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Uncertainties in identifying trends in noise exposure

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ABSTRACT

In 2018, the Ministry of Infrastructure and Water Management published the third END action plan for main roads. Objectives of the END are to identify noise pollution levels and trigger the necessary actions to reduce or prevent increase of environmental noise. For noise policy makers, that raises two questions: 1) Is the number of people exposed to environmental noise growing or decreasing? 2) How effective are noise mitigation measures?

The experience of Rijkswaterstaat with the past three rounds of END noise mapping and action plans has shown that it is challenging to answer these questions. Developments in data, calculation methods, legal requirements and software deteriorates the quality of the data in the trend of the estimated noise exposure.

This paper shows how Rijkswaterstaat has dealt with these sources of uncertainty in determining the development of noise pollution by main roads in the Netherlands. It is recommended that the data from previous END noise mapping round is used with current noise models to improve trend information.

Keywords: Noise, Mapping, Action plans
I-INCE Classification of Subject Number: 76

1. AIM OF THE END

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002, known as the Environmental Noise Directive (END), relates to the assessment and management of environmental noise. The aim of the Directive is: “to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise.” This objective can be broken down into two main elements:

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- a common approach;
- avoiding, preventing or reducing exposure to environmental noise.

In order to achieve a common approach, the END includes the definition of noise sources, noise indicators, noise contour intervals and (interim) assessment methods. In 2003 [1] and 2007 [2], the EC Working Group "Assessment of Exposure to Noise" issued their Good Practice Guidelines, providing "Toolkits" that were developed to stimulate a consistent approach to noise mapping across Europe. Nevertheless, the approach, type of basic input data and algorithms for data manipulation and noise computations vary across the many competent authorities responsible for noise mapping and noise action plans in the EU.

As the second aim of the END is to avoid, prevent or reduce exposure to environmental noise, it is important to identify trends in exposure and to evaluate the effectiveness of interventions (noise measures) in the past. Such trends may help policy makers in answering the question whether or not their noise policy is successful and good value for money.

2. THE PROCESS FOR ACTION PLANS IN THE NETHERLANDS

Strategic noise maps and noise action plans are not made and approved overnight. The reason for this lies in the collecting and processing of the input data, the exchange of modelling data between competent authorities, computation time, result analytics, verification and authorization.

One of the most important data sources for the strategic noise map of the Dutch national road network is the traffic flow volume data per vehicle category (light, medium heavy and heavy vehicles) and differentiated between the day, evening and night periods of the day. These data are combined with a national traffic model, in order to provide traffic flow volume data covering the entire national road network. This process to combine data requires a high level of quality assurance, since traffic counts may be corrupted by erroneous values (by defect counting equipment) and the traffic model may need to be recalibrated if they yield implausible results in complex situations such as motorway junctions. Plausibility checks by experts, as an indispensable part of the production process, require several months after the annual traffic counts have been completed by the 31st of December.

For consistency between the major roads noise map and the noise maps for agglomerations that are exposed to noise from major roads, Rijkswaterstaat shares its noise model items with the other competent authorities. Internal validation and authorization precede the release of this noise model data, in order to assure the quality of the data that the other authorities will use in their noise maps, and subsequently their action plans.

This chain of data collection and processing, validation and exchange, combined with the computation time, and the time for post-processing of calculation results and publication of the noise maps makes it impossible to use real traffic data for the year preceding the year of publication of each noise map. However, article 5 of the END states that the data related to the noise map must not be more than 3 years old, so using slightly less recent traffic data still complies with the requirements of the END. In order to make the latest noise map representative for the year 2016, the 2015 traffic flow volume of all roads was used and increased by 2,9%, the average traffic growth of the whole national roads network between 2015 and 2016.

With respect to noise action plans, article 8 of the END states that: Member States shall ensure that the public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of the action plans, that the results of that participation are taken into account and that the public is informed on the decisions taken. The Dutch General Administrative Law Act defines a minimum of 6 weeks for public participation. Taking this into account, as well as the necessary time for responding to the input obtained from this participation, the draft version of the noise action plan needed to be published early February. Hence, the process from drafting the first version of the action plan until publication had a time span of about three quarters of a year, illustrated roughly by Figure 1.

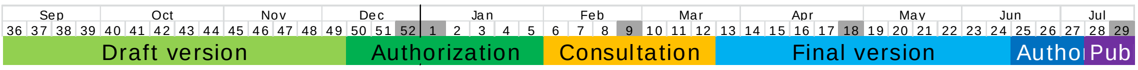

Figure 1 –Time span from draft to publication for the noise action plan

3. TRENDS IN NOISE EXPOSURE BY MAIN ROADS IN THE NETHERLANDS

Figure 2 shows the number of exposed dwellings identified in the noise maps of 2006, 2011 and 2016, as reported in the END noise action plan 2018-2023. Also indicated is the estimation of the expected exposure for 2021. The trend shows a decrease of noise exposure over this period, by nearly 30.000 dwellings (-28%) above 55 dB between 2006 and 2016, with a relatively large difference from 2006 to 2011.

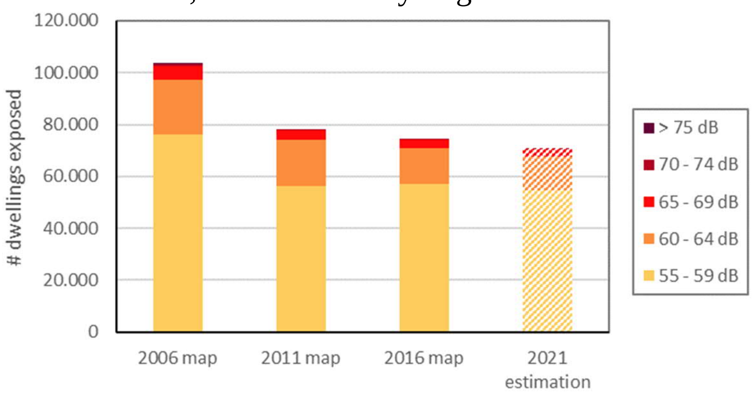

Figure 2 – Noise mapping results as number of dwellings exposed to various noise levels; noise mapping results for 2006 – 2016 and estimation for 2021

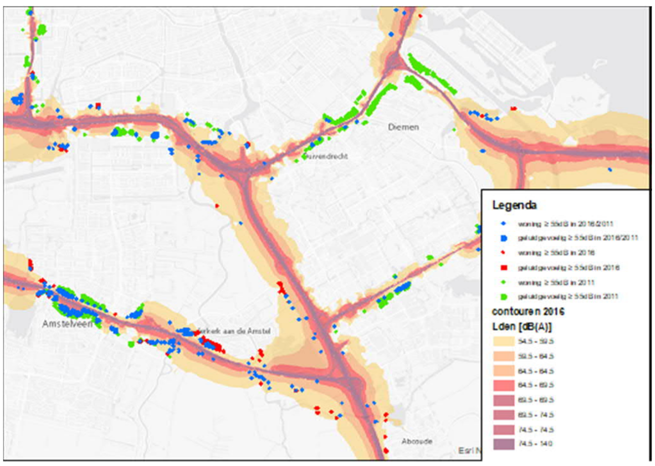

Figure 3 – Development of noise exposure is diverse: green objects: ≥ 55 dB in 2011, < 55 dB in 2016; blue: ≥ 55 dB in 2011 and 2016; red: < 55 dB in 2011, ≥ 55 dB in 2016

An interesting observation from the 2011 and 2016 noise maps is that the total land area exposed to 55 dB or more has increased by 14% (see example in Figure 4), whereas the number of dwellings exposed to 55 dB or more has decreased. This can be interpreted as an indication that noise abatement measures help to reduce noise pollution despite a general increase of the noise emission.

2006 *2011* *2016*

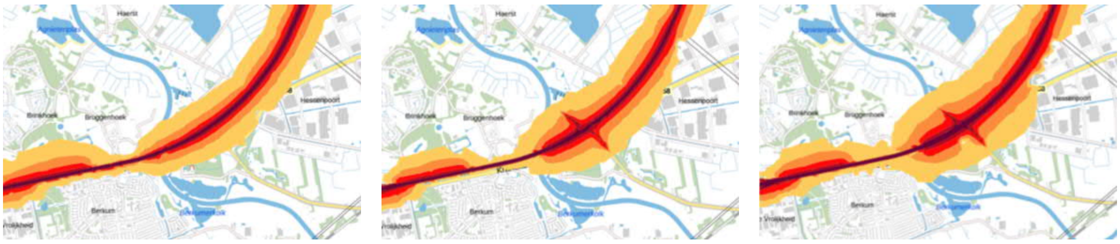

Figure 4 – Increase of land area exposed to 55 dB or more; example of A28 motorway near Berkum

4. UNCERTAINTIES IN TREND ANALYSES

To identify trends in noise exposure, the number of exposed people or dwellings is compared from one noise mapping round to the previous round. If a change in the calculated exposure is observed, there may actually be a decrease in the amount of noise that people are exposed to compared to five years before. But the change in exposure may also arise from several sources of uncertainties that influence the noise mapping results, which may have changed from one round to the next. These uncertainties, and methods that have been used to analyse and/or minimize their influence, are explained below.

4.1 Technical developments in noise mapping between Round 1 and Round 3

<u>Input data quality</u>

Noise mapping requires a large amount of input parameters, including the horizontal and vertical position of roads, barriers and other objects, the terrain profile and acoustic ground characterization, the traffic volumes and speed, the pavement type, noise barrier properties, etc. Several of the data sources for the 2006 noise mapping round have changed in 2011 and/or 2016, usually for the better. The digital terrain height has increased detail and accuracy, for instance, and the coverage of traffic counters has increased, leading to more accurate traffic flow volumes and the addition of slip roads in the 2011 noise map (figure 4 shows an example). Also, each noise mapping round includes a quality check of input data by the NRA, so that the amount of data errors (e.g. wrong pavement or barrier types) decreases from one round to the next. No attempts have been made to quantify the effect of these improvements on the accuracy of the predicted exposure, but the general assumption is that most of the quality improvements do not lead to a systematically higher or lower noise exposure.

<u>Changes and assumptions in assessment method</u>

In 2012, the national Dutch noise assessment methods, including the noise mapping method, have been updated. The RMV2006 method, used for the first round of strategic noise mapping, was replaced by the new Rmg2012. Three important changes were:

- the acoustic properties of the pavement are now based on the average performance over its lifetime, rather than the performance in new conditions. As the Dutch major roads are paved with porous, noise reducing pavements for nearly 90%, this generally means an increase of the calculated noise emission, as the noise reduction for these pavements decreases over time;

- the noise emission parameters for light vehicles, under reference conditions, have been updated based on an extensive measurement campaign in 2009/2010. Previous values, established in 1996-1999, were 1 to 2 dB(A) lower;
- Depending on the road surface type, 1 or 2 dB is subtracted from the calculated noise emission to account for expected future proliferation of quieter tyres and vehicles, so as not to take noise abatement measures that would not be needed. As this is done for all noise assessments, this is also included for the noise mapping.

The combined effect of these three changes is shown in Figure 5 below, as a percentage of the road length vs. the change in noise emission by 0,5 dB steps. Averaged over the total network, there is an increase of 1,6 dB in noise emission parameters between the 2011 and 2016 noise maps. It is obvious that without these changes, that were partly the result of the noise calculation methodology, the number of dwellings exposed to 55 dB or more would have decreased stronger between 2011 and 2016. In retrospect, the approach to the acoustic performance of pavements caused an underestimation of the noise exposure in the first two noise mapping rounds.

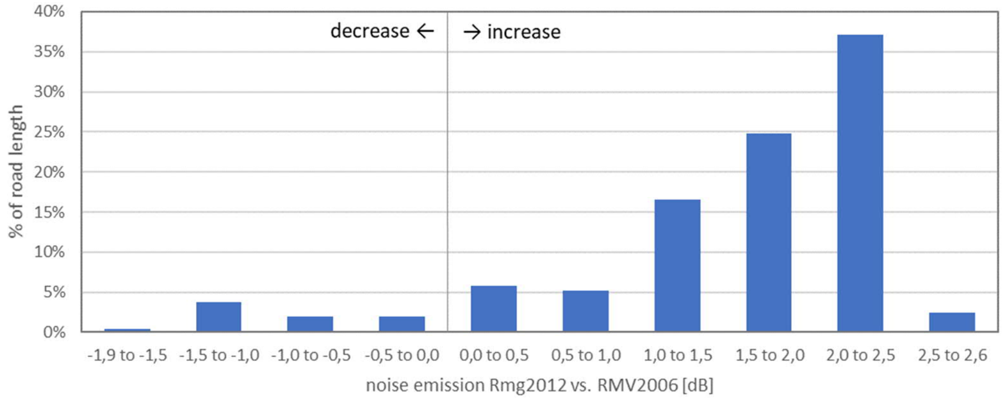

Figure 5 – Total effect of changes in noise emission calculations between the 2006/2011 mapping and the 2016 mapping

To estimate the effect of these changes on the noise exposure, there were two options: either recalculate the 2011 noise map using the new Rmg2012 method, or recalculate the 2016 noise map using the old RMV2006 method. Option 2 was chosen, since a switch from the new to the old method was relatively simple in the noise mapping software, whereas it would have been quite a lot of work to retrieve the input data from the 2011 noise map and prepare these for use in the new model.

The recalculation showed that the number of exposed dwellings above 55 dB calculated with the RMV2006 was 38% smaller than in the 2016 noise map based on Rmg2012 (see Table 1). So the increase in noise emission parameters has a huge influence on the noise exposure calculations. Figure 6 below shows the 55 dB contours calculated with both models.

Table 1 – Number of exposed dwellings on 2016 noise map (Rmg2012 method) and the recalculation of the same noise map with the previous RMV2006 method

Noise level [dB]	55 – 59	60 – 64	65 – 69	70 - 74	≥ 75	Total
2016 noise map (Rmg2012)	57.200	13.800	3.000	400	0	74.400
2016 recalculation (RMV2006)	35.200	9.000	1.900	200	0	46.300
Difference	-38%	-35%	-37%	-50%	--	-38%

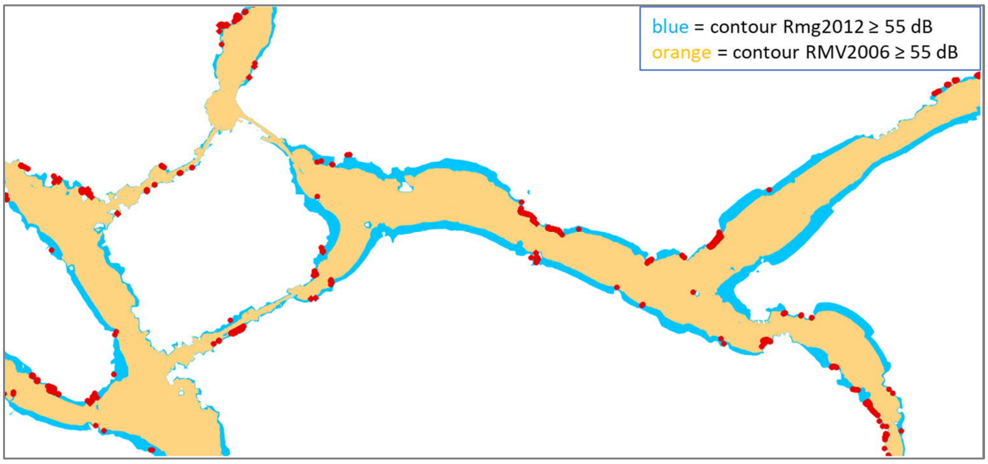

Figure 6 – Noise contours 2016 calculated with Rmg2012 (blue) and recalculated with RMV2006 (orange); red objects are outside RMV2006 but inside Rmg2012 contours

Buildings and their heights

For the 2006 and 2011 noise maps, the buildings were modelled by using 2-dimensional source data, that did not provide explicit building height information. The building height was modelled quite basically, based on a general building type classification, given by Table 2.

Table 2 – Allocation of building height from building type (2006 and 2011)

Description	**Height (m)**	**Colour**
greenhouse/warehouse	3	
storage tank (open or closed)	5	
building/house	9	
building block / tall building	15	
high rise building	25	

Around 95% of all buildings fell into the category "building/house" and the use of the building type as an indicator for the building height proved to be not really distinctive. The left part of Figure 7 shows an example of the occurrence of the different building heights, based on this classification. The outline colour depicts the building height in 2006, whereas the fill colour depicts the building height in 2011. Where these colours differ, the building classification in the source data had changed, and hence a different building height was allocated.

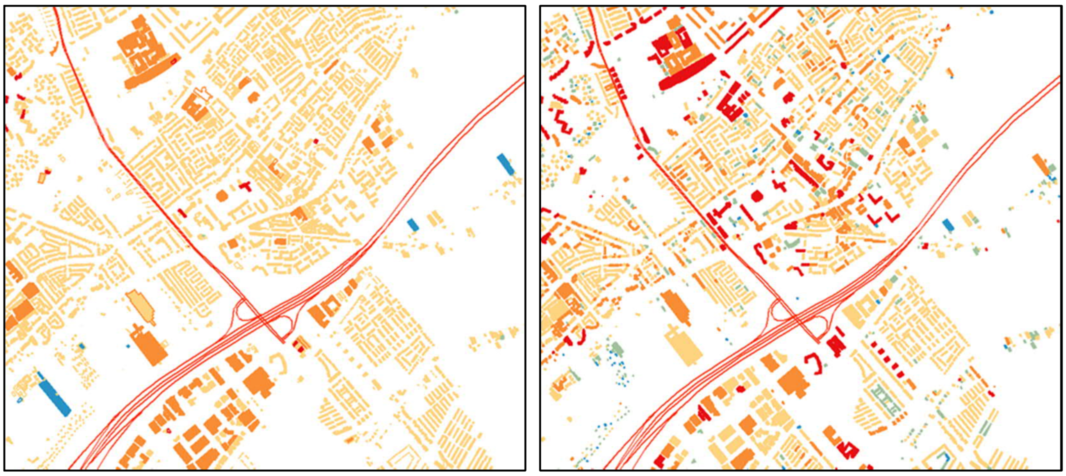

Figure 7 – Example of building height by building type in 2006 and 2011 (left) and specific building height in 2016 (right)

The right part of Figure 7 shows the specific building heights that were available in the source data for the same area in 2016. The colours correspond with those used in the left part of this figure, with the discrete values of the 2006 and 2011 noise maps as the median of five classes. Figure 8 depicts the distribution of the specific building heights, used in 2016. It confirms that the majority of all buildings falls inside the class between 7 m and 12 m height. However, this adds up to only 60%, instead of the 95% of the buildings in 2006 and 2011.

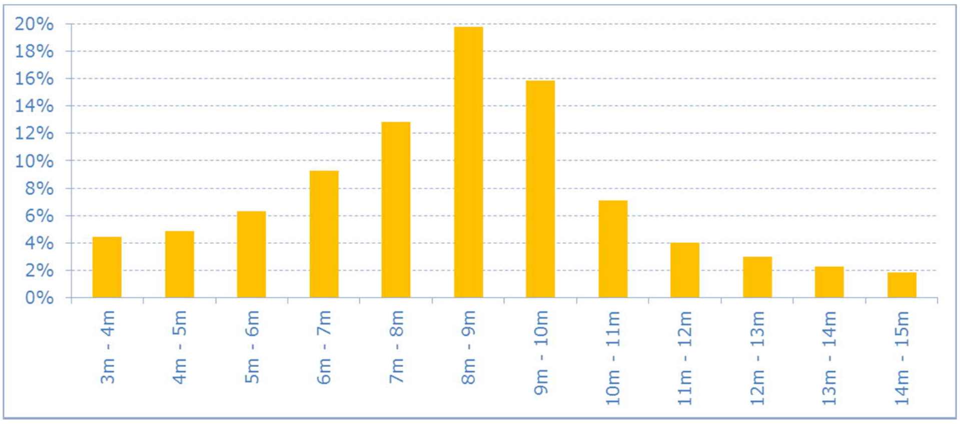

Figure 8 – Distribution of building height (2016)

The exact impact of the use of more detailed building height data in 2016 is unknown, yet it illustrates that the format and accuracy of data will change over time (and likely within the 5 year cycle of the END), affecting the trend in the calculated noise exposure to a certain extent.

<u>Software implementation details</u>

Smaller changes may arise from changes and updates of the noise mapping software and/or the algorithms used for the analysis. The exact interpolation method used to generate the contours from the grid point results, for instance, is not specified and may differ between noise mapping rounds. Another example: noise propagation over urban areas is calculated using a statistical method based on building locations and heights. Also here, the algorithm used to generate the areas with homogeneous conditions is not specified; efforts have been made to generate areas similar to previous mapping rounds, but results are not exactly the same, leading to small changes in attenuation.

4.2 Administrative changes

Changes in road administration

Between 2011 and 2016, but mainly between 2006 and 2011, several roads that were previously administered by the NRA (Rijkswaterstaat) have been transferred to local road administrations (provinces or municipalities). This has led to a decrease of the number of dwelling exposed to noise from major roads, but an increase of the noise exposure by local roads. Of course, this is an administrative effect and not an actual reduction of noise exposure, unless the transfer included actual changes to the road, e.g. maximum speed. Figure 9 shows the difference in the major road network between 2006 and 2016. The magnitude of this effect has not been quantified.

Figure 9 – National road network in 2016 (red) and roads transferred to other road administrations between 2006 and 2016 (black)

Developments in END-requirements

For the first round of strategic noise mapping in 2006, major roads were defined as roads which have more than six million vehicle passages a year. For the Netherlands, that meant that the END applied to approximately 70% of the national road network in 2006. However, Rijkswaterstaat decided to consider its entire road network as major roads, avoiding illogical gaps where the traffic flow fluctuates around six million vehicle passages a year. This also had the benefit that the tightened requirement to include all roads with more than three million vehicle passages a year, from the next round onwards, had no influence on the calculated noise exposure. Road authorities that did apply the different definitions of major roads in 2006 and 2011 may have encountered a significant increase in the calculated noise exposure, caused by these different definitions.

4.3 The effect of major changes in the infrastructure

Reconstruction of highway infrastructure, or new roads, have a major impact on the noise exposure and the observed trends. Such projects take several years to complete and may even span one or more noise mapping rounds. The influence of the infrastructure changes on the noise exposure may only come into force once the new road (or lanes) are opened for traffic, but there can also be intermediate changes when noise measures (barriers, new pavement) are realized.

There will be differences in timing between the real-world realization of these changes and the processing of these changes in the input data for the noise mapping. For the Dutch noise mapping rounds, the convention has generally been that all changes from infrastructure projects will not be included in the noise map before the project is completed and opened to traffic. Exceptions have occurred, for instance for the large Schiphol-Amsterdam-Almere (SAA) project which is currently ongoing, but for which specific subsections have been fully completed in 2014.

<u>Example: A4 Delft/Schiedam</u>

Timing issues for infrastructure projects may lead to discrepancies in the noise mapping and exposure trends that are difficult to justify to the public. The new A4 motorway section between Delft and Schiedam has been constructed starting in 2012 and opened to traffic on December 18th 2015. Substantial parts of the new, 6.5 km long road were built as a depressed road (about 3.5 km) and as a fully covered tunnel (1.5 km). This new link in the national road network had a major effect on other road sections in the region, including the parallel route A13, where the traffic volume dropped significantly after opening of the new A4. As explained in section 2, the process of creating and publishing the noise map in time made it necessary to use traffic data from 2015 as the basis for the 2016 noise map. Traffic flow volumes for the new A4 situation were not yet available in the 2015 data, as well as other input data. Therefore the new situation could not be included in the 2016 noise map.

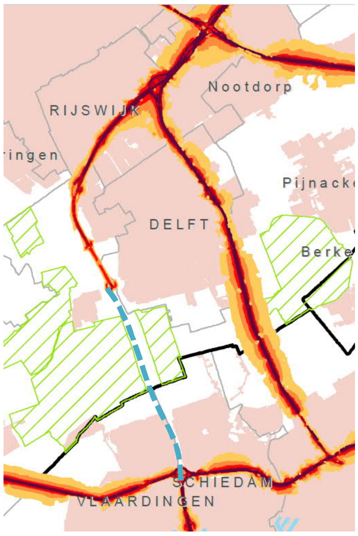

Figure 10 – The A4 Delft-Schiedam (dashed line) is not on the 2016 noise map

Since the formal reference year for the noise map is ‘2016’ and the map was published in July 2017, people expected the effects on noise exposure from the new highway section to be visible on the map. Such infrastructure projects have their own means of communication with the public about environmental effects, so people have generally been well-informed; nevertheless, the influence of the A4 on the noise exposure development will not be visible before the publication of the 2021 noise map in 2022. The trend in noise exposure, presented in the 2023 noise action plan will, to some extent, be affected by this effect that actually took place before the 2018-2023 time window.

4.4 The effect of noise measures

The action plan aims to look back at the development of noise exposure and the effectiveness of the noise policy. It also looks ahead to the next five years and provides an estimate of what the public may expect is being done to further reduce road noise. The action plan 2018 – 2023 lists the noise measures that are to be realized in this period and it also provides an expectation of their effect, by estimating the number of exposed dwellings and people that will be in the 2021 noise map. Such estimations have also been made for the 2011 and 2016 noise maps, reported in the preceding action plans (see Table 3).

Table 3 – Number of exposed dwellings for each noise mapping round, including the estimated exposure in the previous action plan

noise level [dB]	2006	2011			2016			2021
	noise map	estimation 2008	noise map	under/ over	estimation 2013	noise map	under/ over	estimation 2018
55 - 59	76.100	69.400	56.200	**-19%**	47.200	57.200	+21%	54.800
60 - 64	21.100	18.000	14.500	**-19%**	12.500	13.800	+10%	13.000
65 - 69	5.200	3.500	3.600	+3%	3.000	3.000	**0%**	2.700
70 - 74	1.000	600	400	**-33%**	300	400	+33%	400
≥ 75	100	0	0	**0%**	0	0	**0%**	0
total ≥ 55	*103.500*	*91.500*	*74.700*	***-18%***	*63.000*	*74.400*	*+18%*	*70.900*

The noise exposure data that have been reported in the action plans for the upcoming noise maps have been estimated as follows:

- locations of noise measures (noise reducing pavement and noise barriers) are known and have been gathered in a shapefile, together with the estimated noise reduction:
    - for noise reducing pavements, the additional noise reduction with respect to the current pavement has been determined;
    - for noise barriers, the noise reduction is assumed to be 5 dB for receivers within 100 m distance from the barrier and 2 dB for receivers further away;
- the noise reduction has been subtracted from the L_{den} at the grid receiver points;
- new contours have been generated and the number of exposed dwellings within each noise level band has been counted for the future situation;
- for new roads and roads that have significantly changed in location, a manual selection of dwellings that are expected to lie within the noise contours of the future situation has been made and added to the estimation.

The method above is not very precise, as the real effect of noise barriers depends on their exact locations and heights. Given time and budget, however, it was not feasible to process all the planned noise measures in the noise mapping input data and perform a full calculation of this situation.

It is clear from Table 3 that the estimations of future noise exposure in the action plans are not very accurate: the 2011 exposure was overestimated by 18% in the 2008 action plan and the 2016 exposure was underestimated by 18% in the 2013 action plan. The method described above for the estimation of the effect of noise measures is partly to blame for the inaccuracy, but there are other influences that are considered to be equally or more important:

- Some noise measures that were foreseen have not yet been realized because infrastructure projects in which they are planned are not completely finished.
- The noise reduction effect from the noise measures is counteracted by the increase of the noise emission, mainly due to the update in the assessment method.

The timing issues discussed in §4.3 above also affect the estimations of the noise exposure in the upcoming noise map: the 2021 noise map will only include the effects of noise measures that have been realized before January 2021. Some noise measures listed in the 2018-2023 action plan are part of infrastructure projects that will be completed in 2021 or 2022. To prevent an over- or underestimation of the noise exposure in the action plan, the effect of these projects and noise measures have not been included in the estimation. This leads to confusion, since the action plan does list these noise measures for the 2018-2023 period.

4.5 Introduction of CNOSSOS-EU

Looking ahead, the 2021 noise maps, published in 2022, must be calculated by using the new CNOSSOS-EU method, described in EU Directive 2015/996 [3]. Not only the calculation of noise levels itself can be much different than in the first three rounds of noise mapping, but also the method to assign noise levels to population data may be a cause of differences in the calculated noise exposure. To minimize the impact of the new assessment method, the CNOSSOS-EU road noise emission parameters have been corrected and matched to Dutch roadside measurements that also underlie the Rmg2012 [4].

Similar trend breaks may be expected to occur beyond 2021. The 2021 noise mapping will be the first round to utilize the CNOSSOS-EU method. Experiences from this first round are likely to lead to improvements and changes in the method itself for the next round. Currently, some issues have already been found in the 2015/996 Directive (see e.g. [5][6]) that may or may not be resolved and implemented in time for the start of the 2021 noise mapping, and may lead to changes between the 2021 and 2026 assessment methods. As vehicles and tyres develop, their noise emission parameters will be evaluated and, if needed, updated at some time in the future or on a more regular basis, e.g. every five years. Unlike methodological changes, updates of the noise emission parameters represent the development of the "real" noise exposure.

5. CONCLUSIONS AND RECOMMENDATIONS

This paper describes the process of preparing, creating and publishing strategic noise maps and noise action plans for major roads in the Netherlands. Despite the efforts to do this consistently over the years, developments in the available source data, legal noise modelling requirements and noise calculation software will always interfere with the actual development of the noise exposure. Technological developments will continue to make the source data for noise maps more up-to-date, more detailed and more accurate. Paradoxically, the *trends* in noise exposure would be more accurate without these improvements, showing just the development of traffic, urban development and population growth, and the effects of new noise abatement measures that have been taken in the past five years.

The introduction of a common noise assessment method will mean a great improvement towards a common approach to noise mapping across Europe, but for the individual governmental bodies responsible for noise action plans it has the potential to destroy every logic in the existing noise exposure trends. In order to understand which part of the differences in noise exposure should be attributed to "technical developments" and which part can be considered to be the "real" trend in noise exposure, we recommend to recalculate the 2016 noise map as soon as the CNOSSOS-EU method is finalized and implemented in the noise mapping software. If not, there will be no relevant information on the trend in noise levels and the effectiveness of noise measures until 2026. The 2021 noise map could be recalculated with the 'old' Rmg2012 model, but if possible it is preferred that the 2016 noise map is recalculated with CNOSSOS-EU. This would allow not only a comparison with 2021 but would also enable looking back on the 2016 noise map in 2026 and beyond.

The challenges in evaluating the effectiveness of noise policy are also demonstrated in this paper. Considering the necessary time for preparation, creation, consultation and publication, the deadlines for strategic noise maps and noise action plans are such that only a limited part of the action plan time scale can actually be evaluated in the next noise action plan. The END would stimulate to evaluate the effect of noise measures in a more effective way with a two year shift in the action plan time scale. As an example, that would mean for the next round of noise action plans (in 2023):

- Evaluation: 2017-2021
- Prediction: 2022-2026 (to be evaluated in the next round)
- Long-term forecast: beyond 2026 (to be updated and concretized in the next round)

The action plan would then be based on the noise map published in 2022, depicting the year 2021. If the deadline for publication of the noise map would be changed from mid-July to the end of the year (December), that would create the possibility to use real 2021 traffic data.

Publishing a noise action plan in 2023 for the period until 2026 instead of 2028 may look like a lower ambition level for avoiding, preventing or reducing exposure to environmental noise. But in effect, it would add more realism to END induced noise policy and it would reduce the uncertainties that currently thwart the evaluation of the noise abatement measures.

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