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Abstract

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The depreciation of real estate value due to airport noise in the Netherlands is rated at approximately 1 billion euros. This is comparable to the depreciation due to noise from motorways in the Netherlands, which was found in an earlier study by RIVM in 2007. The noise produced by Amsterdam Airport Schiphol contributes about 65% to the social costs. Military airports and flying areas contribute 30% and other civil airports 5%.

Apart from depreciation of real estate, depreciation of land value was estimated by determining the urban areas around airports in which no new houses can be built due to aircraft noise. The depreciation of land value is estimated to nearly 600 million euros for the Netherlands. Amsterdam Airport Schiphol contributes approximately 60% to this amount.

For real estate value, the social losses may decrease with several hundred million euros in case more silent new aircraft will replace current aircraft. More silent aircraft can also increase the value of exposed land, provided also the noise zone for new housing would be reduced accordingly.

These are the main results of a cost-benefit study of aviation noise. The valuation models used in this study were also used in other international studies. However, there is no general consensus on the parameters in these models.

Key words:
noise, aviation, real estate, land prices, cost, benefit

Rapport in het kort

Monetarisatie van luchtvaartgeluid in Nederland
Invloed van geluid op huizenprijzen en grondmarkt

Het waardeverlies van onroerend goed als gevolg van de geluidoverlast door luchtvaart in Nederland wordt geschat op ongeveer 1 miljard euro. Dit is vergelijkbaar met het waardeverlies door lawaai van snelwegen in Nederland als geraamd in een eerdere studie van het RIVM. Het geluid veroorzaakt door Amsterdam Airport Schiphol draagt voor ongeveer 65% bij aan het waardeverlies. Militaire luchthavens en laagvliegroutes hebben een bijdrage van 30 % en andere civiele luchthavens van 5 %.

Naast het waardeverlies van onroerend goed is de waardevermindering van grondprijzen geschat aan de hand van de stedelijk gebieden rond luchthavens waar vanwege geluid geen nieuwe woningen mogen worden gebouwd. Dit komt neer op bijna 600 miljoen euro voor Nederland. Schiphol draagt voor ongeveer 60% bij aan dit bedrag.

Het waardeverlies van onroerend goed kan met enkele honderden miljoenen euro's afnemen indien nieuwe stillere vliegtuigen de huidige toestellen vervangen. Inzet van stillere vliegtuigen kan ook de grondprijzen van belast gebied verhogen als de huidige zonering voor nieuwe woningbouw daarbij kunnen worden gereduceerd.

Dit zijn de belangrijkste resultaten van een kosten-baten studie naar luchtvaartlawaai. De waarderingsmodellen die worden gebruikt in deze studie zijn ook gebruikt in andere internationale studies. Er bestaat echter geen algemene consensus over de parameters in deze modellen.

Trefwoorden:
geluid, luchtvaart, onroerend goed, grondprijzen, kosten, baten

Contents

Summary

In 2007, RIVM performed a study on the cost and benefits of noise and noise measures in the Netherlands. The noise sources examined in that study were road- and railway traffic. This report gives the results of a similar cost and benefit study, aimed at social losses due to airport noise in the Netherlands. The focus of the research will be on two economic aspects that are affected by aircraft noise: noise depreciation of real estate values, and noise depreciation of land values.

Noise depreciation of real estate values were estimated using Hedonic Pricing (HP). HP assesses the decrease of real estate values due to increasing noise levels, using a Noise Depreciation Index (*NDI*) as key parameter. When the noise level at a real estate property surpasses a threshold level, its estate value decreases with *NDI* % for each decibel above the threshold level.

In this study, the NDI value was set at 0.8%, and a threshold level of 50 dB L_{den} was used. Using real estate appraisal values, an indication of house prices in the vicinity of airports was found.

Land value depreciation was estimated by determining the urban areas around airports in which no new houses can be built due to aircraft noise. Depreciation occurs because of noise legislation: within certain noise contours around airports the building of new dwellings is prohibited, which reduces land value. For this study, a depreciation of 50% of the original land value is estimated, the land was for residential purposes. Land value for agricultural or business destination was assumed to not to be affected by aircraft noise.

In the following Table S1, the estimated depreciation values in millions of euros are given for the most important airports and flying areas in the Netherlands (rounded in units of 5 million euros).

Table S1 Estimated depreciation on real estate and land due to noise from several Dutch airports

	Estimated depreciation		
Source	**Estate**	**Land**	**Total**
Schiphol Airport	670	180	850
Low Flying Area LR10	150	60	210
Volkel Airbase	70	45	115
Awacs Area Schinveld	65	60	125
Other Civil Airports	45	15	60
Leeuwarden Airbase	25	30	55
Total	**1025**	**390**	**1415**

The depreciation of real estate value due to airport noise in the Netherlands amounts to 1 billion euros. This is comparable to the depreciation due to noise from motorways in the Netherlands, which was found in an earlier study by RIVM (Jabben et al 2007). The noise produced by Amsterdam Airport Schiphol contributes about 65% towards the cost. Military airports and flying areas contribute 30% and other civil airports 5%.

Concerning the land value, the depreciation amounts to nearly 400 million euros for the Netherlands, with Schiphol Airport contributing almost 50% to this amount. For real estate value, the social losses may decrease with several 100 million euros in case more silent new aircraft will replace current aircraft. More silent aircraft can also increase the value of exposed land, provided the legal spatial limitation for new housing thereby can be reduced. Each generic reduction of noise levels could increase land values by 17%.

It should be noted that the methods used in this study have also been used in several international studies, although no general consensus exists on the model parameters that should be chosen. Especially the chosen threshold value of the noise exposure, below which no effect can be expected of further noise reduction, has a large influence on the calculated benefits. Therefore the social losses as found in this study are indicative.

1 Introduction

1.1 Background

Environmental noise in the Netherlands has a large impact on society. The issue is related to the dense population in combination with a relatively high economic activity rate. This has led to a high environmental impact from transportation by road- and railway traffic and airplanes.

In the valuation of noise effects from new economic activities and opposing noise policies, there are several methods to determine the social costs of the impact of environmental noise. This makes it difficult for decision makers to fully incorporate environmental consequences and treat these on an equal standing with economic interests. For this reason, in the past years methods for monetizing noise effects have been developed and have received increasing attention both from policymakers and researchers. In previous RIVM research, the influence of environmental noise from road- and railway traffic on real estate and land prices was studied (Jabben et al., 2007). In that study the impact of airport noise was not taken into account. This supplementary study aims to specifically address the social costs of airport noise in the Netherlands and was commissioned by the Dutch ministry of Housing, Spatial Planning and the Environment. The study follows the approach adapted in the previous study on the costs and benefits of road and railway traffic noise, in which social costs of noise were estimated using Hedonic Pricing and Contingent Valuation methods. For road- and railway traffic the social loss due to noise was estimated to be around 10 billion euros. The methods used in that study are here applied to both civil and military airports in the Netherlands.

1.2 Goals

This study aims to valuate social losses due to airport noise in the Netherlands. The focus of the research will be on two economic aspects that will be influenced by aircraft noise:

- o Noise depreciation of real estate values. Both national (Dekkers and Van der Straaten, 2009) and international research (Bristow, 2010) show that high noise levels on dwellings tend to reduce their market value. This effect can be rated using valuation methods such as Hedonic Pricing and Contingent Valuation. The Hedonic Pricing method describes how real estate values decrease with increasing noise levels using a Noise Depreciation Index (*NDI*). Contingent Valuation is a stated preference approach, in which hypothetical respondents are asked about there Willingness to Pay (WTP) for real estate in areas with high noise levels.
- o Noise depreciation of land values. Here depreciation can occur, when because of noise legislation the building of new dwellings is prohibited and/or, if new dwellings are allowed, their market value will be reduced by noise exposure.

The study aims to valuate social loss from both civil and military airports. Figure 1 shows a noise map, containing the contribution of different airports in the Netherlands. This data was provided by the Dutch National Aerospace Laboratory, using (NLR, 2007) to determine the noise levels in L_{den}.
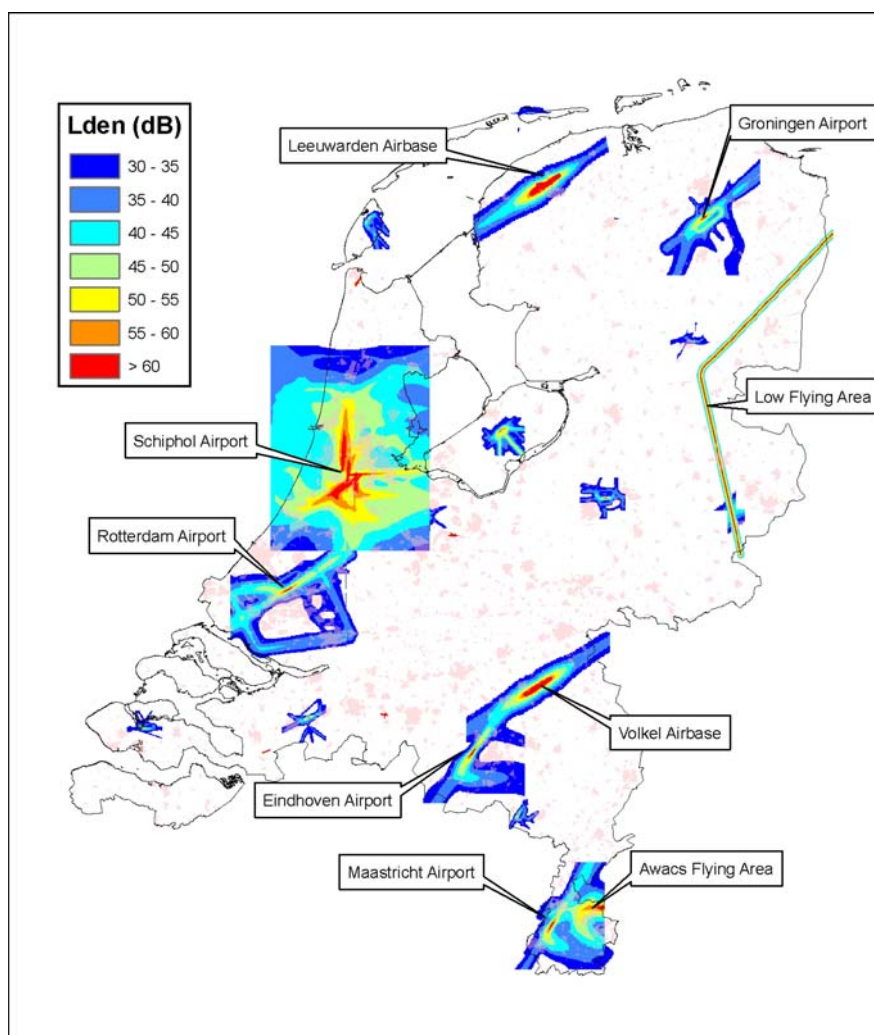
Figure 1 Noise map for Airports in the Netherlands

In this study the social losses were rated for the civil airports such as:
- o Amsterdam Airport Schiphol, where a region of interest of 55x71 km^2 was used.
- o Rotterdam Airport.
- o Eindhoven Airport.
- o Maastricht Airport.

Also military airports and flying areas were considered such as:
- o Volkel Airbase.
- o Leeuwarden Airbase.
- o AWACS Flying Area near Airbase Geilenkirchen.
- o Low Flying Area LR10 in the North Eastern Part of the Netherlands.

This report will first describe the economic loss due to aircraft noise. Chapter 2 deals with the noise depreciation of real estate. Chapter 3 deals with the noise depreciation of land value. Subsequently chapter 4 describes the economic benefits that can be obtained if aircraft become more silent in the future. Finally chapter 5 combines the results of costs and benefits of aircraft noise in the Netherlands.

2 Valuing depreciation of real estate

Both national (Dekkers and Van der Straaten, 2009) and international studies on noise effects (Bristow, 2010) show that real estate values are negatively influenced by high noise levels. There are several different approaches that can be used to value the costs of transport noise. For this research use was made of the most commonly used Hedonic Pricing (HP) method. As an alternative, valuing depreciation of real estate by Contingent Valuation (CV) can be used. The main difference is that HP results in total losses over the lifetime of dwellings, whereas CV results in annual losses. This is further elucidated in Appendix A

2.1 Hedonic Pricing

The Hedonic Pricing method is based on data of many real estate transactions, and the tendency that dwellings endure a loss in market value when high noise levels due to traffic are perceived. A detailed exposition of this method can be found in Baranzini et al. (2008), and the economic loss of real estate can be determined when traffic noise with a noise level L_i surpass a certain threshold level L_{TH}:

$$loss = NDI \sum_i (L_i - L_{TH}) P_i ,$$ (2.1)

in which P_i is the price of the dwelling, L_i is the noise load at each individual dwelling and the summation is carried out over all dwellings. For this study, the noise indicator used is the L_{den}. The constant NDI is the Noise Depreciation Index and gives the rate of depreciation of the market value with increasing noise level above the threshold value (L_{TH}). The NDI is given as a percentage, so if a house is situated in an area where the noise from aircrafts surpasses the threshold value with 1 dB, this would lead to a house price decrease with a percentage given by the NDI.

Individual prices of the dwellings were estimated from real estate appraisal values, which were averaged for each postal code area in the Netherlands. Figure 2 shows these values for the region around Schiphol Airport, as used by Dutch municipalities for tax assessment.
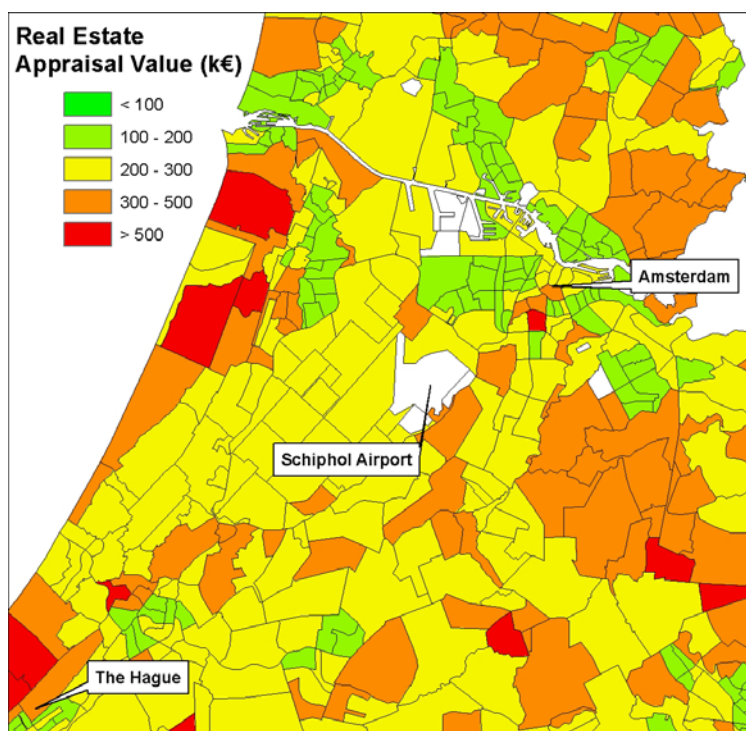
*Figure 2 Real **e**state appraisal values in 2005, for the region around Schiphol Airport (PBL, 2005).*

For this study, it is too complicated to take the value of every single dwelling into account, so this estimation from real estate appraisal values is deemed necessary. The regional data as shown in Figure 2 can be used as the average value of the real estate in the particular region, and multiplying it with the actual amount of real estate properties present, a value for price of the dwelling P_i can be derived.

2.2   Choice of Parameters

2.2.1   *Value of the Noise Depreciation Index (NDI)*

In choosing the *NDI* value, uncertainties cannot be avoided, as largely different values for each of the noise sources are found in different studies. In an earlier study by RIVM on the influence of road and rail traffic noise on real estate values (Jabben et al., 2007), average *NDI* values for road traffic noise were derived from several different studies (Bateman et al., 2000). For road and rail traffic these values were 0.5% and 0.25% respectively. For aircraft noise, the *NDI* is expected to be higher than for road and rail traffic noise, as noise-annoyance relations show that aircraft noise causes more annoyance (Miedema and Oudshoorn, 2001)**.**
Over the past few years, several studies have performed a meta-analysis to combine all the different *NDI* values found in different studies into a single weighted average *NDI* value. However, consensus on a single *NDI* value is not found, as the noise depreciation highly depends on where and when the study was performed. For instance, an *NDI* of around 0.6% was found by (Nelson, 2004), which is a fairly low value, comparable to the 0.5% found for road traffic noise. On the other hand, a study by Schipper et al. (1998) estimated *NDI* values between 0.9% and 1.3%.

For this study, we choose a single *NDI* value of 0.8%, which was found in two recent Dutch studies by CPB (the Netherlands Bureau for Economic Policy Analysis, (Dekker en van der Straaten, 2009) and by RIGO (Kruger-Dokter et al., 2009). This *NDI* value is higher than the *NDI* values chosen for road and railway traffic in the previous study, which were 0.5% and 0.25% respectively (Jabben et al., 2007). In this study an estimate for an *NDI* value for aircraft noise was also found, which with 0.77% is consistent with our chosen value for this study.

2.2.2 *Threshold value*

The threshold value in HP is the value below which no depreciation of real estate is assumed. For noise from road traffic a common international value is L_{den} 55 dB and for railway traffic 60 dB. For airport noise different values are found in literature, ranging from 45 to 55 dB.

In the CPB study it is stated that airport noise has a less constant character, containing more peak levels in comparison to road- and railway traffic and therefore a lower threshold value can be used than for road- and railway noise. The above mentioned CPB and RIGO studies both apply 45 dB as threshold, because at this level already effects on house prices are found around Schiphol. It must be noticed, however, that the calculation uncertainty of noise levels increases rapidly with a decreasing level. Taking a threshold for aircraft noise as low as 45 dB would result in large areas with similarly large uncertainty ranges for the calculated benefits. This will be demonstrated in section 4.2. Also, using a threshold value below 50 dB disregards the fact that the majority of dwellings in urban environments already is exposed to levels above 50 dB due to road traffic. Using a threshold value of 45 dB to rate the depreciation that can specifically be attributed to airport noise only, would probably lead to an overestimation of estimated social losses. In this study it was therefore considered safer to choose a threshold of 50 dB.

2.3 Application to Dutch Airports

Using the real estate appraisal data from 2005 and residential data from 2005, the dwelling prices Pi for equation 2.1 can be estimated. These prices are subsequently combined with the noise levels for the different airports, air force bases and flying areas in the Netherlands, as shown in Figure 1.

Applying equations 2.1 and 2.3 for these airports, the losses as shown Table 1in can be derived. By way of comparison, the group noise level G_{den} as introduced by Jabben et al. (2009) is also included in the table. This indicator is a measure of the accumulation of noise levels on all dwellings in the surroundings of an airport and can also be used to compare different airports. The losses specified in Table 1 all apply for situations between 2008 and 2010 and no discount correction has been applied. This would hardly result in significant differences in view of the uncertainties in NDI and threshold values.

Table 1 Loss in value in millions of euros according to the Hedonic Pricing Method with NDI = 0.8% and L_{TH} = 50 dB (L_{den}).

Source	Loss (millions of euros)	G_{den} (dB(A))
Schiphol Airport	670	109
Rotterdam Airport	11	97
Eindhoven Airport	1	87
Maastricht-Aachen Airport	28	96
Groningen-Eelde Airport	2	84
Volkel Airbase	68	96
Leeuwarden Airbase	24	95
Awacs Flying Area Geilenkirchen	64	97
Low Flying Area LR10	150	100
Other Airports	3	81
Total	**1020**	**110**

2.4 Discussion

Around 65% of the total loss is contributed by Schiphol Airport, and the Low Flying Area LR10 also adds a significant 15% to the total loss. Furthermore, military airbases and flying areas seem to result in more depreciation than civil airports.

In conclusion, with the parameters chosen in this study, the total depreciation of real estate due to aircraft noise will be around 1 billion of euros. Compared to the study on value depreciation due to road and railway traffic noise performed by Jabben et al. (2007), this is a smaller loss, as in the former study a total loss of 10 billion euro was found. This does not mean that the loss due to aircraft noise is negligible, as the loss is experienced in relatively small regions, and in some locations the loss can increase to severe values.

3   Valuing depreciation of land prices

3.1   The Dutch land market

For Schiphol and also for the regional Dutch Airports, a noise zone is defined that determines where new dwellings are not allowed, because of too high noise levels. This means that, as with house prices, land prices may also be affected by aircraft noise. In case construction of new dwellings is restricted due to noise limits, the value of envisaged land areas will tend to decline.

For Schiphol Airport the Dutch air aviation law embodies a land planning decree, the 'LuchthavenIndelingBesluit' (LIB). According to the LIB, construction of new houses is restricted within a certain noise contour. In the LIB, the new dwellings cannot be constructed within the former 20 KE noise contour (LIB4-noise zone). The KE is the old Dutch noise indicator, the use of which has now been replaced by the European noise indicator L_{den}.

For the regional airports, construction of new dwellings is prohibited within the 56-L_{den} contour, as indicated by the 'Regelgeving burgerluchthavens en militaire luchthavens' (RBML, 2009).

For military airports, the construction of new dwellings is still governed by a 35-KE noise zone. The noise zones that were used in this study to assess the depreciation of land prices are summarized in Table 2.

Table 2 Noise zones used to assess depreciation of land value in this study

Ground Use	Noise zone	remark
Schiphol Airport	LIB4-noise zone	Also within the former 20 KE contour there are certain restrictions for new dwellings, but these have not been taken into account.
Regional Airports	L_{den} 56 dB(A)	Provincial administrators tend to pose certain restrictions within L_{den} 48 dB, but these have not been taken into account.
Military Airports	35-KE	

For all airports a threshold value of L_{den} 50 dB has been used to estimate the depreciation of house pricing according to Hedonic Pricing (see chapter 2).

Within these legal noise zones, the market of land prices can be affected. A study of how the environment in general influences the land market and vice versa was done by De Regt (2003). That study found that spatial policies in the Netherlands have led to a segmented land market, in which the average price of residential land is about four to five times the price of agricultural land, as shown in Table 3.

Table 3 Indication of land prices according to use

Ground Use	Average land price ($€/m^2$)	Estimated noise damage if new dwellings are prohibited (%)
Nature	2-3	-
Agricultural	3-4	-
Residential (unprepared)	13 (spread of 4-25)	50
Residential (prepared)	100 (spread of 60-200)	50
Business	55 (spread of 0-225)	-

As Table 3 shows, there is a strong spread in the land value, even if it has the same function. The most expensive land use is the prepared residential land, which means that the land is ready to be built upon. The depreciation of land would theoretically be largest when this type of land lies within the restricting noise contours, as the land can no longer be used for new residential use.

3.2 Approach

For this study it is important to distinguish residential land from agricultural land within the legal noise zones. An indication of the depreciation of ground value can subsequently be estimated by using the percentage of residential land within the contours. As no new houses can be built within these contours, we assumed that land value decreases with 50% of its original value. In addition, a distinction between the unprepared and prepared land within the residential land was made, as Table 3 shows that prepared land is more expensive than unprepared land. As it is difficult to determine exactly which part of the residential land is prepared to be built upon, we assumed a percentage of 20% within the residential land as prepared.

Subsequently the depreciation for unprepared and prepared residential land is 6.5 $€/m^2$ and 50 $€/m^2$ respectively. On the other hand, depreciation of agricultural land and ground used for business functions is not expected, as these practices are unlikely to be influenced by aircraft noise.

The estimated noise damage percentages for each land use type have also been added in Table 3.

Summarizing, the depreciation in value for land inside the legal noise zones can be found by determining the area used for residential use, and by multiplying the prepared 20% of the surface area with a factor of 50 $€/m^2$ and the remaining unprepared part with 6.5 $€/m^2$. The total value can be used as an indication for the total amount of the depreciation of land prices due to aircraft noise. To illustrate this method an example of the calculation is given below.

Example

At a local airport, a residential area of 10,000 m^2 is located within the 58 L_{den} contour. Of this residential area, we assume a prepared percentage of 20%, corresponding with an area 2000 m^2 and a value of 2000 x 100 €/m^2 = € 200,000. The rest of the area (8000 m^2) is considered unprepared, and has a value of 8000 x 13 €/m^2 = € 104,000. As the value of both the prepared and the unprepared land have an estimated value depreciation of 50%, the loss for the prepared land is 2000 m^2 x 50 €/m^2 = €100,000 and for the unprepared land 8000 m^2 x 6.5 €/m^2 = € 52,000. This results in a total loss due to airport noise of € 100,000 + € 52,000 = € 152,000.

3.3 Noise zones preventing new dwellings

In order to estimate the land affected by aircraft noise, the legal noise zones of Figure 3 to Figure 6 were used. Each of these Figures also show which urban areas are affected by aircraft noise
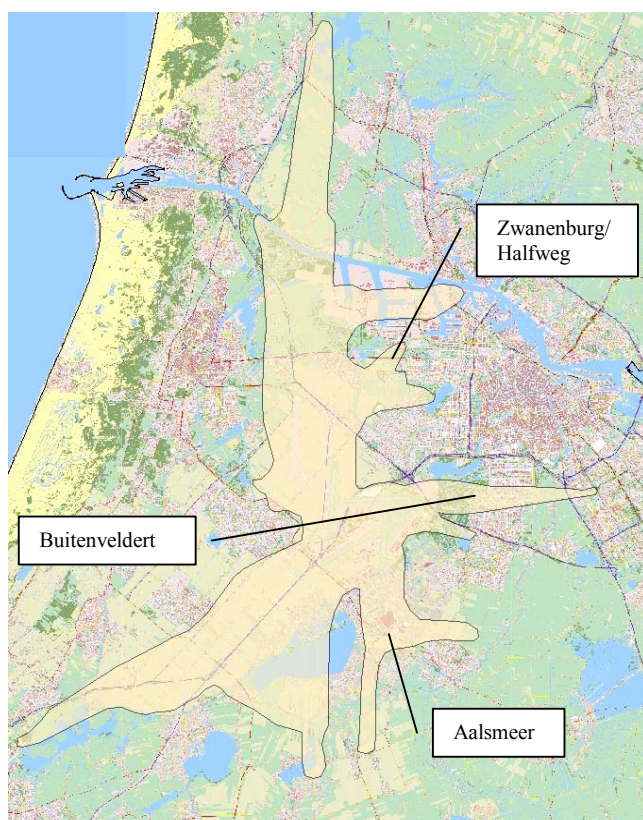

Figure 3 Legal noise (LIB4) - zone around Schiphol airport

In Figure 3 the noise map shows that the noise zone is considerably large, yet only a small amount of urban areas are affected by it. The largest residential areas within the contour are Aalsmeer, Buitenveldert en Zwanenburg/Halfweg, which are affected by the runways: the Aalsmeerbaan, Buitenveldertbaan and the Zwanenburgbaan respectively. The other two runways, the Kaagbaan and the Polderbaan, contribute most to the 58 L_{den}-contour, yet do not include as much residential area as the aforementioned runways. This was expected, as these runways are situated in such a way that the least amount of urban area is affected by the aircraft noise.

Figure 4, Figure 5 and Figure 6 show the 35 KE-zone for Leeuwarden, Volkel Airbase and for the AWACS flying area near Schinveld.
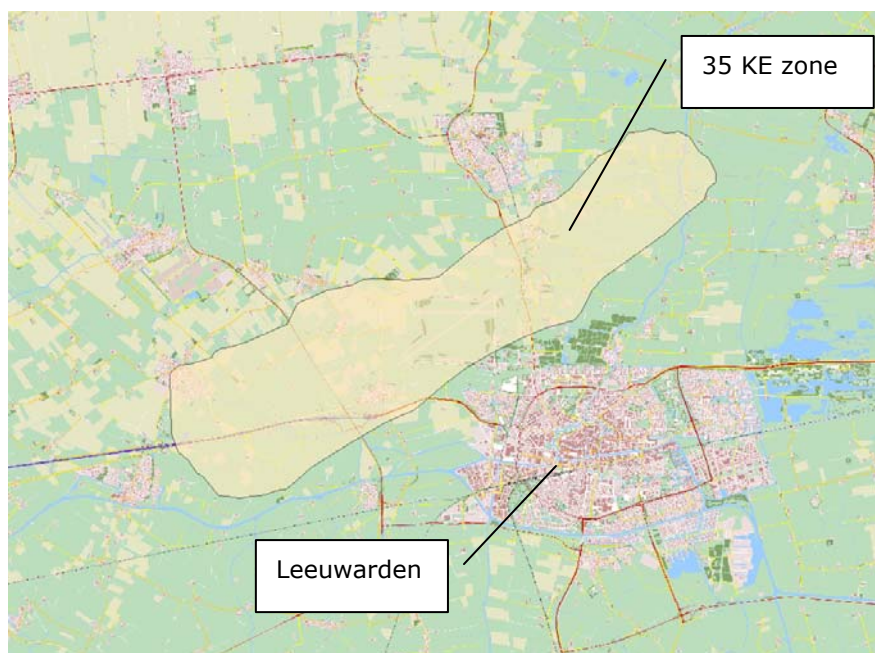

Figure 4 Noise zone (35 KE) at Leeuwarden airbase.
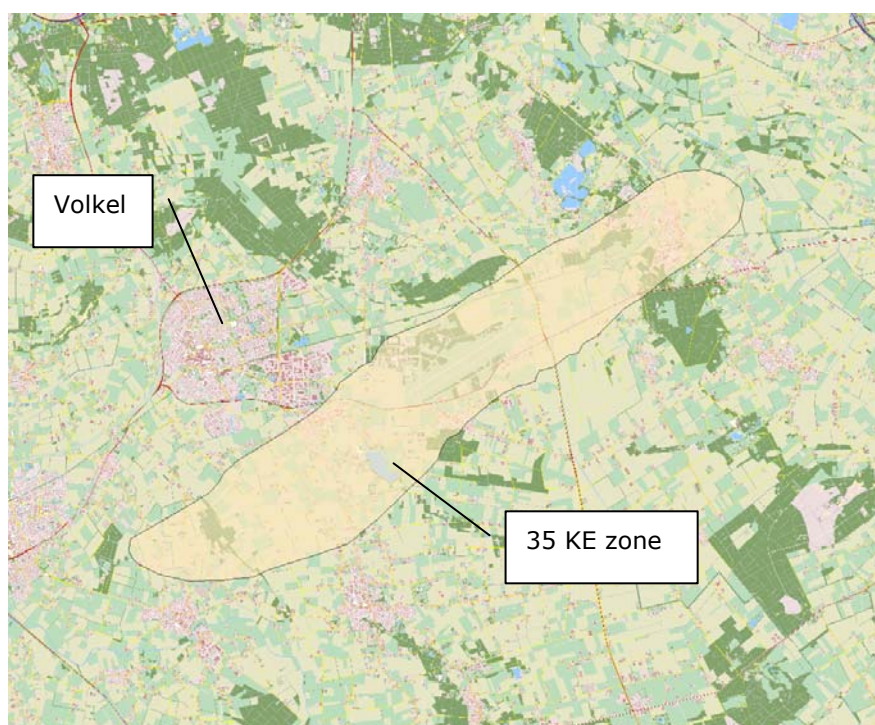

Figure 5 Noise map of the 56 L_{den} contour around Volkel Airbase.

The noise contour of Leeuwarden airbase is slightly larger than the contour of Volkel Airbase, yet within the Leeuwarden contour no large urban areas are affected. This is in contrast with the Volkel contour, which contains parts of the

towns of Volkel and Mill. It is expected that the depreciation of land prices will be higher for the Volkel contour.

Finally, the 35 KE zone at Schinveld for the military airport Geilenkirchen (Germany) is shown in Figure 6.
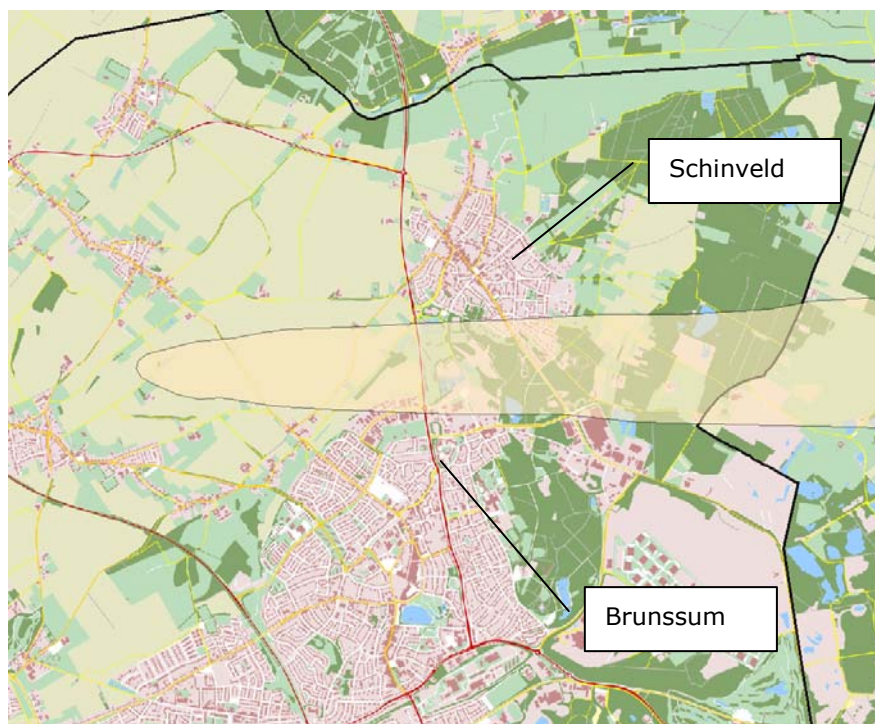

Figure 6 Noise zone (35 KE) for the AWACS airplanes from Geilenkirchen

Here, located within the noise contour are Douvergenhout, parts of Schinveld and Brunssum. As with Volkel Airbase, a relatively large area within the contour is used for residential use, so a substantial depreciation of land value is expected here as well.

3.4   **Results**

Using the surface areas of the noise contours, the depreciation of land prices can be estimated using the method as explained in section 3.1. The results are shown in Table 4.

Table 4 Rated depreciation of land value in millions of euro due to airport noise

Source	Noise contour area (km^2)	surface area for residential use (km^2)	Total loss (millions of euros)
Schiphol Airport	190	24	360
Leeuwarden Airbase	35	3	40
Volkel Airbase	35	6	90
Awacs Area Schinveld	5	2	30
Low Flying LR10	65	4	60
Other Airports	5	1	15
Total	**335**	**40**	**595**

First, the determined surface areas of each of the contours are corrected for the area used by the airport or airbase itself, as that area is not affected by the noise. For instance, the LIB4 zone for Schiphol airport has a surface area of 210 km^2, and the area that is part of Schiphol airport itself is 17 km^2. The total area which is considered to experience a value depreciation is 210 – 20 = 190 km^2. Subsequently for each of the contours the percentage of land within the contour that is used for residential use was estimated by means of the noise maps, and using the factors found in section 3.1 the depreciation can be calculated.

4   Benefits of noise emission reduction at civil airports

4.1   Benefits due to renewal of air fleet

In the previous chapters, it was shown that aircraft noise can cause severe economic damage. As with the study on the benefits of sound measures (Jabben et al., 2007), which focused on road- and railway traffic, also for aircraft noise a benefit analysis can be done. In the former study the benefits of measures against road- and railway traffic noise can be easily quantified, for instance the cost-effectiveness of noise barriers or silent pavings. These measures are not applicable to reduce aircraft noise, but renewal of air fleet, thereby replacing older airplanes by new more silent airplanes, could reduce the amount of aircraft noise in the near future. Rienstra (2000) surveyed the noise production of aircraft types alongside the date of service introduction. The results are shown in Figure 7.
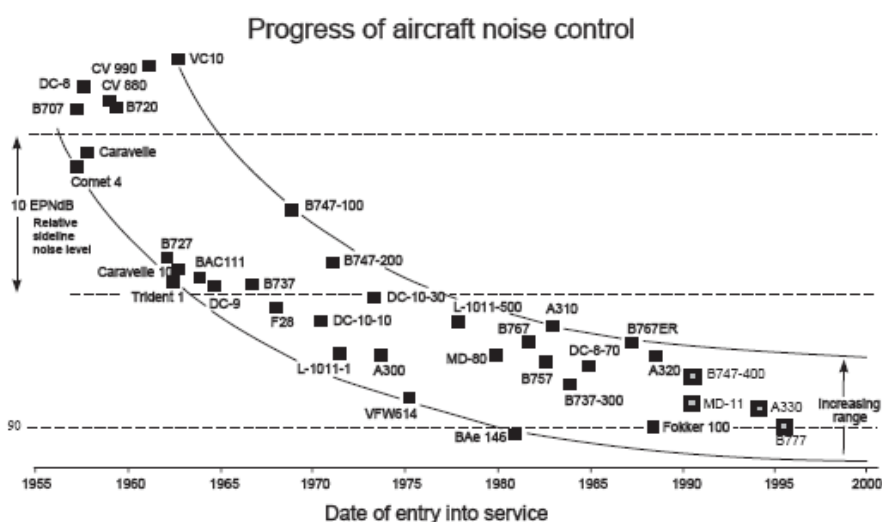

Figure 7 Development of the emission levels of several types of aircraft from 1955 until 2000 according to Rienstra (2000).

Figure 7 only shows the emission of different types of aircraft at the time when it was first brought into use. To provide an estimate of the development of noise emissions from the current fleet, it is necessary to determine how many aircraft of each type are still in use. The development of the noise emission of an average fleet subsequently shows a much slower decline than shown in Figure 7. The life expectancy of an aircraft is often at least 25 years, so an aircraft with a relatively high noise emission from early 1980 may still be used well into the current century. As the older, noisier types will eventually be replaced by newer, quieter aircraft types, it is expected that an air fleet as a whole will be more silent in the near future. Jabben et al. (2009) showed that for Schiphol airport, a reduction in noise emission of 1 dB can be expected due to the renewal of its air fleet by 2020 in case the airport succeeds in their policy of speeding the phase-out of the noisiest 'Chapter 3' airplanes in the current fleet.

4.2   Noise Damage and Group Noise Level Schiphol Airport

If a reduction of 1 dB of aircraft noise emissions from Schiphol could be realized in 2020, this would reduce noise damage in 2020 as compared with a scenario in which only traffic growth is incorporated.

The effect on the real estate and land prices can be roughly estimated using the group noise level G_{den} that accumulates the noise levels on all dwellings around an airport. Jabben et al. (2009) evaluated the development of the group noise level caused by Schiphol Airport from 1993 until 2009 and found that the level has gradually decreased, from 110,5 dB(A) in 1993 to 108 dB(A) in 2009.

In order to relate social losses to the group noise level, the depreciation of real estate for these years was determined by means of Hedonic Pricing. Figure 8 shows the results of the HP-calculated noise damage against the G_{den} level, with a NDI value of 0.8% and a threshold level L_{TH} of 50 dB L_{den} as used in this study.
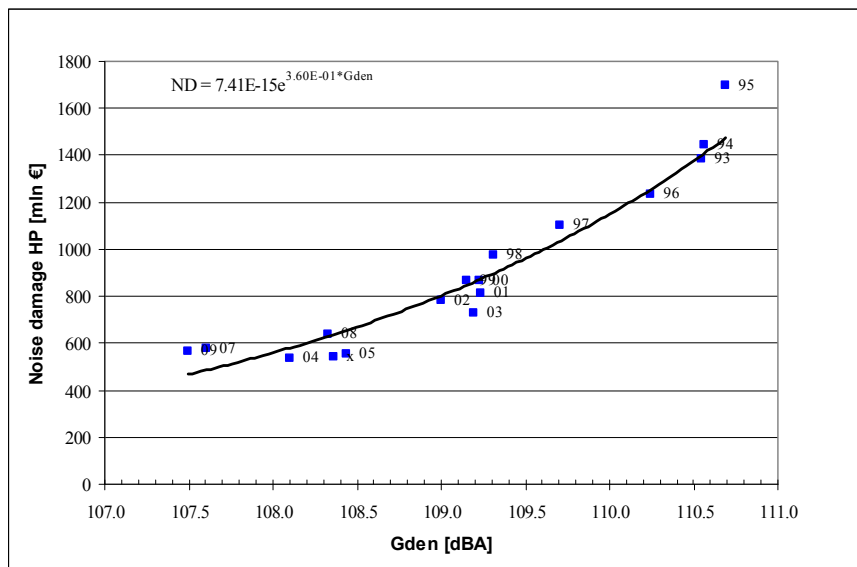

Figure 8 Noise damage found for Schiphol airport versus year-averaged Group Noise Level G_{den} for the period 1993-2009

Figure 8 shows the resulting relation between the noise damage and the G_{den} level. Roughly the noise damage doubles with a 2 dB increase of the group noise level. This rather sensitive relationship can be understood if it is realized that a 2 dB increase of G_{den} is caused by combination of higher noise exposure levels and more dwellings exceeding the chosen threshold of 50 dB L_{den}. This latter effect will be the dominant one, and it thereby underlines the difficulties in choosing an adequate threshold value, see also section 2.2. Schiphol Airport currently (2010) has a G_{den} level of approximately 108.5 dB(A), as shown in **Error! Reference source not found.**. Due to traffic growth, if no noise emission reduction is realized, in 2020 the group level will have increased approximately to 109.5 dB (Jabben et al., 2009). In case a 1 dB reduction of noise emission by renewal of the fleet can be attained, the group noise level will remain at 108 dB in 2020. This would result in a decrease of the noise damage from Schiphol in 2020 of around 300 million euro, approximately 30%. Further reduction of noise damage may be obtained by optimizing the flight routes.

4.2.1   *Comparison to other studies*

In the CPB study (Dekkers et al., 2009) a benefit of 594 million is given for each dB of noise reduction. This is about twice the value found above, which is probably due to the fact that the CBP study uses a 5 dB lower threshold value as compared to this study, thereby taking a much larger area and many more dwellings into account. It should be noted that attainable benefits are easily overrated when using a relatively low threshold value, because then cumulative effects become much more important. Reducing the contribution of airport noise does not remove the noise exposure and depreciation effects from road- and railway traffic.

In addition, the National Aerospace Laboratory conducted a study to the effects of airport noise on real estate an land prices (NLR 2009). Their results however, are only given relatively i.e. by comparing different flight schedules. No absolute values for social losses are specified.

4.3   Benefits from more silent aircraft on land value

More silent aircraft can also increase the value of exposed land. Each generic reduction of 1 dB will lead to a reduction of approximately 17% of the exposed area. As for Schiphol, the loss was tentatively estimated at 360 million Euro. A reduction by 2 dB would bring it down to roughly 260 million Euro. Of course benefits would only be collectable provided also the noise zone for new housing would be reduced accordingly.

4.4   Other civil airports

The accumulated G_{den} value in 2020 may be expected in the order of 101 dB. The noise damage is much lower than for Schiphol airport, approximately 45 million euro. Reducing the noise emission of the average fleet on these airports by 1 dB would lead to a reduction of 14 million euro.

In conclusion, a successful policy in which the noise emission of the Schiphol fleet is kept as low as reasonably possible within state of the art and economical conditions, will considerably contribute to avoiding further increase of noise damage from traffic growth.

5 Conclusions

Using Hedonic Pricing with a Noise Depreciation Index of 0.8% and an threshold level of 50 dB (L_{den}), the depreciation of real estate value due to airport noise in the Netherlands amounts to 1 billion euros. This is comparable to the depreciation due to noise from motorways in the Netherlands, which was found in an earlier study by RIVM. The noise produced by Amsterdam Airport Schiphol contributes about 65% to the cost. It should be noted that using different methods (Contingent Valuation) and parameter settings (*NDI* and L_{den}), other values for depreciation will be found. The result of a loss of 1 billion euros is therefore an indicative value.

Land value depreciation was estimated by determining the urban areas around airports in which no new houses can be built due to aircraft noise. When a depreciation of 50% is assumed to land originally planned for residential use, the total depreciation amounts to nearly 600 million euros for the Netherlands, with Schiphol Airport contributing roughly 60% to this amount.

For both land prices and real estate value, the loss may decrease with hundreds of millions of euros when in the future more silent aircraft will replace older, louder models. The methods used in this study have also been used in several international studies, although no consensus exists on which parameters should be chosen under which circumstances. Therefore the loss values, in particular those estimated for land value in this study are indicative.

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Appendix A Contingent Valuation

Contingent Valuation (CV) can be used as an alternative to the Hedonic Pricing method. This method differs from HP that this is stated preference method, in which the cost of aircraft noise is found from the people's Willingness to Pay (WTP) for the avoidance of the noise. Subsequently most studies using this method are done by surveys, in which people are asked how they would react on a hypothetical scenario involving traffic noise. For instance, a respondent is asked a direct question on willingness to pay for a beneficial change or willingness to accept compensation for a deterioration of their current situation. The WTP found in such studies is denoted in monetary values, usually in €WTP per dB per household per year. This can be summarized with the following equation:

$$loss = WTP \sum_i (L_i - L_{TH}) N_i ,$$
(A.1)

in which the N_i represents the number of households exposed to a noise level of L_i dB(A). L_{TH} is a threshold value. In this study we assumed a threshold value of L_{den} 50 dB in agreement with value used in the HP method.

In choosing a credible value for the WTP, several different aircraft noise studies on CV have been consulted. Most of these studies involve surveys, and because there is not complete agreement on the right methodology which should be used, resulting WTP values differ largely with each study (Brooker, 2006). For instance, according to a study by Pommerehne (1988) at Basel, Switzerland produced a WTP of 43 €/dB/hh/year, and the work done by Thune-Larsen (1995) resulted in a range of WTP values depending on the noise level, with the WTP ranging from 20 €/dB/hh/year to 66 €/dB/hh/year. Nelson (2004) critically reviewed several of these aircraft noise CV studies published up to 2002, and found that the two studies by Pommerehne and Thune-Larsen stand out compared to other studies. In this study the social losses according to CV is based on their results, in which a WTP for airport noise of around 30 – 40 €/dB/hh/year was found. This WTP is higher than the WTP used for road- and railway noise in the study by Jabben et al. (2007), which was 25 €/dB/hh/year. As with the higher *NDI* value for the Hedonic Pricing method, a higher WTP for airport noise is justified as people tend to be more annoyed by airport noise than by road- and railway noise.

If the CV method is to be compared with the HP method, some further assumptions should be made. After all, the main differences are that in the CV method generally the value is independent of the dwelling price and that the method results in an *annual loss*. It also important to note that in the HP method, the loss of the dwelling price is usually an absolute value over its entire lifetime, whereas the CV method results in annual losses. An indirect comparison between the HP and CV methods can subsequently be done if the annual loss of the CV method is multiplied with a factor that accounts for average mortgage durations, including the interest. This was done by Jabben et al. (2007), and in that study it was found out that a rough approximation of the total loss according to CV, that may be compared to the total social loss obtained using

Hedonic Pricing, is obtained by multiplying the annual amount of loss found with the CV method with a factor of 28.
Furthermore, the range of the total loss using the different methods is quite large: with a minimum of 470 million euro and a maximum of 1020 million euro. The fact that the Hedonic Pricing method includes real estate appraisal values can explain the difference in the Hedonic Pricing and the Contingent Valuation methods, as some airports/airbases are located near areas with high real estate appraisal (for instance Amsterdam, Groningen and the region near Volkel).