Data Centre Investment:

An investment model & associated risk-return profile

Master Thesis

Teus Louwerens

Real Estate & Housing | Faculty of Architecture

Management summary

Introduction

The data centre market is an emerging immature market, even though the services housed in these facilities are widely used and mission critical to many companies. Because of this immaturity investors often associate data centre investments with high risk compared to other real estate asset types. However, data centres differ from conventional real estate assets, which make comparison to other real estate types troublesome. The difference arises from the unique blend of locational, physical and technological characteristics as a result of their specialist function.

Even though recent research into office and retail real estate proves that meso and microeconomic factors influence the value-in-use or the value-in-exchange, this knowledge of the data centre real estate market is very limited due to the immaturity and smaller scale of the recently emerged market.

The lifespan is another remarkable difference between conventional real estate and data centre real estate. High technological dependency and continued IT development shortens the usual lifespan of 30^{+} years. The optimal life span of data centre components range from seven to ten years. This shortens the investment horizon, while increasing the investment risk. It's likely that this increased risk drives data centre investors to look for alternative complementing decision-making criteria like it did office and retail real estate investors.

Recent studies researched data centres features, such as locational and physical characteristics. However, the knowledge of the effects of locational (regional) and building features on the value-in-use and the value-in-exchange of this extraordinary real estate asset are limited.

Therefore, the following hypotheses are formulated:

Date centre investments are comparable to other conventional real estate asset classes in terms of risk and return.

Higher returns for investors, owners and operators can be achieved by optimizing the data centre real estate decision-making criteria.

To test the hypothesis the following research question is used:

How do data centre investments compare to conventional real estate investments in terms of risk and return?

How can higher returns for data centre investors, owners and operators be achieved by optimizing the data centre real estate decision-making criteria?

Methodology

In order to answer the research questions the risk-return profile of data centre investments and the current decision-making criteria employed by investors and owners are described. To do so the data centre stakeholders and market were analysed through literature study and expert interviews.

The literature study and expert interviews were expanded to gather all information and data needed to construct the financial model. The findings resulting from the model were validated through sensitivity analyses and expert verification. If needed the model was adjusted.

After the model was validated the decision-making criteria were analysed using an impact analysis. Consequently, the results were interpreted and discussed.

Figure 1 displays the research outline.

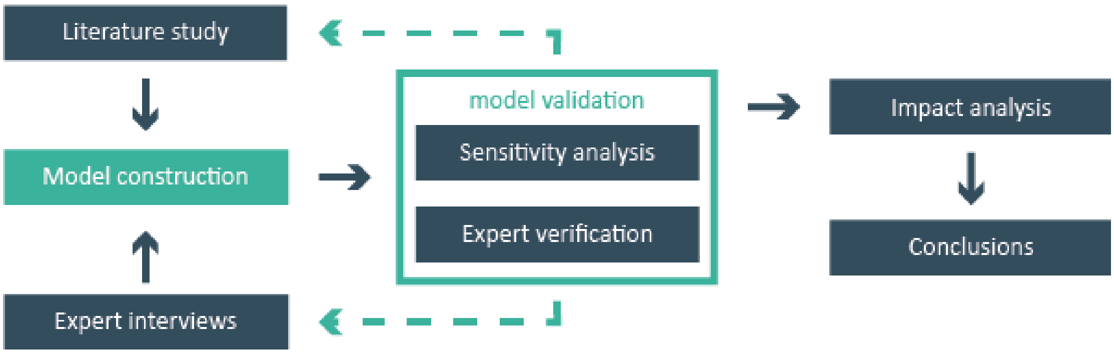

Figure 1: Research outline

Results

Risk-return profile

The REIT analysis yielded some remarkable results. Low average returns on equity and mediocre standard deviation in the returns on equity compared to the other REITs suggest that investors in data centre REITs associate this type of investment with other low risk REIT investments, like residential REITs. Furthermore, their debt to capital, EBITDA and value ratios are the lowest of all REITs analysed. These low levels of debt further decrease the risk associated with the data centre REIT investment.

Important securities of data centre investments are high occupancy levels, stable and predictable incomes, no or limited dependency on resale value speculation, long multi-tenant leases, increasing demand and high threshold for new industry entrants.

However, there are several important risks to take into account. For one specialized and active management of the asset is needed. The risk for data centre investments is further increased by the large initial capital investments needed to construct state-of-the-art data centres. Finally, the risk of obsolescence requires data centre investments to break even in a very short time span, as it is uncertain when the installations are rendered obsolete due to technological innovation.

Another interesting feature of data centre industry as a whole is the fact that the industry seems to move rather independently of other sectors.

Existing data centres with substantial occupancy levels are to be classified as core investments due to long lease agreements and stable income. New data centre projects on the other hand are to be classified as value-added or even opportunistic investments depending on the level of occupancy signed before construction commences.

Risks	**Securities**
Specialized management needed	Stable and predictable income
Large initial capital investment needed	Long lease periods
High vacancy risk	Increasing demand
Risk of obsolescence	High threshold for new entrants
	High switching cost clients

Decision-making criteria

Based on expert interviews and literature study the data centre investment decision is found to be made up of three levels, being the political, locational and building decision process, which can be evaluated rather independently.

Changes in the global economy or geopolitics can easily and rapidly affect a data centres operation. Data centre operators and investors should therefore be well aware of these trends to timely alter their strategy.

On the locational level two main aspects are distinguished, being power and connectivity availability and security. The uninterrupted supply of power and connectivity is vital to data centre operation. In addition, the choice of supplier greatly influences the operating expense. The security aspects such as flooding risk, airfield approach routes and car collisions greatly influence the risk associated with the investment.

On the building level four metrics are crucial to the data centre investment decision, namely Tier level (or level of redundancy), PUE, data centre size and overall power capacity.

The results of the impact analysis suggest that data centre investors should focus on increasing the power density. However, from expert interviews is derived that experts do not expect power density levels to exceed an average of little over 2 kW at rack level. Based on the distribution of power densities derived from the interviews (75% 2kW racks, 15% 3kW racks, 5% 4kW racks and 5% 5kW racks) the ideal power density per rack is 2,4 kW. The main focus when optimizing the data centre power capacity should be on finding the ideal power density to be able to fill the data centre completely at the lowest cost.

The other results suggest that higher returns can be achieved when focusing on minimizing the initial capital expenditure rather than minimizing operational expense, as the impact of capital expenditure parameters such as building cost is much greater than those of operational expenditure such as energy cost or maintenance. The impact of the energy cost is relatively small due to the fact that energy costs are directly billed to the client after multiplication by the power premium.

Vacancy is naturally a parameter that largely influences the returns. Although its absolute effect analysed through the sensitivity analysis is moderate, the impact found in the parameter impact analysis is relatively great as a result of the input data used for this analysis. A high standard deviation is used as input, as the relatively wide spread of vacancy rates in the Amsterdam market. This wide spread and the following impact of this parameter confirms the risk of vacancy and the need for signed lease agreements before construction.

Finally, sustainability should have a greater role in the data centre investment process, as data centres are major energy consumers. The reusability of the data centre building is currently hardly ever incorporated in the investment or design process. The data centre industry should focus on creating reusable facilities as this both increasing sustainable nature of the data centre and even provide a financial benefit.

Conclusion

In many ways data centres are comparable to other real estate types in terms of risk and return. However, data centres differ from other real estate classes in terms of income and lifetime. Data centre investors rely solely on direct income yielded during the period of operation resulting in reduced risk as the income is made solely during operation and is not dependent on future market tendency. Yielding the data centre return in a short period due to technological innovation further decreases the risk.

Data centre investments seem to move rather independently of the general economic cycle than office and industrial space making the investment attractive due to diversification potential.

From the findings can be concluded that the current decision-making criteria seem to suffice. However, some focus areas are indicated. Firstly, finding the right power capacity with only a limited overcapacity is recommended. Second, data centre investment should be focused on lowering capital expenditure rather than operational expenditure. Third, since vacancy prevention is crucial no data centres should be constructed without signed lease agreements. Furthermore, some form of modular building should be used to further mitigate the risk of vacancy. Data centres should be optimized for 2 kW racks. Finally, the data centre industry should focus on improving the reusability of data centre real estate.

Recommendations

- Data centres are interesting investments due to their relative low risk (when high occupancy levels are ensured by signed lease agreements)
- Direct investment in data centres is only recommended when specialized active technical management is available
- The modularity of the data centre industry is an example to the real estate industry in general
- The data centre industry should focus on true modular building
- Add reusability to the data centre design agenda
- Further data centre industry standardization
- Benchmark data centre construction and operation

Preface

To finalize the master Real Estate and Housing at the faculty of Architecture of the Delft University of Technology a master thesis has to be written. The master thesis describes the findings of a research conducted in the area of Real Estate Management.

The subject of the research is the decision-making criteria for investment in data centre real estate. The question that was asked is whether the currently employed decision-making criteria could be improved to yield greater returns.

Hopefully this report will give food for thoughts and provide for new insights.

Gülluk Turkey, August 2014

Word of thanks

About a year ago I started thinking of a subject for my graduation thesis. Without the help of many people I would not have been able to undergo the long process to complete my master thesis.

I have enjoyed my graduation internship at the Rabobank Communication Infrastructure Fund (CIF). I would like to thank Alex Bakker for mentoring me through my internship. Without his patience and industry knowledge many of my questions would have remained unanswered. He also was a challenging sparring partner. I would also like to thank Ivan Kooiman of CIF for the many good conversations and help on my model. Thanks to both of them for the pleasant times in the loudest and smelliest room of the office. I would also like to thank all the other colleagues of CIF for their help and sociability.

Philip Koppels helped me structure my academic thesis and process. I am thankful for the ever-present helping hand and the many times he corrected my report. I am thankful to Hans de Jonge for letting me experience how graduating and researching in general is very similar to uncover an unknown city by visiting its pubs one by one at a difficult moment during my graduation.

I would like to thank all interviewees that made time and helped me to gather the information I needed for my research.

Abbreviation list

Capex	Capital expenditure
CCTV	Closed Circuit TeleVision
DCF	Discount Cash Flow
EATCF	Earnings After Tax Cash Flow
EBIT	Earnings Before Interest & Tax
EBITDA	Earnings Before Interest, Tax, Depreciation & Amortization
EBT	Earnings Before Tax
EUE	Energy Usage Efficiency
GFA	Gross Floor Area
INREV	European Association for Investors in Non-Listed Real Estate Vehicles
IRR	Internal Rate of Return
LFA	Lettable Floor Area
LROE	Levered Return On Equity
LTV	Loan To Value
NAV	Net Asset Value
NPV	Net Present Value
Opex	Operating Expenditure
PBTCF	Property-level Before Tax Cash Flow
PUE	Power Usage Efficiency
REIT	Real Estate Investment Trust
ROE	Return On Equity
ROP	Return On Property
UFA	Usable Floor Area
WACC	Weighted Average Cost of Capital

Table of Contents

1 Introduction

This chapter introduces the research questions and their scientific and societal relevance. The problem analysis is followed by the objective, research questions and the research design. Finally, a reader's guide is provided.

1.1 Motivation

Recent downturns in the major real estate markets, being housing, office and retail, have driven real estate investors and owners to focus on distinctive capacities of their real estate assets to adapt for the growing competition due to increasing vacancy. Next to macroeconomic factors, such as economic growth and employment rates, meso and microeconomic factors have become increasingly important to investors and owners as they largely determine a tenant's willingness to pay.

The influence of these meso and microeconomic factors or locational and building features on the value-in-use and value-in-exchange have been extensively researched for the common real estate assets, being housing, offices and commercial real estate. Several researches, such as those of Gijselaar (2010) and Vink (2012), have proven that meso and microeconomic features partly determine the fitness-for-use of real estate. Both authors prove that better fit results in higher value-in-use or value-in-exchange. Gijselaar (2010) concludes that building features of office real estate cannot be disregarded as investment decision-making criteria.

Even though recent research into office and retail real estate proves that meso and microeconomic factors influence the value-in-use or the value-in-exchange, this knowledge of the data centre real estate market is very limited due to the immaturity and smaller scale of the recently emerged market (McAllister & Loizou, 2009). Because of this immaturity investors often associate data centre investments with high risk compared to other real estate asset types. However, data centres differ from conventional real estate assets, which make comparison to other real estate types troublesome. The difference arises from the unique blend of locational, physical and technological characteristics due to their specialist function (McAllister & Loizou, 2009).

The lifespan is another remarkable difference between conventional real estate and data centre real estate. High technological dependency and continued IT development shortens the usual lifespan of 30 years. The optimal life span of a data centre components range from 10 to 15 years (Heilman, 2011), while most installations have a lifespan of only five years (Renaud, Seader, & Turner IV, 2008). This shortens the investment horizon, while increasing the investment risk. A similar increased risk caused by the economic turndown drove office and retail real estate investors to look for complementing criteria. It's likely that this increased risk drives data centre investors to look for alternative complementing decision-making criteria like it did office and retail real estate investors.

The continued development of IT products and the exponential creation of data drive the demand for data centres and their services (Cushman & Wakefield, 2013). Continued growing future demand is expected due to adaption of cloud computing and growing confidence of senior management in IT outsourcing (CBRE, 2013c).

As of the 1st of January 2014 the European[1] Tier 1[2] data centre market holds 680.926 m^2 LFA data hall floor space[3]. Over the last five years a stable take up of Tier 1 colocation[4] data centre space has shown to fluctuate between 22.000 m^2 and 73.000 m^2 LFA. The demand in 2013 was characterized by a small decrease compared to 2012. The overall European vacancy rate dropped to 13,27% due to a slowdown in new build activities. All European markets are expected to benefit from the improving economic outlook in the coming years. (CBRE, 2014c)

1.2 Problem definition

Data centre real estate investments are associated with a higher risk profile compared to investments in conventional real estate. This conception is mostly driven by limited knowledge of the emerging immature market. Currently, it's unclear how the risk-return profile of data centre investments compares to other investments in other real estate types.

Higher risk profiles resulting from the economic turndown over the last years have made investors in conventional real estate interested in reviewing their investment strategies and decision-making criteria. The described researches by Gijselaar (2010) and Vink (2012) are a result of this growing interest in additional complementing decision-making criteria to limit risk and increase competitive advantage.

Recent studies like those of the Uptime institute (2013) and Covas et al (2013) study additional features of data centres, such as locational and physical characteristics. Figure 2 shows the conceptual model of this principle. However, the knowledge of the effects of locational (regional) and building features on the value-in-use and the value-in-exchange of this extraordinary real estate asset are limited.

As the societal dependency on IT solutions grows, the demand for and public reliance on data centres increase. Real estate investors need to be able to compare data centre investments to other investments in terms of risk and return. Furthermore, investors and operators are in need of further knowledge about data centre real estate investment decisions and decision-making criteria to be able to accommodate the growing future demand with sustainable data centre supply.

[1] Amsterdam, Frankfurt, London, Madrid and Paris (CBRE, 2013c)
[2] Tier 1 data centre is a basic non-redundant server room with an expected availability of 99,671% (TIA, 2010)
[3] Lettable conditioned floor space for server rack placement
[4] Colocation centre is a type of data centre where equipment, space and bandwidth are available for rental or retail customers. (Wikipedia, 2013)

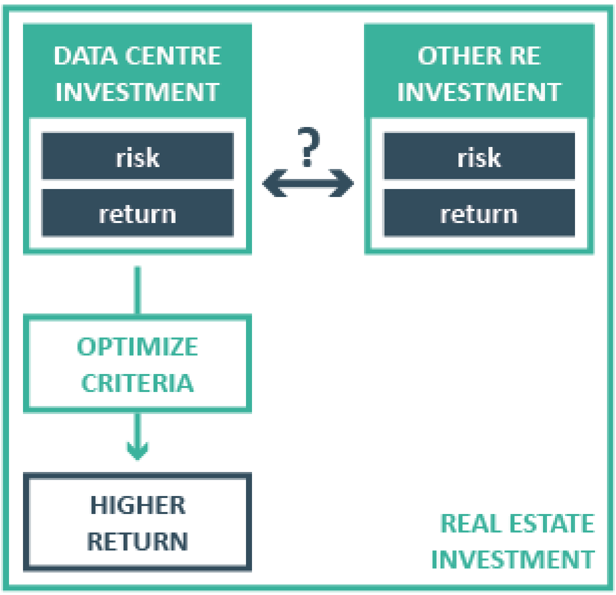

Figure 2: Conceptual model (own illustration)

The following hypotheses are formulated:

Date centre investments are comparable to other conventional real estate asset classes in terms of risk and return.

Higher returns for investors, owners and operators can be achieved by optimizing the data centre real estate decision making criteria.

1.3 Objective

Naturally investors and owners currently employ decision-making criteria for data centre real estate investments. However, many of these criteria are based on gut feeling and past experiences since public knowledge of this emerging market is very limited. However, these past experiences might not prove to be effective in the rapidly changing data centre market.

The objective of this study is to compare data centre investments to other real estate investments in terms of risk and return and to provide knowledge about the current decision-making criteria employed, possible new criteria to be used and the relative weight of these criteria.

The result of this study is a comprehensive description of the risk-return profile of data centre investments and a financial data centre investment model. The study results in recommendations on how to perceive the data centre risk-return profile and how to improve the data centre investment decision-making criteria.

1.4 Research questions

From the problem statement and hypothesis the following research questions follow:

How do data centre investments compare to conventional real estate investments in terms of risk and return?

How can higher returns for data centre investors, owners and operators be achieved by optimizing the data centre real estate decision-making criteria?

The following sub research questions substantiate the main research question:

Exploration

1. How are real estate asset classes compared in terms of risk and return?

   A literature review is conducted to find how the risk and return profiles of real estate investments are described.

2. Which decision-making criteria do data centre real estate investors, owners and operators currently employ could additionally be employed in real estate investment decision-making of this asset type?

   A literature review and expert interviews are conducted to gain insight in the current decision-making criteria employed. Furthermore, possible additional features are identified using literature study and expert interviews.

Empirical research

3. How do data centre investments compare to conventional real estate investments in terms of risk and return?

   Based on the results of the literature study and expert interviews the risk and return profile of data centre investments is described and compared to conventional real estate asset classes using a comparative analysis of Real Estate Investment Trusts.

4. Which of these criteria substantially influence the return of an investment in this real estate asset type? And what is their relative impact?

   A financial model is constructed incorporating the variables to be analysed. By investigating their influence on the Net Present Value and the Levered Return On Equity of the investment the impact of that variable is determined. Through impact analysis the relative impact of those variables are determined.

Application

5. How should the decision-making criteria be optimized to maximize the return for data centre real estate investors, owners and operators?

   Finally the results are translated into recommendations for the data centre industry and real estate industry in general.

1.5 Research outline

The detailed research outline described in Figure 3 follows the sub research questions. Each question resulted in a clear step to be taken to answer the main research question.

The first step was to describe the risk-return profile of data centre investments and the current decision-making criteria employed by investors and owners. To do so the data centre stakeholders and market were analysed through literature study and expert interviews.

Secondly, the literature study and expert interviews were expanded to gather all needed information and data to construct the financial model. The findings resulting from the model were validated through sensitivity analyses and expert verification. If needed the model was adjusted.

After the model was validated the impact of the decision-making criteria were analysed using an impact analysis. Consequently, the results were interpreted. The implications of the results are discussed and recommendations are made on how to adjust the decision-making criteria.

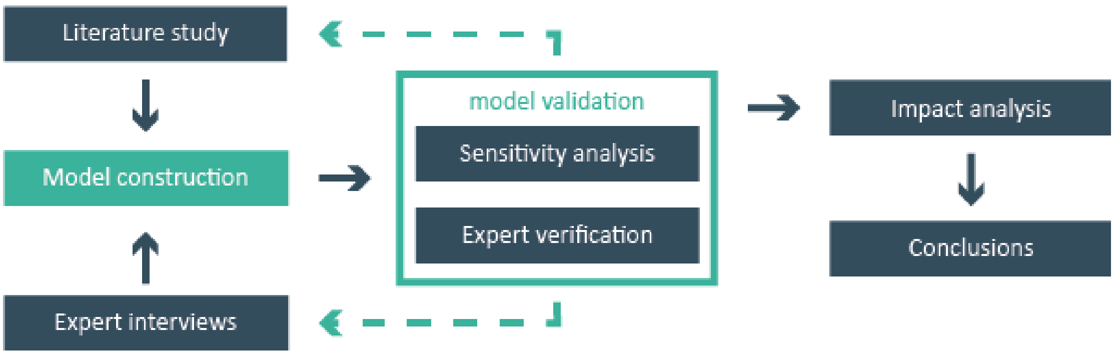

Figure 3: Research outline (own illustration)

1.6 Reader's guide

Chapter 1 introduces the research questions, design, planning and relevance. The theoretical framework is described in chapter 2 followed by the methodology in chapter 3. Chapter 4 describes the results while chapter 5 describes the discussion of the results. Finally, chapter 6 elaborates on the conclusions.

2 Theoretical framework

2.1 Introduction

This chapter describes the literature study conducted. First the basics of investing are described followed by an introduction to real estate investment types and strategies. Consequently, the data centre building, business case and market are described.

Although many researches have been conducted on data centre installations and hardware, the knowledge of the data centre real estate market is very limited due to its relative immaturity and small scale compared to other real estate types as mentioned by authors like Renaud et al. (2008) and McAllister (2009). Because of this immaturity the data centre real estate research field is relatively new. Therefore, the literature study is complemented with information and data gathered from practice through expert interviews.

2.2 The basics of investing

To fully understand the investment decision-making process the basics of the investment practice are introduced followed by the more specific real estate investment process.

2.2.1 Investment objectives

Geltner (2006) distinguishes two fundamental investment objectives:

- The growth or savings objective, which is characterized by a typically long time horizon with no immediate need to use the cash being invested;
- The income or current cash flow objective, which is characterized by a typically short time horizon and an ongoing need to use cash generated from the investment.

Clearly either objective results in entirely different investment strategy and decisions. For instance, pension funds are likely to adhere to the growth objective since their main aim is to manage and hedge the funds for inflation. A private equity firm on the contrary is likely to adhere to the income objective as this type of investor is expected to pay out high dividends to its shareholders.

Roughly, three types of investors are distinguished:

- Institutions (pensions funds and insurance companies);
- Public entities (sovereign wealth funds);
- Private parties (wealthy families and individuals).

2.2.2 Investment diversification

Comprehensive investors like pension funds need to diversify their portfolio to limit risks. This portfolio theory originates from the concept that one should spread capital over a greater number of individual assets to decrease the change of an event of downside affecting all assets invested in. An investor limits risk to a great extent by diversifying its portfolio over the largest number of individually differing assets as possible.

In practice pension funds spread their capital over several investments, such as bonds and stocks as displayed in Chart 1 and Chart 2. Dutch pension funds allocate only a little over 6% of their entire capital to real estate.

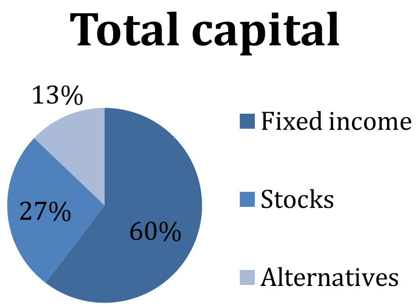

Chart 1: Average spread of capital for Dutch pension funds (CBRE, 2013b)

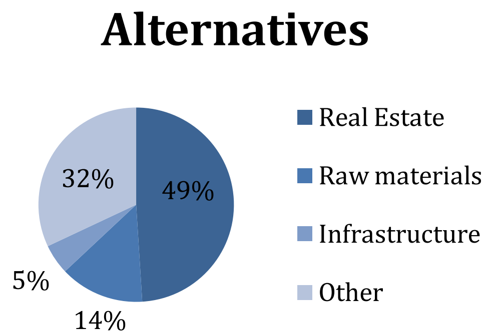

Chart 2: Average alternative allocation of capital for Dutch pension funds (CBRE, 2013b)

2.3 Real estate investments

To fully understand investments in data centre real estate it is needed to understand real estate investments in general. This section focuses on real estate investments in general.

2.3.1 Real estate investment types

There are several ways to invest in real estate. The most crucial distinction is whether to invest directly or indirectly.

Direct real estate investment

Direct investment in real estate refers to the direct purchase of the physical real estate. Evidently, this type of investment requires active and knowledgeable management. The landlord is also compelled to take on additional responsibilities for procurement and property management, both of which require applicable knowledge and experience.

Indirect real estate investment

Indirect investment in real estate refers to the investment in a vehicle that invests in real estate for the investor as shown in Figure 4. By doing so, the investor does not only invest in real estate but also acquires knowledge and skill in managing the assets. Hence, the main reasons for investors to invest indirectly are acquisition of knowledge and expertise and delegation of asset or portfolio management. The investor's control decreases while the direct cost increases as a result of delegated management. However, by holding assets indirectly the investor is able to benefit from economies of scale and better use of leverage. (Trimailova, 2008)

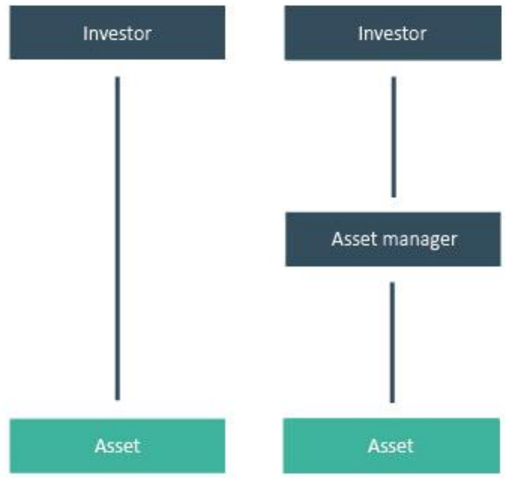

Figure 4: Direct & indirect real estate investment vehicles (own illustration)

Two types of indirect real estate investments are distinguished, namely listed and non-listed vehicles.

Listed real estate investment vehicles

Listed vehicles are real estate funds that trade publicly. Like stocks they're characterized by higher liquidity than other types of real estate investment. The value of the shares moves due to public trading and provides a discount or premium on the actual Net Asset Value (NAV) of the purchased assets due to public trading. These types of funds are known as Real Estate Investment Trusts or better known as REITs.

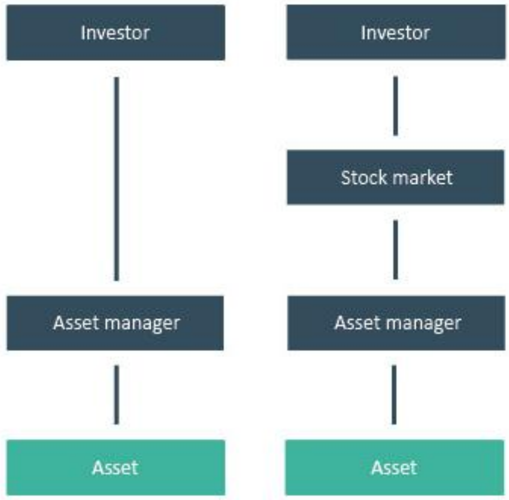

Figure 5: Listed & non-listed real estate vehicles (own illustration)

Non-listed real estate investment vehicles

Non-listed vehicles are not traded publicly. Hence, they're characterized by increased illiquidity and lack of transparency compared to listed funds. The value of the shares in contrast with listed vehicles equals the NAV and therefore depends on valuations of the assets. The difference between listed and non-listed funds is depicted in Figure 5.

2.3.2 Real estate investment strategies

Real estate investments are characterized by two main metrics being the risk-return ratio and the degree of leverage (Trimailova, 2008). The European Association for Investors in Non-Listed Real Estate Vehicles or INREV (2008) identifies the amount of return an investment fund is pursuing and the level of leverage employed as the two determining factors within a real estate investment strategy. The risk-return ratio or target return is usually expressed in the Internal Rate of Return (IRR) ratio, while the degree of leverage is expressed in the Loan To Value (LTV) ratio. The INREV (2008) distinguishes 3 types of investment strategies. Their characteristics are summarized in Table 1 and Chart 3.

Core strategies

Core investments are considered to have the lowest risk profile. As a result the return is relatively low compared to other strategies. The vast majority of the return consists of stable income, while only limited return from capital is expected. Properties are often fully let and occupied by multiple tenants for longer durations. The IRR and LTV are usually low. (INREV, 2008)

Value added strategies

The return of value added investments consist of both capital and income return. These investments are considered riskier than core investments and involve real estate in need of refurbishments or with capital constraints. The IRR and LTV are considered to be medium to high. (INREV, 2008)

Opportunistic strategies
The riskiest investments are named opportunistic investments. These investments are characterized by capital growth driven return. The holding periods for these investments are often short compared to the other strategies. Development projects and properties in distress are often subject of these investments. The IRR and LTV are usually high to very high. (INREV, 2008)

Characteristic	Core	Value added	Opportunistic
Return	Stable income	Income & capital growth	Capital growth
Cash flow	Predictable	Capital constraints	None or limited
IRR ratio	≤ 13%	11,5% ≤ x ≤ 18.5%	≥ 15,5%
LTV ratio	< 60%	30% ≤ x ≤ 70%	> 60%
Risk	Low	Medium to high	High
Holding period	5-10 years	≤ 5 years	≤ 5 years
Real estate status	Income producing, fully let & multi-tenant	Refurbishments or active management	Development or distressed real estate

Table 1: Characteristics of real estate investment strategies (CBRE, 2013b)

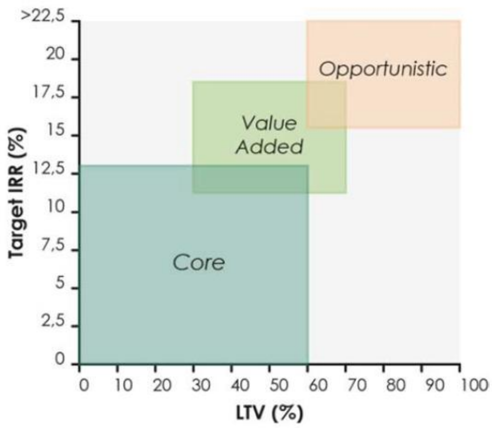

Chart 3: Target IRR & LTV investment strategies (CBRE, 2013b)

2.3.3 Advantages of real estate investments
Real estate investments tend to have the following advantages over other investments:

- High returns in relation to risk
- Diversification potential
- Some capital growth
- Stable and predictable cash flows

Real estate investments tend to fall between stocks and cash in terms of risk and return (Geltner & Miller, 2006). In this regard real estate investments are much like long-term bonds. Unlike bonds real estate investments do offer some capital growth and inflation protection due to the yearly indexed rent levels (Geltner & Miller, 2006). The relative long-term agreements with tenants create predictable and stable earnings. However, the 2008 economic turndown showed that the advantages and securities associated with real estate are entirely dependent on vacancy levels.

Diversification is an essential element of portfolio theory, which is part of all institutional investment strategies. It elaborates on the common sense that one should not invest all their wealth in one single asset type, obviously overly exposing one to losses in the event of downside for this one type of asset. An investor should therefore diversify his portfolio to minimize this risk. Real estate makes a great asset for diversification of an investment portfolio as it significantly differs from other asset types. (Geltner & Miller, 2006)

2.3.4 Disadvantages of real estate investments

Like all other asset types real estate investments also have disadvantages:

- Non-transparent market
- Illiquidity
- Transaction costs
- Management needed

The most important disadvantage of real estate compared to other asset types is the opaqueness of the market. Indices and market information are available on a daily basis at no or low cost for stocks and bonds. Real estate information can only be obtained through experts at high cost. (Geltner & Miller, 2006)

Investors can sell and buy bonds and stocks on a daily basis with short acquisition processes. Real estate acquisition and deposition can take up months making rapid allocation shifting very difficult. (Geltner & Miller, 2006)

Compared to bonds and stocks real estate investments require high transaction costs, varying internationally from 6% to 10% of the acquisition price. This drives the investment costs up. (Geltner & Miller, 2006)

Managing direct real estate investments is very labour intensive and costly. Real estate management requires expertise and resources unlike bonds and stocks. (Geltner & Miller, 2006)

2.4 The data centre

A data centre is a facility that houses computer systems and associated components, such as telecommunications and storage systems. The facility is highly technological and holds large installations for power delivery, cooling and air movement.

2.4.1 Key characteristics

Data centres are characterized as industrial buildings as that category has the most similarities to data centres. This section describes the most important characteristics.

Mission-critical

Data centres house the most crucial aspects of organizational operations, being the IT operations. As companies rely on their information systems for operations, the main concern of data centres is business continuity. Unavailable services easily hinder or even stop company operations. Therefore, it is of great importance to provide reliable infrastructure for IT operations in order to minimize change of disruption.

Drivers of data centre risks are among others the following:

- Physical, electronic and cybersecurity breaches;
- Natural disasters like fire, earthquake, hurricane, flood, tornado;
- Extreme temperatures;
- Water damage;
- Optic fiber cuts;
- Power loss;
- Terrorist acts;
- Sabotage and vandalism.

Redundancy

To increase reliability critical data centre components are duplicated. This duplication is called redundancy. Typically data centre redundancy covers power supply, connectivity and cooling. Increasing levels of redundancy exist caused by different needs of mission-critical IT processes and storage.

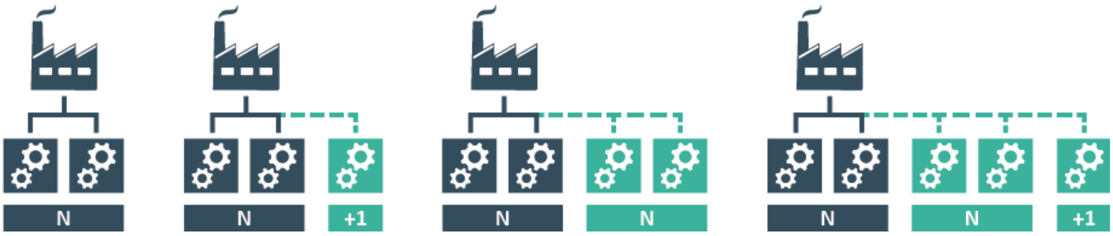

Figure 6: Redundancy levels N, N+1, 2N & 2N+1 (own illustration)

Data centre redundancy is typically described in four groups with increasing resilience to component failure, being N, N+1, 2N, 2N+1 (Figure 6). The N setup is configured to have just the number components it needs to function; meaning that whenever one component fails the entire system fails. The N+1 configuration indicates that there is one extra component on-site regardless of the size of N. This results in one spare component that is to be used whenever a component fails as displayed in

Figure 7. In a 2N configuration the entire system is duplicated resulting in very high levels of redundancy while requiring high investments and operating costs. The most redundant setup in use is the 2N+1 configuration as it holds one spare component for every component even though the entire system is completely duplicated.

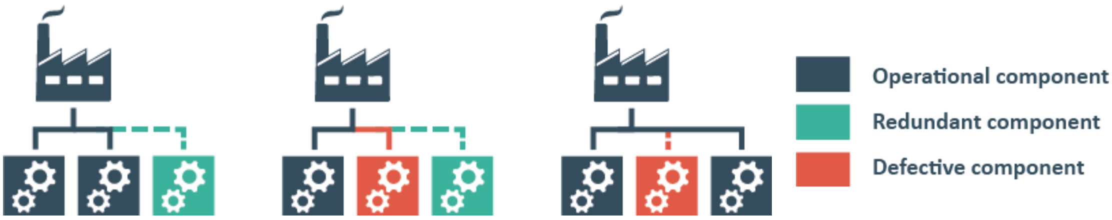

Figure 7: The concept of redundancy (own illustration)

Capital & technology intensive

To meet the requirements for operation of IT equipment and to provide the appropriate level redundancy, extensive technological equipment is needed. As the equipment is costly and depreciates technically and economically rather rapidly capital expenditure is substantial.

Energy dependency
Providing the right climate for the installed IT equipment to function requires tremendous amounts of energy. Most of this energy is used for the actual IT equipment (50%), while cooling, air movement installations, electricity infrastructure and lighting take up respectively 25%, 12%, 10% and 3%. As data centres are highly energy dependent, they're often located near power stations. (Covas et al., 2013)

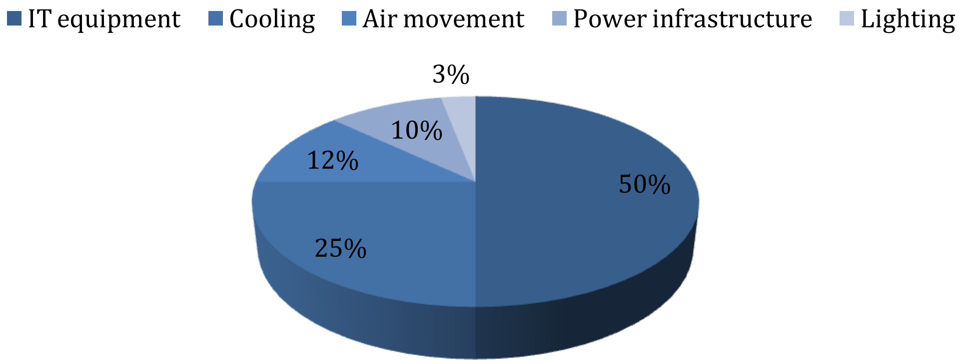

Chart 4: Energy usage data centre operation (Covas et al., 2013)

High operation expenditure
Data centre operation costs are largely determined by the energy used. Energy accounts for 70%-80% of the total ongoing operation cost (Dines, Washburn, Schreck, & Chi, 2011). And these costs are of substantial size, as an average data centre consumes the equivalent energy of 25,000 households (Kaplan, Forrest, & Kindler, 2008).

Connecting globally
The IT equipment is connected to the rest of the world through a network from and to the data centre. This connection is made at different levels within the global network, being connections between data centres individually (called peering), data centres and internet exchanges[5] and internet exchanges individually as displayed in Figure 8. Even though every data centre is physically connected to the global network, it is not connected to every single other data centre it needs to connect with. If needed traffic is routed through other data centres to reach its destination. Internet exchange points aid this process by connecting national and regional networks. Using this principle data centre DC-1 displayed in Figure 8 is able to send traffic to DC-3 by routing via internet exchange IX-1, IX-2 and data centre DC-2.

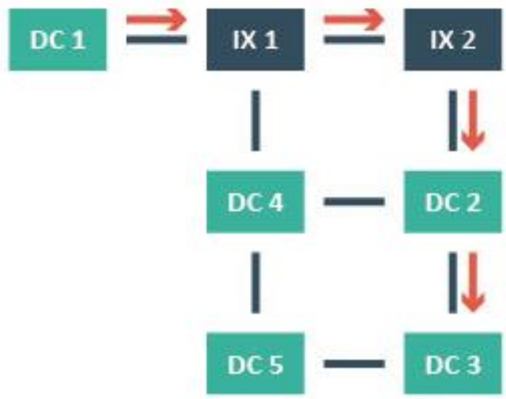

Figure 8: Interconnecting data centres (own illustration)

[5] An internet exchange point is a physical infrastructure through which Internet Service Providers exchange Internet traffic between their networks (Wikipedia, 2014b)

Carrier dependency
Network carries provide data centres with access to their communication services providing connection from one data centre to another or to an internet exchange. Examples of corporates offering this service are KPN, British Telecom & Ziggo.

Most data centres provide access to only one carrier, while other data centres offer access to multiple carriers. This carrier neutrality enables the end-user to switch carrier without physically moving IT equipment to another data centre.

Security
As data centres houses mission-critical business operations and consist of vulnerable IT equipment, security is of great importance. Data centre security comes in many different forms, from camera surveillance and mantraps to permanent security personnel.

Data centre types
Data centres can be grouped based on their function; internet services, telecommunications and corporate business operations. These facilities differ in layout and IT equipment operated in the data hall.

The most commonly used data centre is one providing internet services. These centres are equipped with IT equipment that stores and connects websites and online applications to the World Wide Web. Connection to internet exchanges and other data centres is vital to make the websites and online applications available to the public.

Another type of data centre is one used to support telecommunications. These centres are mostly operated by telecommunication providers such as KPN or British Telecom and are used to enable telecommunications such as (mobile) telephone, ADSL and optic fibre communications. These centres are generally situated in strategic positions to ensure national coverage.

The corporate data centre is a facility used by a corporate company to support its business operations. These facilities mainly store company data and operate business software. They’re typically located in the vicinity of the company’s headquarters to ensure availability.

Standardization
Data centres are increasingly subjected to standardization with the Telecommunications Industry Association (TIA) being the most influential. TIA distinguishes four types of data centres called Tier levels based on a data centre’s redundancy (TIA, 2010). A Tier 1 data centre has an expected availability of 99,671% compared to a Tier 4 data centre with an availability of 99,995%.

2.4.2 Key building elements
The unique characteristics of data centres require extraordinary installations and building elements. This section describes the most important building elements.

Industrial building

A data centre shares many characteristics with a typical industrial building. In most cases the building is supported by a simple steel structure with concrete walls. In some data centres thicker concrete walls are used for security reasons.

Vacant land around the data centre is often considered as desirable as it creates another security layer to the building. This strip of land is frequently equipped with physical barriers such as trees or fences.

Server room

The heart of any data centre is the server room in which the servers and other IT equipment are located. A data centre usually holds several server rooms.

A typical server room is of rectangular shape and filled with server racks aligned in aisles as shown in Figure 11. This aisle configuration aids the cooling of the servers as described below. An aisle is made up out of multiple server racks as shown in Figure 9. Figure 10 displays a standard server rack, which holds up to 42 servers.

Figure 9: Server aisle (datacenterdynamics.com)

Figure 10: Server rack (fcnet.pl)

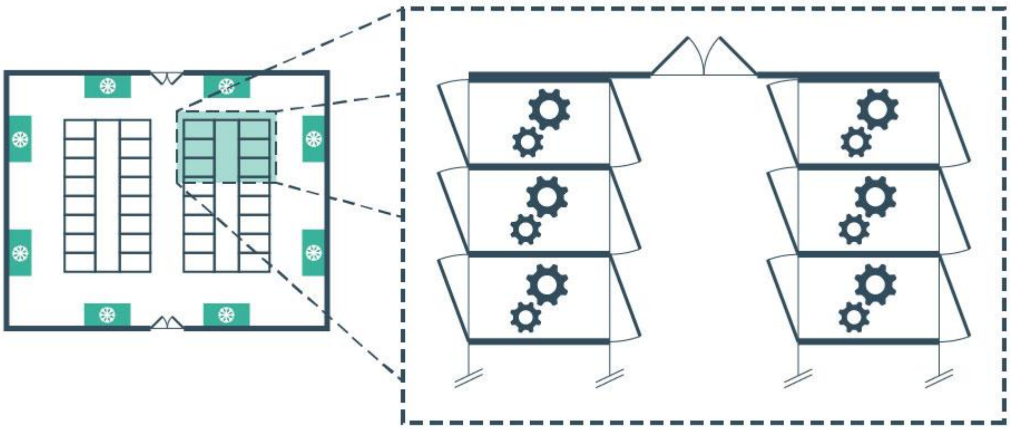

Figure 11: Server room plan (own illustration)

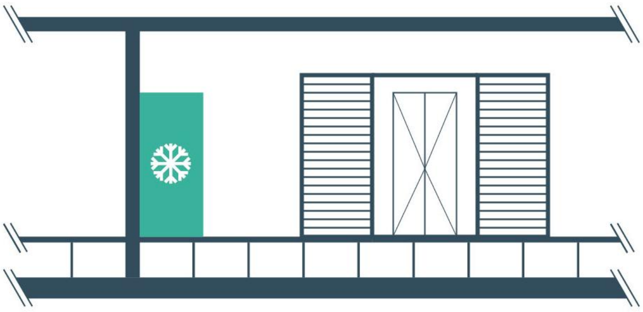

Figure 12: Server room section (own illustration)

A typical server room is equipped with a raised floor (Figure 12). By raising the entire server room about 50 centimetres this construction creates space for routing the network cables and power supply. An additional function of the raised floor is the cooling of the server racks as described below.

Cooling system

Computer Room Air Conditioning units (CRAC units) or Air Handling Units (AHU units) remove the heat produced by the servers from the server and cool the air in the server room (Martin, 2011). Figure 13 shows the cooling process. Heat produced by the servers is pulled into the CRAC units, where the air is cooled. The space between the concrete floor and the raised server floor is used as ventilation shaft. The CRAC units force the cooled air into the space under the raised floor, where the air can only escape under the server racks or in the aisle as described above.

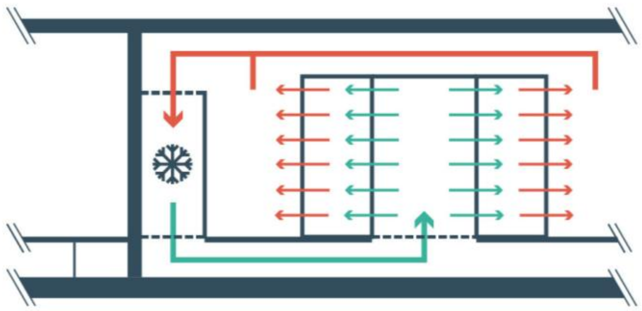

Figure 13: Data centre cooling principle (own illustration)

Automatic Transfer Switch (ATS)

An ATS switches between power delivered by the energy provider and power generated by the alternate power generator in case of power interruption (Wikipedia, 2014d). The ATS is the first step of the data centre power supply system as displayed in Figure 14.

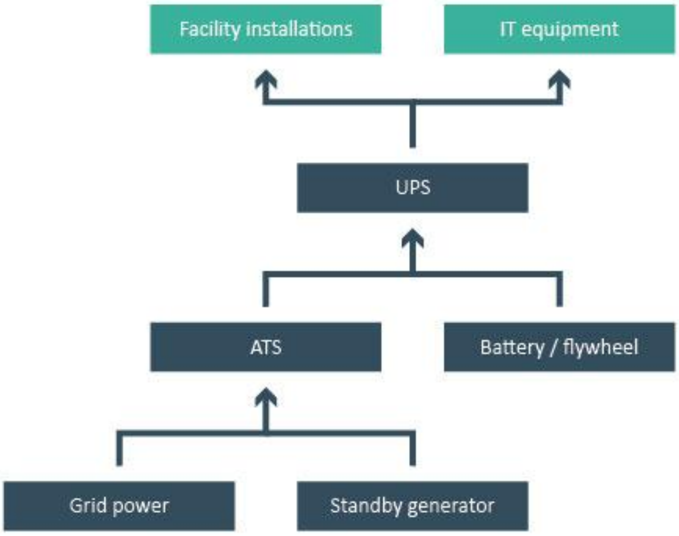

Figure 14: Data centre power system (own illustration)

Alternate power supply
The alternate power supply is automatically switched on in case of power interruption. The power needed until the generator is fully functioning is provided by the UPS system.

Uninterrupted Power Supply system (UPS system)
This system provides the data centre with energy in case of input power interruptions. It supplies power from batteries or a flywheel system until the auxiliary power system is functioning and capable of providing the needed power. An UPS system typically delivers power to the data centre for a period of 1-4 minutes. (Wikipedia, 2014e)

Fire protection
The mission-critical nature of data centres requires optimal fire detection and suppression equipment. All data centres are therefore equipped with smoke detectors and fire alarms, which provide early warning of a fire. Additionally most data centres are rigged with high sensitivity smoke detectors that activate a clean agent fire suppression gaseous system to control a full scale fire if it develops. Gaseous fire suppression is a method of fire fighting that fills the entire room with inert gases. The use of gaseous fire suppression is preferred as this method does not leave corrosive residues minimizing cleanup and downtime. (Lowery, 2014)

2.4.3 Sustainability
Sustainability is an important aspect of data centres, as these buildings are major power users. The currently employed sustainable measures are discussed in this section.

Lowering power usage
Decreasing the power usage is seen by the interviewed experts as the most important and effective measure currently employed. This measure especially focuses on lowering the Power Usage Effectiveness (PUE). The PUE is a measure for data centre efficiency. It is the ratio of total amount of energy used by a data centre to the energy delivered to the computing equipment (Wikipedia, 2014c). Lowering the PUE a data centre means

using less power for supporting installations, such as cooling and power supply. The ideal (theoretical) PUE is 1.0, which is nearly achieved by cloud providers like Google (Lesser, 2012).

However, the PUE is often manipulated for commercial reasons since the energy efficiency substantially influences rent levels. Interviewed experts state that PUEs announced in the market are often more optimistic as they've been calculated based on optimal circumstances such as no to little vacancy, which results in more efficiency in supporting installations, or wintertime, which results in lower cool load. The Energy Usage Effectiveness (EUE) partly solves this problem by calculating the PUE over an entire operational year including both summer and winter (Wiersma, 2012). The EUE is therefore based on actual usage in comparison to often theoretical input used for the calculation of the PUE. All experts agree that only a measured PUE or EUE is a meaningful measure of a data centre's energy efficiency.

Increasing operating temperatures

Over the last years the operating temperatures for IT equipment have risen, 17°C in 2004 to over 30°C in 2013 (Neudorfer, 2013). The cool load decreases as servers operate at a higher temperature. This results in a possible major power usage reduction since cooling accounts for a major part of the power usage.

However, health and safety regulation limit the maximum temperature for working environments. This also applies to the server room, since engineers have to be able to access and work on operating servers. Some the interviewed experts expect this regulation to surely limit the current and future opportunities created by increasing operating temperatures.

New ways of cooling

Since operating the cooling and ventilation installations makes up a large part of the operating costs, new more efficient ways of cooling are employed.

The most radical new way of cooling is the air-side free cooling. This type of cooling uses cooler outside air to ventilate and cool the server room requiring little to no cooling. While free cooling drastically reduces power usage, it introduces two major problems, namely humidity and temperature fluctuations. IT equipment operates best and depreciates slower while operating under constant humidity and temperature. Experts are therefore uncertain whether air-size free cooling will ever truly offer a solution.

Another way of cooling is the use of adiabatic or evaporative coolers. By blowing warm air through water moistened pads the air is cooled. This type of cooling reduces the power usage by 30% to 40% compared to traditional ways of cooling (Rouse, 2013a). An increasing number of contemporary data centres use this type of cooling. Several of the interviewed experts have indicated this type of cooling to be the most promising in the near future.

The biggest power reduction without letting outside air into the server room directly is to be made with the Kyoto wheel. The Kyoto system is a large thermal wheel that transfers heat from the inside of the data centre to the outside through conduction and vice versa. The efficiency of transfer is very high. This way of cooling cuts power usage drastically by 75% to 92% compared to traditional cooling methods (Rouse, 2013b).

Renewable energy

The use of renewable energy is a hot topic among data centre users. Companies like Google and Apple aim at using renewable energy as much as possible. However, the biggest contribution of renewable energy used in Google data centres is bought through trading emission certificates. Several experts pointed out that the use of renewable energy is often a way of masking the inefficiency and other unsustainable aspects of a data centre.

Use of waste heat

In traditional data centres the heat produced by the IT equipment is simply transferred out of the building and thereby wasted. Some modern data centres make use of this waste heat by heating buildings in their direct surroundings. A recent example is the new Equinix data centre in Amsterdam. The waste heat of this data centre is used to heat a university faculty building (Veenman, 2011).

However, experts have pointed out that the use of waste heat is only profitable in extraordinary circumstances as it requires a relatively large user of heat at a close distance.

2.4.4 Future developments

Future technical developments are mostly driven by improvements to the IT equipment.

Higher operating temperatures

Operating temperatures of IT equipment have risen from 17°C in 2004 to over 30°C in 2013 (Neudorfer, 2013). Higher operating temperatures require less cooling capacity pushing operating costs down and leaving more power available to IT equipment.

Greater storage capacity

New data storage technologies, like Solid State Disks (SSD), enlarge data storage capacity while decreasing power usage and operating temperatures. This might result in less needed space and cooling capacity.

More processing power

Over the last decades computer processing power has grown exponentially. New data processing technologies are capable of processing more data at lower operating expense.

2.4.5 Modular building

In response to the capital intensive traditional way of building a data centre modular data centres have come into existence. The benefits of this way of building are ability to lower the initial investment and to adjust more easily for market demand. Four main types of modular centres are to be distinguished.

Containerized data centres

The first modular data centre is a self-contained computing facility housed in a container. The entire facility is completely manufactured in a factory and is equipped with built-in power and cooling installations. The benefits are rapid delivery and location independency. However, the temporary nature of this type of centre makes it unsuitable for long-term solutions. (Denton, 2012)

The interviewed experts pointed out that this type of data centre is currently only being used on a substantial scale by the military and in case of temporary demand.

Modular components
Using this type of modularity manufacturers produce individual pieces of data centre components like the power and cooling installations and offer them as 'off-the-shelf' products, instead of building the entire custom infrastructure on-site. This approach is more cost-effective, even though the customizable nature of the data centre is minimized. (Denton, 2012)

Several progressive industry players like Equinix construct their contemporary data centres using modular components.

Phased modular approach
Currently the most used modular approach is the phased deployment of a data centre. It involves incremental deployment of data centre space only when needed. By doing so, risks are minimized while future opportunities can still be captured whenever they arise. (Denton, 2012)

Modular providers
Instead of individual pieces of the data centre made available for purchase, this data centre as a service approach makes the data centre available as a standardized product. Users will not have to decide what type of data centre simply buy computing power. (Denton, 2012)

2.5 The data centre business case

2.5.1 The data centre value chain

Porter (1985) defines a firm as 'a collection of activities that are performed to design, produce, deliver, and support its product'. To fully understand how this collection leads to competitive advantage he developed the value chain approach. The value chain model is used to characterize the data centre business case and to identify the general competitive advantages found in data centre operations.

Porter's value chain as depicted in Figure 15 displays the total value the firm adds to the industry. This value consists of value activities and margin. The value activities are the building block by which a firm creates a product that is valuable to its customers. The margin is the difference between total value and the collective cost of performing the value activities. This measure is the profit or return made by the firm. (Porter, 1985)

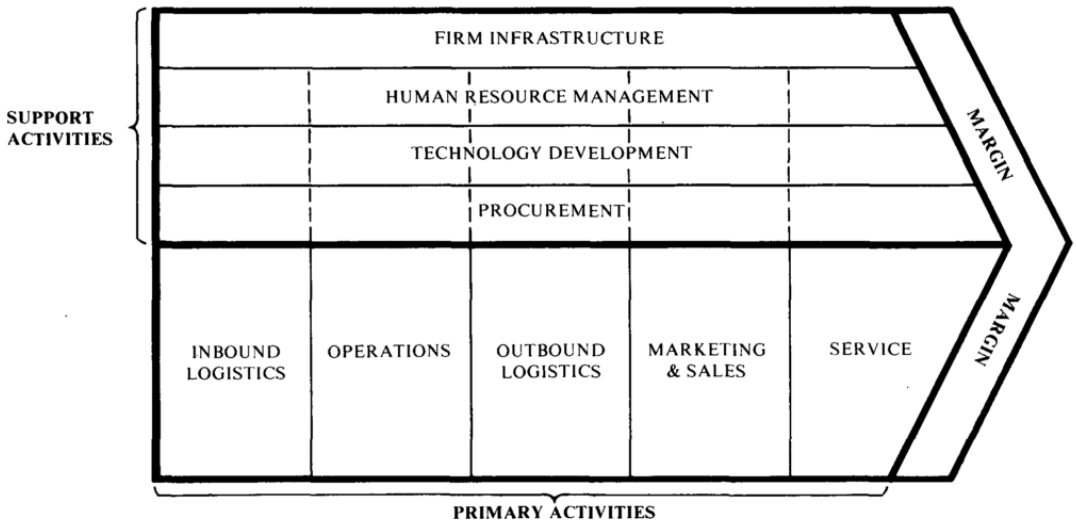

Figure 15: Value chain (Porter, 1985)

Two types of activities are distinguished in the value chain, namely primary and supporting activities. The former involve activities in the physical creation of the product and its sale and transfer to the buyer. Five primary activities are characterized as displayed in the model in Figure 15. The support activities enable the primary activities and each other by providing purchased inputs, technology, human resources and general business operations. The dotted lines in Figure 15 reflect that the supporting activities enable specific primary activities while also supporting the entire value chain. Firm infrastructure however only supports the value chain as a whole. (Porter, 1985)

The primary and supporting activities for the data centre value chain are summarized in Table 2 and Table 3.

Inbound logistics	• Energy supply • Network connection • Water supply (used for cooling) • Fresh air supply (used for cooling) • IT & network equipment
Operations	• Provide conditioned data hall • Provide physical site security • Facility maintenance
Outbound logistics	• Network connection • IT & network equipment (broken or end-of-life)
Marketing & sales	• Pricing • Advertising • Sales force
Service	• Provide qualified technical personnel • Additional technical services (like operating system support) • Office & storage space • Logistic services

Table 2: Primary activities data centre value chain

Firm infrastructure	• General management • Legal • Financing
Technical development	• Data centre information management system • Increased use of sensors (i.e. temperature)
HR management	• Recruiting security personnel • Hiring maintenance engineers • Recruiting marketing & sales personnel

	• Recruiting technical personnel
Procurement	• Energy • Bandwidth • Data centre property • Data centre installations • IT & network equipment

Table 3: Supporting activities data centre value chain

From the data centre client point of view the data centre service is positioned in the firm infrastructure activity as its services are often vital to all primary and supporting activities. This is reflected in the mission-critical nature of data centre operation.

2.5.2 Actors

Real estate investments are dualistic, as it can be seen from an investor's or user's perspective. The former is active in the asset market investing money in real estate assets, while the latter is active in the space market renting real estate space. However, in the data centre case the actors are often active in both markets. There are many examples of data centre operators that also invest in their own real estate. Both groups are discussed individually for data centre real estate. The stakeholders and their mutual relations are summarized in Figure 16.

Investor or Asset market

Private investors or institutional investors like banks, hedge funds or pension funds, provide the equity capital for data centre real estate investments. Data centre real estate is even more capital, time and knowledge intensive as more conventional real estate types like offices. Direct data centre real estate investments therefore require facility and maintenance management. If more properties are acquired, portfolio management is needed. This portfolio is either directly or indirectly managed by the private or institutional investor.

In case of indirect management a Real Estate Investment Trust (REIT) manages the real estate portfolio, while the investors own shares of the trust. The shares of a REIT are either privately of publicly traded. For investing equity in a private or non-listed REIT an investor receives shares and dividend. These trusts can hold a constant number of shares (closed-end funds) or a variable number of shares (open-end fund). These companies are of fairly large size and have employees that manage their relatively large portfolios. Furthermore, these funds can have a limited or an eternal life time.

The investor of equity in a public or listed REIT through the stock market obtains stocks, which gives the right to a share of the profit. These companies also have employees that manage their rather large portfolios. These REITs have another advantage as they're given a special tax status, which exempts them from paying corporate taxes. However, this exemption is subject to strict requirements. The most stringent being the requirement of having to distribute nearly all profit to their shareholders. Currently there are only few data centre REIT in the world like Digital Realty.

User or space market
Tenants requiring data centre space have several possibilities of obtaining this space. Larger tenants, such as large corporations or data centre operators, looking to rent at least an entire server room can directly rent space of the data centre owner. Data centre operators and cloud providers rent or own a data centre and lease space to smaller tenants.

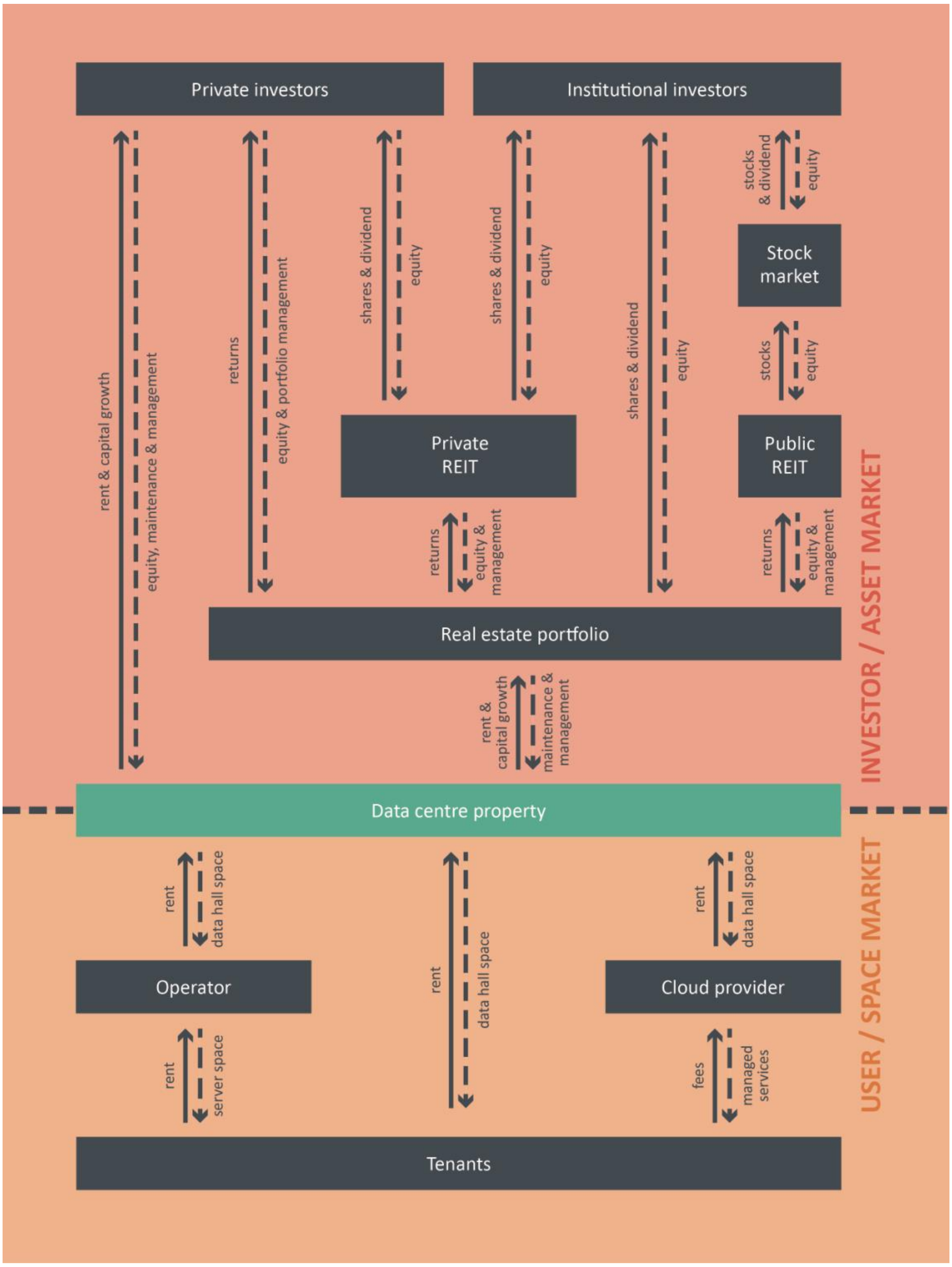

Figure 16: Field of actors

2.5.3 Lease structures
The data centre lease is profoundly different from industrial or office real estate leases due to the unique nature of data centres. Drafting and

negotiating a data centre lease requires in-depth knowledge of data centre facilities and IT equipment (Moerdler, 2012). Data centre leases are grouped in 4 categories as described in Figure 17 where green areas depict tenant responsibility.

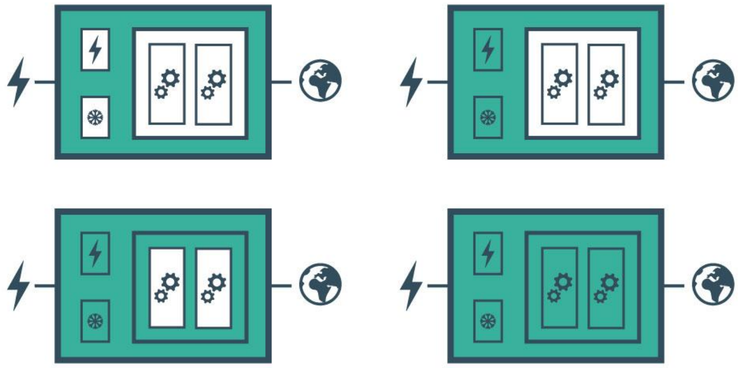

Figure 17: Landlord responsibilities in lease structures (own illustration)

Wholesale or Powered Shell leases

This type of lease is the most basic from an investor's point of view, since the landlord will only be installing the shell building and basic infrastructure. Which installations are parts of the basic infrastructure and are thus the responsibilities of the landlord differ per lease. It is common for the landlord to provide basic power facilities, while the tenant is responsible for all other installations such as UPS and CRAC units. After completion of the facility the landlord is only responsible for power supply to the building and site security (Moerdler, 2014). Wholesale leases are typically long-term contracts because of the large investment made by the tenant. A typical tenant of this type of lease is a company of substantial size or data centre operator. (Moerdler, 2012)

Turnkey or Enterprise leases

A turnkey lease offers the tenant a server room that is ready for operation. The landlord builds the shell building and installs all infrastructure needed including the raised floor. By doing so, the initial investment largely shifts from tenant to landlord. Typical tenants of this type of lease are companies with substantial experience operating their own data centres, but without the experience of building these facilities. These leases are typically medium-term contracts. (Moerdler, 2012)

Colocation agreements

A landlord of a colocation lease offers the tenant a fully equipped server room including the server racks. The tenant only provides the IT equipment needed. These leases are generally short-term agreements and do not give the tenant the legal rights of tenant under a lease. They could therefore be characterized as license agreements instead of leases. However, managed services are often included in the agreements. Typical tenants are small companies. (Moerdler, 2012)

Cloud agreements

A cloud agreement offers IT services to a wide range of tenants with no to substantial experience of data centre operation. The tenant simply rents computing power and is not involved in the choices made for any of the data centre infrastructure or IT equipment. This typically short-term agreements are more like a managed services agreement than a lease. Typical tenants vary largely due to the flexibility cloud computing offers. (Moerdler, 2014)

Lease	Type of contract	Typical duration	Tenant
Wholesale	Lease agreement	Long-term (20-30 years)	Large companies Data centre operators
Turnkey	Lease agreement	Medium-term (10-20 years)	Experienced companies
Colocation	License agreement	Short-term (2-4 years)	Small companies
Cloud	Managed services agreement	Short-term (2-4 years)	Small to large companies

Table 4: Summary lease structures

2.5.4 Business model

The data centre business model is different from any other real estate related model. The model is briefly described in four topics: revenues, costs, partners and clients.

Revenues

Data centre revenues typically consist of recurring streams. The main part of these streams is the rent. The tenant pays a fixed rent per server, rack or entire server room. However, space is no longer the sole factor by which the rent is measured, as power usage in the main driver of operating costs. The rent level is influenced by a series of factors, the most important being:

- Level of redundancy
- Power density (kW per m^2)
- Number of connected network carriers
- Power Usage Effectiveness ratio
- Distance to internet exchanges

Two other important recurring revenue streams are power and bandwidth usage. Both revenues are either directly charged to the tenant based on the actual costs or a premium is charged. The power is usually billed per used kWh. The bandwidth usage on the other hand is billed per used Mbit. The cost per Mbit is dependent on the distance of the data centre to other data centres and internet exchanges.

Next to recurring revenue streams there are one-time payments. Common one-time payments are setup fees and remote hands. Remote hands are on-site technicians a tenant can hire to solve a technical problem.

Costs

The major data centre cost is power, which takes up 70% to 80% of total operational costs (Dines et al., 2011). Throughout the industry experts value the building and infrastructure maintenance at 3% to 5% of the initial building cost. The rapidly depreciating character of data centre infrastructure makes the maintenance costs expensive compared to other real estate types. The final cost is staffing including security, technical and cleaning personnel.

Revenues		Costs	
Recurring	Rent Energy	**Fixed**	Security Maintenance
One-time payments	Setup fees (optional) Remote hands (optional)	**Variable**	Energy Data hall management

Table 5: Summary of data centre revenues & costs

2.6 Data centre market

The data centre market is of a more clustered nature than other real estate types as data centres are located in the vicinity of Internet hubs and locations with secure energy availability (Covas et al., 2013). This clustering nature causes the European market to be geographically concentrated in clusters of which 5 major European locations are distinguished, namely Amsterdam, Frankfurt, London, Madrid and Paris (CBRE, 2013c).

2.6.1 Industry structure

The five forces model depicted in Figure 18 aids to "understand the competitive forces, and their underlying causes revealing the roots of an industry's current profitability while providing a framework for anticipating and influencing competition (and profitability) over time" (Porter, 2006). Porter distinguishes the following forces:

- Threat of new entrants;
- Threat of substitute products or services;
- Bargaining power of customers;
- Bargaining power of suppliers;
- Intensity of competitive rivalry.

Figure 18: Five forces model (Porter, 2006)

Porter's five forces model is used to analyse the data centre industry. The results for the Dutch data centre industry are summarized in Table 6.

Threat of new entrants	Low threat of new entrants due to entry barriers: • Economies of scale incumbents • High initial investment needed • High switching costs costumers • Limited prime locations available • Governmental restrictions new entrants
Threat of substitute product or service	Limited threat of substitute product due to: • Demand for data centres growing in near future • Uncertainty about setup future data centre
Costumer bargaining power	Limited bargaining power of customers due to: • Products differentiated with differing cost structures • High switching costs customers • Customers accept higher price due to mission-critical nature of data centre operations
Supplier bargaining power	Moderate bargaining power of suppliers due to: • Small number of main suppliers available • Energy supplier depended on region
Intensity of competitive rivalry	Moderate competitive rivalry due to: • Small number of competitors • Rapidly growing industry Competition is not mainly focused on price but on product features and support services

Table 6: Summary 5 forces model

Threat of new entrants

The threat of entry in an industry depends on the height of entry barriers and on the reaction new entrants can expect from incumbents. Entry barriers are advantages incumbents have relative to new entrants. (Porter, 2006)

Economies of scale are likely to cause advantages for incumbents as these actors general are of larger scale than new entrants resulting in lower operation and production costs. This effect forces new entrants to enter with relative large scale or to accept high costs. Experts pointed out that data centre incumbents benefit from lower energy and bandwidth costs as a result of their scale and network. On the other hand larger scales create opportunities to offer additional services to data centre clients, such as peering between owned data centers.

Data centres are capital intensive. Both the capital expenditure to buy or build a data centre and the operating expenditure are substantial hindering industry entry. However, Porter (2006) warns to not overstate this entry barrier as there might be investors willing to invest if the returns are attractive and are expected to remain so. Over the last years the industry has seen investors entering the data centre market due to high expected returns. Nonetheless, only a minority of these entrants have shown to be able to yield the expected returns.

Clients switching from an incumbent to a new entrant generally make up the largest part of the new customer base of the new market actor. However, a major prerequisite of this switching of supplier are reasonable switching costs. As data centre operations are seldom easily transferred to another data centre, the switching costs are high in the data centre industry. As a result switching data centre supplier only occurs when great financial benefits are offered and the rental agreement is ended.

In several European cities such as London and Amsterdam the prime data centre locations in terms of connectivity and power supply have largely been occupied. For instance new built locations in Amsterdam with exceptional connectivity are not unavailable. The closed new built locations are situated close to Haarlem, Lelystad and Almere. The city of Amsterdam only appoints existing office and industrial locations for re-use. (Municipiality Amsterdam, 2013)

Next to locational restrictions the municipality of Amsterdam restricts the design of new data centres to buildings with a maximum Energy Usage Effectiveness (EUE) of 1.3 following the recommendation of 1.2 of the Dutch ministry of Infrastructure and Environment (Municipiality Amsterdam, 2013). A maximum EUE of 1.4 is employed for expansions of existing data centres. New entrants are therefore obliged to make relatively large initial investments compared to incumbents. However, the initial higher investment is compensated by the energy cost reduction that is achieved through the lower EUE.

The threat of new entrants is characterized as low due to the great number of restrictions and disadvantages a new entrant faces.

Threat of substitute products or services

The demand for computing power and storage is inevitably increasing over the coming decades due to IT developments like cloud computing and the increasing use of wireless and mobile connections. However, expert opinions on how the increasing computing power and storage will be organized in the future differ. It’s likely that future data centres have a completely different setup compared to the data centres today.

Although IT develops at a rapid pace, it’s not likely that data centres will drastically change over the coming decade or will be substituted by another product or service. Therefore, the threat of substitute products or services in the near future is characterized as low.

Bargaining power of customers

Powerful customers can pressure suppliers to reduce prices. Buyers are powerful if they have negotiating leverage relative to other industry participants (Porter, 2006).

The data centre industry is characterized by a differentiated set of products. The exact product differs largely between data centre operators as these suppliers aim to diversify and widen their service to the costumer to attract new clients. The different cost structures increase this difference even further. This leads to lower costumer bargaining power as the products aren’t easily comparable.

Data centre clients do not change from one data centre to another easily as switching costs are high due to facilities needed to ensure the prolonged and uninterrupted operation of mission-critical processes. These high switching costs drastically influence the customer bargaining power.

Data centre operations generally involve mission-critical operations of the client. As the operation of the IT processes is critical to the client’s operation, the client is willing to accept a higher price for continued uninterrupted operation of its IT processes.

The bargaining power customers is characterized as low due to the differentiated data centre products, high switching costs and need for continued uninterrupted operation of IT processes.

Bargaining power of suppliers

Powerful suppliers can capture more of the industry value for themselves by charging higher prices, limiting quality or services or shifting costs to industry participants. (Porter, 2006)

The most important suppliers for data centre operation are the energy suppliers and network carriers. To limit the bargaining power of these suppliers many data centres aim to involve multiple suppliers to increase their bargaining power. It is therefore common for new built data centres to connect multiple carriers.

The supply of energy is more complicated as only a limited number of energy suppliers are active in a certain geographic region. This limits the choice of energy supplier to a large extent.

Due to the very limited choice in energy supplier and network carrier the bargaining power of suppliers is defined as medium.

Intensity of competitive rivalry

High rivalry among existing competitors limits the profitability of an industry as it drives price discounting, new product introductions and advertising campaigns. The degree to which rivalry drives down an industry's profit depends on the intensity with which companies compete and on the basis on which they compete. (Porter, 2006)

The intensity of competitive rivalry in the data centre industry is moderate due to the relative small number of competitors and rapid industry growth.

Price competition in the data centre market is limited as switching costs are high and fixed costs low compared to energy and bandwidth costs. Competitors largely compete on dimensions like product features and support services. These features improve customer value and can support higher prices, while raise the barriers for new entrants (Porter, 2006).

2.6.2 Global trends

The following global trends are identified:

- Increasing confidence in IT outsourcing;
- Further adaption of cloud computing;
- Global data traffic drastically grows;
- Total data centre workload increases;
- Technology trends drive need for IT capacity.

Increasing confidence in IT outsourcing

Restoring business confidence is a result of an improvement in economic outlook. The opinion that an outsourced IT solution is able to deliver improved cost efficiency is proving attractive to cost-conscious companies. Consequently, interest from corporate occupiers and technology service providers in data centre services is increasing. (CBRE, 2013c)

Further adaption of cloud computing
Companies are deploying cloud services for their IT platforms. The push towards maximizing productivity through efficient use of IT is outweighing fears over security. A CenturyLink (2014) survey shows that half of the companies surveyed currently house their IT services in-house. However, the surveyed companies expect to drastically embrace outsourced cloud services at the expense of the in-house IT services.

Global data traffic drastically grows
The global data traffic is expected to grow substantially, partly as a result of the previous described trends. Cisco (2013) expects global traffic to have doubled by 2017. By this year most of this data (up to 70%) will be used for internet video.

2.6.3 European data centre market

The European data centre market has shown a stable growth in supply over the last decade resulting in a total supply of 667,818 m^2, while take-up is recovering since its decline from 2009 onwards as a result of the global economic turndown (Figure 19). (CBRE, 2013c)

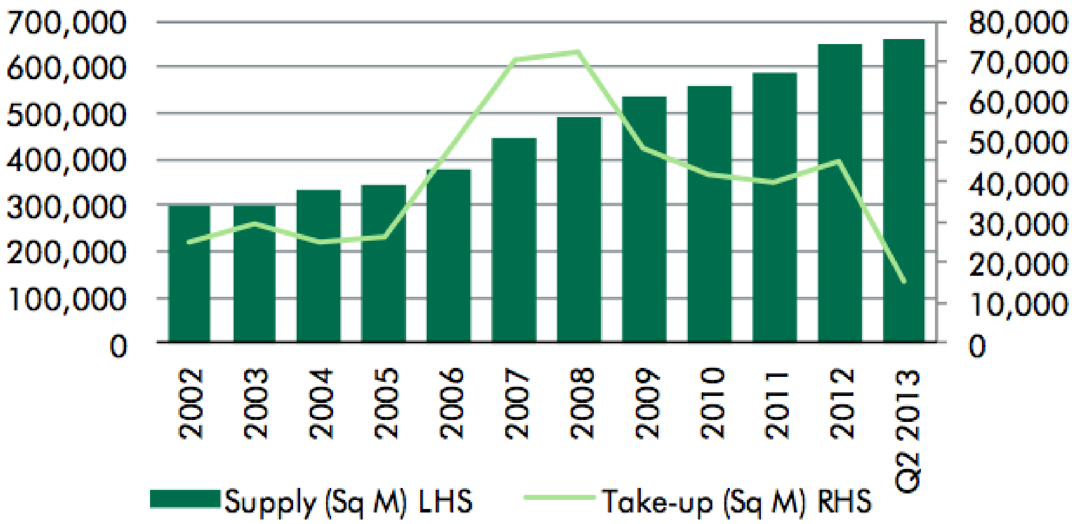

Figure 19: European Tier 1 Colocation Market (CBRE, 2013c)

Data centre operators begin to receive more new enquiries for colocation server space. These new enquiries are mostly driven by telecommunications and IT services companies and companies looking to deploy private clouds[6]. Companies are increasingly comfortable with seeking a third party for their IT infrastructure. Examples of this trend are the agreement Salesforce.com signed with NTT Europe to build a European data centre in the United Kingdom and the Dutch Ministry of Infrastructure along with other Dutch government institutions signed agreed to establish their IT infrastructure in two Equinix data centres in Amsterdam. As a result of this growing user confidence CBRE expects the European market to grow but at lower rates than in 2012. (CBRE, 2013c)

[6] Private cloud is cloud infrastructure operated solely for a single organization. Cloud infrastructure is a computing concept that involves a large number of computers connected through the Internet. (Wikipedia, 2014a)

European markets hold an overall vacancy rate of 15,3% for 2013 Q2 (CBRE, 2013c). This seems to be high compared to the troubling Dutch office vacancy rate of 14,6% for 2012 (DTZ Zadelhoff, 2013). CBRE (2013) attributes the rise of vacant data centre space over the last four years to the last year's expansion plans. Their 2013 report does not raise concern as they expect falling availability in the short-term and expect data centres operators to consolidate their positions in the long-term driving vacancy down.

Historically colocation data centre space has made up the vast majority of data centre take-up up to 90%-100% of the total take-up in Europe (Figure 20). The greater share of colocation data centre space is mainly caused by the growing usage of IT services and the increasing comfortable attitude of companies towards IT outsourcing. This tendency results in the drastic decline of self-build data centres take-up. (CBRE, 2013c)

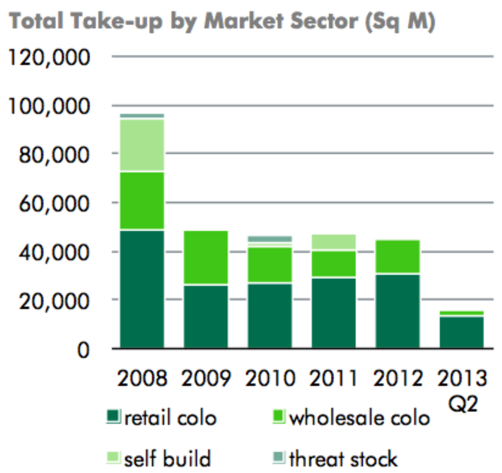

Figure 20: Total take-up by market sector (CBRE, 2013c)

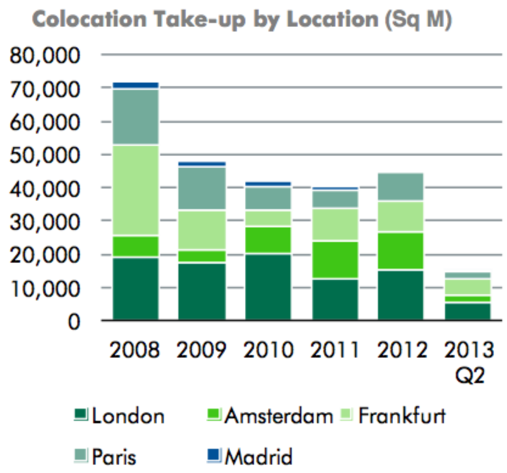

Figure 21: Total take-up by location (CBRE, 2013c)

The 5 major European markets greatly differ in size of supply and vacancy as is shown in Table 7. London is the largest market with a total supply of 282.079 m^2 colocation space. The UK market also holds the highest vacancy rate of 18,57%. The smallest of the 5 markets is Madrid with a supply of 28.564 m2 and a remarkably low vacancy rate of 3,00%. Figure 21 shows that over the last 3 years London and Amsterdam have shown the largest absorption resulting in a take-up of respectively 14,845 m^2 and 11,660 m^2 in 2012 (CBRE, 2013c).

	Supply (sq m)	Vacancy (sq m)	Vacancy (%)
Madrid	28.564	857	3,00%
Amsterdam	95.429	15.294	16,03%
Paris	106.174	12.582	11,85%
Frankfurt	155.572	21.120	13,58%
London	282.079	52.379	18,57%

Table 7: Data centre supply & vacancy by location (CBRE, 2013c)

2.6.4 Dutch data centre market

The Netherlands is one of Europe's hot spots in terms of connectivity due to its central location in Europe and the fibre routes from the United States to Europe. Submarine cables provide links to the US, while five earth satellite stations connect the Netherlands to the rest of the world. The CIA regards the Dutch market as highly developed and well maintained with the only natural hazard being flooding. (CIA, 2014)

The primary Internet exchange is AMS-IX being one of the world's largest and available through multiple facilities in Amsterdam (Datacentermap, 2014).

Datacentermap (2014) lists a total of 77 colocation data centres in the Netherlands. Amsterdam is the largest Dutch region holding 37 colocation data centres, including 3 at Schiphol.

The Amsterdam data centre market is growing rapidly almost doubling its supply in the last 5 years. This rapid growth is caused by increasing interest of end users and operators, clearly marked by the acquisition of 15,900 m^2 data centre space by Digital Realty in Hoofddorp. (CBRE, 2013c)

The Amsterdam market is characterized by its resistance to the downward pressure resulting from periods of economic downturn. The main reason for this is the growing interest of multinationals for the city as prime location for connectivity-driven demand in Europe. Amsterdam attracts telecommunications and information technology companies because of this feature. (CBRE, 2013c)

Mid 2013 the take-up of the Amsterdam market lacked significantly compared to longer-term average at a total of 2,025 m^2. This lower absorption is due to the fact that the transactional process takes longer to complete. CBRE (2013) expects the market to have improved over the last half year of 2013.

3 Methodology

3.1 Introduction

This section of the report emphasizes the methods and materials used to conduct the research. The chosen research method is justified followed by a description of the expert interviews. Since a Discounted Cash Flow (DCF) model is used the basics of a DCF model are introduced. Consequently, the model validation and impact analysis are described.

3.2 Financial modelling

This thesis sets out to analyse the decision-making criteria currently employed by data centre investors. Normally, the hedonic pricing method is used to quantify the effect of certain criteria or object features on the return or eventual value. However, to obtain useful results from a price hedonic model a multitude of input objects are needed. Moreover, detailed numerical (financial) information of every object is needed.

The data centre market is an immature and small market. Actors benefit to a large extent from owning market information others lack. This makes data centre investors, owners and operators reluctant of sharing this information. To answer the research question a more generic research method is chosen, namely financial modelling. Through literature study and expert interviews the input data for the financial model is gathered. The interviewees were asked to cooperate in a generic and universal way, instead of sharing specific business details.

Data centre investment decisions largely influence the operational expense and revenues. This influence is of greater impact compared to other real estate classes due to the high technological nature of the data centre. To correctly analyse the effect of the investment decisions the entire value chain should be included in the model. The difficulty of gathering all needed data for such a model is impossible in the reluctant data centre industry. This makes for another reason to simulate the entire value chain using a financial model.

3.3 Expert interviews

As the published knowledge on data centre real estate is limited, semi-structured expert interviews were conducted to supplement the theoretical framework with practical knowledge and insights. The method of expert interviews was chosen over an expert panel, as much of the information shared by the interviewees was confidential. The interviewees wouldn’t have participated in a panel or wouldn’t have shared all the information they shared in the interviews. Semi-structured interviews were conducted instead of questionnaires as only some questions were clear from the beginning, while many questions and subjects came up during the interviews. The results from the interviews and literature study provided the needed input for the financial modelling.

The following professionals were interviewed:

- Real estate manager at data centre investment firm
- Acquisition manager at data centre investment firm

- Data centre strategy consultants
- Data centre installation consultants
- Commercial director at a data centre operator firm

During these semi-structured interviews the following subjects were addressed:

- Stakeholders involved
- Data centre risk-return profile
- Current business case
- Future lookout & trends
- Decision-making criteria
- Model variable estimation

3.4 Discounted cash flow model

3.4.1 Introducing discounted cash flows

An investor usually invests capital in assets, which he expects to yield the best returns in relation to the acceptable risk. The final return for the investor is calculated by deducting the investment price from the future cash flows generated by the asset. The investor's influence on the future cash flows is limited by exogenous factors such as market forces and inflation. As future income and costs involve substantial risk, the price to pay for the asset is the sole evident driver of the return to be influenced by the investor, as the investor can influence this price through negotiations. In this respect Geltner and Miller (2006) state the following:

"The prices investors pay for properties determine their expected returns, because the future cash flow the properties can yield is independent of the prices investors pay today for the properties."

To apply this pricing principle in practice the multi-period discounted cash flow valuation method (DCF) is widely used. This principle adjusts future cash flows to present values as is conceptualized in Equation 1. In essence, the procedure consists of three steps (Geltner & Miller, 2006):

1. Forecast the expected future cash flows
2. Ascertain the required total return
3. Discount the future cash flows to present value at the required rate of return

Mathematically these three steps are summarized in the following equation:

$$V = \frac{E_0[CF_1]}{1 + E_0[r]} + \frac{E_0[CF_2]}{(1 + E_0[r])^2} + \cdots + \frac{E_0[CF_{T-1}]}{(1 + E_0[r])^{T-1}} + \frac{E_0[CF_T]}{(1 + E_0[r])^T} \quad (1)$$

Where: V = present investment value of the asset
CF_t = net cash flow generated by the asset in period t
$E_o|r|$ = expected average multi-period return or opportunity cost of capital, expressed as the going-in IRR, being the return one would expect to receive from other investments

T = the terminal period in the expected investment holding period

The investment value V calculated in equation 1 is the value of an asset to a particular investor. It is therefore a subjective measure. This subjectivity is reflected in the choices that make up the net future cash flows.

3.4.2 Net Present Value decision making

Investment decisions are commonly made through the use of DCF models in combination with the NPV decision rule. The NPV is the present value of the value calculated with equation 1 minus the price paid for asset (the investment). The NPV therefore is a measure of the financial feasibility of an investment. (Geltner & Miller, 2006)

The NPV decision rule states to do the following (Geltner & Miller, 2006):

1. Maximize the NPV across all mutually exclusive alternatives;
2. Never choose an alternative that has NPV < 0.

Obviously, NPV for a seller is different from the NPV for a buyer of an asset. The NPV's are expressed as follows:

NPV for buyer: $NPV = V_0 - P_0$
NPV for seller: $NPV = P_0 - V_0$

V_0 = value of property at time zero
P_0 = selling price of property at time zero

Maximizing the NPV might suggest that decisions where NPV = 0 are to be avoided. This is not the case. In perfect transparent markets one would expect decisions to settle around equilibrium (being NPV = 0) as both buyer and seller are looking to maximize their NPV (Geltner & Miller, 2006). Furthermore, NPV = 0 decisions do result in profits since these are incorporated in the rate of return used to calculate the Present Value of the asset.

3.4.3 Advantages discounted cash flow

The discounted cash flow method creates clear and consistent decision criteria for all assets evaluated (Mun, 2002). Even assets with largely differing specifications, investment period and risk profiles are comparable based on their NPV. Finally investment decisions for these differing assets can be made using the NPV decision rule.

The method offers quantitative results at a decent level of precision. The theory is based on an economical rational and is not as vulnerable to accounting conventions such as depreciation. (Mun, 2002)

The time value of money is factored in to the method as it discounts all future cash flows to a present value. Risk is also incorporated in a DCF model through the use of the discount rate. The discount rate is calculated as the risk-free rate (such as rates of government bonds) plus the expected inflation and a risk premium adjusting for the expected risk related to this specific investment. (Mun, 2002)

Finally the relative simplicity of the method makes DCF models simple to learn and explain to management. This explains the reason why these models are widely taught and accepted. (Mun, 2002)

3.4.4 Disadvantages discounted cash flow

The assets modelled in a DCF model are subject to risk and uncertainty. Managers and investors have the strategic flexibility to make and change decisions as these uncertainties become known over time (Mun, 2002). However, the DCF method presumes all decisions to be known and quantifiable for the entire model period.

A DCF model is based on the assumption that all future cash flows are predictable and deterministic (Mun, 2002). This evidently leads to forecast errors as the actual future cash flows differ from the forecasted cash flows.

DCF models focus on the long-term investments (McClure, 2013). A DCF model producing high NPV does not mean you can sell that asset for that price at this time. Clearly the asset has to evolve to generate return. Therefore, DCF models are not suited for short-term investments.

Estimation of an asset's economic life is a prerequisite for discounting cash flows. However, the exact life-time of an asset is often unknown when investing. (Mun, 2002)

The tests for plausibility of the final results are limited and insufficient making (complex) model validation strenuous. (Mun, 2002)

Finally the model is entirely based on the input provided, meaning that if your input is not correct your output is incorrect as well. From this characteristic stems the saying: "Garbage in, garbage out".

3.4.5 Modelling the data centre

The eventual commodity produced by a data centre is computing power. For this production vast amounts of energy are needed for operation of the IT equipment. This process is facilitated by valuable installations such as uninterruptable power supplies and cooling systems. These installations are a major capital expenditure and operating expenditure, as they require similar amounts of energy as the IT equipment. Comprehensive calculations of the installation requirements and layout are needed in the model.

As data centre specifications influence both the capital and operating expenses the entire value chain is to be incorporated in the model. In most cases an investment decision influences the investment to build a data centre and the cost of operating of a data centre. For instance, suppose a data centre is to be equipped with less efficient installations to minimize capital expenditure. This decision will result in higher operating cost for the data centre operator and ultimately lead to vacancy as the operator is not able to compete with more efficient data centres.

An approach to incorporate both the initial investment as the future operating cost is the life-cycle costing approach. This method calculates the total cost of ownership over the entire life of an asset. This presumes that the lifetime of the asset and the value of the variables constituting the future cash flows are known. As this is not the case for data centres a simplified version of the life-cycle costing method is chosen incorporating the entire value chain from investment to operation in the DCF model.

3.5 Model validation

3.5.1 Introduction

After the model was constructed it's input and workings were validated using a sensitivity analysis. Consequently, experts verified the model outcome.

3.5.2 Sensitivity analysis

This type of analysis examines how sensitive the model outputs are to changes in the model inputs. Adding and deducting 40% to every parameter measures the relative impact of every parameter on the analysed output parameters. Through this method the most influential parameters are identified. Furthermore, errors in the model are determined through the use of a tornado chart (Figure 22). This chart displays the lower and upper output (by adding and deducting 40% to the input) for all input parameters.

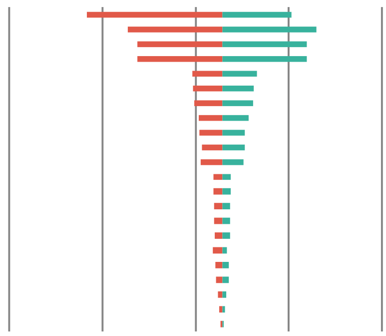

Figure 22: Example of tornado chart

Parameters that render uneven bars (greater negative than positive values or vice versa) in the tornado chart might indicate model errors. These parameters were closely investigated and the model was altered if needed.

Sensitivity analyses are conducted for the output parameters NPV, the Return on Property and the Levered Return on Equity.

3.5.3 Expert verification

After the sensitivity analysis was conducted the model outcome was presented to expert that had also participated in the expert interviews. Changes to the model have been made based on their input.

3.6 Impact analysis

3.6.1 Introduction

To answer the main research question the impact of certain input parameters is analysed. As the values are mostly based on expert interviews, these values cannot be used as absolute and unbiased input. Monte Carlo simulations are used to account for this uncertainty. This type of simulation and its application are introduced in this section.

3.6.2 Accounting for uncertainty

A real-life system is characterized by uncertainty. This uncertainty is imitated in a financial model by implementing Monte Carlo simulation. This method calculates numerous artificial futures of a model by repeatedly picking values from the probability distribution for the uncertain variables and using those values for the calculation of the scenario. As all of these scenarios produce associated results, each scenario has a forecast. Forecasts are defined as important outputs of the model, such as totals, net profits or gross expenses. (Mun, 2002)

Monte Carlo simulations come in two variants: non-parametric and parametric simulations.

Nonparametric simulation
The nonparametric simulation approach is used for simulations based on historical data. Instead of assuming a pre-set distribution (normal, triangular, lognormal, etc), nonparametric simulation uses the data themselves to obtain the needed input. This method randomly picks entries from a dataset for a vast number of times and calculates the average of all entries picked. (Mun, 2006)

By using the nonparametric approach knowledge of the distribution (normal, triangular, lognormal, etc) and assumed parameters (mean, standard deviation, etc) is not needed.

Parametric simulation
The parametric approach forces simulated outcomes to follow well-behaving distributions and is therefore used to forecast variables (Mun, 2002). These distributions are created through the use of a stochastic process. The stochastic process is used to represent the evolution of a random value over time. Based on this random value the value of the forecasted variable is simulated. The most common process to be used for financial modelling is the Geometric Brownian Motion due to its simplicity. (Brewer, Feng, & Kwan, 2012)

The parametric method offers a solution to the absence of a dataset to be used for nonparametric simulation as is the case with forecasting of variables.

3.6.3 Application of Monte Carlo simulations
Based on expert interviews and the sensitivity analysis a short list of variables to be analysed is developed. For every variable a parametric simulation is constructed as the data for a nonparametric simulation is missing. This first step of analysis is to value the parameters used for the simulation. The chosen distribution, mean, median and standard deviation are part of these parameters.

Another sensitivity analysis is conducted based on the chosen distribution after valuing the parameters. This analysis differs from the initial sensitivity analysis as the lower and upper bound are determined by the uncertainty (quantified by the standard deviation) associated with the input parameter instead of using a static lower and upper bound (40%).

The actual simulations are performed one input parameter at a time for the NPV, the Return on Property and the Levered Return on Equity. The simulation will create 10.000 instances of the model. Consequently, the standard deviation of these instances is calculated. The standard deviation is a measure of the spread of the found instances. A larger spread means that a larger range of possible outcomes is possible meaning that more risk is associated with that variable.

4 Results

4.1 Introduction

To understand data centre investment decision-making the current situation is described. Consequently, the data centre investment risk profile is defined. To determine the influence of data centre features on the return for investors a DCF model is constructed. The construction of the model is described followed by a description of the main input variables. Finally, the results from the sensitivity analyses and variable impact analysis are discussed.

4.2 Current situation

As the data centre industry comes of age, actors focus on diversifying and improving their services rather than lowering prices. The data centre industry is more and more characterized by competition on quality instead of price. Especially larger data centre clients tend to prefer better services over lower cost, as their business operations increasingly depend on these services. Key within data centre services is redundant uninterrupted operation of the IT processes staged within the data centre. The primary ingredients for this redundant uninterrupted operation of a data centre lay within the decisions made in the acquisition or construction process. These decisions form the basis for the operation that is later complemented with additional operational services, such as careful maintenance.

Figure 23: Current decision process (own illustration)

Three succeeding decision processes characterize the decision-making process as displayed in Figure 23. Firstly, politics determine possible regions for a data centre. Once a region is selected the location of the investment is determined followed by the exact layout of the data centre building. All processes are described in more detail.

4.2.1 Political decision process

The first step in a data centre investment decision depends on macroeconomic topics, global social and political trends. Changes in the global economy or geopolitics can easily and rapidly affect a data centres operation. Data centre operators and investors should therefore be well aware of these trends. The most recent events that illustrate this dependency are the revelations of the National Security Agency of the United States of America monitoring citizens, companies and statesmen. Because of these revelations companies and government agencies are moving their privacy sensitive operations from data centres in the US to local data centres.

4.2.2 Locational decision process

After the region is chosen the location of a data centre is of vital importance to ensure redundant uninterrupted data centre operation. Choosing the right location minimizes power, connectivity and security risks.

Power and connectivity are the lifelines of a data centre. Interruption of any of the two endangers the data centre operation. Besides possibly impeding the operation both aspects considerably drive the operational costs of a data centre. Determining the right location yields financial advantages during the data centre's lifetime, as it might bring forth lower costs for power and connectivity.

Based on expert interviews and the policy on data centre establishment of the municipality of Amsterdam (2013) five main locational aspects regarding power and connectivity are distinguished:

- Availability of power supply of substantial capacity;
- Supply of multiple power providers;
- Proximity of Internet Exchanges, such as the AMS-IX;
- Availability of optic fibre connections of substantial capacity;
- Proximity of other data centres for peering.

Throughout the data centres industry elaborate security protocols are employed. Locational decisions in the acquisition process enable these protocols. Based on interviews and the policy on data centre establishment of the municipality of Amsterdam (2013) five main locational aspects regarding site security are considered:

- Situation above NAP due to flooding risks;
- Avoiding approach routes of airfields;
- Risks resulting from neighbouring buildings;
- Site occupation previous to data centre operation;
- Danger of car collision.

4.2.3 Building decision process

Once all locational requirements are met building features are considered. As is the case with locational aspects redundancy is the most vital aspect to consider. Throughout the data centre industry Tier levels below 3 are considered to deliver insufficient redundancy for modern IT processes. As a result most Dutch data centres are classified Tier 3 or higher guaranteeing over 99,982% availability throughout their operation (CBRE, 2013a). To deliver this availability dual-powered equipment and multiple uplinks are required. Most new data centres are equipped with fully fault-tolerant uplinks, power distribution and cooling installations.

Essential to new data centres is energy efficiency. Driving PUE down lowers the energy cost, which makes up the larger share of the operational expense. Furthermore, it improves the data centre's competitive advantage as the energy costs generated by IT equipment multiplied by an energy premium to cover for energy used by the facility's installations are generally charged to the client. Thus, lower PUEs generally result in lower operational costs for the client. By using new technologies and processes data centre operators limit the energy used by cooling and air handling installations resulting in PUEs coming close to the theoretical 1,0. The municipality of Amsterdam (2013) currently only allows construction of new data centres with PUEs lesser or equal to 1,3.

All interviewed experts indicated the adoption of modular building is the most prominent development in the data centre industry. This new type of building offers the possibility to expand the data centre based on demand limiting the risk of vacancy. Another reason for modular building is the low PUEs that are associated with the modular units. Even though modular building clearly offers advantages the method is not yet adopted throughout the industry. The main reason for not adopting modular building is the associated higher capital expenditure.

Considerable floor loads and heights characterize the shell building. Modular building drives these values up as the modular units are heavier and as many installations that were conventionally installed on the roof are stationed on top of the module inside the data centre.

The final crucial building aspect is site security. The main aim of the data centre in this regard is keeping the external risks and dangers out. Fencing, obstacles and free land around the building, access control vestibules and CCTV are used to achieve this.

4.3 The data centre risk profile

First a description of the data centre risk profile is given based on the literature review and the expert interviews. The definition is followed by a comparative analysis of risk-return profiles for data centre and other investment class REITs. Finally, the data centre risk-return profile is positioned within the INREV strategy profiles.

4.3.1 Description of the data centre risk profile

The risk profile of data centre investments is described by defining risks and securities of this type of investment.

Risks

Several interviewed experts stress the need for specialized and active management being the major risk for investors new to the data centre industry. Due to the high technological nature of data centre operation specialized personnel throughout the operational organisation is needed.

The need for specialized management drives the operating expenses up. Every multi-tenant data centre requires security personnel. Generally colocation operators additionally offer on-site technical support. From interviews is concluded that the total minimum operational cost for an average colocation data centre amounts to € 65,- per m^2 lettable data hall compared to only € 5,90 (adjusted for inflation) per m^2 LFA of average office space (Jones Lang Lasalle, 2012). The larger part of this operational expense is variable, since supplementary data hall managers are only needed when additional server racks are rented out. However, a minimum number of security personnel are needed at all times.

Maintenance is the main driver of operational expenditure of data centres next to the management costs. As the operation of the IT equipment is relied on numerous installations that age rather rapidly, maintenance and replacement costs are high. Based on expert interviews the cost of maintenance of an average data centre amounts to € 225,- per m^2

lettable data hall compared to € 7,65 (adjusted for inflation) per m^2 LFA of average office space (Jones Lang Lasalle, 2012).

The relatively high operating expenditure of a data centre is justified by the high rental returns compared to office space. An average colocation data centre yields € 2.400,- annual rent per m^2 lettable data hall based on expert interviews compared to € 196,- annual rent per m^2 LFA office space in Amsterdam (DTZ Zadelhoff, 2013).

	Management cost	Maintenance	Revenue
Office space	€ 5,90	€ 7,65	€ 196,00
Data centre space	€ 65,00	€ 225,00	€ 2.400,00
Ratio	1:11	1:29	1:12

Table 8: Operating costs & revenues of office and data centre space in Amsterdam

On the one hand the risk increases due to the high capital investment needed to construct a data centre. According to expert interviews a typically sized Tier level 3 data centre costs over € 5.000 per m^2 GFA compared to a little over 1.000 per m^2 GFA for a average office building with 6 building layers (IGG Bointon de Groot, 2013). On the other hand uncertainty over vacancy increases the risk of not realizing a stable income. Throughout the industry modular building is designated to mitigate these risks. By building in modules data centre expansion is postponed until demand requires new data hall space. By doing so, capital investment is spread over multiple years and space is only created when needed.

Due to rapid technological development the layout and use of data centres and their installations changes constantly and quickly. A data centre setup might be state-of-the-art today, but obsolete in 10 years' time. This role of obsolescence raises the need for expertise when constructing and operating data centres. According to expert the industry mitigates this risk through the use of independent modules of installations used within the modular building practice. For instance, by installing a rather independent cooling and ventilation unit on top of a single data centre module makes it simple to replace by another system when needed in the future. Additionally, experts indicate that lease agreements are signed before data centre construction to further mitigate the risk of vacancy.

As data centres consume vast amounts of energy the uncertainty over future energy prices increases the risk. However, experts state that this risk is mitigated by billing the direct energy used by the client's IT equipment increased by an energy premium.

Summary risks

- Specialized & active management required
- High capital investment needed
- Uncertainty over vacancy
- Risk of obsolescence
- Uncertainty over value of energy

Securities

An important security for data centre operators is the high switching costs for clients. Transferring the client's IT equipment to another data centre is a very costly and risky operation. According to interviewed experts clients often rent the needed data hall space at two locations during the transfer and up to 1 year after transfer of operations to ensure uninterrupted operation. As a result clients are locked in and lease agreements are rather long and stable income is ensured. Average lease terms often exceed 12 years as is the case with Digital Realty (Digital Realty, 2014).

As described in the data centre market description the demand for data centre space is expected to remain stable or further increase in the future as interest from corporate occupiers and technology service providers in data centre services is increasing (CBRE, 2013c).

All interviewed experts confirmed the common practice of accounting for zero asset value at the end of the data centre operation. This means that the operation yields an income of at least the entire capital expenditure during its 10 to 15 years of operation. By doing so, data centre investments rely solely on income. The business case of more traditional real estate classes like offices relies on both income and resale value at the end of asset operation making them more reliant on speculation on resale values.

However, this shorter time of cost-recovery does not apply to depreciation. Data centres are subject to depreciation rules, meaning they must depreciate the building at a certain fixed rate. Based on expert interviews the common practice of dealing with this issue for Dutch data centres is to depreciate the investment at different rates. Firstly, depreciation of the land on which the data centre is built is not allowed in the Netherlands. Secondly, the building is separated in shell building and installations. Since the value of a data centre is driven mostly (up to 80%) by installations the greater part of the investment is depreciated over 10 years, while the shell building is depreciated over 30 years.

Even though no research on volatility of the data centre space market has been found, the market is expected to be less volatile compared to other real estate markets. This lower expected volatility is due to the fact that the data centre market has weaker links to the economic cycle. From Chart 6 and Chart 7 is concluded that the take-up of European office and industrial space roughly follows the economic growth with a trough following the economic turndown in 2008. The data centre market on the other hand shows no to weak links with the economic cycle as shown in Chart 5. The market moves rather independently with only small changes resulting from macroeconomic tendencies. However, further research on this subject is needed to confirm the expected lower volatility.

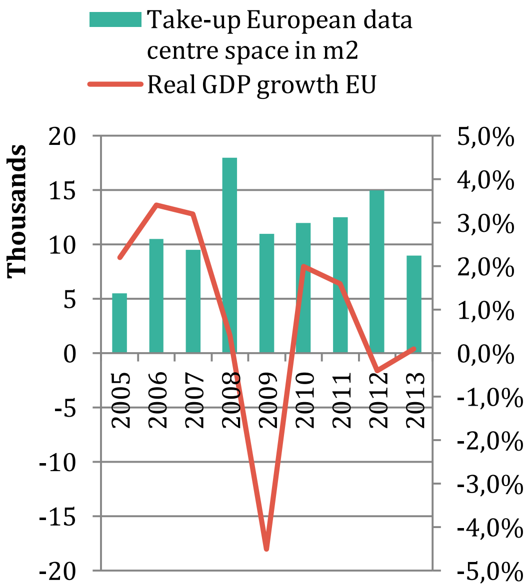

Chart 5: Take-up European data centre space (CBRE, 2014b; Eurostat, 2014)

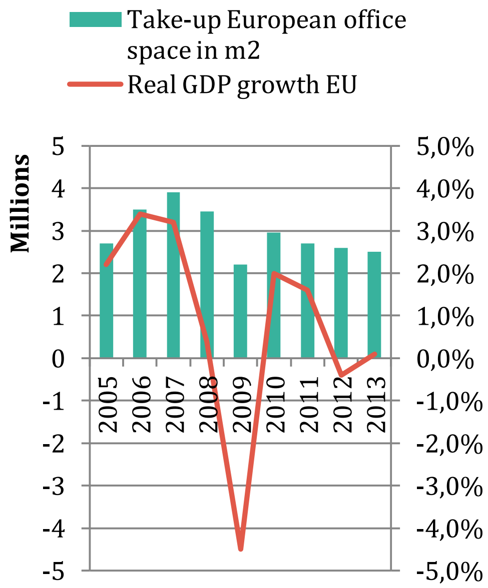

Chart 6: Take-up European office space (CBRE, 2014a, 2014b)

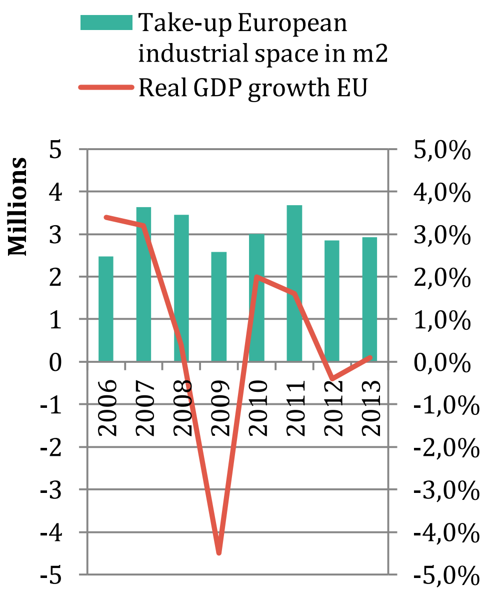

Chart 7: Take-up European industrial space (CBRE, 2014d; Eurostat, 2014)

Finally, the threat of new entrants in the market is low due to the high capital investment needed to enter. Experts also identify limited prime data centre locations as a limiting factor.

Summary securities

- High switching cost results in long contracts & stable income
- Demand for data centres increasing
- No or limited dependency on speculation on resale values
- Expected lower volatility
- Low threat of new entrants

4.3.2 REIT analysis

To compare data centre investments to other real estate investments the specifications of REITs that solely invest in data centres are compared to REITs that invest in other real estate asset classes being offices, residential, retail and industrial. REITs are chosen as the financial information of these institutions is publicly available. For these REITs a number of metrics are examined, namely debt to capital, return on equity, debt to EBITDA and the Loan-To-Value ratio.

Currently there are three REITs that invest solely in data centres, being Digital Realty, Dupont Fabros Technology and CoreSite. For every other asset class five REITs are incorporated in the analysis. If available the financial data for the period 2005-2013 is used for input. The analysed REITs and the averaged input data over this period is described in Appendix 9.1.

Return on equity

The return on equity is used for analysis, as this is the return received by investors. Based on the financial data for the period 2005-2013 the average and standard deviation of the return on equity are displayed in Chart 8.

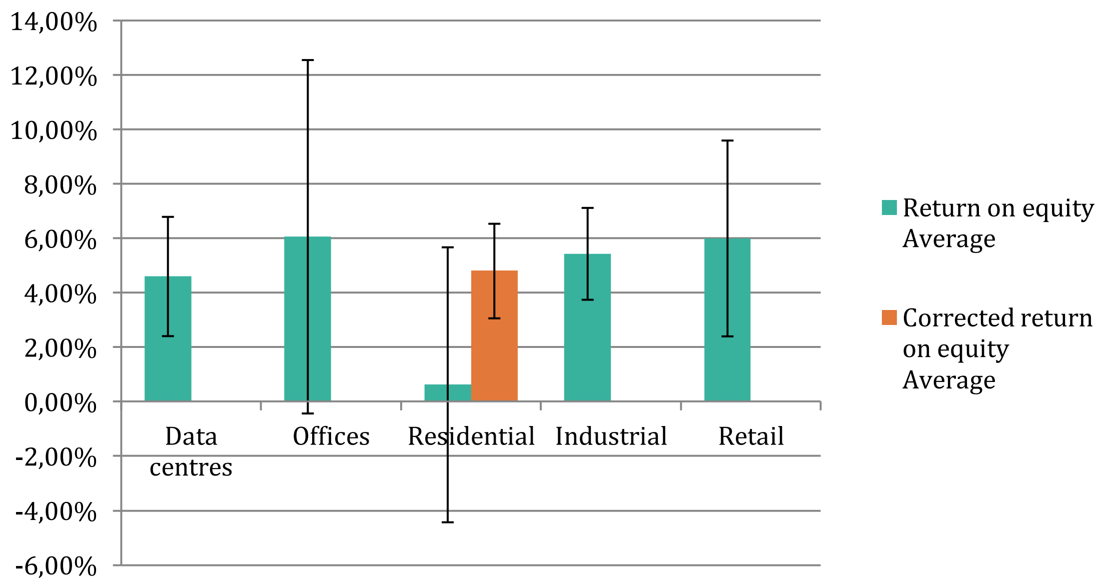

Chart 8: Average and standard deviation of return on equity for REITs

The return on equity of the office and retail REITs show comparable averages (respectively 6,07% and 6,01%). The industrial REITs exhibit a slightly lower average of 5,44%. The residential REITs show the lowest return on equity with an average of 0,63%. This low average is mainly caused by negative returns on equity as a result of the economic downturn and problems on the American residential markets during the period 2008-2012. When the two REITs most affected by the economic downturn are taken out of the analysis, the average return on equity raises to 4,81%. The average return on equity for the data centre REITs is the lowest at 4,61%. This suggests that data centre REIT investments are comparable to residential REIT investments in terms of return.

The spread of returns is a measure of risk associated with an investment, since a larger spread means larger potential upside and downside and thus more uncertainty for the investor. In this light the spread of the return on equity found for the REITs (displayed in Chart 8) supports the general opinion that office and retail real estate is associated with larger risk than industrial and residential real estate. The spread of return on equity of data centre REITs is slightly larger than those of residential and industrial REITs. This implies that data centre REIT investments should be associated with risk profiles close to residential and industrial risk profiles.

Debt

Another important measure influencing the risk-return profile is debt, as leverage increases potential returns and losses. Chart 9 and Chart 10 display several averaged metrics of corporate debt of the analysed REITs over the period 2005-2013. A striking result is the relatively low level of leverage employed by data centre REITs compared to the other REITs. This low level of leverage might be attributed to the immaturity of the market making it harder for data centre REITs to attract debt. The moderate levels of debt decrease the risk associated with data centre REIT investments.

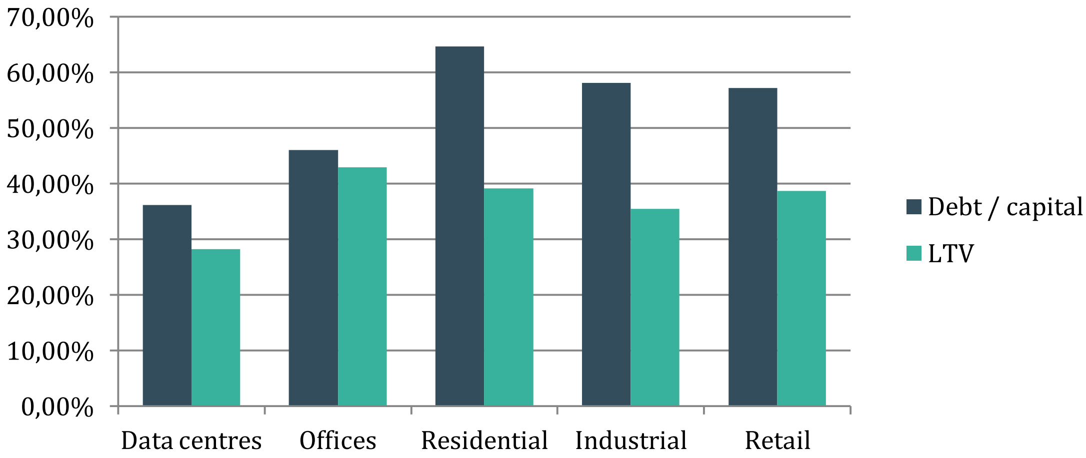

Chart 9: Average debt to capital and LTV of per REIT category

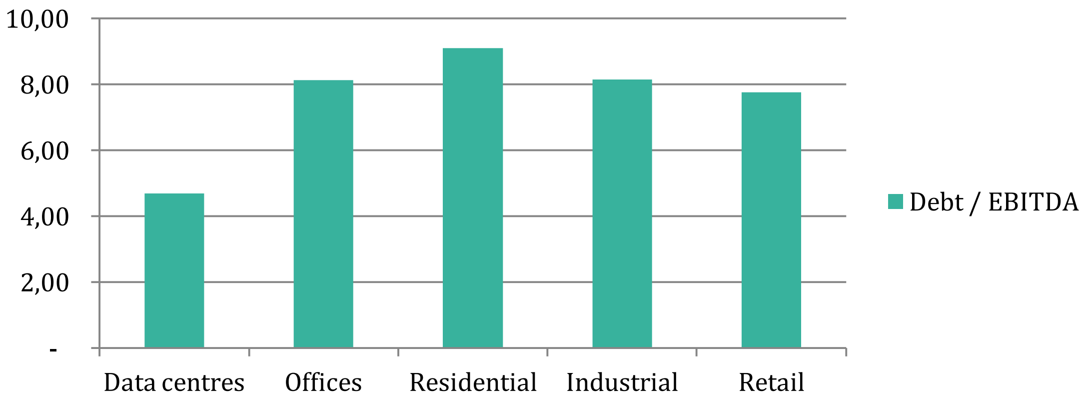

Chart 10: Average debt to EBITDA per REIT category

4.3.3 Positioning data centre investment in INREV strategies

The INREV (2008) distinguishes three investment strategies with different risk-return profiles. The INREV identifies two determining factors within a real estate investment strategy, being the amount of return an investment fund is pursuing and the level of leverage employed. From interviews can be concluded that data centre investments are generally associated with an IRR of 11,0% to 13%. From the financial analysis of the data centre REITs in 4.3.2 a low average LTV of 28% is derived. Both the yield and the LTV position the data centre REIT investments in the INREV core strategy making them investments associated with low risk.

Besides IRR and LTV data centre investments share other characteristics with the INREV core investment strategy. The return of core strategies usually to a large extent consists of stable income. Capital growth is not a main driver of return. Throughout the industry data centre investments are expected to have no residual value at the end of life. The buildings and installations are completed amortized during the asset's life time meaning that the entire return is expected to come from income generated by data centre operation. This income is predictable and stable because of the high switching costs of clients. Average lease terms often exceed 12 years as is the case with Digital Realty (2014).

However, data centres require active and specialized management, which clearly distinguished this type of real estate from other types. Conventional real estate strategies do not necessarily apply to data centres as was the case with the centre constructed and operated by real estate developer TCN. The required active and specialized management and extensive capital investment needed for data centre construction increases the level of risk for investors, as they do need to obtain this expertise. This might suggest to position data centre investments as value added investments.

As described above data centre investments are positioned as core or value added investments. The risk associated with this type of investment is low to medium.

4.4 Constructing the DCF model

Based on the literature study and the expert interviews a DCF model was created to investigate the effect of data centre characteristics on the return for investors. The model consists of three sections being input, calculation and output as displayed in Figure 24. After describing the general assumptions all three sections are addressed individually.

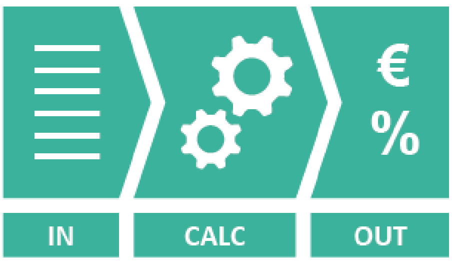

Figure 24: Model sections

4.4.1 General assumptions

As investment decisions influence capital expenditure, operating expenditure and revenues the entire value chain from data centre owner to data centre operator is included in the model. However, only costs directly associated with the operation of the data centre are included. These costs include security and technical data hall management of the data centre. Overhead costs like general management, legal and accounting are excluded from the model.

The modelled data centre is expected to offer pure colocation to its clients to create the purest form data centre operation. This means that the operation offers service (power and connectivity) to the rack. The racks are filled with IT equipment provided and operated by clients.

The model assumes the construction of the centre to be completed within the first year. As a result the vacancy during this year is 100% as the data centre is not yet operational. For the second year a vacancy of 50% is assumed. For all following years an overall long-term friction vacancy is assumed.

4.4.2 Model input

This static section of the model holds all input parameters. These variables are grouped in five groups being data centre specifications, building costs, operating costs, revenues and financial settings. The values of the parameters are based on the literature review and expert interviews and summarized in 9.2.

Data centre specifications

This group of parameters sets all basic specifications of the modelled data centre such as size, redundancy, power availability and energy efficiency.

As the model is constructed from the perspective of both the investor and the operator the number of racks on the data hall floor sets the size of the data hall. Through the use of the area (in m^2) needed per rack the LFA of the data hall is calculated. From expert interviews and observation during data centre visits this parameter was found to be $3m^2$ per rack. This area includes the data hall aisles and ensures enough space to open the doors on the front and back of the rack. A LFA to GFA ratio is included to determine the GFA of the data centre including all supporting functions and installations. This parameter is dependent on the Tier level of the data centre. A higher Tier level requires more installations to ensure higher levels of redundancy. These values are determined based on expert interviews and examination of typical data centre plans. The values are set at 1,5 for Tier level 2 and 3 and 1,9 for level 4 data centres.

The Tier level is included to account for the level of redundancy of the modelled data centre. The levels 2 to 4 are included in the model, as level 1 data centres are virtually not used any more in the European market.

The available power per rack sets the maximum amount of energy available on the data floor. The Amsterdam market overview of CBRE (CBRE, 2013a) shows an average power availability of 2,0. This value was confirmed during several interviews with operators.

The energy efficiency of the modelled data centre is set through the PUE. The municipality of Amsterdam compels new data centres to limit their PUE to 1,3 (Municipiality Amsterdam, 2013). It is now common practice to build data centres with a PUE of less or exactly 1,3.

Building costs

The building costs of a data centre are dependent on the Tier level and size of the data hall as shown in Chart 12. The Tier level is of greatest influence between level 3 and 4, as this higher level requires nearly twice the number of installations needed for level 3. The difference between level 2 and 3 is negligible. Economies of scale cause the size of the data hall to influences the building costs, as a larger data centre is able to employ its installations more efficiently.

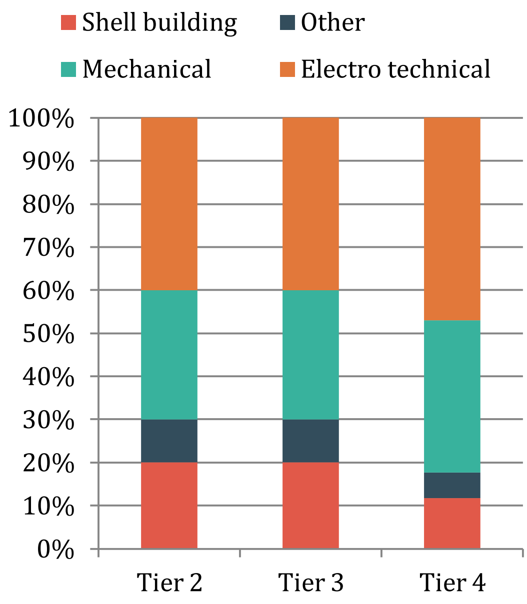

Chart 11: Building cost per building component (own illustration)

The total building costs are divided over four building components being shell building, mechanical installations, electro technical installations and other costs. The proportion of the total building costs of a component is dependent on the Tier level of the data centre as is shown in Chart 11.

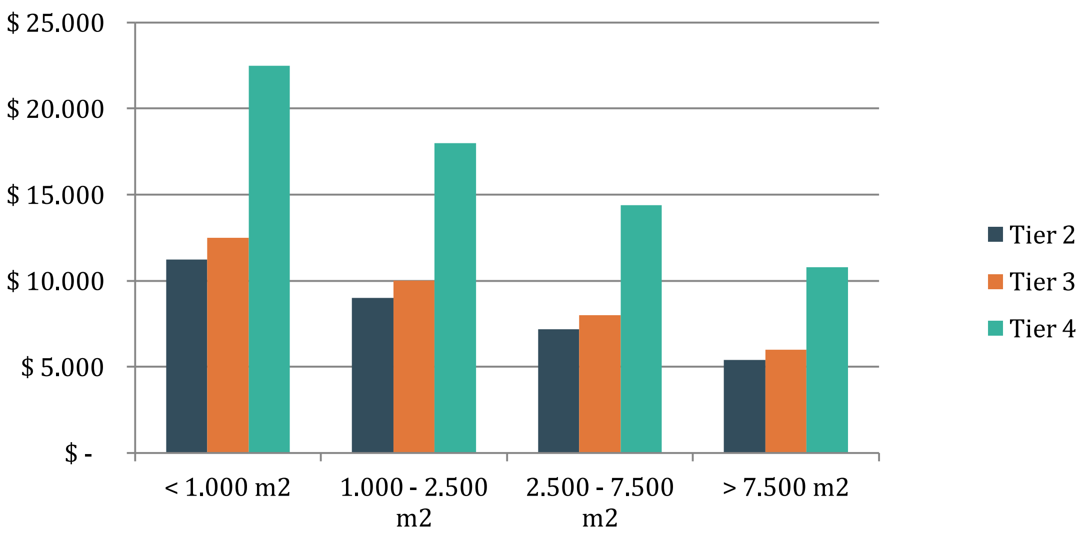

Chart 12: Building costs dependent on Tier level and size of data centre (own illustration)

Operating costs

The operating costs consist of three types of costs being energy, overhead and maintenance costs.

The energy consumed by the data centre is largely dependent on the power used by the IT equipment employed in the centre. The model calculates the power consumption based on the available power per rack and the IT equipment energy usage ratio. This ratio is used to limit the power consumption of the IT equipment, as this type of equipment never uses the maximum. This parameter is therefore set to 70% of the maximum power consumption.

Expert have pointed out that even though the IT equipment employed in the centre drives the energy consumption of a data centre, the consumption will never drop below a certain minimum consumption due to the minimum energy consumption of the mechanical and electro technical installations as shown in Chart 13. This means that a data centre with a higher vacancy at a certain point consumes relatively more energy than another data centre with a lower vacancy. This minimum energy consumption is set at 50%.

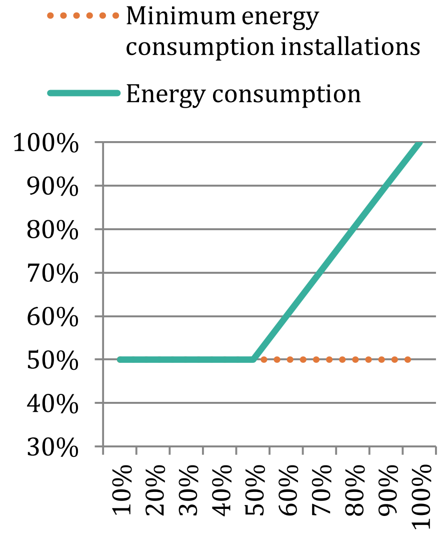

Chart 13: Minimum energy consumption data centre

The energy cost per kWh and the long-term energy growth determine the energy cost. Eurostat (Eurostat, 2013) found the cost of a kWh for industrial consumers in the Netherlands to be 7,5 €cent in 2013. Multiple operators confirmed this value during the expert interviews. The long-term energy growth is set at 2,5% per year.

Employing data hall managers and security personnel drives the operational overhead. Data hall managers are technically trained employees that are able to provide clients with basic technical support. Based on expert interviews the annual salary for this type of employee is set at € 50.000. A data centre needs a data hall manager for every 400 racks in use. To ensure the needed security levels additional security personnel is needed for data centres with over 250 racks in use. In smaller data centres the data hall manager also functions as security guard. From the expert interviews is concluded that data centre of substantial size requires 3 security officers with an annual salary of € 35.000.

The maintenance costs are the final component of the operating costs. Interviewed experts confirmed the use of 3% of the initial building costs for maintenance costs estimation throughout the data centre industry.

Revenues

The model includes two revenue types, namely rental and energy fees. Both types naturally depend on the vacancy level of the data centre. Additional revenues like income resulting from supplementary client support are excluded from the model.

The rental fees are calculated per rack. The height of the fees depends on the Tier level of the data centre and the needed power density per rack. The values are based on expert interviews and summarized in Chart 15. Differing power densities per rack are offered as clients have different IT equipment in place with distinctive goals and uses. For instance, active virtual currency mining installations require an excess of energy (up to 8 kW per rack) compared to normal servers (between 1 and 2 kW per rack). Therefore, data centres generally offer racks with power densities from 2 kW to 5 kW. The model uses a power densities distribution based on expert interviews. This distribution is shown in Chart 14.

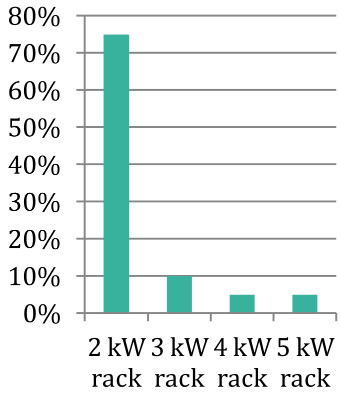

Chart 14: Distribution power densities per rack

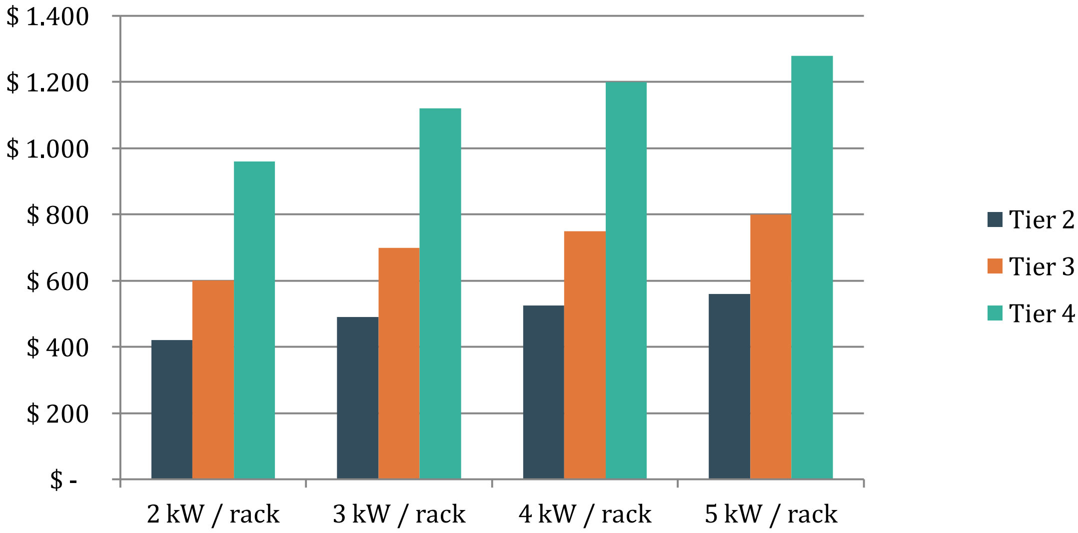

Chart 15: Monthly rents (own illustration)

To account for future rental growth a long-term rental growth of 3% is employed. Finally, a normal friction vacancy of 19% resulting from the expert interviews and examination of the Amsterdam market overview of CBRE (CBRE, 2013a) is used to account for normal vacancy from the third year onwards.

The energy fees are priced per kWh used by IT equipment. In line with common practice the model uses an energy premium on the energy used by IT equipment. Using this premium the energy used by the facility's installations is incorporated in the energy fee. Generally, the premium only compensates the energy usage of the data centre facilities. As modern data centres in Amsterdam have a PUE of less than 1,3 the energy premium employed is set to 30%. Therefore, a typical price for 1 kWh used by IT equipment in Amsterdam is 10 to 11 eurocent, as data centres in Amsterdam purchase their energy at 7 to 8 eurocent per kWh. This energy price is confirmed by interviewed operators.

Financial

The financial parameters set basic assumptions for the financial model. They define the start year of the model (2014) and the length model. Years are automatically added or removed from the model depending on the length of the model.

The tax rate used in the profit and loss calculations is set to Dutch regulation at 25%. The long-term inflation is set to 1,9% (European Central Bank, 2014).

The lifetime of a data centre is mainly determined by the lifetime of its mechanical and electro technical installations. These installations are associated with a 15 years lifetime. The shell building on the other hand is associated with a longer lifetime of 30 years.

From expert interviews with data centre operators and consultants is concluded that operators and investors do not account for any residual value at the 'end-of-life' (15 years after construction). All of the interviewed data centre operators strive to make their return before the end-of-life. The residual value is perceived as a possible additional return. Although this is a plausible conservative position in practice, it does not account for the fact that some residual value is inevitable. Even when the building is invaluable the land will have some value. Therefore, average price of land for commercial land in Amsterdam (€ 300 / m^2 GFA) is used as residual value.

Finally, the parameters defining the financing of the investment are set. The LTV-ratio is set to 0,5. The return on equity and loan are set to 12,5% and 5,5% respectively. The repayment period of the loan is set to 15 years.

4.4.3 Model calculation

All basic model calculations are executed in this section for every year included in the model based on the parameters set in the input section.

Indices

Three indices are set for use throughout the model being an inflation index, energy cost index and rental growth index.

General characteristics

The main data centre characteristics are calculated based on the data centre specifications in the input section. These calculations include total number of racks, UFA data hall, total GFA of the building and total power capacity.

Data centre usage

Based on the distribution of the power densities and the size of the facility the maximum number of racks per density is calculated, as the total number of racks cannot exceed the maximum number of racks and the maximum power capacity of the racks cannot exceed the maximum capacity of the facility. Consequently, the number of racks in use is calculated as a result of the set vacancy rate as shown in Figure 25. The maximum power capacity of the racks rented follows from the total number of racks in use. Through calculation of the maximum energy consumption of the racks in use the annual IT consumption is calculated. Based on the PUE the annual energy consumption of the mechanical and electro technical installations are calculated. Through the sum of the annual energy consumption of the IT equipment and the installations the total annual energy consumption is determined. Finally, the EUE is calculated by dividing the total annual energy consumption by the total annual energy consumption of the IT equipment.

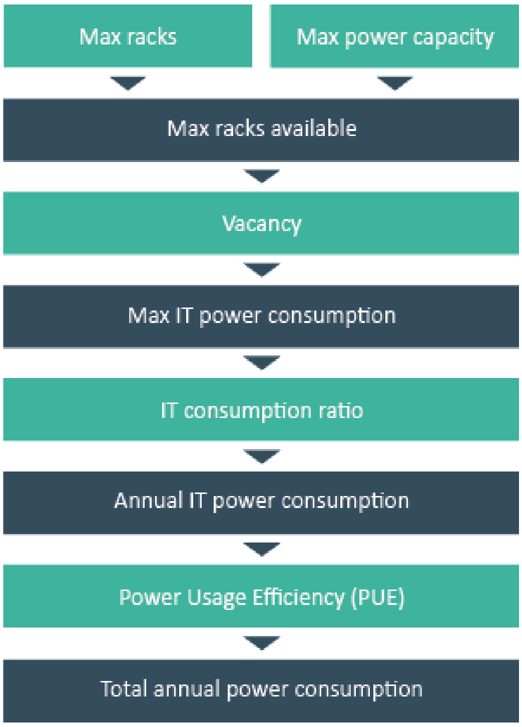

Figure 25: Data centre usage (own illustration)

Capital expenditure

The capital expenditure is calculated through the set building costs in the input section. The capital expenditure is calculated for all four building components for later use in depreciation calculation.

Operational expenditure

The operational expenditure consists of maintenance, energy costs and overhead. The maintenance costs are calculated by multiplying the total initial capital investment by the maintenance percentage set in the input section. The energy costs are calculated by multiplying the total annual energy consumption by the price of 1 kWh.

The overhead costs are calculated by determining how many data hall managers and security officers are needed. Consequently, their annual salary multiplies the number of employees needed.

Revenues

Rental fees are calculated by multiplying the number of racks by the rent for all four power densities. The energy costs are calculated by multiplying the total annual energy consumption by the price of 1 kWh multiplied by the energy premium.

Depreciation & amortization

The depreciation of the shell building is calculated individually from the depreciation of the installations, as the installations depreciate more rapidly than the shell building. Furthermore, the amortization of the loan is calculated per year.

4.4.4 Model output

This dynamic section of the model executes all financial calculations based on the input and calculations sections. The components of this section are described in detail.

Profit & loss statement

This financial statement summarizes the revenues, costs and expenses during a specific period of time. This statement calculates the net result for every year included in the model and is explained in Figure 26.

Cash flow statement

The cash flow statement shows how the changes in the balance sheet account and how the income affects cash. It does so by breaking down the analysis in operating, investing and financing activities. The statement is explained in Figure 27.

Balance sheet

This financial statement summarizes the assets and liabilities at a specific point in time. This statement is explained in Figure 28.

Revenues
- OpEx
= EBITDA
- Depreciation
- Amortization
= EBIT
- Interest
= EBT
- Tax
= Net result

Figure 26: Profit & loss statement

EBITDA
- Tax
= Net cash operating activities

CapEx addition
- CapEx deduction
= Net cash investing activities

Changes in equity
- Equity dividends
Changes in debt
- Debt interest
- Debt repayments
= Net cash financing activities

Figure 27: Cash flow statement

ASSETS
CapEx
- Depreciation
= Total assets

LIABILITIES
Debt additions
- Debt repayments
= Total debt
Share capital
- Equity dividends
- Cumulative result
= Total equity
Total debt
+ Total equity
= Total liabilities

Figure 28: Balance sheet

Net Present Value

The Net Present Value of the project is calculated through the sum of all present values of the project cash flows reduced by the initial investment, as is shown in the following equation. The calculation of the NPV is graphically shown in Figure 29.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where: C_t = Cash flow at time t
r = Internal rate of return
C_0 = Initial investment

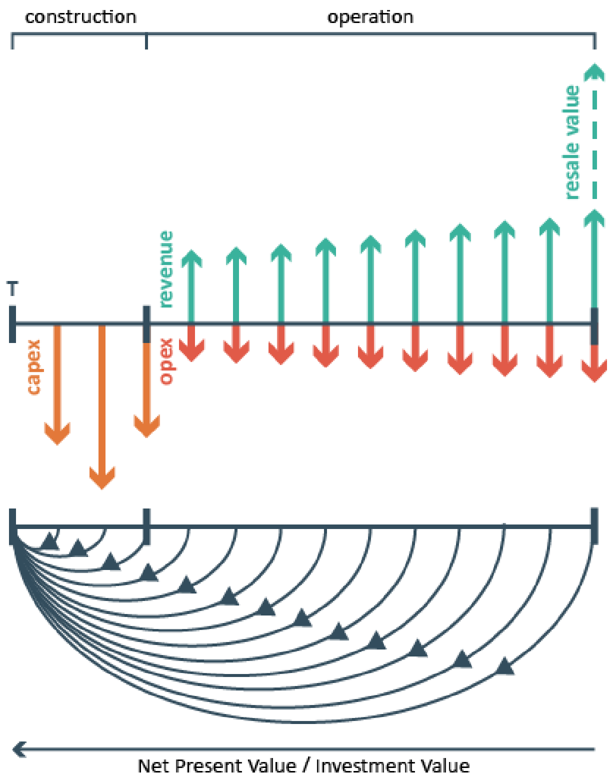

Figure 29: Calculation of the NPV

Return on Property

For the data centre investment modelled the Property-level Before Tax Cash Flow (PBTCF) is used as project cash flow. The calculation of the PBTCF is explained in Figure 30 and Figure 31.

Figure 31: PBTCF

Figure 30: PBTCF

The internal rate of return is set to the Weighted Average Cost of Capital (WACC) of the modelled investment. The WACC is the cost of capital in which each category of capital is proportionally weighted. The WACC is calculated through the following equation:

$$\boldsymbol{WACC = \frac{E}{V} * Re + \frac{D}{V} * Rd * (1 - Tc)}$$

Where:	E	=	Market value of equity
	Re	=	Cost of equity
	D	=	Market value of debt
	Rd	=	Cost of debt
	V	=	E + D
	Tc	=	Tax rate

The return on property is the annualized effective compounded return rate that makes the net present value of all PBTCF's zero. It can also be defined as the rate at which an investment breaks even.

Levered return on equity

The Equity After Tax Cash Flow (EATCF) best describes the return on investment. The calculation of the EATCF is described in Figure 32 and Figure 33.

PBTCF
- Debt principal
- Debt interest
- Tax
= EATCF

Figure 32: EATCF

The levered return on equity is the annualized effective compounded return rate that makes the net present value of all EATCF's zero.

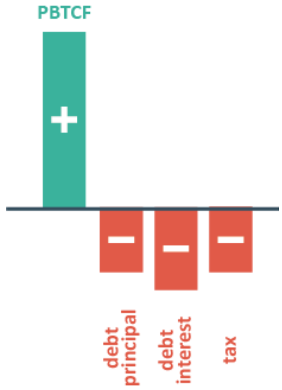

Figure 33: EATCF

4.5 Model validation

4.5.1 Introduction

To validate the model its workings are checked for errors using multiple single-variable sensitivity analyses on the model input variables. These analyses also indicate which parameters have the largest effect on the outcome when the values are changed proportionally.

For every analysed variable the values of the NPV resulting from a 40% increase and decrease of the variable are recorded. Throughout the analysis the data centre is assumed to house 1.500 server racks. The construction is presumed to start in 2014 and the model length is set at 15 years after construction is completed. The results are briefly discussed. The detailed results are found in 9.3.

After the sensitivity analysis experts have verified the model outcomes.

4.5.2 Validation NPV

Based on the sensitivity analysis of the NPV a tornado chart is created (Chart 16). The tornado chart implies a correct model, as all variables seem to influence the NPV to the same degree positively as negatively. The only exception is power density as this parameter shows a greater negative effect as a result of the static number of racks. The power density determines the number of racks used in the data centre when decreasing this parameter. However, when increasing the power density the number of racks housed in the data centre is limited to static maximum number of racks, which is set at 1.500. This maximum limits the positive effect of the sensitivity analysis for the power density.

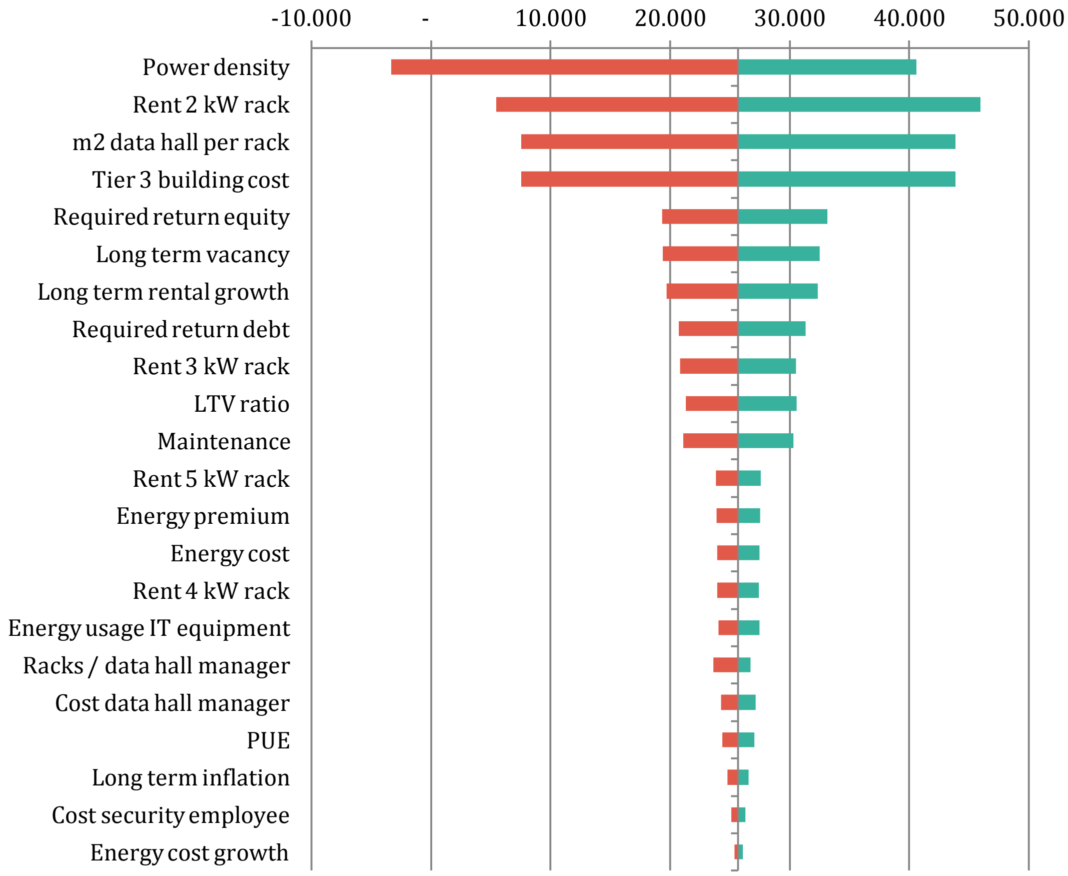

Chart 16: Tornado chart of the Net Present Value

The greatest differences in NPV are found in the variables power density, rent per rack, m^2 data hall per rack and building cost. These are expected as these variables directly and substantially influence the capital expenditure, operational expenditure or revenues.

4.5.3 Validation Return on Property

Based on the sensitivity analysis of the Return on Property (RoP) a tornado chart is created (Chart 17). At first glance this chart implies an erroneous model as several input variables result in uneven bars on the tornado chart. The parameters m^2 data hall per rack and building costs result in a relatively high positive effect on the RoP compared to its negative effect on this parameter. Power density on the other hand results in a relatively high negative effect on the RoP compared to its positive effect. However, this effect is inherent to the calculation of RoP.

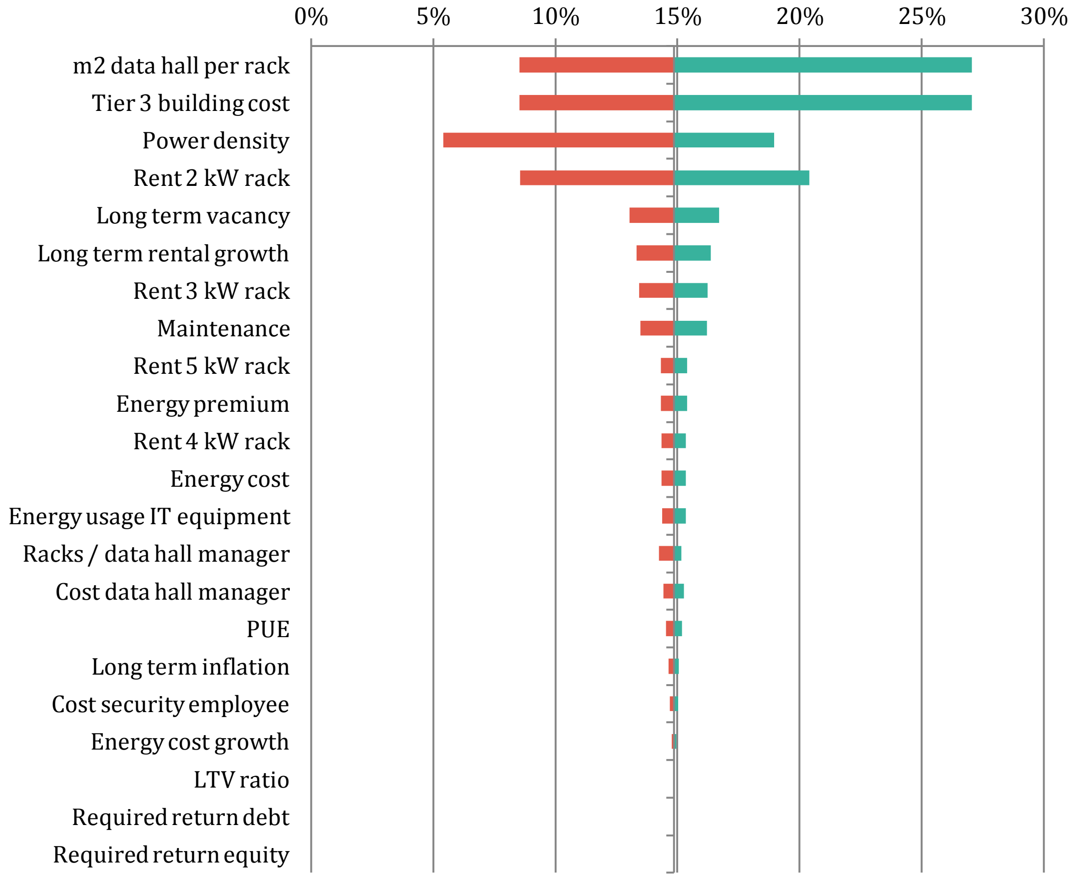

Chart 17: Tornado chart of Return on Property

Both variables building cost and m2 data hall per rack influence the capital expense in year 0 being the construction of the data centre. Increasing this capital expenditure in year 0 results in a relatively lower decrease of the RoP compared to the increase of the RoP resulting from an increase of the capital expenditure in year 0. This effect is illustrated by the following example.

Example

Investment 1
Capital expenditure year 0 = 100
Result year 1 = 110
RoP = 10%

Investment 2
Capital expenditure year 0 = 60
Result year 1 = 110
IRR = 83%
δ RoP = 73%

Investment 3
Capital expenditure year 0 = 140
Result year 1 = 110
IRR = -21%
δ RoP = 31%

In accordance with the sensitivity analysis of the NPV the parameters m2 data hall per rack, building cost, power density and rent per rack result in the largest differences in Return on Property.

4.5.4 Validation Levered Return on Equity

Based on the sensitivity analysis of the Levered Return on Equity (LROE) a tornado chart is created (Chart 18). As expected the chart of the LROE is similar to the chart of the RoP. Because of the leverage the effects of the sensitivity analysis on the LROE are greater than those on the RoP.

Finally, the discrepancy between the lower and upper bound of the parameters m^2 data hall per rack, building cost and power density is also present.

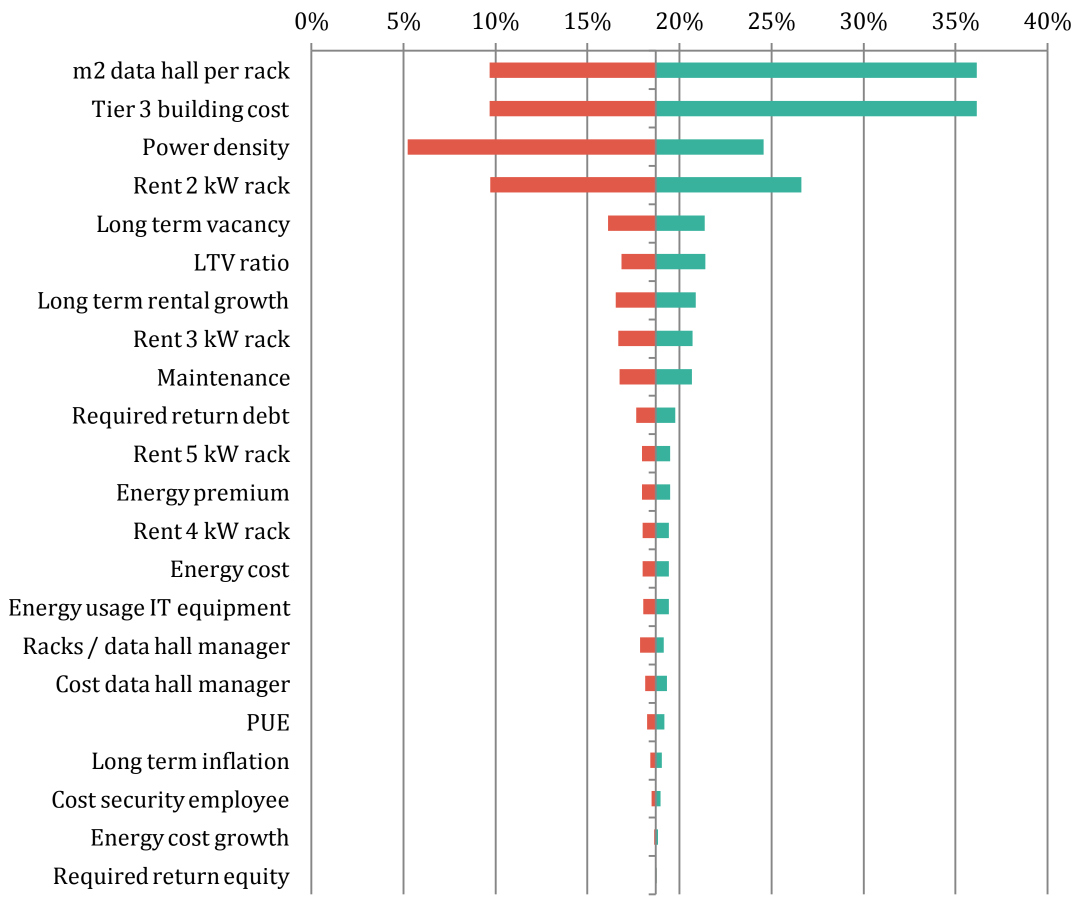

Chart 18: Tornado chart of the Levered Return on Equity

4.6 Impact analysis

To assess the impact of the data centre building features on the NPV, Return on Property and Levered Return on Equity Monte Carlo simulation were performed on most of the model input parameters. The input values and detailed results are summarized in 9.4.

4.6.1 Analysis input

Normal distribution of all parameters is assumed. For every parameter the mean and standard deviation are defined based on the literature study and expert interviews. The values described in 4.4.2 are used as the mean of all parameters. Uncertainty and spread define the standard deviation. For instance, the energy cost growth standard deviation is driven by uncertainty, while the long-term vacancy is driven by the spread of vacancy rates in the Amsterdam market.

The means and standard deviations are summarized in Table 9.

Variable	Mean	SD	Source
PUE	1,3	0,1	Expert interviews; CBRE (2013a), Municipiality of Amsterdam (2013)
Power density	2	0,4	Expert interviews; Cushman & Wakefield (2013)
m2 data hall per rack	3	0,25	Expert interviews
Building cost / m2	8000	750	Expert interviews; Dines et al. (2011)
Energy cost	0,075	0,05	Expert interviews; Eurostat (2013)
Energy growth	2,5	0,25	Expert interviews; Eurostat (2013)
Energy usage IT equipment	70	10	Expert interviews; E.U.C. (2012)
Maintenance	3	0,25	Expert interviews; McAllister & Loizou (2009)
Rent tier 3 2kW	500	25	Expert interviews; CBRE (2013a)
Rent tier 3 3kW	600	25	Expert interviews; CBRE (2013a)
Rent tier 3 4kW	650	25	Expert interviews; CBRE (2013a)
Rent tier 3 5kW	700	25	Expert interviews; CBRE (2013a)
Rental growth	3	0,25	Expert interviews
Long term vacancy	19	8	Expert interviews; CBRE (2013a)
Energy premium	30	10	Expert interviews

Table 9: Impact analysis input values

4.6.2 Analysis results

The results of the parameter impact analysis are summarized both numerically and graphically in 9.4. The results show similar impact on NPV, PoR and LRoE. Once again leverage causes the difference between the impact on PoR and LRoE. From Chart 19 the parameters with the greatest impact are derived:

- Power density;
- Building cost per m^2;
- Long term vacancy;
- m^2 data hall per rack;
- Rent of a 2 kW rack.

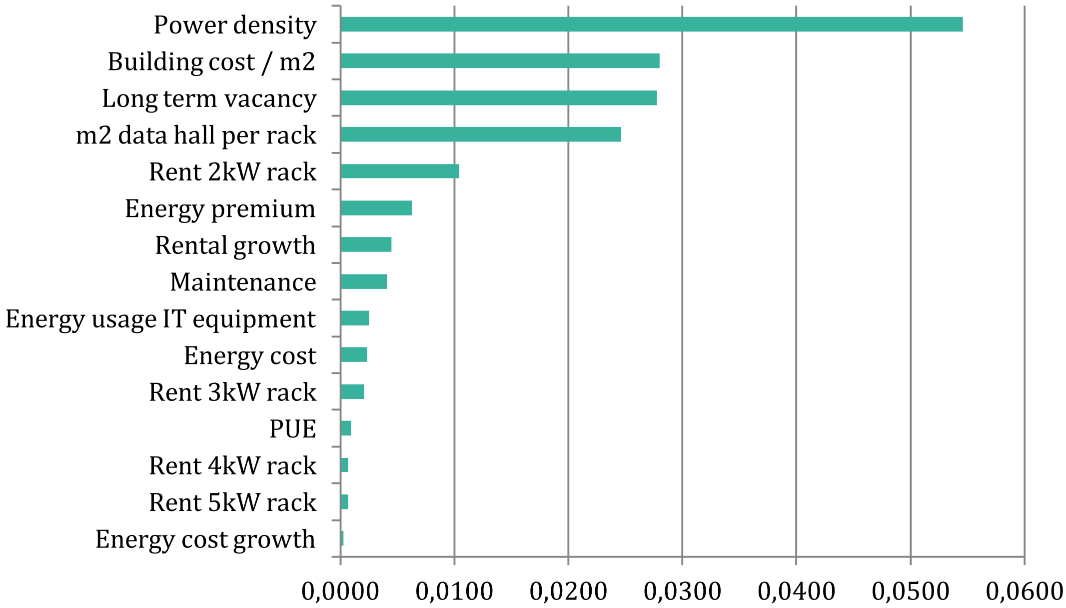

Chart 19: Analysis results Levered Return on Equity

Most parameters show normal distributed results. The histograms of the parameters power density, m^2 data hall per rack and building cost deviate from the normal distribution.

The results on the parameter power density show a heavily positively skewed distribution as shown in Chart 20. This skewness is caused by the static limitation on the number of racks described in 4.5.2.

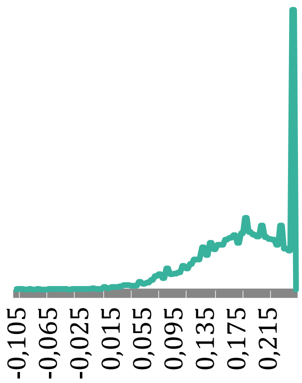

Chart 20: Histogram of LRoE power density

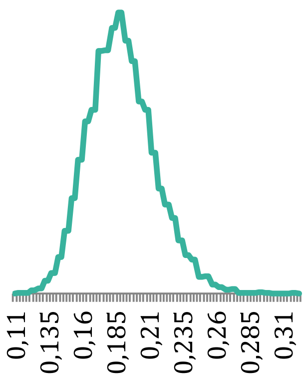

Chart 21: Histogram of LRoE m^2 per rack

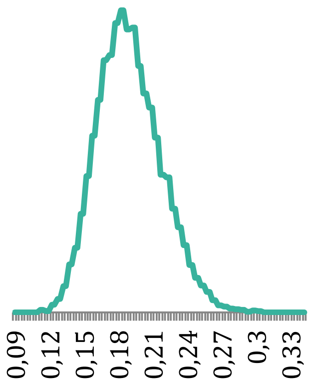

Chart 22: Histogram of LRoE building cost

The results on the parameters m^2 data hall per rack and building cost per m2 data hall are slightly negatively skewed as shown in Chart 21 and Chart 22. This skewness is only very slightly present for the NPV but increases for the RoP and the LRoE, which is clearly visible in Chart 23, Chart 24 and Chart 25.

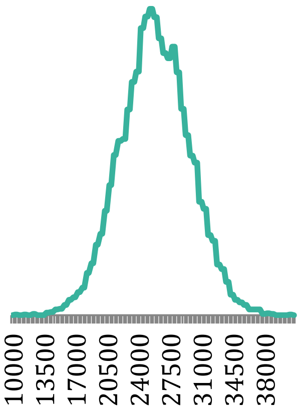

Chart 23: Histogram of NPV building cost

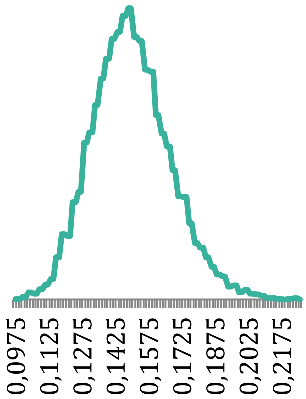

Chart 24: Histogram of RoP building cost

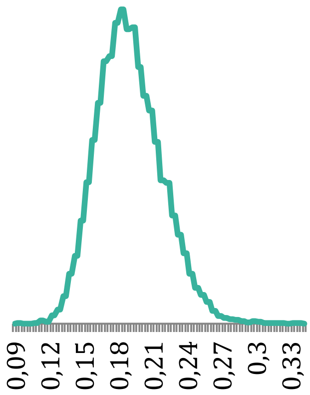

Chart 25: Histogram of LRoE building cost

5 Discussion

5.1 Introduction

The data centre industry is relatively immature since it has only come into existence over the last decades. Data centres are generally considered to be risky investments due to the high risk of obsolescence caused by rapid technological advancements of the IT industry in combination with the high initial investment needed. This research set out to analyse how data centre investments compare to other real estate investments.

Over the recent years many researchers found that additional building and locational features of commercial and retail real estate influence its return. Based on these findings the hypothesis that higher returns could be achieved by optimizing the data centre real estate decision-making criteria was born.

In the following paragraphs the results are discussed and answers to the research questions are provided. Consequently, the restrictions and limitation are acknowledged and recommendations to the real estate industry in general, the data centre industry in particular and further research are provided.

5.2 Discussion of the results

5.2.1 Risk and return profile of data centre investments

The real estate comparison methods are analysed to answer the question how data centres compare to other real estate investments in terms of risk and return. The most commonly used method of comparison is through the INREV investment strategies. This association distinguishes three types of investments with increasing risk and return profiles, namely core, value added and opportunistic investments. Among a number of characteristics the INREV measures the risk-return ratio through the IRR and the degree of leverage using the LTV ratio. Even though these strategies form a simple categorisation based on risk and return, they naturally do not include all risk and return aspects an investor should assess. Therefore, other more specific risks and securities not taken into account by the INREV strategies are described for data centre investments and compared to other real estate investments.

To place data centre investments in the framework of the INREV strategies a REIT analysis was used. This analysis yielded some remarkable results. First of all, the data centre REITs were found to have relatively low average returns on equity and mediocre standard deviation in the returns on equity compared to the other REITs. This suggests that investors in data centre REITs associate this type of investment with other lower risk REIT investments, like residential REITs. Besides low returns relatively low debt levels characterize data centre REITs. Their debt to capital, EBITDA and value ratios are the lowest of all REITs analysed. These low levels of debt suggest lower risk associated with the data centre REIT investment. However, these lower levels might also be attributed to the relative immature nature of data centre real estate making financiers hesitant to finance this type of REIT.

Important securities of data centre investments are high occupancy levels, stable and predictable incomes, no to limited dependency on resale value speculation, long multi-tenant leases, increasing demand and a high threshold for new industry entrants. High switching costs ensure long leases with stable and predictable incomes. For these reasons clients often tend to renew leases when lease periods end. The risks and return of a data centre investment can be more accurately determined compared to other real estate classes, as data centre investments rely solely on this stable and predictable income and are not dependent on speculative resale values. The risk of data centre investments is even further minimized due to the expected increase of demand for data centres for the European market, which cannot necessarily be expected of other real estate asset classes like offices and dwellings. Finally, the barriers for new market entrants decrease risk for currently operational data centre operators.

However, there are several important risks to consider. For one specialized and active management of the asset is needed. Due to the highly technical nature of data centre operation qualified personnel is needed to ensure uninterrupted operation. The risk for data centre investments is further increased by the large initial capital investments needed to construct state-of-the-art data centres. However, modular building progressively mitigates this risk. The stable and predictable income described is only applicable to data centres with a substantial occupancy. High vacancies still remain a great risk for newly constructed data centres. Signing lease agreements substantially filling the data centre before construction commences and making use of modular building methods mitigates this risk throughout the industry. Finally, the risk of obsolescence requires data centre investments to break even in a very short time span, as it is uncertain when the installations are rendered obsolete due to technological innovation.

The comparison of data centre demand with office or industrial real estate demand seems to suggest that the data centre industry moves rather anti-cyclical from other sectors. This effect has been most clearly visible since the economic turndown. Where other real estate asset classes struggled with decreasing demands and resulting vacancy, the demand for data centres only marginally decreased resulting yearly growth since 2008. If this effect would prove to be consistent data centres would make for a great diversification potential in real estate portfolios.

Based on the risks and securities described existing data centres with substantial occupancy levels are to be classified as core investments. These data centres yield a reliable and predictable income due to high switching costs of clients and no to limited capital growth is needed to render a winsome return over a relatively short investment horizon.

New data centre projects on the other hand are to be classified as value-added or even opportunistic investments depending on the level of occupancy signed before construction commences. For these data centres the reliable and predictable income is not ensured. The substantial initial capital investment and risk of obsolescence make for a challenging investment that needs to yield a considerable return in a short time span.

Experts interviewed confirm the mentioned positioning of the data centre investment in the INREV strategies. They name this difference in associated risk is the main driver for current industry players to only commence construction of new data centres with sufficient committed clients.

Risks	Securities
Specialized management needed	Stable and predictable income
Large initial capital investment needed	No or limited dependent on speculation
High vacancy risk	Long lease periods
Risk of obsolescence	Increasing demand
	High threshold for new entrants
	High switching cost clients

5.2.2 Decision-making criteria

Current situation

The current decision-making process and criteria are analysed to answer the question how higher returns can be achieved through optimization of the decision-making criteria. Based on expert interviews and literature study the data centre investment decision is found to be made up of three levels, being the political, locational and building decision process, which can be evaluated rather independently.

On a global level the data centre industry and thus data centre real estate is influenced by changes in the global economy or geopolitics. As data centres have become an elementary part of our society with many business and social processes relying on their continuous operation, they have become subject to greater vulnerability. The recent public disclosure of public surveying by government agencies have caused drastic reactions by both governments and companies worldwide resulting in IT processes and data storage being moved to other locations to safeguard privacy. These unforeseen global changes in the political landscape therefore largely affect the data centre industry, which increases the risk of data centre investments. Data centre investors and operators should therefore be well aware of these trends to be able to steer their strategy accordingly.

On the locational level two main aspects are distinguished, being power and connectivity availability and security. The uninterrupted supply of power and connectivity is vital to data centre operation. In addition, the choice of supplier greatly influences the operating expense. The security aspects such as flooding risk, airfield approach routes and car collisions greatly influence the risk associated with the investment and possible vacancy levels.

On the building level four metrics are crucial to the data centre investment decision, namely Tier level (or level of redundancy), PUE, data centre size and overall power capacity.

The Tier level or the level of redundancy is considered to influence capital expenditure, operational expense and revenues. Obviously, a higher redundancy requires additional or more complex installations to guarantee the needed uninterrupted availability of IT services operated in the data centre. Additionally, increasingly redundant installations operate at higher energy levels resulting in higher operational expense. To compensate for the additional capital and operating expense born by data centre operators clients are willing to pay higher rents for higher redundancy levels. However, the constructed model shows that a Tier 3 data centre yields the greatest Return On Property even if the lifetime is extended to 20 or 25 years. The reason for building Tier 4 data centre lies solely in the ability to attract other clients since some clients like financial institutions are obliged to house their IT operations in data centres with the highest redundancy levels.

The model shows that the PUE mainly influences the operating expense as it is a measure of a data centre's energy efficiency. Lower PUE levels indicate lower energy consumption of data centre installations in relation to the energy used by IT equipment. However, interviewed experts consider the additional cost of minimizing a facility's PUE to be marginal. Lower PUEs improve the data centre's attractiveness from a client's point of view as it eventually leads to less operating costs for the client. However, the PUE is currently considered of less importance for the Amsterdam market, as all newly constructed data centres are obliged to have a maximum PUE of 1,3. This narrows the difference between the maximally permitted PUE and the theoretically lowest PUE of 1,0.

The size of the data centre is considered to largely influence the initial capital expenditure due to economies of scale. Larger data centres are able to employ larger more efficient installations than smaller facilities. However, lower building cost per m^2 data hall resulting from building larger facilities is also associated with higher vacancy risks. Modular building of data centres offers a solution by making building in relatively small units affordable.

Over the years the metric for data centre capacity has shifted from data hall space to power capacity. This metric is therefore considered to be an important building aspect and is mainly dependent on the capacity of the auxiliary power supply and UPS.

Locational aspects	**Building aspects**
Power availability	Redundancy (Tier level)
Connectivity	Power Usage Efficiency
Site security	Data centre size
	Overall power capacity

Throughout the real estate industry sustainability and reusability have become of great importance. These aspects are becoming more important in the data centre industry as well, but are still insufficiently highlighted. Sustainability does play a major role in the operation of the data centre. Especially limiting the operational energy usage is highly prioritized from both environmental and financial point of view. However, the reusability of data centre components and buildings as a whole seem to be neglected. Reuse is hardly ever a goal in the data centre design. Currently the reuse possibilities are very limited as data centre buildings are very specific. This could result in data centre buildings that can no longer be used for operation or other purposes leaving no other solution than demolishment. Therefore, reusability should be added to the data centre design agenda.

Impact building features

From the literature study and expert interviews a list of decision-making criteria that are currently employed or could be employed in the decision-making process is derived, but the question is how do these criteria influence the return for investors. The impact of the building features has been analysed through Monte Carlo simulations on the constructed data centre model. The standard deviation of the found returns and NPV gives the size of the impact of that parameter on the return.

The variable power density has the largest effect on both the NPV and the IRR on equity. This effect is inordinately large. One would not expect the power density to have a larger effect on IRR and NPV than the building cost or rent levels. The inordinate effect of this variable is credited to the fact that the model assumes the capital expenditure of electro technical installations to be static and independent of the power density, while in reality this cost is dependent on the power density chosen. Electro technical installations with higher capacities are needed to deliver higher power densities. As the electro technical installations only make up 40% of the building cost, increasing power densities are associated with relatively higher income growth than cost growth. This makes increasing the power density interesting. However, from a certain density onward the number of racks that can physically be placed in the data hall limits the income. This effect was also visible in histograms found for the parameter power density, as they were heavily positively skewed.

The impact of the building cost per m^2 data hall largely depend on the wide spread of building cost that was observed in the market. Differing quality standards and building approaches (modular or conventional building) result in different building cost per m^2. The high impact of the building cost on the NPV supports the idea of modular building. By building modular a large part of the investment needed for the construction of the facility is postponed.

Vacancy rates used in the model were based on data centre vacancy rates in the wider Amsterdam region. The spread of these rates is rather high due to the fact that many recently completed data centres are included. Naturally, these facilities have larger vacancy rates (even up to over 50%). Elder data centres generally have much lower vacancy rates (often less than 10%). Signing lease agreements that cover a substantial part of the occupancy before construction commences minimizes the risk of vacancy.

The variable m^2 data hall per rack is of substantial impact on the NPV as it influences the building cost per m^2 data hall. Therefore, this variable has the same effect on the NPV in the sensitivity analysis. This makes focusing on building in higher densities within the data hall very lucrative.

The input data for the variable rent per rack is based on rent levels in the Amsterdam market. However, these rents are not uniform as operators include different levels of service in the rental fees. Some operators even include part of the energy costs in the rental fees. This wider spread results in a higher impact on the NPV.

The results suggest that data centre investors should focus on increasing the power density. However, from expert interviews is derived that experts do not expect power density levels to exceed an average of little over 2 kW at rack level. Based on the distribution of power densities derived from the interviews (75% 2kW racks, 15% 3kW racks, 5% 4kW racks and 5% 5kW racks) the ideal power density per rack is 2,4 kW. The main focus when optimizing the data centre power capacity should be on finding the ideal power density to be able to fill the data centre completely at the lowest cost.

The other results suggest that higher returns can be achieved when focusing on minimizing the initial capital expenditure rather than minimizing operational expense, as the impact of capital expenditure parameters such as building cost is much greater than those of operational expenditure such as energy cost or maintenance. The impact of the energy cost is relatively small due to the fact that energy costs are directly billed to the client after multiplication by the power premium. As decreasing the capex results in better returns than decreasing the opex, data centre investors and operators are discouraged to further improve a data centre's sustainability as this often drives the capex up while driving opex down. However, experts pointed out that clients increasingly demand operators to offer sustainable data centre services and are willing to pay a premium for these services.

Vacancy is naturally a parameter that largely influences the returns. Although its absolute effect analysed through the sensitivity analysis is moderate, the impact found in the impact analysis is relatively great as a result of the input data used for this analysis. A high standard deviation is used as input, as the relatively wide spread of vacancy rates in the Amsterdam market. This wide spread and the following impact of this parameter confirms the risk of vacancy and the need for signed lease agreements before construction.

5.2.3 Implications

Finally, what do these results mean for the real estate investors in general and for data centre operators and investors in particular? In other words how can the results be implemented into a practical advice regarding the investment strategy for real estate investors in general and for data centre operators and investors in particular?

Data centre investments

From the findings can be concluded that data centre investments cannot be classified by any general risk-return profile such as the INREV strategies. As with any real estate property the key success factor is tenant occupancy. Data centres with high occupancy levels are investment associated with low risk levels due to predictable and stable income, long lease agreements and low threats of new competitors. Data centres with low occupancy levels on the other hand are investments associated with higher levels of risk, as high capital investments and high operating cost are required. The risk of obsolescence increases this risk since it shortens the investment horizon. Another important risk is the uncertainty of future energy costs. However, this risk is well mitigated by the correct use of the PUE in the calculation of the energy premium billed to clients or through directly billing the total energy cost to the clients when leasing an entire data hall.

Data centre investments seem to offer unique diversification potential for investors besides predictable income and long lease agreements. The results seem to confirm that data centre take-up and thus demand move independently of the general economic cycle in contrast with other real estate types like offices that move more dependently. However, this trend needs confirmation.

Decision-making criteria

The current decision-making criteria used by data centre operators and investors seem to suffice based on the expert interviews, literature study and impact analysis. However, some focus areas are indicated based on the results.

The first focus should be on getting the power capacity just right in terms of capital and operational cost on the one hand and maximum power capacity on the other hand. Data centres equipped with just enough electro technical installations to support the maximum number of racks to be housed in the facility are most cost effective. From the results an ideal power capacity of about 2,4 kW per rack is found. However, from interviews was derived that building a small power capacity surplus does not require additional substantial investments or capital expense. Therefore, small overcapacity is recommended.

Secondly, data centre investors and operators should focus on lowering capital expenditure rather than operational expenditure. The effects of lower initial investments are larger than those of operational cost. The cost reduction should focus on building cost being the main driver of the capital expenditure. Modular building is a great method of lowering the initial investment and spreading the investment over a longer period. Through the use of modules the data centre can grow with the number of clients housed in the facility. However, the degree of modular building depends on the type of investor and client. Cash rich investors or operators should choose for a lower degree of modularity to lower capital expenditure and therefore make greater returns, while cash poor investors or operators should spread their capital expenditure and build with a high level of modularity.

As vacancy is one of the largest liabilities in the data centre business case vacancy prevention should have top priority. Throughout the industry this notion is taken into account. Prudent data centre investors and operators do not start construction of a new data centre or additional data halls in an existing data centre without signed lease agreements for (parts of) that data hall space. Once again modular building further limits this risk, since the number and size of the needed clients to fill the data hall is smaller.

Operators should optimize their facilities for 2 kW racks. From interviews is derived that this type of rack is most commonly used and is expected to remain so for the near future. There are some specific types of clients that require greater power densities like virtual currency miners, but these clients are limited.

Finally, sustainability should have a greater role in the data centre investment process, as data centres are major energy consumers. Fortunately data centre clients are increasingly interested in sustainable data centres. Some are even willing to pay a premium for these sustainable services. However, the reusability of the data centre building is currently hardly ever incorporated in the investment or design process. This results in very specific buildings that are of no use to any other function after their operation, ultimately leaving no other option than demolishment. The data centre industry should focus on creating reusable facilities as this both increasing sustainable nature of the data centre and even provide a financial benefit.

5.3 Restrictions & limitations

This section discusses the restrictions and limitations regarding the findings of this study.

The study conducted is limited by the opaqueness, immaturity and small size of the data centre industry. Because of this opaqueness and immaturity industry information is limited and valuable to industry players. Therefore, it has been difficult to retrieve industry information. Only through confidential interviews were experts willing to talk about the industry and its stakeholders. More confidential information like financial statements, facility layouts and occupancy levels were not available.

Because of the lack of financial statements the model and the input values are based on expert interviews and the literature study. As no real case information was available the model has not been validated to real life circumstances. However, experts have confirmed the model results. Finally, the risk-return profile of data centre investments could not be classified based on financial information such as LTV-ratios and IRRs of data centre operators. Instead data centre REITs were compared to other types of REITs.

The impact of some variables such as the power density might not reflect their real impact in practice due to the fact that some correlated variables could not be modelled in the model used. The Monte Carlo software used didn’t offer a way to adjust the model for these effects. Using other Monte Carlo software might yield other impact results if these variables and effects were taken into account.

Finally, opaqueness in the data centre rent levels made determination of the input rent levels challenging, as the differing rent levels cover varying services.

5.4 Recommendations

5.4.1 Recommendations for real estate industry

Data centres are interesting investments due to their relative low risk (when high occupancy levels are ensured by signed lease agreements) and diversification potential. However, data centre investments are strongly discouraged for facilities with high occupancy levels.

Direct investment in data centres is only recommended when specialized active technical management is available. If this type of management is not available investors are recommended to invest in data centre operators or REITs.

The modularity of the data centre industry is an example to the real estate industry in general. Modular data centres are actively used throughout the industry. The advanced modules are technically optimized to deliver better quality at lower costs and shorter construction periods. Many aspects of these modules can be implemented in other real estate types, such as commercial and industrial real estate.

5.4.2 Recommendations for the data centre industry

Apart from the described focus in decision-making criteria the data centre industry should focus on true modular building. The financial and societal advantages of this type of building greatly outweigh the disadvantages. It mitigates risks such as vacancy and high initial capital investments and it produces more efficient data centres, while it only slightly increases the overall capital expenditure per m^2 data hall depending on the modular system chosen. Furthermore, some modular systems provide the unique opportunity to reassemble the module at another location.

The described modularity could be of even greater advantage when the industry is further standardized. Further standardization could make modules easily transferable to another facility. It will also make the industry more transparent, which will result in better results for the industry as a whole.

The opaqueness of the data centre industry could further be decreased by benchmarking data centre construction and operation. By sharing this information the industry as a whole can be improved.

5.4.3 Recommendations for further research

The diversification potential of data centres looks promising. However, the research conducted is based on limited information. Further research should be conducted to confirm the diversification potential and to describe this potential to real estate investors.

Currently most investment decisions are based on the opinion and experience of expert personnel. Many of these decisions are not supported by research. Therefore, a price hedonic study could confirm the effect of the building and location features of data centres on the return of this type of facilities.

Finally, further research into the financial and societal advantages of modular data centre building is needed to make this type of building more accessible.

6 Conclusion

6.1 General conclusion

It was the objective of this study to compare data centre investments with other types of real estate investment and to examine whether the data centre investment decision-making criteria could be optimized to generate higher returns.

From the REIT analysis and expert interviews is concluded that data centres are in many ways comparable to other real estate types in terms of risk and return. As with other real estate types the key success factor of data centre operation is occupancy levels. However, the risk of occupancy is different in data centres compared to other real estate classes due to the fact that clients are locked in as a result of high switching costs. The relatively short investment horizon of data centre investments, being 15 years, further reduces this risk.

However, data centres differ from other real estate classes in terms of income and lifetime. Most real estate relies on direct (operational) and indirect (resale value) income with an emphasis on the latter. This makes the eventual result greatly depend on future market tendency since a large part of the result comes from the future resale value. Since the resale value of data centres is very difficult to predict due to technological developments data centre investors rely solely on direct income yielded during the period of operation. All data centre investors and operators interviewed take no or very limited (amounting to the land value) resale value in account when calculating the data centre investment value. This practice reduces the data centre risk since the income is made solely during operation and is not dependent on future market tendency. The aforementioned rapid technological developments cause the relatively short lifespan of data centres. Yielding the data centre return in a short period further decreases the risk.

Another interesting feature of data centre investments is that they seem to move independently of the general economic cycle than office and industrial space. This makes the investment attractive due to diversification potential.

From the constructed model can be concluded that the current decision-making criteria seem to suffice. However, some focus areas are indicated. Firstly, finding the right power capacity with only a limited overcapacity is recommended. Second, data centre investment should be focused on lowering capital expenditure rather than operational expenditure. Third, since vacancy prevention is crucial no data centres should be constructed without signed lease agreements. Furthermore, some form of modular building should be used to further mitigate the risk of vacancy. Data centres should be optimized for 2 kW racks. Finally, the data centre industry should focus on improving the reusability of data centre real estate. This could yield both sustainable and financial advantages.

Further research into the diversification potential of data centre investments is required for confirmation. A price hedonic study is needed to measure the effect of building and location features of data centres on their return.

6.2 Reflection

The reason for choosing my research subject stemmed from my passion for IT and real estate. I wanted to combine my two passions with my interest in (real estate) finance. I was also interested in conducting a statistical or price hedonic study.

After reading in on price hedonic studies conducted on other real estate assets I set out to conduct a price hedonic study on data centre decision-making criteria. During my pre-study I found that the data centre industry is very closed world. I contacted multiple industry players only to find that none of them would or could provide me with the data needed for my research. Eventually I found the Communication Infrastructure Fund willing to offer me a graduation internship. They were willing to offer me a great place to work and help me with my questions and data as far as they could for which I am grateful. They helped me finding my way around this unknown industry. However, they couldn’t provide me with the data since they only shortly acquired data centres to add to their portfolio of glass fibre and mobile networks. Even though the gathering of information and data has been a challenge throughout the research process, I was able to gather all information and data needed to construct the model through help of CIF and the conducted expert interviews.

Due to this graduation thesis I have been able to learn many things in different domains. I have amassed knowledge of the data centre industry, (real estate) finance and financial modelling through my literature research and many conversations with Alex Bakker and Ivan Kooiman at CIF. I have learned how to structure an academic thesis and explain difficult concepts through graphical representation with the help of Philip Koppels. Hans de Jonge let me experience how graduating and researching in general is very similar to uncover an unknown city by visiting its pubs one by one. The many conversations and interviews with experts enabled me to look behind the scenes of a very young and rapidly developing real estate class that is both building and machine.

My personal conclusion is that I am satisfied with the results and the model I created. Despite the occasional setbacks and difficulties I encountered along the way, I’m happy I kept positive. I believe my graduation genuinely made me ready to fully pursue my professional career.

7 List of figures

8 Literature

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9 Appendices

9.1 Data REIT analysis

The financial data used as input for the REIT analysis was obtained from S&P Capital IQ. Capital IQ offers financial information on publicly listed companies.

Results REIT analysis

		Data centres	Offices	Residential	Industrial	Retail
Debt / capital	Average	36,15%	46,08%	64,65%	58,16%	57,23%
	SD	15,58%	21,23%	8,89%	7,10%	12,38%
Return on equity	Average	3,98%	6,07%	0,63%	5,44%	6,01%
	SD	2,93%	6,49%	5,05%	1,69%	3,60%
Debt / EBITDA	Average	4,69	8,14	9,10	8,15	7,77
	SD	2,15	8,22	1,91	1,84	1,70
LTV	Average	28,26%	42,98%	39,14%	35,49%	38,70%
	SD	8,73%	7,04%	15,03%	3,44%	11,72%

Input data centre REITs

	Debt / capital	Return on equity	Debt / EBITDA	LTV
Digital realty	54%	5,8%	5,77	36%
Coresite	19%	1,2%	2,64	19%
Dupont Fabros technology	35%	3,3%	5,66	29%
Average	**36%**	**3,5%**	**4,69**	**28%**

Source: (S&P Capital IQ, 2014)

Input office REITs

	Debt / capital	Return on equity	Debt / EBITDA	LTV
Boston Properties Inc.	59%	11,3%	7,30	36%
Brookfield Properties	58%	8,3%	14,30	55%
Franklin Street Properties	29%	2,6%	4,79	44%
Piedmont Office Realty Trust	35%	3,3%	5,49	41%
SL Green Realty	49%	4,3%	8,80	39%
Average	**46%**	**5,9%**	**8,14**	**43%**

Source: (S&P Capital IQ, 2014)

Input residential REITs

	Debt / capital	Return on equity	Debt / EBITDA	LTV
Apartment Investment & Management	76%	-3,1%	10,07	48%
Equity Residential	58%	-0,1%	9,03	32%
Essex Property Trust	59%	5,6%	7,30	19%
Home Properties	66%	4,0%	8,25	38%
UDR	65%	-3,3%	10,83	59%
Average	**65%**	**0,63%**	**9,10**	**39%**

Source: (S&P Capital IQ, 2014)

Input industrial REITs

	Debt / capital	Return on equity	Debt / EBITDA	LTV
Alexandria Real Estate Equities	53%	5,0%	9,18	36%
EastGroup Properties	61%	6,1%	6,31	32%
Monmouth Real Estate Investment Corp.	60%	5,2%	8,96	39%
Average	**58%**	**5,4%**	**8,15**	**35%**

Source: (S&P Capital IQ, 2014)

9.2 Model input data

Data centre specification

Input variable		Value	
Number of racks		1.500	
Tier level		3	
Power density		2,00	
PUE		1,30	
Data hall per rack		3,00	m^2
LFA to GFA ratio	Tier 2	1,50	m^2
	Tier 3	1,50	m^2
	Tier 4	1,90	m^2

Data centre capital expenditure

Input variable		Value	
0 – 1.000 m^2 data hall	Tier 2	11.250	€ / m^2
	Tier 3	12.500	€ / m^2
	Tier 4	22.500	€ / m^2
1.000 – 2.500 m^2 data hall	Tier 2	9.000	€ / m^2
	Tier 3	10.000	€ / m^2
	Tier 4	18.000	€ / m^2
2.500 – 7.500 m^2 data hall	Tier 2	7.200	€ / m^2
	Tier 3	8.000	€ / m^2
	Tier 4	14.400	€ / m^2
7.500$^+$ m^2 data hall	Tier 2	5.400	€ / m^2
	Tier 3	6.000	€ / m^2
	Tier 4	10.080	€ / m^2
Proportion Capex building components	Building	20	%
	Electro technical	30	%
	Mechanical	40	%
	Other	10	%
End of life refit	End of life	15	Years
	Share capex mechanical installations	60	%
	Share capex electro technical installations	60	%

Data centre operational expenditure

Input variable	Value	
Energy cost	0,075	€ / kWh
Long term energy cost growth	2,50	%
Energy usage IT equipment	70	%
Minimum efficiency facility installations	50	%
Cost security employee	35.000	€
Min racks security	250	
Cost data hall manager	50.000	€
Racks / data hall manager	400	
Maintenance	3,00	%

Data centre revenues

Input variable		Value	
2 kW / rack	Tier 2	350	€ / m^2
	Tier 3	500	€ / m^2
	Tier 4	800	€ / m^2
3 kW / rack	Tier 2	420	€ / m^2
	Tier 3	600	€ / m^2
	Tier 4	960	€ / m^2
4 kW / rack	Tier 2	455	€ / m^2

	Tier 3	650	€ / m^2
	Tier 4	1.040	€ / m^2
5 kW / rack	Tier 2	490	€ / m^2
	Tier 3	700	€ / m^2
	Tier 4	1.120	€ / m^2
Long term rental growth		3,00	%
Long term vacancy		19,0	%
Share 2 kW racks		75,0	%
Share 3 kW racks		15,0	%
Share 4 kW racks		5,0	%
Share 5 kW racks		5,0	%
Energy premium		30,0	%

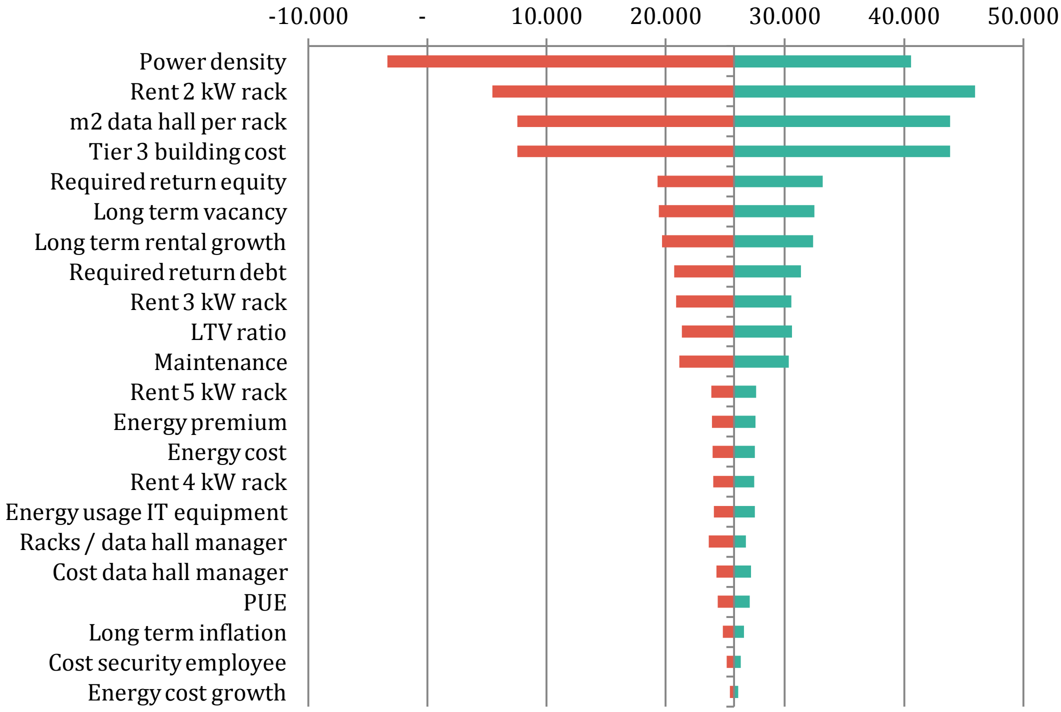
Financial

Input variable	**Value**	
Start year	2014	
Length model	15	years
Tax rate	25	%
Long term inflation	1,90	%
Residual value building	300	€ / m^2 GFA
LTV ratio	0,30	
Required return on equity	12,50	%
Required return on debt	5,50	%
Debt repayment period	15	years
Depreciation shell building	30	years
Depreciation installations	15	years

9.3 Results sensitivity analysis

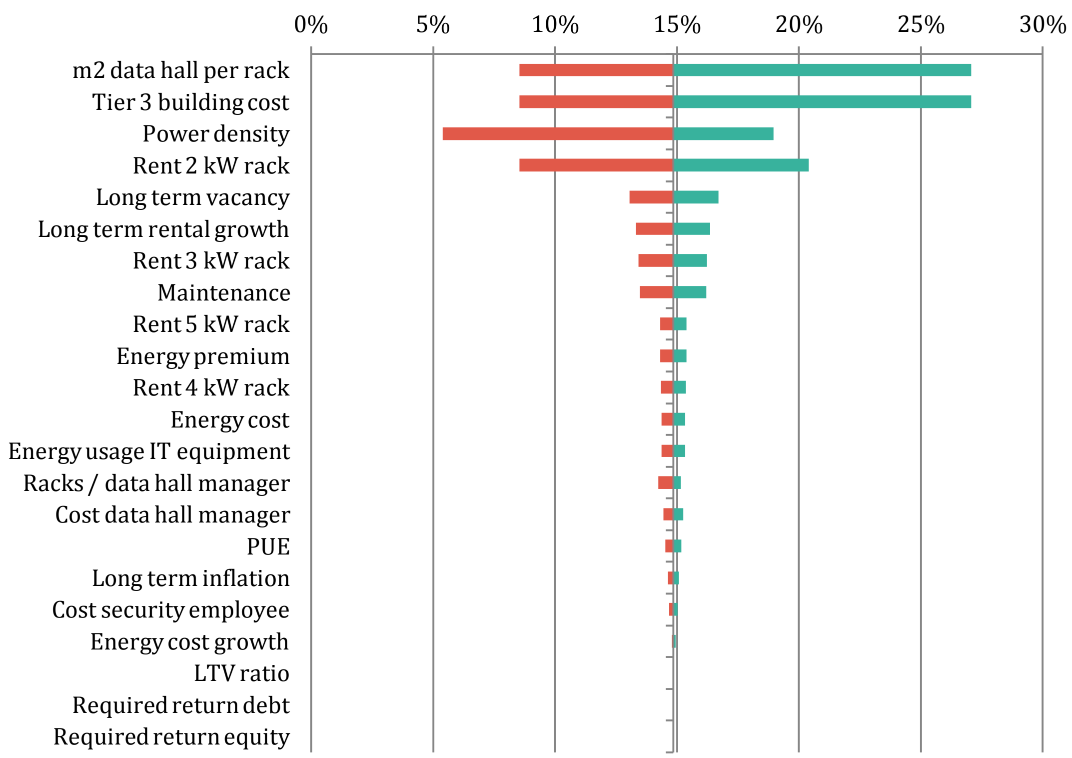
Results sensitivity analysis with dependent variable Net Present Value (NPV)

Variable	NPV min	NPV max	Delta NPV	Sensitivity NPV
Power density	-3.344	40.591	43.935,57	0,00
Rent 2 kW rack	5.447	45.964	40.517,88	0,01
m2 data hall per rack	7.537	43.874	36.337,00	0,00
Tier 3 building cost	7.537	43.874	36.337,00	0,18
Required return equity	19.334	33.171	13.837,03	0,00
Long term vacancy	19.398	32.497	13.098,51	0,00
Long term rental growth	19.690	32.377	12.687,02	0,00
Required return debt	20.713	31.346	10.632,73	0,00
Rent 3 kW rack	20.854	30.557	9.703,53	0,05
LTV ratio	21.328	30.573	9.245,16	0,00
Maintenance	21.113	30.298	9.184,54	0,00
Rent 5 kW rack	23.829	27.582	3.753,42	0,15
Energy premium	23.864	27.547	3.682,22	0,01
Energy cost	23.944	27.467	3.523,45	0,00
Rent 4 kW rack	23.963	27.448	3.485,32	0,15
Energy usage IT equipment	24.037	27.467	3.429,97	0,02
Racks / data hall manager	23.627	26.721	3.093,52	0,10
Cost data hall manager	24.275	27.136	2.861,80	13,98
PUE	24.342	27.069	2.726,39	0,00
Long term inflation	24.786	26.567	1.781,26	0,00
Cost security employee	25.110	26.301	1.190,59	23,52
Energy cost growth	25.382	26.058	676,39	0,00


-10.000
-
10.000
20.000
30.000
40.000
50.000
Power density
Rent 2 kW rack
m2 data hall per rack
Tier 3 building cost
Required return equity
Long term vacancy
Long term rental growth
Required return debt
Rent 3 kW rack
LTV ratio
Maintenance
Rent 5 kW rack
Energy premium
Energy cost
Rent 4 kW rack
Energy usage IT equipment
Racks / data hall manager
Cost data hall manager
PUE
Long term inflation
Cost security employee
Energy cost growth

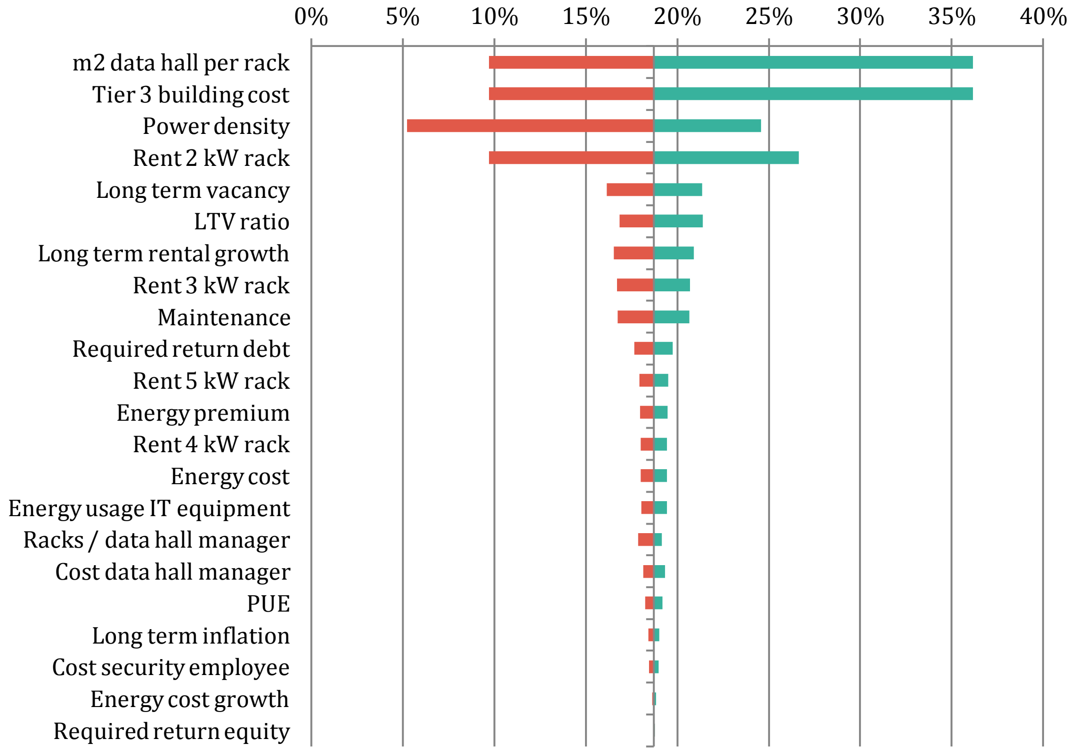
Results sensitivity analysis with dependent variable Return on Property

Variable	ROP min	ROP max	Delta ROP	Sensitivity ROP
m2 data hall per rack	8,53%	27,06%	18,53%	13
Tier 3 building cost	8,53%	27,06%	18,53%	34.530
Power density	5,40%	18,96%	13,56%	12
Rent 2 kW rack	8,55%	20,39%	11,85%	3.377
Long term vacancy	13,04%	16,70%	3,66%	415
Long term rental growth	13,32%	16,37%	3,05%	79
Rent 3 kW rack	13,43%	16,23%	2,80%	17.129
Maintenance	13,47%	16,21%	2,74%	88
Rent 5 kW rack	14,31%	15,39%	1,08%	51.696
Energy premium	14,32%	15,38%	1,06%	2.261
Rent 4 kW rack	14,35%	15,35%	1,01%	51.696
Energy cost	14,35%	15,35%	0,99%	6
Energy usage IT equipment	14,38%	15,35%	0,97%	5.788
Racks / data hall manager	14,24%	15,15%	0,91%	35.192
Cost data hall manager	14,43%	15,27%	0,84%	4.789.945
PUE	14,52%	15,18%	0,66%	159
Long term inflation	14,63%	15,06%	0,44%	349
Cost security employee	14,68%	15,03%	0,35%	7.896.873
Energy cost growth	14,78%	14,94%	0,16%	1.230
LTV ratio	14,85%	14,85%	0,00%	-
Required return debt	14,85%	14,85%	0,00%	-
Required return equity	14,85%	14,85%	0,00%	-



Results sensitivity analysis with dependent variable Levered Return On Equity

Variable	LROE min	LROE max	Delta LROE	Sensitivity LROE
m2 data hall per rack	9,69%	36,17%	26,48%	9
Tier 3 building cost	9,69%	36,17%	26,48%	24.171
Power density	5,22%	24,59%	19,37%	8
Rent 2 kW rack	9,71%	26,64%	16,92%	2.364
Long term vacancy	16,14%	21,37%	5,23%	291
LTV ratio	16,84%	21,40%	4,56%	526
Long term rental growth	16,54%	20,89%	4,36%	55
Rent 3 kW rack	16,69%	20,70%	4,00%	11.991
Maintenance	16,75%	20,66%	3,91%	61
Required return debt	17,64%	19,76%	2,11%	208
Rent 5 kW rack	17,95%	19,49%	1,55%	36.187
Energy premium	17,96%	19,48%	1,52%	1.582
Rent 4 kW rack	18,00%	19,44%	1,44%	36.188
Energy cost	18,01%	19,43%	1,42%	4
Energy usage IT equipment	18,05%	19,43%	1,38%	4.052
Racks / data hall manager	17,85%	19,15%	1,30%	24.635
Cost data hall manager	18,13%	19,32%	1,19%	3.352.962
PUE	18,25%	19,19%	0,94%	111
Long term inflation	18,40%	19,03%	0,62%	244
Cost security employee	18,47%	18,98%	0,51%	5.527.811
Energy cost growth	18,61%	18,85%	0,23%	861
Required return equity	18,73%	18,73%	0,00%	-


0%
5%
10%
15%
20%
25%
30%
35%
40%
m2 data hall per rack
Tier 3 building cost
Power density
Rent 2 kW rack
Long term vacancy
LTV ratio
Long term rental growth
Rent 3 kW rack
Maintenance
Required return debt
Rent 5 kW rack
Energy premium
Rent 4 kW rack
Energy cost
Energy usage IT equipment
Racks / data hall manager
Cost data hall manager
PUE
Long term inflation
Cost security employee
Energy cost growth
Required return equity

9.4 Results impact analysis

Input values

Variable	Mean	SD
PUE	1,3	0,1
Power density	2	0,4
m2 data hall per rack	3	0,25
Building cost / m2	8000	750
Energy cost	0,075	0,05
Energy growth	2,5	0,25
Energy usage IT equipment	70	10
Maintenance	3	0,25
Rent tier 3 2kW	500	25
Rent tier 3 3kW	600	25
Rent tier 3 4kW	650	25
Rent tier 3 5kW	700	25
Rental growth	3	0,25
Long term vacancy	19	8
Energy premium	30	10

Results impact analysis

Variable	SD ROP	SD LROE	SD NPV
PUE	0,0007	0,0009	271,31
Power density	0,0391	0,0546	12780,65
m2 data hall per rack	0,0174	0,0246	3814,87
Building cost / m2	0,0197	0,0280	4243,82
Energy cost	0,0017	0,0024	583,88
Energy growth	0,0002	0,0003	83,57
Energy usage IT equipment	0,0018	0,0025	621,78
Maintenance	0,0029	0,0041	948,07
Rent tier 3 2kW	0,0073	0,0104	2510,66
Rent tier 3 3kW	0,0014	0,0021	511,46
Rent tier 3 4kW	0,0005	0,0007	167,21
Rent tier 3 5kW	0,0005	0,0007	167,96
Rental growth	0,0032	0,0045	1307,72
Long term vacancy	0,0194	0,0278	6847,41
Energy premium	0,0044	0,0063	1534,57

Graphical representation of results

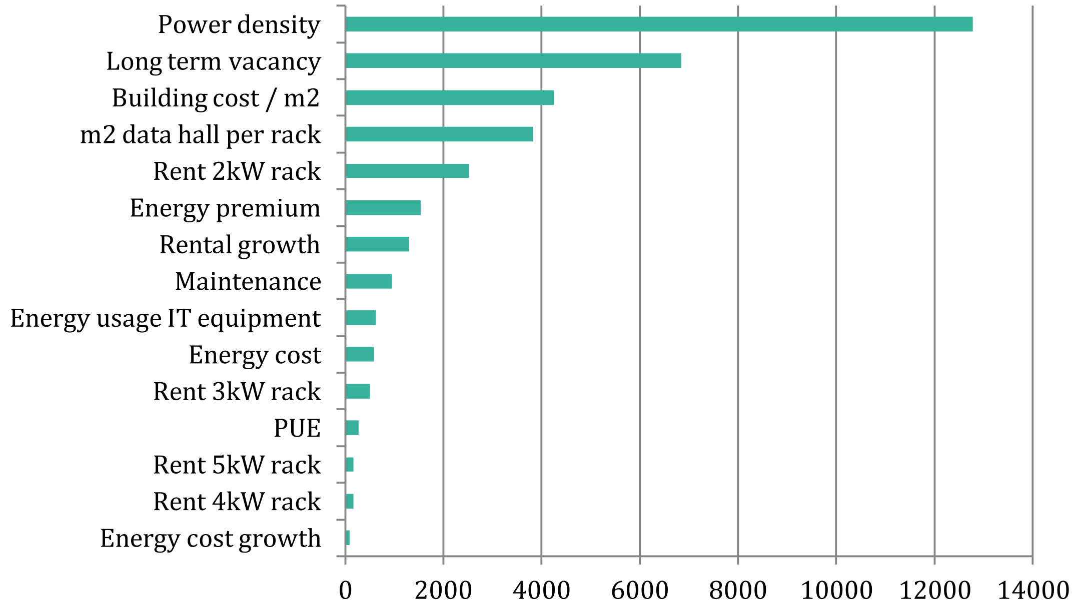


Chart 26: Analysis results Net Present Value

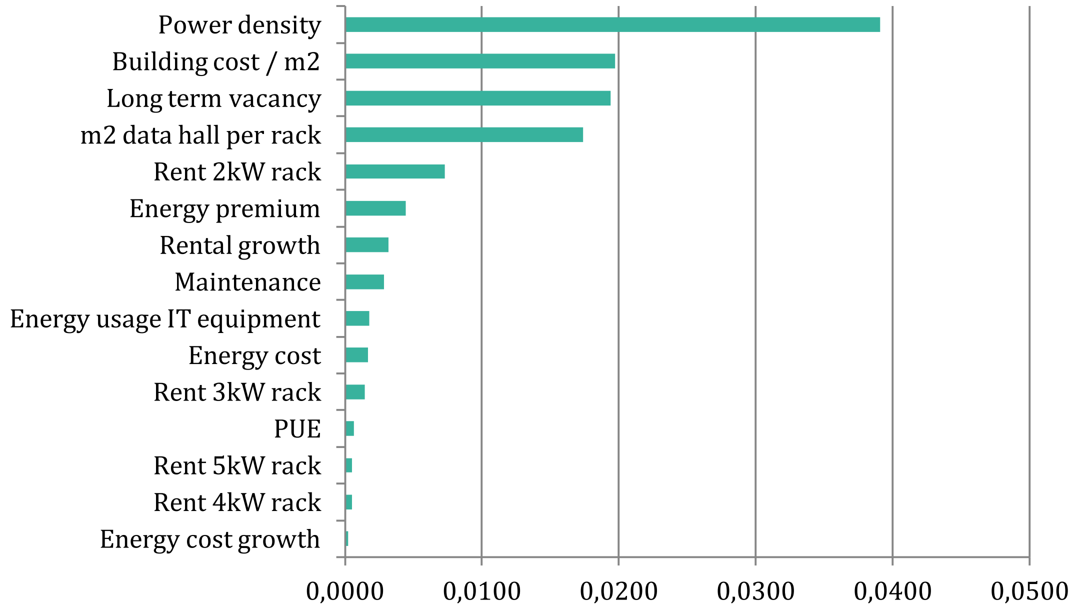


Chart 27: Analysis results Return on Property

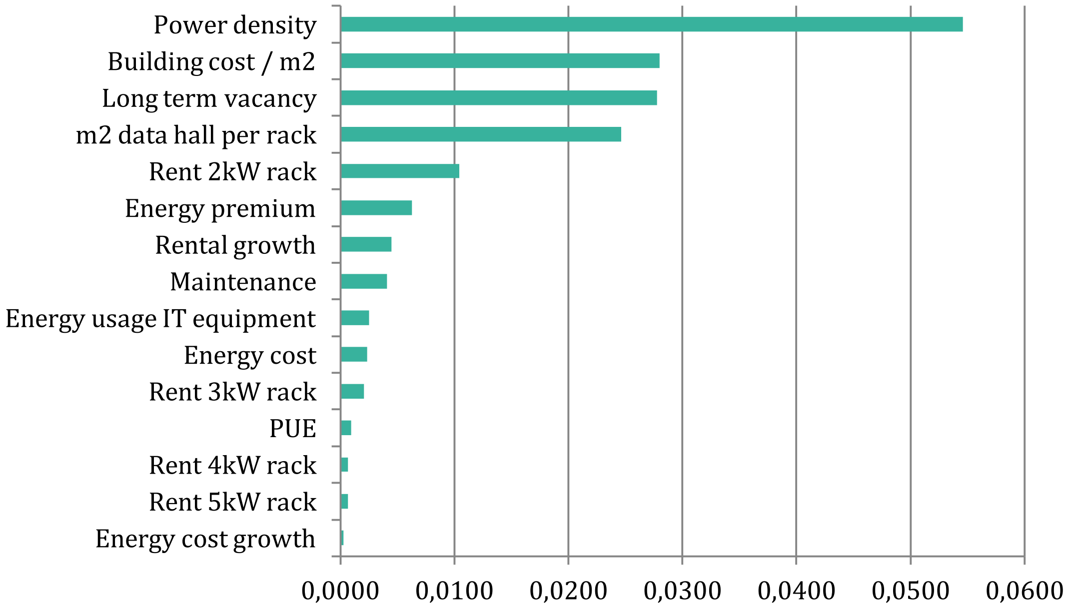


Chart 28: Analysis results Levered Return on Equity

Histograms of non-normal distributed parameter power density

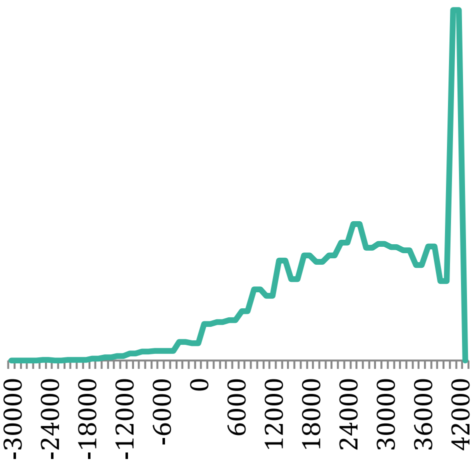


Chart 29: Histogram of NPV power density

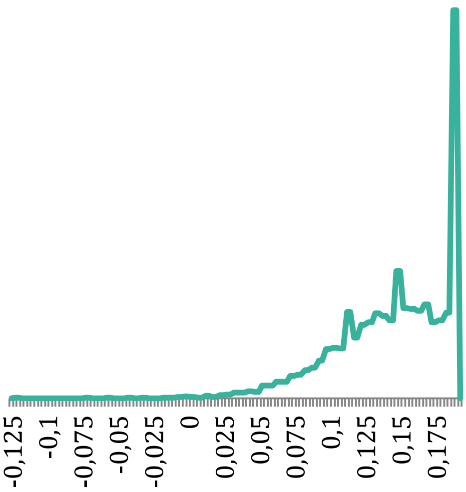


Chart 30: Histogram of RoP power density

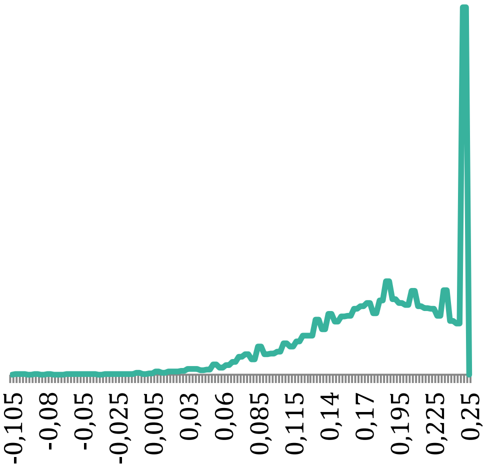


Chart 31: Histogram of LRoE power density

Histograms of non-normal distributed parameter m² data hall per rack

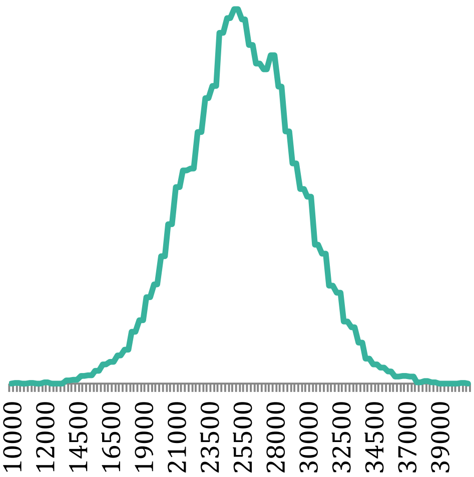


Chart 32: Histogram of NPV m² per rack

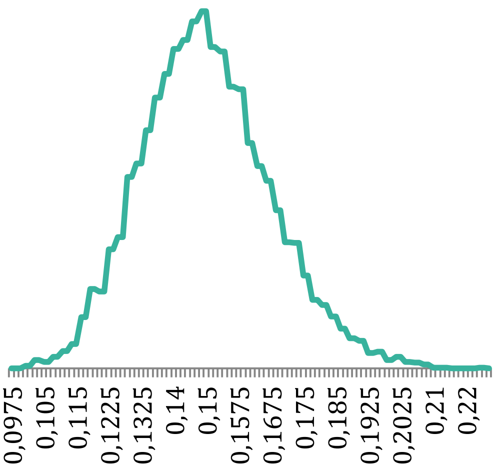


Chart 33: Histogram of RoP m² per rack

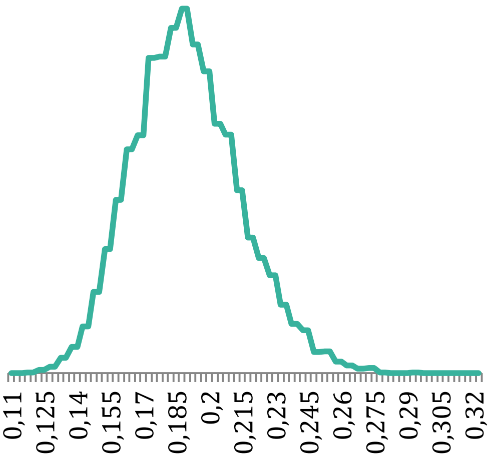


Chart 34: Histogram of LRoE m² per rack

Histograms of non-normal distributed parameter building costs per m² data hall

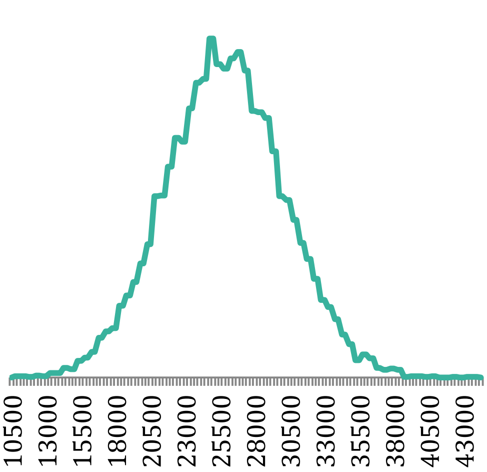


Chart 35: Histogram of NPV building cost

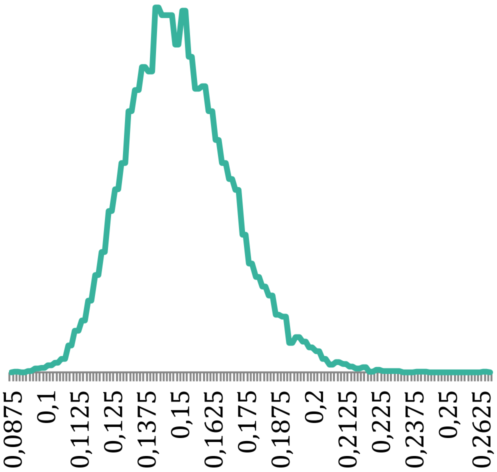


Chart 36: Histogram of RoP building cost

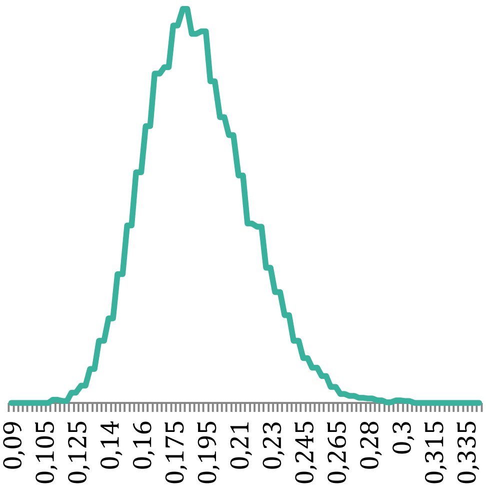


Chart 37: Histogram of LRoE building cost