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Depreciation in the Commercial Real Estate Market

An analysis of rental depreciation of Dutch industrial real estate.

MASTER THESIS

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ABSTRACT

This study investigates the depreciation of industrial properties in the Netherlands. By analyzing data provided by Cushman & Wakefield, the study examines the relationship between property age and rental value. We find variations in depreciation rates across different market districts. Additionally, the study emphasizes the significance of incorporating property characteristics to account for the observed heterogeneity in depreciation rates. Less energy efficient buildings report higher depreciation rates compared to sustainable buildings, thereby offering valuable insights into the economic implication of sustainable building practices. The findings can play a vital role in decision-making processes as it impacts investors, occupiers and society.

Keywords: industrial real estate, hedonic pricing model, depreciation rates, rental value, industrial clustering

CONTENTS

1. INTRODUCTION 5
1.1 Motivation 5
1.2 Literature review 6
1.3 Research problem statement 8
1.4 Structure 9
2. THEORY 10
2.1 Measuring depreciation effects 10
2.2 Hedonic price modeling 11
2.3 Theoretical prediction 12
3. DATA & METHODOLOGY 13
3.1 Context 13
3.2 Data & variables definition 15
3.2 Exploratory data analysis 16
3.3 Empirical model 18
4. RESULTS 20
4.1 Depreciation rates of Dutch industrial assets 20
4.2 Interaction effects 21
4.3 Robustness 23
5. DISCUSSION 26
6. CONCLUSION 29
REFERENCES 31
Appendix A – Definitions and further explanations data 38
Appendix B – Histograms and scatterplot 39
Appendix C – Frequency tables and statistics 43
Appendix D – Correlation matrix 47
Appendix E – Average age-rental relationship of industrial properties 48

1. INTRODUCTION

1.1 Motivation

Economic depreciation, or the decline in value over time, has become an important driver of property investment performance (Baum, 1991). The investment performance of buildings can be described by several factors such as the discount factor, net operating income (NOI) and exit value. The exit value depends on the expected future rental income potential, which reflects the price occupiers are willing to pay for using the space (Grenadier, 2005). A longer holding period can positively impact this rental income as higher quality properties generate higher returns. However, the pace of technical advancements, deterioration and user requirements are especially prominent factors in shaping the life span of real estate (Crosby et al., 2016). Such conditions often lead to an end of their economic life well before they reach the end of their physical life (Dunse & Jones, 2005). Moreover, the impact of economic depreciation extends beyond financial considerations, affecting the overall competitiveness and efficiency of the property. When buildings depreciate, they may no longer be suitable for their original use and require expenditures to maintain their productivity and value. The reduction in suitability may lead to lower rental values and increased vacancy (Crosby et al., 2016). The depreciation of commercial real estate plays a vital role in economic analysis and decision-making processes as it impacts investors, occupiers and society (Yoshida, 2020). As depreciation can impact investment returns, investors will prioritize the competitiveness of buildings in their portfolio. Hence, measuring the depreciation rate and its role in investment appraisal is crucial.

Depreciation may relate to sustainable development goals as low depreciation rates imply slower drains of our resources. Sustainability requirements in terms of reducing economies' reliance on fossil fuels and their related CO2 emissions, and may possibly result in stranded assets (Firdaus & Mori, 2023). As climate policies drive towards a low-carbon transition, energy-using equipment and other activities need to make space for more sustainable practices and technologies. Some assets will be unable to recover their investment cost as intended (Bos & Gupta, 2019). Especially real estate assets experience an increased consumer demand for a more sustainable environment. Currently, the importance of environmental issues has been highly recognized, and the integration of sustainability is rapidly becoming mainstream (Eichholtz et al., 2010). The major influences of the commercial real estate sector on CO2 emissions caused a general consensus among professionals that more action is required on the sustainability front (Ciochetti & McGowan, 2010). Besides the environmental performance, one of the key motivations for green commercial real estate is the fact that it reduces depreciation rates (Fuerst & McAllister, 2011). Sustainable buildings are constructed and designed using durable, high-quality materials and have longer lifespans than traditional buildings. Consequently, sustainable refurbishment involves creating a healthier environment through reduced energy consumption, lower greenhouse gas emissions and incorporation of advanced technologies (Chan, 2014). On the other hand, buildings that no longer meet these environmentally friendly practices, become outdated sooner than expected. This indicates that sustainability requirements may impact economic depreciation and calls for additional research to measure it.

1.2 Literature review

Earlier literature on economic depreciation focused on the age-asset price relationship of both residential and commercial real estate assets. Residential properties are especially popular when measuring depreciation rates. Malpezzi, Ozanne & Thibodeau (1987) conduct a survey on prior literature on housing depreciation and finds that depreciation rates vary significantly between 0.38% and 2.40%. In addition, they indicate that rates vary considerably across metropolitan areas. According to Smith (2004) rates also vary across local neighborhoods. This study states that the depreciation estimates depend mostly on age, time of sale and specific location.

Several studies have measured the depreciation of commercial real estate, both in terms of rental value and/or capital values, and have debated its underlying causes, including market conditions, asset quality and management practices (Dunse & Jones, 2005; Hulten & Wykoff, 1981; Geltner & Bokhari, 2016; Crosby et al., 2021). One of the first influential studies was conducted by Hulten & Wykoff (1981) and they utilized data from a survey conducted by the US Treasury's Office of Industrial Economics in 1972. They asked respondents about the purchase price of their building, excluding the value of the land. Although the value of buildings tends to decrease over time due to obsolescence and deterioration, the value of land depends on the demand and supply of sites in that location (Crosby et al., 2016). Dunse & Jones (2005) investigate whether depreciation rates are higher where the land element is relatively low, but their results are inconclusive in the case of industrial properties. Despite the fact that the study of Hulten & Wykoff (1981) makes a distinction between building and land elements, they report depreciation rates of 2.47% for offices and 2.73% for warehouses. They also find that depreciation rates decline with age. Salway (1986) and Baum (1991) extend the real estate literature on depreciation in the UK, where Baum’s results indicate a lower rate of depreciation for industrial properties than Salway. In both studies, the value of commercial properties is based on the judgement of professional surveyors, one that is consistent with earlier work (Hulten & Wykoff, 1981). Nevertheless, economic circumstances must be also considered. Hulten & Wkoff (1996) discuss how the age-price profile can change in response to economic conditions and that the analysis of depreciation remains a fertile field for further research.

More recent literature that uses variation in asset prices, estimates a depreciation rate of 3% for all commercial real estate (Fisher et al., 2005; Geltner & Bokhari, 2016). Geltner & Bokhari (2018) also studied the topic from an investment perspective. Here, industrial properties indicate a lower overall average depreciation rate of 1.45%. The rate for older and newer buildings ranges from 1.12% to 1.82% and it varies across metropolitan areas. Places with higher supply elasticity have higher average depreciation rates. However, there is only a small body of literature available on the rental depreciation rates of commercial properties. A study conducted by Deloitte-Touche (2000) estimated depreciation rates based on the gross rental income with data on real estate investment trust holdings in the US. Commercial structures tend to depreciate yearly between 1.7% and 2.5%. The Investment Property Forum (IPF) identifies long-term rental depreciation for the retail, industrial and office sectors in the UK between 1993 and 2009. The analysis of 742 assets estimates annual depreciation rates of 0.3%, 0.5% and 0.8% respectively (IPF, 2011). The IPF study is based on comparing the rental growth of the properties using a benchmark based on new properties held in the same location. Problems with using valuation-based data in a benchmark make that these findings are not a good indication of depreciation rates in Europe (Crosby et al., 2011).

As much prior research concentrated on measuring depreciation rates, Crosby et al. (2012) investigate how depreciation rates vary across regions and different building characteristics. To identify causes of rental depreciation, a dataset of 375 UK office and industrial properties was used. A major finding in their study is that newer assets have higher rental value depreciation rates than older stock and in locations with stronger growth, depreciation rates appear to be increased. Yoshida (2020) states the same conclusion about declining rates over time as Hulten & Wkoff (1981), using transaction price data on residential and commercial properties. Depreciation rates are linked to variables including distance to the nearest railway station, site shape, floor area and building height. The study adds to the literature that depreciation is larger for newer properties located away from the CBD in smaller cities. That important differences exist across regions is concluded by several studies (Dunse & Jones, 2005; Geltner & Bokhari, 2018; Crosby et al., 2016). In addition, capital expenditures mitigate the effects on rental depreciation rates (Crosby et al., 2012). While the majority of properties have little spent on them over time, those properties with higher rates of expenditure indicate lower depreciation rates. Upgrading commercial properties is clearly a more sustainable strategy than the process of redevelopment (Chan, 2014).

However, little research has directly measured economic depreciation rates of industrial buildings (Zhang, 2021). This paper aims to address this gap in existing research by focusing on the depreciation of Dutch market rental values between 2007 and 2022. This paper specifically focuses on examining the age-rental value relationship of industrial real estate properties. Further, the depreciation estimate depends on specific location and property characteristics. The study therefore investigates variations across regional markets, while also analyzing the influence of the sustainability level on the depreciation rate. The increase in renewable energy resources and energy efficiency in the industry sector is one of the main challenges at the (inter-)national level and asks for new policies, technologies, increased awareness of people and innovative research (Christiernsson et al., 2021). This research seeks to improve knowledge about how rental values change over time given the different building characteristics of industrial properties, and aims to provide valuable insights for future investment strategies.

1.3 Research problem statement

The aim of this study is to gain insights into the depreciation of industrial properties and provide a deeper understanding of how it varies across different locations. Buildings suffer from depreciation as they age and there are many factors that can influence this (Baum, 1991). Therefore, it is very important to incorporate attributes related to the rental value of an industrial asset, such as property characteristics, location characteristics and transaction characteristics. The market position and competitiveness can be determined by the age-rental value relationship of a property. Older properties might have lower rents due to changing market preferences, reduced functionality and higher maintenance costs. Currently, there is little research on the rental depreciation rates of industrial properties. In order to investigate this, the following research question will be attempted to answer; *To what extent do depreciation rates vary between Dutch industrial properties based on their geographical features and sustainability level?* To answer the research question, the following sub-questions will be addressed:

Research question 1: *Which determinants affect rental values of industrial real estate and how to determine rental depreciation rates?*

The literature can be used to identify factors affecting the rental value of industrial real estate. In addition, it will be examined how economic depreciation can be determined. The literature review will help identify and formulate the main hypotheses.

Research question 2: *To what extent does the rental value of industrial properties vary with age and what is the associated economic depreciation rate?*

To test how rents vary with building year, all Dutch (leasing) transactions from Cushman & Wakefield between 2007 and 2022 will be analyzed. After determining the main factors that can affect the rents of industrial buildings in the first research question, the financial implications of the building will be tested. This variable will be controlled by the transaction year, building size, ZIP code, building period, distance to highway and distance to station. This can also be found in the conceptual model below. The depreciation of industrial real estate will be investigated by using a hedonic regression model.

Research question 3: *How do depreciation rates vary across industrial clusters, geographical districts and between the sustainability of buildings?*

Depreciation rates might differ from the local level to the national level. The industrial cluster is a growing phenomenon and very important for the economic development of countries, also in the Netherlands. Industrial sites contribute significantly to the employment rate. It is therefore very interesting to look further into these areas using Cushman & Wakefield's data in combination with the IBIS (Integraal Bedrijventerrein Informatie Systeem) database for the location and development of industrial business parks. Also, the depreciation rates might vary across geographical districts as some places in the country are more active in the industry sector. In addition to the locational elements, the impact of green labels on buildings might also explain the variation in depreciation rates. Several studies investigate the impact of green certification towards the rental value or asset price (Eichholtz et al., 2010b; Stanley & Wang, 2017; Devine & Kok, 2015). With minor exceptions, the studies provide initial evidence of economic profits from certification. This indicates how well green buildings impact the performance of real estate. It also forms a fundamental basis for determining the impact on depreciation rates as both subjects are related to each other. The energy label will be used to identify how depreciation rates vary between groups with different sustainability levels.

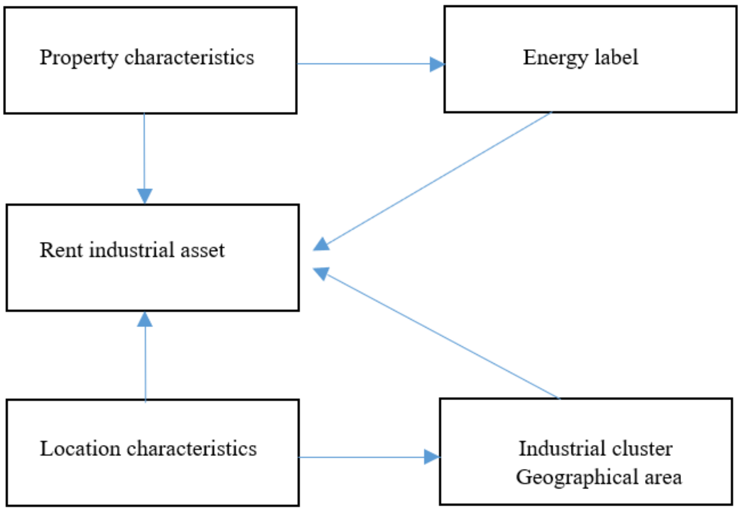


Figure 1: Conceptual Model

1.4 Structure

The remainder of this paper is structured as follows. Section 2 covers the theoretical background of industrial rents and how depreciation rates are measured in the literature. Section 3 presents the empirical model used in the analysis. Subsequently, the results are reported in section 4. The discussion is provided in section 5, and section 6 concludes.

2. THEORY

2.1 Measuring depreciation effects

Economic depreciation rates of real estate are measured by examining the relationship between the age and rental value of a property (Yoshida, 2020; Crosby et al., 2016; Dunse & Jones, 2005). The age-rental value relationship consists of two variables. The age of a property is calculated as the transaction year minus construction year, and the asset price may include rental value, appraisal value or transaction price. This measurement of depreciation in a hedonic framework is quite common. The construction year measures the impact of functional obsolescence (Wilhelmsson, 2008), and the transaction year reflects the general market conditions and land value (Bourassa et al., 2011). It needs to be noted that Goodman & Thibodeau (2005) and Sirmans et al. (2006) incorporate neither maintenance nor construction year as control variables due to a lack of available maintenance data and the multicollinearity problem between construction year, transaction year and age. However, omitting the construction year as control variable will bias the age coefficient (Francke & Van de Minne, 2017). This is particularly relevant in light of the findings of Goodman & Thibodeau (1995), who report evidence through both theoretical and empirical analysis that depreciation is non-linear as newer properties experience higher depreciation rates than older ones. To tackle this non-linear depreciation pattern, researchers have adopted different strategies. Hulten & Wykoff (1981) used a functional form of the age-asset price relationship in their analysis, while Zhang (2021) used a polynomial form based on age.

To address the operationalization of the dependent variable, different methods can be used. Most early contributions used the appraisal-based data method, which carries the risk of not accurately capturing the market value of the property (Hulten & Wykoff, 1981; Salway, 1986; Baum, 1991). Appraisals tend to exhibit a time lag as they serve as reflection of past market conditions rather than the current market value (Darrat and Glascock, 1993; Zhang, 2021). Sale prices capture these fluctuations, but on the other hand, it underestimates depreciation rates as it includes land values (Bokhari & Geltner, 2018). Another measure is the rent per square meter as a measurement, which is often open to criticism, but Dunse & Jones (2005) argue that it represents the market valuations made by professionals operating within their local market. Factors such as location, size and building quality affect the rent and therefore reflects the economic condition and competition of the real estate market.

Lastly, depreciation rates vary considerably across different markets and metropolitan areas. Smith (2004) and Bokhari & Geltner (2018) highlight the importance of spatial variation in the depreciation rates between local commercial property markets. This might be associated with the geographical clustering of economic activity. (Van der Vlist et al., 2019). This emphasizes the importance of considering the regional context when measuring depreciation rates.

2.2 Hedonic price modeling

Hedonic price modeling is a commonly used technique for assessing the value of properties, estimating demand for specific attributes of housing and neighborhoods, and analyzing price indexes for various types of properties (Páez, Long, & Farber, 2007). This approach can be applied to explain the value of heterogeneous goods, such as office buildings, houses, or industrial properties, based on their unique characteristics (Rosen, 1974; Dunse & Jones, 1998). These components include property attributes such as the age, rooms, or size of a property, as well as qualitative features like its overall condition. Additionally, the spatial characteristics of a property, which encompass factors such as its location, elevation, and proximity to neighborhood features, also play a significant role in determining its value. The characteristics that are considered in hedonic price studies for assessing the price of a property vary depending on the type of property being researched. Consequently, the characteristics that are relevant in explaining the value of commercial property may not necessarily be the same as those in housing studies (Beekmans et al., 2014). As this study focuses on industrial sites, only authors that have specifically studied industrial and commercial properties will be examined.

Structural attributes

Most hedonic studies on industrial properties have been conducted in the USA (Dunse and Jones, 2005). In general, the studies report that property-specific characteristics are the most important explanatory variables in determining the prices of industrial properties. Property size can be found as the most important driver as it directly affects the amount of space available for productive activities and storage (Ambrose, 1990; Lockwood and Rutherford, 1996; Buttimer, Rutherford & Witten, 1997). Not surprisingly, age also plays a significant role in these analyses. Older assets might have a negative impact on the rental value as maintenance costs become higher. Other property characteristics include the type of tenant (Sivitanidou & Sivitanides, 1995), the number of loading docks (Ambrose, 1990) and the size of the office area within the industrial property (Black et al., 1997). In addition, the increased awareness and importance of energy efficiency caused a willingness to pay for sustainable features from commercial real estate occupiers (Eichholtz et al., 2010a). Parkinson & Cooke (2012) suggest that Energy Star rate properties have higher rents of 2.5%-5% compared to the unlabeled equivalents. Buildings with LEED certification also achieve higher rents of 3%-4% (Devine & Kok, 2015). Furthermore, Fuerst & Van de Wetering (2015) compared BREEAM-rated buildings to non-BREEAM-rated buildings in the USA and even found average rental premiums of 23-26%. These studies show that energy performance certification is indeed an important factor in determining rent premiums They also argue that the impact of accessibility needs to be incorporated into future research.

Locational attributes

Locational attributes also play a vital role in the hedonic pricing model for commercial real estate as the location choice requires consideration of many factors. It can be influenced by the advantages that agglomeration economies provide such as sharing information, proximity to suppliers and access to labor and technology (Koster et al., 2014). Therefore, firms will tend to be located together which results in industrial clusters. A substantial body of literature tries to explain the concept of collective efficiency and clustering effects and how it is used in developing countries (Sato, 2000; Schmitz, 1995; Rabellotti, 1996). By locating in close proximity to one another, firms can optimize their output levels and maximize profits within these clusters (Liu et al., 2018). They state that industrial clusters promote the performance of firms by facilitating shared production networks and encouraging business specialization. This results in higher rents for firms located in a cluster (Rosenthal & Strange, 2003). The issue of concern is not whether the location is important, but instead, finding ways to integrate it into commercial real estate market analysis. There are several ways to include location in hedonic models. The first method involves estimating the approximate distance between the industrial asset to other spatial landmarks such as rail stations, highways, CBDs, airports and other externalities that affect the rental value (Pace et al., 1998). Secondly, to control for the effect of the neighborhood on prices, as seen in studies by Deryol (2019) and Fell & Kousky (2015), location dummies are used.

2.3 Theoretical prediction

Reflecting on existing theory leads one to observe various factors that influence the rental value of industrial properties. One may expect that rents tend to be higher in geographical clusters, as they provide a range of benefits which can help firms to be more innovative and competitive. In addition, the sustainability level of a building becomes increasingly important which results in a willingness to pay a rent premium for environmentally friendly buildings. Sustainable buildings can potentially have a longer lifespan. Lastly, as industrial activity in some areas of the Netherlands might be higher, the sample will be divided into three districts: North-East, South and West. To identify differences in depreciation rates between sustainability levels, industrial clusters and geographical areas, the following hypotheses are formulated:

Hypothesis 1: The rental value of industrial real estate varies based on the sustainability level

Hypotheses 2: The rental value of industrial real estate varies based on their locational attributes

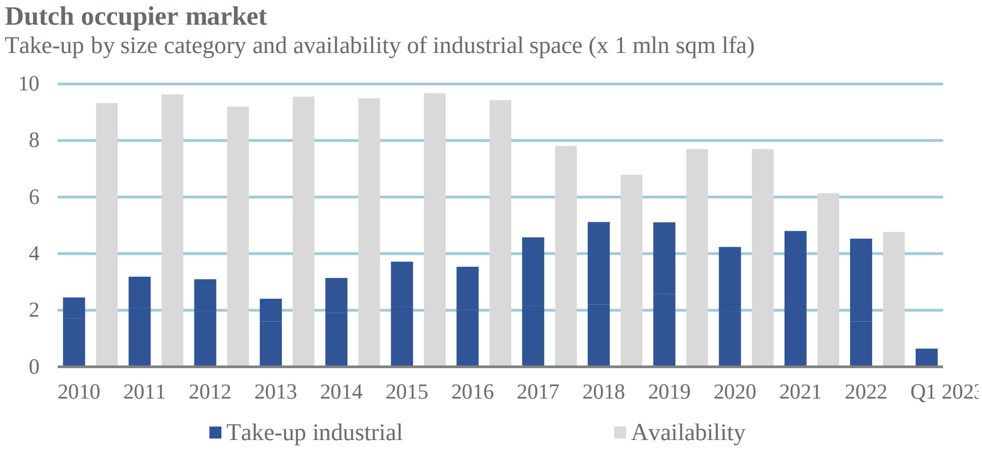
3. DATA & METHODOLOGY

3.1 Context

This research focuses on industrial real estate, which can be defined as buildings that accommodate industrial activities including distribution, production, warehousing, storage and manufacturing. They frequently consist of mixed-zone structures with offices and other commercial areas. The industrial assets are leased for long time periods because of their high level of specialization. In addition, assets are often located near seaports, airports, and highways as accessibility plays a crucial role. This makes some regions particularly interesting to settle (Beekmans et al., 2014). Well-known industrial districts in the Dutch market are the Port of Rotterdam area, the Brainport region in Eindhoven and the Twente region in the eastern part of the country (CBS, 2018). The demand for logistics real estate in these areas increased in the last few years as a result of the expansion of e-commerce, industry and technology. The number of online purchases has been rising for years, but the coronavirus outbreak gave it an extra boost. From a global perspective, it is a very attractive market due to the high occupancy rates and ongoing, strong demand for warehouses. However, the current economic slowdown affects both the investment and the user market (Vastgoedjournaal, 2023).

Last year’s volatile investment climate was caused by an unusually rapid increase in market interest rates. The cost of borrowing money from the government increased quickly as well. As a result, there was a noticeable reduction in trading throughout the year. In the first months of 2023, take-up within the industrial market decreased by 79% compared to the same period last year (Cushman & Wakefield, 2023). This is mainly due to rising interest rates, the demanded compensation for increased uncertainty and the enormous lack of high-quality spaces. These factors have caused a renewed emphasis on the foundations of industrial real estate. The property's quality, accessibility, and multimodality must be improved to meet the demand and preferences of investors and users. Manufacturing companies, retailers and transportation companies are just a few examples of the various forms of occupiers that fall within the industrial real estate industry. As seen in Table 1, a declining take-up of industrial real estate by these users was already visible at the end of 2022. Developers are currently in a difficult position as they are faced with expensive land positions, rising construction costs, rising yield requirements and regulatory pressure. Due to the fact that developing new industrial properties is made more difficult, occupiers experience higher rent levels which are causing a decrease in take-up (Cushman & Wakefield, 2023). The average rent increase within one year was on average 20%, with the most significant rent shifts in Eindhoven, Amsterdam, Tilburg and South Limburg (CBRE, 2023). Due to the great shortage and the government’s strict zoning planning, it is crucial to make efficient use of existing space. Based on the open-source database from the ‘Basisregistrate Adressen en Gebouwen’ (BAG), the Netherlands currently has 100,674 industrial properties with a total surface area of 278,201,000 square meters.

Table 1: Take-up industrial real estate



(Cushman & Wakefield, 2023)

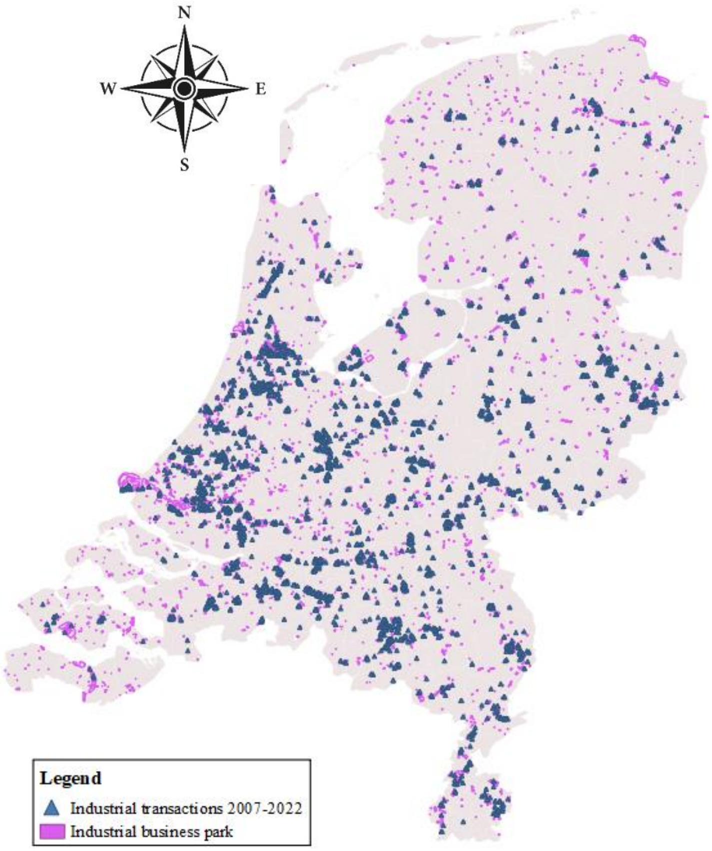


Figure 2: Map of industrial transactions in the Netherlands between 2007-2022

Figure 2 illustrates the rental transactions of industrial buildings in the Netherlands that are used for the analysis. The blue triangles represent this subset of industrial transactions between 2007 and 2022. In addition, the IBIS (Integraal Bedrijventerreinen Informatie Systeem) data data is added to the map, which includes all industrial business parks in the Netherlands. The attractiveness of these plots to companies stems from several advantages, including enhanced growth prospects, higher labor productivity and increased innovation activity. Such advantages contribute to the emergence of agglomeration economies, whereby firms and individuals co-locate in industrial clusters to exploit the potential benefits. These parks are indicated by the purple areas in the map. It shows that industrial transactions predominantly cluster in the regions of Randstad and North Brabant.

3.2 Data & variables definition

The dataset of C&W includes detailed information about commercial real estate, including size in square meters, transaction year, zip code and accessibility. C&W is a leading global real estate services firm that maintains an extensive database of properties worldwide. They operate in more than 70 countries with 53,000 employees and are located in more than 400 offices. Therefore, the data allows for a detailed analysis of market trends and provides insights into the performance of industrial properties. The C&W dataset is enriched with an open-source database from the ‘Basisregistrate Adressen en Gebouwen’ (BAG), which adds the construction year of the properties to the analysis. The BAG dataset manages all building areas and addresses in the Netherlands. Municipalities are responsible for reporting the data which includes the year of construction, the purpose of use, the naming of public spaces and energy labels. Furthermore, the dataset is enriched with data from the Dutch Industrial Sites Database, IBIS. This database provides comprehensive information on industrial sites representing the 12 provinces of the Netherlands.

The operationalization of the measurements of depreciation plays a vital role in conducting an accurate and reliable analysis. In order to address the potential heterogeneity arising from the diverse nature of these assets, various building characteristics are introduced into the analytical model. To ensure a more comprehensive analysis of comparable properties, it becomes imperative to incorporate property-specific attributes such as size, construction year, and accessibility. The rent per square meter of a property is used to form the dependent variable. The year of construction (1950-2022) and year of transaction (2007-2022) are taken into account for determining the age of a property. Further, data on properties’ total leasable floor area in square meters is used as one of the control variables. The variable construction year is divided into 4 construction cohorts which are based on new building regulations that were implemented in the Dutch real estate market in 1992, 2003 and 2012. These so-called Building Codes contain regulations concerning, among other things, safety, health, energy efficiency and the environment. The variables distance to highway and distance to station are incorporated to measure the accessibility of an asset. The binary variable Clustering (1=yes, 0=no) is generated to reflect differences across industrial business parks in the Netherlands. In addition, the dummy variables for sustainability level are generated to reflect possible differences in building types. A detailed description of the variable sustainability is defined in Appendix A1.

3.2 Exploratory data analysis

The sample for estimation includes 3,888 observations (see Appendix A2). The selection of industrial transactions is based on the following; First, I have removed the 1st and 99th percentile of the rent per square meter to minimize the effects of outliers on the outcome. All the variables are deleted for which there is either no rental value or construction year available. In addition, the properties with a construction year below 1950 or negative age are removed from the dataset. A summary of the descriptive statistics of industrial transactions is shown in Table 2. The analysis covers a wide range of industrial properties, ranging from 1950 to 2022. Using the rent from lease contracts as dependent variable allows for an accurate assessment of the property's financial performance as the arrangement is accepted by both the tenant and the landlord. The average rental value of all transactions between 2007 and 2022 is 50.10 EUR per square meter with a standard deviation of 17.56 EUR. This is higher than Dunse & Jones (2005) which reported average rents between 34 EUR and 45 EUR per sq. m. As shown in Appendix B, the distribution of rent per square meter is skewed to the right (Figure B1). The natural logarithm of the realized transaction price will be used in order to ensure a linear relationship between the variables. The use of a log-linear form can help alleviate the issue of heteroscedasticity, or changing variance of the error term, as noted by Malpezzi (2008). Figure B2 shows the adjusted distribution for rent per square meter. The age of a property is the principal variable in measuring depreciation as it captures the impact of obsolescence. The table reports an average age of 24,3 years. It is noteworthy that almost 5% of the transactions report an age of 0, which indicates that these property sales take place in the year of construction. The scatterplot in Figure B6 shows that there is a negative relationship between the age of a property and the rent per square meter, which indicates that older properties generally have lower prices compared to newer properties. The average leasable floor area in square meters is 4,399 with a standard deviation of 8,143. The natural logarithm of the floor area is utilized in the analysis (Appendix B5) to mitigate large differences in scale which creates a skewed distribution (Appendix B4). As previously mentioned, the construction year variable is divided into 4 categories. Table 2 presents that a significant majority of the properties, specifically 44%, were constructed prior to 1991. Location of the industrial property is defined by three variables: zip code, distance to highway and distance to train station. In the Netherlands, postal codes span a range from 1000 to 9999, encompassing various geographical areas. The dataset includes postal codes ranging from 1013 to 9965 and these will be included as location fixed effects to remove variation between observations. The properties report a mean distance to highway and mean distance to train station of 2,375 meters and 2,885 meters, respectively. These variables can be used to control for accessibility, as available transportation methods may be important rent drivers (Dunse & Jones, 2005). In order to achieve scale invariance and facilitate comparison across different scales, the logarithm of this variable is used in the analysis. Another important rent premium might be the result of locating in an industrial cluster. The data reports that approximately 78% of the transactions are located in a Dutch industrial business park (Appendix C2). In addition to the main hypothesis, the impact of green labels on buildings' depreciation rates will be examined. The distinction between the sustainability level of buildings is divided into 3 groups, see Appendix A1. Merging the databases resulted in 1,997 matching energy labels. Most industrial properties in this dataset can be identified as a sustainable building; they report an energy label of B or higher (see Appendix C4). The Pearson correlation matrix for all numerical variables is used to evaluate whether multicollinearity is present within the sample. The problem of imperfect multicollinearity leads to high standard errors and thus imprecise coefficients. However, Appendix D shows that there is only a problem of multicollinearity between the age of a property and the building year as these variables are related to each other.

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	3,888	50.091	17.563	15	128
Age	3,888	24.345	15.344	0	72
LFA (sq.m)	3,888	4398.844	8142.931	750	118696
Transaction year	3,888	2015.188	4.595	2007	2022
Zip code	3,888	4612.609	2193.112	1013	9965
Building period					
<1991 (1=yes)	3,888	.440	.500	0	1
1992-2001 (1=yes)	3,888	.278	.448	0	1
2002-2011 (1=yes)	3,888	.163	.370	0	1
>2012 (1=yes)	3,888	.073	.260	0	1
Accessibility					
Distance to highway (sq m)	3,888	2374.611	1556.138	1	4890
Distance to train station (sq m)	3,888	2884.643	1739.985	1	6473
Clustering					
Industrial park (1=yes)	3,888	.775	.417	0	1

Sustainability level					
Label B or higher (1=yes)	1,997	.710	.454	0	1
Label D or lower (1=yes)	1,997	.290	.454	0	1

Note: The industrial transactions are divided into a set of 4 dummy building cohorts and 3 dummies of sustainability level. The clustering variable indicates whether the transaction is located in an industrial park or not.

3.3 Empirical model

To address the relationship between the construction year and the rental value of industrial properties, I adopt a hedonic framework. This baseline model estimates the implicit price of each attribute by examining the rent of the industrial unit in relation to its individual characteristics (Rosen, 1974). These can be divided into structural and locational characteristics. Accordingly, the model can be summarized as follows:

$$R = f(A, S, L)$$

R stands for rent per square meter, which is determined by the age of a property (A) structural characteristics (S) and locational characteristics (L) of industrial assets. In this model, structural characteristics are defined by the leasable floor area and building period. Distance to highway and distance to train station are included to account for the accessibility and convenience of a location. Furthermore, location fixed effects at the zip code level will be incorporated in the model. Considering that rents vary over time, the transaction year covers time fixed effects. The following empirical model was created to estimate our baseline model (Zhang, 2021):

$$\log(R_{i,j,t}) = \alpha + \beta_1 \mathrm{A}_{i,t} + \beta_2 A_{i,t}^2 + \sum_{k=1}^{K} \emptyset X_{k,i,t} + \sum_{m=1}^{M} \delta C_{m,i} + \gamma_t + \mu_j + \varepsilon_{i,j,t} \tag{1}$$

where $R_{i,j,t}$ is the rent per square meter of a property *i* in region *j* and specific year *t*. $\mathrm{A}_{i,t}$ is the age of the property. Economic depreciation in real estate follows a convex curve, which means that depreciation rates decline with age (Dunse and Jones, 2005; Hulten & Wykoff, 1981). As the industrial properties may have higher rates in the early years, $A_{i,t}^2$ is added to the model. The vector $\chi_{i,t}$ is a set of property characteristics including year of transaction, location, floor area, proximity to station and railway. These structural and locational attributes are involved in the rental value of industrial properties (Malpezzi, 2003). $C_{m,i}$ is a set of 4 dummies for construction cohorts. The market condition regarding building regulations is measured through this dummy variable. In 1992, 2002 and 2011 the Dutch standards for construction, use and safety of buildings were modified. γ_t and μ_j are year and location fixed effects. $\varepsilon_{i,t}$ is the error term and α, $\beta_1, \beta_2, \gamma_t$, μ_j and are parameters to be estimated. Sirmans et al. (2005) state that Ordinary Least Squares (OLS) is widely used in real estate research for estimating relationships.

The empirical model (1) can be used to determine the average depreciation rate in a certain year (Zhang, 2021). The estimated depreciation rate based on transaction data can be calculated as follows:

$$\check{D} = \partial R_t / \partial A = \beta_1 + 2 \times \beta_2 A_{i,t} \tag{2}$$

However, there are some reasons why the estimates for depreciation rates could be biased. According to Smith (2004), not including the construction year as a factor could overlook potential vintage effects. Investors' preferences might be influenced by the construction year and building quality. If both age and construction year are included in the model, multicollinearity issues would arise. To circumvent this problem, the construction year is categorized into construction cohorts, as suggested by Francke & Van de Minne (2017) and Smith (2004). Secondly, unobserved capital expenditures can result in underestimating the actual depreciation rates. It is assumed that the properties being transacted are well-maintained as C&W is a high-end real estate company. Also, any potential lack of maintenance would be reflected in the rental value of a property.

In addition to the baseline model, it will be tested to what extent the estimated coefficients for depreciation vary across a different subset of the data. Testing the variation in coefficients can help identify differences in depreciation patterns between these subsets. Attributes such as energy label and location can have a substantial impact on the rental value of industrial properties. The Netherlands will be divided into three geographical districts, and subsequently, a Chow test will be conducted to examine potential variations across these segments. As previously mentioned, the sustainability factor is increasingly important in real estate and it might cause rental premiums and longer life spans. A Chow test will be conducted as parameter stability test. The data will be divided into two unrestricted models related to their energy performance, whilst the pooled model does not include sustainability level. The result of this test indicates whether different depreciation rates are observed when the effect of the energy label is considered. If the value of this test statistic is greater than the critical F-value, it indicates parameter instability across the samples, which suggests that the sustainability level has a meaningful impact on depreciation rates among industrial assets. Hence, this provides motivation to examine different model specifications for the sample.

4. RESULTS

4.1 Depreciation rates of Dutch industrial assets

Table 3 reports the regression results for depreciation rates using all the transaction data. The first model is the baseline hedonic model and only included the key variables Age, Age^2, leasable floor area and whether the property is located in an industrial business park. Model 2 includes the construction cohorts. Next, to control for year-fixed effects, the year of transaction is added to the analysis. Model 4 is the most complete model where the location-fixed effects are added by including three locational characteristics of the property. The distribution of the number of observations per zip code is included in Appendix B7. Finally, models 4, 5 and 6 include different zip code levels of 4, 3 and 2 digits, respectively.

Table 3: The standard regression results

Variables	(1)	(2)	(3)	(4)	(5)	(6)
				ZIP4	ZIP3	ZIP2
Age	-0.0123***	-0.0070***	-0.0131***	-0.0101***	-0.0098***	-0.0119***
	(0.0011)	(0.0020)	(0.0024)	(0.0028)	(0.0025)	(0.0026)
Age^2	0.0001***	3.84e-05	9.19e-05***	6.37e-05*	5.99e-05*	8.96e-05***
	(1.97e-05)	(2.77e-05)	(3.03e-05)	(3.70e-05)	(2.22e-05)	(3.35e-05)
Log of LFA	-0.0036	-0.0078	-0.0122**	-0.0162**	-0.0194***	-0.0180**
	(0.0056)	(0.0057)	(0.0056)	(0.0071)	(0.0068)	(0.0070)
Cluster (1=yes)	0.0024	0.0021	0.0024	0.0131	0.0102	0.0135
	(0.0131)	(0.0131)	(0.0127)	(0.0180)	(0.0155)	(0.0135)
Construction cohorts	No	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	No	No	Yes	Yes	Yes	Yes
Location-fixed effects	No	No	No	Yes	Yes	Yes
Observations	3,888	3,888	3,888	3,888	3,888	3,888
Adjusted R^2	0.0991	0.1031	0.1556	0.4413	0.3848	0.3130

Note: Dependent variable is the logarithm of the rental transaction price per sq.m. Construction cohorts include different building periods related to the Building Codes adopted in recent years. Year-fixed effects include the year of sale and location-fixed effects include the zip code, distance to the highway and distance to nearest station.
*** $p<0.01$, ** $p<0.05$, *$p<0.1$

As the first model does not include important independent variables, the coefficients will not be interpreted. However, it serves as a reference for the other models. The adjusted R^2 of the first model is very low and this confirms the importance of adding control variables in the model. Therefore, the results of the baseline models including construction cohorts, year-fixed effects and location-fixed effects will be further clarified. The variable Age reports a negative significant result on the 1% level in model 4-6, which suggests that the rental value of a property decreases with age. When comparing the coefficients for the key variables in these models, it is noteworthy that the coefficient for Age has a negative sign, while the coefficient for Age-squared is positive. This indicates that depreciation is a nonlinear process, and the rates of industrial assets decline with age. Based on equation 2, the depreciation rate for this sample can be estimated. The coefficients of -0.0101 and 0.000637 for Age and Age-squared, respectively, suggest that the depreciation rate of a one-year-old property is 1.00%[1]. The depreciation rate of a 5-year-old industrial asset is 0.95%[2]. Nevertheless, independent variables are very important in this analysis. In light of heterogeneity among characteristics of the assets, their impact on rental values might variate. The findings indicate that the rents of the assets are most sensitive to a change in size. When the leasable floor area of an industrial property increases by 1%, its rental value decreases by 0.0162%. There are several contributing factors to this trend, but the primary driver is the diminishing marginal utility. As the property size increases, each additional square meter might not provide value to the tenant (Dunse & Jones, 2005). The variable Cluster, indicating whether the transaction is located in an industrial business park, is unfortunately insignificant in all model specifications.

The findings of models 4-6 indicate differences in depreciation rates based on the zip code level. At zip code level 2, the data is aggregated on a larger scale compared to zip code levels 3 and 4, resulting in a coarser representation of the underlying patterns within the region. However, including all 4 digits of the zip code results in many absorbed observations. Therefore, the results for zip code level 3 (model 5) and zip code level 2 (model 6) are added to the analysis. Model 5 indicates a depreciation rate of 0.96%[3], while coefficients of model 6 report a rate of 1.17%[4]. Elaborating on model 6, the depreciation rate of a 66-year-old property is zero, which indicates that the building at that age no longer declines in value (Appendix E).

4.2 Interaction effects

Table 4 reports results for the specification with interaction effects for property characteristics. The interaction of the key variable Age and two independent variables creates a deeper understanding of how the independent variables influence the rents of industrial properties. Including interaction terms can improve the model's predictive performance and might lead to a more accurate estimation of depreciation rates for industrial properties. Firstly, to investigate the relationship between the age of a property and the rental value, the interaction *Age x Log of LFA* is added in model 1. It may reveal that the age-asset price relationship varies depending on the size of a property. A property with a larger leasable floor area might experience a higher depreciation rate than a smaller property. Larger properties require high maintenance costs which may deter investors from investing in the property, causing depreciation.

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[1] Ď = -0.0101 + 2*0.0000637*1*100%= -0.997%

[2] Ď = -0.0101 + 2*0.0000637*5*100%= -0.946%

[3] Ď = -0.0098 + 2*0.0000599*1*100%= -0.96%

[4] Ď = -0.0119 + 2*0.0000896*1*100%= -1.17%

The positive significant interaction effect at the 1% level indicates that the size of a property has some influence on the depreciation rate. The coefficient for this interaction term is 0.0010. When the age of a property increases by 1%, the rental value decreases by -0.0197 + 2 * 8.91e-05 * Age + 0.0010 * Log of LFA. Substituting the Age and Log of LFA with specific values results in a marginal effect of -0.0185. This finding implies that, when one accounts for the size of a property, a 1% increase in age is associated with a decrease in rent by 1.78%.

The interaction term *Age x Label B+* indicates a significant relationship at the 10% level between depreciation rates and the energy label. The marginal effect of age regarding the sustainability level indicates a lower depreciation rate for buildings with energy label B+ relative to less energy efficient buildings. However, the adjusted R-squared in model 3 exhibits only a slight improvement compared to model 2. It might be interesting to look further into the association between depreciation rates and the sustainability level of industrial properties.

Table 4: Regression results with interaction effects

Variables	(1)	(2)	(3)
Age	-0.0197*** (0.0031)	-0.0165*** (0.0035)	-0.0183*** (0.0034)
Age²	8.91e-05* (3.36e-05)	0.0001*** (4.22e-05)	0.0002*** (4.16e-05)
Age x Log of LFA	0.0010*** (0.0003)		
Age x Label B+			0.0019* (0.0011)
Log of LFA	-0.0401*** (0.0091)	-0.0322*** (0.0092)	-0.0325*** (0.0092)
Label B+			-0.0469 (0.0349)
Construction cohorts	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes
Observations	3,888	1,997	1,997
Adjusted R²	0.3149	0.3539	0.3543
Average marginal effect of			
Log of LFA	-0.0185		
Label B+			-0.0162

Note: Dependent variable is the logarithm of the rental transaction price. Zip code level: 2 digits.
*** p<0.01, ** p<0.05, *p<0.1

4.3 Robustness

As sustainable buildings have longer lifespans, it can be expected that buildings with a better energy performance have lower depreciation rates. After excluding the transactions that do not report an energy label, the sample in model 1 is limited to 1,997 observations. The sustainability level is not included in this pooled model. Next, the data is divided into two categories based on their energy performance (see Appendix A1). The regression results are reported in Table 5. In the separate regressions for the sustainability level of industrial assets, all models still report a negative significant relationship between age and rental value. However, the coefficients of the two sustainability categories differ in value, indicating that the depreciation rates vary by energy label. Compared to the baseline model, the depreciation rate for properties with an energy label B or better report a depreciation rate for a one-year-old property of 1.62%, which is almost 0.62% higher than taking into account the whole sample. A five-year-old property reports a depreciation rate of 1.55%. Properties that report an energy label C or lower, indicate a depreciation rate of 1.85%. On the other hand, the pooled model which only includes observations that report an energy label, suggests a depreciation rate of 1.45% for a one-year-old property. A Chow test is performed to examine whether the coefficients are actually significantly different. The results from Table 5 indicate an F-score of 1.59[5], which is slightly higher than the critical value at the 5% significance level. Based on this, it can be concluded that the energy label has a meaningful impact on the depreciation rates of industrial properties. The correlation between the age of a property and the rental value is different for assets that perform well on the sustainability level.

Table 5: Sensitivity analysis based on sustainability level

Variables	(1) Pooled model	(2) Label B or higher	(3) Label C or lower
Age	-0.0165***	-0.0164***	-0.0187***
	(0.0035)	(0.0038)	(0.0060)
Age²	0.0001***	0.0001***	0.0001*
	(4.22e-05)	(4.88e-05)	(7.89e-05)
Log of LFA	-0.0322***	-0.0431***	-0.0359
	(0.0092)	(0.0101)	(0.0155)
Construction cohorts	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes
Observations	1,997	1,417	580
RSS	164.7998	107.9762	53.7826
Adjusted R²	0.3539	0.3808	0.3470

Note: Dependent variable is the logarithm of the rental transaction price. Zip code level: 2 digits.
*** p<0.01, ** p<0.05, *p<0.1

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[5] F= ((164.7998-107.9762-53.7826) / (2*23-23)/(161.7588/(1997-2*23))= 1.5947

Secondly, to assess the suitability of the pooled model for the entire study area, I will test the heterogeneity of the results across four geographical parts in the Netherlands. Depreciation rates in the local industrial rental market can vary significantly due to different planning policies, infrastructure and demand preferences. As the map in Figure 2 indicates that most transactions are located in the Southern and Western parts of the Netherlands, it can be expected that there is a greater level of demand in these areas. Recognizing heterogeneity in the pooled model can lead to more accurate estimates. The results of the separate regressions are displayed in Table 6. The regression reports insignificant coefficients in the North-Eastern part of the Netherlands for the key variables Age and Age². This might be the result of lower activity of rental transactions in these parts of the country. Nevertheless, the Southern and Western districts display significant results at 1 % and 5%, respectively. The coefficient for Age in West Netherlands exhibits a higher value to the coefficient in the pooled model. However, in the Southern part of the Netherlands, the coefficient displays a relatively lower value. The depreciation rate in this part of the country is 0.88%. With the exception of the pooled and Southern part models, the unrestricted models report a lack of statistically significant outcomes for the polynomial of age. In order to determine whether the coefficients are equal across the districts, a Chow test will be employed here as well. The F-statistic reports a value of 2.19[6], which is higher than the critical F-value with a 95% confidence level. Accordingly, the coefficients for depreciation rates differ significantly across the regions of North-East, South and West.

Table 6: Sensitivity analysis based on part of the country

Variables	(1) Pooled model	(2) North-East	(3) South	(4) West
Age	-0.0118***	-0.0110**	-0.0089***	-0.0136**
	(0.0026)	(0.0049)	(0.0027)	(0.0052)
Age²	8.81e-05***	8.37e-05	6.86e-05*	0.0001
	(3.32e-05)	(5.87e-05)	(3.99e-05)	(7.13e-05)
Log of LFA	-0.0177**	-0.0262***	0.0002	-0.0327**
	(0.0072)	(0.0143)	(0.0055)	(0.0150)
Construction cohorts	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes	Yes
Observations	3,888	1,063	1,157	1,663
RSS	365.7906	111.5480	94.3928	150.4360
Adjusted R²	0.3133	0.2380	0.1920	0.2912

Note: Dependent variable is the logarithm of the rental transaction price. Zip code level: 2 digits.
*** p<0.01, ** p<0.05, *p<0.1

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[6] F= ((365.7906-111.5480-94.3928-150.4360)/ 3*23-23)/(356.377/(3,888-3*23))= 2.1930

Finally, this study examines whether the analysis reports consistent outcomes for the city with the highest number of observations. The city Amsterdam consists of 158 rental transactions between 2007 and 2022. As table 7 suggests, the coefficients report a significant result for Age and Age² at 5%. However, the values of the coefficients are significantly higher in Amsterdam than in the pooled model. The depreciation rate for a one-year-old property is 4.13% and for a five-year-old property 3.7%. These high rates in Amsterdam reflect the extremely dynamic metropolitan area where the highest and best use has been rapidly changing in the last decades. Areas where the supply of real estate is more elastic are associated with higher depreciation rates (Bokhari & Geltner, 2016). However, the disparity observed in the depreciation rates for Amsterdam as compared to the other results in this analysis, calls for considering uncertainty in these findings.

Table 7: Sensitivity analysis based on city with most observations

Variables	(1) The Netherlands	(2) Amsterdam
Age	-0.0118***	-0.0423**
	(0.0026)	(0.0160)
Age²	8.81e-05***	0.0005**
	(3.32e-05)	(1.79e-05)
Log of LFA	-0.0177**	-0.1033*
	(0.0072)	(0.0138)
Construction cohorts	Yes	Yes
Year fixed effects	Yes	Yes
Location fixed effects	Yes	Yes
Observations	3,888	158
Adjusted R²	0.3133	0.5031

Note: Dependent variable is the logarithm of the rental transaction price.
Zip code level: 2 digits. *** $p<0.01$, ** $p<0.05$, *$p<0.1$

5. DISCUSSION

The findings of this analysis indicate that there is a negative relationship between the age of a property and the rental value. This result is consistent with findings of existing literature on commercial properties of Crosby et al. (2016) and Dunse & Jones (2005). Due to the high intensity of use depreciation rates for industrial assets differ from those observed in other real estate sectors (Zhang, 2021). As industrial properties might depreciate at a faster speed, it is important to compare the findings of this study to literature that investigated the same sector. To see whether the exact depreciation rate of the industrial properties is in line with existing literature, the confidence intervals are computed. As seen in Table 8, the depreciation rate of industrial assets in the Netherlands aligns with the confidence intervals reported in existing literature.

Table 8: Depreciation rates based on existing literature

Literature	Depreciation rate	SE	Confidence interval	Country
Crosby et al. (2012)	0.50%	0.00523	-0.6% - 1.5%	U.K.
Bokhari & Geltner (2016)	1.13%	0.00339	0.47% - 1.80%	U.S.
Yoshida (2020)	1.11%	0.001	0.90% - 1.3%	Tokyo
Zhang (2021)	1.17%	0.00421	0.34% - 2.0%	Netherlands
This study, baseline model 6	1.17%	0.00258	0.66% - 1.67%	Netherlands

*The confidence interval is calculated by the following formula: Depreciation rate ± 2*SE. Studies that report two standard errors use both the Age and Age^2 coefficient to compute depreciation rates.

However, it should be noted that a direct comparison of these findings is not feasible due to differences in the modelling approach and the geographical area of the studies. Firstly, Crosby et al. (2016) use time-series data of the transactions U.K. The depreciation rate is for that reason based on a comparison between the value of an individual asset through time and a benchmark for properties in the same location. The study suggests that economic and local real estate market conditions are significantly important in explaining depreciation rates. Considering that there are differences in geographical parts in the Netherlands already, the circumstances in other countries must be considered. The empirical finding of this study indeed provides evidence of the crucial role of locational attributes within the framework of the hedonic model. Taking this into account, the depreciation rate of this study bears a strong resemblance to the study undertaken by Zhang (2021). Comparing these rates, they demonstrate a high degree of alignment with each other. However, there are also differences between geographical areas in the Netherlands. The Chow test statistic rejects the null hypothesis that there are no significant differences in the coefficients across different parts of the country. From the agglomeration point of view, it is surprising that the outcome of the industrial cluster coefficient is insignificant in all models. One would expect higher rents for a property located in an industrial business park, as it provides access to labor, knowledge and technology (Koster et al., 2014). The operationalization of the Cluster variable might have been inadequate, leading to the imprecise categorization of properties being part of it or not. Measuring the distance to the cluster could potentially address this problem as it allows for a more nuanced examination of the Cluster variable.

Additionally, it is interesting to examine how the rest of the results can be compared to findings from other literature. The statistical model in this study uses a wide set of property characteristics in combination with year of sale fixed effects and location-fixed effects. In baseline models 4-6, the coefficients of the size of a property report a negative significant result. This indicates that rents tend to decrease with unit size and is in line with the study of Dunse & Jones (2005). However, the results regarding property density are not consistent among established literature. Whereas most hedonic studies that investigate the association between age and size report positive coefficients for floorspace (Bokhari & Geltner, 2016; Zhang, 2021; Crosby et al., 2016), others suggest a negative relationship between these variables (Yoshida, 2020; Dunse & Jones, 2005). As observed in the sensitivity analysis regarding sustainability level, industrial assets report a lower depreciation rate when the energy performance is better. Besides the fact that there is currently no literature addressing this topic, this outcome was expected. Sustainable buildings have a longer lifespan than traditional buildings due to the use of durable and high-quality materials (Fuerst & McAllister, 2011). However, one may argue the quality of the energy performance data of industrial properties. Despite the growing environmental awareness, there exists currently no obligation pertaining to the acquisition of an energy label for industrial properties. Embracing sustainable practices by policy and society can significantly impact the occupier demand requirements. Properties that do not align with these changed preferences and other technological advancements may face functional obsolescence. The age of a property captures the role of functional obsolescence, but additional variables that include the asset’s condition and quality are essential factors in determining the obsolescence rate. This study’s scope is therefore limited to the depreciation process, but investigating both depreciation and obsolescence allows for a more accurate market analysis, better risk assessment and suitable strategies for property management.

There are some other data limitations of the study that need to be considered. A very important issue relating to the comparability among industrial assets is the availability and quality of transaction data of commercial real estate. This could potentially be explained by two factors. One is the reluctance of property owners to share confidential information with third parties. In addition, the heterogeneous character of the real estate market in combination with the highly segmented local markets results in quality issues of the data. The problem of potential endogeneity can only be resolved by conducting a time series analysis. Furthermore, the transaction database of Cushman & Wakefield does not provide information regarding the capital expenditures of the property.

Considering that this variable is significantly important in determining the asset-price relationship in hedonic studies, the data could be biased due to omitted variables (Crosby et al., 2016). Another limitation of the available data is the low number of property-located characteristics. Including more characteristics such as the number of loading docks, the size of the office area within the industrial property and whether the property is rented by a single-tenant or multi-tenant could give more precise depreciation rates (Ambrose, 1990; Black et al., 1997).

6. CONCLUSION

The main purpose of this research is to investigate the depreciation rate of industrial properties, and consequently assess whether there is a correlation between the age and rental value of assets. Measuring depreciation rates helps investors to evaluate financial performance and to make informed decisions regarding strategies of acquisition and property management. Moreover, it assists owners in optimizing several activities; anticipating the decline in value, assessing the risk associated with the investment and creating effective portfolio management. A dataset of 3,888 rental transactions was studied in order to measure the economic depreciation of Dutch industrial real estate. These estimates are calculated based on the coefficients for Age and Age^2. The control variables account for differences in observed heterogeneity in locational and structural characteristics. Therefore, it can be assumed that the analysis is conducted based on comparable properties. The study also examines the potential variation in depreciation rates based on differences in the sustainability level and geographical areas.

The results of the study indicate that there is a negative relationship between the key variables, which means that industrial properties depreciate over time. The coefficients indicate a depreciation rate of 1.17% for a new property and 1.10% for a five-year-old property. The depreciation rate becomes zero at the age of 66. At this turning point, the property no longer declines in value. As suggested in the literature, various factors can influence the economic depreciation rate of commercial real estate. These findings formed the basis for hypotheses on variation in depreciation rates. The empirical evidence presented in this research contributes to the existing literature by confirming the importance of incorporating property characteristics such as size and location in the analysis. Firstly, it can be concluded that depreciation rates vary significantly across market districts. The southern part of the Netherlands indicates a lower depreciation rate (0.88%) compared to the whole sample. This might be the result of high industrial activity in this area, which makes it interesting for firms to settle. The findings related to the sustainability level are somewhat contradictory to what was expected. Analyzing the sample with energy label B or better indicates a higher depreciation rate than the whole sample. As sustainable buildings report a lower age than non-sustainable buildings, and considering that depreciation rates decline with age, this outcome was expected. However, it is noteworthy that buildings with energy label C or worse suggest a higher depreciation rate than sustainable buildings. This implies a more substantial decline in the value over time which can be caused by higher operating costs and lower demand for non-sustainable buildings. These results have some policy implications. Introducing stricter regulations for buildings that depreciate faster and promoting more energy efficient alternatives can extend the durability of buildings.

This study enhances the understanding of depreciation rates in the Dutch industrial real estate market. It shows that location and size are important factors in determining economic depreciation rates. This analysis on regional data can be used to decide where to invest, as the Southern part of the Netherlands suggest lower depreciation rates. Further research should build on these findings and use a larger dataset covering more observations in each industrial cluster and geographical district. In addition, the transactions that report an energy label, report higher depreciation rates than the whole sample. However, sustainable buildings report lower rates than buildings with energy label C or worse. This observation could be associated with the necessity of incorporating building quality variables into the model. Utilizing these variables allows for a more comprehensive approach, and can also facilitate the examination of functional obsolescence. Further research on depreciation rates thus needs to include the sustainability aspect in combination with these quality measurements, as energy efficiency is one of the key factors in reducing greenhouse gas emissions and mitigating the impacts of global warming.

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APPENDICES

Appendix A – Definitions and further explanations data

Table A1: Definition of the sustainability level groups

Sustainability level	**Definition**
Label B of higher	Buildings that report an energy label of A+++++, A++++, A+++, A++, A+, A or B
Label C or lower	Buildings that report an energy label of C, D, E, F or G

Table A2: Data cleaning procedure

Data cleaning	**Observations left**
Raw data	17,072 observations
Drop if construction year is missing	15,560 observations
Drop if rental value is missing	5,334 observations
Remove outliers: - drop if construction year is before 1950 - remove 1% highest + lowest values of rental value	4,045 observations
Drop if the age of the property is smaller than 0	3,888 observations

Appendix B – Histograms and scatterplot

Figure B1: Rental value per square meter

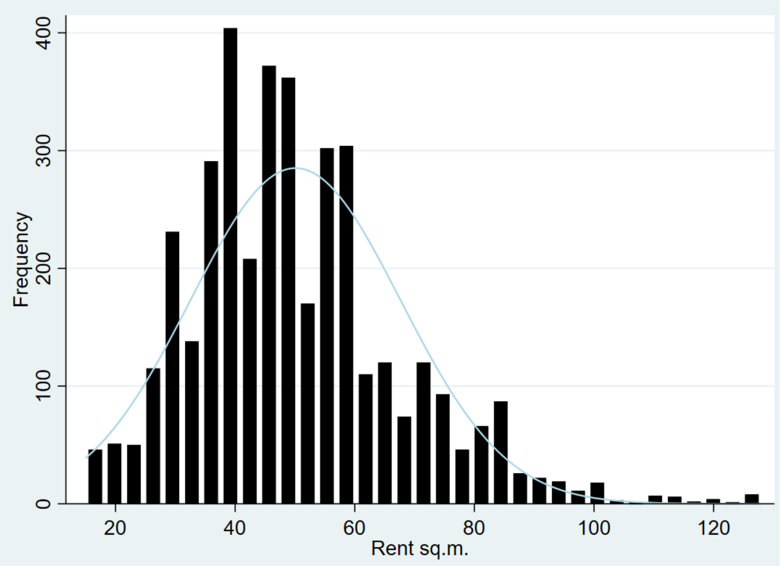


Figure B2: LnRental value per square meter

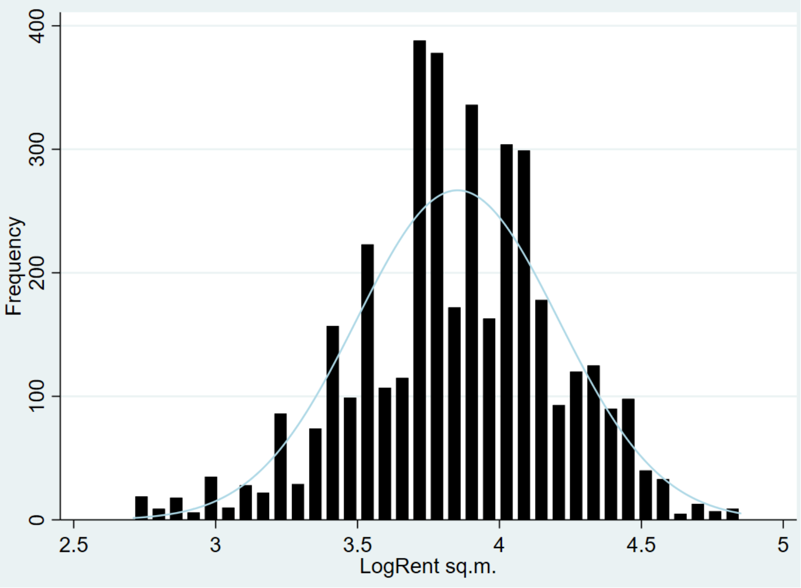


Figure B3: Age

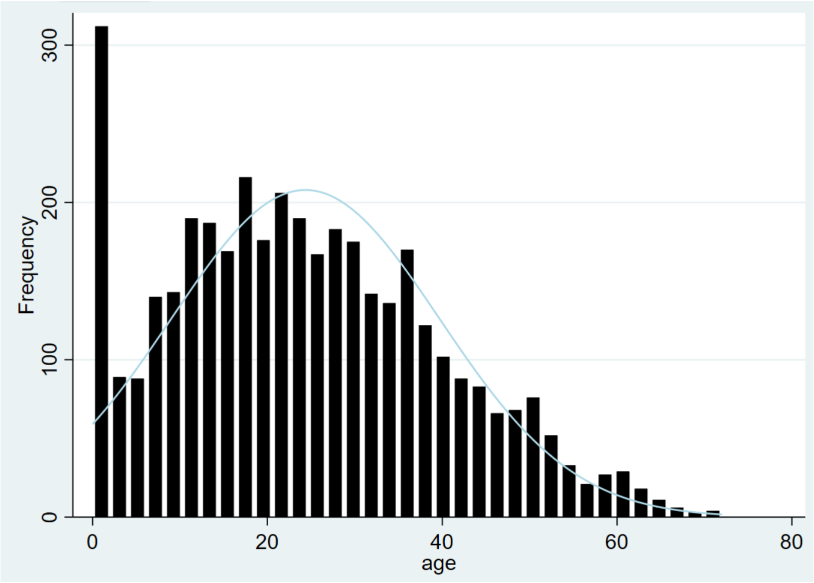


Figure B4: Leasable floor area

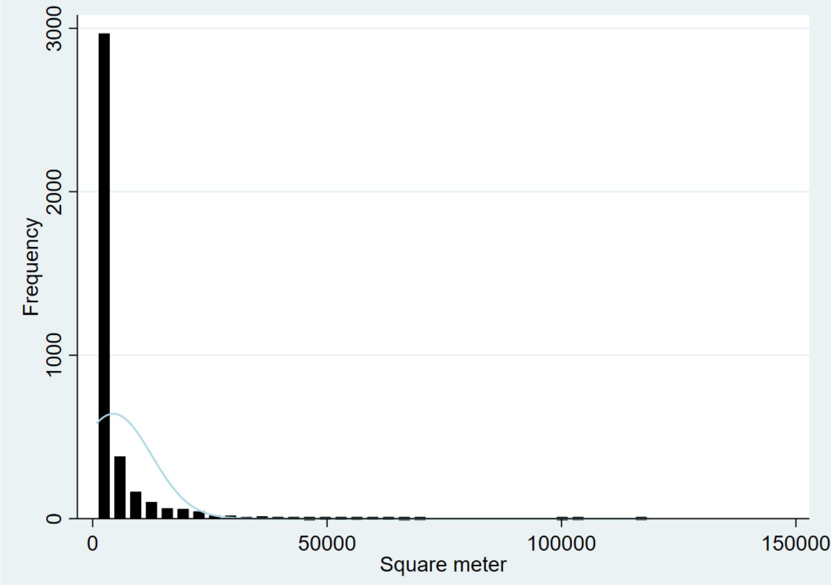


Figure B5: LnLeasable floor area

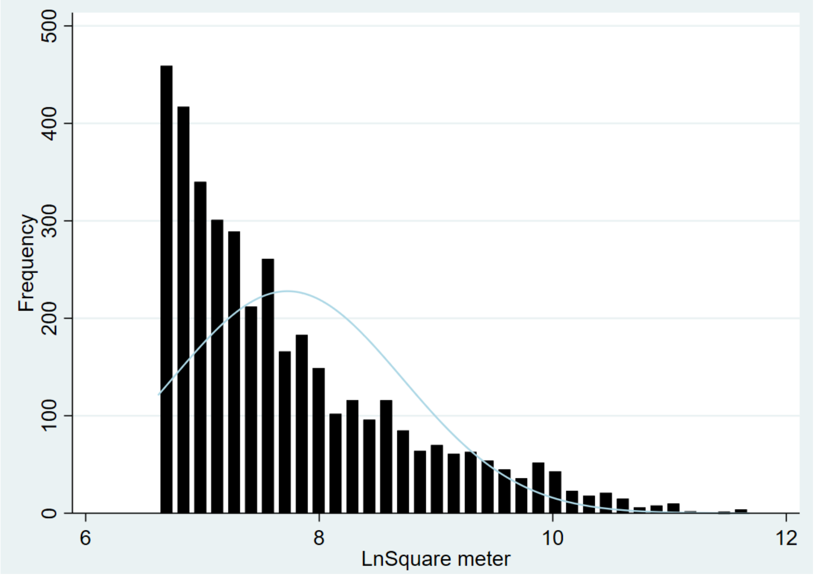


Figure B6: Age in relation to LnRent per square meter

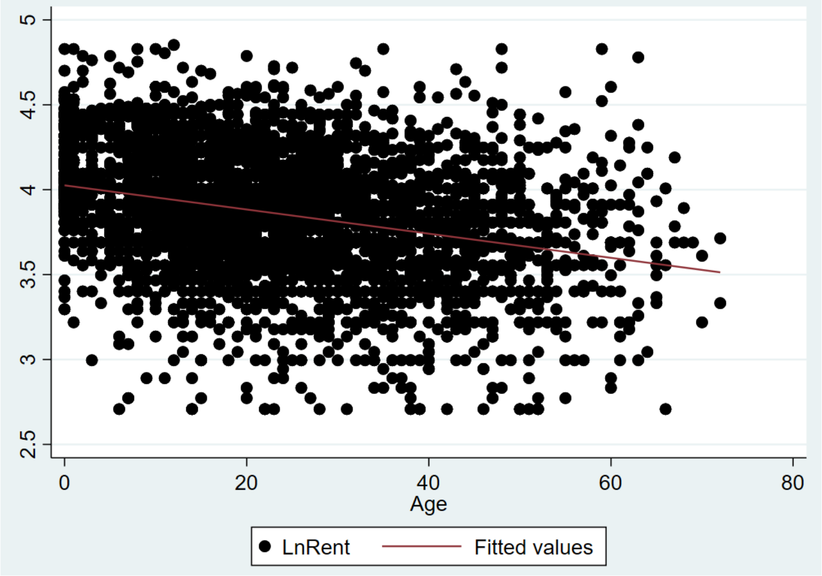
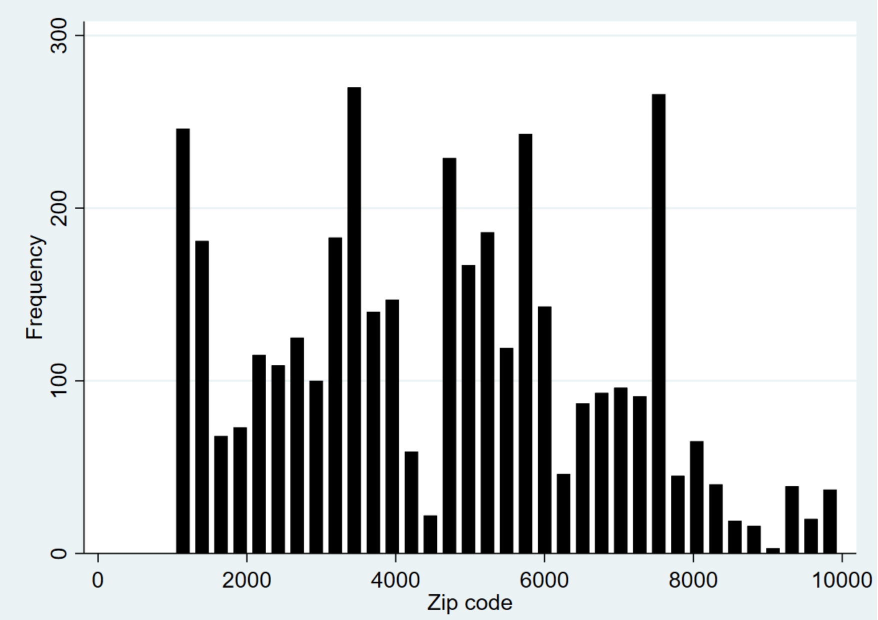


Figure B7: Distribution zip codes



Appendix C – Frequency tables and statistics

Table C1: Frequency table of building periods

Building period	Frequency	%	Cum.
<1991	1,891	48.64	48.64
1992-2001	1,079	27.75	76.39
2002-2011	635	16.33	92.72
>2012	283	7.28	100.00
Total	3,888	100.00	

Table C2: Frequency table industrial cluster

Located in cluster	Frequency	%	Cum.
Yes	3,014	77.54	77.54
No	873	22.46	100.00
Total	3,888	100.00	

Table C3: Frequency table sustainability level

Energylabel	Frequency	%	Cum.
A+++++	10	0.50	0.50
A++++	15	0.75	1.25
A+++	53	2.65	3.90
A++	89	4.46	8.36
A+	129	6.46	14.82
A	851	42.61	57.43
B	270	13.52	70.95
C	295	14.77	85.72
D	118	5.92	91.64
E	65	3.25	94.89
F	33	1.65	96.54
G	69	3.46	100.00
Total	1,997	100.00	

Table C4: Frequency table based on sustainability groups

Energy label	Frequency	%	Cum.
Label B or higher	1,417	70.96	70.96
Label C or lower	580	29.04	100.00
Total	1,997	100.00	

Table C5: Statistics Label B +

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	1,417	53.318	17.292	15	125
Age	1,417	19.097	13.939	0	67
LFA (sq.m)	1,417	4989.291	8163.700	750	98827
Transaction year	1,417	2015.581	4.508	2007	2022
Construction year	1,417	1996.483	14.192	1950	2022

Table C6: Statistics Label C -

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	580	48.672	16.960	15	128
Age	580	30.255	14.964	0	72
LFA (sq.m)	580	3815.255	6169.262	750	60000
Transaction year	580	2014.838	4.554	2007	2022
Construction year	580	1984.583	14.017	1950	2011

Table C7: Frequency table based on part of the country

District	Frequency	%	Cum.
North-East	1,068	18.78	27.47
South	1,157	29.76	47.23
West	1,663	42.77	100.00
Total	3,888	100.00	

Table C8: Statistics North-East

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	1,068	44.505	16.162	15	128
Age	1,068	25.768	15.375	0	72
LFA (sq.m)	1,068	3088.940	5490.107	750	64000
Transaction year	1,068	2015.129	4.698	2007	2022
Construction year	1,068	1989.361	14.929	1950	2022

Table C9: Statistics South

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	1,157	45.954	14.795	15	125
Age	1,157	23.888	15.596	0	72
LFA (sq.m)	1,157	6056.845	10670	750	104322
Transaction year	1,157	2015.104	4.576	2007	2022
Construction year	1,157	1991.216	15.743	1950	2011

Table C10: Statistics West

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	1,663	56.557	18.102	15	125
Age	1,663	23.749	15.324	0	70
LFA (sq.m)	1,663	4086.559	7309.199	750	118696
Transaction year	1,663	2015.285	4.454	2007	2022
Construction year	1,663	1991.536	15.324	1950	2011

Table C11: Frequency table Amsterdam

District	Frequency	%	Cum.
Amsterdam	158	4.06	4.06
Other	3,730	95.94	100.00
Total	3,888	100.00	

Table C12: Statistics Amsterdam

Variable	Obs.	Mean	Std. Dev.	Min	Max
Rent per sq m (EUR)	159	62.075	18.740	20	122
Age	159	24.289	17.311	0	66
LFA (sq.m)	159	4223.597	5404.953	759	33000
Transaction year	159	2015.711	4.301	2007	2022
Construction year	159	1991.421	17.371	1950	2022

Appendix D – Correlation matrix

Table D1: Correlation matrix

This table shows the pair-wise correlation among the numerical variables used in this thesis

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Rent	1.000						
(2) Age	-0.293*	1.000					
(3) LFA	0.031	-0.129*	1.000				
(4) Year	0.057*	0.149*	0.162*	1.000			
(5) Building year	0.310*	-0.955*	0.178*	0.154*	1.000		
(6) Distance highway	-0.006	-0.041*	-0.007	0.031	0.051*	1.000	
(7) Distance train	0.014	-0.025	0.019	0.006	0.027	0.033*	1.000

*p<0.05

Appendix E – Average age-rental relationship of industrial properties

Figure E1: The age-rental relationship

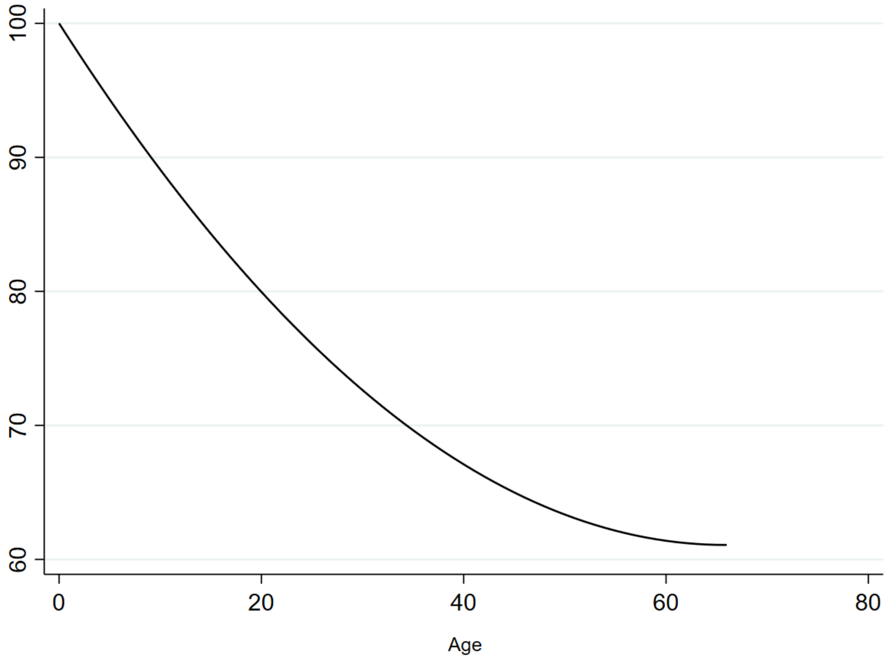


Table E2: Calculation of depreciation estimate

Age	Rate	Value property
0	0%	100%
1	1.17%	98.83%
5	1.10%	94.32%
10	1.01%	89.09%
20	0.83%	80.0%
40	0.47%	67.10%
60	0.11%	61.39%

*The value of the property in year 5 is 100% minus the depreciation rates in year 1 till 4.