Evaluation of a noise barrier project with critical neighbours
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ABSTRACT
The Danish Road Directorate established a noise barrier along the E45 highway in Frederikshavn, Denmark in 2012 with the objective to reduce traffic noise in a residential area. The noise barrier reduced the number of dwellings that exceeded the noise exposure limits by more than 50%. The residents along the road were informed during the whole process including planning, design and construction where the Road Directorate created high visibility and information flow through the press and individual letters. It was the general impression that the dialog with the neighbors went well, but by the end of the project critical articles appeared in the local press, where some of the residents expressed their dissatisfaction with the new noise barrier. Therefore the Road Directorate ordered a detailed evaluation of the project which included; 1) analysis of the communication process, 2) technical analysis, 3) qualitative data collection through interviews and a questionnaire survey among the affected neighbors. This paper presents the findings of the evaluation project. It also includes a list of specific recommendations for optimization of dialog with neighbors. The recommendations are not only beneficial for similar noise barrier projects but also give input for improved communication during other projects where residents are part of the process.

Keywords: Environmental Noise Directive, Noise Barrier, Road Traffic Noise.

1. INTRODUCTION
The Danish Road Directorate established at the end of 2012 a noise barrier on a stretch along the highway E45 in Frederikshavn in North Jutland, Denmark. The objective was to improve the conditions of a number of affected dwellings in a residential area east of the road. The noise barrier is a result of the Parliamentary Green Transport Policy from 2009, which allocated funding for abatement of noise from existing state roads and railways. The funding made it possible to carry out a series of noise barrier projects and noise insulation of dwellings during 2009 – 2014 along state roads.

The project in Frederikshavn was selected as a result of a political process combined with a cost-effect analysis of possible noise barrier projects along all state roads in Denmark. Over the years there have also been frequent enquiries from residents in Frederikshavn on the possibilities of getting a noise barrier.

The plan for a noise barrier was first mentioned in the local press in 2011. In January 2012 the residents were informed in writing and invited to a public meeting with information on the project. The construction work took place during the summer and the noise barrier was completed in November 2012. The neighbours were informed all through the course of the project, and there was no major inconvenience for traffic during construction. It was the general impression of the project management that the project went quite well and during planning and construction there were no indications that something was about to go wrong. Still, the need for an evaluation of the project came when a critical article appeared in a local newspaper a few weeks after the barrier was finished. Four neighbors spoke in strong terms critically of the finished noise barrier. The criticism was about lack of noise reduction, loss of open views and difficult dialogue with the Road Directorate. Some neighbors also called into question whether there was any need for a noise barrier at all.

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2. THE NOISE BARRIER PROJECT

2.1 The road and the traffic

The residential area along the selected stretch of E45 in Frederikshavn consists of separate houses with different age and size. Most houses are single level with utilized attics. Along most of the route, the houses lie lower in the terrain than E45 – up to 4 meters. There are noise exposed dwellings on both sides of the E45 road. The Road Directorate has plans for noise barriers on both sides, but this first project only includes a barrier on the east side.

The average amount of traffic on the road is 15,500 vehicles per day (annual daily traffic). Approximately 13% of traffic consists of trucks and other heavy vehicles. The road has 4 lanes – two in each direction. The speed limit is 70 km/h. The E45 is the connection from south of Denmark to ferry lines from Frederikshavn to Norway and Sweden. This means that the southbound traffic in periods is extra intense when a ferry has arrived.

![Figure 1. The 750 meters long noise barrier along E45 (Europavej) in Frederikshavn. The Road Directorate consider the noise barrier (marked with a red line) as the first stage of an overall project that includes an extension to the south and a screen to the north on the west side of E45. There is currently no funding of these future noise barriers.]

2.2 The noise barrier design

The noise barrier is located along the east side of E45, immediately behind the crash barrier, and on top of the slope that exists between the housing in the first row of houses and the road space.

The screen has on the entire stretch of 750 meters a height of approximately 3.25 meters above the ground. The lower about 2 meters consist of elements built by two aluminum plates with mineral wool in the gap. The aluminum plate against the roadside is perforated making the barrier noise absorbing to avoid reflections of noise to the other side of the road. The barrier's roadside is for aesthetic reasons cladded with vertical strips of wood.

The top meter of the barrier consists of transparent elements made with acrylic panels mounted in an aluminium frame. This part of the design was incorporated into the project after requests by some of the residents to make the barriers look lower and to reduce shadow casting. The barrier elements are mounted on steel columns, which are aligned with a standard distance of 5 meters. The foundation consists of circular point foundations for the columns and horizontal concrete elements which forms the transition between the acoustic elements and the terrain. In four sections the full height of the barrier consists of transparent elements. The intention of these elements is to create a variation in the visual impact of the barriers and to introduce landmarks where intersecting roads and paths cross under the E45. The total budget for the project was 2.1 million euros.
Figure 2. The noise barrier seen from the road side.

Figure 3. The noise barrier seen from the dwellings. The barrier is located on the top of the slope along the road. The result is a construction with a top level up to 6 – 7 meters above the garden level.
2.3 Noise calculations

The traffic noise levels in the residential areas along the road were calculated without and with the noise barrier using the Nord2000 calculations model. This model is mandatory for planning purposes in Denmark. In Figure 10, the calculation results are shown as noise maps. Individual dwellings in the first row of houses on the east side of E45 were exposed to noise levels up to \( L_{\text{den}} \) 69 dB before the noise barrier was established.

![Noise calculations showing noise in the calculation area with and without the noise barrier.](image)

Figure 4.

Table 1 and Table 2 summarize the calculation result as numbers of dwellings exposed to different noise levels. The calculated levels are façade noise levels 1.5 meters above the ground and includes only dwellings in the calculation area shown on Figure 4. After the establishment of the screen none of these dwellings are exposed to noise levels above \( L_{\text{den}} \) 63 dB, and the number of affected dwellings (above \( L_{\text{den}} \) 58 dB) is reduced from 53 to 22. Most of the dwellings in the 1\(^{\text{st}}\) and 2\(^{\text{nd}}\) row of houses relative to Europavej have experienced a noise reduction between 2 and 4 dB. For 11 dwellings the noise has been reduced with more than 4 dB.
Table 1. Summary of affected dwellings. A dwelling is considered to be noise exposed if the noise level is above $L_{den}$ 58 dB which is the Danish guideline noise limit for new housing.

<table>
<thead>
<tr>
<th>Noise level at dwelling</th>
<th>Number of Dwellings Without Noise Barrier</th>
<th>Number of Dwellings With Noise Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 55 dB</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>55 – 58</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>58 – 63</td>
<td>47</td>
<td>22</td>
</tr>
<tr>
<td>63 – 68</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Above 68 dB</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Sum of noise exposed dwellings (above 58 dB)</td>
<td>53</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 2. Achieved noise reduction at dwellings

<table>
<thead>
<tr>
<th>Noise reduction, dB</th>
<th>Number of dwellings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1</td>
<td>10</td>
</tr>
<tr>
<td>1 – 2</td>
<td>17</td>
</tr>
<tr>
<td>2 – 3</td>
<td>35</td>
</tr>
<tr>
<td>3 – 4</td>
<td>29</td>
</tr>
<tr>
<td>4 – 5</td>
<td>7</td>
</tr>
<tr>
<td>More than 5</td>
<td>4</td>
</tr>
</tbody>
</table>

To summarize, the noise barrier has reduced road traffic noise in the residential area with typically 2 - 4 dB and the number of noise exposed dwellings is reduced from 53 to 22. At 11 dwellings the noise levels has been reduced with more than 4 dB. The highest levels of noise reduction have been achieved at the dwellings in the first row of houses closest to the E45.

3. DIALOG WITH NEIGHBOURS

The noise barrier project in Frederikshavn included a variety of information initiatives, including leaflets, letters, information meetings, individual meetings with residents and press releases.

2010/2011 : Governmental decision to provide funding for a noise barrier in Frederikshavn. The decision is briefly mentioned in local newspapers.

A short introduction to the project is published on the website of the Road Directorate and the project is mentioned a few times in local press with information on the specific location, barrier height etc.

January 2012 : The Road Directorate issues an information leaflet with information on the project; the political decision, general information on noise with facts about the barriers on E45 with design and location and traffic flow. The leaflet also includes visualizations based on the specific location.

All owners of dwellings in the area receive a letter with an invitation to an information meeting about the noise barrier. The meeting is also announced several times in local newspapers.

Approximately 30 people attend the meeting. The agenda includes a general presentation of the project, the barrier design and dimensions and the time schedule. It is announced that the Road Directorate will get into directed contact to all owners that are directly affected by the barrier. Many participants is raising questions on the height of the noise barrier, transparency, loss of open sight, shadow cast and maintenance of the barrier.
and the area between the barrier and the nearest gardens. Some neighbours prefer a lower and some a higher noise barrier. Some do not want a noise barrier at all.

February 2012: The Road Directorate visits all owners of dwellings in the first row along the road to inform and discuss individual issues.

March 2012: Letter to all owners of dwellings in the area with information on the issues that was raised at the information meeting.

May 2012: Letter to all owners of dwellings informing that the construction work will start in June. The letter also informs that the top 1 meter of the barrier will be transparent.

July 2012: Press release with information on the project.

Local newspapers bring stories based on the press release.

November 2012: Press release informing that the project is finished. The fine dialog and unproblematic cooperation with the neighbours is highlighted.

Local newspapers bring stories based on the press release.

December 2012: A local newspaper brings several critical articles on the noise barrier. Four neighbours are interviewed and cited for opinions like “It’s like living in a prison cell”, “East of the wall”, “The noise is not reduced”, “Our open view is now a wall”, “We have never been annoyed by the noise” and “The dialog with the Road Directorate was difficult”.

In general the dialog and information worked well, gave visibility, understanding of purpose and satisfaction with the project among many of the neighbours. It was the general impression of the project management that the project went quiet well and there were during planning and construction no indications that something was about to go wrong. Still, the need for an evaluation of the project came when the critical article appeared a few weeks after the barriers was finished.
4. EVALUATION OF THE COMMUNICATION PROCESS

4.1 Components of the evaluation

The evaluation of the project had the following main components:

1) Personal interviews with four neighbours including the most critical that were cited in the press coverage in December 2012. The aim was to get a direct insight into the project seen from the neighbouring side and ensure that all relevant issues were included in the subsequent questionnaire. The interviews were conducted in April 2012.

2) A questionnaire survey among the directly affected neighbours (see below).

3) A technical evaluation that examined the project's technical base and the solutions (see section 2.2 and 2.3).

4) An evaluation of the project's communication and dialogue through two workshops with key people from the Danish Road Directorate supported by Ramboll. The workshops discussed the total communication process, the results from the interviews, the questionnaire survey and the technical evaluation and how the whole communication process was experienced by the project management.

The conclusions, documentation and suggestions for future optimization and learning were finally presented in a report prepared by Ramboll. This paper is based on that report.

4.2 The questionnaire survey

The survey covered 42 properties. It was conducted in May 2012 and got 32 replies. It included questions on noise annoyance after the barrier was erected, the noise barrier design, information and dialog with the Road Directorate and it asked for proposal on how the Road Directorate can improve the processes in future noise barrier projects.

The questions concerning the perceived noise were designed in accordance with the Danish translation of ISO / TS 15666: 2003 Acoustics - Assessment of noise annoyance by means of social and socio-acoustic surveys.

The residents were asked how they experience road noise after the noise barrier has been erected. 6% are annoyed or disturbed by road traffic noise when they are inside their homes with the windows closed. 16% are annoyed or disturbed by road traffic noise when they are inside their homes with open windows. 19% of respondents are annoyed or disturbed by road traffic noise when they are outdoors at their home. 22% of respondents are in one or another situation annoyed or disturbed by road traffic noise at their residence.

To the question "How satisfied are you with the noise barrier?", the answers were: 22% very satisfied, 28% satisfied and 22% neither satisfied nor dissatisfied.

The neighbours who attended the information meeting in January 2012 were asked what they thought about the meeting. 89% were either satisfied or very satisfied with the professional presentations, the answers to their questions and information on the timetable for the construction of noise screen. To a question on the overall communication during the project 20% were very satisfied, 47% were satisfied, 13% were neither satisfied nor dissatisfied and 3% did not know.

As an addition, it can be mentioned that some of the participants in the personal interviews indicated that the "nice" side of the noise barrier (with wooden strips) faces the road and not the garden side. They also emphasize that the barrier on top of the slope appears very high. This means that some, but not all, is experiencing shade and a limited view. One resident, however, would like to have agreed to a 2 meters higher screen if it had led to more noise reduction. A resident noticed that the screen provides good shelter from the wind and less waste from the road is flying into the gardens.

During the interviews it also became clear that the most critical voice from the newspaper article had been predominantly positive towards the project. When he had contacted the newspaper, it was because he had been provoked by the wording of a press release from the Road Directorate stating the good cooperation with the neighbours. He decided that this conclusion should not go unchallenged.

4.3 Main conclusions of the evaluation

The overall evaluation shows, in line with the Road Directorate experience along the way that the project went well. In general the questionnaire survey shows that most of the residents are satisfied with the noise barrier and the communication and dialog during the planning and construction of the barrier. This demonstrates that there is no direct correlation between how the project was handled by
the project management and the critical articles by the end of the project. But the evaluation also shows
that in many ways it is possible to optimize the process and communication in the planning and
execution of future projects.

5. RECOMMENDATIONS

Based on the lessons learned from the project in Frederikshavn and from other similar projects, we
have developed recommendations on how to ensure that noise barrier projects along existing roads can
be a success also seen from the perspective of the neighbours.

Communication on construction projects is a special discipline that can be complicated and
demanding. Projects leading to permanent and significant changes of the environment close to peoples
home often leads to attention and scepticism among the neighbours who, regardless of the public
benefits the project can generate, will respond with a "not in my backyard". The construction phase can
be noisy and annoying. Also there can easily occurs a conflict between the "here and now" interests of
the present neighbours that inhabit the area and the authorities considerations on the needs of future
residents.

Since there is typically larger organizations or authorities behind construction projects, one gets
easily a perception that it is "the system against the little man," and you identify yourself immediately
with the neighbours that get their lives affected by a project. These factors mean that critical press
coverage can be difficult to avoid. Construction projects meet all the news criteria (timeliness,
importance, conflict, sensation and identification).

Although a noise barrier project is conceived as a project with obvious benefits for the neighbours,
it is still not obvious that necessarily all neighbours support a noise barrier and some might consider
the downsides of a barriers as more important than the noise reduction (e.g. shadow cast, loss of open
view, barrier effects, visual impact). This makes it evident that the responsible authorities must be
clear in their communication on why the project is being implemented.

Neighbours of a future planned noise barrier often have a number of questions: Where exactly will
it be located? Will it remove all the noise? How will it look? Will it take the open view? Who will
maintain the screen and the area on both sides? Why is the barrier planned for this location – are you
going to send more traffic in this direction? Who is behind? What happens during construction? How
long does it take? It is important to be able to come up with clear answers, but it is also through
listening and asking the neighbours that you can get detailed information on the local conditions
information that may ultimately help to create better planning and better projects.

5.1 The academic arguments

It is complex and not clearly positive information to be disseminated, if you want to make it
absolutely clear what the purpose of a noise barrier is. The communication is complicated by the fact
that there are both political and health arguments for the project.

During the early information meeting in January 2012, when the design of the barrier was initiated,
the attending neighbours were presented to the project and the Government Agreement "A Green
Transport Policy" that had let to a governmental decision to erect this noise barrier. This was the basic
reason for the project that was presented to the neighbours, but the very reason why it is important to
reduce noise, such as annoyance and health consequences for present and future residents, did not
stand out clear in the information. One would expect that the plan for a noise barrier is good news for
all residents, but the focus neighbours brought about at the first information meeting was not primarily
on noise, but on how the barrier would affect open views, shadow cast and how the area between the
barrier and the first row of gardens will be maintained and cleaned from garbage. This was a good
example of the fact that the neighbours’ interests are different and individual and not necessarily
focussed on noise. The Road Directorate responded to the requests by changing the barrier design to
include more transparent elements.

5.2 The first information

The local debate about a possible noise barrier is often started long before the project team is set.
Already when political decisions are made on funding of a noise barrier or when the first technical
surveys begins, there will be a public awareness in the local media.

Therefore it is important when the project starts to be aware of the publicity that has been there
already and to consider the expectations that have already been created among the neighbours. To
avoid misunderstandings, it is a good idea to inform early in the process and explain the scope of the
project. Here you have to shed light on who is working with the project, where we are in the process, what we know at this stage and what we can only say something about later in the process.

A web site with updated, reliable information can be a good basis for a proactive information effort that can be combined with articles in the local press and direct letters to the affected neighbours. By making yourself visible as responsible for planning of the noise barrier and telling where you are in the process, you can establish yourself as a reliable source that the press and other local stakeholders can contact. Thus you can quickly lay myths to rest and save many resources in the long run.

5.3 Who should you aim your communication at?

How do we define the target group for a noise barrier project - and how far away from the project area, for instance, should you live to be considered as a neighbour? Who should consequently receive information material? Tenants? Owners? The directly affected neighbours are a key target group for information. Neighbours in the 2nd and 3rd row of houses will often also be interested in gaining knowledge about the project. It is therefore important to uncover how far away from the road you will extend your communication when you send materials, invites to information meetings etc. Look on a map, ask people with local knowledge, and be sure to check that the address lists are updated so that not only owners but also tenants get information. Be aware that other users of the site can also be important targets for information, for instance a school or another institution or a company in the area.

There may also be residents on the opposite side of the road, which may have questions about the influence of open view, light reflections or noise reflected from the noise barrier.

5.4 What should the information and dialogue include?

A "Frequent Questions and Answers" (FAQ) is an easy and useful tool that can prepare the project organization to proactively handle the information and dialogue process. Preparation of a good and comprehensive FAQ can be based on the following:

- Sit with key people who know the problem and stakeholder issues, preferably from different angles
- Look at the project and other similar projects. What questions will appear? Which issues will people be most interested in? Make sure to provide good and adequate responses.
- Be thorough and critical. Discuss each question and answer, and think about what other questions they may lead to.
- Give the FAQ an introduction with a purpose, which is based on the specific project and send it around the entire project organization.

The FAQ can be used on the project website and at information meetings as background information for press relations etc. and it should be updated as the project progresses.

Issues that usually will need answers are:

- The noise barrier dimensions (height, length, position)
- The noise reducing effect of the barrier and how it will be perceived
- Appearance of the barrier – not at least on the side facing the neighbours
- Shadow casting and transparency
- Location, especially compared to the neighbours' own property boundaries
- Plans for removal of existing vegetation and possible replanting
- Conditions for use of any roadside area that will end up lying between the barrier and the nearest properties (who will take care of maintenance, can the neighbours use this area?)
- Rules for use of the noise barrier side facing the neighbours
- Rules for road authority access to the noise barriers side facing the neighbours
• Openings for foot paths and bicycle lanes (can ease traffic, but also open access for outsiders, mopeds etc. and it can affect the feeling of safety in the area)

• Neighbours on the opposite side of the road will typically have an interest in the appearance of the barrier as well as the risk of reflected noise and light.

5.5 Use illustrations and sound examples

The best way to explain the coming changes in the physical environment is to support the technical explanations with examples that are based on the current location. Sketches or photo visualizations showing how the noise barrier will look from the neighbouring side and the roadside are good tools. One can also make a simple height marker on a neighbour's property, for example, a mark on a lamppost, which shows how high the barrier will be. One should remember that the neighbours will be more interested in noise barrier's appearance from the neighbouring side than from the roadside.

Through a number of projects there has been achieved good experience with the use of listening examples (auralisations) illustrating the noise with and without a noise barrier. It can increase credibility if the examples are based on sound recordings from the local area that are processed to fit the purpose. Listening examples are a good way to convey how a noise barrier reduces noise but do not remove the noise. It will still be possible to hear the vehicles on the road, just not as strongly as before.

Noise is perceived differently, and different people will have different views on how annoying road noise is. Therefore it must be expected that often the neighbours to a noise barrier project will have different views on how important it is that the project is implemented.

As road traffic noise is not only a matter of annoyance but also has potential health effects it is important that this information is included in the information to the neighbours.

5.6 The dialogue at information meetings

In order to provide reassurance about the project, it is often necessary to work with a combination of meetings, direct letters and visits to individual properties. From the start there will be a need for clear and precise answers to residents' questions. There should be paid great importance on providing technical information on the noise reducing effect of the noise barrier and to make sure that residents' expectations are aligned with the noise reduction that will be achieved. As an example, the effect of the noise barrier is not the same in the first and second row of houses.

An open information meeting for all neighbours is a good way to present the project and the neighbours' diverse interests and concerns can come forward and be heard. Smaller groups, such as the board of homeowners can more easily be informed by direct contact.

It is recommended to make notes of all requests or proposals from concerned neighbours already at the first meetings to ensure that they, if possible, can be implemented in the project. At the same time these meeting are useful to uncover information on local conditions that could influence the project's design and processes.

5.7 What can you influence?

When neighbours are invited to an information meeting there will be many different opinions and concerns among the participants, and it will often be expected that it is possible to influence the project. To ensure a good dialogue it is therefore important to explain what part of the project that has been decided finally and where there are possibilities for compromises on the exact location of the noise barrier or on the detailed design.

In this process, the road authority must be aware of its responsibility to achieve a good solution with the necessary noise reduction and fulfilling the visual and aesthetic requirements, with respect to both present and future residents. The road authority must ensure the overall interest in reducing noise exposure of residential areas, including the interests of future residents.

The questions asked by the neighbours during information meetings will typically be both within and outside the project. It creates credibility to be able to respond to what interests people have. It is therefore recommended to be well prepared also by including other disciplines, for instance the department that will maintain the noise barrier.

5.8 Information during construction

The construction phase is the period where there are the greatest changes in the neighbours' physical environment. For this reason there is a need for ongoing, detailed information about the time
schedule; start and finish of each stage of construction, delays and possible nuisances (noise, dust, heavy machinery etc.) The ability to provide unambiguous information is dependent on good internal communication between planners, contractors and operations departments. The information can be sent out through newsletters, notices in local newspapers and on the project website. Consider when the information should go into each medium, which target groups to be given priority in the individual phases of the project, and how the choice of media best serves the purpose. Generally, it is important to inform early and possibly several times on the same subject. During the whole process, special attention should be paid to the need for information from and to the neighbours who are directly affected by the construction work.

5.9 When the noise barrier is finished

The final noise barrier is often the result of a long process that has led to major changes in the neighbours' physical environment and which, in addition to a long-term construction work, has included information and dialogue with a variety of target groups. Therefore, it may be a good idea to end the project with a press release and/or a letter to the neighbours. Be aware not to set success criteria for the project, which is not consistent with the neighbour's experience. Relate to the overall objectives and thank the neighbours for their patience. As we do for your patience in reading this paper.

REFERENCES