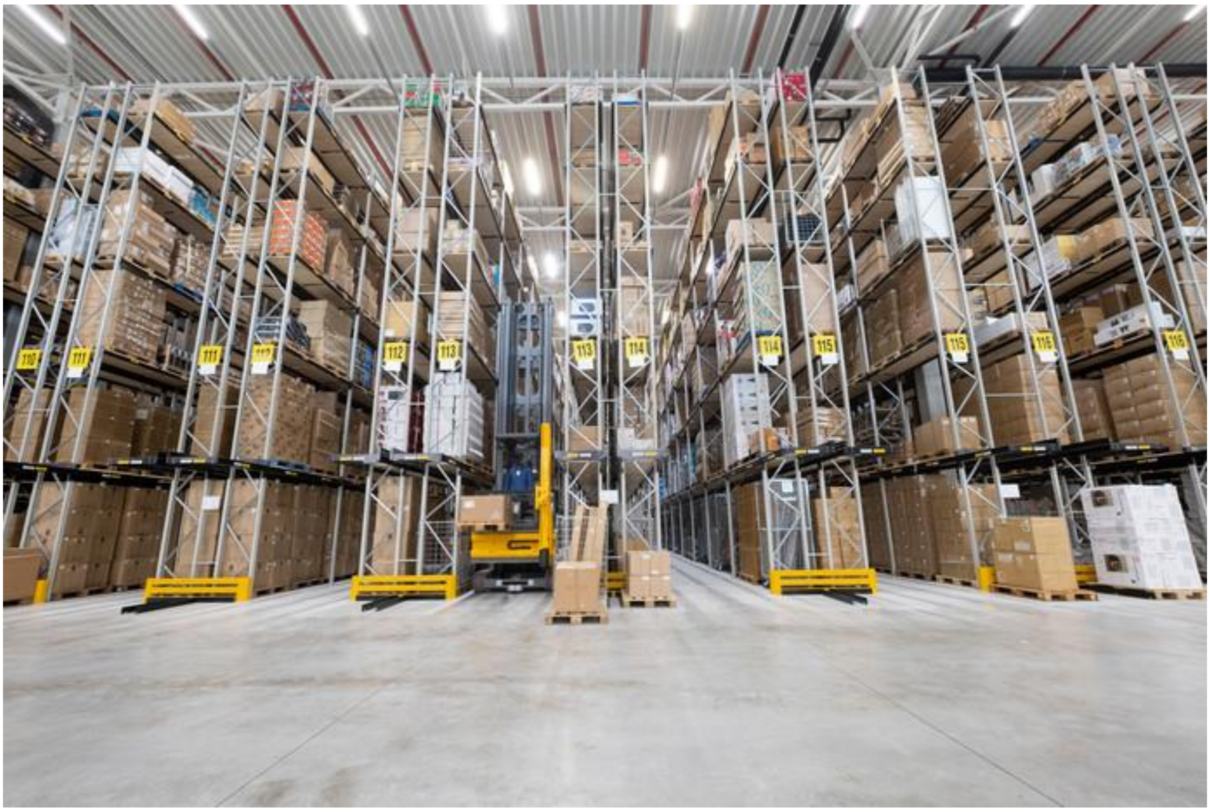
High and Mighty?

The influence of ceiling height on competitive viability of Dutch logistics real estate



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Abstract

This thesis aims to provide data on the effect of ceiling height on competitive viability of logistics real estate. This understanding is necessary to explain how and where lower logistics buildings become more economically irrelevant as time progresses. Utilizing data from the national building registry, combined with their height obtained through remote sensing, correlations between ceiling height, year of construction and location are measured for logistics buildings. Statistical analysis makes it clear that there is a small positive correlation between ceiling height and time, meaning that lower-built warehousing facilities have become more scarce over the years. Additionally, buildings outside of functional urban areas have, on average, higher ceilings than those inside. These observations are in line with economic theory, but crucially use systematic data analysis to underpin common observation with empirical evidence. Even so, regardless of the positive effects of clustering in the logistics sector, the niche market segment outside of functional urban areas is still a profitable one and should certainly be taken into account by real estate investors and logistics enterprises when exploring settlement options.

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1. Introduction

1.1. Background

Within both academic and popular discourse, there is increasing awareness for the causes and effects of rampant urban development. Batty (2008) stresses the necessity of continuous observations of real estate market trends and existing data for making informed development decisions about the future. This can prevent unfavorable situations such as one described in Van Bokkum's news article (2019), in which the expansion of urban areas causes deterioration of the surrounding landscape, to much dismay of local residents. The recent surge in regional and international interest in the Dutch logistics real estate market calls for a better understanding of how logistics real estate development affects urban and rural areas.

One important aspect of this are the physical characteristics of warehousing facilities, which have seen a shift over time. The minimum requirements for warehousing space have risen, due to a need for more efficient storage (Van Zwet & Weck, 2019). The prevalence of online shopping in society, among others, has greatly contributed to this increasing demand for storage space. As companies have started upscaling, the total amount of transportable goods has increased considerably, which in turn leads to a rise in the demand for storage space. Importantly, where a short time ago a ceiling height of 10.8m would have sufficed for the majority of the logistics sector, 12.2 meters has now become the new standard; this leaves 73 percent of the existing warehousing stock unfit for purpose, which has led to a wave of newly built logistics real estate that do comply to these new standards. Thus, the competitive positions of lower-built warehouses has deteriorated over time, as many companies have moved to the larger buildings. This weakened competitive position in the market is reflected in their value: there is much less demand for the older, smaller buildings, often leaving them empty and worthless These buildings need to be either repurposed or demolished, a major task usually paired with large costs.

A possible scenario is that the Dutch landscape will be ridden with big, empty boxes, which are unusable by logistics enterprises for their specific purpose and unprofitable for real estate owners to rent out, but too costly to demolish. A major cause for concern are the effects that these big boxes have on the preservation of the Dutch landscape (Van Bokkum, 2019). Although the demand for logistics real estate in the Netherlands currently exceeds the supply, meaning that even the less suitable facilities will be taken up for now (Bak, 2019), the effects of supply-side changes in the real estate market are known to experience severe lag due to the long lifespan of buildings and the importance of the existing supply in the price mechanism on the market. It is, however, predicted that the considerable growth that the logistics sector has experienced will start stagnating soon enough due to uncertainties surrounding the Brexit and other relevant political relations, which could lead to demand dropping quickly and unexpectedly again (Van Zwet & Weck, 2019). If this happens, the lower-built, less suitable warehouses will be the first to be left vacant, because there are competitively more relevant alternatives available. Therefore, precautions have to be taken before demand starts dropping again to prevent a large increase in vacancy rates. This is why the effects of physical attributes of buildings on their future value need to be considered at the moment of construction, and this thesis serves to provide insight in the role of ceiling height.

The uncertainty of asset value dynamics becomes apparent when looking through past researches on the matter. Knowledge of the role of ceiling height in determining real estate value has been very inconsistent. Many researchers have attempted to discover a connection between the two, but their results do not agree (e.g. Ambrose, 1990; Buttimer et al., 1997; Fehribach et al., 1993; McDonald and Yurova, 2007; Oh, 2019). On the one side are studies that do not support the notion that asset value increases with ceiling height. Ambrose (1990) tested various physical characteristics, including ceiling height, on their effect on the asking price and lease rents of light industrial real estate (which includes warehousing facilities), but found no statistically significant relation between the ceiling height and the asking price. As for the lease rent, ceiling height had a significant, but negative effect ($0.29 rent decrease per square foot of building for every extra foot of ceiling height). He explains this by saying that office space in general is more expensive, which requires a lower ceiling height than warehousing. Additionally, large companies that purchase space usually require larger buildings more suited for industrial needs with little office space, whereas smaller companies that lease space require more office space rather than specialized industrial space. Buttimer et al. (1997) support these findings, although they ended up with a lower annual real rent decrease per square foot surface area for every extra foot of height (about $0.11), reinforcing that warehouse space is less expensive when calculated on a per square foot basis.

On the other hand, some studies do find a positive relation between ceiling height and asset value. Fehribach et al. (1993) expanded upon Ambrose's research, using the same physical variables and calculation methods, but also tried to improve the model by adding locational, financial and economic factors into the analysis (such as the industrial capitalization rate, date of sale, distance from an important economic hub etc.). Their model had a substantially higher R^2 than Ambrose's, implying that their model was more competent in explaining the property value. They found a statistically significant, but positive effect of ceiling height on the sales price. However, no further explanation of this finding is given by the authors. McDonald and Yurova (2007), using similar methods, found a positive relation between ceiling height and selling price, but this relation was statistically insignificant. More recent literature, such as Oh (2019) also confirms a positive relation.

Do note that the disagreements within this selection of literature span a long time period; shifts in the warehousing real estate market in different countries over time may well be the cause of this inconsistency. This, however, further proves the necessity of performing ongoing research and data collection on real estate market trends and mechanisms. The real estate market is volatile because of constantly changing conditions and guidelines. Continuous measurements and analyses are essential for obtaining a better understanding of future real estate market dynamics, which is currently lacking. This importance will be explained in further detail in the theory section, in the context of the work of Batty (2008) regarding the growth of cities.

1.2. Research aim

The aim of this thesis is to discover the effects of ceiling height on the competitive position of warehousing facilities, and to find a spatial pattern of the irrelevance of lower-built facilities. The main focus will be on the size of the building, to what extent it contributes to their decreasing value and in which regions in the Netherlands this depreciation is felt the most. The main research question is: *How has ceiling height affected the competitive position of Dutch warehouses over time?* First, the mechanisms behind economic depreciation in the real estate market, as well as the role of physical building characteristics on asset value and redevelopment, are explored through literature research. Assuming that higher ceilings are necessary in modern times to accommodate for tighter minimum requirements and increased storage needs, these factors need to be discussed to gain an understanding of how ceiling height influences the competitive viability of the building. Afterwards, statistical and GIS data will be employed to establish key stylized facts, show the trend in ceiling height over time and where depreciation is most prevalent: within functional urban areas (FUA's) or outside.

The next section will discuss relevant literature regarding important mechanisms in the real estate market. Afterwards, in part 3, the data sources and collection process will be described, as well as how the resulting data will be analyzed. The results and analyses will be discussed in part 4.

2.The mechanisms of competitive position and depreciation

2.1. Literature: competition and obsolescence

The value of warehousing facilities, or real estate in general, is determined by many factors simultaneously playing off of each other, but one of the most important factors is its advantages in comparison to alternatives. Porter (2008) analyzed in great detail the forces of competition in industrial markets. He identifies five important forces that drive competition, and therefore subsequently the profitability: the threat of new entrants, the bargaining power of buyers, the threat of substitute products, the bargaining power of suppliers and existing rivalries within the industry branch. Most of his model is equally applicable to the logistics real estate market: newer, more suitable facilities make the older, less suitable buildings irrelevant, driving their profitability down. Furthermore, the availability of substitutes prevents the real estate owner from charging whatever rent they want, because the cheaper alternative will be more attractive. Suppliers of warehousing facilities hold greater power when their buildings are more catered to special storing needs; they can ask a higher rent because their facility serves a more restricted sector within the logistics industry, and therefore faces less competition from other facilities. Fierce competition between logistics firms restricts them in relaying the high rents to their service fees, as that would lower their competitive position. Logistics firms can also face large switching costs when moving to a new facility if they have invested resources in their warehouse for necessary structural changes, which would have to be repeated if they were to switch to a new location.

A number of these factors are influenced by ceiling height. As reported by Van Zwet & Weck (2019), the average amount of goods stored in warehouses has increased, meaning that the need for larger storage space has risen. This led to new market opportunities and new gaps for real estate investors to fill up. Those who were on the forefront of this development initially experienced little competition, and could capitalize on that fact. This profitable market attracted subsequent adaptation from other investors, increasing competition and reducing the profitability. In time, the lower-built warehouses are no longer considered substitutes for what is now the norm in the market, due to their unsuitability. These developments are reflected in their long-term investment value: a building will become less profitable if it is expected that it needs to undergo redevelopment in a shorter time.

Establishing a connection between ceiling height and asset value is important to make the link between the building's ceiling height and its loss of value over time. In real estate, property depreciation is defined as the loss of investment value. As the literature has shown, this loss has two causes: physical deterioration of the building (aging, wear and tear etc.), and obsolescence. This thesis will focus on the latter, as under normal circumstances the height of the building should not deteriorate with age or wear and tear. As Mansfield and Pinder (2008) extensively discuss, the term 'obsolescence' is vague and especially hard to fully define. There are many different factors simultaneously at play, which all could potentially lead to a building being declared obsolete. These factors can roughly be categorized in 3 types of obsolescence: physical, economic and functional obsolescence (Bokhari & Geltner, 2016; Mansfield & Pinder, 2008). In broad terms, physical obsolescence means the physical neglect of a building leading to wear and tear over time (meaning it is synonymous with deterioration and therefore not actually a form of obsolescence, according to Mansfield and Pinder (2008); economic obsolescence means that the building is no longer fulfilling the highest and best use (HBU) due to external economic factors (e.g. commercial real estate becoming more profitable than residential on the same plot of land); functional obsolescence means that the building is no longer the most suitable for its function compared to other buildings (Bokhari & Geltner, 2016). As building height inarguably falls under the domain of functional obsolescence, this is the primary aspect of depreciation which this thesis will discuss. An important aspect in functional obsolescence is that it is mostly driven by speculative building: brand-new buildings with the highest level of technical innovation can quickly become the new market standard when adopted by other market participants. This process forces the older buildings into irrelevance, because in reassessing their values, they fall below the now risen benchmark (Mansfield & Pinder, 2008). Economic rationale dictates that once the value of a building has dropped to a point where it is no longer profitable to retain it, compared to the HBU plus any relevant reconstruction, renovation or demolition costs, the decision for redevelopment will be taken.

This means that land prices are another essential factor to be considered, as they can make up a sizable portion of the total costs of redevelopment. Wheaton (1974) summarized the previous revolutionary works of Alonso (1964), Muth (1961) and Mills (1967) into one aggregated model, connecting land prices to distance from metropolitan centers. At the basis of his model lies a number of assumption. First is the assumption that travel costs increase linearly with distance to the city center. The second assumption is a monopolistic land market, meaning that the land will always be sold to the highest bidder. These two assumptions lead to a model showing decreasing land prices the further a location is removed from the city center. As such, density increases in the city center, because these locations are considerably more attractive for real estate developers to invest in. It should naturally follow that logistics buildings settle at the edges of cities, mainly due to lower land prices and higher land availability, which are favorable for such buildings which take up large amounts of space. This is, of course, a very simplified image, and does not factor in important aspects such as the importance of accessibility in the logistics sector, as well as the restrictions that zoning may impose on settlement options.

Whereas the timing of redevelopment has been made relatively clear, it is not always obvious where such redevelopments will take place at any given moment. After all, taking into account the theoretically decisive factors discussed above, there remain plenty of options in any given city for logistics firms to settle or develop. This is one of the many uncertainties in city growth. Batty (2008) points out that city development has always been an unpredictable process. Past trends and theories are more often than not insufficient in explaining outward city growth. Therefore, in order to obtain the best possible understanding of this process, continuous gathering of empirical facts is essential. This is what this thesis primarily aims to do.

2.2. Conceptual model

Figure 1 shows a conceptual model in which the theoretical connections are laid out. Based on the first part of the theoretical framework, the conclusion can be drawn that the building height is connected to the value of the building. However, a higher ceiling does not necessarily mean a better competitive position. If every building becomes taller, the relative difference in ceiling height remains roughly the same. Furthermore, there is a limit to the profitability of a higher ceiling. Real estate developers cannot keep building upwards indefinitely, because at some point the construction costs will exceed the investment value. This precarious balance denies the possibility of a one-way causal relation between the relative ceiling height and the competitive position of a building. What can be said, though, is the negative relation between rising building standards and competitive position. It has been shown that changing demands within the real estate market leads to new standards against which the entire market is compared (Mansfield & Pinder, 2008). If the current ceiling height of a warehouse does not comply with the new standards, it gradually becomes more functionally obsolete, which is reflected in the building value (Bokhari & Geltner, 2016). The minus sign serves to represent that process. Using this model, the effect of ceiling height on the competitive position on Dutch warehousing facilities will be analyzed.

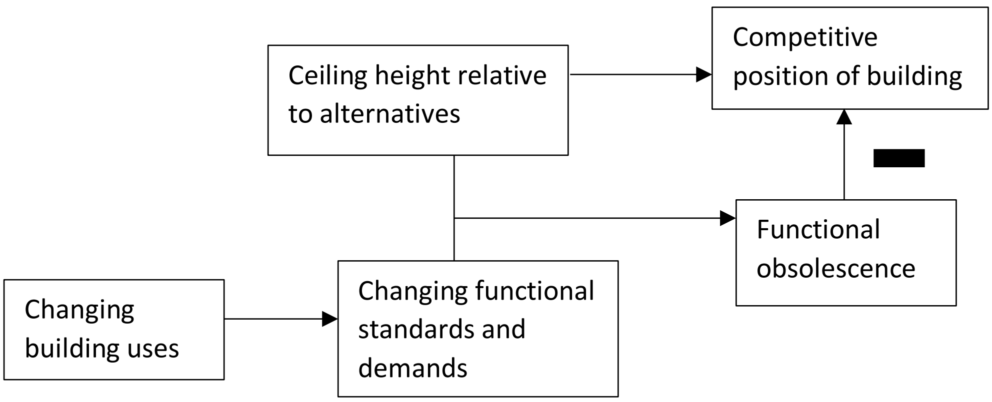

Figure 1: conceptual model of the effect of ceiling height on competitive viability.

2.3. Hypotheses

The main hypothesis is that the lower-built warehouses in the Netherlands have become more economically irrelevant over time due to rising standards in building height. To support this, it is expected that the ceiling height has increased over time to meet and subsequently create newer standards. As growth within cities has always been unpredictable and can only be deciphered by careful measurements (Batty, 2008), it will be valuable to know whether this increase has been steady or erratic. It is also hypothesized that depreciation will hit hardest outside of important logistics regions, as the spaces in those regions are still more valuable due to their proximity to important transport hubs such as the Rotterdam port, or the logistics clusters with favorable locations providing good access to their hinterland (such as Venlo).

3. Methodology and data

This thesis mainly serves to provide insightful data on current market trends. Therefore, quantitative data analyses and maps will be employed to explore available real estate data sources. The largest task is compiling the relevant data. This data needs to be retrieved from multiple sources. First off, to obtain the locations and information on buildings, the *Basisregistratie Adressen en Gebouwen* (BAG) (Address and Building Registry) will be obtained from the land registry office (Kadaster, 2019). This data is free to use for everyone, and contains, among others, its full address, surface area, year of construction, primary function, coordinates and several identification numbers for every building in the Netherlands. The 'primary function' allows for a preliminary filter for logistics real estate: warehousing belongs to 'industry functions', so this is the only category which will be considered for analysis. Additionally, only buildings which are currently built and in use will be analyzed (the BAG also contains data on to-be-built sites). The aforementioned identification numbers are a nationally used system to register buildings, which allows multiple data sets to be linked to one another. This is crucial in gathering the remaining necessary data and linking them to their respective buildings.

Another essential piece of data to be collected is, naturally, the ceiling height. The *Actueel Hoogtebestand Nederland 2* (AHN2) (AHN, 2019) is a data set containing the height for every 0.2m^2 in the Netherlands. This data was gathered through remote sensing: every piece in the raster data is the result of lasers shot from helicopters and airplanes, resulting in a point cloud. This allowed for measurements at multiple levels, based on how many points are on the given percentile. For example, the results at the 75th percentile mean that 75 percent of all the points are equal to or lower than the given height. One drawback to remote sensing, however, is that it might produce rather inaccurate data. This needs to be taken into account when interpreting the results in part 4. This data set in itself would be insufficient to determine the height of every building in the Netherlands. To make this data more usable, the 3D Geoinformation group (2019), under the supervision of the Delft University of Technology (TU Delft) merged together the ID numbers from the BAG with the height measurements of the AHN2 to create BAG 3D. The ID numbers are used to connect the height data to the original BAG to give every individual building its corresponding height. While it is assumed that most ‘big boxes’ have approximately flat roofs, the 75th percentile will be used to account for any offshoots that might be present, such as chimneys or antennae. Following this assumption, any buildings with a given height of less than 2 meters will be left out of the analysis, compliant to the minimum requirements as stipulated in the Bouwbesluit 2012 (Rijksoverheid, 2011).

The next task is to filter out which buildings fall into the logistics sector. As mentioned before, the ‘industry function’ makes for a preliminary selection. Additionally, only those buildings with a surface area of more than 10000m^2 are used to filter out the small storage facilities which cannot be classified as ‘big boxes’. This still leaves a number of irrelevant buildings, such as gardening centers, greenhouses etc. Due to limitations in the available data, it is nigh impossible to filter out only those buildings which qualify as logistics real estate. To maximize the chance that the data set is made up of only buildings used for logistics purposes, the *Landelijk Informatiesysteem voor Arbeidsplaatsen* (LISA) (2019) will be used. The LISA data provides for every building a description of the primary function of the company renting the building. However, it does not specify the function of the building itself. For example, a distribution center of a supermarket chain would receive the description of a wholesale food company with a general supply. This is rather vague, which makes it hard to discern which categories are actually usable for this research. A manual check for each building is unfeasible due to the large amount of cases, time constraints and inaccuracy in the listed addresses. Therefore, a careful selection of categories will be made (which can be seen in Appendix A), and to account for the possibility of analyzing buildings which should not fall under the scope of this research, the analyses will be performed in two steps. The first step includes both logistics companies and many wholesale branches, which also utilize logistics real estate, but might also include less suitable buildings. The second step includes only those companies which are purely for logistics purposes (storage and road transport to be precise). This categorization is still not entirely devoid of unsuitable buildings, but it is the closest approximation possible with this data. Comparisons will be made between the results and the implications of the two analyses. The building year will be used to draw a scatterplot showing the development of ceiling height over time, assuming that no additional construction has taken place to raise a building after its initial completion.

Ideally, the economic relevance of a building is measured by its current asset value. This data is not publicly available as it is, and moreover fragmented and privately held by real estate industry actors. Therefore, the results will be limited to producing statistics on the dynamics of ceiling height over time and between regions, as well as constructing maps to show spatial patterns, and drawing conclusions from these. It is expected that construction year, ceiling height and location away from urban centers all contribute to the determination of a building’s value. To verify the aspect of location, this thesis will take a look at differences between buildings according to their location within or outside of a functional urban areas (FUA's). The concept of FUA's was designed by the Organization for Economic Co-operation and Development (OECD), and is defined as ''economic units characterised by a city (or core) and a commuting zone that is functionally interconnected to the city'' (OECD, 2019, p.1). The borders of these areas are freely available as a shapefile on the website of the OECD. To determine whether their location has an effect on their competitive viability, a binary variable for FUA's will be made in the data ("1" if located within a FUA, "0" if not). This will allow for an observation of the spatial spread of lower-built warehouses, and statistical analyses between the groups. Lastly, to make the distinction between areas with high and low population densities more clear, the correlation between ceiling height and population density per municipality will be calculated. Population density is obtained from Statistics Netherlands (CBS, 2019). Using the statistics from Bak (2019), important logistics regions can be distinguished from the less important regions. To make an estimate of a building's competitive position, the ceiling height, building age, location and availability of reasonable substitutes in the same area need to be taken into account.

4. Economic viability in Dutch logistics real estate

4.1. Height trend over time

As mentioned in the previous section, every analysis will be done twice: one for those buildings which are certain to be used for logistics purposes (will be referred to as the 'pure' selection), and one for a more broad selection of buildings. Due to inaccuracy of the BAG 3D, there were a number of unusual outliers. After manual verification, it was found that these cases had an incorrect given height (between 60 and 100 meters high). Even if there are chimneys or antennae present which may have caused this error, these occurrences should have been accounted for by utilizing the 75th height percentile, as discussed in the section regarding data and methodology. These outliers have been filtered out of the sample to avoid incorrect analyses.

Figure 2A shows the frequency of buildings per year for the broad selection, Figure 2B for the pure selection. The majority of the buildings were constructed after 1950. The most recent records are from 2016, meaning that no conclusions can be made regarding the state of the logistics real estate market from 2017 onward. This problem is inherent to the construction of real estate: due to their long production times, there is a severe lag in the availability of the data on these buildings. This makes it even more important to gather and analyze as much data on real estate as possible, as Batty (2008) illustrates: there is a larger degree of uncertainty present, which makes predicting future real estate market trends a harder task.

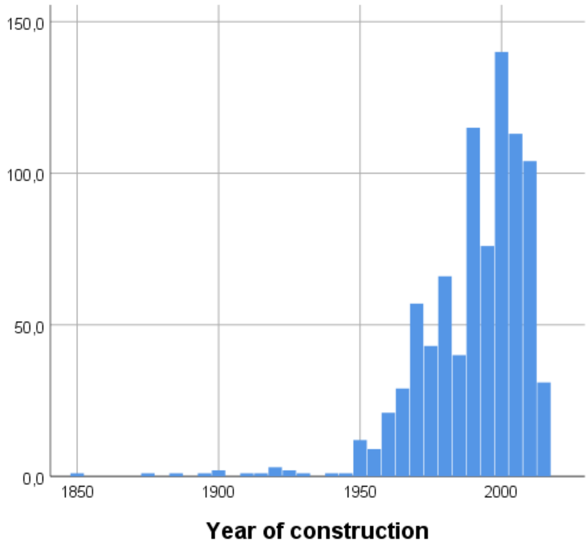

Figure 2A: distribution of buildings over time, broad selection. N = 872

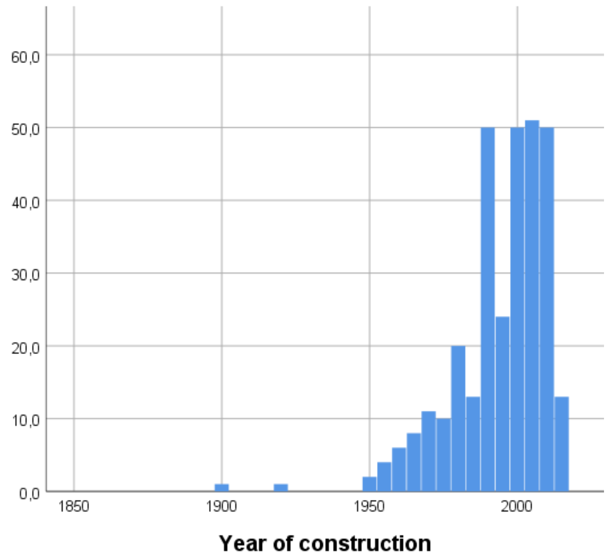

Figure 2B: distribution of buildings over time, pure selection. N = 314

To get a general idea of the distribution of ceiling height in the market, a histogram showing the ceiling height on the x-axis was made (Figure 3A and 3B). Of note is that the two selections show a very similar distribution pattern: a large peak between 8-20m high, a drop afterwards and then another small peak between the 30-40m range. Again, there are still some buildings with less than believable given heights, but these were not statistically defined as outliers, and as such were not removed from the sample.

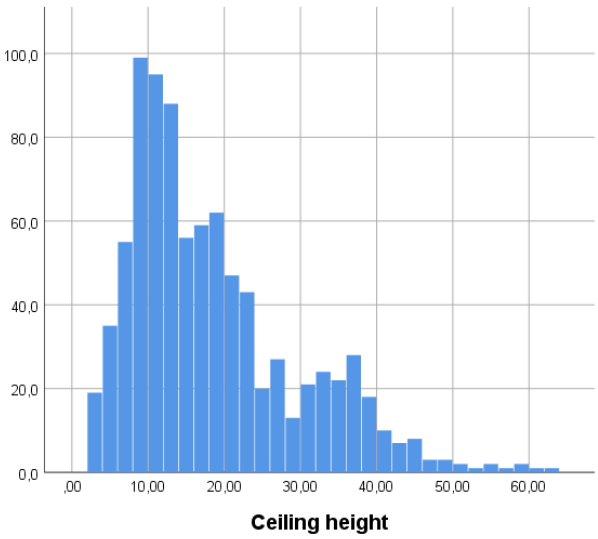

Figure 3A: distribution of ceiling height, broad selection. N = 872

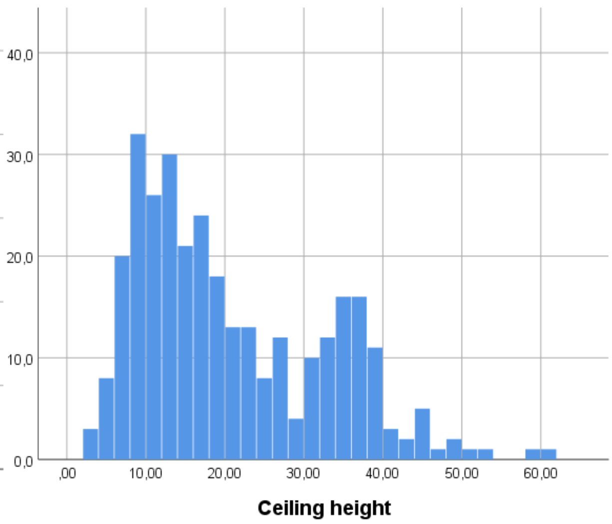

Figure 3B: distribution of ceiling height, pure selection. N = 314

To assess whether the ceiling height has indeed increased over time as the reports would suggest (Van Zwet & Weck, 2019), a Pearson Correlation coefficient is calculated. These statistics are shown in Table 1A and 1B. In both selections, there appears to be a statistically significant ($p < 0.05$), albeit weak, positive correlation between the two variables, with a slightly stronger correlation when only looking at the pure selection. This confirms the second hypothesis made in the theory section.

Table 1A: Pearson Correlation coefficient between year of construction and ceiling height, broad selection.

		Ceiling height
Year of construction	Pearson Correlation	,128
	Sig. (2-tailed)	,000
	N	872

Table 1B: Pearson Correlation coefficient between year of construction and ceiling height, pure selection.

		Ceiling height
Year of construction	Pearson Correlation	,168
	Sig. (2-tailed)	,003
	N	314

The scatterplots in Figure 4A and 4B serve to visualize this apparent correlation. The regression line is shown in red. The similarity in distribution becomes apparent once again. When glancing over the figures, the wave-like distributions mentioned earlier are visibly present as separate concentrations of points on the graph, divided by a noticeably thinner line of points. Notice that both plots are roughly shaped like upwards slanting triangles, further reinforcing the idea of a slight trend of increasing ceiling height over time. What can also be seen, especially in the broad selection, is that the density of buildings shifts slightly upwards after approximately 1980, meaning that the modal height has also increased. Nevertheless, there is still a number of buildings built before 1950 that are still in use and have not been redeveloped yet, meaning that these buildings are still profitable after all these years relative to the next best use of the underlying land.

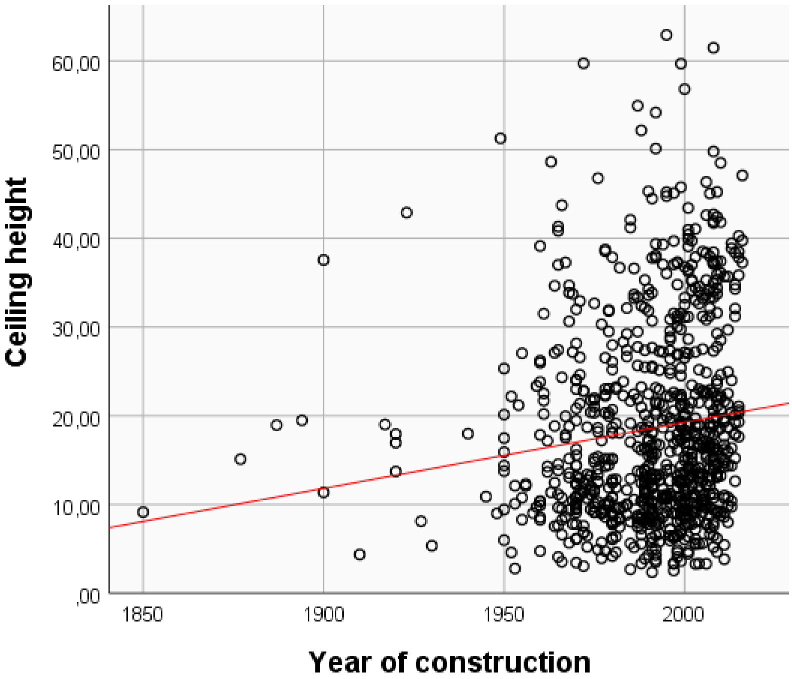

Figure 4A: scatterplot of ceiling height over year of construction, broad selection.

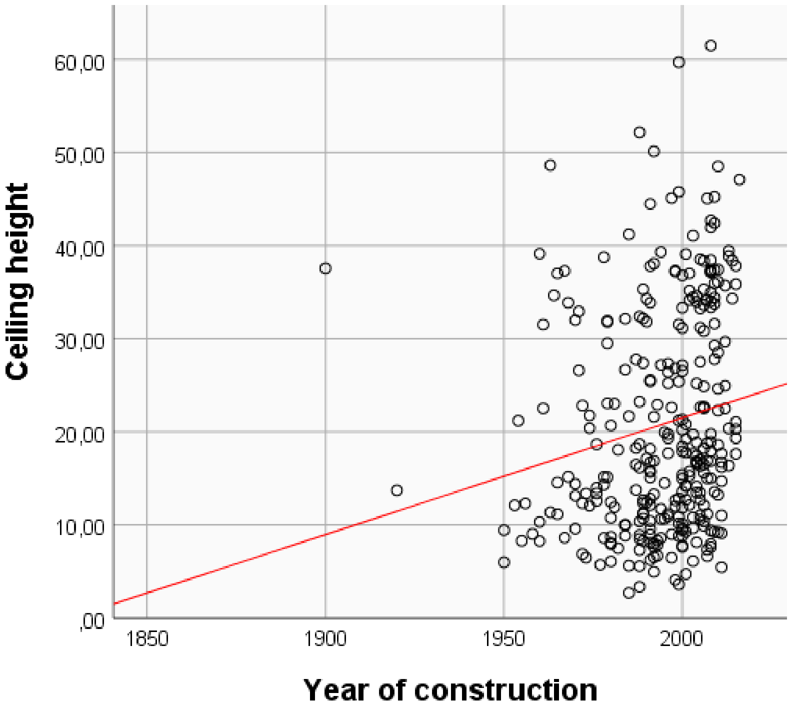

Figure 4B: scatterplot of ceiling height over year of construction, pure selection.

4.2. Spatial distribution of logistics activities

Figure 5 on the next page shows the locations of the buildings as points on a map of the Netherlands (note: all buildings in the pure selection are also in the broad selection), as well as the borders of the FUA's. The reason these borders may appear strange, like stretching over bodies of water around Flevoland, is because they were drawn in such a way that they includes the entire area from which the majority of the core region's commuters come from. This might also include inhabitants on the other side of a body of water, which can be crossed by bridges or dykes. The prevalence of important logistics clusters as mentioned in Bak's report (2019) is made clear in this map: many buildings are located in the vicinity of Amsterdam, Haarlemmermeer, Rotterdam (or the Randstad in general), Tilburg and Venlo. The northern and eastern parts of the Netherlands, however, appear to be far less interesting locations for logistics activities. This is likely the case due to the absence of major ports and the inconvenient location with respect to the rest of Europe, making operations in these areas less profitable. The industry branches in the broad selection are seemingly more dispersed as opposed to the pure selection; aside from the expected clusters as mentioned above, there are many facilities outside of these areas as well, filling in the areas in between.

Next, the split between inside and outside of a FUA will be made. Afterwards, the average heights will be statistically compared to each other. The tables containing the results of the independent samples t-test can be seen in Table 2 and 3 on page 17.

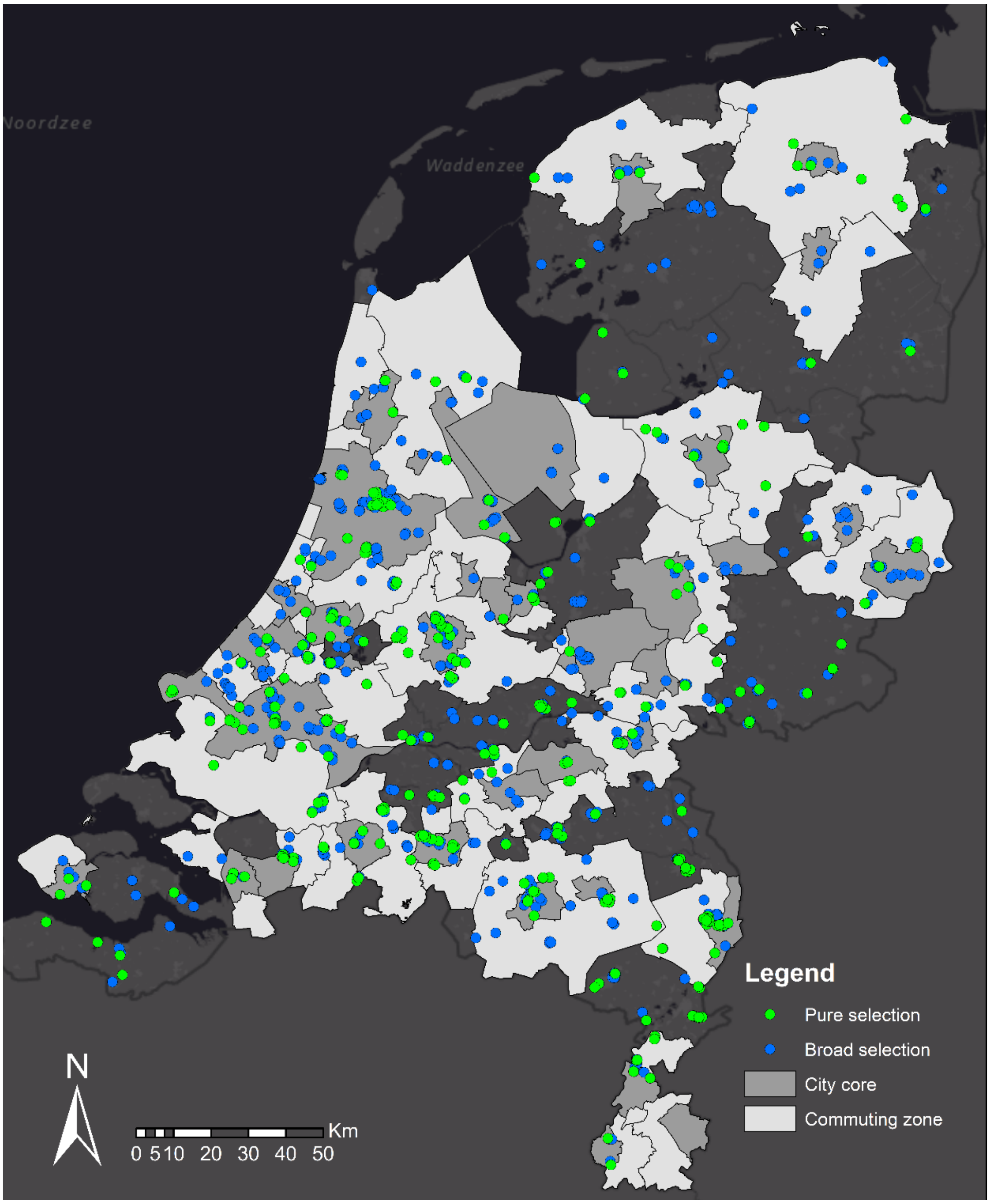

Figure 5: map showing the spatial distribution of logistics activities and functional urban areas.

Table 2: Group statistics of mean ceiling height divided by inclusion in FUA, both selections.

		FUA	N	Mean	Std. Deviation	Std. Error Mean
Ceiling height	Broad selection	No	214	19,9016	10,44957	,71432
		Yes	658	18,0977	11,31556	,44113
	Pure selection	No	79	23,1611	11,13436	1,25271
		Yes	235	19,9487	12,03536	,78510

For both selections, the collection of buildings outside of a FUA has a higher average ceiling height compared to the buildings within the FUA's. Table 3 below shows that this difference is statistically significant for both selections ($p < 0,05$). This might mean that due to their more remote location, they need to offer higher ceilings for specialized purposes to remain profitable, whereas buildings within FUA's do not need such heights to hold a competitively strong position thanks to their more favorable location. Real estate developers would prefer new assets be created inside of FUA's rather than outside for the prospect of better returns. As a result, competition within FUA's is much more fierce than outside, with about 75% of all selected buildings being located within FUA's. As Porter (2008) pointed out, this prevalence of suitable alternative locations for logistics enterprises to settle in imposes a limit on the profitability of these locations; an issue buildings in outside regions experience less. Additionally, with buildings so close to one another, there is considerably less room to expand if necessary. Even so, in order to stay relevant, real estate developers need to continue innovating, which may include rising higher. All in all, the distinction between inside and outside of FUA's regarding profitability and competitive viability is not as clear-cut as one might assume.

Table 3: Results of the independent samples t-test for mean ceiling height between inside and outside of FUA's, both selections.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Broad selection	Equal variances assumed	,133	,716[1]	2,063	870	,039	1,80387	,87427	,08795	3,51979
Pure selection	Equal variances assumed	,059	,808[1]	2,090	312	,037	3,21246	1,53677	,18872	6,23620

[1] Because $p > 0,05$ for equal variances, the rows concerning unequal variances were omitted from the table to remove unnecessary clutter.

Lastly, the correlation coefficient between municipal population density and ceiling height is calculated, the results of which can be seen in Table 4A and 4B. For both selections, population density and ceiling height are negatively correlated, meaning that municipalities with lower population densities (e.g. outside of FUA's) have, on average, higher ceilings. This further reinforces the points made on the previous page. It may well be worth for future research to further dig into this phenomenon.

Table 4A: Pearson Correlation coefficient between ceiling height and municipal population density, broad selection.

		Municipal population density per km^2
Ceiling height	Pearson Correlation	-,142
	Sig. (2-tailed)	,000
	N	872

Table 4B: Pearson Correlation coefficient between ceiling height and municipal population density, pure selection.

		Municipal population density per km^2
Ceiling height	Pearson Correlation	-,160
	Sig. (2-tailed)	,004
	N	314

5. Conclusions

In this thesis, the current situation in the logistics real estate market was explored through extensive data analysis. The focus was on the effect that ceiling height has on the competitive position of logistics buildings. Batty (2008) emphasized the necessity of continuous data collection and analysis, saying that this process is the best way to obtain an understanding of how cities will grow and take shape in the future. Scientific theory and corporate reports show that not all logistics buildings are built equally; as new guidelines and requirements regarding free storage space are instated, the market determines which buildings survive and which are left vacant. Functionally restricted buildings become obsolete, resulting in new real estate sprouting in favorable locations, oftentimes setting new precedents (Mansfield & Pinder, 2008). Fed by this cycle of ever-changing guidelines, ceiling heights are on the rise, both to comply to official standards and to remain profitable in the fierce competitive landscape. To confirm these theories, national registry data on logistics buildings in the Netherlands, including their ceiling heights, have been thoroughly discussed and analyzed. First, a correlation between ceiling height and construction year was calculated to try to confirm the assumption of an increasing ceiling height over time. A weak but positive correlation between ceiling height and construction year has been found, meaning that, on average, logistics buildings are being built slightly higher than in the past. Additionally, location has also been shown to be of importance. The South and West of the Netherlands are convincingly more profitable when compared to the North and East, thanks to their proximity to major ports or along road transport networks. The Randstad remains the center for logistics activities, especially the urban centers. However, when it comes to location in relation to functional urban areas, it becomes apparent that outside regions, should not be disregarded: they still amount to a sizable portion of the market share with great opportunities. An independent samples t-test found that logistics buildings outside FUA's have a higher average ceiling height. Because of this, combined with greater expansion potential, these buildings provide a profitable niche for the logistics real estate market, while the buildings inside of FUA's must overcome severe competition to remain one step ahead.

The findings in this thesis can prove useful for real estate investors and logistics companies alike to explore potential locations for new developments. A better insight in the role of ceiling height on their building's profitability makes way for more educated construction to increase the longevity of the building and postpone the moment of redevelopment as much as possible. Additionally, more insight in the locational factors of a building's profitability allows for more creative spatial planning solutions, allowing developers to keep running their business while also preserving the pleasing aesthetics of open landscapes. Real estate development remains a market segment rife with uncertainty, but more data means more insight in past trends and more informed decision-making in the future (Batty, 2008).

While the information in this thesis provides an introduction to the role of ceiling height in a building's competitive viability, it would have been much more substantial with data on asset value. This had to be approximated by locational and physical factors of the building in this thesis. For a much more substantial argument, actual asset and land values need to be used to create a more clear insight in the effect of ceiling height on rents. Furthermore, the data used in this research is only a snapshot of the current situation. If there were available data on past real estate developments on the same locations as current buildings, a per-location timeline of redevelopment timing could be made, which would give much more insight in local market dynamics and deterioration rates. Such data appears to be unavailable to the general public, and as such could not be included here.

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Appendix A: Selection of industry branches

Pure selection:

-49.41 Goederenvervoer over de weg (geen verhuizingen)

-52.10.2 Opslag in koelhuizen e.d.

-52.10.9 Opslag in distributiecentra en overige opslag (niet in tanks, koelhuizen e.d.)

-52.21 Dienstverlening voor vervoer over land

-52.24.2 Laad-, los- en overslagactiviteiten niet voor zeevaart

-52.29.1 Expediteurs, cargadoors, bevrachters en andere tussenpersonen in het goederenvervoer

Broad selection:

-45.1 Handel in auto's en aanhangers, eventueel gecombineerd met reparatie

-45.3 Handel in auto-onderdelen en –accessoires

-45.4 Handel in en reparatie van motorfietsen en onderdelen daarvan

-46.3 Groothandel in voedings- en genotmiddelen

-46.4 Groothandel in consumentenartikelen (non-food)

-46.5 Groothandel in ICT-apparatuur

-46.6 Groothandel in machines, apparaten en toebehoren voor industrie en handel

-46.7 Overige gespecialiseerde groothandel

-46.9 Niet-gespecialiseerde groothandel

-47.91 Detailhandel via internet

-49.41 Goederenvervoer over de weg (geen verhuizingen)

-50.20.1 Zee- en kustvaart (vracht- en tankvaart; geen sleepvaart)

-50.40.1 Binnenvaart (vrachtvaart)

-50.40.2 Binnenvaart (tankvaart)

-51.2 Goederenvervoer door de lucht

-52.1 Opslag

-52.21 Dienstverlening voor vervoer over land

-52.24 Laad-, los- en overslagactiviteiten

-52.29.1 Expediteurs, cargadoors, bevrachters en andere tussenpersonen in het goederenvervoer