Noise pollution and residential property prices- announcement effects of an expansion of Lelystad Airport

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The significant increase in the number of global aircraft movements over recent years, resulting in an increasing spatial integration between settlement areas and airport locations, is controversial. Discussions about negative external effects of airports have originated. In this context, this study analyses the influence of the announcement of the expansion of Lelystad Airport on transaction prices of residential real estate under possible flight paths, by applying a hedonic price model with a difference-in-difference approach. Unlike most studies, I focus on the announcement effects (*ex ante*). The findings indicate that transaction prices of homes within a 4-kilometer distance from the possible flight paths decrease by 2.1% in the period after the announcement. In this context, changing economic values of residential real estate become an important aspect for both owners of residential properties and policy makers.

Keywords: noise pollution, transaction prices, property values, hedonic price model, regression analysis, difference-in-difference design, Lelystad airport

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Content

1. Introduction

Over the last decade, flying has become a more common good for a broad section of the world's population; as a result, commercial airlines carried over four billion passengers on scheduled flights in 2017 (Airport Council International, 2017). Statistics show that the number of scheduled passengers handled by the airline industry globally increased by 7% in 2017 compared to 2016 (IATA, 2017). Furthermore, the aviation organization IATA predicts that the number of air passengers will double in the next twelve years (IATA, 2017). In the context of the increasing amount of globally aircraft movements, spatial integration between airport locations and settlement areas become an ever-growing challenge.

Societal discussions, some of them controversial, have arisen mainly about the negative effects of airports, mainly due to aircraft noise. Noise, produced by airplanes, can be seen as an important disutility negatively affecting the property prices in regions within flight routes and airports (Mense & Kholodilin, 2014). The first controversy about feared loss of real estate assets value arose with regard to the expansion of London Heathrow in the early 1970 (Mackie, 2016). More recent, the importance of this topic is highlighted in discussions surrounding the development of the Berlin Brandenburg Airport, the construction of the new runway in Frankfurt am Main, as well as the expansion of London Heathrow Airport with a third runway (Lehrke, 2017; Erlenbach, 2016; Departement For Transport, 2009). Following these examples, great public debates appear between proponents who admonish the effects on noise and pollution and proponents who accentuate the local economic development and associated benefits to quicken region's economic growth (Jud & Winkler, 2006). This thesis seeks to contribute to the controversial discussion between residents and policy makers by estimating the economic effects of an airport expansion in the local housing market.

Concerning the Netherlands, controversial discussions arose about the prospective expansion of Lelystad airport. The largest airport of the Netherlands, Schiphol Airport, faces capacity problems for the reason that a maximum number of 500.000 flight movements per year may not be exceeded (Volkskrant, 2017). Respecting this, Lelystad Airport will expand to buffer the additional growth by taking over the charter flights from Schiphol. From 2019 onwards, Lelystad Airport will start processing 10.000 flight movements and will be expanded to 45.000 (NOS, 2017). The announcement of the expansion of Lelystad Airport in March 2015 led to concern among residents and politicians in the potentially affected areas (Province of Drenthe, Flevoland, Gelderland and Overijssel) (NOS, 2017). Municipalities under the expected flight paths predicted an effect of noise and air pollution due to low altitude flight paths of the airlines. Higher flight paths are not possible despite the fact that higher layers of airspace are reserved for Schiphol Airport and the Dutch Air Force (NOS, 2018). The change in property prices beneath flight routes is cited as an argument against further expansion.

While most studies of airport noise have found that a high noise level has a negative effect on property values, only a few studies were able to assay the announcement effects on property values. Two extensive studies that have investigated the announcement effects on sale prices so far are by Jud and Winkler (2006) and by Mense and Kholodilin (2014). According to Jud and Winkler (2006) housing property prices in a 2.5 distance band declined approximately 9.2 % in the period after the announcement. Mense and Kholodilin (2014) seek to relate the sales price of residential real estate to a range of independent variables to assess the impact of airport noise. As a result, in both studies the property values are declining through the noise expectations. It can be assumed that the expansion of Lelystad Airport causes a suchlike effect. However, the impact on transaction prices of residential housing in the possible affected areas has not been investigated before. This is precisely what this study does.

This thesis studies the effect of announcement of the expansion of Lelystad airport on the transaction prices of residential real estate. A transaction dataset (N= 25,310) provided by the Dutch Association of Realtors (NVM) is used. The possible effect is analyzed by adjusting a hedonic regression to a difference in difference approach.

Literature of negative airport externalities on housing values, especially those of noise discounts are quite extensive (Trojanek et al., 2017). Empirical studies indicate that the external effects are reflected in sales prices (Cheshire & Sheppard, 1995, Wilkinson, 1973). Frequent studies have found a negative effect of airport noise on property values (Salvi 2007; Theebe 2004; McMillen 2004; Püschel and Evangelinos 2012; Nelson 2004).

Compared to the existing literature, a contribution can be made by this study. In contrast to most other papers, this thesis highlights in particular on the announcement effect of an airport expansion on property values beneath the planned flight paths. Most of the studies about airport noise exposure examine the effects of noise after the noise level has increased and the property value adapted (*ex post*). The *ex post* approach has the disadvantage that noise is very highly correlated with other aspects of the residential property market, such as air pollution and traffic congestion (Jud & Winkler, 2006). The *ex ante* approach has the advantage that there is no change in city- and locational attributes and the price can't adjust to the market before operational use of the airport (Jud & Winkler, 2006). Pennigton, Topham and Ward (1990) state that this is the reason for their insignificant findings for their study. Property data collected after the noise exposure is not reliable because noise is more dependent on other important location variables. According to this, this study seeks to measure the possible change in transaction prices in relation to the distance to the flight path, prior to and after the announcement. Potential homebuyers however, act on expectations of the outcome of flight noise, since the airport is not in operational use yet. A better understanding of the expected effects opens up the debate on societal relevance and can help policy makers with the decision-making process towards airport expansions.

The remainder of this thesis is organized as follows. The second section describes a theoretical background about general market forces, bid rent theory and the existence of externalities in the housing market. The third section describes the empirical strategies, which are used in this thesis. Section four introduces the dataset and section five describes the results. In the final section, section six, conclusions are drawn.

2. Theoretical Framework

2.1 Theoretical market forces

Studies about sales price consider the housing market as an competitive market under several assumptions; both buyers and sellers for housing are numerous, buyers and sellers don't conspire, buyers and sellers are free to enter or exit the market at any point in time, sales or purchase of a unit are small with regard to the total volume of transactions, buyers and sellers have perfect knowledge about the housing market and take every advantage of every opportunity to increase profits and utility, the housing service is a homogenous commodity (Olsen, 1969). However, a perfect competitive market does not exist because the housing market is imperfect (Campbell, Giglio & Pathak, 2011). Nevertheless, hedonic price models introduced by Rosen (1974) are acceptable for the housing market due to the market's size and housing being a competitively traded heterogeneous good. It is used to estimate the extent to which housing characteristics affect the transaction price of a dwelling. Since housing is a composite and heterogeneous good, the value of a property consists of many different determinant factors (Rosen, 1974). Concrete characteristics of residential real estate such as age or living space explain only one part of the value of a property (Cheshire and Sheppard, 1995). Wilkinson (1973) made a fundamental distinction between the dwelling-specific factors and the location-specific factors. For an exact determination of the value of a property, it is of great importance to consider the location of a property and related aspects such as the quality of a neighborhood and environmental qualities. Therefore, the market price is composed of underlying individual value characteristics, such as location quality, unit size and outdoor environmental attributes (Cheshire and Sheppard, 1998, Lancaster, 1966; Freeman, 2003; Paggourtzi et al., 2003; Palmquist, 1991; Sheppard, 1999; Sirmans et al., 2005).

In practice, it turns out that hedonic models have become established as a suitable method in relation with real estate valuations (Wilhelmsson, 2002). This hedonic analysis is a common method for estimating effects of amenities and disamenities on the value of residential real estate. Preferences of a consumer together with the variety of available houses generate an equilibrium hedonic price function (Palmquist, 2005).

2.2 Bid rent theory

According to the bid-rent theory, households weigh between good accessibility close to the central business district (CBD) and more living space further away from the CBD. The supply of land at a specific location is fixed (Nelson, 1979). Due to this fact relocation will bid up rents close to the CBD and decline rents at a larger distance. Thus, equilibrium requires that the price per unit of land (residential purpose) decrease with distance to the CBD (Nelson, 1979).

However, at present the bid-rent theory can be extended. Households aspire to maximize utility in relation to their constraints (noise pollution). De Vany (1976) and Richardson (1977) state that land rents reflect externalities of a neighborhood. This can be a social feature of the population (income and ethnicity), good living conditions (housing characteristics) and environmental amenities (good air

quality). In relation to the topic of this thesis, these aspects can change the value of residential real estate (Rosen, 1974).
From a historical perspective, the theories of von Thünen (1842) and Alonso (1964) refer that the value of a location of a property is considered as a reflection of the utility derived from its accessibility to a central location, like a central business district. These theories presumed that households are willing to pay a premium for a better location to reduce travel costs.

With regard to this thesis, when introducing externalities, Nelson (1979) states that living closer to an airport can reduce unit's rents. The essence is to balance the advantages against the disadvantages of an airport, such as increased aircraft noise.

2.3 Externalities and housing markets

Basically, the principle of the free market economy applies for the real estate sector. Demand and supply determine the value of real estate and can change over time and can lead to price corrections (Post, 2004). When looking at specific elements of a property, the relationship often seems very clear. A balcony, a fireplace or larger living room add value and increase the existing value of a property. The same applies to the price of land since a view overlooking the ocean or the mountains is limited (Schill et al., 2002).

However, not in every area the interpretation of the price effect is as easy as mentioned above. Because when a property is located near a railway, a final statement about the price effect is hardly possible. While industry that depends on a good infrastructural network is likely to benefit from it, a homeowner may prefer a quiet residential area. Housing externalities defined by the effect characteristics of a house have on the environment (Rossi-Hansberg et al., 2008). Depending on the perspectives, externalities can influence the value of a property differently (Nelson, 1979). Generally, locational quality of a property can be valued by its amenities, which can influence where people want to live (Hiller, 2014). Principally, amenities can be seen as essential locational housing characteristics (Cheshire and Sheppard, 1995). Compared with the theories of von Thünen (1842) and Alonso (1964) mentioned above, the principle is the same, which is that households are willing to pay more to have a better locational quality that maintain positive externalities.

Based on the theory that positive externalities positively influence housing markets, there is also an extensive amount of literature about externalities that negatively influence wellbeing. Negative externalities can affect wellbeing on many different ways, for example crime, air pollution or noise (Boyle and Kiel, 2001). Noise can be a crucial disutility negatively affecting wellbeing as well as the house price, especially when it exceeds certain thresholds (Jude & Winkler, 2006). A typical example of an amenity that has negative externalities is an airport. Living near an airport is less attractive due to the noise pollution. If properties are associated with airports, there is generally a lower demand for housing and therefore also a lower transaction price (Mense & Kholodilin, 2014; Theebe, 2004, Nelson, 1979).

According to Lane (1986) airports could depress residential property values in two ways. First, airport operations could reduce property values due to the proximity to an airport runway. Therefore, the same residential property transported to an identical location without close airport proximity would raise the property value (Lane, 1986). Second, airports could have impact on the residential property value caused by the proximity to the airport's flight paths. Lane (1986) named this a "shadow effect", a degraded environment by noise and air pollution. So, besides several economic benefits associated with a large airport, results of studies show that residential property value under or nearby flight paths decline by the negative impact (Bell, 1997). Besides, not only airport noise causes lower transaction prices. Other studies with similar subjects also verify that negative externalities have an impact on the sales price (for example Pope, 2008; Ceccato & Wilhelmsson, 2011; Gamble & Downing, 1982; Boyle & Kiel, 2001).

2.4 Hypotheses

The purpose of this study is to elucidate whether the announcement of the expansion of Lelystad Airport on March 2015 has an economic effect on the transaction prices within the region of the expected flight routes. Several studies concerning airport noise exposure found that great noise levels diminish the value of a property (Collins & Evans, 1994; Pennington, To-Pham, & Ward, 1990; Tomkins et al., 1998, Nelson, 2004). Mense & Kholodilin (2014) examined the effects of an airport expansion on property prices located under planned flight paths of the Berlin Brandenburg Airport. They found that property-listing prices were reduced extensively in the possible affected areas after the publication of the flight paths. Due to the results of this studies, negative effects on the housing market can be expected when the Lelystad Airport expansion create negative externalities.

On the basis of the theoretical background mentioned above, I test the fowling hypotheses:

1. The announcement of the expansion of Lelystad Airport has no effect on the transaction price of residential property under the possible flight paths.
2. The announcement of the expansion of Lelystad Airport has an effect on the transaction price of residential property under the possible flight paths.

3. Methodology

3.1 Empirical specification

In order to investigate whether the announcement of the expansion of Lelystad Airport has a negative effect in the transaction price of residential property under the possible flight paths, hedonic regression and sensitivity analysis have been used in this research. It turns out, that hedonic analyses are a common method for estimating effects of amenities and disamenities on the value of residential real estate (Palmquist, 2005). Hedonic price models are based on the idea that every good can be subdivided into a bundle of different characteristics. Through the choice of a different bundle of characteristics by individuals, the prices they pay for a house get affected (Palmquist, 2005). Therefore, it is possible to implicitly explain the price of a good by its underlying attributes (Sheppards,1999).

Starting with the standard hedonic framework by Rosen (1974), this can be formally written as:

$$Tp = f\,(S, H, L, E, T)$$

The transaction price of a residential property (Tp) is dependent on the transaction characteristics (S), the structural housing characteristics (H), the locational characteristics (L), the externality characteristics (E) and the temporal characteristics (T). The value of each of these vectors will be defined by a unique combination of characteristics as mentioned before in the theoretical background.

The first category (S) indicates the transaction characteristics, such as the transaction date and number of days on the market. The second category (H) indicates the structural housing characteristics, such as the living area, number of rooms and building period of the property. The third category (L) refers to the locational characteristics of a property.

3.1.1 Difference-in difference approach

To make this research more specific, the model specification gets extended with a difference- in difference specification established by Schwartz et al. (2006). Schwartz et al. (2006) model analysis the external effects caused by housing investments. In this research, the transactions prices of residential real estate in a predefined target area, within 4km of the flight paths, and in a control area- both are being compared before and after the announcement of the extension was made. According to the described categories above and with regard to the difference- in difference approaches in the study of Mense & Kholodilin (2014), the statistical model can be written as:

$$\log(Tp_i) = \beta_0 + \beta_1 L_i + \beta_2 E_i + \beta_3 N_i + \beta_4 H_i + \beta_5 B_i + \beta_6 D_i + \beta_7 T_i + \beta_8 A_i + \beta_9 TR_i + \beta_{10} C_i + \beta_{11} Y_i + \varepsilon_i$$

with the dependent variable as the log of transaction prices *log (*Tp) for a residential property *i*; the constant (β_0), the living area in m2 (L_i); a dummy variable for the presence of external storage (E_i); N_i for the number of rooms of a property; H_i defines the different house types of the observations; B_i defines the building period, which is measured by a set of dummy variables for the different periods; D_i is a dummy ring variable for the different distances to the flight paths; T_i is a dummy ring variable that describes whether particular properties lie within a predefined target area of 4km (one for property that lies within the predefined target area of 4km, zero otherwise); A_i is a dummy variable for the announcement of the expansion. This variable shows whether the transactions occurred before or after the announcement of the expansion of Lelystad airport; TR_i is the interaction variable, called treatment, it captures the possible effect of the announcement on the transaction prices. This variable is the interaction composed by A_i (the announcement dummy) * T_i (the target area dummy); Moreover, C_i is a dummy variable, which controls for the spatial fixed effects on a city level. Y_i is a time fixed effects that controls for the economic trend within a year; Finally, the last variable is the stochastic error term (ε_i).

The aim of this model is to measure the effect of the announcement of the expansion on transaction prices. Therefore, the model specification is based on the basic model specification of Mense & Kholodilin (2014). The authors also use an interaction term composed by the distance to the airport and the announcement that was made. The studies of Schwartz et al. (2006) and van Duijn et al. (2016) are also taken into consideration due to the difference- in difference approaches. However, they analyze the external effect that influence house prices before, between start and completion and after the completion of a redevelopment (ex post effects). This means that they were able to measure also the effect of house prices during construction of redevelopment. With regard to this thesis, this is not possible because the airport expansion is not yet implemented, only announced. Despite the fact that I analyze the ex ante effect my model specification is more related to the study of Mense & Kholodilin (2014) than to the studies of Schwartz et al. (2006) and van Duijn et al. (2016).

Moreover, in this research different periods in time (before and after the announcement) and different areas, the target area (within 4km) and the control areas (further away than 4 km till 10km) are used. By including both, year (announcement dummy) and area (target area dummy), the effect of the announcement of the expansion can be isolated in the regression. Different periods in time (before and after the announcement) and different areas, the target area and the control areas (within 4 km or and further away than 4 km) have been added. Subsequently, the average change in transaction prices in the control group before and after the announcement can be calculated. This has also been done for the target group. Finally, the difference between the average change in transaction price of the control- and target group is pointed out. This outcome is the actual treatment effect of the target group and is presented by the interaction variable TR_i (Treatment). The dependent variable $LogTp_i$ is regressed on the independent variables. The dummy variable A_i (Announcement) take care of the time trend and the dummy variable T_i (Targetarea) controls for inherent differences between the target- and the control group. The interaction variable TR_i (Treatment) tests whether the announcement of the expansion has an effect on the transaction prices under the possible flight paths by showing the treatment effect of the target group. By means of this, the interaction of the announcement dummy (A_i) with the target area dummy (T_i), the interaction variable (TR_i), is the focal point of the analysis. It captures the effect of the announcement.

In section 2.3 is mentioned that there are several factors that influence the locational characteristics. However, in practice, it turns out, that it is generally difficult to know whether the spatial variable varies on a different scale (von Greavenitz & Panduro, 2015). Due to the fact that we do not know the optimal scale of controls for omitted spatial variable bias, we used the strategy of Abbot and Klaiber (2011). Amenities have been estimated at a spatial multi-scale level within statistical model. We account for effects on different spatial scales, 4-digit zip code scale and city scale.

The fourth category (E) refers to the externality. According to Jud and Winkler (2006) noise exposure is till a 6km band present. This is why we use in this study range dummies of 0-2km, 2-4km, 4-6km and more than 6km (till 10km) away from the possible flight paths. The impact of smaller ranges will also be tested. The last category (T) indicates the temporal characteristics. To control for economic conditions changes through time, we use dummy variables on a yearly basis.

Mense and Kholodilin (2014) describe that planned flight paths provided by the policy makers define much better the decrease of housing values in comparison to noise projections within a research. Based on their findings, I use the published possible flight paths of the MER (2014) of Lelystad Airport to measure the noise exposure. A critical note could be that there are limitations, due to the quality of the data. I couldn't investigate the effect of lobbying against the expansion of the airport for environmental, social or political reason that was unrelated to the noise exposure. By cause of the great attention on the topic by the media, there could be an overreaction in transactions caused by the media attention. This aspect must be kept in mind concerning this research because there were a lot of controversial discussions through the research period.

4. Data

4.1 Dataset

The dataset used for analysis was acquired from the Dutch Association of Real Estate Agents (NVM). This dataset provides broad types of information on housing transactions in the Dutch property market. It consists of a share between 70-80% of owners-occupied house transactions. The dataset of the NVM was used because of the unique coverage of the database, made accessible for scientific research. Due to this fact, most of the existing Dutch research is based on NVM data (for example Van Duijn et al., 2016). The NVM database contains a large amount of detailed housing characteristics

(NVM, 2018). We have information about number of rooms, living area (in m2), the type of a house, et cetera.

Because this study focuses on the expansion of Lelystad Airport, a preselected sample is drawn from properties sold in nine different cities (Almere, Biddinghuizen, Dronten, Emmeloord, Elburg, Harderwijk, Kampen, Lelystad and Zwolle) from January 1st 2011 till Jun 16, 2018 (see fig. 1).

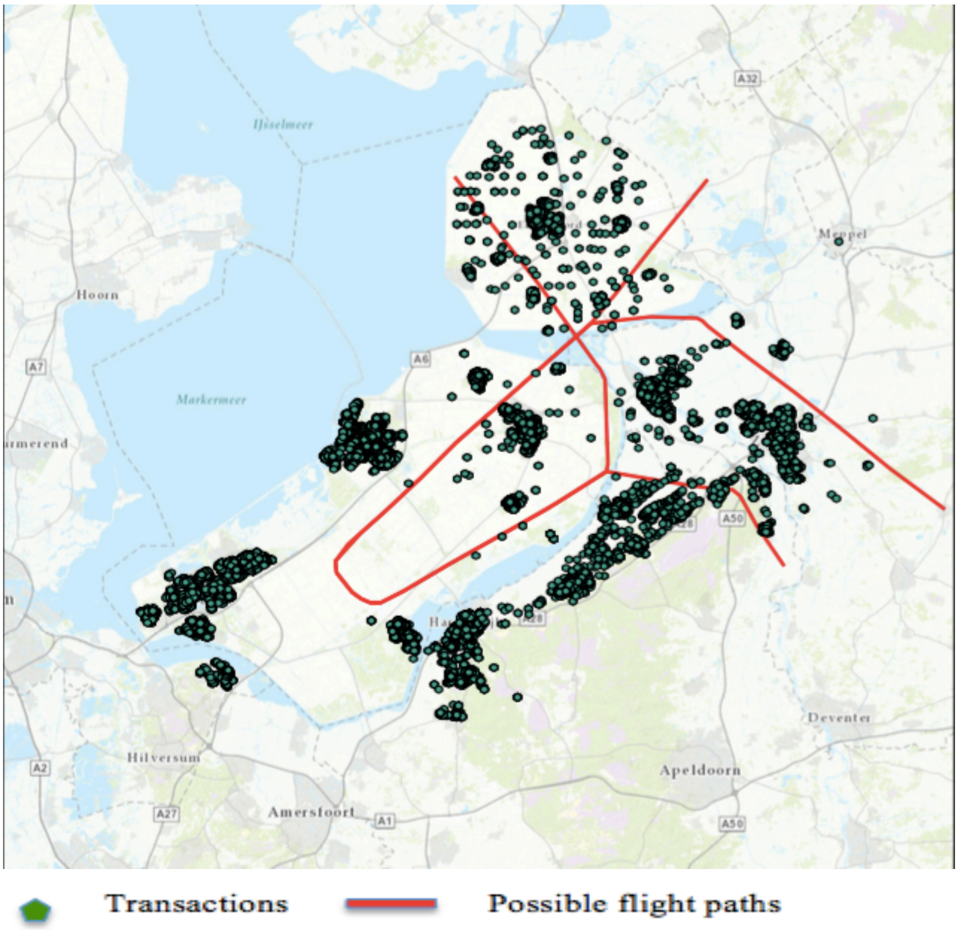

Figure 1. Residential Real Estate around the possible flight paths of Lelystad Airport. Source: author

The total sample includes 25,310 property transactions. Of the total sample, 8,825 were sold during pre-treatment, while 16,485 were sold from 2015 till 2018.

The selection of the cities mentioned above are based on their location; they lie below or close to the possible flight path. Transaction within a radius of 10km around the cities were used in this study. In total, transaction data for 45 cities and 21 municipalities are used. All this residential real estate could notice an effect on transaction prices through the expansion of Lelystad. However, as mentioned in 2.3, in principal, amenities can be seen as essential locational housing characteristics and can influence the value of a property. The possible difference between the cities and municipalities will be tested in the sensitivity analysis.

According to Jud and Winkler (2006) and Mense & Kholodilin (2014) property prices decline in a 10 km distance band after the announcement was made and most expected noise exposure lies within a range of 4km. Nonetheless, it is important to take the flight heights into account. In this research, a flight height of 3000 feet (1km) was chosen. This height is based on the indicated noise projections by the European Civil Aviation Conference (1997) and the published possible flight height and flight paths by the Milieueffectrapportage (MER) (2014). The exact route-climb gradients, flight paths and flight altitudes were not published while the announcement was made. According to the European Civil Aviation Conference (1997) noise projections take into account flight altitudes up to 1km (3000 feet). Furthermore, flight maps, published by the MER (2014) present a possible low altitude flight paths (3000 feet) despite the fact that higher layers of airspace are reserved for Schiphol Airport and the Dutch Air Force (MER, 2014; NOS, 2018). The 3000 feet flight altitude give an indication to better understand the expectations concerning possible noise level. However, as a result of analyzing an announcement effect of the expansion, the altitude remains an indication. The exact altitude and the accompanying noise can be determined when the airport is in operational use.

In this research, only those observations were used for which the exact coordinates and address were known. Also, properties that were sold more than once were included.

The date of announcement (March 31st, 2015) is used in this research because it was the official announcement that Lelystad Airport may expand. Even though there were a lot of discussions and changes concerning the Airport, on this date the expansion is officially announced.

The information about the possible flight paths, which were used in this study, are derived from the MER 2014 and the Advice Schiphol Business Plan for the Development of Lelystad Airport published by Hans Alders, chairman of the Alder tables for the airport Schiphol, Eindhoven and Lelystad in 2014. The flight paths that were used in this analysis are according to the MER 2014 and the Advice Schiphol Business Plan.

Furthermore, the dataset was geo-referenced at property-level using the most common Dutch coordinate system RD-New (Rijksdriehoekscoördinaten). With the Geographic Information System, distance buffers were made to categorize the distance of residential real estate to the flight paths and to define the target area and control area. The data trimming process is done with the statistical program *R* and the script is listed in Appendix B.

4.2 Variables

The adjusted dataset consists of 38 variables on information about the transactions, housing characteristics and location. In reference to Jud & Winkler (2006); Schwartz et al. (2006), Mense & Kholodilin (2014) and van Duijn et al. (2016), who use related statistical approaches (difference- in difference method), a choice of certain variables for the analysis has been made. The variables used on this thesis were set up for statistical analysis. Table 1 presents information about the used variables, scilicet categories of the variables, the different variables and the description of the variables. The dependent variable was transformed into a natural logarithm, missing and improbable values were removed (Figure 2). Changes in locational- and temporal characteristics are taken into account by adding spatial fixed effects and time fixed effects.

Table 1. Observed variables in different categories. Source: author based on dataset

Category	Variables	Symbol	Description
Dependent variable			
Transaction	Transaction price (log)	*log (Tp)*	Transaction price , transformed in natural logarithm
Independent variable			
	Targetarea	*Ti*	Dummy of transaction within 4km or not
	Announcement	*A i*	Dummy for before or after the announcement
Structural characteristics	Living area	*Li*	Living area in m2
	External space	*Ei*	Dummy for external space (1=yes)
	House type	*Hi*	Categorical variable for different house types
	Building period	*Bi*	Categorical variable for different buidling periods
Interaction variable	Treatment	*TRi*	Target area dummy * Announcement dummy
Locational characteristics	Distance	*Di*	Dummy for distance bands 0-10km.
	4-digit-ZIP		Dummy variable for each 4-digit Zip code
Fixed effects	Time fixed effects	*Yi*	Dummy to correct economic trends per year
	Spatial fixed effects	*Ci*	Dummy variabel for each city (fixed effects)

The target group (pre-announcement and post-announcement within 4km) is defined as the sold properties (transaction) that received treatment. A sold property gets treatment if it lies within a distance of 4km to the possible flight paths and the transaction year is after the announcement (March 31st, 2015). The control group (pre-announcement and post-announcement more than 4km away till 10km from the flight path) consists of the transactions that do not get treatment.

In this research, we start with a main specification with target and control groups as defined above. Subsequently, we use several robustness checks to measure the possible difference within the target area of 4km. By testing this, we can determine up to which distance transaction prices are affected by possible noise exposure. We expect proximity to the possible flight paths decline a transaction price.

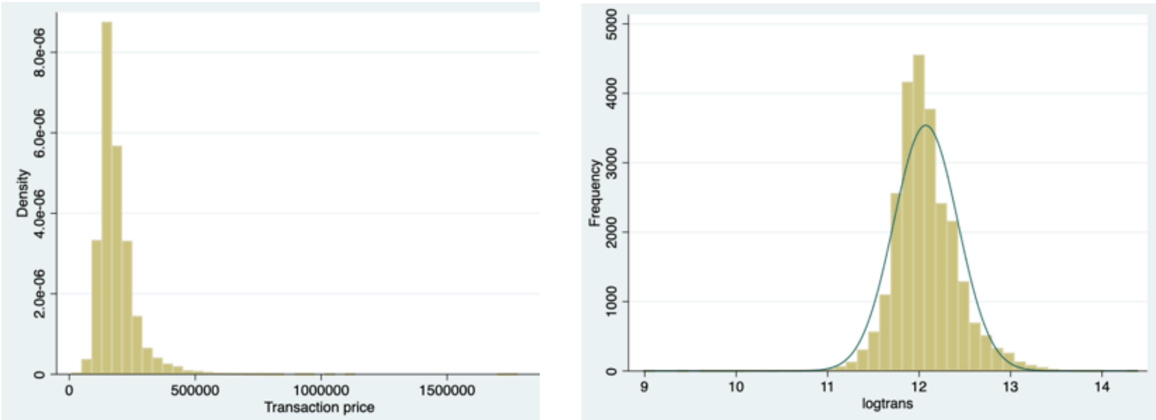

Figure 2. Transformation of Transaction price variable; left: original variable, right: transformed variable. Source: author

4.3 Descriptive statistics

Table 2 shows the descriptive statistics for all variables in the sample. The observations are divided into the target group (pre-announcement and post-announcement within 4km) and the control group (pre-announcement and post-announcement more than 4km). The sample sizes are 8,825 for the target group and 16,485 for the control group. There is made a distinction between the target group and the control group. The target group lies within 4km distance band around the possible flight paths and observations are made before and after the announcement of March 31st, 2015. The variables presented in table 2 are all rational values that form the total data. We can observe differences in transaction prices between the target group and the control group. Compared to the mean of transaction price of the control group (€178,915), the mean of the transaction price of the target group is 20.137 euros higher. The price differences between the target- and control group can be explained by the included data of high value properties within the target area. Thus, the mean of the living area in the target area is therefore also high.

Furthermore, comparing the amount of sold properties within the target- and control group, it can be observed that the target group has far fewer properties sold post-announcement, compared to properties sold in pre-announcement. While in the control group a lot more properties are sold post-announcement. The control group (16485) has twice as much observation as the target group (8825).

Table 2. Descriptive statistics Target group (pre- and post announcement) and Control group (pre- and post announcement). Source: author based on dataset

	Target group (Obs. 8825)						**Control group (Obs. 16485)**						**Total (Obs. 25310)**		
	Pre-announcement within 4 km Obs. 6736			**Post-announcement within 4km Obs. 2089**			**Pre-announcement more than 4 km Obs. 4548**			**Post-announcement more than 4km Obs. 11397**					
	Mean	**St. Dev.**	**Sum**	**Mean**	**St. Dev.**	**Sum**	**Mean**	**St. Dev.**	**Sum**	**Mean**	**St. Dev.**	**Sum**	**Mean**	**St. Dev.**	**Sum**
Transaction price in €	191,233	80,07	399486915	206,872	85,673	940856228	168,606	62,445	1135731344	189,225	79,989	2258789231	187,074	77,895	4734863718
Living area in m2	115.10	36.86	240450	116.61	38.46	530333	103.03	31.07	693978	105.96	36.00	1264801	107.85	35.67	2729562
External storage space	14.63	74,95142	30572	13,8208	73,01943	62857	7,78058	33,12304	52410	9,12675	40,41986	108946	10,06657	49,89891	254785
Number of rooms	4,63092	1,27277	9674	4,70954	1,34071	21419	4,22506	1,22646	28460	4,30033	1,3292	51333	4,38111	1,31309	110886
Building period before 1900 (1=yes)	0.008	0.087	16	0.013	0.112	58	0.017	0.128	113	0.022	0.147	263	0.018	0.132	450
Building period 1902-1930 (1=yes)	0.052	0.221	108	0.038	0.192	175	0.047	0.211	314	0.044	0.204	521	0.044	0.205	1118
Building period 1931-1944 (1=yes)	0.010	0.099	21	0.011	0.103	49	0.018	0.134	124	0.019	0.135	222	0.016	0.127	416
Building period 1945-1959 (1=yes)	0.074	0.262	155	0.057	0.233	261	0.044	0.204	294	0.044	0.205	527	0.049	0.216	1237
Building period 1960-1970 (1=yes)	0.186	0.389	388	0.178	0.382	809	0.084	0.278	569	0.083	0.275	985	0.109	0.311	2751
Building period 1971-1980 (1=yes)	0.186	0.389	389	0.161	0.367	730	0.165	0.371	1111	0.179	0.383	2131	0.172	0.378	4361
Building period 1981-1990 (1=yes)	0.077	0.266	160	0.076	0.265	345	0.290	0.454	1956	0.259	0.438	3091	0.219	0.412	5552
Building period 1991-2000 (1=yes)	0.219	0.414	457	0.225	0.418	1024	0.178	0.382	1196	0.171	0.376	2037	0.186	0.389	4714
Building period 2001-2010 (1=yes)	0.169	0.374	352	0.197	0.398	896	0.117	0.321	788	0.135	0.342	1611	0.144	0.351	3647
Building period 2010-2018 (1=yes)	0.021	0.142	43	0.044	0.206	201	0.040	0.197	271	0.046	0.209	549	0.042	0.201	1064
Housetype Bungalow (1=yes)	0.044	0.204	91	0.041	0.199	188	0.021	0.142	139	0.027	0.163	324	0.029	0.169	742
Housetype EGW (1=yes)	0.757	0.429	1582	0.753	0.431	3424	0.682	0.466	4594	0.679	0.467	8104	0.699	0.458	17704
Housetype Herenhuis (1=yes)	0.023	0.148	47	0.024	0.152	108	0.013	0.112	85	0.011	0.105	134	0.015	0.121	374
Housetype MGW (1=yes)	0.131	0.338	274	0.131	0.338	598	0.266	0.442	1794	0.257	0.437	3069	0.227	0.419	5735
Housetype Other (1=yes)	0.003	0.058	7	0.004	0.061	17	0.001	0.024	4	0.002	0.048	27	0.002	0.047	55
Housetype Villa (1=yes)	0.025	0.156	52	0.031	0.174	142	0.012	0.110	83	0.017	0.130	206	0.019	0.137	483
Housetype Woonboederij (1=yes)	0.017	0.130	36	0.016	0.124	71	0.005	0.074	37	0.006	0.078	73	0.009	0.092	217

5. Empirical results

In this section, the estimation results of the base model of the difference–in-difference hedonic price model are presented in table 3 (see Appendix C for full estimation results). In the base model, the adjusted R^2 is 0.6941, which means that this is a good model fit because the OLS can explain 69 percent of the variation in transaction prices (see for hedonic price literature examples van Duijn et al. (2016)).

The coefficient of the treatment variable is negative (-0.021) and significantly different from zero on a 99% significance level. The log-linear relation is interpreted as a decline in the transaction prices by 2.1 %. This result indicates, that due to the announcement of the expansion of Lelystad Airport the transaction prices within a range of 4km of the flight path deceased with 2.1 %. This suggests that expected flight paths could be a disamenity for the nearby residential real estate.

The announcement variable is significantly different from zero on a 99% percent significance level. This result shows that the announcement effect has a positive impact on the transaction prices.

Table 3. Regression results base model

	Model 1 Sample (0-10km) Target (0-4km) Control (5-10km)
Variable	
External storage dummy	0.002
	(0.00272)
Living area in m2	0.006***
	(0.00006)
Number of rooms	0.010***
	(0.00147)
Announcement dummy	0.041***
	(0.00670)
Targetarea	-0.018
	(0.01157)
Treatment	-0.021***
	(0.00594)
Constant	11.581***
	(0.04614)
Distance dummies (7)	Yes
Building period dummies (9)	Yes
House type dummies (6)	Yes
Year fixed effects (8)	Yes
City fixed effects (45)	Yes
Observations	25310
Adj. R2	0.6941

Note: dependent variable is log (transaction price). The coefficients of control variables can be found in Appendix C. Robust standard errors are reported between parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

5.1. Sensitivity analysis

Additionally, to the base model, we provide supplementary regressions to measure and analyze the robustness of our results, in three steps. First, we add to our base model two other models, presented in table 4 (full regression results listed in the Appendix C). In these two regression models, we divide the treatment area into smaller ranges. Larger ranges were not made because flying noise detracts with greater distance to the flight paths. Model 3 has a range of 0-2km and model 4 a range of 0-3km. This allows us to see the treatment effect on the transaction prices within a smaller distance to the possible flight paths. Both models have the same Adjusted R-squared (0.69). Also, in these models the OLS explains 69 percent of the variation in transaction prices. As we can see in table 4, the treatment effect within a range of 0-2km is greater than within a range of 0-3km and 0-4km. The transaction prices decline within the 0-2km target area by 5%, within the 0-3km target area by 2,7% and within 0-4km target area 2,1%.

Table 4. Regression results base model (2) and models (3),(4) with different target area

	Model 2	**Model 3**	**Model 4**
	Sample (0-10km)	Sample (0-10km)	Sample (0-10km)
	Target (0-4km)	Target (0-2km)	Target (0-3km)
	Control (5-10km)	Control (3-10km)	Control (4-10km)
Variable			
External storage dummy	0.002	0.002	0.002
	(0.00272)	(0.00272)	(0.00272)
Living area in m2	0.006***	0.006***	0.006***
	(0.00006)	(0.00006)	(0.00006)
Number of rooms	0.010***	0.010***	0.010***
	(0.00147)	(0.00147)	(0.00147)
Announcement dummy	0.041***	0.038***	0.038***
	(0.00670)	(0.00657)	(0.00659)
Targetarea	-0.018	0.011	-0.006
	(0.01157)	(0.01795)	(0.01680)
Treatment	-0.021***	-0.050***	-0.027**
	(0.00594)	(0.0115635)	(0.00843)
Constant	11.581***	11.582***	11.583***
	(0.04614)	(0.04612)	(0.04613)
Distance dummies (7)	Yes	Yes	Yes
Building period dummies (9)	Yes	Yes	Yes
House type dummies (6)	Yes	Yes	Yes
Year fixed effects (8)	Yes	Yes	Yes
City fixed effects (45)	Yes	Yes	Yes
Observations	25310	25310	25310
Adj. R2	0.6941	0.6942	0.6941

Note: dependent variable is log (transaction price). The coefficients of control variables can be found in Appendix C. Robust standard errors are reported between parentheses. * p<0.10, ** p<0.05, *** p<0.01

In the second step of this sensitivity analysis, we investigate whether there is a dissimilarity between different spatial fixed effects. We run an additional regression, presented in table 5 (full regression results listed in the Appendix D). This model possesses instead of city fixed effects, 4-digit Zip code fixed effects. As could be expected, in model 2 the adjusted R2 is 0.722, which means it has also a good model fit. However, the treatment coefficient is significantly different from zero on a 95% level and suggests that transaction prices decline by 1.8% after treatment. This, in fact, confirms the main results.

Table 5. Regression results 4-digit ZIP code effects

	Model 5 Sample (0-10km) Target (0-4km) Control (5-10km)
Variable	
External storage dummy (1=yes)	0.005*
	(0.00263)
Living area in m2	0.005***
	(0.00005)
Number of rooms	0.010***
	(0.00142)
Announcement dummy	0.039***
	(0.00640)
Targetarea	-0.033*
	(0.01654)
Treatment	-0.018**
	(0.00568)
Constant	11.735***
	(0.03605)
Distance dummies (7)	Yes
Building period dummies (9)	Yes
House type dummies (6)	Yes
Year fixed effects (8)	Yes
4-digit-ZIP fixed effects (149)	Yes
Observations	25310
Adj. R2	0.7227

Note: dependent variable is log (transaction price). The coefficients of control variables can be found in Appendix C. Robust standard errors are reported between parentheses. * p<0.10, ** p<0.05, *** p<0.01

The third and last step of this sensitivity analysis is to investigate whether rural areas or large cities drive the results of this thesis. One would expect that rural areas experience less noise exposure in daily life and therefore the effect could be greater. And on the other side, we would expect that the ground noise in a city is higher than in rural areas, so the noise exposure could be less.

To test this, the dataset is split up into two datasets. One dataset only includes the 4 largest cities (Almere, Lelystad, Kampen and Zwolle). The other dataset contains the remaining smaller cities and rural areas. The regression that we use is similar to the previous regression base model. Table 6 shows the results of the different models.

Table 6. Regression results of 4 largest cities (6) and remaining cities (7)

	Model 6	**Model 7**
	Sample (0-10km)	Sample (0-10km)
	Target (0-4km)	Target (0-4km)
	Control (5-10km)	Control (5-10km)
Variable		
External storage dummy	0.010**	-0.004
	(0.00317)	(0.00440)
Living area in m2	0.006***	0.006***
	(0.00008)	(0.00008)
Number of rooms	0.010***	0.013***
	(0.00193)	(0.00216)
Announcement dummy	0.035***	0.034**
	(0.00751)	(0.01132)
Target area	-0.014	-0.027**
	(0.00864)	(0.00930)
Treatment	0.010	-0.004
	(0.01536)	(0.00871)
Constant	11.705***	11.534***
	(0.06274)	(0.05478)
Distance dummies (7)	Yes	Yes
Building period dummies (9)	Yes	Yes
House type dummies (6)	Yes	Yes
Year fixed effects (8)	Yes	Yes
Obs.	12979	12331
Adj. R2	0.7123	0.6341
Residual	329.13	585.28

Note: the dependent variable is log (transaction price). The robust standard errors are reported in parentheses. The Chow test shows the statistic F (38/25244), * p<0.10, ** p<0.05, *** p<0.01

The results of re-estimating our main model (1) in models (6) and (7), on the urban and rural datasets, respectively can be used to conduct a Chow (1960) test. The null hypothesis of this test is that the intercepts and slopes are identical between the four largest cities and the remaining smaller cities and rural areas. The coefficients of the key variable (treatment) are different than in the pooled model (base model). In both models the significance disappears completely. The Chow F-statistic (16.11) shows that the intercepts and slopes are identical between the 4 largest cities and the remaining smaller cities and rural areas. There is no observed difference in transaction prices decline between large cities and rural areas.

6. Conclusions and Discussion

This thesis analyzed the possible effects on transaction prices to the announcement of new flight paths due to the expansion of Lelystad Airport by using a difference-in-difference hedonic methodology. I compared transactions prices within a certain treatment area (within 4km) before the announcement of the expansion was made and after. The results of this thesis do confirm the alternative hypothesis as indicated in chapter 2.4. Even after controlling for locational, temporal and housing characteristics, a decline of 2,1% in transaction prices of residential real estate is observed after the announcement within 4km from the possible flight paths of Lelystad Airport. Therefore, the alternative hypothesis of this research can be accepted.

The pre and post-announcement methodology of this study is very helpful for policy makers and real estate professionals to get a better understanding of the expected noise exposure prior to the actual airport expansion. The advantage of measuring changes in transaction prices *ex ante* is that location- and neighborhood attributes don't change in the first place. This is valuable advantage because when the airport is operational after expansion, the location- and neighborhood attributes often changes considerably. Therefore, noise measurements are also attainable *ex post*, but the net effect is hard to detect after a period of time, when the market had time to adjust (change in attributes) (Jude and Winkler, 2006). This is why, unlike most other studies (Nelson 2004; Püschel and Evangelinos 2012; Salvi 2007; Theebe 2004), we used in this research *ex ante* methodology.

The results of Jud and Winkler (2006), using an event study methodology and Mense and Kholodilin (2014), using an OLS regression with three treatment groups can only be partially compared with this study due to differences in the methodology used.

However, both studies estimated declining property prices in the period after the announcement, based on distance discounts. Furthermore, both studies used a distance range around the flight paths of 4km. Jud and Winkler (2006) found a 9% decline in property prices around an airport that would be expanded. Mense and Kholodilin (2014) found a 9,6% loss of property values within a distance of 4km from possible flight paths. A possible clarification for the stronger decrease of house prices can be that there are differences between the research areas, such as densely populated areas, like in the study of Mense and Kholodilin (2014). Another possible reason could be the size of an airport. Larger airports have greater facilities and better capacities, which again results in a larger number of possible flights, which could cause more noise exposure.

Although the transaction prices in this study do not decline as much as in the studies of Jud and Winkler (2006) and Mense and Kholodilin (2014), it appears that the negative price effects get smaller, the further the distance to the possible flight paths. The farther the distance ranges of the target area (0-2 to 0-4km), the smaller the decline in transaction prices. These results were also found by Mense and Kholodilin (2014).

Another important point of discussion is that as reported by Abbot and Klaiber (2011) amenities and disamenites addressed by hedonic price models are most of the times multidimensional. We controlled with spatial effects on 4-digit postal codes. Our results show that on city level the treatment variable is significant at a 99 percent level. On the 4-digit postal code level, the treatment variable is significant at a 95 percent significance level. These results explain that the 4-digit postal code level does not contribute as strong as the city fixed effects to the treatment effect. The less significant value of the treatment variable can be explained by a lower amount of observations per 4-digit postal codes. Furthermore, the 4-digit postal code are on street level. With regards to that, it seems to be logical that there isn't a great difference between houses within a street. We don't expect great difference within one street only if streets are very long. As a result, the estimates are less significant. Because of this result, controlling for spatial fixed effects on a multi-scale level can add value to the analysis. It can be observed, whether there are differences in outcome regarding multi-scale levels. Furthermore, there is no structural difference between the larger cities and smaller cities and rural areas. This leads to a better understanding of the possible effects on transaction prices in both rural areas and cities. Property prices within low-density and cities residential areas react both sensitively to noise pollution by an airport. This is in line with the findings of Ahlfeldt (2008).

Caution must be taken when translating the distance band of housing price changes to noise level changes. Comparing the results measuring noise exposure of this study with other *ex ante* studies is complicated due to the fact that we don't express our results in terms of the Noise depreciations index (NDI) or decibel (dB). A direct comparison would require a translation of distance discounts into noise discounts. Jud and Winkler (2006) translate their results into an NDI. They use NDI measures from different studies with a range of 0.50-0.84% per decibel. So, the results of 9,2% decline in housing prices suggest an increasing noise level if 11 to 18 dB (Jud and Winkler, 2006).

The range of decibel used in the article of Jud and Winkler (2006) is based on data from other studies of airports with different exclusive characteristics. Besides the possible effect of an increasing NDI rely upon the initial noise level. Furthermore, distance bands perform a range around the possible flight paths but might not be consistent due to the fact that there are different start- and landing patterns (Jud and Winkler, 2006).

With regard to these facts, in this research, we decided not to translate the results into NDI because this could cause deficits. Recall, however, Mense and Kholodilin (2014) states that projected noise levels do not contribute as much as flight paths to forming expectations about noise-underlying the strength of the current study.

One may note that, once Lelystad Airport is in operational use, it will be possible to see whether the results of this study based on the flight paths foresee a good approximation of the actual noise externality's effect on transaction prices. Moreover, it should not be assumed that the estimated reduction of residential real estate within 4km around the flight paths, as estimated in this study, will continue to exist after the opening of Lelystad Airport.

Lastly, an additional study, concerning the actual impact of noise exposure on transaction prices after the expansion, could be essential to measure the actual differences, when the market had time to adjust and air traffic is in progress. This may guide interest, whether residents' perception of negative externalities will persist, while also possible positive effects may arise from the airport's extension.

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Appendices

Appendix I.

Tabel 7. List of Cities

Cities	Freq.	Cities	Freq.
t Harde	445	Ijsselmuiden	404
t Loo Oldebroek	41	Kampen	2,01
Almere	4,106	Kamperveen	22
Bant	66	Kraggenburg	51
Biddinghuizen	302	Lelystad	3,719
Blaricum	36	Luttelgeest	66
Creil	84	Marknesse	173
Doornspijk	177	Nagele	91
Dronten	1,764	Noordeinde GLD	10
Elburg	573	Nunspeet	1,097
Emmeloord	1,491	Oldebroek	265
Ens	158	Oosterwolde GLD	70
Ermelo	701	Putten	186
Espel	82	Swifterbant	359
Genemuiden	55	Tollebeek	104
Grafhorst	25	Urk	30
Harderwijk	1,531	Wapenveld	68
Hasselt	175	Wezep	147
Hattem	198	Wilsum	25
Hattemerbroek	22	Zalk	14
Hierden	11	Zeewolde	843
Huizen	328	Zwolle	3,144
Hulshorst	20		

Appendix II. R-statistics output

```
#####
# Session 1
#####

library(plyr)
library(fastDummies)


backup <- read_excel("versie-4-stata.xlsx")
data <- read_excel("versie-4-stata.xlsx")


# Building period renaming
data$bperiod_cat <- cut(data$`Building period`,
                          breaks = c(0, 1901, 1930, 1944, 1959, 1970,
1980,1990,2000,2010,Inf),
                          labels = c("before_1901", "1902-1930", "1931-
1944", "1945-1959", "1960-1970", "1971-1980", "1981-1990","1991-
2000","2001-2010","2011-2018"),
                          right = T)



# Property type renaming
data$`Property type`[which(data$`Property type`=='geschakelde 2-onder-
1-kapwoning')] <- '2-onder-1-kapwoning'
data$`Property type`[which(data$`Property type`=='eindwoning')] <-
'hoekwoning'
data$`Property type`[which(data$`Property type`=='0')] <- NA
data$`Property type`[which(data$`Property type`=='verspringend')] <-
'tussenwoning'


# House type renaming
data$`House type`[which(data$`House type` %in% c('grachtenpand',
'landhuis', 'woonboot'))] <- 'other'


# Quality status missing value renaming
data$`Quality status`[which(data$`Quality status`=='0')] <- NA


# Treatment effect dummy
data$announcement_dummy_2015 <- ifelse(data$`Date of
transaction`>'2015-03-31',1,0)
data$announcement_dummy_2015_weeklater <- ifelse(data$`Date of
transaction`>'2015-04-07',1,0)


# Create distance dummies for buffer zone
data$`Buffer in meters`[which(is.na(data$`Buffer in meters`))] <-
'>7000'

dummies <- dummy_cols(as.factor(data$`Buffer in
meters`),remove_first_dummy = F,remove_most_frequent_dummy = F)[,-1]
colnames(dummies) <- c('buffer_6km', 'buffer_7km', 'buffer_>7km',
'buffer_3km', 'buffer_4km', 'buffer_2km', 'buffer_1km', 'buffer_5km')
```

```
dummies <- data.frame(dummies$buffer_1km, dummies$buffer_2km,
dummies$buffer_3km, dummies$buffer_4km, dummies$buffer_5km,
dummies$buffer_6km, dummies$buffer_7km, dummies$`buffer_>7km`)
colnames(dummies) <- c('buffer_1km', 'buffer_2km', 'buffer_3km',
'buffer_4km', 'buffer_5km', 'buffer_6km', 'buffer_7km', 'buffer_>7km')

data <- cbind(data, dummies)


# city dummies
dummies_city <-  dummy_cols(as.factor(data$City),select_columns =
NULL,remove_first_dummy = F,remove_most_frequent_dummy = F)
colnames(dummies_city) <- gsub(x = colnames(dummies_city),replacement =
"city", pattern = '.data')
data <- cbind(data, dummies_city[,-1])


# economic trend dummies
dummies_year <-  dummy_cols(as.factor(substr(data$`Date of
transaction`,1,4)),select_columns = NULL,remove_first_dummy =
F,remove_most_frequent_dummy = F)
colnames(dummies_year) <- gsub(x = colnames(dummies_year),replacement =
"year", pattern = '.data')
dummies_year <- dummies_year[, sort(colnames(dummies_year))]

data <- cbind(data, dummies_year[,-1])


write.csv(data, file='Data_versie_5.csv',row.names = F)


#####
# Session 2
#####

backup <- read_excel("Data_final.xls")
data <- backup

data$logtp <- log(data$`Transaction price`)

summary(data$`Transaction price`)
summary(data$logtp)


drop <- c('FID',
          'KEY',
          'X',
          'Y',
          'Street',
          'House number',
          'Addition',
          'Original list price',
          'Transaction price per m2',
          'Soort OG',
          'announcement_dummy_2015_weeklater')

data <- data[,-which(names(data) %in% drop)]

# drop transaction outside 20.000 & 2.000.000
```

```
data <- data[-which(data$`Transaction price` > 2000000 |
data$`Transaction price` < 20000),]

# drop living area smaller than 25 m2
data <- data[-which(data$`Living area in m2` <= 25),]

# drop number or rooms larger than 23
data <- data[-which(data$`Number of rooms` >= 23),]



#####
# Dummies
#####

# dummy for storage room
data$exstoragedummy <- ifelse(data$`External storage space` > 0,1,0)

# Dummies for housingtype
dummies_housetype <- dummy_cols(as.factor(data$`House
type`),remove_first_dummy = F,remove_most_frequent_dummy = F)[,-1]
names(dummies_housetype) <- gsub(pattern = '.data_', replacement = '',
x = names(dummies_housetype))
dummies_housetype <- dummies_housetype[ ,
order(names(dummies_housetype))]
names(dummies_housetype) <- c('h_type1', 'h_type2', 'h_type3',
'h_type4', 'h_type5', 'h_type6', 'h_type7')


# Dummies for housingtype
dummies_bperiod <-
dummy_cols(as.factor(data$bperiod_cat),remove_first_dummy =
F,remove_most_frequent_dummy = F)[,-1]
names(dummies_bperiod) <- gsub(pattern = '.data_', replacement = '', x
= names(dummies_bperiod))
dummies_bperiod <- dummies_bperiod[ ,
shift(order(names(dummies_bperiod)),places = 1, dir = 'right')]
names(dummies_bperiod) <- c('b_period1', 'b_period2', 'b_period3',
'b_period4', 'b_period5', 'b_period6', 'b_period7', 'b_period8',
                              'b_period9', 'b_period10')

data <- cbind(data, dummies_bperiod, dummies_housetype)

#####
# Build targetarea and treatmentdummy
#####


# Create target area
data$targetarea <- data$buffer_1km + data$buffer_2km + data$buffer_3km
+ data$buffer_4km

# Create treatment dummy
data$treatment <- data$targetarea*data$announcement_dummy_2015



descr <- c('Transaction price', 'Living area in m2', 'External storage
space', 'Number of rooms',
```

```
            names(dummies_housetype), names(dummies_bperiod))


total <- round(t(sapply(data[,which(names(data) %in% descr)],
function(x) c('mean'=mean(x), 'sd'=sd(x), 'sum'=sum(x)))),5)
post_out_4 <- round(t(sapply(data[which(data$announcement_dummy_2015==1
& data$targetarea==0),which(names(data) %in% descr)], function(x)
c('mean'=mean(x), 'sd'=sd(x), 'sum'=sum(x)))),5)
post_in_4 <- round(t(sapply(data[which(data$announcement_dummy_2015==1
& data$targetarea==1),which(names(data) %in% descr)], function(x)
c('mean'=mean(x), 'sd'=sd(x), 'sum'=sum(x)))),5)
pre_out_4 <- round(t(sapply(data[which(data$announcement_dummy_2015==0
& data$targetarea==0),which(names(data) %in% descr)], function(x)
c('mean'=mean(x), 'sd'=sd(x), 'sum'=sum(x)))),5)
pre_in_4 <- round(t(sapply(data[which(data$announcement_dummy_2015==0 &
data$targetarea==1),which(names(data) %in% descr)], function(x)
c('mean'=mean(x), 'sd'=sd(x), 'sum'=sum(x)))),5)


write.csv(data, file='data_27-9.csv')
```

Appendix III. Full regression results

Table 8. Full regression results base model (1) and models with different target areas (2), (3).

	Model 1	**Model 2**	**Model 3**
	Sample (0-10km)	Sample (0-10km)	Sample (0-10km)
	Target (0-4km)	Target (0-2km)	Target (0-3km)
	Control (5-10km)	Control (3-10km)	Control (4-10km)
Variable			
External storage dummy (1=yes)	0.002	0.002	0.002
	(0.00272)	(0.00272)	(0.00272)
Living area in m2	0.006***	0.006***	0.006***
	(0.00006)	(0.00006)	(0.00006)
Number of rooms	0.010***	0.010***	0.010***
	(0.00147)	(0.00147)	(0.00147)
Buffer 1km (1=yes)	0.007	0.000	0.000
	(0.01435)	(.)	(.)
Buffer 2km (1=yes)	0.000	-0.009	-0.008
	(.)	(0.01436)	(0.01435)
Buffer 3km (1=yes)	0.023*	-0.010	0.015
	(0.00983)	(0.00933)	(0.01490)
Buffer 4km (1=yes)	0.009	-0.024***	-0.024***
	(0.00924)	(0.00698)	(0.00698)
Buffer 5km (1=yes)	-0.010	-0.010	-0.010
	(0.00666)	(0.00666)	(0.00666)
Buffer 6km (1=yes)	0.015*	0.015*	0.015*
	(0.00618)	(0.00618)	(0.00618)
Buffer 7km (1=yes)	-0.023***	-0.023***	-0.023***
	(0.00593)	(0.00593)	(0.00593)
t Harde	0.240***	0.241***	0.240***
	(0.04337)	(0.04336)	(0.04337)
t Loo Oldenbroek	0.420***	0.421***	0.420***
	(0.05203)	(0.05203)	(0.05204)
Almere	-0.006	-0.006	-0.007
	(0.04275)	(0.04274)	(0.04275)
Bant	-0.095*	-0.095	-0.095
	(0.04867)	(0.04866)	(0.04867)
Biddinghuizen	-0.056	-0.056	-0.056
	(0.04396)	(0.04395)	(0.04396)
Blaricum	0.098	0.099	0.098
	(0.05350)	(0.05349)	(0.05350)

Creil	-0.104*	-0.104*	-0.105*
	(0.04733)	(0.04732)	(0.04733)
Doornspijk	0.271***	0.272***	0.271***
	(0.04468)	(0.04467)	(0.04468)
Dronten	0.107*	0.108*	0.107*
	(0.04256)	(0.04256)	(0.04257)
Elburg	0.294***	0.295***	0.294***
	(0.04321)	(0.04321)	(0.04321)
Emmeloord	0.016	0.017	0.016
	(0.04264)	(0.04263)	(0.04264)
Ens	0.017	0.014	0.016
	(0.04642)	(0.04643)	(0.04643)
Ermelo	0.174***	0.174***	0.173***
	(0.04317)	(0.04316)	(0.04317)
Espel	0.006	0.004	0.006
	(0.04880)	(0.04880)	(0.04881)
Genemuiden	0.150**	0.148**	0.151**
	(0.04995)	(0.04994)	(0.04996)
Grafhorst	0.092	0.093	0.092
	(0.05739)	(0.05738)	(0.05739)
Harderwijk	0.263***	0.263***	0.262***
	(0.04264)	(0.04264)	(0.04265)
Hasselt	0.056	0.057	0.056
	(0.04510)	(0.04509)	(0.04510)
Hattem	0.154***	0.156***	0.154***
	(0.04481)	(0.04480)	(0.04481)
Hattemerbroek	0.201***	0.197***	0.200***
	(0.05950)	(0.05952)	(0.05952)
Hierden	0.118	0.118	0.118
	(0.07207)	(0.07206)	(0.07207)
Huizen	0.070	0.071	0.070
	(0.04404)	(0.04404)	(0.04405)
Hulshorst	0.030	0.030	0.030
	(0.06065)	(0.06064)	(0.06065)
Ijsselmuiden	0.199***	0.200***	0.199***
	(0.04348)	(0.04348)	(0.04348)
Kampen	0.073	0.074	0.073
	(0.04258)	(0.04257)	(0.04258)
Kamperveen	0.088	0.089	0.088
	(0.05919)	(0.05918)	(0.05919)
Kraggenburg	-0.015	-0.018	-0.016
	(0.05046)	(0.05047)	(0.05047)
Lelystad	-0.047	-0.046	-0.047

	(0.04248)	(0.04247)	(0.04248)
Luttelgeest	-0.130**	-0.129**	-0.130**
	(0.04860)	(0.04860)	(0.04860)
Marknesse	0.016	0.016	0.015
	(0.04484)	(0.04483)	(0.04484)
Nagele	0.038	0.038	0.038
	(0.04718)	(0.04718)	(0.04719)
Noordeinde GLD	0.202**	0.199**	0.203**
	(0.07450)	(0.07448)	(0.07451)
Nunspeet	0.393***	0.393***	0.392***
	(0.04291)	(0.04290)	(0.04291)
Oldenbroek	0.312***	0.313***	0.312***
	(0.04397)	(0.04396)	(0.04397)
Oosterwolde GLD	0.289***	0.289***	0.288***
	(0.04848)	(0.04848)	(0.04849)
Putten	0.293***	0.293***	0.292***
	(0.04487)	(0.04487)	(0.04487)
Swifterbant	0.009	0.009	0.009
	(0.04367)	(0.04367)	(0.04367)
Tollebeek	0.002	0.000	0.002
	(0.04662)	(0.04662)	(0.04662)
Urk	0.093	0.093	0.093
	(0.05525)	(0.05524)	(0.05525)
Wapenveld	0.135**	0.135**	0.135**
	(0.04972)	(0.04972)	(0.04972)
Wezep	0.171***	0.165***	0.170***
	(0.04716)	(0.04720)	(0.04718)
Wilsum	0.133*	0.134*	0.133*
	(0.05740)	(0.05740)	(0.05741)
Zalk	0.271***	0.272***	0.271***
	(0.06680)	(0.06679)	(0.06680)
Zeewolde	0.104*	0.105*	0.104*
	(0.04291)	(0.04291)	(0.04291)
Zwolle	0.159***	0.159***	0.158***
	(0.04249)	(0.04248)	(0.04249)
Year 2012	-0.026**	-0.026**	-0.025**
	(0.00913)	(0.00913)	(0.00913)
Year 2013	-0.088***	-0.088***	-0.087***
	(0.00746)	(0.00746)	(0.00746)
Year 2014	-0.069***	-0.069***	-0.069***
	(0.00690)	(0.00689)	(0.00689)
Year 2015	-0.084***	-0.084***	-0.083***
	(0.00847)	(0.00847)	(0.00847)

Year 2016	-0.034***	-0.034***	-0.033***
	(0.00932)	(0.00932)	(0.00932)
Year 2017	0.027**	0.027**	0.028**
	(0.00938)	(0.00938)	(0.00938)
Year 2018	0.042***	0.042***	0.042***
	(0.01196)	(0.01196)	(0.01196)
Building period 1902-1930	0.046***	0.046***	0.046***
	(0.01102)	(0.01102)	(0.01102)
Building period 1931-1944	0.095***	0.095***	0.095***
	(0.01332)	(0.01332)	(0.01332)
Building period 1945-1959	0.098***	0.098***	0.098***
	(0.01136)	(0.01136)	(0.01136)
Building period 1960-1970	0.001	0.001	0.001
	(0.01050)	(0.01050)	(0.01050)
Building period 1971-1980	-0.008	-0.008	-0.008
	(0.01026)	(0.01026)	(0.01026)
Building period 1981-1990	0.055***	0.055***	0.055***
	(0.01022)	(0.01022)	(0.01022)
Building period 1991-2000	0.156***	0.156***	0.156***
	(0.01028)	(0.01027)	(0.01028)
Building period 2001-2010	0.208***	0.208***	0.208***
	(0.01043)	(0.01043)	(0.01043)
Building period 2010-2018	0.206***	0.206***	0.206***
	(0.01139)	(0.01139)	(0.01139)
Housetype Herenhuis	-0.230***	-0.230***	-0.229***
	(0.01611)	(0.01610)	(0.01611)
Housetype EGW	-0.333***	-0.333***	-0.333***
	(0.01442)	(0.01442)	(0.01442)
Housetype Herenhuis	-0.234***	-0.235***	-0.234***
	(0.01737)	(0.01736)	(0.01737)
Housetype MGW	-0.371***	-0.371***	-0.371***
	(0.01522)	(0.01522)	(0.01523)
Housetype Other	-0.195***	-0.194***	-0.194***
	(0.02938)	(0.02937)	(0.02938)
Housetype Villa	-0.047**	-0.047**	-0.047**
	(0.01679)	(0.01679)	(0.01679)
Announcement dummy	-0.018	0.011	-0.006
	(0.01157)	(0.01795)	(0.01680)
Target area	0.041***	0.038***	0.038***
	(0.00670)	(0.00657)	(0.00659)
Treatment	-0.021***	-0.050***	-0.027**
	(0.00594)	(0.01156)	(0.00843)
Constant	11.581***	11.582***	11.583***

	(0.04614)	(0.04612)	(0.04613)
Observations	25310	25310	25310
Adj. R2	0.6941	0.6942	0.6941

Note: dependent variable is log(transaction price). Robust standard errors are reported between parentheses. * p<0.10, ** p<0.05, *** p<0.01

Table 9. Full regression results of 4 largest cities dataset and remaining cities dataset

	Model 4 Sample (0-10km) Target (0-4km) Control (5-10km)
Variable	
External storage dummy	0.010**
	(0.00317)
Living area in m2	0.006***
	(0.00008)
Number of rooms	0.010***
	(0.00193)
Almere	-0.109***
	(0.00806)
Lelystad	0.000
	(.)
Kampen	-0.147***
	(0.00576)
Zwolle	0.085***
	(0.00543)
Announcement dummy	0.035***
	(0.00751)
Targetarea	-0.014
	(0.00864)
Treatment	0.010
	(0.01536)
Constant	11.705***
	(0.06274)
Distance dummies (7)	Yes

Building period dummies (9)	Yes
House type dummies (6)	Yes
Year fixed effects (8)	Yes
Observations	12979
Adj. R2	0.7123
Residual	329.13

Note: dependent variable is log(transaction price). Robust standard errors are reported between parentheses. * p<0.10, ** p<0.05, *** p<0.01

Table 10. Regression results of remaining cities

	Model 5 Sample (0-10km) Target (0-4km) Control (5-10km)
Variable	
External storage dummy	-0.004
	(0.00440)
Living area in m2	0.006***
	(0.00008)
Number of rooms	0.013***
	(0.00216)
t Harde	0.229***
	(0.04896)
t Loo Oldenbroek	0.427***
	(0.05889)
Bant	-0.089
	(0.05489)
Biddinghuizen	-0.036
	(0.04969)
Blaricum	0.108
	(0.06065)

Creil	-0.079
	(0.05355)
Doornspijk	0.280***
	(0.05058)
Dronten	0.121*
	(0.04820)
Elburg	0.294***
	(0.04891)
Emmeloord	0.014
	(0.04816)
Ens	0.025
	(0.05107)
Ermelo	0.180***
	(0.04864)
Espel	0.013
	(0.05373)
Genemuiden	0.181**
	(0.05641)
Grafhorst	0.073
	(0.06493)
Harderwijk	0.251***
	(0.04822)
Hasselt	0.067
	(0.05086)
Hattem	0.149**
	(0.05059)
Hattemerbroek	0.194**
	(0.06695)
Hierden	0.122
	(0.08157)
Huizen	0.056
	(0.04984)
Hulshorst	0.064
	(0.06854)
Ijsselmuiden	0.174***
	(0.04911)
Kamperveen	0.077
	(0.06697)

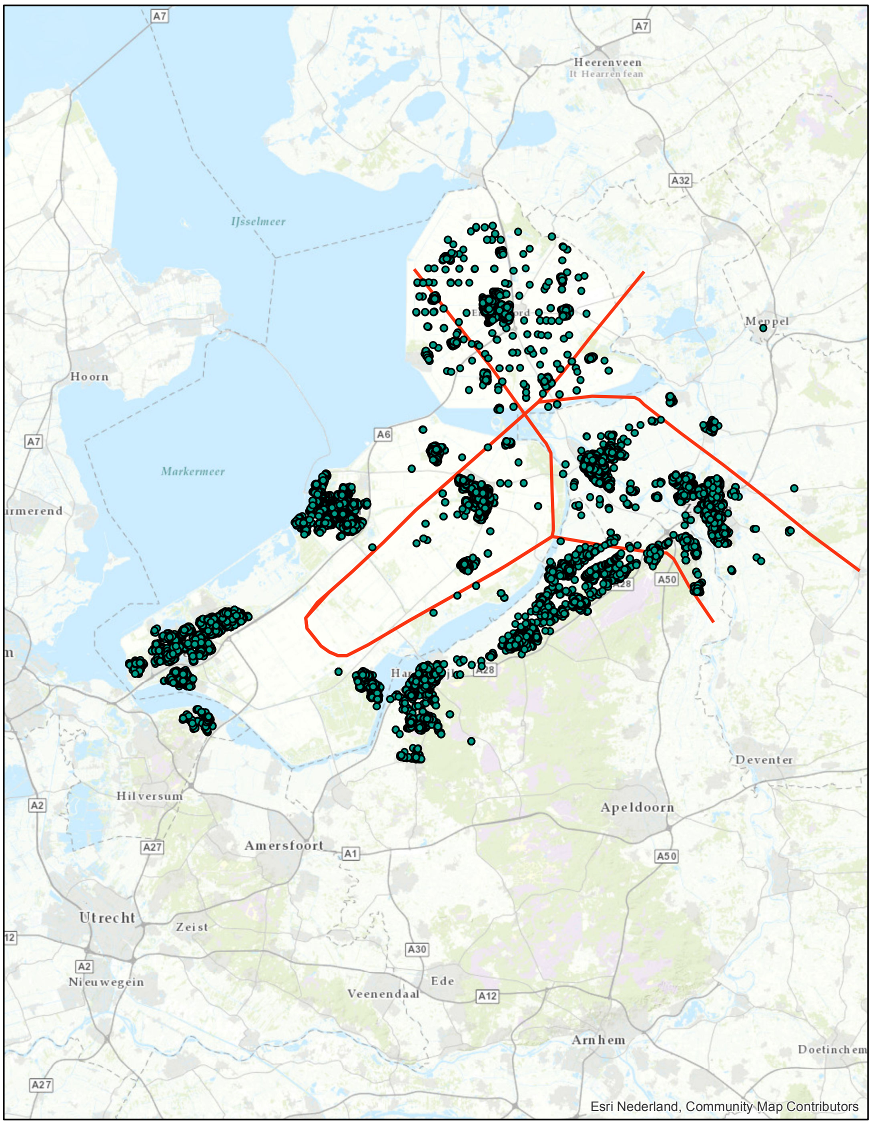
Kraggenburg	-0.021
	(0.05698)
Luttelgeest	-0.144**
	(0.05490)
Marknesse	0.020
	(0.05066)
Nagele	0.051
	(0.05319)
Noordeinde GLD	0.228**
	(0.08422)
Nunspeet	0.392***
	(0.04831)
Oldenbroek	0.316***
	(0.04979)
Oosterwolde GLD	0.285***
	(0.05476)
Putten	0.290***
	(0.05060)
Swifterbant	0.022
	(0.04946)
Tollebeek	0.008
	(0.05260)
Urk	0.114
	(0.06255)
Wapenveld	0.138*
	(0.05488)
Wezep	0.172***
	(0.05136)
Wilsum	0.103
	(0.06488)
Zalk	0.236**
	(0.07551)
Zeewolde	0.111*
	(0.04855)
Announcement dummy	0.034**
	(0.01132)
Target area	-0.027**
	(0.00930)

Treatment	-0.004
	(0.00871)
Constant	11.534***
	(0.05478)
Distance dummies (7)	Yes
Building period dummies (9)	Yes
House type dummies (6)	Yes
Year fixed effects (8)	Yes
Obs.	12331
Adj. R2	0.6341
Residual	585.28

Note: dependent variable is log (transaction price). Robust standard errors are reported between parentheses. * p<0.10, ** p<0.05, *** p<0.01

Appendix IV. Map of research area

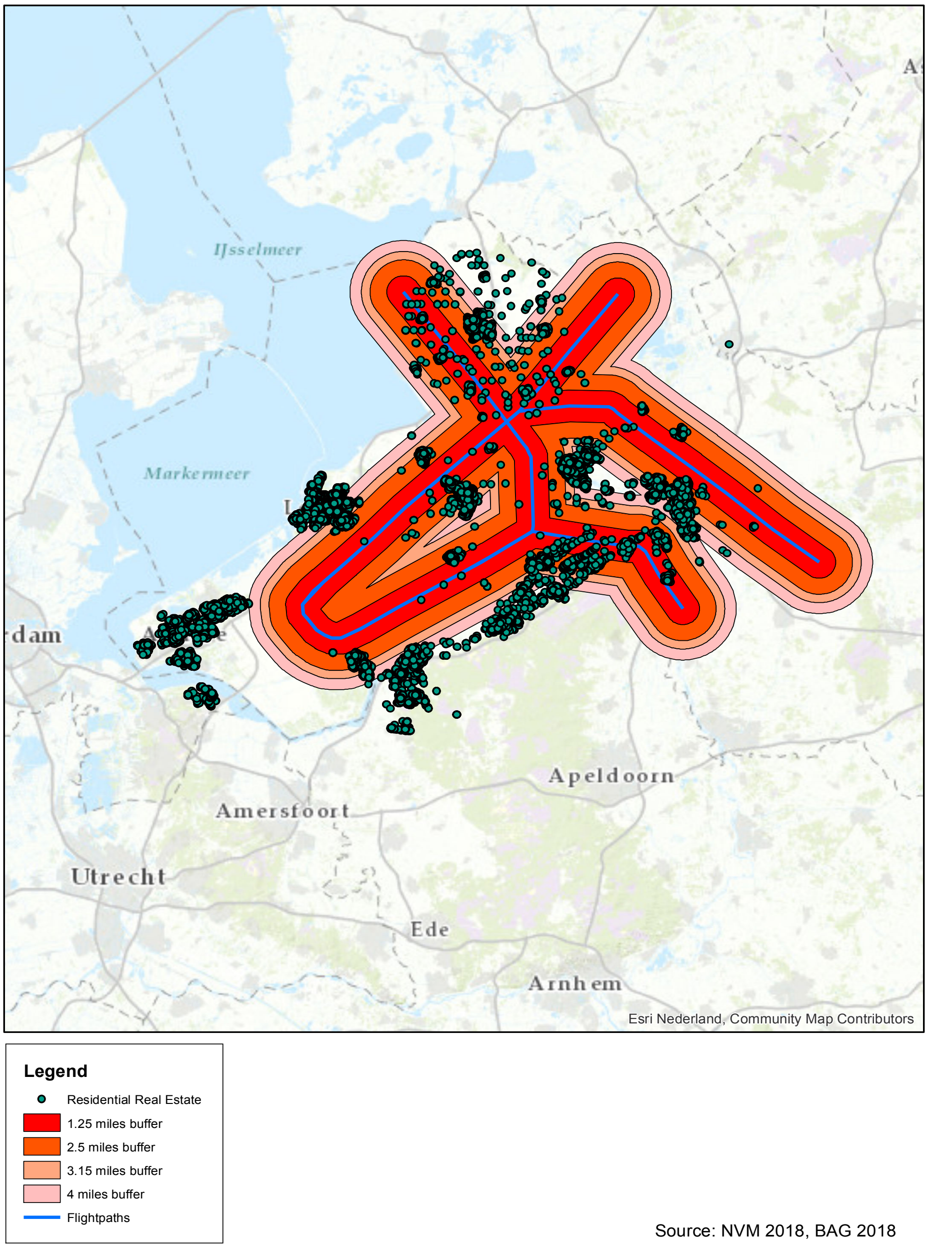
Residential real estate around flightpaths Lelystad Airport



Source: NVM 2018, BAG 2018

Appendix V. Distance buffers around possible flight paths Lelystad Airport

Buffers around flightpaths Lelystad Airport



Source: NVM 2018, BAG 2018

1.25 miles = 2km, 2.4 miles =4km, 3.15 miles= 5km and 4miles= 6km