



## Guidebook: How to reduce noise annoyance from road traffic

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### ABSTRACT

*The objective of the FAMOS project was to develop a guidebook with practical applications for the European National Road Administrations on how to handle noise annoyance by non-acoustic moderators in planning of roads. When all technically feasible and economically possible measures to reduce the noise have been used, there can still be need for further reduction of the annoyance. Analyses reveal that only about 1/3 of the variance in the annoyance response is caused by the noise level itself. 2/3 are determined by so-called non-acoustic factors. The annoyance response therefore can be altered without changes to the actual noise level. The project searched for moderators that have an impact on the annoyance without changing the noise level. The search has been based on an international literature survey on annoyance studies. Moderators found were:*

- *Expectations to and visual appearance of noise barriers*
- *Presence of vegetation/greenery*
- *Access to a quiet façade*
- *Neighbourhood soundscape*
- *Attitudes towards authorities and road owners*
- *Perceived traffic safety*

*Experimental tests using sound walks, questionnaires and listening tests have been performed to quantify some moderators. Various methods have been used to find, extract and analyse data and turn the results into models for moderators formulated for practical use.*

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## 1. INTRODUCTION

The FAMOS project is about how noise annoyance from road traffic can be reduced by applying non-acoustic moderators. Even when the road administrations have used all the technically feasible and economically possible measures to reduce the noise, there might still be a need for a further reduction of the annoyance perceived by people exposed to road noise to achieve acceptable conditions.

Former analyses of the results from noise surveys reveal that only about 1/3 of the variance in the annoyance response is caused by the noise level itself. The other 2/3 are determined by other factors, among these are those often referred to as “non-acoustic factors” [1].

According to the World Health Organization (WHO) [2], road traffic noise is one of the most important environmental risks to health” and a major contributor to 1.6 million healthy life-years are lost annually in Europe due to road traffic noise. About half of these can be related to the subjective element “annoyance.

The surveys display a wide range for the annoyance response. Differences in noise levels of up to  $L_{den}$  20-25 dB to evoke a certain percentage of annoyance are not uncommon. This means that the annoyance response can be altered within wide limits without doing any changes to the actual noise level. So, when all practical noise reduction measures have been applied, the noise impact can still be reduced by making changes in the non-acoustic factors known to moderate the annoyance response.

The FAMOS project is about analysing and testing if non-acoustic moderators for noise annoyance can be a promising tool for obtaining an additional supplement to other noise and annoyance mitigation measures to reduce the annoyance without reducing the noise level further. Non-acoustic moderators in FAMOS covers a large range of “activities” from performing a good public participation process integrating the neighbours of a road in the decision process, over having access to silent side of the residence, to using greenery to improve the visual environment. FAMOS is the acronym for “Factors MOderating people's Subjective reactions to road noise”. The scientific and technical documentation and reports from the project can be found here: <https://famos-study.eu/>.

The project consortium consisted of three partners:

- FORCE Technology in Denmark (Project leader)
- LÄRMKONTOR in Germany
- SINTEF in Norway

Scientific methods have been used to find, extract, and analyse data and turn the results into models formulated for practical use with illustrative examples. It has been quantified how different factors modify people's subjective reactions to road traffic noise. Reports from previous surveys of annoyance caused by road traffic noise have been systematically analysed in order to describe the different annoyance moderators, and the effect of these moderators have been expressed in equivalent subjective decibel changes, the “Annoyance equivalent noise level shift”,  $L_{eas}$ .

The main practical result of the FAMOS project is the “Guidebook how to reduce noise annoyance” [3] developed to be used by National Road Administrations as well as others working with noise and development and maintenance of road infrastructure. The scientific work is documented in the FAMOS project report [9].

## 2. THE “ANNOYANCE EQUIVALENT NOISE LEVEL SHIFT”

The “Annoyance equivalent noise level shift”,  $L_{eas}$ , is the (hypothetical) shift in noise level that will give the same change in annoyance as the presence or absence of a moderator. This is a practical way to express the effect of a moderator (Remark: Although in expert judgement of the FAMOS team, some moderators are likely to have a dependence on the time of the day (day, evening, night), a distinction e.g. between daytime and night-time was not considered or possible due to insufficient data).

As data was only found in relevance to  $L_{den}$ , the changes stated are only valid for this noise index. It should not be confused with any actual changes in noise levels. The following is an example.

An example: At the same noise level  $L_{den}$ , persons who are not affected by one moderator (blue curve in Figure 1, e.g. “traffic visible”) could be more annoyed than people that are affected by a moderator (orange curve in Figure 1, e.g. “traffic not visible”).

The difference of percentage of Highly Annoyed (%HA) may e.g. be 30 % points. The same annoyance reduction may be observed by lowering the noise level  $L_{den}$  by 13 dB (see the black arrows in Figure 1). The “Annoyance equivalent noise level shift”,  $L_{eas}$  in this example is about 13 dB.

In this example the moderator will change the annoyance response in the same way as a reduction of about 13 dB in the noise level. The “Annoyance equivalent noise level shift” should not be confused with the actual noise level difference, e.g. between the most and the least exposed façade.

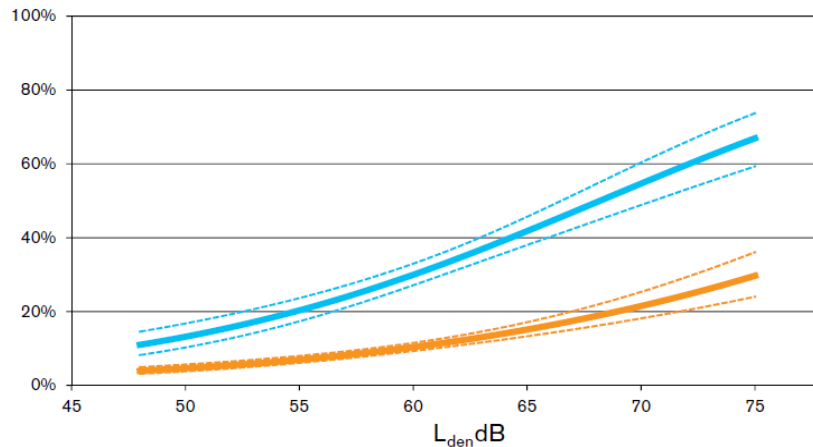


Figure 1: The blue curve shows an example for the percentage of people being highly annoyed in a situation without moderators (traffic visible). The orange curve shows the percentage of highly annoyed in a situation where a moderator (hidden traffic) has been implemented.

### 3. MODERATOR SEARCH AND QUALIFICATION

#### 3.1. Identification and literature analysis

As a main fundamental of the FAMOS project, the identification of possible moderators was carried out through an international literature study of previous noise annoyance surveys. It revealed that several factors can change the perceived annoyance by people exposed to road traffic noise [9]. Reducing the noise is an obvious factor, but many other factors have an influence on the annoyance. Moderators are factors that can change the relation between the noise exposure and the perceived annoyance response.

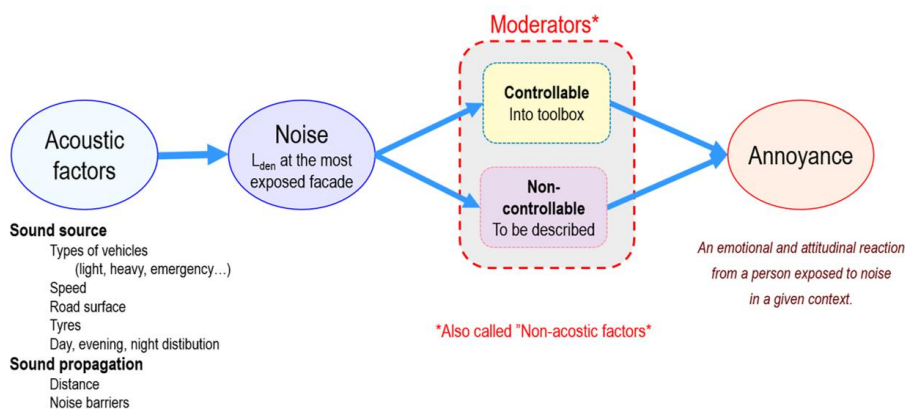


Figure 2: Connection from acoustic factors leading to noise and moderators influencing the perceived annoyance [9].

A list of possible moderators was systematically derived on the background of the international literature survey on moderators to perceived annoyance performed in the first work package of FAMOS. The non-acoustic factors that will modify the annoyance response can be categorized in different ways:

- The **road itself** and its **immediate surroundings** such as type of road, traffic volume, speed limit, road pavement, barriers, visual appearance, etc. These are factors that to a large extent can be controlled or influenced by the road owner – the road administration.
- Factors pertaining to the **neighbourhood** such as type and location/orientation of residences, prevalence of community conveniences like shops, schools, parks, playgrounds, etc. neighbourhood traffic conditions and so on. These factors can only to a small extent be influenced by the road owner. Chances for control are better at completely new developments than for projects in existing communities.
- **Relationship** between the local residents and the road owner. Do the residents feel a personal ownership to the road and benefit from its existence? Have the residents had a chance to be involved the planning and construction process? Do the residents/neighbours trust the decision makers and road administration? These factors deal with public relations and can to a large extent be controlled and managed by the road owner.
- Factors completely **out of control by the road owner**. However, it is important to recognize that such factors exist and to know how they affect the annoyance response. These are typically personal and demographic factors like age, gender, income, noise sensitivity, etc.

### 3.2. Prioritized moderators

The results from surveys on annoyance from road traffic noise indicate that the annoyance response is affected by a set of non-acoustic factors in this project defined as moderators. The influence of these moderators, *i.e.*, the magnitude of the effect, varies, and the feasibility and practicality of manipulating these factors depends on local circumstances. The objective of the FAMOS project was to focus on moderators that have a large potential for annoyance reduction, and that are easily implemented by road administrations. In order to prioritize different modifiers, the following criteria have been considered:

- To which degree is this moderator controllable by the road authority?
- What is the potential for shift in the annoyance response?
- What is the quality of existing data that support the conclusions?

The following preliminary list of moderators for further studies has been developed based on these criteria:

- Visual appearance of the road and its immediate surroundings, e.g., visibility of traffic, greenery/vegetation and the type and visual appearance of mitigation measures like noise barriers and earth walls etc.
- Orientation of dwelling, access to a quiet side of the dwelling
- Attitudes and relations between the community and the road authorities
- Neighbourhood soundscape – the noise in the local areas where people are living
- Perceived traffic safety
- Traffic volume on main noise source

## 4. DATA COLLECTION AND HYPOTHESIS TESTING

Three different methods for data collection on perceived noise annoyance were investigated in FAMOS within a limited experimental setup to investigate the suitability of methods for measuring the effect of moderators in future road projects, for hypothesis testing of the order of magnitude for already identified moderators and for gap filling for knowledge missing for important moderators retrieved [9]. The methods used were:

- Soundscape measurements (sound walks)
- Mini survey using questionnaires
- Listening tests performed in the laboratory.

The **soundscape measurements (sound walks)** [4] are performed by a group of persons who on a tablet evaluate the soundscape at different locations. The soundscape measurements were successful in the sense that they gave a good representation of the sound sources in a sound source hierarchy. The results gave detailed characteristics of the six measuring positions used. A “systems factor map” could be constructed, which gave a clear picture of the relations between the six measuring positions, and why they differed. By combining the assessments of annoyance from the sound walks with the measured noise levels it was possible to make a model (dose-response curve) for the annoyance as function of the noise level ( $L_{Aeq}$ ) with a good fit ( $R^2 = 0,9$ ). The results for the moderators’ greenery and the visibility of the traffic are summarized as part of the hypothesis testing.

The **mini survey** [5] based on questionnaires was designed with limited extent and the non-personal address of respondents. A general correlation and a confirmation of earlier project results was assessed. As for noise annoyance in general, the responses mostly showed an expected outcome although several respondents reported a higher annoyance although the noise levels were supposed to be reduced. Results for as well visibility and greenery as expectations and expectations met were analysed as part of the hypothesis testing. Overall, the results showed that moderators previously identified in the FAMOS project had a contribution to the perceived noise annoyance. A quantification on the effect, i.e., changes in noise level, could not be derived due to the low number of participants.

The **audio-visual listening tests** [6, 7] were performed in the laboratory where a group of assessors (listeners) are presented for road traffic noise at various locations and at the same time a video of the location. Several locations were selected so that there were variations in moderators of interest (visibility of the traffic, amount of greenery, type, and appearance of noise screens). For all positions, a significant increase of the annoyance with the noise level increasing was found. From the results on the annoyance assessments, logistic dose-response curves could be constructed with a good fit ( $R^2 > 0.95$  on the mean values). The dose-response curves show that the visual perception has a clear and significant influence on the perception of annoyance from the noise. Differences in the annoyance corresponded to level differences, the annoyance equivalent change in noise levels, up to 4 dB for the same sound stimuli. Some of the results deviated from findings elsewhere and it was concluded that it is important that the assessors (the persons participating in the test) have a full understanding of the context, e.g. by a short introductory video tour showing the road and its surroundings or by using virtual reality to enhance the assessors envelopment in the scenario.

## 5. MODELLING

The overall objective of FAMOS was to quantify how different factors modify people's subjective reactions to road traffic noise. Therefore, the purpose was to establish models [8] for the effect of moderators expressed as dose-response curves for the moderators in various context and use case situations. The aim was to describe the models in practical terms, which use cases they are applicable for and which context variables to control or specify as input and to get reliable output estimates of the moderator effect with a specified uncertainty.

The model is based on input in the form of raw data from two Danish questionnaire surveys [10, 11, 12]. Within the project work has been done to collect data from other sources, but it turned out that it is not at all easy-to-get access to raw data from former questionnaire surveys from other countries. Based on input from the two large questionnaire surveys on noise annoyance, the model can demonstrate the effect of various moderators.

The model found -not surprisingly- that the annoyance increases with  $L_{den}$  [8]. There was good compliance between the model prediction and the data it was built on, which is a good validity check on the math and statistical principles for the model. The model results were also compliant to the results found in the original simpler models for the same data reported earlier. On this background it was concluded that the models are trustworthy and representative for the input data.

The impact of specific moderators can be expressed in  $L_{aes}$  "annoyance equivalent noise level shifts" so that the presence or absence of certain moderators is expressed as a corresponding perceived increase or decrease in the noise level,  $L_{den}$ .

From the model the following "annoyance equivalent noise level shifts" are found [8]:

Motorway dataset:

- Orientation of outdoor areas: 10 dB (8.4-11.8 dB)
- Access to a quiet side: 10 dB (8.0-11.8 dB)
- Special bedroom windows: 10 dB (4.2-14.8 dB)
- Causes to annoyance by traffic: 16 dB (8.4-24.1 dB)  
(This is a general question including: Feeling unsafe at the roads and surroundings, unsafe for children, noise, vibrations, air pollution and dust from the traffic)
- Motorway visible 4 dB (2-6 dB)

Annoyance equivalent noise level shifts:

- Acceptance of road traffic noise: 20 dB (19.1-21.6 dB)
- Causes of annoyance by traffic: 17 dB (11.6-23.1 dB)
- Feeling unsafe because of the road traffic corresponds to an annoyance equivalent noise level shift of 5 dB.

Based on input from the two large Danish questionnaire surveys on perceived noise annoyance, the developed model could demonstrate the effect of various moderators.

A total of the answers from 6316 respondents are used in the analysis of the two datasets included in this analysis [8]. This is a very high number of respondents and much higher than what is seen in many other international annoyance surveys.

The results must be considered valid for Denmark as well as for similar north European countries/regions and they can be considered a first good step towards a model valid for the whole of Europe. At the present stage this may not be a sufficient data basis for making a road traffic annoyance model that can provide representative predictions for all of Europe.

So, even if the models may not be considered representative for all citizens of Europe, they provide strong evidence for the effect of the moderators that are found significant in this study. While the data basis of only two studies may not be sufficient, the Danish studies had a very high quality and covered a broad range of questions many of which were identified in the literature as relevant. The models based on Danish raw data confirms the findings in the literature study to a very large extent [9]. The models provide strong evidence for the effect of the moderators that are found significant in this study.

## 6. SUMMARY OF POSSIBLE MODERATORS

### 6.1. Moderators pertaining to attitudes and public relations

Based on the results of literature analysis, the modelling and information from external researchers, a first list of moderators was assembled [9]. They were amended and/or revised by further investigation done within the project. The results on the final moderators give an overview on possible effects with a general order of magnitude. However, it has to be considered that the effect size (the annoyance equivalent noise level shift) itself may depend on other moderators not controllable.

#### **Attitudes towards authorities and road owners**

Many annoyance surveys indicate that the relationship between the authorities (noise source owners) and the neighbourhood is an important non-acoustical moderator [9]. People that have a high trust in the authorities and believe that a road is being constructed to impose a minimum impact on the neighbourhood and society are less annoyed than people with a low trust and people that feel alien to the road work and having a feeling of not being treated fairly.

Overall, trust and acceptance can yield in an annoyance equivalent noise level shift of about 20 dB from highest trust to lowest trust.

This effect can be taken into account "two way" based on an "average trust", i.e. resulting in a possible shift of 10 dB towards "less annoyance" for good trust and a shift of 10 dB towards "higher annoyance" for mistrust.

Note: The FAMOS project did not investigate how this moderator changes/evolves. Trust and acceptance are likely no steady constant that will remain at a certain value over a longer period of time. It may change due to changes in residents (residents leaving the area, new residents moving in) or by external influence (e.g. from other projects in other areas). However, events influencing trust and acceptance (both positive and negative) may just fade after a longer time, making the influence on annoyance smaller.

### **Expectations / public relations**

In the aviation industry a "high-rate change airport" (HRC) is characterized by large and abrupt changes in the operation pattern (but not necessary changes in the noise exposure level) [9]. If plans for future changes are launched, and especially if these plans are controversial and not rooted properly in the community, the airport may also be characterized as an HRC airport. Likewise, negative media attention may lead to an HRC characteristic. It is quite likely that a similar situation may be found for road traffic. In the aviation industry the average difference between a typical airport and an HRC airport is equivalent to an annoyance equivalent noise level shift of about 9 dB.

Attention is needed if plans for future changes are launched, especially if these plans are controversial and not rooted properly in the community. This is especially the case when large and abrupt changes occur.

An unfortunate presentation of plans of noise mitigation can trigger adverse actions in the community and thus can completely reverse the expected positive effects. The effect of expectations and expectations met can result in a shift of about 5-10 dB. This is about the same shift that can be expected from the erection of a typical noise barrier or extensive noise mitigation measures of the local traffic situation in an existing community.

## **6.2. Controllable factors pertaining to the road**

### **Traffic volume**

The traffic volume, i.e. the number of vehicles, affects the annoyance response. As the number of passing vehicles increases, the noise exposure level will increase and consequently the prevalence of noise annoyed residents will increase. However, the annoyance increases more rapidly than would be expected from the noise level itself [9]. At equal noise levels, a high number of vehicles appear to be more annoying than a small number. The annoyance equivalent noise level shift has been reported to about 1.5 dB per doubling of the number of vehicles.

### **Safety expectation**

People may feel unsafe about both local and national roads in their neighbourhood. For local roads, typically belonging to the municipalities, improvements could be affected e.g. by reduced speed, speed control, humps, chicanes, bike lanes, pedestrian crossings, traffic light regulation, removing heavy traffic to other routes etc. NRA could help the municipality with technical advice and also money to do the improvements. For national roads, the perceived safety can also be influenced by the proximity of traffic to residential usage and the presence or absence of guardrails speed limits and speed control. The effect corresponds to an annoyance equivalent noise level shift of about 5 dB [9].

### **Vegetation and greenery influencing the visual appearance of the surroundings**

The visual appearance of the road and its immediate surroundings have a significant impact on the annoyance response. Visual greenery in the form of single trees or bushes, strips of grass, etc. have no effect as a noise-reducing element, but never-the-less such elements may cause a reduction in the annoyance equivalent noise level of as much as 10 dB [9].

However, studies indicate that trees close to a noise barrier can affect the noise reduction of the barrier itself when higher than the barrier.

This should be considered as a possible negative effect. The effect might be caused by an influence on the diffraction on the top of the noise barrier or when leaves are on the trees reflections of the road noise will occur from the treetops.

Regarding the effect of vegetation, a decrease in vegetation and greenery can often occur after trimming of bushes and cutting of trees as part of maintenance that is carried out every couple of years. This should be considered as it may have a major influence on noise annoyance (increase due to reduced vegetation/greenery), maybe even leading to loss of trust/acceptance.



Figure 3: Greenery surrounding a motorway and covering the view to the noise barrier is a moderator that reduces the perceived noise annoyance.

### **Noise barriers (expectations and visual appearance)**

Noise barriers are often used as a means to reduce the noise from a major road. Different constructions and different materials are being used; earth berms, solid walls made of concrete, steel or wood, transparent walls made of glass, etc. The walls may be acoustic reflective or fitted with absorption on the side facing the road. The screening effect of a noise barrier is primarily defined by the effective height, dependent on as well the distance to the road as to the receiver. A barrier introduces an insertion loss of 5-6 dB when the direct line of sight from the source to the receiver is just barely broken. An effective height of 3-4 metres will provide an insertion loss of up to about 10 dB. A typical noise barrier will provide an insertion loss of about 6-12 dB, but the subjective effect, i.e. the corresponding reduction in the annoyance equivalent noise level is dependent on a number of other factors:

- Did the effect of the barrier meet the expectations of the residents?
- Were they involved in the visual design or were they left alien to the design process?

The physical effect, i.e. the reduction in noise level, may often be offset by an opposite shift in the annoyance response. This is partially due to expectations (see “Expectations / public participation” on the previous pages) which can result in a shift of 5-10 dB [9].

Regarding the visual appearance, the influence of the design itself is mostly unclear, but most likely lower with about 2 dB [9]. Greenery and vegetation may result in a higher shift (see section on “vegetation and greenery” on the previous pages).

### **6.3. Factors pertaining to the neighbourhood**

#### **Locations and orientation of residences / access to a quiet side**

The noise response is per definition presented as a function of the most noise-exposed façade of the residence. The house itself can act as an effective noise barrier and it has been observed that it may be advantageous to locate noise-sensitive rooms of the residence away from the noise source. Living room and especially bedroom windows should not be facing the roadside.

Likewise, balconies, terraces and similar outdoor areas should preferably be located on the quiet side of the house.

Various studies report having access to a quiet side of the residence will reduce the annoyance equivalent noise level by about 10 dB [9].



## Neighbourhood soundscape

It has been shown [9] that the annoyance reported by a resident is not only dependent on the noise level at the (most exposed) façade of the residence, but also depends on the soundscape qualities of the neighbourhood, i.e. the outdoor area around the dwelling.

Neighbourhoods characterized by general high levels of road traffic noise are assessed as being more annoying than a quieter neighbourhood even if the residence is not directly exposed to this noise [9]. It may therefore be worthwhile to re-direct the neighbourhood traffic and divide the traffic in local streets and through-streets according to origin and destination. This may even increase the noise in some areas, but the net effect may be a reduction in the overall community annoyance. Based on observations from Oslo, FAMOS estimates that the annoyance equivalent noise level shift may be up to 10 dB [9].

### 6.4. Non-controllable personal and demographic variables

One of the objectives of the FAMOS project was to identify and quantify non-acoustical factors (moderators) that have an influence on peoples' annoyance reactions to road traffic noise. A number of such moderators that to a greater or lesser extent can be controlled by the road owner, have been discussed. Control is a matter of necessity if the objective is to use a certain moderator actively in road planning, traffic control and noise abatement.

However, there are also many personal and demographical factors that may or may not be important for annoyance assessment. Such factors are for instance age, gender, dependency of road transportation, house ownership, social status, income, education, etc. Information about these may be important when assessing the results from annoyance surveys.

## 7. CONCLUSION - SUMMARY ON MODERATORS OF NOISE ANNOYANCE

Evidence was found that a wide range of moderators affects the noise annoyance [9]. Regarding the “direction” of the effect size, it depends on the situation itself: when implementing a “favourable moderator”, like improving greenery, the effect size works towards “lower annoyance”. Whenever a moderator is removed (like greenery) or changed towards a less favourable situation (like increase in neighbourhood noise), the same effect might occur towards “higher annoyance”. The selected moderators and their order of magnitude can be seen in the figure below.

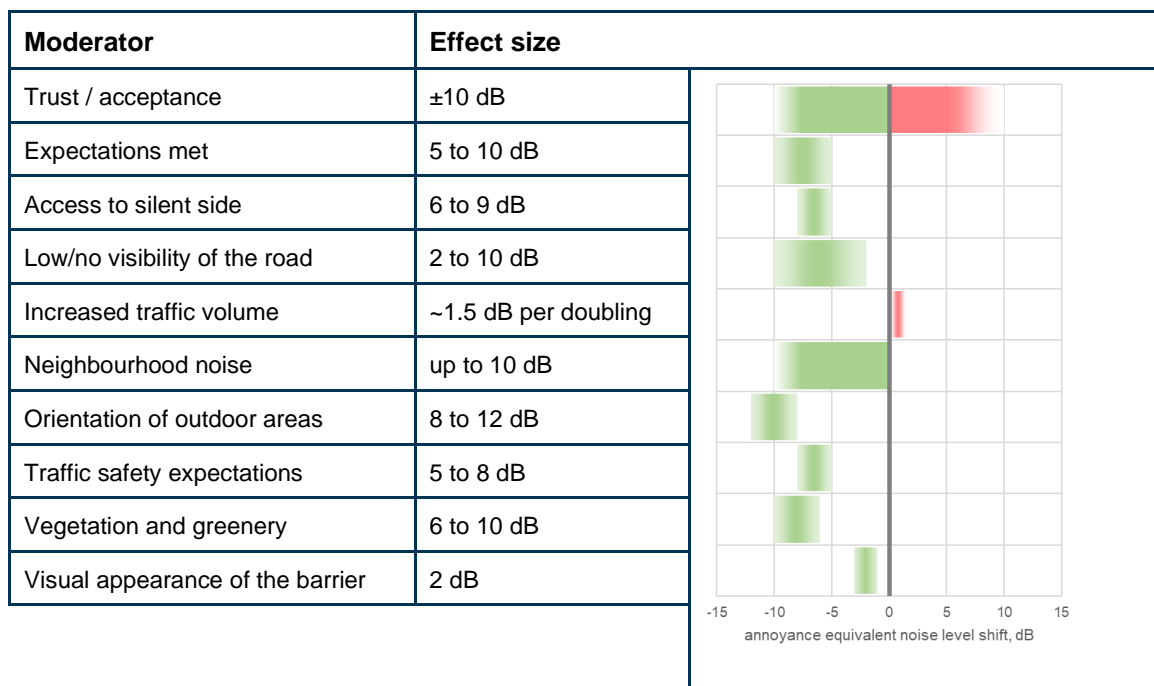


Figure 4: Overview on approximate effect sizes of moderators. The sizes depend on the context and the effects are not directly additive [9].

Except “trust/acceptance”, only the “positive effect” is plotted. This depicts the possible gain that is achievable by National Road Administrations for each moderator, based on a situation “without positive influence of a moderator”.

For “trust/acceptance”, the possible effect size of  $\pm 10$  dB shows that this moderator might in most cases have an “average” from which a change is possible in both directions. So even without further influence or consideration, the annoyance might increase.

Regarding uncertainties, the literature analysis shows a high variance in the annoyance equivalent noise level shifts for some moderators between different surveys. Results of listening tests, mini surveys and sound walks also showed uncertainty, mostly due to a low number of respondents.

For some moderators, dependencies and interactions can be found. The effect size suggests that the effects are not simply to combine for different moderators, as they would result in a change higher than actual noise levels (e.g.,  $\pm 10$  dB for trust, up to 10 dB for expectations, 10 dB for vegetation and greenery and so on).

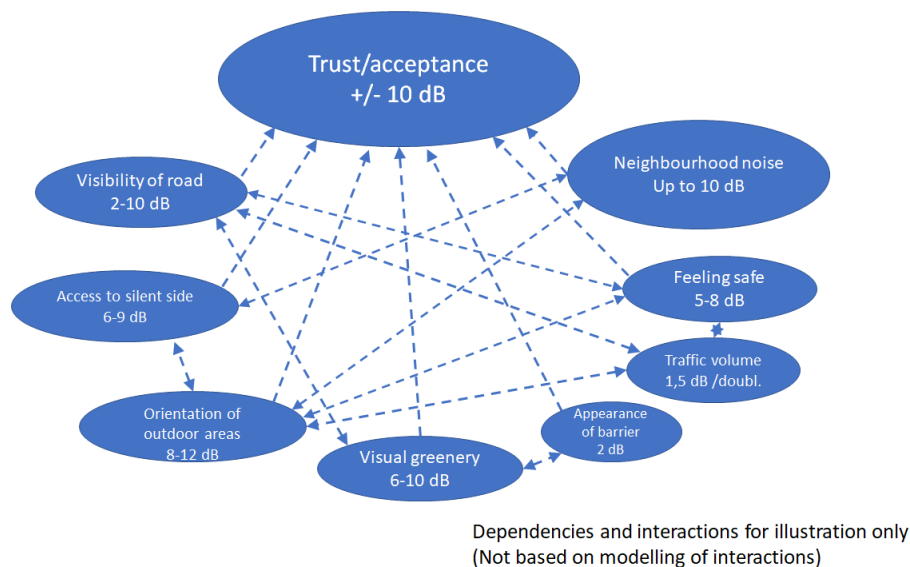


Figure 5: Possible dependencies and interactions between moderators. The effect in dB of the moderators is the average order of magnitude found in the FAMOS project [9].

Different moderators might have a positive or negative influence on each other. For most effects, an increase can be expected when interacting. For trust/acceptance, a poor quality of the other moderators can result in negative effects.

Possible positive or negative influence of the different moderators might be:

- The appearance of a green noise barrier might influence the visual greenery and thus have a higher effect.
- Visual greenery might cover the view to a noise barrier and thus make the influence of the visual appearance of the barrier irrelevant.
- If the road is not visible, the perceived safety might increase.
- If access to rooms on quiet side is given, outdoor areas can be oriented there as well.
- Reduced neighbourhood noise can increase the chance of a quiet side.
- Noise mitigation measures like barriers, embankments or noise reducing pavement on a major road might not only decrease noise levels at dwellings, but also in the whole neighbourhood. In opposite, soundproof windows only decrease the noise for residents of single dwellings indoors.

Whenever multiple moderators could apply, these with the highest effect and the highest emphasis should primarily be considered. Those moderators which are just slightly addressed like a minor change in visual greenery, could be considered with their effects to other moderators but otherwise neglected.

## 8. OUTLOOK

In the FAMOS project, a series of moderators was investigated that can change the noise annoyance for people living in neighbourhoods exposed to road traffic noise e.g. from motorways. The effect of these moderators is present even though no measures are taken to reduce the actual noise levels. Primary research subject were acoustic moderators that could be controlled by (national) road administrations. Non-controllable factors and personal factors have not been investigated.

To facilitate future data collection, the FAMOS project has tested three rather simple methods to investigate the annoyance of road traffic noise. Insights on conducting those methods can help road administrations in order to investigate the effect of new road or noise abatement projects (best practice / worst practice). Valuable information includes information on number of respondents, suggestions for common questions, situations/locations for surveys etc.

Results of comparable surveys can be used to derive new and improved information about moderators and their effect on perceived annoyance. Elaboration of a common basis for questions to be used in future surveys would be helpful for getting more and more reliable data on the effect of the moderators.

An advanced data foundation from surveys will make it possible to improve the models for noise annoyance including the influence of the moderators. Questions relating to the moderators should be included in the survey questions in future surveys (for inspiration find the questions used in the Motorway and Copenhagen study (see [8]) which is basis for the modelling in this project and the mini survey for the Hamburg region (see [5]).

The knowledge found in the FAMOS project on these moderators has been used as the foundation for developing the FAMOS guidebook (Guidebook how to reduce noise annoyance [3]) that National Road Administrations as well as other administrations can use in planning of new roads, enlargements of existing roads as well as in noise abatement projects.

## 9. ACKNOWLEDGEMENTS

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In this study we have compared and used the results of many well-known and respected international researchers. We are very thankful to the brilliant work done by these researchers.

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