR, in the real estate market. The real estate market is currently not as well-researched as the other financial markets, whereas most of the research regarding real estate revolves around REITs (Real Estate Investment Trusts), which are publicly traded companies which generate income via real estate and offer a steady income stream for their investors. This research adds to this body of knowledge by diving deeper into the direct investment in physical real estate and especially the risks involved in these investments and how to manage them. Also, the method of correlating the variables in the Monte Carlo model is a contribution to theory, since it is not common to correlate multiple variables with different distributions using a combination of the Cholesky decomposition and quantile mapping. How this is done, as well as the research surrounding it, contributes to the current theory.

In conclusion, this research has done most of its contribution directly to Company X, who can directly implement the model and tool in order to quantify the key risks faced in their operations. However, the research done into the key risks and the VaR and volatility will add to the current body of knowledge. The result of this research shows that even though the real estate market is often seen as hard to predict and of qualitative nature, it is possible to analyse risks and estimate bounds for the KPIs and overall performance of a real estate investment or project.

7.2 Future research

This section suggests topics for future research and recommendations for Company X following the outcomes of this research. For future research it would be beneficial if more research was done into correlating all relevant variables directly. Currently, the correlation between the variables is mostly done on a one-on-one basis, meaning that a variable is correlated directly with one other variable. This is not a problem, since the indirect correlations caused by this way of modelling still depict the real-world correlations between all variables, however, it would be more elegant to expand on the Cholesky transformation used in the modelling to let each variable be directly correlated with all relevant variables. Also, due to quantile mapping, the correlations are slightly different from the inputted correlation coefficients, it would be interesting to see research be done to determine whether this can be improved and how.

Another interesting topic of future research would be the validation of the used distributions per relevant variable. Even though we used reasoning and the current literature to determine the distributions, it would be beneficial to validate these distributions with the use of historical data. Currently, there was not enough time and resources available to validate these distributions, however, if Company X closely monitors the values for all relevant variables over time, it will become possible to create histograms and thus validate the distributions by comparing the histograms with each distribution.

As mentioned in the limitations in Section 6.2, the model itself is not yet completely validated. We recommend Company X to continue this process of validation in the future by collecting enough data on all relevant variables and KPIs for each project or investment in order to be able to fully back-test the model in the future. This back-testing can be done by comparing the realised results with the estimations made by the model, if these are accurate for enough projects and investments, the model will be validated.

We also recommend Company X to install new software and tools that can monitor the analysed key risks and relevant variables in real time. This would be beneficial for Company X since they can then adjust their allocation of funds and strategy according to the development of these key figures. Company X currently certainly keep track of these key figures, however, software that can display these figures in a dashboard would make it easier. Also, this could help in logging events that are cost-inducing, which makes it easier for Company X to understand why a certain risk occurred and it will help in preventing it in the future.

The final recommendation is for Company X to split the variable indexation into two new variables, one for the development of revenues and one for the development of costs. This would be beneficial since the revenues generated from rent and the selling of assets does not necessarily follow the same pattern of growth as the costs induced by the building process and exploitation. Splitting the indexation rate into two separate rates will better reflect the reality and make the model, tool, and overall prognosis of a project or investment more realistic.

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Appendix A – Additional information on used distributions

This appendix provides additional information on the Probability Distribution Functions (PDFs) of the triangular distribution, the normal distribution, and the lognormal distribution. Per distribution an example is given of how values can be generated using their respective PDF, as well as an example in the form of a histogram belonging to each PDF.

Triangular distribution

The PDF of the triangular distribution is shown in Formula 15, this PDF will be used in an example that illustrates how random values can be generated for the triangular distribution.

$$f(x|a,b,c) = \begin{cases} a + \sqrt{x(b-a)(c-a)} & if\ x < (b-a)/(c-a) \\ c - \sqrt{(1-x)(c-b)(c-a)} & otherwise \end{cases}$$

Formula 15 – PDF of the triangular distribution.

Where $f(x|a,b,c)$ equals the value for the random variable, x equals the randomly generated uniform number, and a, b and c equal the under limit, mean, and upper limit respectively.

In this example, random values for the variable vacancy rate are generated. This variable follows the triangular distribution, meaning that we first need the under limit, mean, and upper limit (a, b and c respectively). These values are given in the model by the user, this is often (one of the) the stakeholders. The values are filled in based on experience, expertise, and market research. In this example, the under limit, mean, and upper limit are equal to 2%, 3%, and 4% respectively.

After having determined these parameters, the random variable x needs to be determined. This is done using the RND() function from VBA, which generates a sequence of uniformly distributed random values between 0 and 1. If the value of x is smaller than the difference between the mean and the under limit divided by the difference between the mean and the upper limit, there will be a value generated between the under limit and the mean, if the generated random number is bigger, a value will be generated between the mean and the upper limit. After having identified which of the two equations shown in Formula 15 will be used based on the value of x, the corresponding calculations will determine the value of the variable.

In the case of this example, the randomly generated value for x is equal to 0.4, meaning that a value between the under limit and the mean will be generated. After having inserted all parameters and having done the calculations, the PDF dictates that the generated value of the variable equals about 2.9%, relatively close to the mean as is expected since 0.4 is relatively close to 0.5. After having done this same process for 10.000 iterations, a histogram can be made, as is shown in Figure 30.

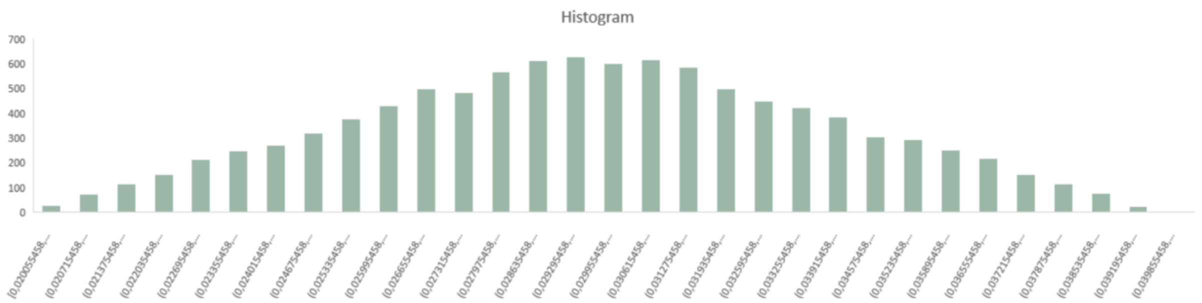


Figure 30 – Histogram of the Triangular distribution.

As can be seen in Figure 30, the generated values form a triangle, where the most common value is at the mean, and none of the generated values surpass the previously given limits, which is characteristic for the triangular distribution.

The idea behind the PDF of the triangular distribution is that the under- and upper limits are known, and a 'best guess' is represented by the mean. The calculations then allow for the 'best guess' to be the most likely value, whereas the probability corresponding to a certain value becomes increasingly (and linearly) smaller when approaching the under- and upper limits. This distribution is best used in situations where it is hard to find enough data to pinpoint a certain mean, but there is a 'best guess' and an idea of what the limits are, which is the case for the vacancy rate of a real estate asset. Each real estate asset is unique and dependent on idiosyncratic variables, such as the area in which it is located. This makes it hard to find a value for the mean using the available data, however, investors can use their 'best guess' to approximate the possible values for the vacancy rate.

Normal distribution
The PDF of the normal distribution is shown in Formula 16 will be used in an example that illustrates how random values can be generated for the normal distribution.

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

Formula 16 – PDF of the normal distribution.

Where $f(x)$ is equal to the randomly generated value for the relevant normally distributed variable, σ is the standard deviation, μ is the mean, and x is the randomly generated number between 0 and 1 following an uniform distribution.

In this example, random values for the variable interest rate are generated. This variable follows the normal distribution, meaning that we first need the standard deviation and the mean (σ and μ respectively). These values are given in the model by the user, this is often (one of the) the stakeholders. However, the standard deviation is not given directly, but by letting the stakeholders give an under- and upper limit and then letting the standard deviation equal the average difference between the given mean and the under- and upper limit divided by 2. This is done to make it easier for the stakeholders to fill in each variable by letting the input parameters be the same for each variable, which is determined in collaboration with the stakeholders, and to let the standard deviation not be too high, which will result in unrealistic outcomes. Also, this way of calculating the standard deviation is done relatively ad hoc, however, by letting the standard deviation be dependent on the under- and upper limit, the standard deviation will always be in line with the expectations of the stakeholders, which is key to the model.

The values are filled in based on experience, expertise, and market research. In this example, the under limit, mean, and upper limit are equal to 0.8%, 1.8%, and 2.8% respectively, meaning that the standard deviation is equal to 0.5%, and that the mean is equal to 1.8%.

After having determined these parameters, the random variable x needs to be determined. This is done in the same manner as for the triangular distribution. The value for x used in this example will be 0.6, meaning that we are interested in the threshold value corresponding with the probability $x = 0.6$. This means that the probability that the value of the variable is lower than the threshold value $f(x)$ is equal to $x = 0.6$. This value $f(x)$ is then used as the generated value for the variable. After having inserted all parameters and using the NORM.INV function of excel, the PDF dictates that the generated value of the variable interest rate equals about 1.9%, relatively close to the mean of 1.8% as is expected since 0.6 is relatively close to 0.5. After having done this same process for 10.000 iterations, a histogram can be made, as is shown in Figure 31.

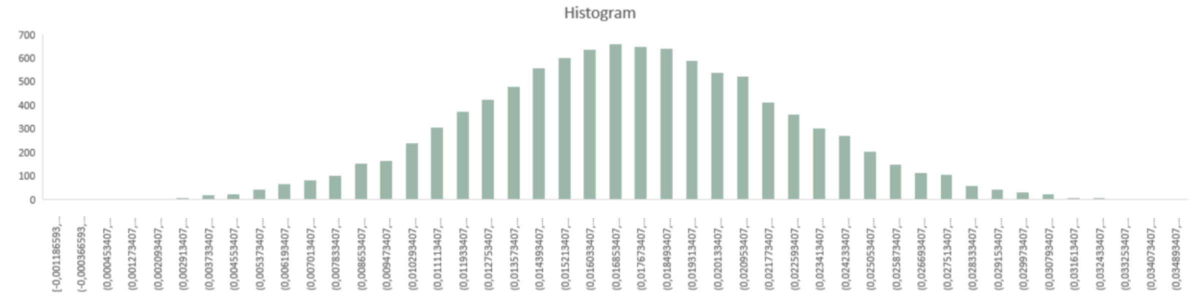


Figure 31 – Histogram of the normal distribution.

The histogram of the normal distribution shows a bell-shaped graph with most observations around the mean as is expected. The normal distribution characteristically shows observations both under and over the given limits, meaning that this distribution allows for extremities, much like in the real world. The normal distribution is best-used for variables that cannot be assumed to have a distinct distribution, where, according to the central limit theorem, the sum of many independent and identically distributed variables is approximately normal, even if the variables themselves are not normally distributed (Rosenblatt, 1956).

Lognormal distribution

The PDF of the normal distribution is shown in Formula 17 will be used in an example that illustrates how random values can be generated for the lognormal distribution.

$$f(x) = \frac{1}{x\sqrt{2\pi SD(X)^2}} \exp\left(-\frac{(ln\, x - E(X))^2}{2\sigma^2}\right)$$

Formula 17 – PDF of the lognormal distribution.

Where $f(x)$ is equal to the randomly generated value for the log normally distributed variable, x is a randomly and uniformly generated number between 0 and 1, $SD(X)$ is the standard deviation, and $E(X)$ is the mean.

In this example, random values for the variable indexation are generated. This variable follows the lognormal distribution, meaning that the logarithm of the variable indexation is normally distributed. In order to generate a random value for the indexation, we first need the standard deviation and the mean ($SD(X)$ and $E(X)$ respectively). In the model, these values are given indirectly by the user, namely by first determining the standard deviation σ and mean μ, which are the parameters belonging to the variable indexation, whereas the standard deviation $SD(X)$ and the mean $E(X)$ are the parameters belonging to the natural logarithm of the indexation. σ and μ are determined in the same manner as is done for the normal distribution. After having identified these parameters, the parameters of the natural logarithm of the variable can be determined with Formula 18 and Formula 19.

$$SD(X) = \ln\left(1 + \left(\frac{\sigma^2}{\mu^2}\right)\right)$$

Formula 18 – Standard deviation of the natural logarithm of the variable.

$$E(X) = \ln(\mu) - \frac{SD(X)^2}{2}$$

Formula 19 – Mean of the natural logarithm of the variable.

The values are filled in based on experience, expertise, and market research. In this example, the under limit, mean, and upper limit are equal to 2%, 3%, and 4% respectively, meaning that the standard deviation σ is equal to 0.5%, and that the mean μ is equal to 3%. These values lead to a value for the standard deviation $SD(X)$ of about 0.03 and a mean $E(X)$ of about -3.51.

After having determined these parameters, the random variable x needs to be determined. This is done in the same manner as for the triangular distribution and the normal distribution. The value for x used in this example will be 0.4, meaning that we are interested in the threshold value corresponding with the probability $x = 0.4$. This means that the probability that the value of the variable is lower than the threshold value $f(x)$ is equal to $x = 0.4$. This value $f(x)$ is then used as the generated value for the variable. After having inserted all parameters and using the LOGNORM.INV function of excel, the PDF dictates that the generated value of the variable indexation equals about 2.9%, relatively close to the mean of 3.0% as is expected since 0.4 is relatively close to 0.5. After having done this same process for 10.000 iterations, a histogram can be made, as is shown in Figure 32.

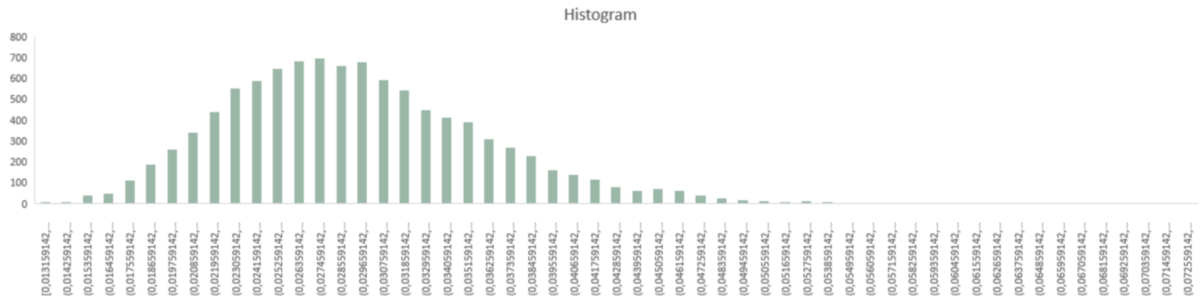
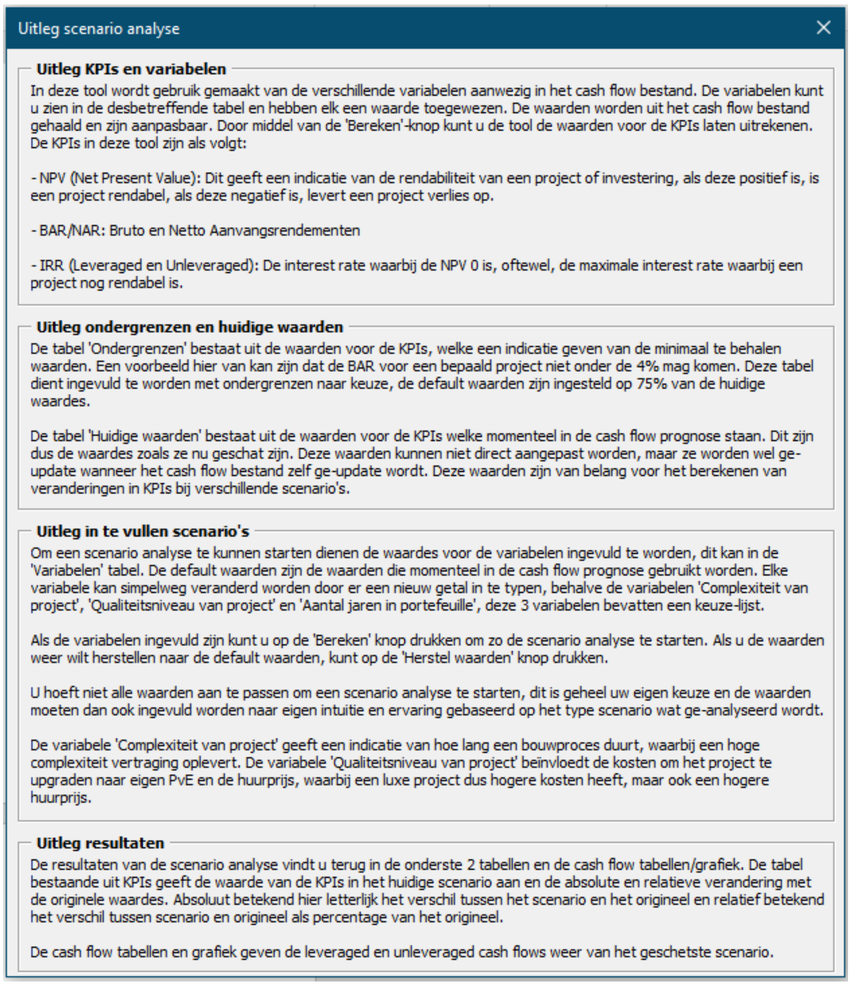


Figure 32 – Histogram of the lognormal distribution.

The histogram of the lognormal distribution resembles a normal distribution which is skewed to the right, this skewness is characteristic to the lognormal distribution, as well as the property that it can never generate values below 0. The lognormal distribution is used to generate values for variables which logarithm follow the normal distribution, and which values cannot be lower than 0. In the case of this research, the lognormal distribution is used to model the variable indexation, which is assumed by stakeholders to never go below 0 and follows the same pattern as the inflation (which historical data resembles the shape of a lognormal distribution).

Appendix B – Screenshot of an example of the 'help'-button


Uitleg scenario analyse

Uitleg KPIs en variabelen

In deze tool wordt gebruik gemaakt van de verschillende variabelen aanwezig in het cash flow bestand. De variabelen kunt u zien in de desbetreffende tabel en hebben elk een waarde toegewezen. De waarden worden uit het cash flow bestand gehaald en zijn aanpasbaar. Door middel van de 'Bereken'-knop kunt u de tool de waarden voor de KPIs laten uitrekenen. De KPIs in deze tool zijn als volgt:

- NPV (Net Present Value): Dit geeft een indicatie van de rendabiliteit van een project of investering, als deze positief is, is een project rendabel, als deze negatief is, levert een project verlies op.

- BAR/NAR: Bruto en Netto Aanvangsrendementen

- IRR (Leveraged en Unleveraged): De interest rate waarbij de NPV 0 is, oftewel, de maximale interest rate waarbij een project nog rendabel is.

Uitleg ondergrenzen en huidige waarden

De tabel 'Ondergrenzen' bestaat uit de waarden voor de KPIs, welke een indicatie geven van de minimaal te behalen waarden. Een voorbeeld hier van kan zijn dat de BAR voor een bepaald project niet onder de 4% mag komen. Deze tabel dient ingevuld te worden met ondergrenzen naar keuze, de default waarden zijn ingesteld op 75% van de huidige waardes.

De tabel 'Huidige waarden' bestaat uit de waarden voor de KPIs welke momenteel in de cash flow prognose staan. Dit zijn dus de waardes zoals ze nu geschat zijn. Deze waarden kunnen niet direct aangepast worden, maar ze worden wel ge-update wanneer het cash flow bestand zelf ge-update wordt. Deze waarden zijn van belang voor het berekenen van veranderingen in KPIs bij verschillende scenario's.

Uitleg in te vullen scenario's

Om een scenario analyse te kunnen starten dienen de waardes voor de variabelen ingevuld te worden, dit kan in de 'Variabelen' tabel. De default waarden zijn de waarden die momenteel in de cash flow prognose gebruikt worden. Elke variabele kan simpelweg veranderd worden door er een nieuw getal in te typen, behalve de variabelen 'Complexiteit van project', 'Qualiteitsniveau van project' en 'Aantal jaren in portefeuille', deze 3 variabelen bevatten een keuze-lijst.

Als de variabelen ingevuld zijn kunt u op de 'Bereken' knop drukken om zo de scenario analyse te starten. Als u de waarden weer wilt herstellen naar de default waarden, kunt op de 'Herstel waarden' knop drukken.

U hoeft niet alle waarden aan te passen om een scenario analyse te starten, dit is geheel uw eigen keuze en de waarden moeten dan ook ingevuld worden naar eigen intuïtie en ervaring gebaseerd op het type scenario wat ge-analyseerd wordt.

De variabele 'Complexiteit van project' geeft een indicatie van hoe lang een bouwproces duurt, waarbij een hoge complexiteit vertraging oplevert. De variabele 'Qualiteitsniveau van project' beïnvloedt de kosten om het project te upgraden naar eigen PvE en de huurprijs, waarbij een luxe project dus hogere kosten heeft, maar ook een hogere huurprijs.

Uitleg resultaten

De resultaten van de scenario analyse vindt u terug in de onderste 2 tabellen en de cash flow tabellen/grafiek. De tabel bestaande uit KPIs geeft de waarde van de KPIs in het huidige scenario aan en de absolute en relatieve verandering met de originele waardes. Absoluut betekend hier letterlijk het verschil tussen het scenario en het origineel en relatief betekend het verschil tussen scenario en origineel als percentage van het origineel.

De cash flow tabellen en grafiek geven de leveraged en unleveraged cash flows weer van het geschetste scenario.

Figure 33 – Screenshot of an example of the 'help'-button

Figure 33 shows a screenshot of the pop-up window that appears when the 'help'-button of the scenario analysis tool is clicked. This pop-up window is the same in terms of lay-out and design for all other 'help'-buttons in the model. The window, belonging to the scenario analysis tool, shows an explanation of the used KPIs and variables; of the limits, threshold values, and current values; of the possible scenarios; and of the results. The text is in Dutch since this window is designed to help the stakeholders at Company X, which are all Dutch and preferred a Dutch text.