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FAMOS - FActors MOderating people's Subjective reactions to noise

Guidebook on how to reduce noise annoyance

FAMOS a CEDR project

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FActors MOderating people's Subjective reactions to noise
Guidebook on how to reduce noise annoyance

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Content

Introduction and summary

This practical guidebook from 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), road traffic noise is one of the most important environmental risks to health and a major contributor to healthy life-years lost in Europe[2]. About half of these can be related to the subjective element "annoyance".

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 very good public participation process integrating the neighbours of a road in the decision process, over having access to silent side, 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/.

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}.

This is the (hypothetical) shift in noise level that will give the same change in annoyance as the presence or absence of a moderator and a practical way to express the effect of a moderator. It should not be confused with any actual changes in noise levels. So, as an example: The existence of a moderator will change the annoyance response in the same way as a reduction (or increase) of a given range in decibels in the noise level.

1 R. e. a. Guski, "WHO environmental noise guidelines for the European region: a systematic review on environmental noise and annoyance," Int. J. Env. Res. Pub. Health, 207, p. 1539, December 2017

2 Environmental Noise Guidelines for the European Region, WHO 2018 https://www.euro.who.int/en/publications/abstracts/environmental-noise-guidelines-for-the-european-region-2018

This guidebook of the FAMOS project provides a brief overview on the topic with strong focus on the moderators itself and practical application. The moderators retrieved are presented together with the order of magnitude of their “effect” and a series of examples on how they can be used are described. For further details, the **full FAMOS project report**[3] is available.

[3] FActors MOderating people's Subjective reactions to noise – Project Report – Deliverable D.4.6

1. Fundamentals

1.1. Impact of traffic noise and annoyance

The World Health Organization has estimated that **about 1.6 million healthy life-years are lost annually** in Europe due to road traffic noise[4]. About half of these can be related to the subjective element: annoyance.

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 cumulative noise level itself (L_{EQ}, L_{DN}, L_{DEN}, or similar)**, whereas the other **2/3 are partially also determined by so-called "non-acoustic factors"**[1]. 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, technically feasible and economically possible noise reduction measures have been applied, the noise annoyance impact can in some cases still be reduced by making changes in the non-acoustic factors known to moderate the annoyance response.

1.2. Non-acoustic factors

Several factors can change the perceived annoyance by people exposed to road traffic noise. 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 annoyance response.

When all conventional noise reduction measures have been applied, the noise annoyance impact can still be reduced by making changes in so called non-acoustic factors. We will interpret the term "non-acoustic factors" as: All factors that do not have an influence on the L_{den} at the most expose façade. This means that some acoustic factors in this context also fall in the category "non-acoustic factors" e.g. noise reducing windows and facades, local noise screens in a garden etc.

Figure 1: Examples of barrier design and surroundings affecting the perception of traffic noise annoyance.

4 Environmental Noise Guidelines for the European Region, WHO 2018 https://www.euro.who.int/en/publications/abstracts/environmental-noise-guidelines-for-the-european-region-2018

The connection of factors and moderators can be seen in Figure 2. Acoustic factors at the noise source, such as the types of vehicles, speed, and road surface, as well as the sound propagation, influenced e.g. by buildings and barriers, lead to resulting noise levels at the most exposed façades. The annoyance itself is "moderated" by factors ("moderators"). Regarding the FAMOS project, they are further distinguished between controllable (by the National Road Administrations (NRA)) and non-controllable moderators.

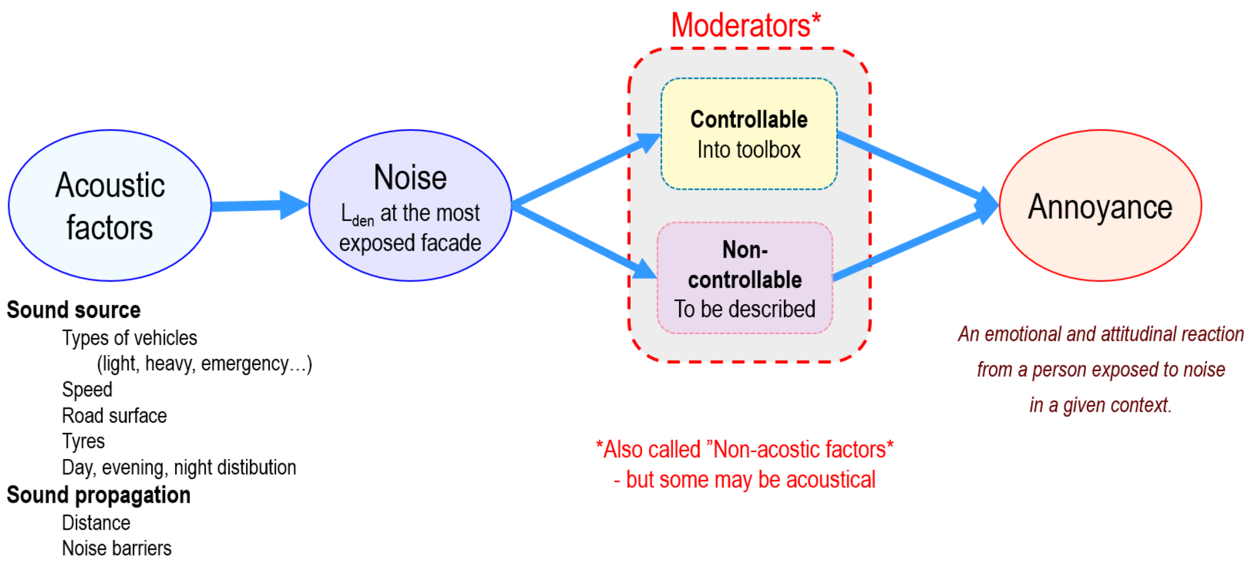

Figure 2: Connection from acoustic factors leading to noise and moderators influencing the annoyance.

A list of possible moderators was systematically derived. 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.
- 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.
- **Relationship** between the local residents and the road owner. Do they feel a personal "ownership" to the road as well as its design and visual appearance and benefit from its existence? Have the residents had a chance to be involved the planning and construction process? Do they have a feeling of being treated fairly by the road owner? 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.

1.3. 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. It should not be confused with any actual changes in noise levels.

Figure 3: Examples of visibility affecting the perception of traffic noise.

At the same noise level L_{den}, persons who are not affected by one moderator (blue curve in Figure 4, e.g. "traffic visible", left part of Figure 3) could be more annoyed than people that are affected by a moderator (orange curve in Figure 4, e.g. "traffic not visible", right part of Figure 3).

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. The **"Annoyance equivalent noise level shift", L_{eas}** in this case 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 level difference, e.g. between the most and the least exposed façade.

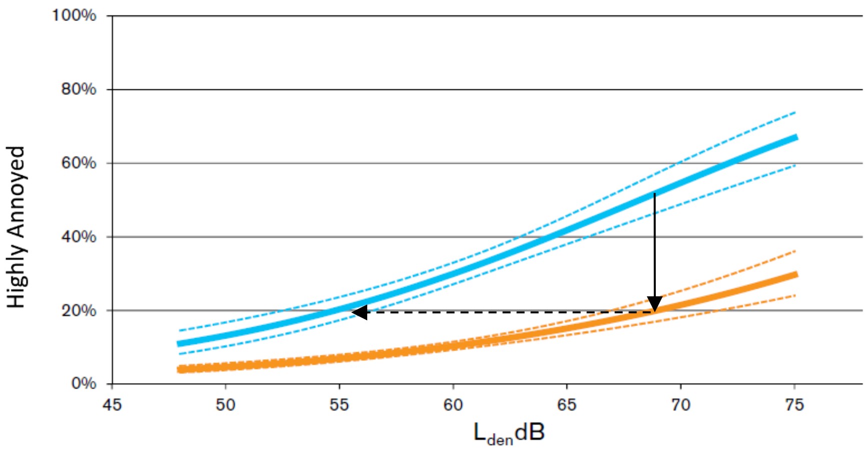

Figure 4: The blue curve shows an example for the percentage of people being highly annoyed in a situation without moderators. The orange curve shows the percentage of highly annoyed in a situation where a moderator has been implemented. Change in annoyance for one moderator with change in annoyance in percent annoyed (solid arrow) and "annoyance equivalent noise level shift" in dB (dashed arrow).

2. Moderators

2.1. 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 factor. 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.

Figure 5: Open discussion between road authorities and residents at a public meeting on a new road project.

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.

2.2. Expectations / public relations

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. Likewise, negative media attention may lead to a similar reaction.

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.

Figure 6: Listening examples (calibrated auralisations) at a public meeting about a road project for better correspondence of the neighbours' expectations and results.

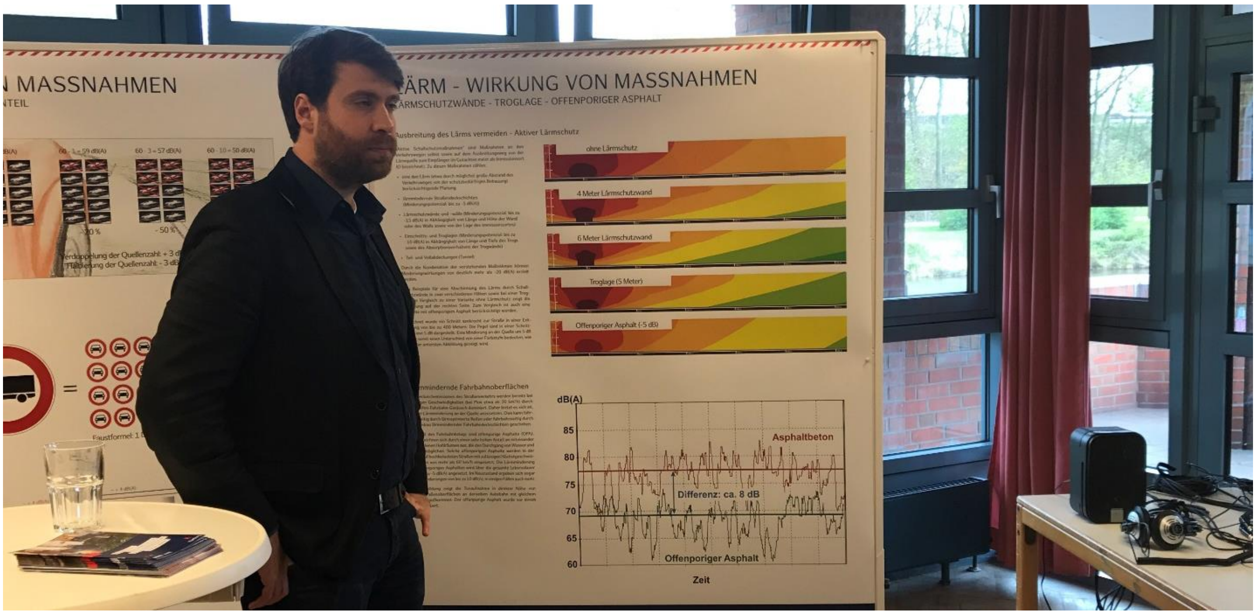

Figure 7: Exhibition during the planning phase of a road project, answering questions and explaining noise in dialog between citizens by experts.

2.3. Increase in 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. 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.

Figure 8: Similar road types (motorway) with low traffic (top) and high traffic volume (bottom).

2.4. 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, 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 etc.

The effect corresponds to an annoyance equivalent noise level shift of about 5 dB.

Figure 9: Guard rails, enforcement of speed limits to improve safety on a national highway.

Figure 10: Improving safety on local roads, e.g. with speed reductions.

2.5. 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. will only give a marginal noise reduction, except for very wide areas of trees (> 100 meters). The psychological effect, however, *i.e.* the reduction in annoyance has often been observed to be much greater than what could be expected from the actual often marginal reduction in the noise level.

The use of greenery along roads may cause a reduction in the annoyance equivalent noise level of **as much as 10 dB**.

However, studies from the Netherlands indicate that trees (very) 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 11: Greenery surrounding a motorway and covering the view to the steel noise barrier.

Figure 12: Noise barrier with greenery, reducing the visual impact. Possible negative influence on noise propagation!

2.6. Noise barriers (expectations and visual appearance)

Noise barriers are often used as a means to reduce the noise from a major road. Different designs 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 meters will provide an insertion loss of up to about 15 dB. A typical noise barrier will provide an insertion loss of roughly 10 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?
- Do they feel an “ownership” to the noise barrier?

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** which can result in a **shift of 5-10 dB**.

Regarding the **visual appearance**, the influence of the design itself is mostly unclear, but most likely lower with **about 2 dB**.

Greenery and vegetation may result in a higher shift (see section on “vegetation and greenery” on the previous pages).

Figure 13: Embankment covering the view to a motorway (not visible on the left), also improved with greenery.

Figure 14: Wooden noise barrier adapting to the surroundings. It is designed in a way that is similar to the design and materials used in the local community.

Figure 15: Greenery covering the lower part of a high noise barrier.

2.7. 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. The construction of local noise barriers around a terrasse can improve the situation by creating a better quiet side. Also, the construction of glass shielding of a balcony can improve the situation.

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

Figure 16: Improving the ambience quality with local noise barriers to protect terraces.

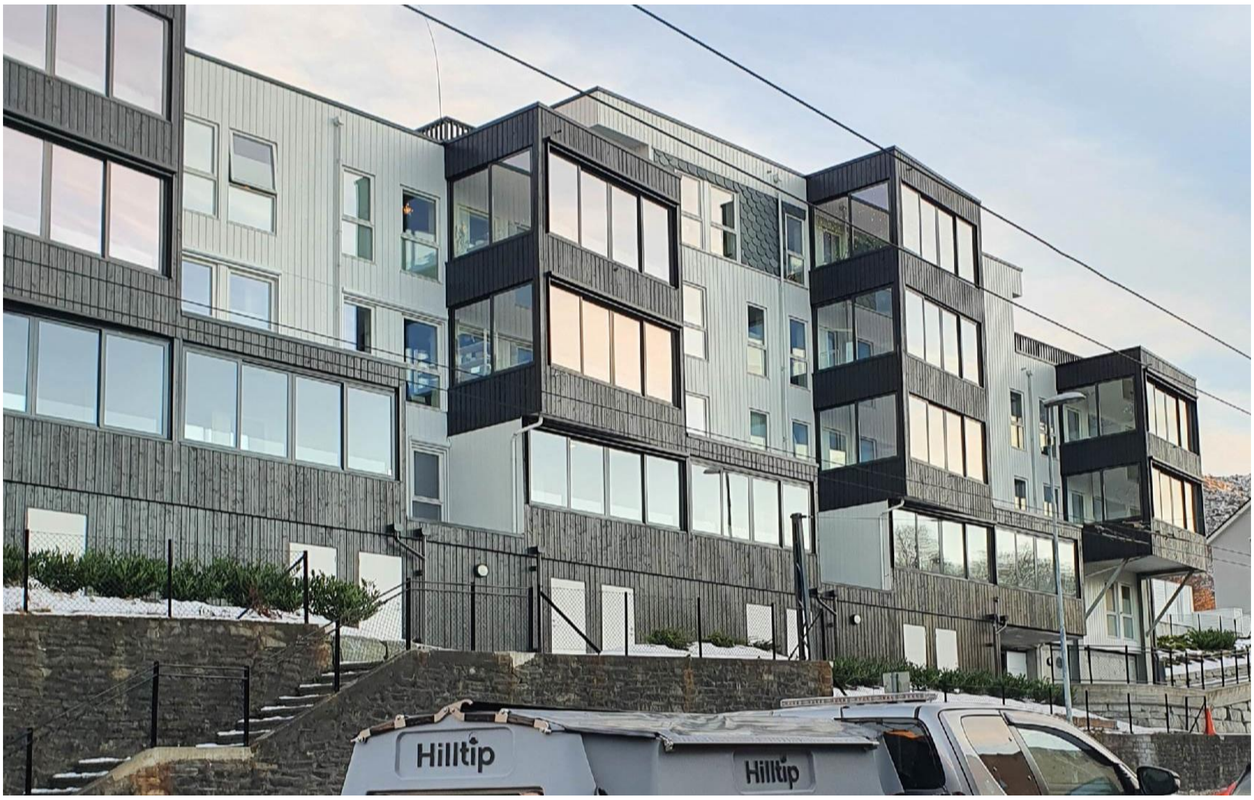

Figure 17: Covering a balcony with glass can improve the situation giving the feeling of having access to a quieter area. At the same time, it can function as noise insulation for the rooms facing the balcony.

Figure 18: One facade facing the noise from the 6-lane motorway in the front, with chance to a quiet side on the far side. Typical two-room apartments, balconies suggesting living rooms on the loud side, giving a silent side for bedrooms.

2.8. Neighbourhood soundscape

It has been shown 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 and also in the local district.

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. 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 we estimate that the annoyance equivalent noise level shift may be **up to 10 dB.**

Figure 19: Reducing local traffic, improving outdoor qualities, and reducing the noise in the local neighbourhood.

2.9. Non-controllable personal and demographic variables

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

However, there are also many personal and demographical factors that may or may not be important for annoyance assessment. Such factors are for instance noise sensitivity, 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. But it has not been the primary goal of the FAMOS project to try to quantify such personal and demographical factors. And it is factors that road administrations barely can influence or change.

3. Practical application

Evidence was found in the FAMOS project[5] that a wide range of moderators affects the perceived noise annoyance[5]. The selected moderators and their order of magnitude can be seen in Figure 20.

Moderator	Effect size
Trust / acceptance	±10 dB
Expectations met	5 to 10 dB
Access to silent side	6 to 9 dB
Low/no visibility of the road	2 to 10 dB
Increased traffic volume	~1.5 dB per doubling
Neighbourhood noise	up to 10 dB
Orientation of outdoor areas	8 to 12 dB
Traffic safety expectations	5 to 8 dB
Vegetation and greenery	6 to 10 dB
Visual appearance of the barrier	2 dB

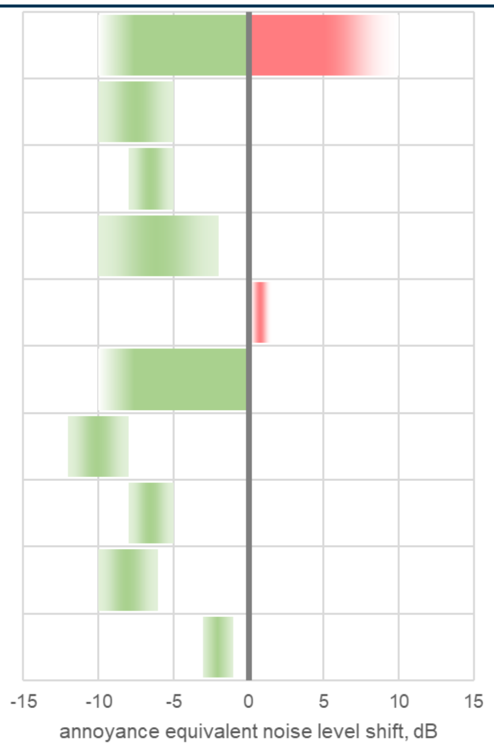

Figure 20: Overview on effect sizes of moderators selected for the FAMOS project.

The spread shown is already simplified to the most likely effect size. Regarding uncertainties, the literature analysis shows a high variance in the annoyance equivalent noise level shifts for some moderators between different surveys[5]. Results of listening tests, mini surveys and sound walks performed as part of the FAMOS project also showed[6] a high uncertainty, mostly due to a low number of respondents.

Based on the results of two very vell documented annoyance studies, the FAMOS project has performed modelling work to investigate the order of magnitude of different moderators[7]. The results of the modelling show differences regarding the uncertainty of the moderators:

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5 FAMOS Project Report, Deliverable 4.6 of the FAMOS project, 2022
https://famos-study.eu

6 FAMOS Deliverable 2.2: Audio-visual listening test of moderators for perception of road noise, 2021
FAMOS Deliverable 2.2: Soundscape measurements of moderators for perception of road noise, 2021
FAMOS Deliverable 2.2: Mini surveys on noise annoyance and moderators for perception of road noise, 2021
https://famos-study.eu

7 FAMOS Deliverable 3.1: Modelling noise annoyance moderators, 2021
https://famos-study.eu

- A relatively **low variance** was found e.g. for access to **quiet sides** and **orientations of bedroom windows** and the **acceptance**, i.e. attituded towards road noise and authorities. Both moderators show an effect within a 3 dB confidence interval.
- **Higher variance (uncertainties)** were found whenever **several moderators** were affected at once, like feeling unsafe, presence of vibrations, smell and air pollution. These result in a spread of about 12 dB in effects, although the effect size and thus uncertainty of single factors is much lower.

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. ± 10 dB for trust, up to 10 dB for expectations, 10 dB for vegetation and greenery and so on). Therefore, if a series of different moderators are implemented the effect of the individual moderators cannot be simply added to get the total effect.

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. An example of possible dependencies and interactions between moderators is shown in Figure 21.

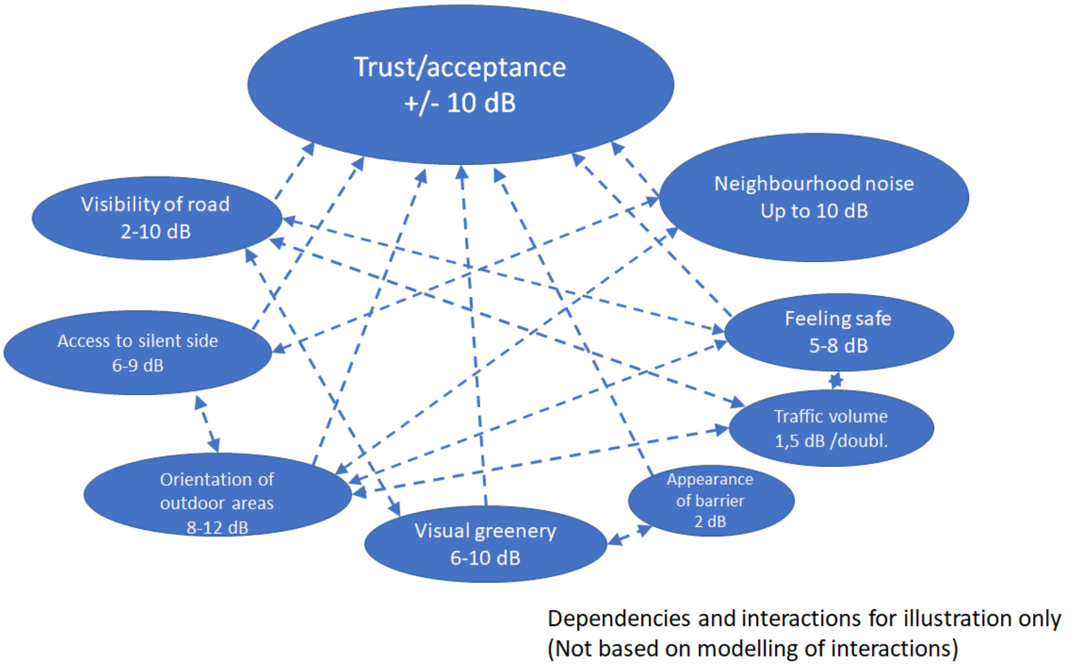

Figure 21: Possible dependencies and interactions between moderators. The effect in dB of the moderators is the average order of magnitude found in the FAMOS project.

These connections are not based on modelling of interactions but anyway give an overview of moderators "related" to each other and having a similar influence, like visibility and greenery, appearance of the barrier and possible greenery or the influence of most moderators towards change of trust and acceptance.

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 traffic safety might increase**.
- If access to rooms on **silent side** is given, **outdoor areas** can be oriented there as well.
- **Reduced neighbourhood noise** can increase the **chance of a silent side**.
- Noise mitigation measures like barriers, embankments, noise reducing pavement or speed reductions 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.

4. Examples of using different moderators

In order to illustrate the concept of working with moderators, some examples in the following, will show how the moderators apply in real life situations and how the effects can be estimated. The examples also show how some moderators can have effects applicable even after a longer time period for new projects. This for example can be improving the trust in authorities or the acceptance of noise in an area, leading to an advantage for future projects.

4.1. Expectations and change effect

For bigger noise mitigation projects, expectations might arise on the effect on noise level change. This can also be the case in situations of road enlargements where an extension could even result in a higher level of noise protection due to stricter limits that have to be met.

From an expert's view, a decrease of 2-3 dB (e.g. due to noise reducing pavement) is common, mitigation of 4-10 dB (open porous asphalts or noise barriers in ideal situations) is less common. For some road extensions, the noise levels after construction are planned to be equal to the noise level before although the traffic volume increases (mitigation counteracting the noise level increase), though a change of near 0 dB will be the result.

For residents, whenever noise mitigation measures are explained, expectations on a perceptible change of noise levels can arise. Although noise level changes of about 3 dB are commonly only perceptible in favouring conditions, the annoyance effects seem to be higher.

However, the same effect which improves the reduction of noise annoyance can also apply when noise levels rise. For example, during construction on a motorway, the traffic is shifted to one roadside. In addition, speed limits apply that are mostly lower than the regular speed limit (e.g. 60-80 km/h instead of 100-120 km/h).

Figure 22: Situation during construction phase – traffic shifted to one side and reduced speed limits are introduced.

The whole construction phases could result in the following noise level changes:

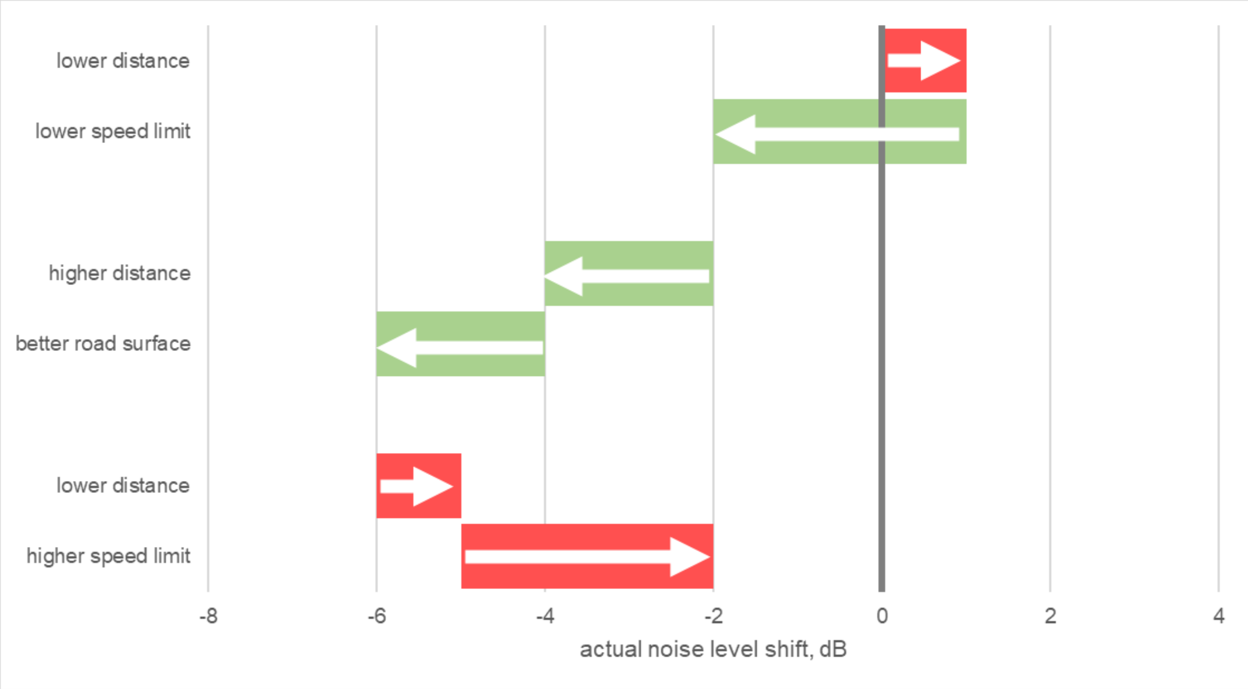

Figure 23: Changes in actual noise level over time during construction phases (red: increase, green: decrease).

For a situation with noise barrier, the decrease of noise levels could be even higher during the phase where the barrier starts to have effect.

After all, the noise level decreases, but in the final phase, the noise level increases by about 4 dB. Although the noise level is lower than before the construction process, expectations that were satisfied during that time period were counteracted due to the perceivable increase after construction. This might result in complains and unsatisfied citizens. This can to some extend be avoided by conducting a good and very informative public participation process where these changes of the noise levels during the whole construction process are explained.

Noise measurements could be performed before and after the construction phase, although these will only have documentary character. Convincing people after a negative experience (in this case: emotions vs. technical data) is expected to be harder to achieve than good public relation and good communication beforehand.

4.2. Construction site noise

In addition to the noise level changes of the road traffic, possible noise from the construction process might affect residents and result in annoyance: e.g. hammering down foundation, braking down old concrete, using heavy machinery etc. If the noise from the construction process is handled in an open and active process involving the citizens, negative attitudes towards the whole project can be reduced or avoided. Information on how to handle noise from road construction projects can be seen in the "ON-AIR Guidance Book on integrating Noise in Road Planning"[8] published by CEDR.

Figure 24: Construction site noise at a major motorway enlargement.

To gain trust, noise monitoring during the construction process can be useful to ensure compliance of the contractors to e.g. previously agreed processes (use of less noisy machinery and working processes, limited usage of certain machinery, limited time of machine usage etc.) and to document fulfilment of noise limits.

Although the influence of construction site noise itself was not investigated in the FAMOS project, it is a major influence on the noise levels during a change process of the major noise source, the road itself. Thus, it is a possible contributor to changes in noise acceptance and trust in authorities.

8 ON-AIR Guidance Book on the Integration of Noise in Road Planning, 2017 https://www.cedr.eu/docs/view/606327090dcd8-en

4.3. Trust in authorities

A negative effect on trust towards authorities and noise acceptance by the local citizens can result in situations with expectations that were not met, or negative changes were experienced. This can even be the case if only the annoyance is increased whereas the real noise level was not increased. The effects can lead to higher annoyance with a potential annoyance shift of up to 10 dB that counteracts the noise level reduction.

In situations like in the previous example, without further influence of other moderators such a negative effect could easily counteract the benefits of a noise barrier and noise reducing pavement, resulting in zero change of annoyance for the next years to come[9]. However, the negative effect of trust is likely to change over a longer time, resulting in "average" annoyance after some years.

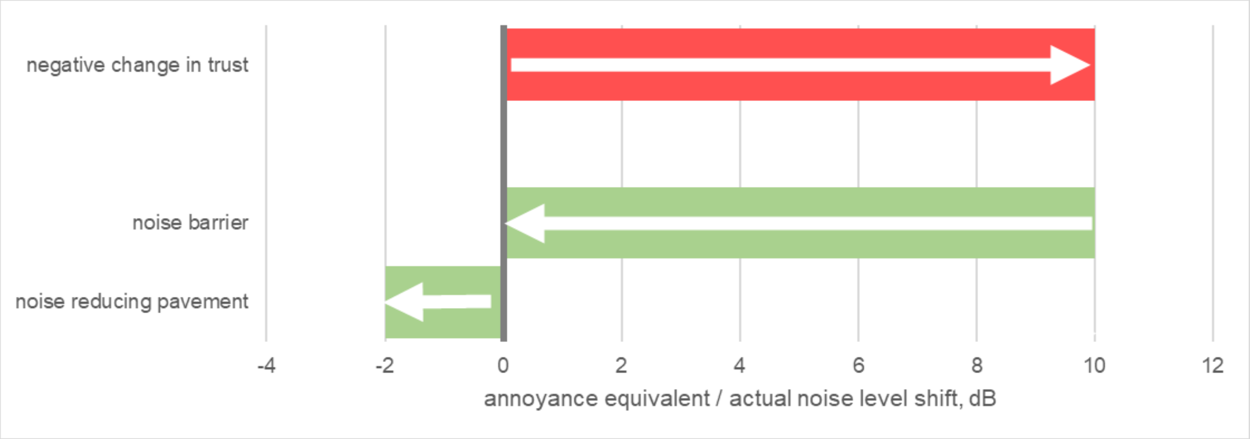

Figure 25: Increase in annoyance equivalent change (red) counteracting reduced noise levels (green).

An improvement could be achieved by good public relations work, explaining the noise level change that is to be expected and the temporary effects during construction. When including audio examples, residents will experience the realistic amount of change in noise levels to expect, which can counteract high expectations that could not be fulfilled.

9 Note: The FAMOS project did not investigate the long-term effects of trust.

4.4. Visibility and greenery

As part of construction processes but also due to regular roadside maintenance work, trimming and cutting of trees and bushed could be necessary. As documented before, visibility of the traffic and a general greenery in the surroundings can result in a shift of about 10 dB.

In one documented example (see Figure 27), extensive work was carried out at the roadside, cutting and trimming bushes and small trees. This resulted in an open view to the traffic (in the picture: from road to dwellings, but also vice versa). Without further announcement, this could also affect the trust in authorities, resulting in negative effects even years after the change of visibility. As for the greenery, although the bushes and trees would grow back, a negative influence on annoyance could remain.

An improvement for a similar situation would be to make announcements on necessary tree works before start of work and at the same time highlighting that the trees/bushes will grow up again over the following years, resulting in the same visual appearance as before. In addition, information on the acoustic effects could be given to residents, informing on marginal effects on actual noise levels. This could lower expectations on the noise mitigating effect of greenery. However, such information could also result in lower positive change after greenery was used to reduce visibility of traffic.

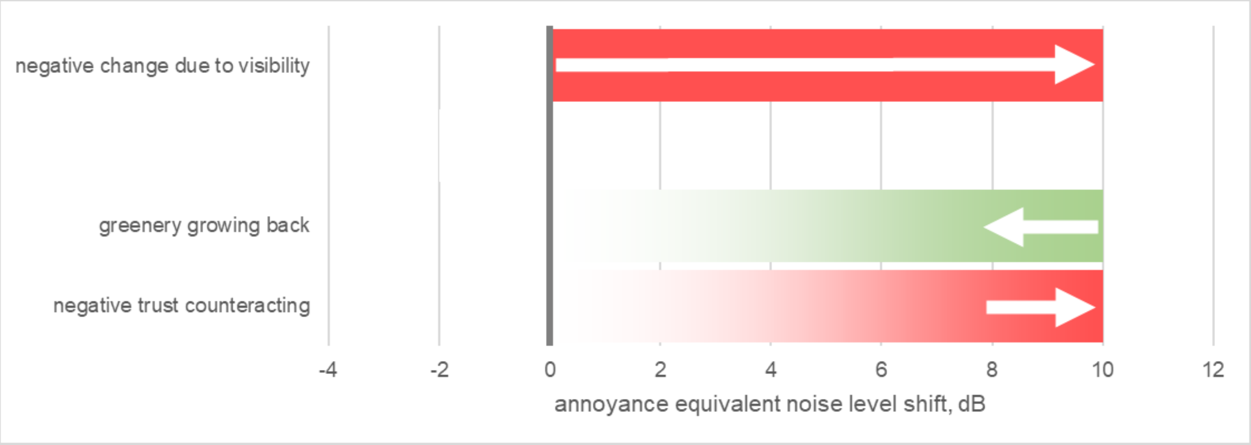

Figure 26: Negative effect by change by visibility, effect decreasing by greenery growing back, but still negative effects due to trust possible.

Whenever changes in greenery are necessary due to road construction, timing of such work can have a possible influence. In combination with the example above, a change in greenery before start of construction could result in a higher annoyance due to change of greenery and visibility at the start and a lower trust, resulting in a higher annoyance throughout the whole construction process. If cutting trees down is carried out during or shortly after noise level reductions, the negative experience could be lower.

In addition, cutting trees in a timely manner to the construction process (i.e. cutting trees shortly before/during construction of a noise barrier, not one year or more in advance) improves the awareness of the necessity and appropriateness, counteracting possible negative effects on trust.

Figure 27: Before (in the autumn period) and after trimming of bushes and small trees (in the winter period); visibility of the road changes as well as visible greenery (some due to change in season between pictures).

4.5. Improved greenery in the surroundings

In one example, the motorway was enlarged from 2x2 lanes to 2x3 lanes. The green zone between the motorway and the dwellings was redeveloped in an open participation process with the National Road Administration, the municipality, and residents. Although there have been no annoyance surveys carried out, conversations showed that residents are satisfied with the new situation.

Figure 28: Local situation between motorway and residential buildings before enlargement of the motorway (left picture); improved greenery, landscaping and footpaths after the enlargement was finalized (right picture).

After cutting of trees on the roadside for construction of the noise barrier, the opportunity was taken to improve the green zone between residential buildings and motorway. This area had a significant value as recreational area even before the changes.

With the noise barrier, the overall noise level could be lowered also for this area, resulting in a better outdoor environmental quality. Changes made in the surroundings (see Figure 28) focused on improved greenery (additional trees and bushes in front of the lower, non-transparent part of the barrier), creation of new wet areas (e.g. a small natural pond) and improved spatial quality of the pedestrian network (mainly improving paths between buildings and the area). Also, five monumental trees were relocated to the area from a close by urban development project.

Regarding the moderators mentioned, the following might apply:

- Participation / public relation
- Visual appearance of the noise barrier
- Visibility
- Greenery

With positive changes in those moderators, an even larger effect could result. This was not investigated within the project, but literature and own data shows effect sizes even larger than those up to -10 dB for single moderators (see Figure 29).

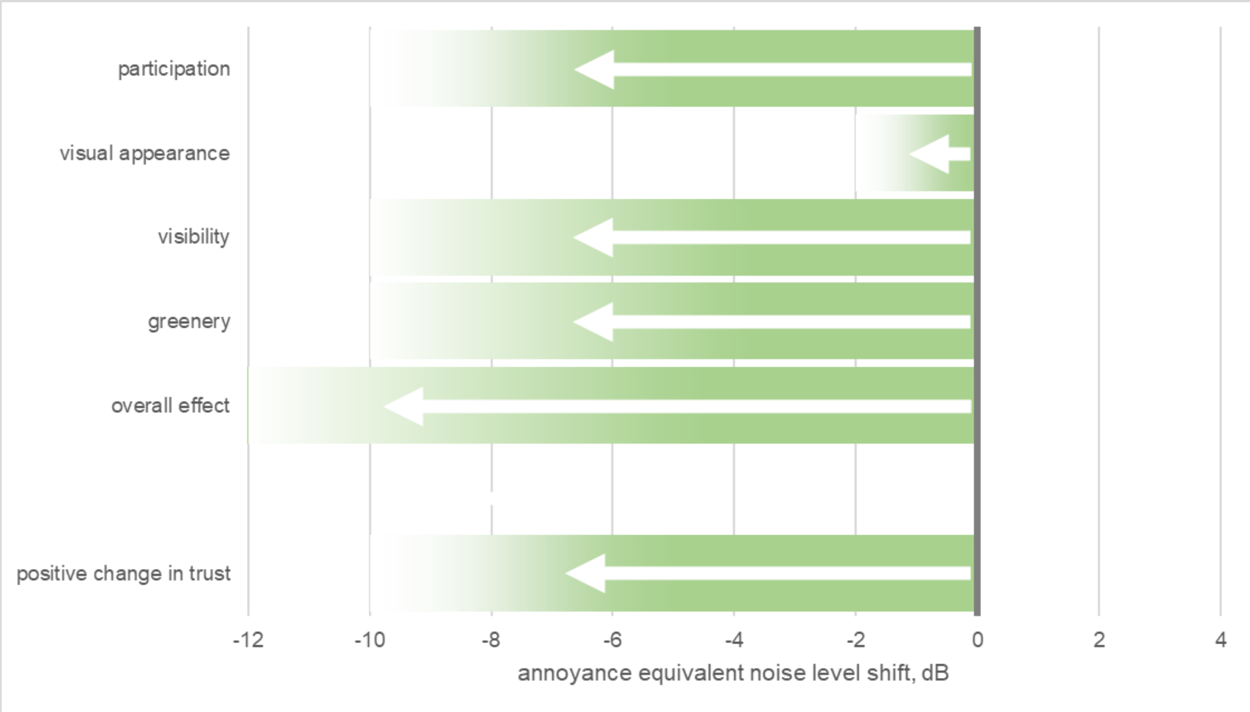

Figure 29: Combination of different moderators.

Resulting from an overall good change, the trust in authorities might improve, giving a “bonus” for a concurrent construction process or even for future changes. In the example, the improvement was finalized after completion of the construction process.

In this case, annoyance during road construction was not positively influenced by the changes in environment as they were carried out after the road construction. Nevertheless, a final “good change”, in this case improvement of environment, can have a final positive impression on the whole measure and thus improve acceptance.

5. Outlook

5.1. Methods for data collection

This guidebook presents the current knowledge on moderators. New sources can be used to derive new information about moderators and their effect on perceived noise annoyance. An advanced data foundation from surveys will make it possible to improve the models for noise annoyance developed in the FAMOS project[10] including the influence of the moderators.

To facilitate future data collection, the FAMOS project has also tested three rather simple methods to investigate the perceived annoyance of road traffic noise:

- Mini surveys using questionnaires
- Soundwalks in neighbourhoods
- Listening tests performed in the laboratory

Insights on conducting those methods can help road administrations in order to investigate the effect on perceived annoyance of new road or noise abatement projects (best practice / worst practice). Valuable information presented below includes information on number of respondents needed, suggestions for common questions to be used in questionnaires etc, requirements for situations/locations where surveys might be conducted etc.

Elaboration of a common basis for questions to be used in surveys would be helpful for getting more and more reliable data on the effect of the moderators. Questions relating to the moderators identified should be included in the survey questions in future surveys. A solid starting point could be the questions used in the Motorway[11] and Copenhagen[12] studys which is basis for the modelling in this project and the mini survey for the Hamburg region[13].

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[10] FAMOS Deliverable 3.1: Modelling noise annoyance moderators, 2021
https://famos-study.eu

[11] J. Fryd, L. N. Michelsen, H. Bendtsen, L. M. Iversen und T. H. Petersen, „Noise annoyance from urban roads and motorways. Vejdirektoratet Report 565," Vejdirektoratet , 2016.
J. Fryd, L. MIchelsen, H. Bendtsen, L. Iversen und T. Pedersen, „Støjgener fra byveje og motorveje, Vejdirektoratet Rapport 551," 2016.

[12] T. Pedersen, G. Le Ray, H. Bendtsen und J. Kragh, „Community response to noise reducing road pavements Vejdirektoratet Report 502," 2014.
T. Pedersen und G. Le Ray, „Befolkningsreaktioner på støjreducerende vejbelægninger, Rapport 442," 2013.

[13] FAMOS Deliverable 2.2: Mini surveys on noise annoyance and moderators for perception of road noise, 2021
https://famos-study.eu

5.2. Soundscape measurements

The results of the FAMOS project suggest that **soundscape measurements**[14] may be a useful tool for investigating the annoyance from traffic noise and the effect of non-acoustic variables, e.g. greenery and visible traffic. Soundscape measurements are carried out by groups of 5-7 persons. They stand at a place where the soundscape is to be measured and answer a series of systematic questions related to how they perceive the soundscape at this location on a tablet. For this to be successful some details should be considered.

At the places investigated, the holistic situations may differ for other reasons than the differences in the variables under investigation. Thus, a higher number of positions is needed to avoid unwanted bias. Alternatively, special care should be taken that the main differences only or primarily are caused by differences in the moderators of interest. There shall also be sufficient and independent variation in the moderators under investigation in the chosen measuring positions. As a rule of thumb, we would recommend having four times as many measuring positions as the number of moderators of interest.

To summarise, sound walks…

- may be a useful tool for investigating the annoyance from traffic noise and the effect of non-acoustic moderators, e.g. greenery and visible traffic,
- should be limited in the numbers of moderators (variables) analysed,
- measuring positions with independent variation in the moderators under investigation should be selected/included,
- may need a high degree of participation, at least 20 persons (e.g. in groups of 5-7 persons),
- cannot directly be adopted at new/planned locations (presence of different places of interest; prediction of future changes / situation after a construction etc.). Similar places elsewhere may serve as substitute.

Figure 30: Sound walk at a busy urban road. The panel of persons are answering questions on the perceived soundscape and annoyance on an iPad. At the same time the actual noise level is measured. At the same time the noise level is measured.

[14] FAMOS Deliverable 2.2: Soundscape measurements of moderators for perception of road noise, 2021 https://famos-study.eu

5.3. Mini surveys

In a mini survey a questionnaire about noise and annoyance are used in a well-defined local area in the vicinity of a road or noise abatement project. The results from the **mini survey**[15] performed in FAMOS suggest that mini survey may a useful tool for investigating relevant moderators that contribute to annoyance from traffic noise. The survey carried out as a part of FAMOS showed that postal mailings can give a good control on coverage and could address more people than via electronic mailing (for which the addresses of possible respondents must be known beforehand).

However, it is suggested to just send out invitations to the survey itself which will be carried out electronically. If so, the costs for the questionnaire itself are negligible. A mailed survey needs an extensive mailing as well as the possibility of returning the results. If paper is to be returned, the postal fees have to be considered as well as the digitalisation of the returned questionnaires.

As one of the biggest disadvantages, the exact assessment of the location of a dwelling showed a big uncertainty in determination of noise levels related to the dwelling. Focus on a survey design should be a good way for respondents to give information on location of their residency, but also taking privacy reasons and concerns into account. A higher reliability for the location could also be achieved in face-to-face or telephone interviews in the survey areas.

The mini survey showed that a survey itself is applicable for different aims. These can as well be focused locally (”expectations to be considered,” like importance of greenery) as give a general overview on attitudes towards noise (as well as towards authorities etc.). For future comparison, a common set of questions should be used.

To summarise, mini survey…

- are suitable for areas, analysing e.g. expectations on noise and the general development (need for greenery, improvement of neighbourhood etc.),
- may also be suitable to ascertain general factors when summarizing results from different areas, as attitudes towards authorities, annoyance from different types of roads, effects of greenery and visibility etc.,
- are best based on an unchanged “common set of questions” throughout different surveys,
- quantification with acceptable uncertainty is possible if the number of respondents is 300 or more,
- for correct calculations of noise levels, the addresses of the respondents should be known.

Figure 31: Flyer for postal mailing used in FAMOS.

[15] FAMOS Deliverable 2.2: Mini surveys on noise annoyance and moderators for perception of road noise, 2021 https://famos-study.eu

5.4. Listening test

An audio-visual listening test is performed in the laboratory. A group of representative listeners (assessors) are presented for road traffic noise at various locations and at the same time a video of the location. On a PC they answer a series of questions related to their perception of the noise at each location**. Audio-visual listening tests[16]** may be used to quantify the effect of noise characteristics and moderators. For the listening tests, several locations could be selected, so that there are variations in moderators of interest (visibility of the traffic, amount of greenery, type, and appearance of noise screens etc.). It is important that good practice[17] for such tests is followed to avoid bias in the results.

By following good practice, it is relatively easy to get reliable results in listening tests with objective and well-defined attributes. When making listening tests on subjective attributes such as noise annoyance, the following factors should be taken into account:

- Preferable more than 20 assessors should participate.
- The assessors should be representative for “normal (untrained) citizens” preferable living in residences under similar conditions as simulated in the test.
- For assessment of annoyance the context is important. Make the test surrounding as realistic/“home-like” as possible. Avoid laboratory like setups as much as possible and hide them behind curtains if necessary.
- Give a realistic visual presentation (pictures/video/Virtual Reality) as possible.
- Make sure that the assessors understand and imagines the scenario when they make the assessments.
- Use standardized scales and scale labels.
- If the effect of more than one moderator is tested, then stimuli should include independent variations in each of the moderators.

The audio-visual listening tests performed in FAMOS indicated that besides the visual input, thorough supplementary information on the actual surroundings is important for obtaining a representative result.

Figure 32: Listening room at FORCE Technology – sound is played from the stereo setup and the video is shown at the large screen. The assessors are answering questions on a PC.

[16] FAMOS Deliverable 2.2: Audio-visual listening test of moderators for perception of road noise, 2021 https://famos-study.eu

[17] e.g. T. Pedersen and R. Skov, “Guideline: Listening tests for measurement of the relative annoyance and the annoyance potential of noise“

6. Conclusions

In the FAMOS project, a series of moderators was retrieved based on an international literature study, modelling of previous results of questionnaires as well as by conducting small investigations using both mini surveys, sound walks and listening tests. The results showed that the **noise annoyance** perceived by people living in neighbourhoods exposed to road traffic noise e.g. from motorways in some situations can be changed without changing the actual noise level. The effect of these moderators is present even though **no measures are taken to reduce the actual noise levels**. Evidence was found that a wide range of moderators affects the noise annoyance.

Acoustic moderators that could be controlled by (national) road administrations have been the primary focus of this investigation. Factors non-controllable by (national) road administrations and non-acoustical factors (such as personal factors) are not investigated. The moderators retrieved as well as the order of magnitude of their effect can be seen in the below figure.

Moderator	Effect size
Trust / acceptance	±10 dB
Expectations met	5 to 10 dB
Access to silent side	6 to 9 dB
Low/no visibility of the road	2 to 10 dB
Increased traffic volume	~1.5 dB per doubling
Neighbourhood noise	up to 10 dB
Orientation of outdoor areas	8 to 12 dB
Traffic safety expectations	5 to 8 dB
Vegetation and greenery	6 to 10 dB
Visual appearance of the barrier	2 dB

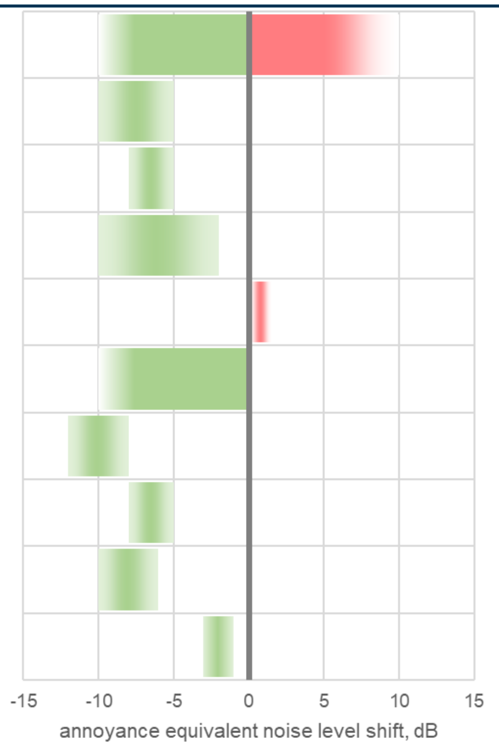

Figure 33: Overview on moderator effect sizes

CEDR Call 2018 Noise and Nuisance

FAMOS D4.5 Guidebook on how to reduce noise annoyance

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