



Mapping and socioeconomic analysis of transportation noise in Sweden, 2018

Kartläggning samt samhällsekonomisk analys av
trafikbuller i Sverige, 2018

Ludvik Brodl, SMHI

Stefan Andersson, SMHI

Wing Leung, SMHI

Jenny Lindén, IVL

Gabriella Villamor, IVL

Marcus Justesen, SCB



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SMED (Swedish Environmental Emissions Data), is a collaboration between IVL Swedish Environmental Research Institute, Statistics Sweden (SCB), Swedish University of Agricultural Sciences (SLU) and the Swedish Meteorological and Hydrological Institute (SMHI). The collaboration commenced in 2001 with the long-term aim of gathering and developing the competence in Sweden within emission statistics. SMED is, on behalf of the Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management, heavily involved in the work related to Sweden's international reporting obligations on emissions within six subject areas (air, water, waste, hazardous substances, noise and measures). A central objective of the SMED collaboration is to develop and operate national emission databases. SMED data also supports national, regional and local governmental authorities for decision making. For more information visit the SMED website www.smed.se (in Swedish).



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PROTECTION AGENCY

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ENVIRONMENTAL
MONITORING
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noise

Kartläggning samt samhällsekonomisk analys av trafikbuller i Sverige, 2018

Report authors Ludvik Brodl, SMHI Stefan Andersson, SMHI Wing Leung, SMHI Jenny Lindén, IVL Gabriella Villamor, IVL Marcus Justesen, SCB	Responsible publisher Swedish Meteorological and Hydrological Institute Postal address Street address, postcode, postcode area Telephone +4611 - 495 80 00
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The results from the calculated population noise exposure in Sweden 2018 and costs is summed up in Table 1.

Table 1. Calculated number of the population exposed to $Leq,24h > 55 \text{ dBA}$ (re-sults merged with reported END-results), $LAFmax > 70 \text{ dBA}$ and the total socioeconomic cost in million Swedish krona (Msek).

Noise source	Number of exposed people in Sweden		Socioeconomic cost per year, Msek
	$L_{Aeq} > 55 \text{ dB}$	$L_{AFmax} > 70 \text{ dB}$	
Road	1 513 000	7 200 000	19 500
Railway	407 000	1 200 000	1 800
Aviation	19 000	-	70

Since 1998, the Environmental Protection Agency has produced national noise analysis, similar to this one for the years; 1992 (Wittmark, 1992), 1995 (Wittmark, 1997), 2000 (Ingemannsson Technology AB , 2002), 2006 (WSP Akustik, 2009), 2011 (SWECO, 2014).

Even though the task and method for these previous reports were similar, there are many differences. Therefor a trend analysis is not feasible. There are many aspects that could improve accuracy for future national mapping such as including definition of hard and soft ground effect due to different ground types, estimation of exposure point height using building geometries. Most likely the most important change is to include buildings and noise barriers effects on noise.

Förord

Flera myndigheter genomför miljöövervakning på olika områden och med olika perspektiv. Inom programområdet för hälsorelaterad miljöövervakning (HÄMI) finansierar Naturvårdsverket övervakning av miljöfaktorer i den omgivande miljön som kan påverka människors hälsa.

Övervakning av miljöfaktorer görs exempelvis genom att uppskatta människors exponering för fysikaliska mätdata (såsom buller) i den omgivande miljön och genom att utföra analyser som kopplar samman miljöexponering och hälsoeffekter. Härigenom kan HÄMI bland annat ge underlag för riskbedömning, regleringar och råd.

I delprogrammet ”Fysikaliska mätdata – buller” följs hur många personer som exponeras för förhöjda nivåer av buller utomhus. Syftet med delprogrammet är att uppskatta antalet boende i Sverige som utsätts för bullernivåer som kan påverka människors hälsa negativt.

Den senaste bullerkartläggningen inom HÄMI gjordes under perioden 2012 - 2014 och omfattar data från 2011. Det görs även en bullerkartläggning enligt EUs bullerdirektiv som utförs vart 5e år och omfattar kommuner med mer än 100 000 invånare samt större vägar/järnvägar och större flygplatser. Senaste kartläggningen genomfördes 2017 och omfattar data från 2016. Undersökningar inom HÄMI är viktiga för att täcka de kunskapsluckor som finns i bullerkartläggningen enligt EU:s bullerdirektiv.

På grund av att bullerkartläggningar inom HÄMI täcker hela Sveriges yta och befolkning behöver man förenkla datainsamling och beräkningar för att få hanterbarhet. Det innebär att undersökningen bland annat inte tar hänsyn till alla bullerdämpande åtgärder som vidtagits så de ska ses som översiktliga uppskattningar av exponerade och negativa hälsoeffekter. Det kan tex. leda till att bullernivån beräknas ha ökat, men de upplevda besvären blir mindre än vad som uppskattas.

Tidigare har dessa förenklingar skett på olika sätt och därfor är bullerkartläggningarna inte jämförbara och trender kan inte uppskattas utifrån dessa. Ett utvecklingsarbete har påbörjats inför framtida bullerkartläggningar inom delprogrammet, i syfte att skapa likvärdighet i metod och genomförande mellan gångerna för att bland annat kunna följa trender över tid.

Användning av metod, framtagande av resultat och dragna slutsatser står SMED (Svenska Miljö Emissions Data) och rapportförfattarna själva för. Naturvårdsverket har finansierat rapporten inom delprogrammet ”Fysikaliska mätdata – buller” inom HÄMI.

NATURVÅRDSVERKET

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Summary

SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute.

This study has examined noise exposure on a national scale for Sweden by calculating road and rail noise for the entire country. Calculations have been made according to the Nordic Prediction Method for both road and rail. For aviation noise, data is extracted directly from Swedavias yearly noise report with addition of military flights.

Because of the large scale of noise mapping, several simplifications have been made in both data and calculations. For validation, the national noise mapping has been compared to noise data reported to EU via the Environmental Noise Directive (END), indicating a ratio of 0.4-1.5 compared to END data for road in intervals between 52.5 and >72.5 dBA and 1-1.8 for rail for the intervals between 49 and >69 dBA.

The results from the calculated population noise exposure in Sweden 2018 and costs is summed up in **Fel! Hittar inte referenskälla..**

Table 1. Calculated number of the population exposed to $Leq, 24h > 55$ dBA (results merged with reported END-results), $LAFmax > 70$ dBA and the total socioeconomic cost in million Swedish krona (Msek).

Noise source	Number of exposed people in Sweden		Socioeconomic cost per year, Msek
	$L_{Aeq} > 55$ dB	$L_{AFmax} > 70$ dB	
Road	1 513 000	7 200 000	19 500
Railway	407 000	1 200 000	1 800
Aviation	19 000	-	70

Since 1998, the Environmental Protection Agency has produced national noise analysis, similar to this one for the years; 1992 (Wittmark, 1992), 1995 (Wittmark, 1997), 2000 (Ingemansson Technology AB , 2002), 2006 (WSP Akustik, 2009), 2011 (SWEPCO, 2014). Even though the task and method for these previous reports were similar, there are many differences. Therefor a trend analysis is not feasible.

There are many aspects that could improve accuracy for future national mapping such as including definition of hard and soft ground effect due to different ground types, estimation of exposure point height using building geometries. Most likely the most important change is to include buildings and noise barriers effects on noise.

Keywords: road noise, rail noise, train noise, airport noise, aviation noise, socio-economic cost from noise, European Noise Directive (END), Nordic Prediction Model

Sammanfattning

Denna studie har undersökt bullerexponering på nationell nivå för Sverige från väg-, spår- och flygtrafik. Beräkningar av ljudnivåer har utförts för alla statliga och kommunala vägar samt statliga spår. För flygbuller har resultat använts från Swedavias årliga bullerrapport med tillägg av antalet exponerade för militära flyg.

På grund av den stora omfattningen av en nationell bullerkartläggning har flera förenklingar och antaganden gjorts på både underlag och beräkningar. Därför har validering utförts mot det resultat som rapporteras till EU från alla större svenska kommuner i enlighet med det europeiska bullerdirektivet (END). Valideringen indikerar på ett förhållande på 0,4-1,5 för vägtrafikberäkningarna i intervall mellan 52,5 och >72,5 dBA och ett förhållande på 1-1,8 för spårtrafikberäkningarna i intervallen mellan 49 och >69 dBA.

Resultatet från den beräknade befolkningsexponeringen i Sverige 2018 och socioekonomisk kostnad presenteras i Tabell 2.

Tabell 2. Antalet personer i Sverige exponerade för ekvivalent ljudnivå >55 dBA (resultat sammanslagna med rapporterade END-värden), maximal ljudnivå >70 dBA samt total socioekonomisk kostnad i miljoner svenska kronor (Msek).

Källa	Antal exponerade personer		Total socioekonomisk kostnad per år, Msek
	L _{Aeq} >55 dB	L _{Amax} >70 dB	
Väg	1 513 000	7 200 000	19 500
Järnväg	407 000	1 200 000	1 800
Flyg	19 000	-	70

Naturvårdsverket har sedan år 1998, publicerat flera bullerkartläggningar över Sverige gällande år; 1992 (Wittmark, 1992), 1995 (Wittmark, 1997), 2000 (Ingemansson Technology AB, 2002), 2006 (WSP Akustik, 2009), 2011 (SWECO, 2014). Även om syfte och metod har varit liknande mellan tidigare versioner, finns det många stora skillnader i metodikval och antaganden. Det är därför inte rimligt att utföra en trendanalys med data ifrån de föregående rapporterna.

Det finns flera aspekter som kan förbättra noggrannheten för framtida nationella bullerkartläggningar. Det inkluderar exempelvis definiering av hård eller mjuk mark på grund av olika marktyper, uppskattning av exponerings-punkters höjd och placering i relation till tredimensionella byggnadsstrukturer. Den metod-förbättring som mest sannolikt har störst inverkan på resultatet är införandet av byggnader och bullerskärmars inverkan på buller.

Nyckelord: buller, nationell bullerkartläggning, nordisk beräkningsmodell, European Noise Directive (END), socioekonomisk kostnad för buller, vägtrafikbuller, järnvägsbuller, flygbuller

1 Introduction

Noise exposure causes negative health effects, which are both physical and psychological. Prolonged exposure to high levels of noise can, for example, cause hearing impairment, tinnitus, annoyance, sleep disturbance, hypertension, (Kerns, 2018) (Thomas Münzel, 2018). Approximately 10 000 premature deaths are caused by prolonged exposure to road traffic noise in the EU each year according to calculations by the European Environment Agency (European Environment Agency, 2014).

The national noise exposure mapping presented in this report is a complement to the data reported every fifth year to the EU from Sweden according to European Noise Directive (END). The END reported data covers agglomerations with a population >100 000 and roads of annual average daily traffic (AADT) >8200 vehicles/day or railways with >82 trains/day or airports with >50 000 movements/year. There are 15 agglomerations that fit this description in Sweden, for the END report representing year 2016. These 15 agglomerations include a total of 3 400 000 inhabitants, the remaining 6 720 000 population of Sweden is not included. The main purpose of this report is to fill the gap and consider the remaining 6 720 000 inhabitants.

This report is organized as follows. This section defines the purpose of this report and presents all the acronyms, abbreviations and basic concepts which are required to understand this report. It is followed by a section that presents the method used to calculate noise immissions and exposure from road, rail and aviation traffic. A set of results are presented in the section after. The report is concluded with a discussion and conclusion based on the findings.

1.1 Acronyms, abbreviations and basic concepts

1.1.1 SMED

SMED is an abbreviation for “Svenska MiljöEmissionsData” which can be translated to “Swedish Environment Emission Data” and is the name of a consortium, in which four organizations; IVL, SCB, SLU and SMHI cooperate. In this study; IVL, SCB and SMHI participated.

1.1.2 IVL

Swedish Environmental Research Institute.

1.1.3 SCB

Statistics Sweden

1.1.4 SMHI

Swedish Meteorological and Hydrological Institute.

1.1.5 SLU

Swedish University of Agricultural Sciences.

1.1.6 NVDB

“Nationell vägdatabas”, direct translation is “National road database”. This database is produced by Swedish Transportation Administration.

1.1.7 NJDB

“Nationell järnvägsdatabas, direct translation is “National railroad database”. This database is produced by Swedish Transportation Administration.

1.1.8 END

European Noise Directive. Noise data for 2016 found at (European Environment Agency, 2017). Noise exposure study, for the year 2016, covers 15 of the largest municipalities of Sweden where approximately 1/3 of Sweden’s population live.

1.1.9 NMHE15

Swedish National Health Enquiry, year 2015. (Nationella MiljöHälsoEnkät 2015)

1.1.10 Noise

Noise can be defined as unwanted sound but in theory there is no difference between sound and noise. Sound that is perceived to be disturbing is individual. It can be influenced by many factors such as the nature of the sound, the strength, the time of day it occurs and how it varies over time. In this report noise refers to the sound caused by road, rail and air traffic.

1.1.11 Decibel and A-weighing

The sound pressure level is used as a measure of the effective pressure of a sound relative to a reference value. The scale is logarithmic; 0 dB corresponds to the lowest sound a person can perceive, and 130 dB corresponds to the sound pressure level when humans experience physical pain.

The sensitivity of the ear varies with frequency and sound pressure level. In order to compensate for the varying sensitivity of the ear at different frequencies, the total measured or calculated sound pressure level is often corrected. In other words, lower frequencies are weighted down as the ear is more sensitive to higher frequencies. The most common weighing, A-weighing, is adapted to the ear's sensitivity at normal sound levels and is abbreviated as dBA or dB(A).

1.1.12 Frequency

The sound pressure varies around an equilibrium position, the normal air pressure. The number of oscillations around the equilibrium position per second, the frequency, is indicated by the unit hertz (Hz). The pitch increases with frequency. Humans can perceive sound within the frequency range of 20 Hz - 20 kHz.

1.1.13 Spectrum

Other than describing sound in total level in dBA, sound can be also described more detailed in spectrums. To get an idea of the frequency of the sound, a frequency analysis is performed with a band filter. The various filters emit frequencies between internationally standardized upper and lower limits. For noise measurements, it is common to use octave filters where the sound level is specified for the octave bands, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. This is for example used for the train immissions in the NTM96 method.

1.1.14 Equivalent (L_{eq}) and Maximal (L_{AFmax}) Sound Level

When calculating noise, a logarithmic mean of the sound energy over a period is often used to obtain a representative value, which is referred to as the equivalent continuous sound level L_{eq} , L_{Aeq} , or $L_{Aeq, 24h}$.

The equivalent continuous sound level is the constant sound pressure level that corresponds to the same total sound energy that is produced over a given period.

In calculating traffic noise, a 24-hour period is primarily used for the calculation.

Frequency weighing is often applied to the calculated sound level to describe what humans are physically capable to hear. The letter A in L_{Aeq} , or $L_{Aeq, 24h}$ represents that A-weighting filter has been applied to the calculated sound.

Maximum sound pressure level shows the highest measured or calculated sound level for a specified period. Maximum levels can have different time weighing constants including Fast, Slow and Impulse. For noise from road and rail traffic, time weighing Fast is used which is a peak in noise of 125 milliseconds. The magnitude for maximum sound pressure level is often referred to as L_{AFmax} . In this project, the method used for calculating maximum sound pressure level has been carried out according to the Nordic Prediction Method for road and rail. The method differs between road and rail and is described separately in the methods chapter.

1.1.15 Equivalent (L_{eq}) and day-evening-night (L_{den}) sound level

In Sweden the commonly used sound level is A-weighted equivalent sound level, L_{Aeq} . However, the END data is reported in day, evening, night sound level, which is defined as:

Equation 1. Definition of L_{den} in terms of day, evening and night noise.

$$L_{den} = 10 \lg \frac{1}{24} [12 \times 10^{L_{day}/10} + 4 \times 10^{(L_{evening}+5)/10} + 8 \times 10^{(L_{night}+10)/10}]$$

In words, the L_{den} can be described as noise during the evening and night are worse than noise during the day.

All model runs in this report uses a height of 4m, as required for L_{den} calculations. Thus, the conversion between NORD96 results in L_{Aeq} to END L_{den} format is +7 dB for road noise and +6 dB for rail noise as per recommendation in (Jonasson, 2005).

1.1.16 NORD96

The Nordic Prediction Methods (NORD96) (Naturvårdsverket, Vägverket, 1997) for road and rail were produced to be jointly used for noise predictions in the Nordic countries. At the time this report is written the recommended noise model is NORD96 for all physical planning and mapping in Sweden (Nationell samordning av omgivningsbullen, 2014). Other models may be used, if they provide equivalent accuracy. After the 31st of September 2018, all mapping for END must use the Cnossos-EU (Common Noise Assessment Methods in EU), although, measurement and validation for Cnossos-EU to be implemented for Swedish conditions is still work in progress.

The Nordic Prediction Methods are based on approximations and validated empirical calculation models to predict $L_{eq,24h}$, and L_{AFmax} . There are three parts when calculating with NORD96. The first part involves the source model, which for rail and road traffic, the source is defined from validated measurements as a function of traffic intensity, speed and other parameters. Since the release of the method in 1996, the Nordic Prediction Method for Road has not updated the immission inventory for vehicles. However, for the Nordic Prediction Method for train immissions (NMT96) (Naturvårdsverket, Banverket, 1998), several new train measurements have been added since.

The second part includes corrections for distance attenuation and the third part includes corrections for parameters that further contribute to sound attenuation such as reflections and barriers.

1.1.17 Simplified NORD96 – SMHI's NORD96 v1.0 (road)

This is the model used to produce noise exposure for road traffic noise in this report.

1.1.18 CadnaA

CadnaA is a program produced by DataKustik GmbH to calculate and to map noise from road, rail, aviation or other point and line sources. The program has several standards implemented, including the NORD96 for rail, road and industry. In this project, the Nordic Prediction Method for rail (NMT96) has been used to calculate train immissions.

2 Method

Noise propagation for both road and rail is calculated according to NORD96. Assumptions have been made to simplify the calculations by for example not including terrain, barriers or reflections.

Data from detailed noise exposure mapping of 15 municipalities from the END report is used for comparison with the results from the simplified NORD96 as validation. In addition, the self-reported citizen data from NMHE15 was used to further validate our data on a national level. Results from individual roads or rails are not presented, as it is of low value for the purpose of this report, since the aim is to have a noise predictive model on a national scale.

When considering aviation noise, both immission and exposure, there is readily available data of very high quality from Swedavia (Swedavia, 2019). Swedavia's reported data is extracted from their report for the year 2018 and includes the ten national airports in Sweden; the remaining private airports are not included in this report.

For an overview of the methodology used to produce this mapping of see Figure 1.

Note that the calculation of noise pressure levels from roads and rails are completely separated. The resulting exposure from road and rail are thus independent of each other.

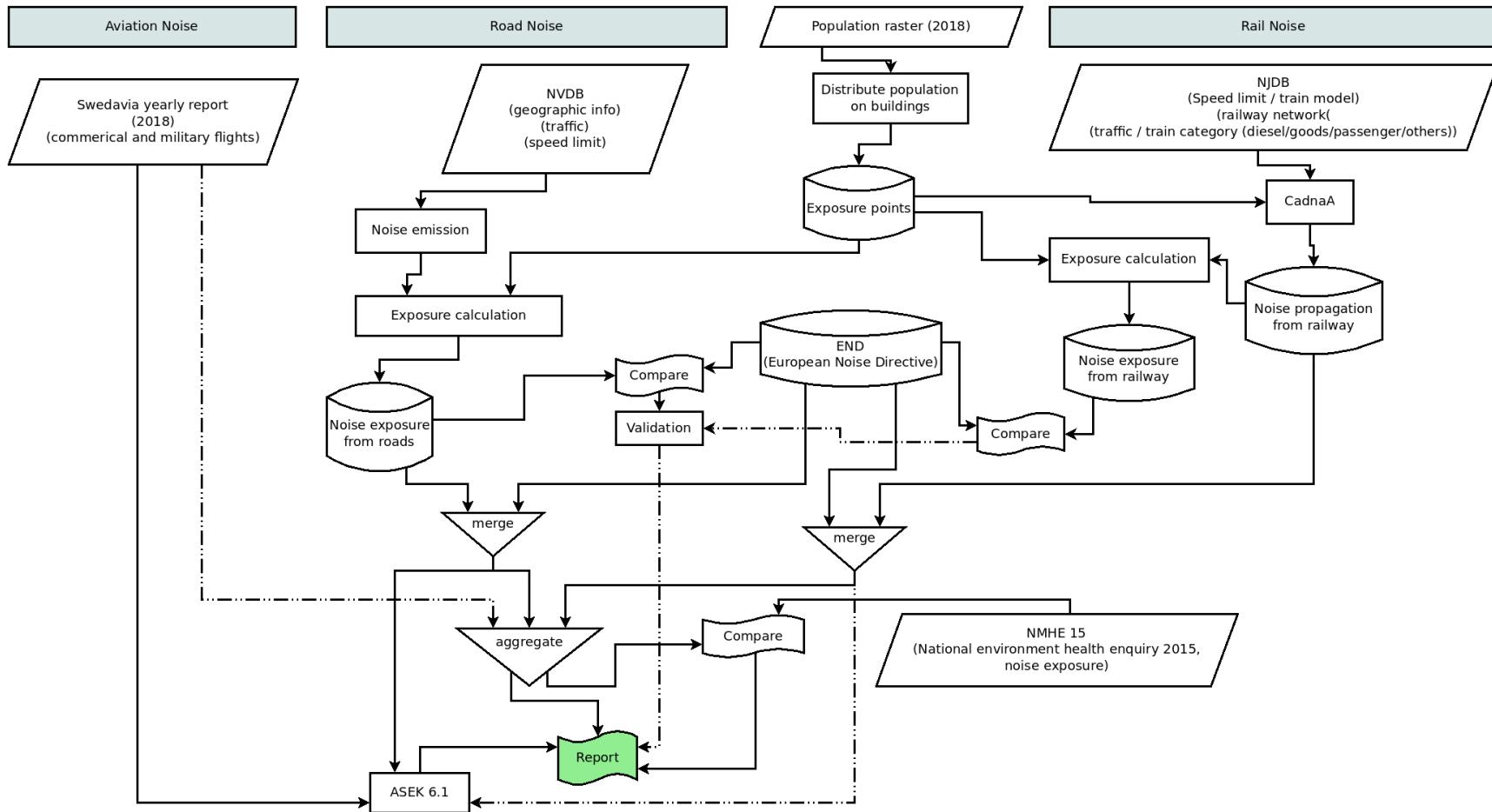


Figure 1. Overview of the data flow for this report: Aviation noise immission is taken directly from Swedavias report. Road noise uses NVDB as its primary data source for road traffic, which is fed into Simplified NORD96 – SMHI's NORD96 v1.0 (road) along with the exposure points produced with the population raster as explained in 2.1.1. Rail noise uses NJDB as it's primary source for railway traffic and uses the model CadnaA for simulation, the same receptor points as for road noise is used for railway noise. Both road noise and traffic noise results are compared to END reported data. The results are merged with END to produce a nation wide noise mapping. And the modeled results (along with the END data) is combined with ASEK to provide a socioeconomic cost.

2.1 Noise immission, exposure model and input used for calculations

Immission and exposure calculations are done by using a simplified version of NORD96 for both $L_{Aeq,24h}$ and L_{AFmax} . Below the model adaptations and simplifications are presented. Note that calculation and results of both noise propagation and exposure for roads and rails are separated.

2.1.1 Population data (receptor points)

Receptor points are defined geographically for Sweden. This is done by combining SCB's 2018 population grid, 250 m × 250 m for urban areas and 1000 m × 1000 m for rural areas, with Lantmäteriet's Fastighetskartan which includes all buildings in Sweden with an assigned building type. The algorithm to distribute the population grid to the buildings works as follows:

Residential building polygons are converted into single lines.

Each 50 m along the line, a receptor point is created, starting at 0 m, resulting in 4 035 348 receptor points. The points are then assigned a population number, which is equal to the value of the population grid they are contained within, divided by the number of points, see Figure 2.

The advantage with the methodology described above (population distributed to buildings) in comparison with population by addresses, is that statistical confidentiality can be avoided which entail; anyone with the right computer skills can reproduce the results in this report and further improve on the method. There are some shortcomings of this method, for example the location of the receptor points is determined by the way the building polygons were saved, as the extracted line can have an ambiguous start in a closed polygon. See Appendix 5 for details of the receptor point creation algorithm. The receptors' municipality origin is determined by their position relative the dataset ak_riks.shp from (Lantmäteriet, 2019).

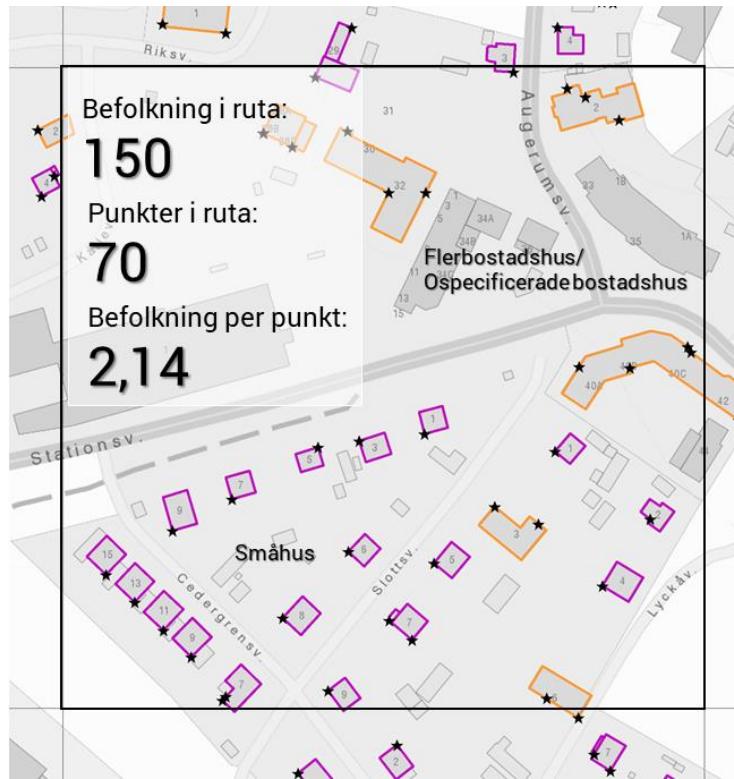


Figure 2. Receptor points used. Buildings that are non-residential are ignored. Population in grid: 150, Points in grid: 70, Population per point: 2.14.

2.1.2 Data used for road traffic noise

Data from Nationell vägdatabas (NVDB) (Trafikverket, 2018) provided by Trafikverket to SMHI within the air quality modeling system SIMAIR (SMHI) provides annual average daily traffic, fraction of heavy vehicles, speed limit, geometry and geographic position for the roads. NVDB contains information on national roads (~200 000 links), including annual average daily traffic for different vehicle types, speed limits, cold start fraction, etc. Moreover NVDB includes information about all communal roads in Sweden. Outside of the road network in NVDB there are areas (SAMS-ytor) defined for modeling trips to and from the road network, i.e. road construction. For the communal road network; information on the roads are based on SAMPERS model simulations, which in turn lead to larger uncertainties on the roads. SMHI have made improvements to communal roads by distributing the “local traffic”¹ which is defined by SAMS-ytor, ranging in size from few hundred square meters to a couple of square kilometers. This area is given a number representing the total number of transported meters by vehicles in total.² Therefore, the accuracy for individual small roads is uncertain. However, as larger roads are the main source of noise >55 dBA, the accuracy on a national level is likely not very affected by this uncertainty.

¹ “Inomområdestrafik” in Swedish.

² For more details of how NVDB is processed see (Andersson, et al., 2019 pp. 49-53).

2.1.3 Data used for railway traffic noise

Data containing the following information for each track in Sweden during the year 2017 was obtained from the Swedish Transport Administration (Jvg_Planerad_trafik_T17.shp):

- Types of trains that are operated on the track.
- The distribution between different types of trains.
- Number of trains as annual average of passages.
- Train lengths (average and maximum).
- The limiting speed from either the maximum permitted speed for each train type in general or the maximum permitted speed for each train type on a certain track was chosen for each segment.

The data include the national and regional tracks but not local tram and commuter lines.

NMT96 consist of a database with sound immissions and spectrums that derive from measurements of Swedish trains. Available trains in the database are the following:

- High-speed passenger train X2
- Conventional passenger trains, mainly with Rc-locomotives (PASS and PASS wood)
- Freight trains, mainly with Rc-locomotives (gods)
- Freight trains, mainly with T44-locomotives (GodsDi)
- Local trains (X10Di), which also includes train types X10 and X12

The method provides the possibility to include new train types that have been added to the Swedish fleet since 1996. The following approved reports, that include sound immissions and spectrums from measured data, have been used to add new train types to the database:

- Bullerimmissioner från nya svenska tågtyper, WSP Akustik, 2004-11-04
- Indata till bullerberäkningsmetoder för motorvagn X60, VTI notat 9-2010
- Elmotorvagn Coradia Duplex – Littera X40 Indata till beräkningsmodellerna NMT och Nord 2000, WSP Akustik, 2012-02-06

Tracks without specification on the type of train and number of passages (normally because of infrequent traffic) were excluded from the calculations. For the calculation of $L_{eq,24h}$, the average train length was used while for the calculation of L_{AFmax} the maximum train length was used.

2.1.4 Data used for Aviation traffic noise

For aviation, noise exposure from domestic flights is extracted from (Swedavia, 2019). Number of noise exposed from military flights are taken from previous report (Sweco, 2014), which uses exposure from the year 2006. This exposure has been confirmed to be applicable for the year 2018 via email by FÖRSVARSMAKTEN, LEDS TF Hållbarhetssektion.

2.1.5 Data used to validate and extend the national mapping

The results from the road and rail model are merged with data from (European Environment Agency, 2017) which is a noise mapping of the year 2016 for 15 of the largest municipalities in Sweden.

2.2 Simplified NORD96 – SMHI's NORD96 v1.0 (road)

In this study NORD96 was implemented using a mix of Python and GDAL. As calculations included the whole of Sweden, several simplifications were made to reduce complexity and reach a manageable calculation time. The major simplification made is the exclusion of terrain, buildings and other barriers.

For road, NORD96 noise calculation for a single exposure point with multiple sources can be broken up into four steps. The first step is calculation an immission and the following three steps involve different effects on propagation.

For each exposure point, only roads that intersect a radius of 300 m are included in the calculations for that exposure point.

2.2.1 Baseline Immission calculation

Annual average daily traffic, fraction of heavy vehicles, speed limits and geometry and geographic position for the roads are used. This step is complete and no deviation from the original NORD96 is made. The following equations are used from (Naturvårdsverket, Vägverket, 1997);

- Part 2, Eq 2.17
- Part 2, Eq 2.18
- Part 2, Eq 2.19
- Part 2, Eq 2.21
- Part 2, Eq 2.24
- Part 2, Eq 2.31
- Part 2, Eq 2.32
- Part 2, Eq 2.33

2.2.2 Distance correction

With the receptor points defined geographically we can deduct the required parameter; distance between road and receptor. For the remaining parameters we use default values;

- road height (default value: 0 meters)
- receptor height (default value: 4 meters³)

The equations used from (Naturvårdsverket, Vägverket, 1997) are;

- Part 2, max of Eq. (2.27, 2.28)

³ The use of 4 meters comes from END. (Directive 2002/49/EC, 2015) (Chapter M2. 2.8)

- Part 2, Eq 2.34
- Part 2, Eq 2.35

2.2.3 Ground and barrier correction

Information of road height, topography, ground type or barriers were not included in the calculations. Soft ground is assumed and a road height of 0 m and receptor height of 4 m. No correction factor for topography or barrier is applied.

The equations used from (Naturvårdsverket, Vägverket, 1997) are;

- Part 2, Eq 2.36
- Part 2, Eq 2.37

2.2.4 Other corrections

Due to lack of input information as well as to reduce calculation time, the following correction factors are excluded in the calculations:

- thick barriers (no data)
- inclines (no data)
- short distance between road and receptor (requires road width, no data)
- multiple reflections from side roads (requires exact exposure point location (x, y, z) relative buildings, not applicable since we produce our own exposure points)
- multiple reflections in inner courtyard (same as above)
- multiple reflections between buildings (same as above)
- reflection from singular surfaces (same as above (except for receptor height) and no data)
- barriers and detached houses (not applicable)

This leaves us with a single correction factor;

- angle of the road source relative exposure point (allows multiple road sources to be used), which can be easily calculated since the road geometry and exposure point is known. This is especially important since roads are seldom straight, which is an assumption that must be used if this correction factor is skipped.

The equations used from (Naturvårdsverket, Vägverket, 1997) are;

- Part 2, Eq 2.51

Lastly for a given receptor point we sum the contributions for multiple roads with the equation (Part 2, Eq 2.51).

For the calculations of L_{AFmax} , the 95th percentile was used, in line with description in Part 2, chapter 2.2.3 of NORD96 for road.

2.3 Rail (NMT96)

The calculation of noise immission and propagation from rail traffic has been carried out using the software CadnaA version 2019. The calculations were calculated according to the method NORD96 but with the exclusion of input data such as topography, buildings and other barriers. The simplifications have been made due to lack of input information as well as to reduce calculation time. The configurations used in the calculations are presented in Table 3.

Table 3. Configurations used for calculation of $L_{Aeq,24h}$ and L_{AFmax} in CadnaA.

Parameter	Configuration	Comment
Search Radius	1000 m	Limited accuracy for distance >300-500 m.
Max. Error	0,1 dB	
Reflection order	0	No barriers included.
Ground absorption	G = 1	Soft ground
Terrain	0 m	Terrain height has been set to 0 m for the entire model.
Buildings	0	Not included
Receiver height	4 m above ground	
Source height	0 m above ground	
Switches/bridges	0 dB	No corrections for switches or bridges are included.
Train chosen for maximum sound pressure level calculations.	Iteration	CadnaA calculates maximum sound pressure level for each train and chooses the highest contributing train type for each receptor point.

The search radius was set to 1000 m to make sure all tracks were contributing to a certain noise level.

$L_{Aeq,24h}$ is calculated for a given receptor point with the summation of the contributions for multiple rails. L_{AFmax} is calculated through iteration of which train and position on rail that gives the highest contribution in relation to the receptor point. The method is described in detail in the method chapter in (Naturvårdsverket, Banverket, 1998).

2.4 Aviation

The report (Swedavia, 2019) includes exposure for the ten largest Swedish airports. However, this dataset does not include airports which are quite large, for example Stockholm-Skavsta (NYO) with 2 100 000 passengers and Skellefteå (SFT) with 400 000 passengers for the year 2017. No attempt is made to weigh in the data of noise exposure from airports which were not included in the Swedavia report.

The military aviation noise used is the same as from the previous report (Sweco, 2014). In this data noise is based on a mapping from 2006.

2.5 European Noise Directive (END)

On European level there are directives for member states to report noise from road traffic, rail traffic, aviation and industries of significant scale every 5 years. The latest as of this report being year 2017 with noise mapping of the year 2016. These reports are of various qualities and it is up to each member state to coordinate and produce the data.

In Sweden, the final data are reported to EU by the Swedish EPA (Naturvårdsverket). Naturvårdsverket do not produce the data themselves but instead they request the data from each municipality. For Sweden this resulted in noise pollution from 4 000 km road, 1 400 km rail and the 3 largest airports; Arlanda (ARN), Landvetter (GOT) and Bromma (BMA) being mapped. The noise mapped for the 2017 END report represents noise for the year 2016. The individual reports from the different municipalities in Sweden are of different quality, but in general, the detail level is a lot higher compared to the model used in this report as factors such as building geometries, noise barriers, topography and multiple noise reflection are included.

2.6 NORD96 merged with END

END reported data is based on calculation with higher detail compared to the nation-wide exposure calculations in this study. Therefore, the exposure calculations in this study were replaced with END reported data (not including aviation data) where available, in order to obtain the highest level of detail for the population exposure mapping.

2.7 Socioeconomic analysis

One of the main goals of this report is to provide decision basis for noise pollution reducing actions. In order to assess socioeconomic costs caused by health effects linked to noise exposure Trafikverket have developed a guide, ASEK 6.1 (Trafikverket, 2018). ASEK can be used for calculating how much a given equivalent continuous sound level ($L_{Aeq,24h}$) costs in terms of property value loss and socioeconomic cost related to cardiovascular disease. The socioeconomic costs per 1-dB interval for exposure between 50-70 dBA per person, is presented in Table 4 and Table 5. ASEK is indirectly including sleep deprivation because of the connection between sleep and the risk for cardiovascular disease. Examples of effects that are not included in the socioeconomic costs are inferior speaking comprehension, learning disabilities and poorer performance.

The population exposure used to calculate the total socioeconomic costs is based on both results from the calculation in this study according to NORD96 and the reports to END. For the municipalities that have reported according the END-directive, these numbers replace the results from NORD96. Since values in ASEK are defined in 1-dB intervals, see Table 4 and Table 5, assumptions are made for the END-values that are reported in 5-dB intervals. The END reported lower value

in the interval plus 2 is used. For example END report exposed between 49-54 dBA will be combined with the ASEK-value 50 dBA, 54-59 dBA is combined with the ASEK-value 55 dBA etc.

For aviation, ASEK recommends using the same values as for road but multiplied by a factor 1.4. The results from Swedavias calculations are based on FBN_{TBU}⁴, which is the value for equivalent aviation noise weighted for evening and night hours. As the FBN-value is considered to already be weighted, the adjusting factor will be excluded for the calculation of socioeconomic cost for 55 dBA of 3 746 SEK, in line with the previous national mapping (Sweco, 2014).

⁴ FBN = Flygbullernivå, TBU = Trafikbullerförordningen

Table 4. Socioeconomic cost of road noise before and after real adjustment (KPI + BNP per capita), according to (Trafikverket, 2018). The cost is in Swedish krona (SEK per person and year). The adjustment factor is an increase of the price with 1.5 % per year.

L _{Aeq,24h} dBA	Cost (SEK) from disturbance (2014)	Cost (SEK) from nega- tive health effects (2014)	Total cost (SEK) (2014)	Adjusted cost (SEK) (2018)
50	155	0	155	165
51	483	0	483	513
52	985	0	985	1 045
53	1 660	0	1 660	1 762
54	2 508	0	2 508	2 662
55	3 529	0	3 529	3 746
56	4 723	0	4 723	5 013
57	6 091	0	6 091	6 465
58	7 632	68	7 700	8 172
59	9 346	123	9 469	10 050
60	11 233	205	11 439	12 141
61	13 294	301	13 595	14 429
62	15 528	424	15 952	16 931
63	17 935	574	18 509	19 645
64	20 515	739	21 254	22 558
65	23 268	916	24 185	25 669
66	26 195	1 122	27 317	28 993
67	29 295	1 354	30 649	32 530
68	32 568	1 614	34 182	36 280
69	36 014	1 891	37 0905	40 231
70	39 634	2 211	41 845	44 413
71	43 427	2 546	45 972	48 793
72	48 393	2 907	50 300	53 387
73	51 532	3 296	54 828	58 192
74	55 844	3 713	59 557	63 212
75	60 330	4 170	64 500	68 458

Table 5. Socioeconomic cost of rail noise before and after real adjustment (KPI + BNP per capita), according to (Trafikverket, 2018). The cost is in Swedish krona (SEK per person and year). The adjustment factor is an increase of the price with 1.5 % per year.

L _{Aeq,24h} dBA	Cost (SEK) from disturbance (2014)	Cost (SEK) from negative health ef- fects (2014)	Total cost (SEK) (2014)	Adjusted cost (SEK) (2018)
50	62	0	62	66
51	19	0	192	204
52	389	0	389	413
53	653	0	653	693
54	985	0	985	1 045
55	1 383	0	1 383	1 468
56	1 849	0	1 849	1 962
57	2 383	0	2 383	2 529
58	2 983	68	3 051	3 238
59	3 651	123	3 774	4 006
60	4 386	205	4 591	4 873
61	5 188	301	5 489	5 826
62	6 057	424	6 481	6 879
63	6 994	574	7 568	8 032
64	7 998	739	8 737	9 273
65	9 069	916	9 986	10 599
66	10 208	1 122	11 329	12 024
67	11 413	1 354	12 767	13 550
68	12 686	1 614	14 300	15 177
69	14 026	1 891	15 917	16 894
70	15 434	2 211	17 645	18 728
71	16 909	2 546	19 454	20 648
72	18 450	2 907	21 358	22 669
73	20 060	3 296	23 356	24 789
74	21 736	3 713	25 449	27 011
75	23 480	4 170	27 650	29 347

2.8 Validation

To validate the results in this report and assess the impact of the simplifications made due to lack of input information as well as to reduce calculation time in the presented calculations, results are compared with the noise exposure studies presented in the following chapters.

2.8.1 Nationella Miljöhälsoenkäten 2015 (NMHE15)

Miljöhälsrapporten 2017 is a report based on national surveys performed every 4 years in Sweden. The report for 2017 represents data aggregated from the enquiry NMHE15. The data used is self-reported from 37 133 people between the ages 18-84 from all over the country. Sweden's eligible population was ~7 100 000 meaning that roughly 5% of Sweden's population for year 2015 is represented. Since it is not common knowledge what $L_{Aeq,24h}$ of 55 dB sounds like, more subjective questions are used in the enquiry, such as "How bothered are you by road traffic noise?", "Do you have trouble sleeping because of traffic noise?". The subjective nature of the questions makes the use of this data for model validation purposes quite hard; however, it might provide some insight into the quality of the model results.

2.8.2 SMED vs END

The reported values to EU via END serve as a control for the results for road and rail model used in this report. Our hope is that given the large scale and number of data points, we will statistically, come close to the very detailed END reported data. One issue with this comparison is that NORD96 works with $L_{Aeq,24h}$ and END works with L_{den} , making direct comparison impossible. To compare, we adjust the END data intervals and thresholds according to (Jonasson, 2005):

Equation 2. Conversion from NORD96 noise exposure results to END noise exposure results for road.⁵

$$L_{Aeq,24h\ Road} = L_{den} - 2.5$$

Equation 3. Conversion from NORD96 noise exposure results to END noise exposure results for rail.

$$L_{Aeq,24h\ Rail} = L_{den} - 6$$

⁵ END data is produced with NPM96, thus only the daily time distribution factors should be applied (+3 – 0.5).

3 Results

3.1 Noise immission

3.1.1 Road

A heatmap of $L_{Aeq,24h}$ noise immissions from roads across Sweden is shown in Figure 3. These are the results of Simplified NORD96 – SMHI's NORD96 v1.0. The figure is heavily correlated to a map of population density.

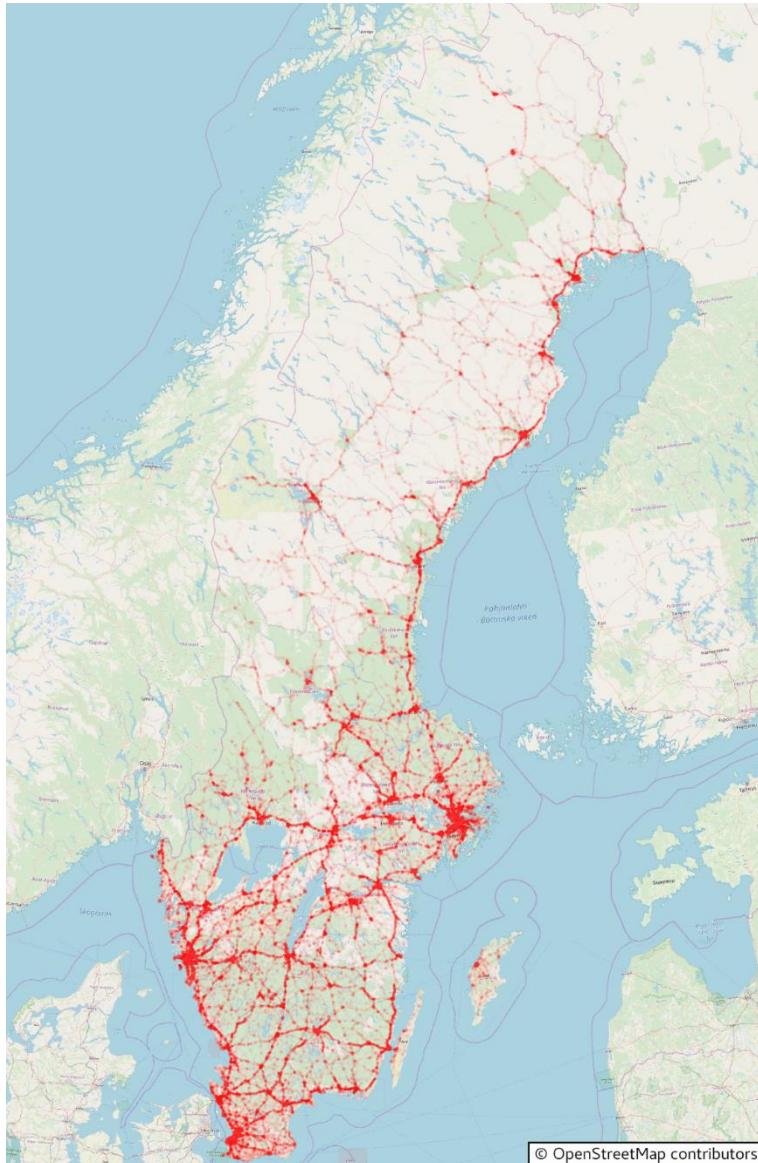
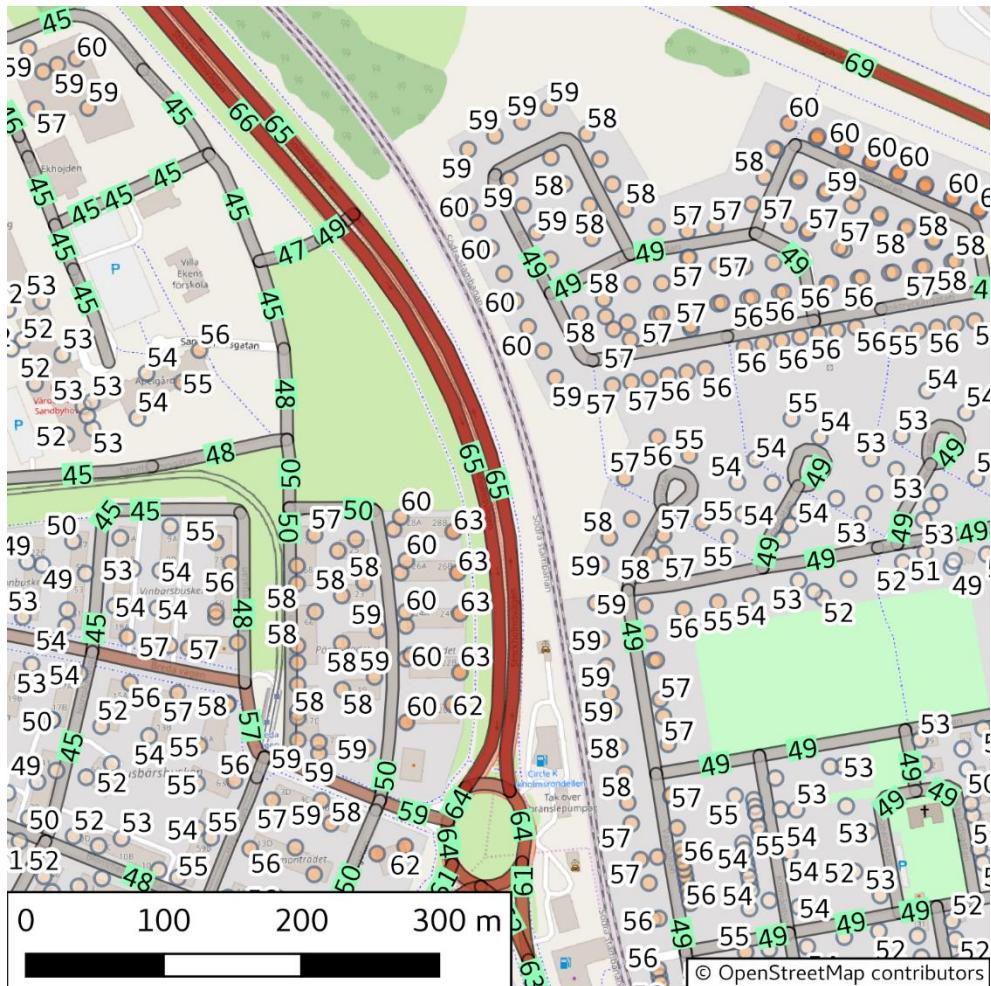


Figure 3. Heatmap representation of $L_{Aeq,24h}$ immission from **road traffic** in Sweden for the year 2018, values from Simplified NORD96 – SMHI's NORD96 v1.0 (road). A denser red, implies higher immissions.

A visual representation of exposure to $L_{Aeq,24h}$, **road** noise, for a small area in Norrköping, is presented in Figure 4. The figure shows a congested road with a baseline noise immission of 65 dBA. Exposure points with a distance of ~10 m experience 63 dBA while at ~100 m the noise is down to 55 dBA. Note that for a given receptor point, it is the sum of all noise immissions from roads within 300 m that are represented.



*Figure 4. $L_{Aeq,24h}$ immissions and exposure from **road traffic** in a residential area in Norrköping, Sweden for the year 2018. Immission and exposure is calculated using Simplified NORD96 – SMHI's NORD96 v1.0 (road). Noise immission is represented by the value with green background. The other values are exposure.*

3.1.2 Rail

For NTM96 it is not possible to produce a graphical representation of $L_{Aeq,24h}$ since the noise immissions are based on the relative location of the receptor. An overview of the railway network in Sweden can be seen in Figure 5. The number of rail tracks are fewer than the number of roads, however the noise immission for rail is much higher per segment.

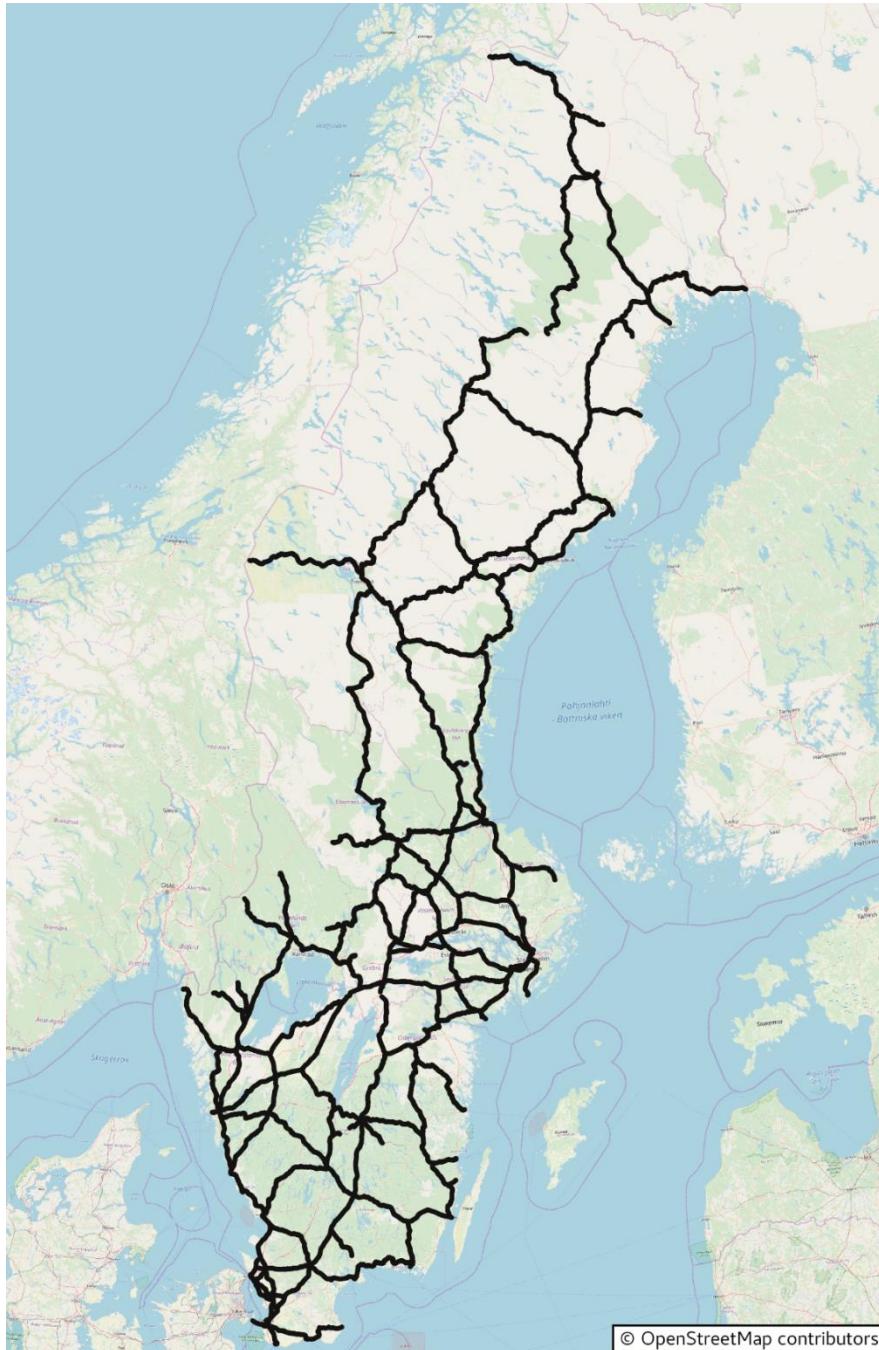


Figure 5. Rails in Sweden for the year 2018 included in the calculations.

3.1.3 Aviation

Noise immission is not available in (Swedavia, 2019), data includes only noise exposure. See Figure 6 for a geographic overview of the civil airports.

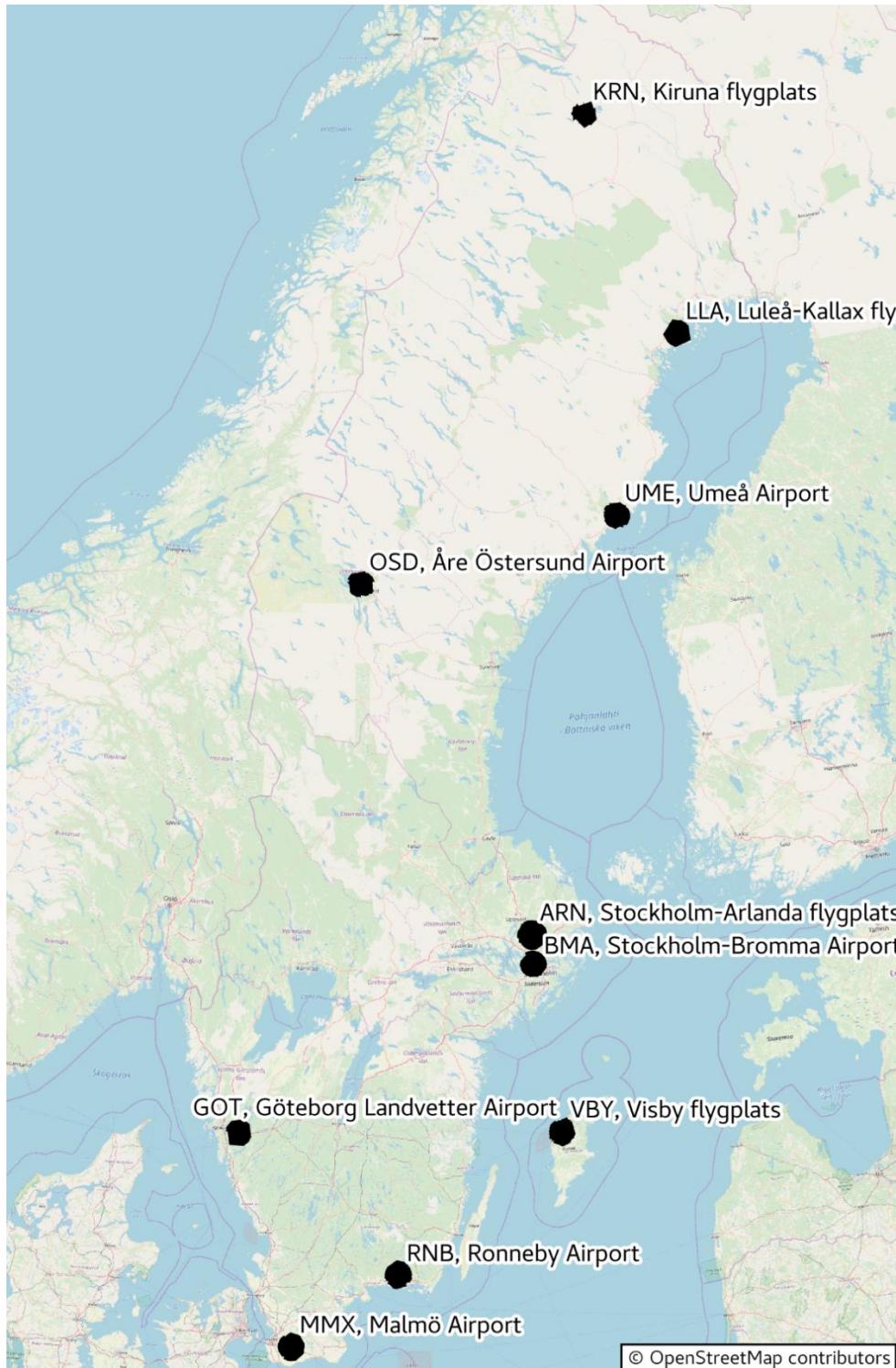


Figure 6. Civil airports included in this report.

3.2 Noise exposure

Results from the calculation with the Simplified NORD96 – SMHI's NORD96 v1.0 (road) are presented for the 15 municipalities with the largest number of inhabitants. The remaining municipalities' results are available in Appendix 1, Appendix 2, Appendix 3, Appendix 4.

3.2.1 Road

As can be seen in Table 6 and Table 7, our model yields ~1 400 000 exposed to $L_{Aeq,24h}$ of >55 dBA and ~7 250 000 exposed to L_{AFmax} of >70.

3.2.1.1 $L_{Aeq,24h}$

Table 6. The $L_{Aeq,24h}$ road traffic results from Simplified NORD96 – SMHI's NORD96 v1.0 (road) for the 15 municipalities that are included in the END report. See Appendix 1 for a complete table with all municipalities. SUM includes all 290 municipalities.

Name	Population	Road exposure $L_{Aeq,24h}$						
		>55	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	1 412 143	2 083 972	1 017 717	322 347	59 578	9 997	2 504
Borås	112 068	16 896	24 347	11 378	4 631	843	44	0
Eskilstuna	105 717	17 842	28 152	12 704	4 936	202	0	0
Göteborg	569 373	135 699	153 680	86 367	37 822	8 427	2 410	673
Helsingborg	144 553	24 321	33 802	18 213	5 620	442	44	2
Huddinge	110 668	13 368	20 928	9 616	2 797	908	44	3
Jönköping	139 100	24 246	28 050	16 939	5 630	1 516	161	0
Linköping	160 898	20 169	42 308	16 682	3 379	99	9	0
Lund	122 768	13 579	24 194	10 816	2 435	284	44	0
Malmö	338 114	95 418	111 988	67 145	24 421	3 671	178	3
Norrköping	141 528	24 399	33 655	18 335	5 717	342	5	0
Stockholm	962 390	339 718	286 571	219 895	90 634	23 212	4 758	1 219
Umeå	127 010	12 282	30 941	9 819	2 154	300	9	0
Uppsala	224 839	37 226	49 723	26 981	8 945	1 284	4	12
Västerås	151 830	22 132	30 460	14 753	5 519	1 458	374	28
Örebro	153 132	23 618	28 720	16 761	6 039	796	18	4

3.2.1.2 L_{AFmax}

Table 7. The L_{AFmax} road traffic results from Simplified NORD96 – SMHI's NORD96 v1.0 (road) for the 15 municipalities that are included in the END report. See Appendix 2 for a complete table with all municipalities. SUM includes all 290 municipalities.

Name	Population	Road exposure L_{AFmax}						
		>70	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	7 247 553	203 322	411 988	726 265	1 348 362	3 712 728	3 534 825
Borås	112 068	82 085	2 136	3 959	6 846	14 114	41 968	40 117
Eskilstuna	105 717	73 165	2 114	4 044	8 368	14 457	41 227	31 938
Göteborg	569 373	420 167	7 028	22 419	43 822	75 420	211 715	208 452
Helsingborg	144 553	100 734	2 923	7 785	11 706	20 224	57 684	43 050
Huddinge	110 668	80 102	270	3 713	9 633	16 600	43 004	37 098
Jönköping	139 100	99 276	2 671	6 051	10 521	18 470	53 378	45 898
Linköping	160 898	136 834	1 519	2 384	4 427	13 040	48 873	87 961
Lund	122 768	73 912	3 936	9 726	13 161	19 603	42 457	31 455
Malmö	338 114	234 586	3 359	14 251	27 082	58 392	140 612	93 974
Norrköping	141 528	100 016	2 114	6 323	11 272	19 585	55 412	44 604
Stockholm	962 390	841 368	508	3 081	24 328	93 039	338 133	503 235
Umeå	127 010	75 884	4 370	8 870	12 786	21 790	47 635	28 249
Uppsala	224 839	136 466	6 132	13 814	24 629	37 288	80 083	56 383
Västerås	151 830	99 280	3 639	11 143	14 748	19 590	52 430	46 850
Örebro	153 132	95 552	5 466	11 731	15 411	21 096	51 764	43 788

3.2.2 Rail

As presented in Table 8 and Table 9 the results show that ~450 000 are exposed to $L_{Aeq,24h}$ of >55 dBA and ~1 200 000 to L_{AFmax} of >70 dBA.

3.2.2.1 $L_{Aeq,24h}$

Table 8. The results from the $L_{Aeq,24h}$ calculation of noise from trains in CadnaA for the 15 municipalities that are included in the END report. See Appendix 3 for a complete table with all municipalities. SUM includes all 290 municipalities.

Name	Population	Rail exposure $L_{Aeq,24h}$						
		>55	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	447 444	643 223	318 342	104 688	20 589	2 926	899
Borås	112 068	2 723	7 208	2 330	388	5	0	0
Eskilstuna	105 717	4 878	10 489	4 082	781	15	0	0
Göteborg	569 373	23 159	40 097	17 300	4 742	846	222	49
Helsingborg	144 553	2 997	7 221	2 655	329	13	0	0
Huddinge	110 668	14 209	13 121	9 825	3 604	720	60	0
Jönköping	139 100	5 693	9 596	4 268	1 276	149	0	0
Linköping	160 898	2 547	7 826	2 162	347	34	4	0
Lund	122 768	13 838	13 841	9 399	3 586	716	110	27
Malmö	338 114	23 844	43 574	16 980	5 569	1 206	89	0
Norrköping	141 528	5 444	9 576	4 127	1 190	125	2	0
Stockholm	962 390	46 322	56 252	28 480	11 892	3 838	1 392	720
Umeå	127 010	697	4 086	677	17	3	0	0
Uppsala	224 839	6 401	14 841	4 992	1 226	182	1	0
Västerås	151 830	1 506	5 911	1 385	118	3	0	0
Örebro	153 132	14 192	17 683	10 225	3 353	563	51	0

3.2.2.2 L_{AFmax}

Table 9. The L_{AFmax} calculation of noise from trains in CadnaA for the 15 municipalities that are included in the END report. See Appendix 4 for a complete table with all municipalities.

Name	Population	Rail exposure L_{AFmax}						
		>70	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	1 212 179	138 065	581 000	1 163 249	851 104	618 341	593 838
Borås	112 068	20 185	6 626	8 222	14 063	13 575	10 642	9 543
Eskilstuna	105 717	16 335	1 962	7 369	12 761	11 035	8 918	7 417
Göteborg	569 373	38 367	2 811	24 579	56 876	36 684	24 380	13 987
Helsingborg	144 553	17 113	15 787	18 134	21 132	12 392	8 712	8 401
Huddinge	110 668	24 250	0	5 428	17 205	13 992	11 460	12 790
Jönköping	139 100	28 604	1 640	13 294	21 982	17 811	14 319	14 285
Linköping	160 898	12 379	5 530	11 156	19 429	10 920	7 836	4 543
Lund	122 768	19 682	12	607	18 140	12 193	8 606	11 076
Malmö	338 114	39 396	17 375	34 001	67 252	42 699	24 077	15 319
Norrköping	141 528	14 048	2 982	7 287	12 346	10 129	7 312	6 736
Stockholm	962 390	75 717	6 807	105 401	108 944	67 116	41 648	34 069
Umeå	127 010	11 569	0	7 695	11 897	8 515	6 567	5 002
Uppsala	224 839	29 714	1	3 183	22 107	18 033	13 823	15 891
Västerås	151 830	15 396	28	11 606	18 896	11 090	7 908	7 488
Örebro	153 132	17 584	0	9 360	19 223	14 101	9 732	7 852

3.2.3 Aviation

For the year 2018; 18 680⁶ people were exposed to a $L_{Aeq,24h}$ of 55 dBA and 112 213 exposed to a L_{AFmax} ⁷ of 70 dBA. Note that these values are not for all Swedish airports, but for the ten largest (the $L_{Aeq,24h}$ number includes military flights).

3.3 Validation results

Results from comparison with other noise exposure studies are presented below, with possible explanation for discrepancies discussed further in section 4.

3.3.1 NMHE 15

NMHE 15, the extent to which traffic noise disturbs the population is answered by questions about *how often* people are bothered by traffic noise. Earlier surveys also included the question about *how much* people are bothered by traffic noise. There were in general more people that were bothered by noise often, than those who were bothered by noise very much.

NMHE 15 indicates that 8 % of the people who answered the survey were bothered by traffic noise (road, rail or aviation noise). It has decreased 2 % since the previous survey from 2007 (NMHE 07). In comparison to our calculated noise exposure results, this percentage is higher than the percentage population (6 %) exposed to $L_{Aeq,24h}$ of >54 dBA from road traffic (Table 13) than those (5 %) who were exposed to $L_{Aeq,24h}$ of >54 dBA from rail traffic (Table 14).

6.4 % that participated in the NMHE 15 has pointed out that they were bothered by road traffic noise, and this percentage has also decreased with 1.6 % since 2007 (8%). The decrease could be explained by increased consideration of the noise problem in the new building constructions and increased measures in existing properties to target the heavily noise exposed areas.

Around 1.5 % and 1.2 % were bothered by rail traffic noise and aviation noise, respectively in NMHE 15. A significant amount of people also replied that they have residential or bedroom windows in noise-exposed position. Both our calculated noise exposure results and NMHE 15 suggest that the percentage population bothered by road traffic noise was a lot higher than those bothered by rail and aviation traffic noise.

Reports from Swedavia show that approximately 1.1 % of the population was exposed to a maximum sound pressure level of 70 dBA from aviation traffic⁸, which is comparable to the statistic (1.2%) from NHME 15. Miljöhälsrapport (2017) further suggests that aviation traffic noise is more of a problem to those who are

⁶ 15080 from Swedavia's airports and 3600 from military flights.

⁷ The report presents L_{AFmax} as maximum sound level occurring 3 times per day/evening. Military flights are excluded.

⁸ The report presents L_{AFmax} as maximum sound level occurring 3 times per day/evening. Military flights are excluded.

living in single houses in the biggest cities. 4.4 % of those living in single houses in big cities has answered that they were bothered by aviation noise.

NMHE 15 also points out that noise disturbance caused by environmental noise outdoors is reduced if one is indoors with windows and doors closed. However, many people choose to have windows and/or doors open, which may increase the noise level indoors. Most studies on health effects of traffic noise in the residential area are based on traffic noise levels outdoor at the building façade.

3.3.2 Modelled exposure vs. END

There is a difference in the number of inhabitants used in the calculations in this study in comparison to the number of inhabitants included in the END-reports. The reported number of inhabitants according to END is approximately 6% lower than the population count of exposure points in this study, see Table 10. This difference in population can cause the exposure results from our simplified model to be overestimated when compared to the END reported data. The sum of Sweden's population from the exposure points in our simplified model is 10 216 373⁹. The number of inhabitants inside agglomerations as per defined by the END data is 3 367 282 while the receptor points used in this report represent 3 563 988.

⁹ The reason there is a difference of ~14 000 in population from the official statistic of 10 230 185 for 2018 is because there is not coordinate data for 14 000 people in Sweden as explained in Appendix 5.

Table 10. The population count of all the exposure points used in Simplified NORD96 – SMHI's NORD96 v1.0 (road) and CadnaA compared to the number of inhabitants reported to END. There is a clear predominant overestimation of the population in the dataset used in this report. Note that the year for SMHI-NORD96 is 2018 while END is population of 2016.

name	SMHI-NORD96 population	END population	ratio population
SUM	3 563 988	3 367 282	1.06
Borås	112 068	107 022	1.05
Eskilstuna	105 717	100 923	1.05
Göteborg	569 373	541 145	1.05
Helsingborg	144 553	135 344	1.07
Huddinge	110 668	104 185	1.06
Jönköping	139 100	132 140	1.05
Linköping	160 898	151 881	1.06
Lund	122 768	115 968	1.06
Malmö	338 114	318 107	1.06
Norrköping	141 528	135 283	1.05
Stockholm	962 390	911 989	1.06
Umeå	127 010	119 613	1.06
Uppsala	224 839	207 362	1.08
Västerås	151 830	143 702	1.06
Örebro	153 132	142 618	1.07

3.3.2.1 Road

The comparison between the modeled road noise exposure in this study and END reported road noise exposure, for the 15 municipalities that participate in END reporting data, are given in Figure 7 and Table 11.

In general, the ratio of the number of exposed to each interval in Simplified NORD96 – SMHI's NORD96 v1.0 (road) vs END data is > 1.0. There is a clear overestimation in the exposure in simplified model compared to END data.

The differences vary depending on noise interval, where, for example the 57.5-62.5 dBA interval has a ratio of 0.94 while 67.5-72.5 has a ratio of 0.43 and the interval >72.5 has a ratio of ~1.5. Differences are also found when considering independent municipalities, Where Eskilstuna, for example, has a ratio of 1.37, while Huddinge has a ratio of 0.49 for the interval 57.5-62.5 dBA. The lowest ratio for any given municipality and interval is 0.03 and the maximum is 2.88.

3.3.2.2 *Rail*

The comparison between our CadnaA modeled rail noise exposure and END reported rail noise exposure for the 15 municipalities that participate in END reporting data are given in Figure 8 and Table 12.

Compared to the modeled road data, these ratios are a lot more variable, which is most likely due to that the railway network is a lot smaller, and thus affect $\sim 1/5$ as many inhabitants. Consider the interval 54-59 dBA, the ratio of the number of exposed from the CadnaA data vs. END data, not considering population difference, is 1.75. For Stockholm the ratio is 2.46. The results for Västerås; 0.37 and Huddinge; 6.79, indicate a large discrepancy. Possible explanation for this discrepancy is discussed further in the section 4.

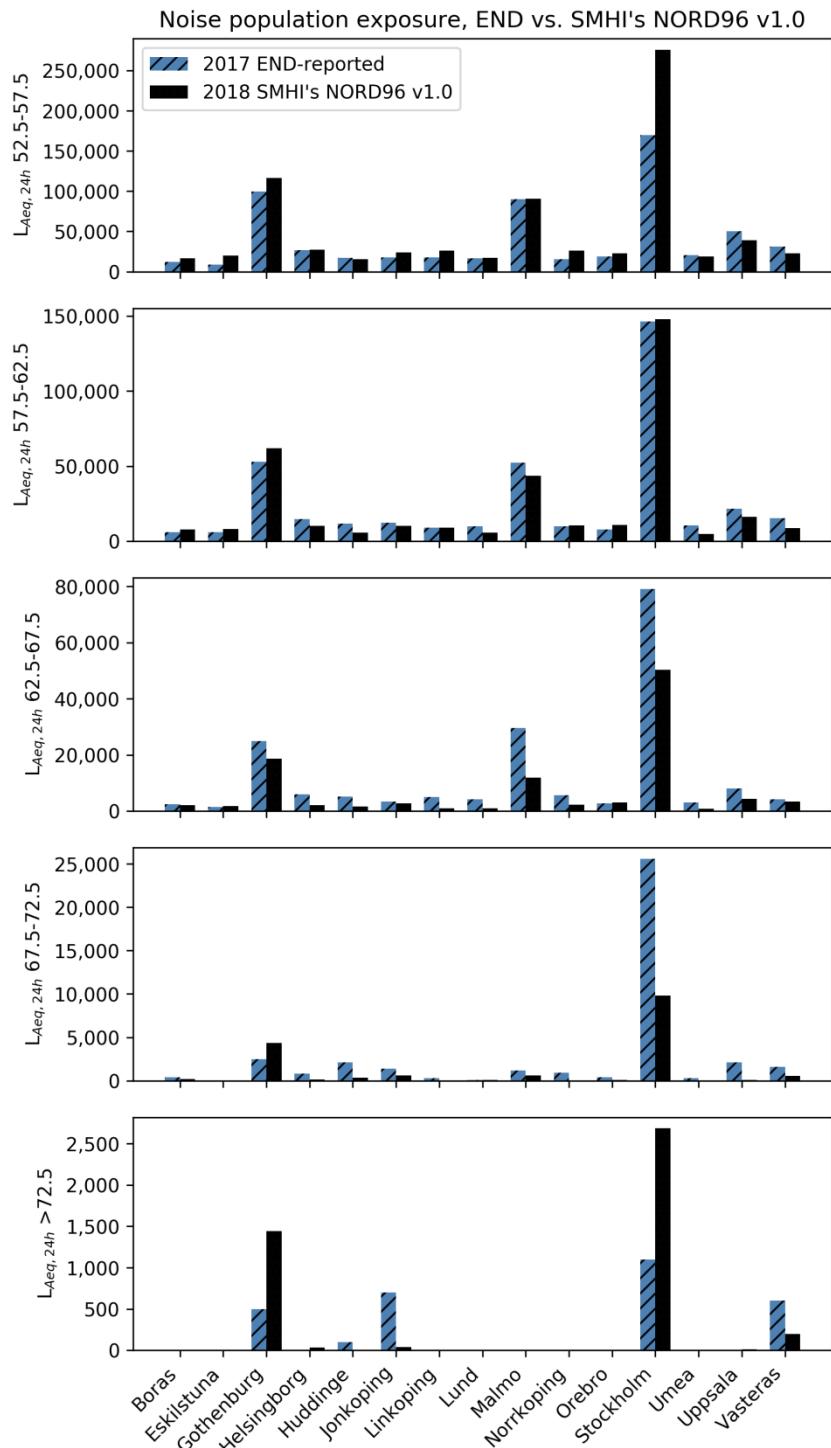


Figure 7. Comparison between noise exposure ($L_{Aeq,24h}$) from road traffic between Simplified NORD96 – SMHI's NORD96 v1.0 (road) and END reported data. The same data can be seen in table format in Table 11.

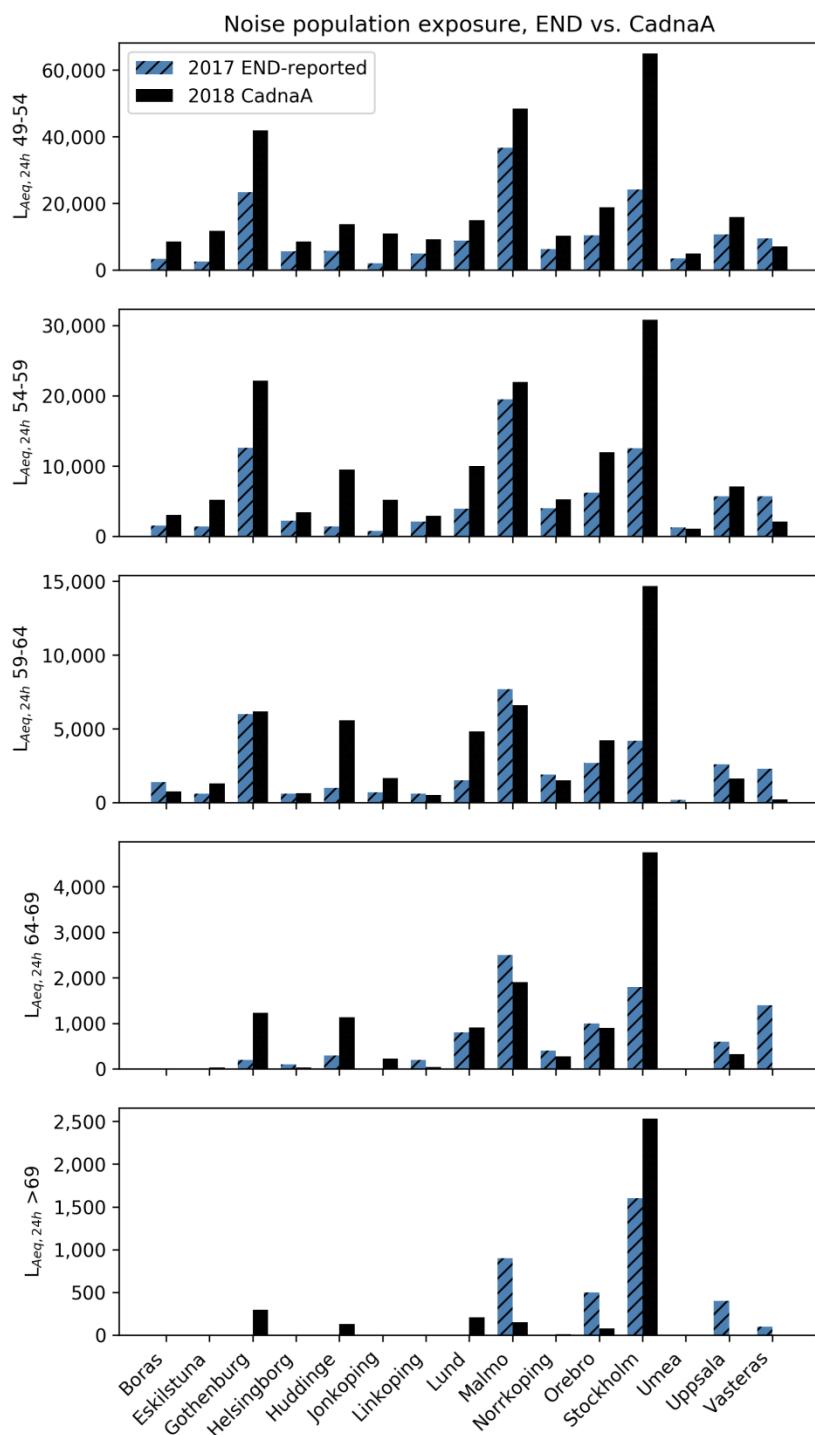


Figure 8. Comparison between noise exposure ($L_{Aeq, 24h}$) from railway traffic between calculation in CadnaA and END reported data. The same data can be seen in table format in Table 12.

*Table 11. Comparison between noise exposure ($L_{Aeq,24h}$) from **road traffic** between Simplified NORD96 – SMHI's NORD96 v1.0 (road) and END reported data. The same data can be seen in diagram format in Figure 7.*

name	population			52.5-57.5 dBA			57.5-62.5 dBA			62.5-67.5 dBA			67.5-72.5 dBA			>72.5 dBA		
	SMHI-NORD96	END	ratio	SMHI-NORD96	END	ratio	SMHI-NORD96	END	ratio	SMHI-NORD96	END	ratio	SMHI-NORD96	END	ratio	SMHI-NORD96	END	ratio
SUM	3 563 988	3 367 282	1.06	760 146	613 400	1.24	361 947	387 100	0.94	106 666	184 900	0.58	17 016	39 700	0.43	4 437	3 000	1.48
Boras	112 068	107 022	1.05	16 851	12 200	1.38	7 853	6 100	1.29	2 105	2 400	0.88	188	400	0.47	3	0	NA
Eskilstuna	105 717	100 923	1.05	19 944	8 800	2.27	8 239	6 000	1.37	1 789	1 500	1.19	4	0	NA	0	0	NA
Gothenburg	569 373	541 145	1.05	116 399	99 900	1.17	62 064	52 900	1.17	18 685	24 900	0.75	4 328	2 500	1.73	1 442	500	2.88
Helsingborg	144 553	135 344	1.07	27 078	26 800	1.01	10 401	14 800	0.7	2 157	6 000	0.36	126	800	0.16	34	0	NA
Huddinge	110 668	104 185	1.06	15 360	17 200	0.89	5 719	11 700	0.49	1 551	5 200	0.3	366	2 100	0.17	3	100	0.03
Jonkoping	139 100	132 140	1.05	24 116	17 500	1.38	10 326	12 400	0.83	2 767	3 300	0.84	606	1 400	0.43	41	700	0.06
Linkoping	160 898	151 881	1.06	26 342	17 800	1.48	9 031	9 000	1	911	4 900	0.19	22	300	0.07	4	0	NA
Lund	122 768	115 968	1.06	16 943	16 800	1.01	5 880	10 000	0.59	892	4 200	0.21	95	100	0.95	6	0	NA
Malmo	338 114	318 107	1.06	90 863	90 000	1.01	43 590	52 400	0.83	11 842	29 600	0.4	622	1 200	0.52	6	0	NA
Norrkoping	141 528	135 283	1.05	26 387	15 700	1.68	10 674	10 000	1.07	2 178	5 700	0.38	47	900	0.05	0	0	NA
Orebro	153 132	142 618	1.07	22 990	18 600	1.24	10 748	7 800	1.38	3 073	2 800	1.1	109	400	0.27	4	0	NA
Stockholm	962 390	911 989	1.06	275 956	169 700	1.63	147 677	146 200	1.01	50 305	79 100	0.64	9 789	25 600	0.38	2 686	1 100	2.44
Umea	127 010	119 613	1.06	19 042	20 600	0.92	4 755	10 700	0.44	837	3 100	0.27	31	300	0.1	0	0	NA
Uppsala	224 839	207 362	1.08	38 985	50 500	0.77	16 184	21 800	0.74	4 279	8 100	0.53	109	2 100	0.05	12	0	NA
Vasteras	151 830	143 702	1.06	22 890	31 300	0.73	8 806	15 300	0.58	3 295	4 100	0.8	574	1 600	0.36	196	600	0.33

Table 12. Comparison between noise exposure ($L_{Aeq,24h}$) from rails between CadnaA and END reported data. The same data can be seen in diagram format in Figure 8.

name	population			49-54 dBA			54-59 dBA			59-64 dBA			64-69 dBA			>69 dBA		
	CadnaA	END	ratio	CadnaA	END	ratio	CadnaA	END	ratio	CadnaA	END	ratio	CadnaA	END	ratio	CadnaA	END	ratio
SUM	3 563 988	3 367 282	1.06	289 927	157 400	1.84	141 612	80 800	1.75	50 365	34 000	1.48	11 790	9 300	1.27	3 420	3 500	0.98
Boras	112 068	107 022	1.05	8 490	3 300	2.57	3 037	1 500	2.02	762	1 400	0.54	15	0	NA	0	0	NA
Eskilstuna	105 717	100 923	1.05	11 701	2 500	4.68	5 180	1 400	3.70	1 299	600	2.17	33	0	NA	0	0	NA
Gothenburg	569 373	541 145	1.05	41 885	23 400	1.79	22 142	12 600	1.76	6 186	6 000	1.03	1 228	200	6.14	296	0	NA
Helsingborg	144 553	135 344	1.07	8 576	5 600	1.53	3 407	2 200	1.55	626	600	1.04	35	100	0.35	0	0	NA
Huddinge	110 668	104 185	1.06	13 728	5 700	2.41	9 508	1 400	6.79	5 594	1 000	5.59	1 138	300	3.79	133	0	NA
Jonkoping	139 100	132 140	1.05	10 964	2 000	5.48	5 217	800	6.52	1 676	700	2.39	231	0	NA	0	0	NA
Linkoping	160 898	151 881	1.06	9 283	4 900	1.89	2 899	2 100	1.38	512	600	0.85	40	200	0.20	8	0	NA
Lund	122 768	115 968	1.06	14 927	8 800	1.70	9 983	3 900	2.56	4 831	1 500	3.22	908	800	1.14	209	0	NA
Malmo	338 114	318 107	1.06	48 373	36 700	1.32	21 981	19 500	1.13	6 600	7 700	0.86	1 905	2 500	0.76	152	900	0.17
Norrkoping	141 528	135 283	1.05	10 319	6 300	1.64	5 227	4 000	1.31	1 514	1 900	0.80	278	400	0.69	11	0	NA
Orebro	153 132	142 618	1.07	18 842	10 400	1.81	11 963	6 200	1.93	4 226	2 700	1.57	898	1 000	0.90	79	500	0.16
Stockholm	962 390	911 989	1.06	64 927	24 100	2.69	30 778	12 500	2.46	14 668	4 200	3.49	4 752	1 800	2.64	2 529	1 600	1.58
Umea	127 010	119 613	1.06	4 906	3 500	1.40	1 095	1 300	0.84	38	200	0.19	4	0	NA	0	0	NA
Uppsala	224 839	207 362	1.08	15 897	10 700	1.49	7 077	5 700	1.24	1 626	2 600	0.63	320	600	0.53	3	400	0.01
Vasteras	151 830	143 702	1.06	7 109	9 500	0.75	2 118	5 700	0.37	207	2 300	0.09	5	1 400	0.00	0	100	NA

3.4 Results after merging with END

In this section, the result for population exposure to equivalent noise level, $L_{Aeq,24h}$, from road and rail, is presented merged with the END-reported results.

3.4.1 Road

Excluding the municipalities present in the END reported data, the Simplified NORD96 – SMHI's NORD96 v1.0 (road) yields a total exposure according to Table 13. It's interesting to note that the END reported exposure for 52.5-57.5 dBA is ~55% of the merged results while the END reported exposure for >72.5 dBA is 78% of the total exposure in the merged results. The result is that the simplified model accounts for ~2/3 of the exposure values, this will result in the socioeconomic cost being primarily driven by the simplified model, even though it is the crudest data; which is not ideal.

Table 13. Combined results from Simplified NORD96 – SMHI's NORD96 v1.0 (road) and END data, yields a final result of noise exposure due to road noise in Sweden.

		Road exposure $L_{Aeq,24h}$				
name	population	52.5-57.5	57.5-62.5	62.5-67.5	67.5-72.5	>72.5
SMHI-NORD96	6 652 385	761 303	249 133	43 488	5 498	838
END	3 367 282	613 400	387 100	184 900	39 700	3 000
SUM	10 019 667	1 374 703	636 233	228 388	45 198	3 838

3.4.2 Rail

Excluding the municipalities present in the END reported data; the railway calculations yield a total exposure according to Table 14.

Table 14. Combined CadnaA results and END data, yields a final result of railway noise exposure due to rail noise in Sweden.

		Rail exposure $L_{Aeq,24h}$				
name	population	49-54	54-59	59-64	64-69	>69
CadnaA	6 652 385	415 940	236 646	85 439	17 968	1 932
END	3 367 282	157 400	80 800	34 000	9 300	3 500
SUM	10 019 667	573 340	317 446	119 439	27 268	5 432

3.5 Socioeconomic cost

The socioeconomic cost for noise exposure above 50 dBA, calculated using ASEK, is estimated to 19.5 billion SEK from road noise and 1.8 billion SEK from rail noise. The socioeconomic cost for exposure of >55 dBA from aviation noise is estimated to 70 million SEK. For road and rail the cost for every integer of noise exposure from the results from Simplified NORD96 – SMHI's NORD96 v1.0

(road) and CadnaA are combined with the socioeconomic cost in Table 4 and Table 5 to yield the final cost. Since the models produce decimal numbers, all exposure values are rounded down to integers, for example, a dBA of 55.8 will use the ASEK cost associated with 55 dBA. For the END data, the cost of the middle of the interval is used, as specified in Table 15.

Table 15 The associated cost used from ASEK in combination with the END reported data to produce the socioeconomic cost in municipalities where END data is available. The ASEK cost used for the aviation results are also presented.

Road		Rail		Aviation	
END interval	ASEK dBA	END interval	ASEK dBA	Swedavia dBA	ASEK dBA
52.5-57.5	55	49-54	51	55	55
57.5-62.5	60	54-59	56		
62.5-67.5	65	59-64	61		
67.5-72.5	70	64-69	66		
>72.5	72	>69	69		

4 Discussion

In this section, the calculated national noise exposure and related socio-economic costs found in this study will be discussed in relation to previous national noise exposure assessments, as well as other noise exposure studies. Underlying causes of exposure differences will be addressed, with focus on influence of differences in methodology when applicable. Finally, potential methodology development and improvement of future national exposure assessment will be presented.

4.1 Validation and error quantification

The differences found between population in this study and the END reported data has not been established. As presented in Table 10, there is an average of 6% larger population in our calculations. One possible explanation is that the exposure points have been grouped to municipality based on polygons from (Lantmäteriet, 2019). The END reported data may have used a different grouping method in which the exposure points were most likely to be grouped into “agglomerations >100 000 inhabitants”.

The method used in this report has strong correlation between noise exposure and population close to traffic due to the nature of the NBM96 model. One important uncertainty in this study is that the effect of noise reducing measures, such as terrain, buildings or noise walls are not included in the calculations. This should be considered, especially in regard to results for individual municipalities where noise reduction measures may play an important role. Considering the limited number of input parameters, the data from the Simplified NORD96 – SMHI’s NORD96 v1.0 (road) performs acceptably with ratios of 0.43-1.24 for the intervals with breakpoints at 52.5, 57.5, 62.5, 67.5, 72.5 when comparing to the sum of END data in the intervals. However the lowest ratio of 0.03 (>72.5 dBA in Huddinge) and highest ratio of 2.44 (>72.5 dBA in Stockholm) are less impressive. When comparing the CadnaA rail results to the END rail data a similar behavior of the ratio can be seen, with the ratios spanning 0.01-6.8 when inspecting individual municipalities, however the sum of all the municipalities have more acceptable ratios of 1-1.8. For both road and rail there are also scenarios where no ratio can be calculated since there are exposed population according to one data source but not the other indicated by NA in Table 11 and Table 12. These “ratios” exist primarily in the interval >69 dBA. It should also be noted that the ratios are calculated without correcting for the population difference of ~6% for the municipalities.

4.1.1 NMHE15

Comparing the merged results with NMHE15 yield some interesting information. Although there is no direct relation between “number of bothered by noise” and noise exposure to certain threshold of $L_{Aeq,24h}$. Both our calculated noise exposure results and NMHE15 point out that there was a larger population bothered by road traffic noise than rail or aviation traffic noise. According to the results of our meth-

od, 1.1 % of the population were exposed to a L_{AFmax}^{10} of 70 dBA from aviation traffic, which is comparable to the statistic (1.2%) from NHME15 of number of bothered by aviation noise.

4.2 Trends in population exposure

Since 1998, the Environmental Protection Agency has produced national noise analysis, similar to this one for the years; 1992 (Wittmark, 1992), 1995 (Wittmark, 1997), 2000 (Ingemansson Technology AB , 2002), 2006 (WSP Akustik, 2009), 2011 (SWEKO, 2014). Even though the task for these previous reports were very similar, there are many differences in methods and their results cannot be directly compared or used for in-depth trend analysis, since different organizations performed the simulations with various input and methods.

The total number of inhabitants exposed to $L_{Aeq,24h} > 55$ dBA from road traffic has been specified in all the studies mentioned above. Combining the sum from Table 6, Table 8 and section 3.2.3, the number is 1.8 million people are exposed to > 55 dBA of which ~1.4 million are from road. Separate from the 1.8 million; aviation has ~19 000 exposed to > 55 dBA. It should be noted that summing number of people exposed to road, rail and aviation noise exposure very likely results in double counting, since the calculations of the exposure are completely separate¹¹.

Although all the previous reports are based on NORD96 for road and rail noise exposure calculations, there are still many differences especially the switch from gridded population data to receptor points, which prevents direct comparison of exposure trends.

Analysis of trends in this study will therefore be limited to a basic comparison of total socioeconomic costs connected to noise exposure, see Table 16, with a discussion of potential influence caused by method changes presented below.

¹⁰ The report presents L_{AFmax} as maximum sound level occurring 3 times per day/evening. Military flights are excluded.

¹¹ It's not unlikely that an exposure point has both high noise levels from road and rail at the same time, such an exposure point would get represented twice in the mentioned 1.88 million.

*Table 16. Basic comparison in socioeconomic cost results with previous studies. These values **cannot** be used for trend analysis.*

Year	Socioeconomic cost, Msek		
	Road	Rail	Aviation
2006	2 076	101.7	28
2011	16 105	908	62
2018	16 023	1 807	70

4.2.1 Influence of method differences

There is a particularly high difference between previous calculations for socioeconomic cost connected to rail traffic in comparison to this study. One of the reasons for the higher cost for rail is the increased exposure in high levels of equivalent sound levels. For example, the study from 2011 calculated that no more than 1 400 people were exposed to levels >70 dBA from rail noise, while this study calculated the number of people exposed to >69 dBA to ~5 400. There are also a lot more exposed to all lower intervals. This has a great effect on the socioeconomic cost as the cost increases substantially with higher equivalent sound level. A major factor, is likely, but not limited to, the fact that previous studies used a 100x100 m grid for the population count and removed all buildings within 20 m from the track, while we used exposure points geographically positioned by buildings, hence using real distance between rail and track. This means that there could be, in the previous study, a great underestimation of exposed to higher levels, such as above 70 dBA.

The difference between previous calculations for road is low. The method with previous study is similar as previous calculation (Sweco, 2014) in the case where NORD96 has been used with the exclusion of terrain, other objects and reflections. The origin of the large difference is likely the use of grid for the population versus exposure points as mentioned above.

4.3 Possible improvements of the national noise mapping

In general, in calculations based on a large dataset, a decent average variation can be assumed. Therefore, while the simplifications and standard values applied in these large-scale calculations may affect the result in individual considerably, the final aggregated results still have the potential of being accurate.

There are, however, many ways the method used in this report could be improved to yield more reliable results that closer reflect real life conditions.

4.3.1 Exposure points

The exposure points are placed along the building polygon's lines at every 50 meters. This means that tall but small areal of buildings are given less population than a low building with high areal. This is only an issue when these different building geometries are in the same 250 x 250 m grid. It can be resolved by including building height data and estimating number of levels and distributing the population according to the number of levels in the building.

Another shortcoming of the exposure point production is that for some buildings there are two adjacent buildings, with the same starting node. This results in two exposure points in the exact same coordinate, see Figure 9 for an example.

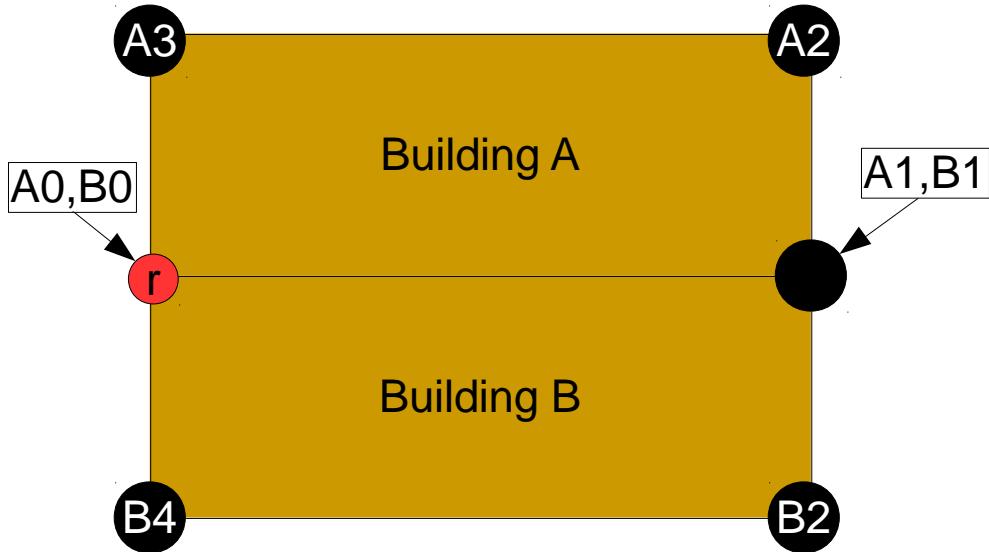


Figure 9. Building A and Building B are defined by the lines created by their node A0-A3 and B0-B3 respectively. The algorithm chooses the first node when creating the exposure points. For building A that is A0, and for building B it is B0. Provided that the polygons' length are less than 50 meters, the result from this scenario is that we get two receptor points in the exact same location, in this case; the red circle "r".

4.3.2 Barriers and other objects

The calculations did not include barriers of any sort; terrain, buildings or noise walls. This leads to an overestimation of the exposure levels. Depending on the height (and thickness for NORD96 and road) of the screen, the maximum damping effect of screens can be calculated up to 25 dBA for road and 20 dBA for rail according to NORD96.

What kind of barriers that should be included in calculations depends on which factor that could have the largest screening impact. NORD96 assumes all barriers such as buildings or terrain as screens, se example in Figure 10. The highest screen will be used to calculate the screening effect. Therefore, only the effect of one screen is considered according to NORD96. For urban areas, most likely, buildings will lead to the largest screening effect.

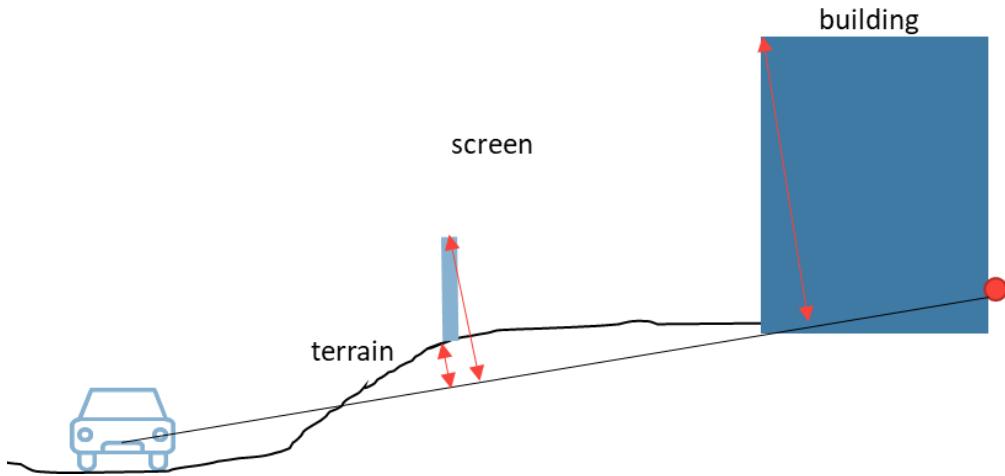


Figure 10. Screen height according to NORD96 is perpendicular to the path between the source and receptor (red dot).

4.3.2.1 Buildings

Including buildings in future calculations can improve the accuracy of calculations. The accuracy can increase due to both including building as barriers but also enabling reflections and creating receptor points on all floors of a building. It is especially important to include building effects in urban areas, mostly due to the screening effects and reflections. Including buildings can also lead to that calculations can be executed according to the standards for calculation; placing the receptor point on a façade and calculating it by ignoring reflections from the receptor's own façade¹².

To include buildings on a large national scale can lead to a high amount of data and heavy calculations. Both for including more parameters such as reflections and screen calculations, but also because of the increased amount of receptor points.

Assuming building heights according to Lantmäteriets Fastighetskarta (national map) is accurate enough to obtain building heights (Novak, o.a., 2016).

One possibility to avoid heavy calculations is to assume a correction of dB/m of a building effect, depending on the building density in a certain area (Jonasson, o.a., 2010). Although, to choose which factor for building effect to use can be hard as there is not much information in the literature for building density's effect in noise calculations.

4.3.2.2 Terrain

If terrain was included, it could significantly affect the results due to height difference and inclination between the source and receptor point. Combined with ground absorption, this can have a particularly high impact on the results.

¹² Swedish: frifältsvärde.

For calculation of road, the inclination of the road can also give higher noise levels (up to 5 dBA for light vehicles and 15 dBA for heavy vehicles). Our results are therefore possibly underestimating due to this factor.

The inclusion of terrain could lead to other parameters to consider, such as ensuring sources and receptors are placed on the right height above ground. On a large national scale this might be very hard to ensure, which could diminish the added accuracy of including terrain in the first place.

4.3.3 Reflections

The method used for this report does not include any reflections. For future calculations, the inclusion of reflections can lead to significant higher accuracy, especially in urban areas. In noise mapping calculations it is recommended to use 3 reflections but at least one. For calculations on this large scale this can become computationally hard to handle, since every extra reflection step increases computational time exponentially relative the number of reflection rays.

For calculations on a large national scale, the computational time could be optimized by ignoring reflections in areas with scarcity of buildings. Another optimization/compromise is to restrict the distance from the source and receptor point where reflections are valid.

4.3.4 Ground absorption

For the entire Sweden, soft ground has been assumed in our calculations with NORD96. This results in a dampening of noise, of ~0.03 dBA per meter further than 40m¹³ while hard ground gives 0 dampening regardless of distance (road calculations). This implies that the ground can affect noise exposure by 6 dBA at a distance of 240m. One simple way to work around this problem is by setting the ground type to hard for receptor points positioned in densely populated areas, assuming that it is an urban area with mostly concrete and pavement. Another way to is to map ground use from (Lantmäteriet, 2019) to a specific ground type (Novak, o.a., 2016).

4.3.5 CNOSSOS-EU

Migrating to using CNOSSOS-EU (Kephalopoulos, et al., 2012) is most likely the single most important improvement to the method used for this report. A large benefit is the fact that the program code for the method is open source. The migration to a new model is not in any way trivial and most likely requires extensive adaptation to fit the available data for Sweden. For example, CNOSSOS-EU does not produce maximal sound level. Since maximal sound level is commonly used in Sweden to produce strategic action plans to prevent noise exposure, this parameter

¹³ This is true only when receptor height is set to 4 m and source height is 0 m. As mentioned these are the values used throughout this report, and many other reports from EU member states regarding noise exposure.

is also very interesting to map geographically. There has been a report produced by Västra Götalandsregionens Miljömedicinska Centrum, which estimates the work needed to adapt CNOSSOS-EU for Sweden to 30 person months for the minimum effort solution and 103 person months for the recommended solution (Ögren, et al., 2015). This includes railway noise but excludes aviation noise. The work has begun and is performed within the project “Kunskapscentrum om buller”, spearheaded by VTI (Genell, 2019).

4.3.6 Aviation

Improving aviation results can be done by including other large airports that are excluded in the (Swedavia, 2019) report. For example Stockholm Skavsta airport is not included in the calculations. This airport has more yearly air traffic than six of the ten airports included in Swedavias report. However, no noise exposure assessment is presented for this airport and inclusion was therefore not possible in this study.

4.3.7 Use of commercial noise calculating software

In these calculations, the NORD96 method has been used, but with two different software. For road calculations SMHI's simplified model implemented with Python and for rail the software program CadnaA. There are pros and cons against both ways. Both for the adaption to calculate large datasets but also in the control of configurations and parameters in relation to a calculation method such as NORD96.

Software program such as SoundPLAN or CadnaA differ regarding the possibility to choose and control configurations in relation to NORD96, but also in the disclosure of quality insurance for updates (Villamor, o.a., 2018). Though this can also be of benefit, knowing that the program has gone through quality insurance when implementing the calculation method as these programs are well used and accepted in the acoustic community. In the future, with the use of CNOSSOS-EU, there are many possibilities due to the open source code. One of the most beneficial aspect of developing a custom-tailored software to run the national noise mapping is that very specific optimizations, that might not feasible in a software such as SoundPLAN or CadnA, can be made.

4.3.8 Trend

One of the main interests in studies like this is to determine trends in noise exposure and connected costs. For a direct comparison between different years, identical methods and input management are crucial. As discussed above, the methods and input varies between this and previous reports to an extent where direct comparison of results are not possible.

The trend analysis represented in the previous report for the year 2011 does not take this into consideration, when using results from different methods in direct comparison. To improve trend analysis in future studies, the effect of any further development of the methods used need to be thoroughly analyzed, with compara-

tive calculations. A more frequent update of the study would allow for a more continuous analysis of trends and reduce uncertainties connected to changes in, for example, data collection methods.

4.3.9 Correction factor

There is a clear overestimation of the modeled results for both road and rail noise exposure. A correction factor for road and one for rail could be applied to adjust the results of the noise exposure outside of municipalities included in the END reported data. This correction factor could improve the final aggregated results. This adjustment would lead to a decrease in socioeconomic cost compared to the results presented in this report. Population suffers from the same effect, a systematic error of ~6%, and a correction factor of 0.94 could be applied, on the NORD96 results, to align the population count to that of the END data. Note that applying a correction factor without validating the modeled results to more accurate modelling can yield false accuracy.

5 Conclusion

- The calculated population noise exposure in Sweden 2018 and related costs are summed up in Table 17.

Table 17. Calculated number of the population exposed to $L_{eq,24h}>55$ dBA (results merged with reported END-results) and $L_{AFmax}>70$ dBA. The socioeconomic cost is based solely on L_{Aeq} exposure.

Noise source	Number of exposed people in Sweden		Socioeconomic cost per year, SEK
	$L_{Aeq} > 55$ dB	$L_{AFmax} > 70$ dB	
Road	1 513 000 ¹⁴	7 200 000	20 billion
Railway	407 000	1 200 000	1.8 billion
Aviation	19 000	-	70 million

- The methods used in this report are rather crude; hence, the results have rather large uncertainties.
- It is possible to do a quite simple national noise exposure calculation, with acceptable results, compared to very detailed models that require a lot more input data than the method used in this study.
- Future national noise mapping could be improved by including different ground types, estimation of exposure point height using the building types from Fastighetskartan and including building 3D geometries. All these changes could significantly improve the results further.
- A trend analysis of socioeconomic cost could be created but it requires the use of the same method and assessments which is not the case for this report and the ones for the years 1992, 1995, 2000, 2006 and 2011.

¹⁴ For the END interval 52.5-57.5 dBA (road noise) with 613 400 exposed, only half is added to yield this result.

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Appendix 1 Modeled road results: Equivalent sound pressure level, $L_{Aeq,24h}$

Table 18. The $L_{Aeq,24h}$ road results from Simplified NORD96 – SMHI's NORD96 v1.0 (road) for every Swedish municipal. The intervals are in the unit $L_{Aeq,24h}$ in dBA population noise exposure.

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	1 412 143	2 083 972	1 017 717	322 347	59 578	9 997	2 504
Ale	31 197	3 088	4 042	2 035	812	223	18	0
Alingsås	41 021	4 509	8 578	3 139	1 161	199	10	0
Alvesta	20 116	910	2 907	797	100	13	0	0
Aneby	6 801	269	1 156	252	16	1	0	0
Arboga	14 109	912	2 787	809	102	1	0	0
Arjeplog	2 793	36	236	35	1	0	0	0
Arvidsjaur	6 309	490	761	440	50	0	0	0
Arvika	26 078	1 496	6 020	1 272	217	7	0	0
Askersund	11 260	550	1 765	451	94	5	0	0
Avesta	23 295	742	3 383	643	86	13	0	0
Bengtsfors	9 853	358	1 380	324	34	0	0	0
Berg	7 121	318	606	255	62	1	0	0
Bjurholm	2 445	108	260	106	2	0	0	0
Bjuv	15 488	810	2 601	708	101	1	0	0
Boden	28 053	2 342	5 241	1 949	364	29	0	0
Bollebygd	9 441	629	1 180	557	62	6	4	0
Bollnäs	26 973	2 038	5 115	1 579	430	29	0	0
Borgholm	10 855	329	1 054	256	69	4	0	0
Borlänge	52 157	3 728	8 854	2 406	651	212	174	285
Borås	112 068	16 896	24 347	11 378	4 631	843	44	0
Botkyrka	93 077	5 818	16 053	4 682	1 024	112	0	0
Boxholm	5 463	166	699	122	38	6	0	0
Bromölla	12 879	413	1 691	313	94	6	0	0
Bräcke	6 362	312	461	254	58	0	0	0
Burlöv	18 047	5 975	5 161	4 829	972	150	10	14
Båstad	14 903	1 026	1 803	832	179	15	0	0
Dals-Ed	4 785	198	540	180	18	0	0	0
Danderyd	33 382	3 863	4 485	2 480	1 005	225	111	42
Degerfors	9 685	698	1 034	592	106	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Dorotea	2 570	72	160	69	3	0	0	0
Eda	8 574	313	1 543	275	35	3	0	0
Ekerö	28 281	991	2 182	762	217	12	0	0
Eksjö	17 658	891	2 963	709	162	20	0	0
Emmaboda	9 407	328	1 122	282	46	0	0	0
Enköping	44 373	4 453	10 348	3 841	551	58	3	0
Eskilstuna	105 717	17 842	28 152	12 704	4 936	202	0	0
Eslöv	33 528	2 657	6 786	2 065	534	53	5	0
Essunga	5 685	276	950	264	10	2	0	0
Fagersta	13 416	1 044	3 303	822	205	17	0	0
Falkenberg	44 674	3 155	6 914	2 552	520	17	66	0
Falköping	33 170	2 864	7 001	2 512	346	6	0	0
Falun	58 849	5 816	10 641	4 228	1 492	93	3	0
Filipstad	10 819	576	1 456	419	157	0	0	0
Finspång	21 722	1 331	2 964	1 203	120	8	0	0
Flen	16 679	825	1 400	686	132	7	0	0
Forshaga	11 513	308	1 201	246	51	11	0	0
Färgelanda	6 599	347	695	273	74	0	0	0
Gagnef	10 256	713	1 206	475	193	45	0	0
Gislaved	29 849	1 375	3 520	1 065	297	5	8	0
Gnesta	11 265	369	1 411	337	32	0	0	0
Gnosjö	9 769	231	1 342	201	27	3	0	0
Gotland	59 267	6 686	13 655	5 814	849	23	0	0
Grums	9 020	659	1 199	536	109	14	0	0
Grästorp	5 722	427	827	289	127	11	0	0
Gullspång	5 295	601	972	419	145	37	0	0
Gällivare	17 599	3 403	5 658	2 592	771	40	0	0
Gävle	101 329	15 289	19 971	11 604	3 499	172	14	0
Göteborg	569 373	135 699	153 680	86 367	37 822	8 427	2 410	673
Götene	13 208	300	1 215	231	50	19	0	0
Habo	12 137	573	2 061	455	95	23	0	0
Hagfors	11 718	664	1 662	621	40	3	0	0
Hallsberg	15 858	1 719	2 548	1 433	283	3	0	0
Hallstahammar	16 166	557	1 908	438	111	7	1	0
Halmstad	101 135	15 772	20 058	11 194	4 191	367	20	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Hammarö	16 484	335	2 459	275	56	4	0	0
Haninge	89 752	6 527	13 146	5 702	757	68	0	0
Haparanda	9 742	303	1 317	290	11	2	0	0
Heby	13 898	644	1 883	566	77	1	0	0
Hedemora	15 446	1 244	2 269	955	281	8	0	0
Helsingborg	144 553	24 321	33 802	18 213	5 620	442	44	2
Herrljunga	9 480	640	1 046	610	30	0	0	0
Hjo	9 199	206	893	190	16	0	0	0
Hofors	9 608	389	720	343	44	2	0	0
Huddinge	110 668	13 368	20 928	9 616	2 797	908	44	3
Hudiksvall	37 415	2 574	6 104	2 104	453	17	0	0
Hultsfred	14 357	795	1 483	703	91	1	0	0
Hylte	10 916	467	1 247	430	36	1	0	0
Hällefors	6 974	269	1 049	245	24	0	0	0
Härjedalen	10 154	370	1 632	326	44	0	0	0
Härnösand	25 076	2 799	4 343	2 012	694	93	0	0
Härryda	37 625	3 027	5 046	2 161	549	205	35	77
Hässleholm	52 058	5 452	8 471	4 260	1 063	115	14	0
Håbo	21 545	651	1 683	429	199	22	1	0
Höganäs	26 557	2 223	4 574	1 971	249	3	0	0
Högsby	6 079	584	1 004	516	68	0	0	0
Hörby	15 606	974	2 591	799	150	25	0	0
Höör	16 594	1 186	1 838	807	327	52	0	0
Jokkmokk	4 979	89	502	89	0	0	0	0
Järfälla	78 211	7 680	14 796	6 198	1 246	200	34	2
Jönköping	139 100	24 246	28 050	16 939	5 630	1 516	161	0
Kalix	16 053	702	2 341	567	132	3	0	0
Kalmar	68 446	6 440	14 831	5 667	718	55	0	0
Karlsborg	6 940	605	1 257	543	62	0	0	0
Karlshamn	32 261	3 810	5 652	3 115	680	15	0	0
Karlskoga	30 397	3 817	6 309	2 709	827	277	4	0
Karlskrona	66 601	7 008	11 728	5 523	1 251	232	2	0
Karlstad	92 463	13 479	25 304	9 933	2 758	749	39	0
Katrineholm	34 509	3 881	7 930	3 189	684	8	0	0
Kil	11 967	541	1 500	440	99	2	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Kinda	9 950	538	1 216	438	100	0	0	0
Kiruna	22 981	1 222	4 466	1 058	162	2	0	0
Klippan	17 591	1 048	2 314	950	91	7	0	0
Knivsta	18 724	435	2 049	351	78	6	0	0
Kramfors	18 416	1 211	1 920	832	338	41	0	0
Kristianstad	84 791	9 340	13 513	6 900	2 072	313	52	3
Kristinehamn	24 290	2 194	4 442	1 804	363	27	0	0
Krokom	14 886	300	1 311	268	26	6	0	0
Kumla	21 711	1 288	3 789	1 118	161	9	0	0
Kungsbacka	83 418	4 723	15 208	4 020	598	91	14	0
Kungsör	8 658	861	1 357	651	198	12	0	0
Kungälv	45 022	4 149	7 680	3 434	614	96	5	0
Kävlinge	31 515	2 301	5 091	1 655	556	76	6	8
Köping	26 268	1 936	6 136	1 713	222	1	0	0
Laholm	25 457	2 350	4 679	1 816	493	41	0	0
Landskrona	46 232	3 088	8 172	2 313	616	146	13	0
Laxå	5 653	532	630	382	130	20	0	0
Lekeberg	8 103	294	771	261	31	2	0	0
Leksand	15 869	479	1 365	401	70	8	0	0
Lerum	42 072	3 905	5 130	2 774	777	321	33	0
Lessebo	8 789	416	1 144	325	83	8	0	0
Lidingö	47 724	3 193	8 635	2 380	559	244	10	0
Lidköping	39 878	1 804	4 320	1 440	360	4	0	0
Lilla Edet	14 085	1 336	2 470	1 048	251	37	0	0
Lindesberg	23 566	1 886	3 396	1 669	190	27	0	0
Linköping	160 898	20 169	42 308	16 682	3 379	99	9	0
Ljungby	28 511	2 015	5 798	1 768	243	4	0	0
Ljusdal	19 041	1 618	3 389	1 311	307	0	0	0
Ljusnarsberg	4 852	233	617	183	49	1	0	0
Lomma	25 087	1 370	6 899	1 236	98	33	3	0
Ludvika	26 982	2 120	3 933	1 431	604	85	0	0
Luleå	77 800	12 241	16 500	10 080	1 978	183	0	0
Lund	122 768	13 579	24 194	10 816	2 435	284	44	0
Lycksele	12 219	667	2 163	643	24	0	0	0
Lysekil	14 612	921	1 265	691	219	11	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Malmö	338 114	95 418	111 988	67 145	24 421	3 671	178	3
Malung-Sälen	10 091	1 303	1 577	1 024	276	3	0	0
Malå	3 121	59	350	59	0	0	0	0
Mariestad	24 362	1 252	3 535	1 035	165	51	1	0
Mark	34 746	2 131	5 190	1 746	376	9	0	0
Markaryd	10 260	907	1 557	789	75	4	0	39
Mellerud	9 349	611	1 330	420	180	11	0	0
Mjölby	27 333	1 688	4 577	1 494	177	13	4	0
Mora	20 382	1 260	4 477	928	303	29	0	0
Motala	43 672	2 949	7 345	2 628	293	28	0	0
Mullsjö	7 307	350	457	310	34	6	0	0
Munkedal	10 501	443	1 147	414	29	0	0	0
Munkfors	3 776	132	246	109	23	0	0	0
Mörlndal	69 344	12 384	18 021	9 551	2 488	315	30	0
Mönsterås	13 560	1 320	1 933	1 023	279	18	0	0
Mörbylånga	15 031	673	1 865	542	124	7	0	0
Nacka	102 774	14 628	13 360	10 348	3 108	1 024	148	0
Nora	10 724	403	1 634	371	28	3	1	0
Norberg	5 796	325	686	288	37	0	0	0
Nordanstig	9 514	502	1 138	346	104	52	0	0
Nordmaling	7 121	93	442	89	4	0	0	0
Norrköping	141 528	24 399	33 655	18 335	5 717	342	5	0
Norrtälje	61 692	5 165	10 800	4 468	690	7	0	0
Norsjö	4 089	67	711	62	5	0	0	0
Nybro	20 295	1 208	3 237	893	302	13	0	0
Nykvarn	10 951	192	523	153	36	3	0	0
Nyköping	55 935	4 756	13 544	3 590	973	167	26	0
Nynäshamn	28 288	584	2 373	501	78	5	0	0
Nässjö	31 494	2 014	5 075	1 739	271	4	0	0
Ockelbo	5 911	467	610	424	43	0	0	0
Olofström	13 501	617	2 357	509	106	2	0	0
Orsa	6 896	282	642	228	49	5	0	0
Orust	15 079	804	2 019	694	108	2	0	0
Osby	13 242	508	1 417	434	42	32	0	0
Oskarshamn	26 922	2 030	4 977	1 710	291	29	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Ovanåker	11 671	333	1 181	275	55	3	0	0
Oxelösund	12 074	584	2 028	457	127	0	0	0
Pajala	6 046	229	698	215	14	0	0	0
Partille	38 179	5 384	6 724	3 178	1 517	500	184	5
Perstorp	7 464	477	1 093	350	98	29	0	0
Piteå	42 084	2 805	8 334	2 500	274	31	0	0
Ragunda	5 350	254	577	226	28	0	0	0
Robertsfors	6 771	156	453	103	32	17	4	0
Ronneby	29 621	1 953	4 535	1 657	279	16	1	0
Rättvik	10 890	726	1 239	547	163	16	0	0
Sala	22 785	1 262	4 209	1 095	129	36	2	0
Salem	16 736	747	2 752	689	58	0	0	0
Sandviken	39 155	3 867	8 382	3 222	621	24	0	0
Sigtuna	48 008	2 927	8 255	2 464	438	24	1	0
Simrishamn	19 271	1 294	2 838	1 104	179	11	0	0
Sjöbo	19 103	973	3 118	767	181	24	1	0
Skara	18 798	2 213	4 075	1 797	331	72	13	0
Skellefteå	72 423	9 012	17 129	7 019	1 815	178	0	0
Skinnskatteberg	4 418	124	489	113	11	0	0	0
Skurup	15 683	1 112	2 043	790	280	41	1	0
Skövde	55 691	5 540	12 586	4 732	753	55	0	0
Smedjebacken	10 797	454	848	336	107	11	0	0
Sollentuna	72 703	11 906	13 267	7 337	3 237	1 119	155	58
Solna	82 106	29 635	29 296	20 300	8 252	960	120	3
Sorsele	2 526	38	212	38	0	0	0	0
Sotenäs	9 051	552	1 916	459	89	4	0	0
Staffanstorp	24 669	1 939	5 745	1 425	377	87	49	1
Stenungsund	26 446	1 290	4 074	991	258	32	9	0
Stockholm	962 390	339 718	286 571	219 895	90 634	23 212	4 758	1 219
Storfors	4 044	92	389	86	6	0	0	0
Storuman	5 883	266	1 013	258	8	0	0	0
Strängnäs	35 691	1 505	4 559	1 404	99	2	0	0
Strömstad	13 227	1 023	1 896	919	99	5	0	0
Strömsund	11 696	616	1 202	554	62	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Sundbyberg	47 907	7 905	16 659	5 867	1 857	181	0	0
Sundsvall	98 750	14 572	19 546	10 742	3 223	574	33	0
Sunne	13 268	1 054	2 470	853	184	17	0	0
Surahammar	10 070	47	568	37	10	0	0	0
Svalöv	14 092	1 263	1 683	1 077	168	17	1	0
Svedala	21 588	1 746	3 976	1 397	321	24	1	3
Svenljunga	10 642	464	1 218	413	49	2	0	0
Säffle	15 617	1 213	2 388	980	180	53	0	0
Säter	11 101	609	1 325	392	197	20	0	0
Sävsjö	11 606	613	1 674	458	145	10	0	0
Söderhamn	25 687	1 189	3 110	1 029	146	14	0	0
Söderköping	14 630	818	2 418	510	300	8	0	0
Södertälje	97 091	10 701	14 748	8 033	2 294	341	33	0
Sölvesborg	17 462	903	2 166	829	70	4	0	0
Tanum	12 849	659	1 959	581	78	0	0	0
Tibro	11 146	782	1 900	678	95	9	0	0
Tidaholm	12 795	908	1 793	781	118	9	0	0
Tierp	21 150	683	2 156	641	41	1	0	0
Timrå	18 033	3 054	3 083	1 600	763	529	162	0
Tingsryd	12 396	829	1 300	627	194	8	0	0
Tjörn	15 892	758	2 574	606	140	12	0	0
Tomelilla	13 538	1 212	1 831	881	292	39	0	0
Torsby	11 734	797	2 505	729	68	0	0	0
Torsås	7 143	731	1 252	588	138	5	0	0
Tranemo	11 885	381	1 480	351	27	3	0	0
Tranås	18 993	2 743	3 466	2 453	290	0	0	0
Trelleborg	44 842	5 763	9 444	4 644	1 074	44	1	0
Trollhättan	58 601	9 937	16 607	8 322	1 555	60	0	0
Trosa	13 297	470	927	424	37	9	0	0
Tyresö	47 730	2 816	9 529	2 420	334	62	0	0
Täby	71 896	6 628	14 774	4 594	1 605	341	88	0
Töreboda	9 313	663	1 360	610	53	0	0	0
Uddevalla	56 200	8 615	12 336	6 238	1 927	382	56	12
Ulricehamn	24 400	1 664	4 516	1 485	174	5	0	0
Umeå	127 010	12 282	30 941	9 819	2 154	300	9	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Upplands Väsby	45 383	3 525	9 464	2 693	622	192	18	0
Upplands-Bro	28 711	1 784	3 147	1 393	335	54	2	0
Uppsala	224 839	37 226	49 723	26 981	8 945	1 284	4	12
Uppvidinge	9 572	290	1 348	269	21	0	0	0
Vadstena	7 506	411	1 883	383	28	0	0	0
Vaggeryd	13 967	976	2 125	919	53	4	0	0
Valdemarsvik	7 954	219	919	203	16	0	0	0
Vallentuna	32 597	1 109	5 639	1 000	104	5	0	0
Vansbro	6 774	508	866	391	116	1	0	0
Vara	15 953	804	2 362	671	107	26	0	0
Varberg	63 633	4 084	10 128	3 283	723	77	1	0
Vaxholm	11 974	650	1 314	525	124	1	0	0
Vellinge	36 457	2 185	3 965	1 604	507	67	2	5
Vetlanda	27 532	1 775	4 580	1 478	284	13	0	0
Vilhelmina	6 742	354	1 420	317	37	0	0	0
Vimmerby	15 750	812	1 777	736	68	8	0	0
Vindeln	5 456	406	745	340	66	0	0	0
Vingåker	9 153	910	1 377	801	108	1	0	0
Vänersborg	39 405	3 188	6 427	2 447	680	61	0	0
Vännäs	8 778	299	1 294	278	20	1	0	0
Värmdö	44 422	1 965	5 504	1 599	317	49	0	0
Värnamo	34 412	1 989	6 551	1 694	277	18	0	0
Västervik	36 676	2 405	5 684	1 992	384	28	1	0
Västerås	151 830	22 132	30 460	14 753	5 519	1 458	374	28
Växjö	92 483	8 750	19 073	7 122	1 392	231	5	0
Vårgårda	11 629	904	1 581	716	111	71	6	0
Ydre	3 717	67	357	62	5	0	0	0
Ystad	30 256	4 695	9 072	3 869	666	155	5	0
Älmhult	17 543	1 124	2 183	908	216	0	0	0
Älvdalens sameby	7 093	506	1 037	386	120	0	0	0
Älvkarleby	9 354	338	1 186	310	28	0	0	0
Älvbyn	8 141	242	544	203	39	0	0	0
Ängelholm	42 287	3 666	10 099	3 197	393	66	10	0
Åmål	12 721	718	2 197	609	104	5	0	0
Ånge	9 404	520	1 186	424	94	2	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Åre	11 498	1 184	1 770	900	275	9	0	0
Årjäng	9 997	479	805	360	107	12	0	0
Åsele	2 815	46	211	45	1	0	0	0
Åstorp	15 877	2 070	4 046	1 690	342	33	5	0
Åtvidaberg	11 542	416	1 102	354	57	5	0	0
Öckerö	12 931	179	1 220	177	2	0	0	0
Ödeshög	5 324	316	913	269	35	12	0	0
Örebro	153 132	23 618	28 720	16 761	6 039	796	18	4
Örkelljunga	10 192	721	1 230	536	175	10	0	0
Örnsköldsvik	56 067	5 008	8 146	3 885	941	179	0	3
Östersund	63 157	5 682	10 420	4 475	1 168	37	2	0
Österåker	44 772	3 378	6 814	2 563	773	41	1	0
Östhammar	22 025	978	2 426	764	211	3	0	0
Östra Göinge	14 930	922	1 984	681	207	34	0	0
Överkalix	3 298	237	588	202	35	0	0	0
Övertorneå	4 409	118	478	113	5	0	0	0

Appendix 2 Modeled road results: Maximum sound pressure level, LAFmax

Table 19. The L_{AFmax} road results from Simplified NORD96 – SMHI's NORD96 v1.0 (road) for every Swedish municipal. The intervals are in the unit L_{AFmax} in dBA population noise exposure.

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	9 734 168	203 322	411 988	726 265	1 348 362	3 712 728	3 534 825
Ale	31 197	21 262	816	1 507	2 395	3 960	9 637	11 625
Alingsås	41 021	29 260	761	1 701	3 017	5 363	14 322	14 938
Alvesta	20 116	15 073	326	425	967	2 637	7 843	7 230
Aneby	6 801	4 205	183	273	549	1 281	2 482	1 723
Arboga	14 109	9 499	403	656	1 020	1 946	5 213	4 286
Arjeplog	2 793	1 892	85	92	184	403	1 109	783
Arvidsjaur	6 309	4 939	75	123	329	720	2 611	2 328
Arvika	26 078	16 595	801	1 109	1 777	4 451	8 785	7 810
Askersund	11 260	7 284	373	616	914	1 451	3 506	3 778
Avesta	23 295	17 858	384	628	1 195	2 503	9 194	8 664
Bengtsfors	9 853	7 190	227	311	407	1 096	3 388	3 802
Berg	7 121	2 340	716	836	850	1 349	1 603	737
Bjurholm	2 445	1 514	101	133	166	313	763	751
Bjuv	15 488	12 683	127	350	607	1 390	6 390	6 293
Boden	28 053	19 898	534	936	1 756	4 051	11 344	8 554
Bollebygd	9 441	6 066	431	502	671	1 022	2 736	3 330
Bollnäs	26 973	16 574	1 166	1 851	2 131	3 690	8 281	8 293
Borgholm	10 855	5 973	460	696	1 086	1 922	3 587	2 386
Borlänge	52 157	33 799	1 538	2 692	4 645	8 049	20 145	13 654
Borås	112 068	82 085	2 136	3 959	6 846	14 114	41 968	40 117
Botkyrka	93 077	61 050	550	3 546	10 827	16 506	31 905	29 145
Boxholm	5 463	3 868	119	199	311	662	1 879	1 989
Bromölla	12 879	9 569	239	434	700	1 520	5 869	3 700
Bräcke	6 362	3 637	310	368	532	880	2 192	1 445
Burlöv	18 047	10 947	38	1 565	2 450	3 001	6 425	4 522
Båstad	14 903	10 110	320	606	1 187	2 073	5 300	4 810
Dals-Ed	4 785	2 959	170	236	420	671	1 245	1 714
Danderyd	33 382	25 651	44	348	2 060	5 267	15 785	9 866
Degerfors	9 685	7 147	170	172	508	1 381	4 661	2 486

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Dorotea	2 570	1 512	106	138	228	398	909	603
Eda	8 574	5 387	366	502	636	1 198	2 858	2 529
Ekerö	28 281	18 855	574	1 352	2 227	3 955	10 376	8 479
Eksjö	17 658	13 002	207	424	1 163	2 493	6 743	6 259
Emmaboda	9 407	7 470	141	152	362	1 093	3 915	3 555
Enköping	44 373	27 073	1 518	2 859	3 770	6 572	14 637	12 436
Eskilstuna	105 717	73 165	2 114	4 044	8 368	14 457	41 227	31 938
Eslöv	33 528	24 038	625	1 675	2 167	3 947	14 292	9 746
Essunga	5 685	3 719	233	188	361	681	1 684	2 035
Fagersta	13 416	10 465	174	299	550	1 607	5 442	5 023
Falkenberg	44 674	33 847	840	1 485	2 217	5 043	17 328	16 519
Falköping	33 170	23 689	667	1 060	1 919	4 745	13 112	10 577
Falun	58 849	37 376	1 962	3 237	5 429	8 401	19 521	17 855
Filipstad	10 819	8 645	214	242	407	918	4 035	4 610
Finspång	21 722	14 809	471	1 077	1 684	2 974	7 942	6 867
Flen	16 679	11 110	552	665	1 200	1 960	5 734	5 376
Forshaga	11 513	9 309	112	179	363	1 314	4 967	4 342
Färgelanda	6 599	3 807	246	286	501	1 013	1 972	1 835
Gagnef	10 256	6 168	559	640	845	1 260	3 207	2 961
Gislaved	29 849	22 171	552	1 024	1 577	3 930	13 317	8 854
Gnesta	11 265	6 248	439	645	1 203	1 530	3 247	3 001
Gnosjö	9 769	7 292	240	309	508	1 130	3 919	3 373
Gotland	59 267	33 958	3 224	4 348	5 567	7 985	17 464	16 494
Grums	9 020	6 210	175	327	720	1 250	3 329	2 881
Grästorp	5 722	3 571	179	263	344	878	1 909	1 662
Gullspång	5 295	3 675	116	147	277	786	2 092	1 583
Gällivare	17 599	11 963	556	859	1 177	2 247	6 732	5 231
Gävle	101 329	64 586	1 679	5 443	10 575	17 313	39 664	24 922
Göteborg	569 373	420 167	7 028	22 419	43 822	75 420	211 715	208 452
Götene	13 208	8 254	389	525	975	2 255	4 313	3 941
Habo	12 137	9 484	371	391	503	1 001	4 689	4 795
Hagfors	11 718	8 163	329	532	700	1 448	4 337	3 826
Hallsberg	15 858	11 106	343	576	1 301	1 892	4 731	6 375
Hallstahammar	16 166	11 719	201	539	1 062	2 228	7 221	4 498
Halmstad	101 135	75 986	2 388	5 009	5 957	10 560	33 953	42 033

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Hammarö	16 484	12 031	240	480	898	2 064	6 342	5 689
Haninge	89 752	54 772	1 560	5 272	11 296	15 511	27 491	27 281
Haparanda	9 742	6 946	185	424	623	1 209	4 031	2 915
Heby	13 898	9 151	427	626	950	1 888	4 881	4 270
Hedemora	15 446	11 718	406	533	773	1 359	5 542	6 176
Helsingborg	144 553	100 734	2 923	7 785	11 706	20 224	57 684	43 050
Herrljunga	9 480	6 292	281	316	610	1 371	2 797	3 495
Hjo	9 199	6 500	229	290	522	1 244	3 743	2 757
Hofors	9 608	7 399	134	233	464	1 043	3 302	4 097
Huddinge	110 668	80 102	270	3 713	9 633	16 600	43 004	37 098
Hudiksvall	37 415	23 465	1 156	1 971	3 628	5 333	12 595	10 870
Hultsfred	14 357	11 274	172	262	674	1 717	5 379	5 895
Hylte	10 916	8 714	50	123	430	1 493	4 166	4 548
Hällefors	6 974	4 940	166	266	362	923	3 063	1 877
Härjedalen	10 154	6 609	422	471	664	1 331	3 716	2 893
Härnösand	25 076	17 286	501	950	1 900	3 464	9 463	7 823
Härryda	37 625	27 987	658	1 149	2 586	4 394	12 645	15 342
Hässleholm	52 058	36 153	975	1 827	3 043	8 249	21 601	14 552
Håbo	21 545	15 646	673	920	1 575	2 334	8 382	7 264
Höganäs	26 557	20 614	314	737	1 260	3 338	11 113	9 501
Högsby	6 079	4 439	94	164	346	890	2 178	2 261
Hörby	15 606	11 319	380	459	691	1 898	6 289	5 030
Höör	16 594	12 315	376	439	922	1 950	6 270	6 045
Jokkmokk	4 979	3 678	93	152	200	702	2 227	1 451
Järfälla	78 211	55 950	459	3 071	6 967	11 710	29 001	26 949
Jönköping	139 100	99 276	2 671	6 051	10 521	18 470	53 378	45 898
Kalix	16 053	11 780	273	564	832	2 315	6 604	5 176
Kalmar	68 446	45 619	1 194	3 611	5 876	11 024	26 540	19 079
Karlsborg	6 940	5 039	113	177	361	933	3 049	1 990
Karlshamn	32 261	23 725	439	1 055	2 325	4 000	10 684	13 041
Karlskoga	30 397	22 494	383	1 097	1 841	4 128	12 656	9 838
Karlskrona	66 601	49 741	1 267	1 861	3 562	8 153	25 288	24 453
Karlstad	92 463	66 858	1 913	3 925	6 091	12 616	36 167	30 691
Katrineholm	34 509	25 707	617	805	1 487	4 293	13 451	12 256
Kil	11 967	8 413	292	598	623	1 445	5 013	3 400

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Kinda	9 950	7 044	221	336	695	1 157	2 923	4 121
Kiruna	22 981	17 877	404	831	1 044	2 019	8 526	9 351
Klippan	17 591	13 298	431	519	747	1 942	7 202	6 096
Knivsta	18 724	10 930	773	1 516	1 724	2 347	5 706	5 224
Kramfors	18 416	11 631	720	905	1 361	2 880	6 149	5 482
Kristianstad	84 791	57 969	1 318	3 758	6 414	12 876	34 186	23 783
Kristinehamn	24 290	19 284	280	535	986	2 917	9 491	9 793
Krokom	14 886	6 614	942	1 234	1 953	2 334	3 743	2 871
Kumla	21 711	16 214	554	711	1 236	2 418	9 335	6 879
Kungsbacka	83 418	55 608	2 980	3 692	6 089	9 559	27 694	27 914
Kungsör	8 658	5 995	170	250	475	1 299	3 116	2 879
Kungälv	45 022	23 841	1 854	3 552	4 321	6 617	11 745	12 096
Kävlinge	31 515	25 647	351	694	1 303	2 796	12 152	13 495
Köping	26 268	16 440	1 128	1 725	2 386	3 922	9 037	7 403
Laholm	25 457	19 661	545	632	1 097	2 692	9 292	10 369
Landskrona	46 232	33 319	678	2 178	3 447	6 172	18 309	15 010
Laxå	5 653	3 932	140	186	343	755	2 277	1 655
Lekeberg	8 103	4 548	468	512	698	1 205	2 695	1 853
Leksand	15 869	9 993	801	830	962	1 861	5 137	4 856
Lerum	42 072	27 098	1 180	1 895	3 409	5 733	14 367	12 731
Lessebo	8 789	7 448	70	70	253	799	4 299	3 149
Lidingö	47 724	37 144	478	1 059	2 413	6 362	21 446	15 698
Lidköping	39 878	25 886	1 030	1 741	3 047	5 892	15 377	10 509
Lilla Edet	14 085	9 427	551	565	797	1 271	3 586	5 841
Lindesberg	23 566	16 204	672	1 071	1 638	2 589	8 322	7 882
Linköping	160 898	136 834	1 519	2 384	4 427	13 040	48 873	87 961
Ljungby	28 511	21 772	695	1 050	1 258	2 672	9 669	12 103
Ljusdal	19 041	10 922	1 116	1 321	1 729	2 566	5 316	5 606
Ljusnarsberg	4 852	3 473	91	124	270	661	1 817	1 656
Lomma	25 087	20 307	138	439	1 056	2 932	11 027	9 280
Ludvika	26 982	19 358	850	1 107	1 659	3 082	10 061	9 297
Luleå	77 800	54 786	1 230	3 788	6 221	9 493	28 181	26 605
Lund	122 768	73 912	3 936	9 726	13 161	19 603	42 457	31 455
Lycksele	12 219	7 105	227	973	1 545	1 989	4 189	2 916
Lysekil	14 612	9 522	392	562	1 104	2 048	3 533	5 989

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Malmö	338 114	234 586	3 359	14 251	27 082	58 392	140 612	93 974
Malung-Sälen	10 091	5 290	380	668	1 179	2 254	3 077	2 213
Malå	3 121	2 315	80	77	198	311	1 127	1 188
Mariestad	24 362	19 074	357	536	886	2 687	9 207	9 867
Mark	34 746	25 511	980	1 438	2 061	3 443	11 326	14 185
Markaryd	10 260	7 988	146	253	370	1 269	4 220	3 768
Mellerud	9 349	6 638	278	309	415	791	2 653	3 985
Mjölby	27 333	20 435	569	1 133	1 523	3 069	10 284	10 151
Mora	20 382	12 334	865	1 124	1 823	3 211	7 223	5 111
Motala	43 672	29 104	977	2 114	3 476	6 925	16 566	12 538
Mullsjö	7 307	5 660	86	201	394	796	3 088	2 572
Munkedal	10 501	6 985	418	440	588	1 115	3 214	3 771
Munkfors	3 776	2 325	51	178	479	672	1 530	795
Mölndal	69 344	54 126	594	1 778	3 991	8 446	26 777	27 349
Mönsterås	13 560	10 277	209	299	696	1 799	5 626	4 651
Mörbylånga	15 031	10 816	265	511	1 010	1 977	6 139	4 677
Nacka	102 774	69 392	2 881	4 672	9 840	15 794	37 459	31 933
Nora	10 724	7 076	317	501	905	1 323	3 584	3 492
Norberg	5 796	3 783	127	259	550	871	2 173	1 610
Nordanstig	9 514	4 636	625	814	959	1 499	2 586	2 050
Nordmaling	7 121	4 409	175	320	663	1 253	2 640	1 769
Norrköping	141 528	100 016	2 114	6 323	11 272	19 585	55 412	44 604
Norrtälje	61 692	30 459	3 727	4 855	6 086	8 398	17 146	13 313
Norsjö	4 089	2 727	106	182	324	560	1 597	1 130
Nybro	20 295	14 084	300	754	1 456	3 430	9 055	5 029
Nykvarn	10 951	6 774	388	526	853	1 280	3 424	3 350
Nyköping	55 935	39 783	972	2 104	3 707	6 334	19 319	20 464
Nynäshamn	28 288	20 257	558	772	1 972	3 145	8 728	11 529
Nässjö	31 494	22 796	482	917	1 491	4 982	14 100	8 696
Ockelbo	5 911	3 320	345	397	525	904	1 634	1 686
Olofström	13 501	10 382	186	253	665	1 682	5 123	5 259
Orsa	6 896	4 039	370	431	622	965	2 270	1 769
Orust	15 079	7 123	999	1 191	1 496	2 002	3 050	4 073
Osby	13 242	8 139	245	553	1 560	2 242	5 016	3 123
Oskarshamn	26 922	20 981	233	591	1 409	3 232	10 864	10 117

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Ovanåker	11 671	7 557	407	577	883	1 536	3 887	3 670
Oxelösund	12 074	8 046	205	854	1 262	1 674	4 653	3 393
Pajala	6 046	3 571	242	427	594	823	2 044	1 527
Partille	38 179	26 199	691	2 415	3 647	5 180	12 309	13 890
Perstorp	7 464	5 474	107	148	358	1 124	3 453	2 021
Piteå	42 084	30 561	863	1 386	2 353	5 150	18 646	11 915
Ragunda	5 350	2 799	323	381	533	825	1 495	1 304
Robertsfors	6 771	4 303	228	297	515	1 020	2 333	1 970
Ronneby	29 621	22 632	775	1 158	1 264	2 923	10 351	12 281
Rättvik	10 890	6 209	510	790	899	1 761	3 649	2 560
Sala	22 785	14 795	694	1 121	1 837	3 170	8 484	6 311
Salem	16 736	9 148	338	897	3 148	3 101	4 570	4 578
Sandviken	39 155	27 447	1 074	1 277	2 944	5 346	13 622	13 825
Sigtuna	48 008	26 217	1 477	4 533	6 979	7 449	14 227	11 990
Simrishamn	19 271	14 450	418	512	789	2 133	6 845	7 605
Sjöbo	19 103	12 355	1 006	1 009	1 166	1 753	5 647	6 708
Skara	18 798	11 863	366	738	1 728	3 651	6 650	5 213
Skellefteå	72 423	46 656	2 172	3 695	6 295	11 378	29 231	17 425
Skinnskatteberg	4 418	2 852	176	194	273	550	1 498	1 354
Skurup	15 683	11 493	375	467	821	1 767	5 949	5 544
Skövde	55 691	47 729	529	762	1 627	4 248	18 803	28 926
Smedjebacken	10 797	8 029	325	345	511	922	3 253	4 776
Söllefteå	19 450	12 598	722	1 063	1 462	2 332	6 221	6 377
Sollentuna	72 703	48 321	656	3 756	7 600	12 126	26 928	21 393
Solna	82 106	60 385	200	3 505	6 614	11 399	32 270	28 115
Sorsele	2 526	1 482	107	117	210	397	869	613
Sotenäs	9 051	7 513	160	167	288	541	1 841	5 672
Staffanstorp	24 669	19 946	460	538	840	2 281	10 094	9 852
Stenungsund	26 446	16 114	1 089	1 677	2 649	3 232	7 553	8 561
Stockholm	962 390	841 368	508	3 081	24 328	93 039	338 133	503 235
Storfors	4 044	3 050	99	143	173	398	1 551	1 499
Storuman	5 883	4 061	172	245	375	765	2 294	1 767
Strängnäs	35 691	20 594	1 451	2 371	3 097	4 895	11 030	9 564
Strömstad	13 227	7 615	721	787	790	1 335	3 246	4 369
Strömsund	11 696	7 221	567	610	855	1 383	3 722	3 499

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Sundbyberg	47 907	33 773	805	2 700	4 671	5 885	18 453	15 320
Sundsvall	98 750	64 452	3 549	5 111	8 368	13 851	34 492	29 960
Sunne	13 268	7 942	538	711	933	2 167	4 762	3 180
Surahammar	10 070	8 131	61	123	384	1 222	4 692	3 439
Svalöv	14 092	10 721	310	379	563	1 265	4 600	6 121
Svedala	21 588	15 169	557	872	1 526	2 559	7 461	7 708
Svenljunga	10 642	7 381	275	317	659	1 608	4 037	3 344
Säffle	15 617	10 272	322	800	946	2 653	6 220	4 052
Säter	11 101	7 570	337	395	787	1 367	4 056	3 514
Sävsjö	11 606	8 954	195	277	482	1 306	4 950	4 004
Söderhamn	25 687	17 862	756	1 225	2 037	3 072	8 610	9 252
Söderköping	14 630	9 541	515	624	997	1 892	4 585	4 956
Södertälje	97 091	69 437	1 453	2 830	7 923	12 194	33 359	36 078
Sölvesborg	17 462	12 622	182	526	1 486	2 453	5 718	6 904
Tanum	12 849	7 388	596	694	994	1 612	3 219	4 169
Tibro	11 146	8 364	218	370	737	1 255	4 899	3 465
Tidaholm	12 795	9 133	238	454	786	1 580	4 487	4 646
Tierp	21 150	13 863	665	996	1 740	2 850	7 909	5 954
Timrå	18 033	12 936	349	531	1 167	2 310	7 375	5 561
Tingsryd	12 396	8 474	271	457	869	1 844	3 756	4 718
Tjörn	15 892	9 191	877	1 034	1 183	1 286	3 603	5 588
Tomelilla	13 538	9 567	398	418	560	1 660	5 066	4 501
Torsby	11 734	7 395	344	504	1 025	2 071	3 761	3 634
Torsås	7 143	5 208	98	196	488	888	2 672	2 536
Tranemo	11 885	9 428	189	216	475	1 229	5 010	4 418
Tranås	18 993	14 163	302	648	916	2 585	7 914	6 249
Trelleborg	44 842	36 438	391	799	1 494	4 605	18 391	18 047
Trollhättan	58 601	44 885	654	1 687	3 650	6 462	21 629	23 256
Trosa	13 297	9 004	446	521	836	1 138	3 403	5 601
Tyresö	47 730	40 297	48	474	1 753	5 131	16 801	23 496
Täby	71 896	55 121	279	1 451	5 140	9 834	28 585	26 536
Töreboda	9 313	5 969	315	334	621	1 455	3 441	2 528
Uddevalla	56 200	36 128	1 769	2 493	4 227	7 354	17 896	18 232
Ulricehamn	24 400	18 786	503	782	1 088	2 540	8 612	10 174
Umeå	127 010	75 884	4 370	8 870	12 786	21 790	47 635	28 249

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Upplands Väsby	45 383	30 142	838	2 567	4 565	6 453	15 790	14 352
Upplands-Bro	28 711	17 952	1 151	1 915	2 940	3 642	8 706	9 246
Uppsala	224 839	136 466	6 132	13 814	24 629	37 288	80 083	56 383
Uppvidinge	9 572	6 982	162	190	581	1 430	3 796	3 186
Vadstena	7 506	5 865	82	186	314	857	3 002	2 863
Vaggeryd	13 967	10 414	229	331	742	1 806	5 929	4 485
Valdemarsvik	7 954	5 238	295	386	547	842	2 117	3 121
Vallentuna	32 597	21 763	818	1 716	2 985	4 288	11 197	10 566
Vansbro	6 774	3 723	469	540	517	892	2 063	1 660
Vara	15 953	10 865	497	610	915	1 918	5 380	5 485
Varberg	63 633	44 624	1 558	2 657	4 403	7 997	24 066	20 558
Vaxholm	11 974	9 604	73	190	559	1 292	4 473	5 131
Vellinge	36 457	28 815	307	378	1 110	5 306	16 558	12 257
Vetlanda	27 532	20 185	414	936	1 422	3 819	11 966	8 219
Vilhelmina	6 742	3 099	280	605	757	1 576	1 951	1 148
Vimmerby	15 750	11 870	237	625	906	1 630	5 017	6 853
Vindeln	5 456	3 396	261	246	406	868	1 902	1 494
Vingåker	9 153	6 876	232	331	447	795	3 707	3 169
Vänersborg	39 405	26 559	826	2 307	3 158	5 234	13 959	12 600
Vännäs	8 778	6 348	209	350	437	1 034	3 627	2 721
Värmdö	44 422	27 740	1 577	2 188	3 598	6 516	14 009	13 731
Värnamo	34 412	22 778	555	1 275	3 485	5 356	12 832	9 946
Västervik	36 676	26 964	640	1 762	2 435	3 788	12 215	14 749
Västerås	151 830	99 280	3 639	11 143	14 748	19 590	52 430	46 850
Växjö	92 483	65 877	1 506	3 854	6 435	13 376	36 260	29 617
Vårgårda	11 629	6 774	381	763	1 193	2 018	3 562	3 212
Ydre	3 717	2 205	156	222	325	548	1 040	1 165
Ystad	30 256	22 466	500	932	1 678	3 737	11 325	11 141
Älmhult	17 543	13 293	407	482	850	1 955	6 757	6 536
Älvudalen	7 093	3 823	392	511	715	1 124	2 273	1 550
Älvkarleby	9 354	7 206	109	191	504	1 153	4 016	3 190
Älvbyn	8 141	5 735	244	363	535	830	3 209	2 526
Ängelholm	42 287	31 217	530	785	2 232	6 357	18 302	12 915
Åmål	12 721	8 930	268	470	770	1 713	4 271	4 659
Ånge	9 404	5 308	390	589	983	1 478	3 084	2 224

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Åre	11 498	5 539	947	1 048	1 226	1 599	3 035	2 504
Årjäng	9 997	5 586	455	595	943	1 510	2 754	2 832
Åsele	2 815	1 820	112	95	175	440	1 095	725
Åstorp	15 877	12 654	200	390	485	1 916	7 589	5 065
Åtvidaberg	11 542	8 445	188	293	651	1 611	3 917	4 528
Öckerö	12 931	11 558	25	79	262	975	4 690	6 868
Ödeshög	5 324	3 753	168	183	281	598	1 942	1 811
Örebro	153 132	95 552	5 466	11 731	15 411	21 096	51 764	43 788
Örkelljunga	10 192	7 053	257	272	437	1 472	4 094	2 959
Örnsköldsvik	56 067	40 211	1 560	2 235	3 482	5 886	18 634	21 577
Östersund	63 157	39 243	1 790	3 990	7 135	8 890	22 542	16 701
Österåker	44 772	27 450	1 532	2 266	3 916	6 246	13 686	13 764
Östhammar	22 025	13 074	701	1 189	1 998	3 514	6 936	6 138
Östra Göinge	14 930	10 238	290	590	1 127	2 062	5 871	4 367
Överkalix	3 298	1 865	199	230	320	467	921	944
Övertorneå	4 409	2 733	184	227	378	686	1 454	1 279

Appendix 3 Modeled rail results: Equivalent sound pressure level, $L_{Aeq,24h}$

Table 20. The $L_{Aeq,24h}$ rail results from CadnaA for every Swedish municipal. The intervals are in the unit $L_{Aeq,24h}$ in dBA population noise exposure.

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
SUM	10 216 373	447 444	643 223	318 342	104 688	20 589	2 926	899
Ale	31 197	2 915	6 811	2 607	308	0	0	0
Alingsås	41 021	6 526	5 128	4 348	1 690	443	45	0
Alvesta	20 116	4 653	3 756	2 985	1 274	364	28	2
Aneby	6 801	1 055	1 415	706	241	96	12	0
Arboga	14 109	1 669	2 177	1 284	287	97	1	0
Arjeplog	2 793	0	0	0	0	0	0	0
Arvidsjaur	6 309	0	0	0	0	0	0	0
Arvika	26 078	943	1 607	732	192	19	0	0
Askersund	11 260	194	457	149	38	7	0	0
Avesta	23 295	2 284	3 403	1 723	518	43	0	0
Bengtsfors	9 853	27	175	21	6	0	0	0
Berg	7 121	0	0	0	0	0	0	0
Bjurholm	2 445	0	0	0	0	0	0	0
Bjuv	15 488	746	1 612	616	124	6	0	0
Boden	28 053	2 125	4 469	1 534	535	54	2	0
Bollebygd	9 441	734	1 201	598	132	4	0	0
Bollnäs	26 973	2 239	4 356	1 552	571	105	11	0
Borgholm	10 855	0	0	0	0	0	0	0
Borlänge	52 157	3 215	7 088	2 714	479	20	2	0
Borås	112 068	2 723	7 208	2 330	388	5	0	0
Botkyrka	93 077	1 019	2 537	951	64	4	0	0
Boxholm	5 463	622	1 306	429	133	57	3	0
Bromölla	12 879	173	594	162	7	4	0	0
Bräcke	6 362	928	949	616	285	27	0	0
Burlöv	18 047	5 576	5 845	3 921	1 251	385	19	0
Båstad	14 903	116	326	98	13	2	3	0
Dals-Ed	4 785	194	381	177	17	0	0	0
Danderyd	33 382	0	0	0	0	0	0	0
Degerfors	9 685	934	1 873	697	215	22	0	0
Dorotea	2 570	0	0	0	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Eda	8 574	538	548	291	208	38	1	0
Ekerö	28 281	0	0	0	0	0	0	0
Eksjö	17 658	15	86	15	0	0	0	0
Emmaboda	9 407	116	446	110	6	0	0	0
Enköping	44 373	21	476	21	0	0	0	0
Eskilstuna	105 717	4 878	10 489	4 082	781	15	0	0
Eslöv	33 528	4 860	4 805	2 988	1 612	215	43	2
Essunga	5 685	0	0	0	0	0	0	0
Fagersta	13 416	978	1 195	727	231	20	0	0
Falkenberg	44 674	855	1 229	588	175	59	25	8
Falköping	33 170	6 402	5 317	4 365	1 726	302	9	0
Falun	58 849	2 705	4 175	2 217	451	36	1	0
Filipstad	10 819	42	139	40	2	0	0	0
Finspång	21 722	0	0	0	0	0	0	0
Flen	16 679	2 969	3 404	2 103	669	186	11	0
Forshaga	11 513	0	0	0	0	0	0	0
Färgelanda	6 599	0	0	0	0	0	0	0
Gagnef	10 256	291	659	261	28	2	0	0
Gislaved	29 849	180	288	152	28	0	0	0
Gnesta	11 265	3 081	2 237	2 003	879	190	9	0
Gnosjö	9 769	357	834	276	81	0	0	0
Gotland	59 267	0	0	0	0	0	0	0
Grums	9 020	304	635	235	67	2	0	0
Grästorp	5 722	11	35	11	0	0	0	0
Gullspång	5 295	139	44	76	50	13	0	0
Gällivare	17 599	461	1 819	405	55	1	0	0
Gävle	101 329	6 355	9 989	4 649	1 571	133	2	0
Göteborg	569 373	23 159	40 097	17 300	4 742	846	222	49
Götene	13 208	0	1	0	0	0	0	0
Habo	12 137	536	1 331	404	126	6	0	0
Hagfors	11 718	0	0	0	0	0	0	0
Hallsberg	15 858	5 359	2 545	2 786	1 937	606	30	0
Hallstahammar	16 166	478	1 212	429	49	0	0	0
Halmstad	101 135	3 387	6 137	2 689	582	116	0	0
Hammarö	16 484	0	0	0	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Haninge	89 752	15	361	15	0	0	0	0
Haparanda	9 742	0	0	0	0	0	0	0
Heby	13 898	271	668	260	10	1	0	0
Hedemora	15 446	622	939	543	72	7	0	0
Helsingborg	144 553	2 997	7 221	2 655	329	13	0	0
Herrljunga	9 480	1 619	1 485	1 021	461	135	1	1
Hjo	9 199	0	0	0	0	0	0	0
Hofors	9 608	338	440	252	78	8	0	0
Huddinge	110 668	14 209	13 121	9 825	3 604	720	60	0
Hudiksvall	37 415	668	2 283	548	83	37	0	0
Hultsfred	14 357	51	275	51	0	0	0	0
Hylte	10 916	0	36	0	0	0	0	0
Hällefors	6 974	234	714	224	10	0	0	0
Härjedalen	10 154	7	13	7	0	0	0	0
Härnösand	25 076	85	801	85	0	0	0	0
Härryda	37 625	1 019	2 498	887	126	6	0	0
Hässleholm	52 058	7 945	8 000	5 518	1 939	447	41	0
Håbo	21 545	64	707	64	0	0	0	0
Höganäs	26 557	0	0	0	0	0	0	0
Högsby	6 079	8	118	8	0	0	0	0
Hörby	15 606	0	0	0	0	0	0	0
Höör	16 594	3 637	2 000	2 026	1 115	435	50	11
Jokkmokk	4 979	19	26	16	2	1	0	0
Järfälla	78 211	17	1 081	14	3	0	0	0
Jönköping	139 100	5 693	9 596	4 268	1 276	149	0	0
Kalix	16 053	27	130	27	0	0	0	0
Kalmar	68 446	569	2 263	533	33	3	0	0
Karlsborg	6 940	0	0	0	0	0	0	0
Karlshamn	32 261	303	712	263	40	0	0	0
Karlskoga	30 397	0	0	0	0	0	0	0
Karlskrona	66 601	34	456	31	3	0	0	0
Karlstad	92 463	7 487	10 983	5 578	1 754	148	7	0
Katrineholm	34 509	8 546	6 778	5 701	2 527	313	3	2
Kil	11 967	715	1 850	628	64	10	13	0
Kinda	9 950	34	175	33	1	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Kiruna	22 981	218	115	152	48	18	0	0
Klippan	17 591	477	1 298	416	60	1	0	0
Knivsta	18 724	3 251	2 895	2 312	726	213	0	0
Kramfors	18 416	256	781	244	7	5	0	0
Kristianstad	84 791	1 103	2 172	868	223	12	0	0
Kristinehamn	24 290	1 545	3 043	1 228	292	25	0	0
Krokom	14 886	153	706	127	23	3	0	0
Kumla	21 711	4 859	4 018	3 339	1 267	247	6	0
Kungsbacka	83 418	3 077	4 817	2 225	730	118	4	0
Kungsör	8 658	471	1 114	354	98	19	0	0
Kungälv	45 022	87	645	87	0	0	0	0
Kävlinge	31 515	3 134	3 978	2 221	819	85	9	0
Köping	26 268	122	419	104	12	6	0	0
Laholm	25 457	168	145	165	3	0	0	0
Landskrona	46 232	322	1 064	310	12	0	0	0
Laxå	5 653	965	839	602	309	54	0	0
Lekeberg	8 103	0	0	0	0	0	0	0
Leksand	15 869	519	1 231	432	81	6	0	0
Lerum	42 072	4 542	6 727	3 395	915	220	12	0
Lessebo	8 789	219	481	187	32	0	0	0
Lidingö	47 724	0	0	0	0	0	0	0
Lidköping	39 878	0	1	0	0	0	0	0
Lilla Edet	14 085	242	279	193	44	5	0	0
Lindesberg	23 566	1 915	2 873	1 264	527	114	10	0
Linköping	160 898	2 547	7 826	2 162	347	34	4	0
Ljungby	28 511	0	0	0	0	0	0	0
Ljusdal	19 041	2 119	2 342	1 511	514	89	5	0
Ljusnarsberg	4 852	226	541	205	19	2	0	0
Lomma	25 087	2 005	2 146	1 399	584	19	3	0
Ludvika	26 982	890	2 568	740	149	1	0	0
Luleå	77 800	1 122	3 462	820	284	17	1	0
Lund	122 768	13 838	13 841	9 399	3 586	716	110	27
Lycksele	12 219	2	176	2	0	0	0	0
Lysekil	14 612	0	0	0	0	0	0	0
Malmö	338 114	23 844	43 574	16 980	5 569	1 206	89	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Malung-Sälen	10 091	0	0	0	0	0	0	0
Malå	3 121	0	0	0	0	0	0	0
Mariestad	24 362	0	10	0	0	0	0	0
Mark	34 746	0	66	0	0	0	0	0
Markaryd	10 260	6	51	6	0	0	0	0
Mellerud	9 349	399	1 060	344	52	3	0	0
Mjölby	27 333	3 500	4 201	2 749	690	59	2	0
Mora	20 382	190	527	172	18	0	0	0
Motala	43 672	1 318	2 522	1 094	215	9	0	0
Mullsjö	7 307	284	792	195	85	4	0	0
Munkedal	10 501	0	0	0	0	0	0	0
Munkfors	3 776	0	0	0	0	0	0	0
Mörlund	69 344	4 633	9 862	3 854	688	91	0	0
Mönsterås	13 560	54	269	48	6	0	0	0
Mörbylånga	15 031	0	0	0	0	0	0	0
Nacka	102 774	0	0	0	0	0	0	0
Nora	10 724	0	0	0	0	0	0	0
Norberg	5 796	129	83	96	30	3	0	0
Nordanstig	9 514	157	334	123	32	2	0	0
Nordmaling	7 121	149	153	104	35	9	1	0
Norrköping	141 528	5 444	9 576	4 127	1 190	125	2	0
Nortälje	61 692	0	0	0	0	0	0	0
Norsjö	4 089	78	167	69	9	0	0	0
Nybro	20 295	392	1 147	368	23	1	0	0
Nykvarn	10 951	809	2 033	715	94	0	0	0
Nyköping	55 935	2 741	6 581	2 406	306	26	3	0
Nynäshamn	28 288	0	0	0	0	0	0	0
Nässjö	31 494	4 464	4 719	2 969	1 195	295	5	0
Ockelbo	5 911	957	875	707	229	21	0	0
Olofström	13 501	14	26	14	0	0	0	0
Orsa	6 896	6	56	6	0	0	0	0
Orust	15 079	0	0	0	0	0	0	0
Osby	13 242	2 746	2 569	1 413	929	341	63	0
Oskarshamn	26 922	0	5	0	0	0	0	0
Ovanåker	11 671	0	0	0	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Oxelösund	12 074	32	324	26	6	0	0	0
Pajala	6 046	0	0	0	0	0	0	0
Partille	38 179	3 667	4 832	2 674	812	181	0	0
Perstorp	7 464	614	818	483	125	6	0	0
Piteå	42 084	90	56	58	28	4	0	0
Ragunda	5 350	255	292	133	106	16	0	0
Robertsfors	6 771	0	0	0	0	0	0	0
Ronneby	29 621	119	433	106	12	1	0	0
Rättvik	10 890	132	425	120	10	2	0	0
Sala	22 785	863	1 837	737	120	6	0	0
Salem	16 736	14	93	11	3	0	0	0
Sandviken	39 155	1 843	4 144	1 400	407	36	0	0
Sigtuna	48 008	2 922	5 742	2 816	93	13	0	0
Simrishamn	19 271	0	0	0	0	0	0	0
Sjöbo	19 103	0	0	0	0	0	0	0
Skara	18 798	0	0	0	0	0	0	0
Skellefteå	72 423	419	1 741	356	60	3	0	0
Skinnskatteberg	4 418	235	352	220	11	4	0	0
Skurup	15 683	44	362	43	1	0	0	0
Skövde	55 691	10 651	9 012	6 873	3 212	535	31	0
Smedjebacken	10 797	34	204	34	0	0	0	0
Söder om Sollefteå	19 450	816	1 180	607	186	23	0	0
Sollentuna	72 703	21 130	12 856	13 806	5 905	1 349	67	3
Solna	82 106	13 044	15 412	8 548	3 698	558	184	56
Sorsele	2 526	0	0	0	0	0	0	0
Sotenäs	9 051	0	0	0	0	0	0	0
Staffanstorp	24 669	2 408	1 097	1 450	861	83	14	0
Stenungsund	26 446	111	433	92	19	0	0	0
Stockholm	962 390	46 322	56 252	28 480	11 892	3 838	1 392	720
Storfors	4 044	0	25	0	0	0	0	0
Storuman	5 883	0	8	0	0	0	0	0
Strängnäs	35 691	968	1 952	704	173	68	23	0
Strömstad	13 227	0	0	0	0	0	0	0
Strömsund	11 696	0	5	0	0	0	0	0
Sundbyberg	47 907	73	776	73	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Sundsvall	98 750	1 700	4 765	1 412	286	2	0	0
Sunne	13 268	0	23	0	0	0	0	0
Surahammar	10 070	197	631	188	9	0	0	0
Svalöv	14 092	1 293	1 799	883	359	49	2	0
Svedala	21 588	33	196	24	9	0	0	0
Svenljunga	10 642	48	89	45	2	1	0	0
Säffle	15 617	332	820	252	67	13	0	0
Säter	11 101	540	955	422	117	0	1	0
Sävsjö	11 606	1 889	2 332	1 139	653	96	0	1
Söderhamn	25 687	106	204	65	32	9	0	0
Söderköping	14 630	0	0	0	0	0	0	0
Södertälje	97 091	3 894	3 064	2 504	1 162	223	5	0
Sölvesborg	17 462	191	627	169	19	3	0	0
Tanum	12 849	0	0	0	0	0	0	0
Tibro	11 146	0	0	0	0	0	0	0
Tidaholm	12 795	0	0	0	0	0	0	0
Tierp	21 150	1 228	1 969	924	267	37	0	0
Timrå	18 033	170	1 420	163	7	0	0	0
Tingsryd	12 396	0	0	0	0	0	0	0
Tjörn	15 892	0	0	0	0	0	0	0
Tomelilla	13 538	0	0	0	0	0	0	0
Torsby	11 734	0	9	0	0	0	0	0
Torsås	7 143	0	0	0	0	0	0	0
Tranemo	11 885	259	614	242	17	0	0	0
Tranås	18 993	4 888	3 885	3 192	1 280	410	6	0
Trelleborg	44 842	257	1 544	229	28	0	0	0
Trollhättan	58 601	2 475	5 773	2 004	398	46	20	7
Trosa	13 297	326	654	283	38	5	0	0
Tyresö	47 730	0	0	0	0	0	0	0
Täby	71 896	0	0	0	0	0	0	0
Töreboda	9 313	1 986	1 893	1 336	498	128	24	0
Uddevalla	56 200	194	1 188	160	34	0	0	0
Ulricehamn	24 400	0	0	0	0	0	0	0
Umeå	127 010	697	4 086	677	17	3	0	0
Upplands Väsby	45 383	4 725	5 739	4 039	593	16	77	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Upplands-Bro	28 711	20	262	20	0	0	0	0
Uppsala	224 839	6 401	14 841	4 992	1 226	182	1	0
Uppvidinge	9 572	0	0	0	0	0	0	0
Vadstena	7 506	0	0	0	0	0	0	0
Vaggeryd	13 967	0	46	0	0	0	0	0
Valdemarsvik	7 954	0	0	0	0	0	0	0
Vallentuna	32 597	0	0	0	0	0	0	0
Vansbro	6 774	27	184	27	0	0	0	0
Vara	15 953	11	103	11	0	0	0	0
Varberg	63 633	1 832	3 780	1 501	316	15	0	0
Vaxholm	11 974	0	0	0	0	0	0	0
Vellinge	36 457	172	412	157	14	1	0	0
Vetlanda	27 532	5	20	5	0	0	0	0
Vilhelmina	6 742	0	0	0	0	0	0	0
Vimmerby	15 750	14	79	14	0	0	0	0
Vindeln	5 456	711	1 122	544	148	19	0	0
Vingåker	9 153	1 463	971	751	586	119	7	0
Vänersborg	39 405	949	1 695	711	218	20	0	0
Vännäs	8 778	853	1 871	692	147	14	0	0
Värmdö	44 422	0	0	0	0	0	0	0
Värnamo	34 412	562	1 879	500	58	4	0	0
Västervik	36 676	0	0	0	0	0	0	0
Västerås	151 830	1 506	5 911	1 385	118	3	0	0
Växjö	92 483	1 932	3 059	1 433	385	104	10	0
Vårgårda	11 629	1 909	1 677	1 298	465	140	6	0
Ydre	3 717	0	0	0	0	0	0	0
Ystad	30 256	70	604	70	0	0	0	0
Älmhult	17 543	4 319	3 206	2 474	1 512	305	18	10
Älvtdalen	7 093	0	0	0	0	0	0	0
Älvkarleby	9 354	487	1 640	345	130	12	0	0
Älvbyn	8 141	512	1 180	445	67	0	0	0
Angelholm	42 287	1 396	2 898	1 155	217	24	0	0
Åmål	12 721	557	1 328	480	76	1	0	0
Ånge	9 404	707	1 356	600	90	17	0	0
Åre	11 498	33	229	33	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Årjäng	9 997	0	0	0	0	0	0	0
Åsele	2 815	0	0	0	0	0	0	0
Åstorp	15 877	1 028	1 969	837	177	14	0	0
Åtvidaberg	11 542	0	0	0	0	0	0	0
Öckerö	12 931	0	0	0	0	0	0	0
Ödeshög	5 324	0	0	0	0	0	0	0
Örebro	153 132	14 192	17 683	10 225	3 353	563	51	0
Örkelljunga	10 192	0	0	0	0	0	0	0
Örnsköldsvik	56 067	945	1 886	631	252	58	4	0
Östersund	63 157	569	1 994	528	41	0	0	0
Österåker	44 772	0	0	0	0	0	0	0
Östhammar	22 025	0	19	0	0	0	0	0
Östra Göinge	14 930	0	0	0	0	0	0	0
Överkalix	3 298	0	0	0	0	0	0	0
Övertorneå	4 409	0	0	0	0	0	0	0

Appendix 4 Modeled rail results: Maximum sound pressure level, L_{AFmax}

Table 21 The L_{AFmax} rail results from CadnaA for every Swedish municipal. The intervals are in the unit L_{AFmax} in dBA population noise exposure.

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
	10 216	1 212	138	581	1 163	851	618	593
SUM	373	179	065	000	249	104	341	838
Ale	31 197	5 936	0	1 544	5 543	6 132	4 019	1 917
Alingsås	41 021	8 157	0	1 588	4 210	3 617	3 829	4 328
Alvesta	20 116	7 260	64	887	2 411	3 065	2 551	4 709
Aneby	6 801	1 853	0	45	838	1 301	865	988
Arboga	14 109	3 484	0	252	3 304	2 302	1 655	1 829
Arjeplog	2 793	0	0	0	0	0	0	0
Arvidsjaur	6 309	0	0	0	0	0	0	0
Arvika	26 078	3 205	0	1 073	4 001	3 557	1 711	1 494
Askersund	11 260	659	3	106	363	340	397	262
Avesta	23 295	5 579	14	1 810	4 239	3 964	2 951	2 628
Bengtsfors	9 853	829	703	949	716	532	404	425
Berg	7 121	617	280	336	430	445	253	364
Bjurholm	2 445	0	0	0	0	0	0	0
Bjuv	15 488	3 091	678	1 295	2 847	2 214	1 648	1 443
Boden	28 053	4 107	400	2 893	6 217	4 621	2 474	1 633
Bollebygd	9 441	2 771	0	234	904	904	941	1 830
Bollnäs	26 973	6 374	1	1 467	4 029	4 270	3 288	3 086
Borgholm	10 855	0	0	0	0	0	0	0
Borlänge	52 157	11 018	1 465	4 187	6 837	6 751	6 014	5 004
Borås	112 068	20 185	6 626	8 222	14 063	13 575	10 642	9 543
Botkyrka	93 077	9 530	2	997	11 872	8 617	5 178	4 352
Boxholm	5 463	1 544	0	62	939	957	953	591
Bromölla	12 879	1 857	99	288	1 961	1 489	838	1 019
Bräcke	6 362	2 299	0	108	397	999	921	1 378
Burlöv	18 047	6 639	0	41	4 992	4 559	3 192	3 447
Båstad	14 903	427	0	255	1 513	486	217	210
Dals-Ed	4 785	1 161	0	135	768	800	559	602
Danderyd	33 382	0	0	0	0	0	0	0
Degerfors	9 685	3 378	0	874	1 608	1 457	1 658	1 720

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Dorotea	2 570	0	0	0	0	0	0	0
Eda	8 574	1 401	0	423	1 067	902	623	778
Ekerö	28 281	0	0	0	0	0	0	0
Eksjö	17 658	2 503	26	2 155	3 366	2 250	1 621	882
Emmaboda	9 407	1 707	197	516	1 353	863	789	918
Enköping	44 373	5 947	0	2 882	3 668	3 557	2 775	3 172
Eskilstuna	105 717	16 335	1 962	7 369	12 761	11 035	8 918	7 417
Eslöv	33 528	10 970	0	444	4 769	4 678	4 403	6 567
Essunga	5 685	0	0	0	0	0	0	0
Fagersta	13 416	2 283	3	1 414	3 695	2 537	1 160	1 123
Falkenberg	44 674	3 565	891	2 666	5 296	3 026	1 719	1 846
Falköping	33 170	8 793	0	870	6 219	5 009	4 391	4 402
Falun	58 849	7 298	11	3 276	8 250	4 651	3 497	3 801
Filipstad	10 819	432	0	39	289	241	205	227
Finspång	21 722	0	0	0	0	0	0	0
Flen	16 679	5 463	0	521	1 735	2 714	2 807	2 656
Forshaga	11 513	0	0	0	0	0	0	0
Färgelanda	6 599	0	0	0	0	0	0	0
Gagnef	10 256	2 190	428	1 179	1 462	1 407	1 146	1 044
Gislaved	29 849	2 292	1 135	1 592	1 284	1 322	1 103	1 189
Gnesta	11 265	3 997	0	348	1 699	1 757	1 666	2 331
Gnosjö	9 769	2 303	0	742	1 592	1 121	1 059	1 244
Gotland	59 267	0	0	0	0	0	0	0
Grums	9 020	1 543	0	952	2 034	1 867	964	579
Grästorp	5 722	447	669	485	492	415	198	249
Gullspång	5 295	856	0	143	318	240	428	428
Gällivare	17 599	2 149	3	1 164	3 582	1 963	1 577	572
Gävle	101 329	15 576	5 390	9 093	12 698	10 567	8 021	7 555
Göteborg	569 373	38 367	2 811	24 579	56 876	36 684	24 380	13 987
Götene	13 208	531	583	533	583	420	285	246
Habo	12 137	3 215	0	520	1 987	1 986	1 806	1 409
Hagfors	11 718	0	0	0	0	0	0	0
Hallsberg	15 858	6 049	78	516	2 498	2 341	2 352	3 697
Hallstahammar	16 166	3 623	0	823	4 893	2 593	1 746	1 877
Halmstad	101 135	11 340	14	5 052	18 267	7 178	5 938	5 402

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Hammarö	16 484	0	0	0	0	0	0	0
Haninge	89 752	8 042	139	2 727	10 187	9 891	4 511	3 531
Haparanda	9 742	483	0	121	1 410	1 922	353	130
Heby	13 898	2 451	0	103	752	1 285	1 064	1 387
Hedemora	15 446	2 166	0	1 083	2 156	1 720	899	1 267
Helsingborg	144 553	17 113	15 787	18 134	21 132	12 392	8 712	8 401
Herrljunga	9 480	2 159	288	385	1 126	1 159	1 014	1 145
Hjo	9 199	0	0	0	0	0	0	0
Hofors	9 608	742	0	321	544	332	286	456
Huddinge	110 668	24 250	0	5 428	17 205	13 992	11 460	12 790
Hudiksvall	37 415	5 587	33	2 603	4 291	4 767	2 744	2 843
Hultsfred	14 357	2 345	479	2 125	2 050	1 467	1 137	1 208
Hylte	10 916	859	129	347	435	682	478	381
Hälfors	6 974	2 115	0	584	1 388	1 331	984	1 131
Härjedalen	10 154	144	696	824	590	333	80	64
Härnösand	25 076	3 638	4	2 717	3 585	2 130	1 678	1 960
Härryda	37 625	7 252	0	2 823	6 230	4 442	3 812	3 440
Hässleholm	52 058	17 173	0	1 996	9 930	8 234	7 590	9 583
Håbo	21 545	5 360	0	682	1 715	2 590	2 488	2 872
Höganäs	26 557	0	0	0	0	0	0	0
Högsby	6 079	880	548	915	864	659	370	510
Hörby	15 606	0	0	0	0	0	0	0
Höör	16 594	4 555	0	51	1 778	1 571	1 434	3 121
Jokkmokk	4 979	48	0	0	5	7	19	29
Järfälla	78 211	17 549	0	8 954	13 136	10 565	8 335	9 214
Jönköping	139 100	28 604	1 640	13 294	21 982	17 811	14 319	14 285
Kalix	16 053	1 358	0	924	3 117	1 333	705	653
Kalmar	68 446	7 525	2 294	5 035	8 221	5 882	3 845	3 680
Karlsborg	6 940	0	0	0	0	0	0	0
Karlshamn	32 261	2 927	720	1 848	5 797	3 008	1 566	1 361
Karlskoga	30 397	0	0	0	0	0	0	0
Karlskrona	66 601	2 347	5 082	4 457	3 825	2 791	1 440	907
Karlstad	92 463	18 418	30	4 497	14 635	10 360	8 134	10 284
Katrineholm	34 509	11 419	0	1 348	5 560	5 180	5 513	5 906
Kil	11 967	2 036	252	1 067	2 895	2 228	1 280	756

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Kinda	9 950	962	1 816	1 403	967	722	368	594
Kiruna	22 981	327	214	837	324	91	116	211
Klippan	17 591	2 930	0	580	3 190	2 085	1 473	1 457
Knivsta	18 724	4 293	0	563	3 726	2 639	1 974	2 319
Kramfors	18 416	3 583	7	903	1 905	1 417	1 418	2 165
Kristianstad	84 791	6 760	8	3 378	8 463	4 982	3 349	3 411
Kristinehamn	24 290	6 149	0	1 258	3 303	4 229	2 865	3 284
Krokom	14 886	3 356	0	348	1 528	1 664	980	2 376
Kumla	21 711	6 034	0	1 148	2 397	3 116	2 664	3 370
Kungsbacka	83 418	6 242	0	801	11 926	6 457	3 426	2 816
Kungsör	8 658	1 418	0	1 140	2 146	1 282	917	501
Kungälv	45 022	3 017	0	1 293	2 066	1 786	1 320	1 697
Kävlinge	31 515	6 744	2	598	3 225	2 668	3 058	3 686
Köping	26 268	1 023	0	4 596	1 545	895	557	466
Laholm	25 457	2 205	0	163	1 280	1 137	914	1 291
Landskrona	46 232	2 428	0	2 222	5 663	3 412	1 396	1 032
Laxå	5 653	1 352	0	251	747	654	549	803
Lekeberg	8 103	0	0	4	0	0	0	0
Leksand	15 869	3 175	0	663	2 346	1 969	1 641	1 534
Lerum	42 072	6 365	0	2 018	8 336	5 684	3 550	2 815
Lessebo	8 789	2 467	0	146	1 228	1 503	1 235	1 232
Lidingö	47 724	0	0	0	0	0	0	0
Lidköping	39 878	1 069	4 985	3 608	2 724	1 619	572	497
Lilla Edet	14 085	392	0	454	581	259	212	180
Lindesberg	23 566	6 643	3	933	4 789	4 197	3 237	3 406
Linköping	160 898	12 379	5 530	11 156	19 429	10 920	7 836	4 543
Ljungby	28 511	0	0	0	0	0	0	0
Ljusdal	19 041	4 703	0	984	2 114	2 144	1 904	2 799
Ljusnarsberg	4 852	1 321	0	171	916	1 483	530	791
Lomma	25 087	4 364	0	840	4 966	2 806	1 818	2 546
Ludvika	26 982	6 556	14	1 858	3 308	3 706	3 598	2 958
Luleå	77 800	6 123	0	2 990	10 328	6 494	3 958	2 165
Lund	122 768	19 682	12	607	18 140	12 193	8 606	11 076
Lycksele	12 219	2 218	294	1 795	1 506	1 518	1 275	943
Lysekil	14 612	0	0	0	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Malmö	338 114	39 396	17 375	34 001	67 252	42 699	24 077	15 319
Malung-Sälen	10 091	0	0	0	0	0	0	0
Malå	3 121	0	0	0	0	0	0	0
Mariestad	24 362	1 425	2 281	3 066	2 248	1 628	848	577
Mark	34 746	1 309	3 761	3 570	2 287	1 348	765	544
Markaryd	10 260	2 468	0	71	591	895	1 138	1 330
Mellerud	9 349	2 591	206	636	1 698	1 381	1 206	1 385
Mjölby	27 333	6 682	0	1 593	6 303	4 972	3 161	3 521
Mora	20 382	1 362	50	1 024	718	904	631	731
Motala	43 672	3 907	0	3 181	5 777	2 269	2 075	1 832
Mullsjö	7 307	1 699	2	573	1 406	1 413	909	790
Munkedal	10 501	499	1 008	1 136	1 129	600	293	206
Munkfors	3 776	0	0	0	0	0	0	0
Mörlndal	69 344	12 692	10	2 213	13 239	11 255	7 660	5 032
Mönsterås	13 560	1 719	577	1 708	1 380	1 582	887	832
Mörbylånga	15 031	0	0	0	0	0	0	0
Nacka	102 774	0	0	0	0	0	0	0
Nora	10 724	0	0	0	0	0	0	0
Norberg	5 796	208	0	7	26	17	88	120
Nordanstig	9 514	895	0	114	596	353	356	539
Nordmaling	7 121	713	0	23	1 107	595	413	300
Norrköping	141 528	14 048	2 982	7 287	12 346	10 129	7 312	6 736
Norrtälje	61 692	35	1 008	868	378	138	31	4
Norsjö	4 089	217	0	4	49	138	122	95
Nybro	20 295	4 096	0	176	3 378	2 265	1 928	2 168
Nykvarn	10 951	3 651	0	373	1 756	1 640	1 835	1 816
Nyköping	55 935	13 903	0	3 057	9 501	7 045	6 753	7 150
Nynäshamn	28 288	0	0	0	0	0	0	0
Nässjö	31 494	9 531	316	1 899	7 115	6 672	4 819	4 712
Ockelbo	5 911	1 915	0	37	840	685	579	1 336
Olofström	13 501	132	334	2 360	1 179	391	93	39
Orsa	6 896	575	232	1 761	712	749	347	228
Orust	15 079	0	0	0	0	0	0	0
Osby	13 242	4 607	19	388	2 449	2 103	1 911	2 696
Oskarshamn	26 922	796	2 546	3 546	1 666	610	455	341

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Ovanåker	11 671	0	0	0	0	0	0	0
Oxelösund	12 074	1 379	13	1 803	4 932	1 862	816	563
Pajala	6 046	0	0	0	0	0	0	0
Partille	38 179	5 243	0	1 923	6 078	3 974	3 028	2 215
Perstorp	7 464	2 193	0	261	1 156	951	927	1 266
Piteå	42 084	188	0	44	121	114	75	113
Ragunda	5 350	517	0	15	82	184	263	254
Robertsfors	6 771	0	0	0	0	0	0	0
Ronneby	29 621	1 771	2 401	3 449	2 837	1 718	863	908
Rättvik	10 890	1 417	0	699	2 291	1 271	920	497
Sala	22 785	4 502	0	1 093	3 392	2 922	2 184	2 318
Salem	16 736	3 678	0	506	5 614	3 356	2 209	1 469
Sandviken	39 155	4 780	11	5 740	6 710	4 834	3 035	1 745
Sigtuna	48 008	7 335	0	1 153	3 178	3 911	3 975	3 360
Simrishamn	19 271	0	0	0	0	0	0	0
Sjöbo	19 103	0	0	0	0	0	0	0
Skara	18 798	0	0	0	0	0	0	0
Skellefteå	72 423	10 157	15	5 784	9 658	8 091	5 807	4 350
Skinnskatteberg	4 418	531	0	168	550	304	269	262
Skurup	15 683	3 400	0	374	2 429	2 465	1 778	1 622
Skövde	55 691	13 718	0	2 173	10 497	6 890	6 227	7 491
Smedjebacken	10 797	1 183	1	1 123	1 931	545	414	769
Söllefteå	19 450	4 041	767	2 081	2 256	2 526	2 225	1 816
Sollentuna	72 703	24 113	0	2 768	10 221	9 188	11 248	12 865
Solna	82 106	25 666	234	11 863	15 246	16 203	12 717	12 949
Sorsele	2 526	0	0	0	0	0	0	0
Sotenäs	9 051	0	0	0	0	0	0	0
Staffanstorp	24 669	2 848	0	112	1 086	748	767	2 081
Stenungsund	26 446	4 321	467	1 687	2 656	2 528	2 168	2 153
Stockholm	962 390	75 717	6 807	401	108 944	67 116	41 648	34 069
Storfors	4 044	647	7	388	995	381	301	346
Storuman	5 883	616	150	685	461	478	418	198
Strängnäs	35 691	3 978	0	613	6 479	2 563	2 013	1 965
Strömstad	13 227	67	465	150	51	65	29	38

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Strömsund	11 696	114	324	356	259	209	71	43
Sundbyberg	47 907	8 515	132	7 797	9 167	7 165	4 353	4 162
Sundsvall	98 750	11 249	461	8 553	15 146	9 588	6 352	4 897
Sunne	13 268	1 705	237	1 478	1 651	974	923	782
Surahammar	10 070	2 292	0	334	2 292	1 904	1 101	1 191
Svalöv	14 092	4 351	0	335	3 024	2 109	1 948	2 403
Svedala	21 588	3 329	0	570	3 199	2 738	1 932	1 397
Svenljunga	10 642	346	0	11	140	211	196	150
Säffle	15 617	1 921	48	1 635	2 985	1 913	1 188	733
Säter	11 101	2 402	0	588	1 425	1 300	1 285	1 117
Sävsjö	11 606	3 406	0	12	1 680	2 276	1 620	1 786
Söderhamn	25 687	671	0	256	2 532	1 722	363	308
Söderköping	14 630	0	0	0	0	0	0	0
Södertälje	97 091	7 639	0	3 086	6 639	3 978	3 696	3 943
Sörvästborg	17 462	1 828	729	2 635	2 254	1 317	982	846
Tanum	12 849	131	113	176	171	97	58	73
Tibro	11 146	0	0	0	0	0	0	0
Tidaholm	12 795	0	0	0	0	0	0	0
Tierp	21 150	3 533	24	78	2 246	2 330	1 650	1 883
Timrå	18 033	4 426	21	2 046	2 707	2 454	2 280	2 146
Tingsryd	12 396	0	0	0	0	0	0	0
Tjörn	15 892	0	0	0	0	0	0	0
Tomelilla	13 538	0	0	0	0	0	0	0
Torsby	11 734	538	727	929	723	572	303	235
Torsås	7 143	0	0	0	0	0	0	0
Tranemo	11 885	1 998	1	277	613	849	984	1 014
Tranås	18 993	7 689	0	472	2 375	2 569	2 782	4 907
Trelleborg	44 842	4 070	0	3 191	6 502	2 318	1 801	2 269
Trollhättan	58 601	6 550	0	3 763	10 662	6 152	4 226	2 324
Trosa	13 297	1 416	0	191	1 133	1 077	791	625
Tyresö	47 730	0	0	0	0	0	0	0
Täby	71 896	0	0	0	0	0	0	0
Töreboda	9 313	2 840	0	303	1 754	1 386	1 296	1 544
Uddevalla	56 200	5 397	3 595	4 812	7 879	4 009	2 830	2 567
Ulricehamn	24 400	0	0	0	0	0	0	0

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Umeå	127 010	11 569	0	7 695	11 897	8 515	6 567	5 002
Upplands Väsby	45 383	5 689	0	1 451	8 625	4 680	3 596	2 093
Upplands-Bro	28 711	4 250	0	3 189	4 872	3 531	1 825	2 425
Uppsala	224 839	29 714	1	3 183	22 107	18 033	13 823	15 891
Uppvidinge	9 572	0	0	0	0	0	0	0
Vadstena	7 506	0	0	0	0	0	0	0
Vaggeryd	13 967	2 947	592	1 514	2 704	1 858	1 733	1 214
Valdemarsvik	7 954	0	0	0	0	0	0	0
Vallentuna	32 597	0	0	0	0	0	0	0
Vansbro	6 774	1 066	320	1 076	1 102	786	572	494
Vara	15 953	953	1 440	1 709	1 333	870	491	462
Varberg	63 633	4 360	1 195	5 151	9 083	5 709	2 559	1 801
Vaxholm	11 974	0	0	0	0	0	0	0
Vellinge	36 457	1 535	0	33	185	459	726	809
Vetlanda	27 532	1 075	3 662	2 254	1 980	1 397	737	338
Vilhelmina	6 742	0	0	0	0	0	0	0
Vimmerby	15 750	540	2 365	1 445	1 159	613	248	292
Vindeln	5 456	1 919	0	47	486	772	782	1 137
Vingåker	9 153	1 787	0	475	1 046	845	612	1 175
Vänersborg	39 405	4 475	4 856	4 409	4 089	3 287	2 088	2 387
Vännäs	8 778	2 492	0	368	1 596	2 127	1 415	1 077
Värmdö	44 422	0	0	0	0	0	0	0
Värnamo	34 412	6 087	1 229	4 655	6 080	4 257	3 189	2 898
Västervik	36 676	443	3 813	1 702	1 037	510	254	189
Västerås	151 830	15 396	28	11 606	18 896	11 090	7 908	7 488
Växjö	92 483	7 796	0	1 749	7 068	4 516	3 060	4 736
Vårgårda	11 629	2 388	0	244	1 553	1 356	1 089	1 299
Ydre	3 717	0	0	0	0	0	0	0
Ystad	30 256	5 525	123	867	4 057	4 067	2 364	3 161
Älmhult	17 543	6 053	0	44	2 180	2 368	2 141	3 912
Älvdalens	7 093	0	0	0	0	0	0	0
Älvkarleby	9 354	2 434	0	140	1 442	1 177	1 389	1 045
Älvby	8 141	1 888	0	422	1 460	992	965	923
Ängelholm	42 287	6 252	7	378	6 298	4 873	3 443	2 809
Åmål	12 721	2 798	4	1 666	2 124	1 586	1 446	1 352

name	population	>55	50-55	55-60	60-65	65-70	70-75	>75
Ånge	9 404	3 013	2	574	1 516	1 994	1 441	1 572
Åre	11 498	4 384	8	526	1 051	1 766	1 683	2 701
Årjäng	9 997	0	0	0	0	0	0	0
Åsele	2 815	0	0	0	0	0	0	0
Åstorp	15 877	3 430	163	1 854	3 208	2 460	1 870	1 560
Åtvidaberg	11 542	59	734	301	169	67	45	14
Öckerö	12 931	0	0	0	0	0	0	0
Ödeshög	5 324	0	0	0	0	0	0	0
Örebro	153 132	17 584	0	9 360	19 223	14 101	9 732	7 852
Örkelljunga	10 192	0	0	0	0	0	0	0
Örnsköldsvik	56 067	8 595	0	215	6 450	6 448	4 207	4 388
Östersund	63 157	10 962	269	3 475	10 556	6 566	5 824	5 138
Österåker	44 772	0	0	0	0	0	0	0
Östhammar	22 025	328	1 255	1 565	1 094	474	189	139
Östra Göinge	14 930	0	0	0	0	0	0	0
Överkalix	3 298	0	0	0	0	0	0	0
Övertorneå	4 409	0	0	0	0	0	0	0

Appendix 5 Production of exposure points

Marcus Justesen – SCB (Department RM/SBT)

Datum: 2019-02-15

Version 1 dokumentation

Befolkning från rutor till byggnader

Med syfte att förbättra kvalitén för beräkning av befolkningsexponering har en ny typ av befolkningsdata tagits fram. Sedan länge har befolkningsdata hos SCB funnits som öppen data eller via geodatasamverkan i aggregerad form som rutor i olika storlekar, samt som sekretessbelagd individdata för varje folkbokförd person, d.v.s. befolkning per adress.

Användning av aggregerad befolkningsdata som är allmänt tillgänglig kan ge missvisande resultat vid en beräkning av bullerexponering, och det kan vara svårt att bedöma hur missvisande det är. Användning av högre upplösta data som befolkning per adress motsvarar försvarar samtidigt för andra aktörer än SCB att göra beräkningar för bullexponering. Det har därför i detta projekt utvecklats en metod där aggregerad befolkningsdata per ruta skalats upp och i hög grad motsvarar noggrannheten och geografiska upplösning som data för befolkning per adress har. Metoden som utvecklats beskrivs nedan.

Levererad data

SCB levererar härmed en Shape-fil med punkter (projektion Sweref99 TM) som är en fördelning av befolkning från rutdata till byggnadspunkter, enligt nedan beskrivna metod. Här är en beskrivning av attributten:

ATTRIBUT	FÖRKLARING
LANKOD	Länstillhörighet, härstammar från byggnadsskiktet från fastighetskartan
OBJEKT_ID	Byggnadens ID från fastighetskortan
ANDAMAL_1	Vilket ändamål byggnaden har i numeriskt format
ANDAMAL_1T	Vilket ändamål byggnaden har i textformat
In_befruta	Eget skapat id för vilken ruta punkten finns i
Bef_per_punkt	Befolkningen per punkt- d.v.s. hur många som ”bor” på respektive punkt

Antalet punkter är totalt 4 035 348 stycken. Några punkter har inget värde för flera av attributten ovan. Dessa punkter har inte skapats utifrån byggnader från fastig-

hetskartan, utan istället direkt från rutdata och representerar rutans mittpunkt. Detta beskrivs nedan.

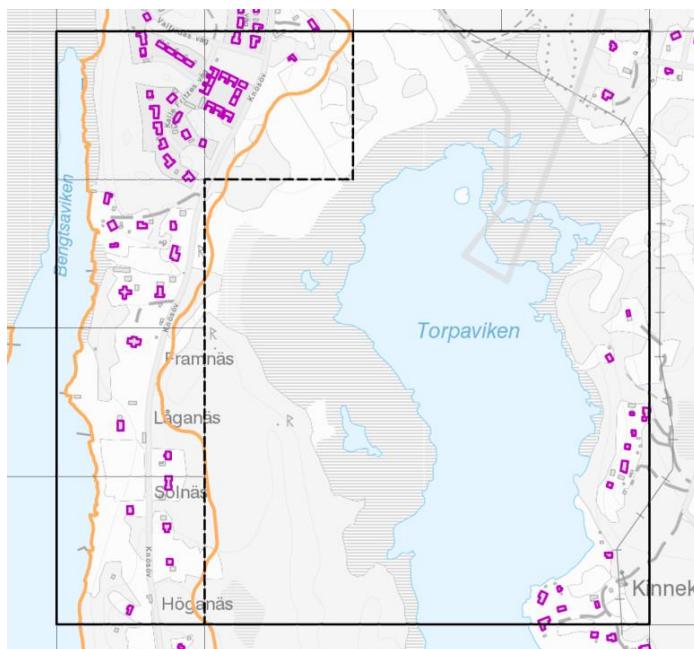
Indata som används

1. Befolknings per ruta där rutstorleken är 250×250 m i tätort och 1000×1000 m (1 km) utanför tätort.
2. Fastighetskarts byggnadsskikt (by) där byggnader med bostadsändamål används som urval (d.v.s. andamal_1= 130-135 och 199, vilket motsvaras av Småhus friliggande, småhus kedjehus, småhus radhus, småhus med flera lägenheter, flerfamiljshus och ospecifierat bostadshus).
3. Fastighetskarts skikt med anläggningssområden (ba) märkta med koloniområden som funktion.

Metod

Förbearbetning av rutor

- Rutor som levererades som indata överlappade varandra, d.v.s. 1 km stora rutor täcker i vissa fall samma område som 250 m stora rutor. De olika rutstorlekarna kombinerades på ett sätt så de inte överlappade, vilket illustres i Figur 1.



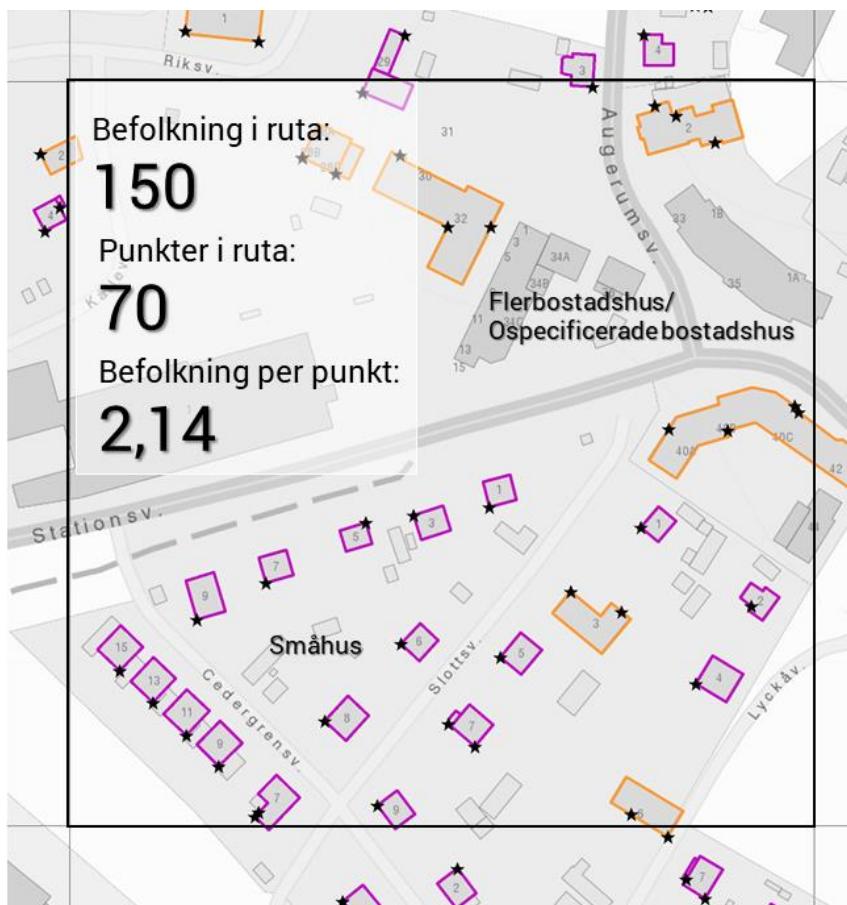
Figur 1 hantering av rutor. Den svarta ramen är 1 km ruta men befolkningssiffran för rutan motsvarar den befolkning som bor i byggnader på östra sidan om vattnet, vilket är utanför tätort. Västra sidan är tätort och där finns fem rutor i 250 m storlek, med uppgifter om befolkning i tätort. Efter att rutdata kombinerats så är 1 km rutan klippt och ytterkanten går vid den streckade linjen.

- Ett antal 1 km rutor var helt täckta av 250 m stora rutor (rutorna täcker ett område med befolkning både innanför och utanför tätort). Dessa rutor särbehandlades, 33 stycken med totalt 1644 personer. Dessa 33 rutor konverterades till mittpunkter och all befolkning sattes på mittpunkten.

Byggnader till punkter

- Byggnadspolygoner från fastighetskarta med alla typer av bostadsändamål konverterades till linjer
- Var 50:e meter längs linjerna skapades en punkt
 - Byggnader med omkrets kortare än 50 m får en punkt, byggnader med omkrets 50-99 m får två punkter etc.
- Punkter i koloniområden togs bort.

Processen illustreras i Figur 2.

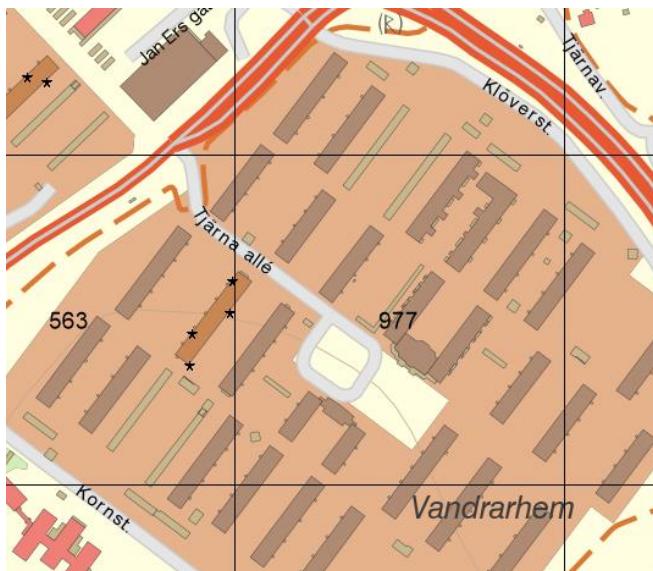


Figur 2 Befolkning från ruta till byggnadspunkter. Lila linjer är alla typer av småhus och orangea flerfamiljshus och ospecifierat. Det blir oftast några fler punkter på flerfamiljshus än småhus. Varje punkt har samma värde.

Från befolkning per ruta till befolkning per punkt

- För varje ruta summerades antal punkter som fanns innanför rutan.

- Befolkningsmängden för rutan dividerades med antalet punkter i rutan – och ett värde för befolkning per punkt skapades då, se Figur 2.
- Ett antal rutor saknade helt punkter (2 284 rutor, med totalt 29 189 personer)
 - För dessa rutor skapades en mittpunkt och all befolkning i rutan sattes till mittpunkten, se Figur 3.



Figur 3 Exempel på rutor som saknar punkter för byggnader. Det här är ett större bostadsområde i Borlänge där byggnader är klassade som annat än för bostadsändamål i fastighetskorten. Rutan med 977 (befolkningen) får en mittpunkt där dessa personer hamnar. I rutan västerut, med 563 personer finns en byggnad med bostadsändamål som dessa personer lokaliseras till.

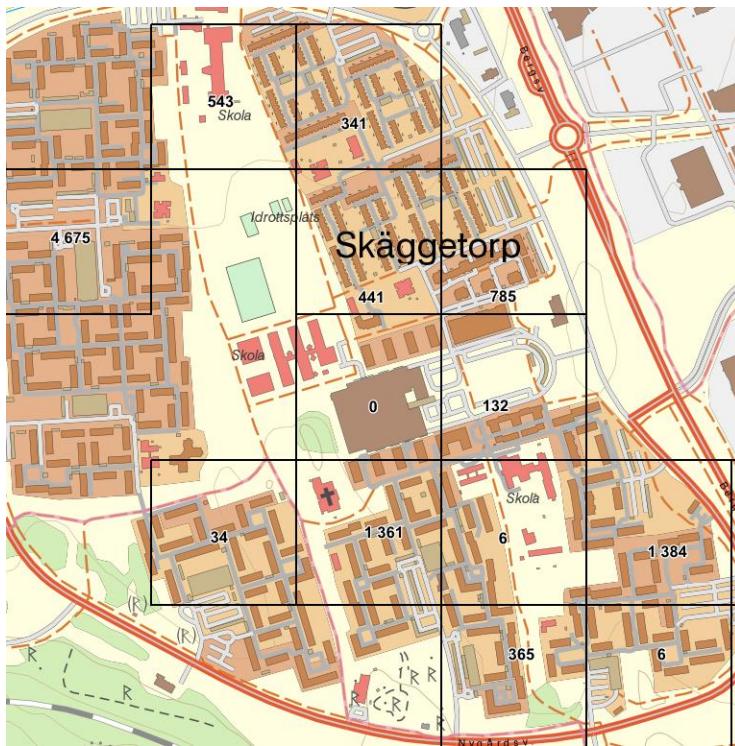
Kvalitetsaspekter

I de levererade rutorna saknas ca 14 000 personer p.g.a. att det saknas uppgift om koordinat.

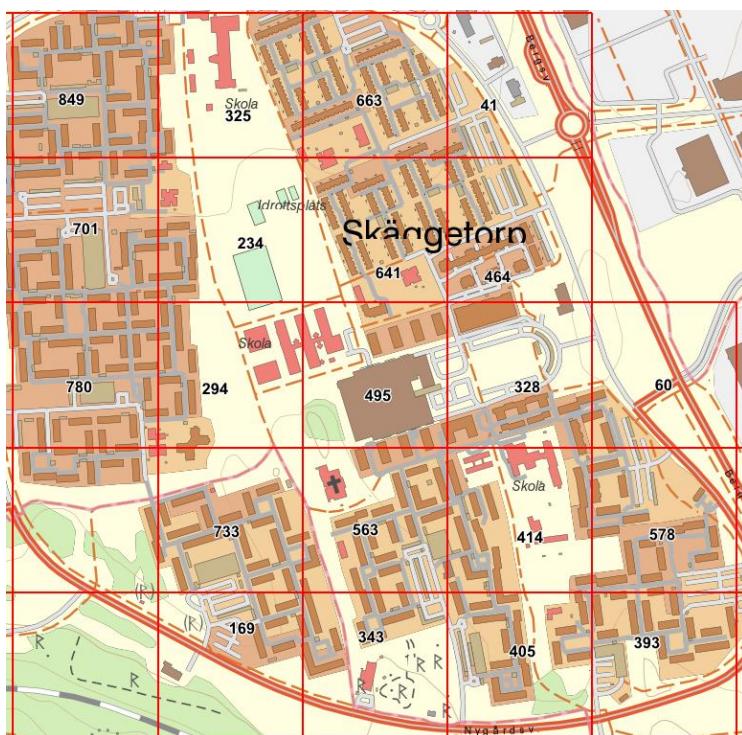
Som beskrivits ovan har ca 30 000 personer inte kunnat fördelats från ruta till byggnad. Detta främst p.g.a. av ”fel” klassningar av byggnader i fastighetskorten, men också p.g.a. hantering av överlappande 250 m rutor mot 1 km rutor. För områden liknanden den i Figur 3 blir det avsevärt försämrat kvalitet än om befolkningen kunnat fördelats på byggnaderna, där dessutom en större väg finns i närheten. På det stora hela, sett för riket är det dock liten påverkan.

Det är troligt att det finns en viss skevhetsgrad i fördelningen till byggnader i de rutor som innehåller både småhus och flerfamiljshus. I många fall kan det tänkas att mer befolkning hamnar på småhus än vad som är rimligt. En förbättringspotential skulle kunna vara att skilja på flerfamiljshus och småhus, så att mer befolkning lokaliseras till flerfamiljshus. Det skulle ge en bättre fördelning av befolkningen.

Aggregering till rutor har för första gången gjorts från befolkning till adress. Tidigare år har befolkning per fastighet aggregerats till ruta. Detta innebär en kvalitetsförbättring, vilket Figur 4 och Figur 5 visar.



Figur 4 Befolkning *per fastighet* aggregerat till rutor



Figur 5 Befolkning *per adress* aggregerat till rutor