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CHALLENGES FOR THE SUSTAINABLE DEVELOPMENT OF ROAD SYSTEMS

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ABSTRACT

The report discusses 5 major issues of importance for planning and design of national roads in Denmark during recent years: (a) interaction with landscape and with spatial planning in neighbouring areas; (b) consulting and informing the public of road projects; (c) effects of fauna passages of motorways; (d) the Nordic prediction method for road traffic noise; (e) test of thin pavements for noise reduction.

a. Danish motorway planning is indebted to international traditions for aesthetics and external harmony with the landscape. This tradition and its architectonic visions are challenged by metropolitanisation and commercial constructions intruding on the motorway vicinity. There is an urgent need for new guidelines for the spatial planning in areas bordering and neighbouring the motorways of the future.

b. The consultation of the public and NGOs in the environmental impact assessment (EIA) phase of road projects is a demanding and expensive, but very rewarding activity that involves hearings, public meetings with large attendance and topic-dependent group involvement in the evaluation of impacts. The paradigm for this element of road projects is routinely evaluated and developed.

c. The use of fauna passages in road design has developed significantly in recent years. A study on the usage of various types of underpasses and overpasses for the fauna shows distinct differences that may be related to types, dimensions, locations and animal species. Overpasses seem very suitable to serve major mammals, such as roe.

d. The upgraded Nord2000 model is used by Denmark and the other Nordic countries to calculate the sound pressure at any point in the vicinity of well-defined sources of traffic noise. In consonance with the European “Harmonoise” project it separates tyre/road noise and propulsion noise. The propagation model allows for variations in ground type, terrain shape and weather. Calculations are facilitated by standard inputs for so-called type cases.

e. In joint research with the Dutch Road Administration (RWW) Denmark is testing the noise reductions from several types of thin surface pavements on a high-traffic motorway in suburban Copenhagen. Main measurements are based on the “Statistical Pass-By” method, while surface developments are monitored on surface texture as well as friction.

1. THE CITY, THE ROAD AND THE LANDSCAPE

1.1. Danish Motorway - Roads to the future

In 1995 the Danish Road Directorate formulated the “Strategy for Beautiful Roads” to focus on problems in the relationship between the road and its surroundings both in the cities and in open land.

The purpose of the project and this research project “The City, the Road and the Landscape” are to develop a spatial strategy and an architectonic vision for the future planning of the Danish motorway network and its interaction with the landscape and the city. This is based upon analyses of commuting along with investigations of the landscape and the urban areas.

Motorways have a potential for transport and visual benefits which attracts urban development and the placing of commercial and industrial activities. Given this, the design of the road and the planning of the neighbouring areas should be undertaken with a broader perspective and be seen as a deliberate chosen unity.

The starting point for this project is a Dutch investigation for Rijkswaterstaat “A room with a view”. The investigation elaborates on a strategy for developing travel routes instead of random and unplanned motorway sections with neighbouring areas. In the strategy the motorway is divided into different archetypes, an idea the present project “The City, the Road and the Landscape” has adopted. Three archetypes, or ways to see the motorway, have been developed and these give the framework for a strategy to discuss the future development of the Danish motorway.

Previously, the Danish have not undertaken any analyses on the consequences of motorway construction on the development of urban areas or on the landscape along the motorway and its interrelation with the road.

1.2. Traditions under pressure

Motorways are a part of modern Denmark and the 1000 km of motorway are a product of landscape considerations and architectonic finish. Therefore, the motorways represent a trace of culture where both the geometry and the external harmony with the landscape are of great importance.

The biggest part of the Danish motorway network by far has been planned to be situated in an open landscape. Based upon the German and the American planning traditions the motorways have been developed by considering their aesthetics through the landscape. This aesthetic is based upon the goal of creating internal and external harmony when driving on the motorway and in the perception of the landscape.

The legacy from the American and German motorway traditions is significant. The geometry and the alignment are decided upon with soft curves adjusted to the view and scale of the landscape.

Primarily the function-based aesthetic behind the detailed planning of the Danish motorway network has, with the participation of aesthetic consultants, architects and landscape architects resulted in many road sections having a very harmonic alignment. The roads go through the landscape in a unique visual interconnectedness between the motorway and the landscape.

The relationship between the motorway and the Danish landscape is a product of careful planning of the alignment based upon the scenic ideals of visualising the cultivated land to the driver. In areas with special landscape qualities the alignment of the motorway has been planned taking into consideration the perception of the landscape.

This has given the drivers some precious landscape experiences which have importance as land marks or points of orientations on the journey. In the detailed alignment and the design of the cross sections the visual contact to edges of woods, hedges, property lines and grave mounds has been considered carefully. This creates variation and a rhythmic perception of the landscape.

Over time different types of cross sections have been developed with optimised centre strip, cultivated slopes and flat troughs. A careful design has been made of the elements of the cross section of the motorway taking into consideration safety, passability, sight conditions and landscape aesthetics which have been united in design principles.

Today with the knowledge of these elements it is possible to time set motorway sections. The motorway with its size and alignment has become a significant element in the cultural landscape and represents at this stage of time an important contribution to the cultural environment of the open landscape.

In the open cultivated land the considerations to the agricultural sector has resulted in only the least possible area of land being used in the building of the road. Therefore the use of planting along the road has been reduced to almost only include the motorway embankments. The consequences of the construction works have not always left the best conditions for planting and this can be noticed in later years. Ideally the intended function of the planting has been to fit in the motorway to the surrounding landscape, screen the road from the landscape and create a frame of the road environment to optimise driver perception of the cinematic course and the rhythmic perception of the landscape.

1.3. The effect of motorways

During the last 20 years from 1982-2002 the Danish motorway network has been extended by approximately 80 %. From being isolated motorway sections around the biggest cities the motorways in Denmark today have developed into a national network.

Several measures indicate that the motorways have changed the conditions and also the development of the areas that they pass through.

During the last 20 years the number of commuters has increased along with a considerable increase in the distances they are prepared to travel, particularly in the transport corridors where the motorway network has been extended. The tendency is that the urban areas have been integrated and now form a functional community. People no longer commute to the nearest big city, but crisscross over bigger distances which has been made possible by the motorway network.

The question arises as to whether the still growing urban areas between the previous separated functional cities also will develop into coherent communities? A tendency shown is that the shorter travelling time, which is a result of the motorways, means that the commuters travel on the motorway network over a longer distance. Also, it seems as if the motorway has not only influenced the travelling time but also is an important factor for the choice of people’s residence. The commuting from residential areas close to a motorway

has increased along with demand for these areas and probably contributing to the new building of residential areas close to the motorway network.

A consequence of this tendency might be that the character of the motorway changes from being a high class road network for drivers travelling from one part of the country to another, to a traffic machine serving the big cities.

It is also possible to trace a tendency of the fact that the urban development between the big cities takes place within the existing transport corridors close to the motorways. Considering this from an overall level it is only possible to talk about tendencies in the development at this stage of time. If more detailed focus is put on the location of commercial development and the growth in employment within the municipalities and local areas where a motorway passes through, there is a significant tendency of constructing more commercial buildings in the areas closest to the motorway. It is particularly areas within a distance of 1 km from the motorway network which experience a big growth in the construction of commercial buildings.

Considering development at a local level it is often the case that the opening of a motorway is followed by a relocation of commercial buildings in the cities that the motorway passes through; the commercial buildings are moved to locations between the city and the motorway. The reasons can be due to both the area planning of the municipality or the desire of a company to be visible from the motorway and make access easier.

Additionally, this tendency puts into focus that there should be sufficient connection or relation between the planning considerations regarding the design of the motorway and the considerations of area planning.

1.4. Motorways in the future

Motorways in the future deal with the classic motorway, but also include paragraphs regarding the interaction of the motorway with the suburbs, industrial areas of the city and the city itself.

The classic motorway is thought of as a road for travelling through open land, planned with a rhythmic course, where the goal is a balance between monotony and experience.

The ideal is a route with enough variety that it maintains the attention of the driver, but at the same time presents the landscape around the motorway in a beautiful, almost cinematic, way. With this idea as a starting point, the base for the alignment of several well considered beautiful and harmonic road sections in the Danish cultural landscape has been founded.

However the classic motorway is very vulnerable to changes which take place in a dynamic society. The surroundings of the motorway close to the bigger urban areas change at a pace of almost explosive character. The industrial areas grow rapidly in what is almost a random growth. The suburbs move closer to the motorway with flags and posters, the cities come closer to the motorway with demands of noise barriers meanwhile the delimitation of the motorway and its near surroundings becomes occupied. This development increases the demands on the architectonic design of the road and challenges the overall architectonic planning, not just the planning of the road.

The classic motorway which, as an archetype, could be described as the golden age road is the basis for the majority of the Danish motorway network. In open land it will still be the way of constructing motorways in the future. The golden age road contains qualities that should be cherished and some should be developed further.

Around cities and suburbs the motorway can be described as archetype urban motorway or the trucker path. These particular archetypes and the challenges related to the interaction between the road, the city and the landscape are the main topics of this part of the book. Suggestions to the future development and adaptation of the urban motorway or the trucker path have been presented. This is with respect to the classic motorway and its principles. The motto is “We build to keep clear” which means that based upon local analyses and planning, special areas are selected for the development of buildings / construction and other activities close to the motorway and its encounter with the landscape. The potential of using spare areas which arise from the encounter between the motorway and the city is analysed. These are redundant areas which occurred randomly or were planned as areas free of construction. How can these spare areas be used and become attractive and valuable places related to the city?

Focus is also put on the challenge of how commercial and other building enclaves can be developed in an interactive way with the trucker path. How can we plan and develop enclaves of great architectonic quality which can generate a continued growth in society? We in Denmark are not alone in these considerations and challenges. There are several European examples of active and visionary infrastructure planning and development. In several places it has been seen that it is based on how to influence in a broad sense and the development of cooperation between private and public players.

1.5. Visions and challenges

For many years in Denmark it has been the intention to secure and to protect the nature and the perception of the landscape when new motorways have been constructed. It should be easy to find one's bearings on the journey, it should be safe to drive on the motorways and the hundreds of thousands of drivers should every day be able to enjoy the Danish landscape.

Today these values and this inheritance have been threatened considerably by the development illustrated in this book.

Denmark has a tradition of coherent planning both in urban areas and in open land. This has been necessary due to the limited size of the country and because there has been a wish to protect the landscape, the qualities of the cities and to assure a dynamic and viable development.

It has become more common to commute and the industrial / commercial sectors in Denmark have got a greater interest in a location closer to the motorway both due to recruitment of personnel, distribution of goods and profiling with great visibility to all drivers on the motorway.

To a greater extent the urban communities are integrated in regional urban areas and the limits between city and land are becoming more difficult to define. This takes place at such a pace and to such an extent that one can talk about a qualitative jump. In international research this development in direction of “boundlessness“ is described as “metropolitanisation”.

The research project “The City, the Road and the Landscape” has surveyed how buildings are almost attracted to the motorway and how the motorway affects the planning of new residential areas in the cities.

The project has also presented different visions on how it will be possible to meet the needs of the modern society in the future regarding passability and how to fulfil the needs of the industrial / commercial sector while simultaneously the Danish golden age landscape is maintained for future generations.

The values are described along with the development, but the future chapters of the development are not described. It should be discussed and debated how the future administration of the landscape close to the motorways should be organised considering the interests of the municipalities close to motorways, the drivers, business and the cultural environment.

The development proceeds at a fast pace – let the debate and the qualified planning do the same!

2. PUBLIC PARTICIPATION/CONSULTING IN ROAD PROJECTS IN DENMARK

As the road administrator of the trunk road network the Danish Road Directorate plans and constructs major as well as smaller new roads with a view to improving the environment, traffic safety and passability. The larger new road building projects include new road links, by-passes and capacity improvements for existing roads together with other larger construction works. The smaller road projects cover a large range of works with the primary aim of improving traffic safety and the environment.

Today the challenges particularly involve solutions to solve the capacity problems on existing roads near the larger cities in Denmark – areas with dense population. In accordance with the overall political objectives for traffic and the environment, the Danish Road Directorate works actively to develop the Danish transport sector towards environmental sustainability. To achieve this goal The Danish Road Directorate in cooperation with authorities in- and outside Denmark, citizens and other stakeholders in the areas of transport and the environment, participates in furthering environmental-friendly, safe and efficient transport solutions. The Danish Road Directorate also involves environmental considerations in management decisions at all levels in its work and motivates and trains employees to act in accordance with its environment policy and strives to prevent and minimise the negative environmental impact of the road infrastructure on people and nature. The Danish Road Directorate communicates openly on its environmental policy, environmental impacts of the activities and its ongoing efforts on behalf of the environment.

Due to the Aarhus-convention and the EIA directive the public are consulted about the environmental aspects during the various stages of developing, planning, designing, constructing and maintaining/extending roads.

Figure 1 - Capacity problems on a motorway near Copenhagen

2.1. Phases in major road projects

Typically many years will pass from the first ideas of a major infrastructure project until the project is decided and built. A project is normally characterized by the following phases:

- Feasibility study
- Designing phase – EIA planning phase
- Detail planning/designing phase
- Construction phase
- Opening

The rules on environmental assessment in the Planning Act comprise Denmark's implementation of the EU directive about EIA. However for the larger state road projects the rules are different.

The EU EIA Directive, article 1(5) states that the Directive shall not apply to projects of which are adopted by a specific act of national legislation, since the objectives of this Directive, including that of supplying information, are achieved through the legislative process.

The minor roads are planned according to the Planning Act.

Before a larger state road project can be implemented the Danish parliament passes construction acts for the majority of large road constructions. These types of projects are financed in the annual state budget as project appropriations. Because the large state roads are adopted by a construction act, the Directive does not apply to these projects. However the objectives in the Directive are achieved through the environmental assessment process and the legislative process.

The consulting of the public is to a great extent similar to the projects adopted through the Planning Act but still there are some essential differences.

In this passage focus is on the public involvement during the EIA phase, when the Danish Road Directorate plans and designs the larger state roads.

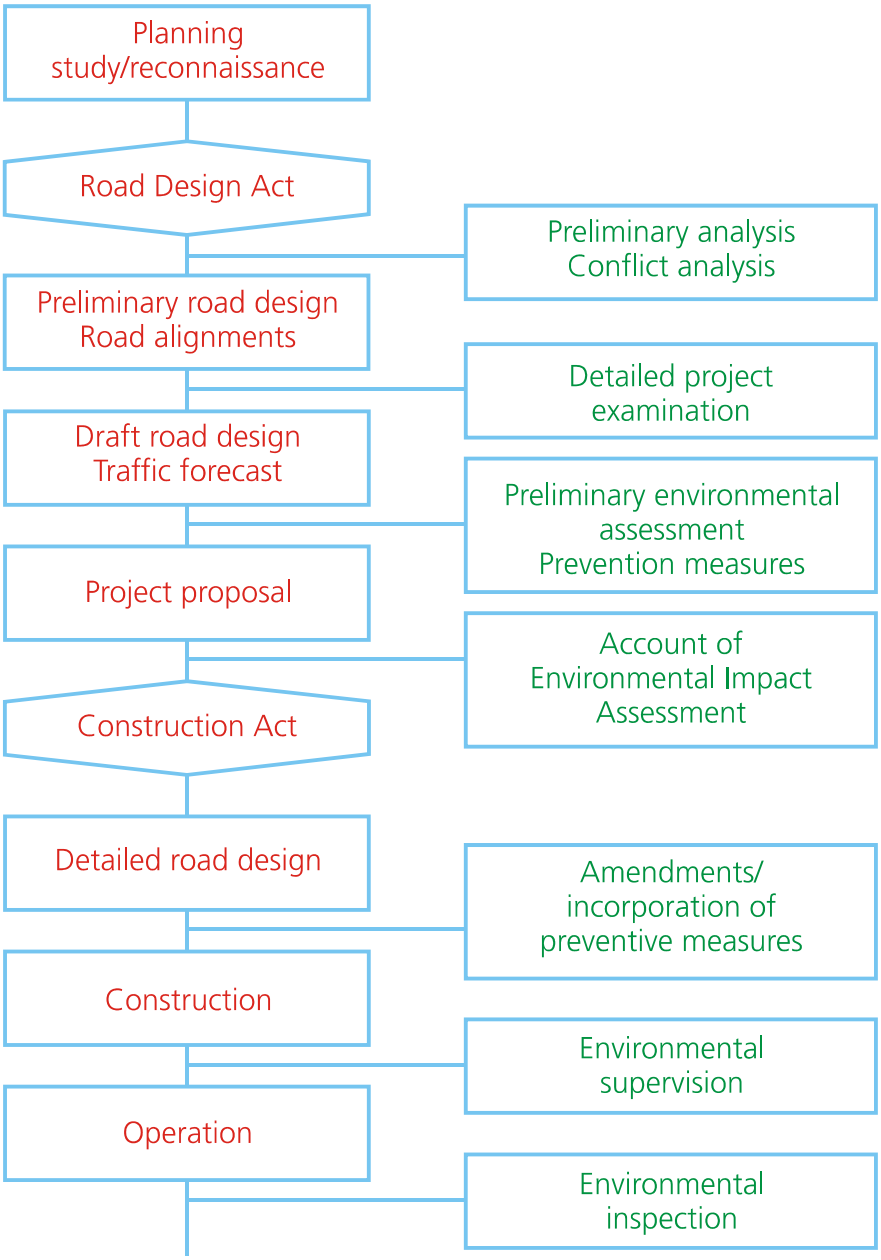

Figure 2 - The different phases and the decision process – Larger state road projects adopted by a specific act

An EIA (Environmental Impact Assessment) including public hearing etc. on the road project, is carried out in connection with the design and planning phase of the project and before a proposed Act of Construction is presented in the parliament.

2.2. The EIA planning and design phase

As the EIA process is started a committee is set up. In the committee the local authorities as well as regional authorities are represented. Furthermore representatives from the Ministry of Environment are present in the committee. The purpose of the committee is to ensure a proper local and regional consulting while carrying out the EIA and also to ensure that matters concerning especially nature, habitats and culture heritage are examined properly.

Previously the public as a whole was - and still is - consulted in the EIA process due to the two public hearings:

- An initial hearing – public announcement of project proposals (a period of minimum 4 weeks) where a calling up of ideas and suggestions for the project in question is made and
- a second hearing – public consultation (a period of minimum 8 weeks) where the project in question is presented and where the public can make comments.

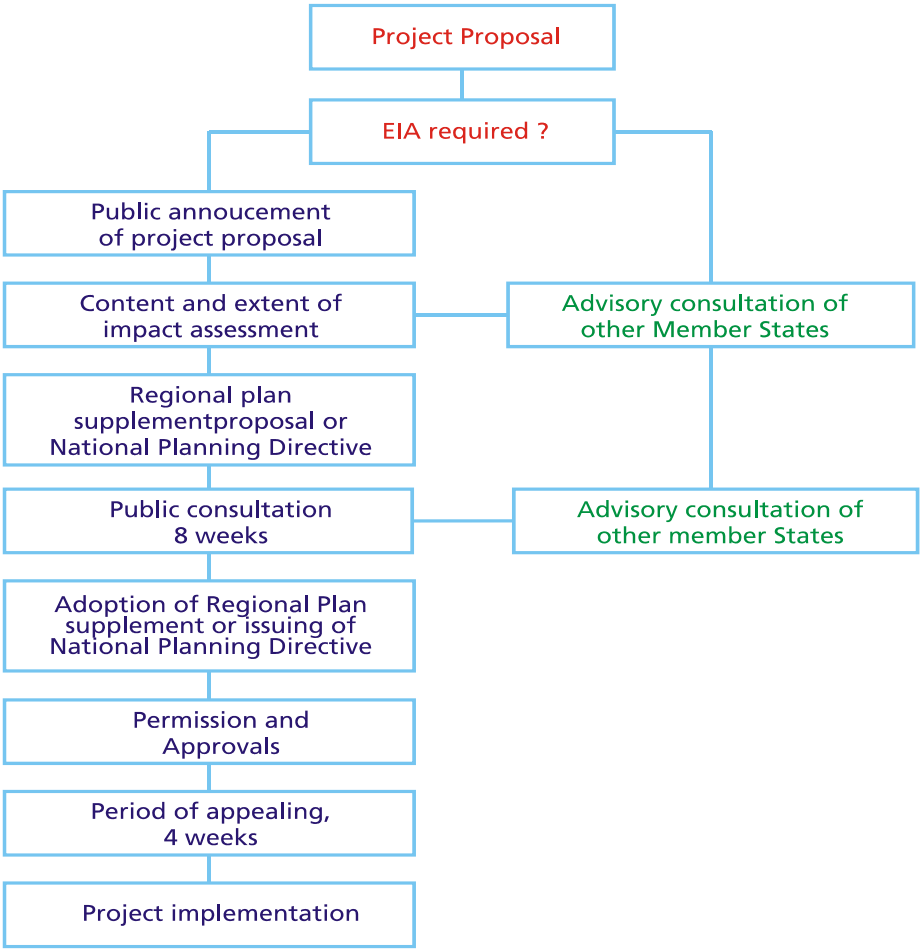

Figure 3 - Consulting the public during the EIA process according the Planning Act

These hearings are attended by public meetings held in the local area by the Danish Road Directorate. These meetings are very popular and many citizens, neighbours and road users attend actively. In connection with the public meetings the Danish Road Directorate makes an exhibition of the actual project. In the initial hearing a publication that debates the road plans is send out in beforehand. At the second public hearing the Danish Road

Directorate issues the EIA reports. The EIA reports describe the project and alternatives and the assessment of the environmental impacts. The EIA reports are also available on the internet as well as they are handed out in printed editions or CD-ROMs at libraries, city halls etc.

The most appropriate is that the public meetings are held without participation from the political level. In this way the purpose and the subject of the meeting is clear – it is the actual plan and road project that is for discussion, not different local political matters.

The meetings are normally divided into three parts:

- A presentation of purpose of the meeting and the project including a clarification how the individual can influence the project and process.
- A break with possibility to watch the exhibition about the project
- Discussion and questions to clarify the project.

Depending on the actual EIA project and the area where the project is located 100 to 1000 people participate in each public meeting.

Figure 4 - Public meeting

In the recent years The Danish Road Directorate furthermore has invited the most interested parties/groups as neighbours, NGO's etc. to participate in the EIA process. The most interested parties are organised and involved in different ways dependent on which interest the specific group may have (traffic, nature, actual suggestion to the project in question etc.) not only in connection with the public hearings, but also during the establishment of the basis on which the evaluation of impacts are made as well as the design of the road project.

The purpose of forming these groups is to improve the public involvement so that it is made at the right time in the beginning and during the design of the project and not when the EIA-reports have been finish and made public. These groups also contribute to ensure that valuable knowledge about the specific local area is established and they can supply their support base with information about the road project.

The consulting of the public is important and necessary to qualify the basis upon which the assessments are made and also to ensure that all relevant alternatives have been examined. However the actual assessment of the environmental impacts of road projects is the responsibility of the Danish Road Directorate.

To ensure consensus about the purpose of these groups, a paper is made describing the task for each group, the expected activities, responsibilities and role of the group. The paper is approved by the Danish Road Directorate as well as the NGO members in the group.

As a result of the public participation extra relevant alternatives have been included in the EIA made by the Danish Road Directorate. In one project an alterative proposed in the public hearing actually became the preferable alternative, which formed the basis for an act of construction that passed the parliament.

Involving local NGO's also has the benefit that it has been possible to optimise e.g. the field investigations with reference to map the different species of fauna and flora to take into account while planning the road project.

The public participation improves the EIA-process but it also requires many resources for meetings, seminars, publications with information about the project e.g. Typically expenses concerning public participation amount to 5-10% of the total budget for the planning phase for the large road projects in Denmark.

The efforts involving the public in the EIA of road projects is a benefit to both the actual project and to the process. It is however not enough to prevent that opponents of the road project may delay the decision-making process if they want.

2.3. Appeals

Projects that are permitted due to the EIA process according to the Act of Planning and the regional/municipal plans can be appealed within 4 weeks after the permit has been issued.

When planning larger state roads The Danish Road Directorate makes a recommendation – based on the EIA and the results from the public hearing (White book) – to the Minister of Transportation and Energy.

The Minister of Transportation and Energy now may carry out a draft Bill for a Construction Act for the road project. By allowing experts as well as representatives of interest groups to take part in the meetings of the committee in question, one makes sure that all problems are taken into consideration in the Bill.

The Minister of Transportation and Energy presents a bill to Parliament regarding an act on road construction. During the reading of the bill – three readings must be done before the parliament can adopt the act - the public may contact the committee that reads the bill and through the committee ask question to the Minister about the bill. Based upon the answers to the possible questions the bill is discussed and amendments are often made

before eventually adopting the entire Bill at the third reading. Hereafter there is no possibility to appeal the decision to construct the road within the Danish legislation.

2.4. Questionnaire about the quality of the public participation

To improve the public participation/consulting in road projects the Danish Road Directorate frequently asks the opinion of the public about the process and quality of the public participation at different phases in the road projects.

The latest questionnaires in connection with an EIA process in the Danish Road Directorate have resulted in the following proposals to improve the public participation:

- The EIA reports made by the Danish Road Directorate get very high scores from the public. However the reports are very extensive and often include several hundred pages of detailed descriptions and evaluations of the project and the environmental impacts. Therefore the Danish Road Directorate now issues an easily read short version as e.g. a kind of news paper as a supplement to the EIA report and the non-technical resume of the EIA.

- Half of the questioned people answered that they had got their information about the actual project from the EIA reports and the other half got the information from the public meetings. Hence reports as well as public meetings are considered as necessary means in the public participation.

- It is important to spend enough time at the public meetings for the discussion and the questions to clarify the project – at least as much time as spend for the presentation of the project. Do not use technical language and terms.

- The announcement of the public hearings and meetings should - besides writing directly to the most interested parties (neighbours, NGO's e.g.) - be made on several occasions in beforehand. With advantage the announcement can be made in local newspapers and in connection with other general frequently read information from the municipal.

- It is important to clarify in beforehand what subjects are to debate

- Even if stated in announcements and reports it is important at the public meetings to clarify how, to whom and when the public can influence and make comments about the project.

2.5. Visualizing of the projects as a part of the public participation

Visualizing of the projects has appeared to be a very preferable way to give the public an idea of the dimension and character of the actual project. Also the decision-makers prefer and ask for visualizing of the projects.

The Danish Road Directorate has used visualizing for many years, and now the project normally are also simulated by films in the planning and EIA phase.

The simulations on the Internet are characterized with some limitations due to the requirements of the capacity of the computer. So far the simulations therefore as a supplement are handed out on CD-ROMs with the EIA reports.

Figure 5 - Motorway M3 today and after extension and with new noise screens.

3. A BIOLOGICAL ASSESSMENT ON PLACEMENT AND EFFECT OF FAUNA PASSAGES OVER AND UNDER THE MOTORWAYS IN NORTHERN JUTLAND, DENMARK.

Transport infrastructure acts as barriers, often preventing freely migration of the wildlife in the landscape. When animals are crossing an arterial road e.g. a motorway, there is a risk of collision with vehicles. Establishment of fauna passages can be a mean to avoid collisions. Their placement in accordance with the landscape structures on arterial roads has so far followed the general guidelines worked out by the Danish Road Directorate in cooperation with the Danish Forest and Nature Agency and the National Environmental Research Institute in Denmark (NERI).

The establishment of fauna passages has raised several questions about the placement and effect: 1) Do the fauna passages function as planned, i.e. are they placed in the landscape where the various animal species easily find them? 2) Are the surroundings of the fauna passages made in a way that the animals actually are led to the entrances of the fauna passages? 3) Are the fauna passages designed and dimensioned in a way that the needs for mobility of water-living as well as terrestrial-living animals are fulfilled, and 4) Which animal species in the surroundings actually do or do not use the passage?

The Road Directorate has requested the NERI to perform an investigation and a follow-up assessment on placement and effect of fauna passages at the motorways in Northern Jutland.

3.1. Criteria for assessment

The National Environmental Research Institute has selected 11 fauna passages from the following criteria in order to ensure that all the types of construction are represented:

- Dry underpass
- Wet underpass
- Overpass
- Dimensioning
- Design
- Suitability of field studies throughout the year
- The location of the passages related to driving distances at the field studies.

The field studies were carried out throughout a year from 1st of June 2005 to 31st May 2006.

Establishment of fauna passages at other motorway sections in Denmark has given much experience on the development of design, dimensioning and adaptation of fauna passages. The experience was brought into use when planning the 39 fauna passages at the motorway section in Northern Jutland. Their establishment took place from 1996 to 2001.

3.2. New generation of fauna passages

The first types of fauna passages were pipeline constructions with a pipe dimension as broad as the watercourse in order to ensure free passage of water and water-living animals. However, many terrestrial-living animal species, especially mammals, use the watercourses and lines in the surroundings as corridors for dispersal and movement in the landscape. Thus, the fauna passages are now constructed with man-made banks, so-called banquettes, between the water body and the wall of the fauna passage. The height of the pipe varies with the distance from the wall which implies that the adaptation of some banks is not always optimal, especially for larger mammal species, primarily roe deer. A banquet designed with a plane surface that is dry all the year along the pipe wall and a slope towards the watercourse fulfils the need of various species (Figure 6).

Figure 6 - Wet underpass. The fauna passage has been constructed with banquettes on each side of the watercourse. The banquettes have plane surface at the top and sloping sides towards the water.

Experience on the needs of different animal species have caused in alterations of the construction of the fauna passage profile. When fauna passages are established the design is now either a rectangular or square profile. Furthermore, the banquettes are constructed with a height that the plane surface is not flooded by normal water level in the watercourse. The sides of the banquettes are sloping towards the water surface and often strengthened with e.g. stones in order to avoid erosion. This concept – called the wet underpass – provides the basic fauna passage design at watercourses at the motorways in Northern Jutland (Figure 6).

Moreover, fauna passages have been established on terrestrial locations where it is presumed that animal species occur and move frequently in the landscape, e.g. in connection with hedgerows, dikes, and fences. On such locations dry underpasses have been established and like the wet underpasses, the design is either rectangular or square dependent on the surroundings (Figure 7).

Figure 7 - Dry underpass with the closest entrance opening into an artificial depression as the road surface of the motor way is constructed in level with the surroundings.

Figure 8 - The overpass at Jyske Ås, Northern Jutland. The road surface is cut into the landscape so the upper surface of the overpass is in level with the surroundings.

A new type of fauna passages, namely the overpass, was introduced in Denmark when the motor way was cut through the wooded ridge 'Jyske Ås' (Figure 8). Overpasses are established where forest areas and other important corridors are met by road constructions. The overpass is placed at the same level as the surroundings and facilitates the crossing of the road construction for most mammal species. The establishment of overpasses is possible on locations where the road surface is already lower than the surroundings or where the road surface can be lowered under ground level.

Besides at Jyske Ås another overpass has been established at the motorway section Århus - Låsby west of Århus (Figure 9). More overpasses are under construction at other motorway sections in Denmark.

Figure 9 - Overpass at the motorway Århus - Låsby, Middle Jutland.

3.3. Many species of animals use the fauna passages

26 species of mammals are recorded in Northern Jutland. Except from *Sciurus vulgaris* and *Cervus elphus* all species were recorded in one or more of the studied fauna passages (table 1).

SPECIES	NORTHERN JUTLAND	DRY PASSAGE	WET PASSAGE	OVER-PASS
Microtus agrestis	X	X	X	X
Micromys minutus	X	X	X	X
Apodemus flavicollis	X	X	X	X
Mus musculus ssp. musculus	X		X	
Clethrionomys glareolus	X		X	X
Apodemus sylvaticus	X	X	X	X
Sorex araneus	X	X	X	X
Sorex minutus	X	X	X	X
Neomys fodiens	X	X	X	X
Mustela nivalis, M. erminea	X	X	X	X
Sciurus vulgaris	X			
Meles meles	X	X	X	X
Lepus europaeus	X	X	X	X
Mustela putorius, M. vison	X	X	X	X
Talpa europaea	X		X	X
Martes foina, M. martes	X	X	X	X
Lutra lutra	X	X	X	
Erinaceus europaeus, Rattus norvegicus, Arvicola terrestris	X	X	X	
Vulpes vulpes	X	X	X	X
Cervus elaphus	X			
Capreolus capreolus	X	X	X	X

Table 1 - Occurrence of terrestrial mammals recorded in Northern Jutland, Denmark and in the various types of fauna passages. Footprints of some species could not be distinguished with certainty: Mustela nivalis and M. erminea, Mustela putorius and M. vison, Martes foina and M. martes and Erinaceus europaeus, Rattus norvegicus and Arvicola terrestris. Bats are not represented in the table since they are not recorded by the applied methods.

The species' use of the fauna passages is promoted by placing the passages in connection with landscape corridors such as hedgerows, dikes and fences or by establishing wire fences along the road constructions that lead to the entrance of the fauna passage and prevent the animals to cross the motor way. The animal species have had five to ten years to locate the fauna passages, but there seems not to be a linear relation between the level of activity and the age of the fauna passage. Apparently, the different species' density in the surroundings of the single fauna passage may be the reason for the varying use of the fauna passages.

There is a clear relationship between the size of the underpasses and the number of medium sized mammal species using them, when the activity level is related to the dimension of the entrance of the fauna passage and the total tunnel effect. The larger the entrance or the tunnel effect the greater the number of medium sized mammal species is actually using the underpasses.

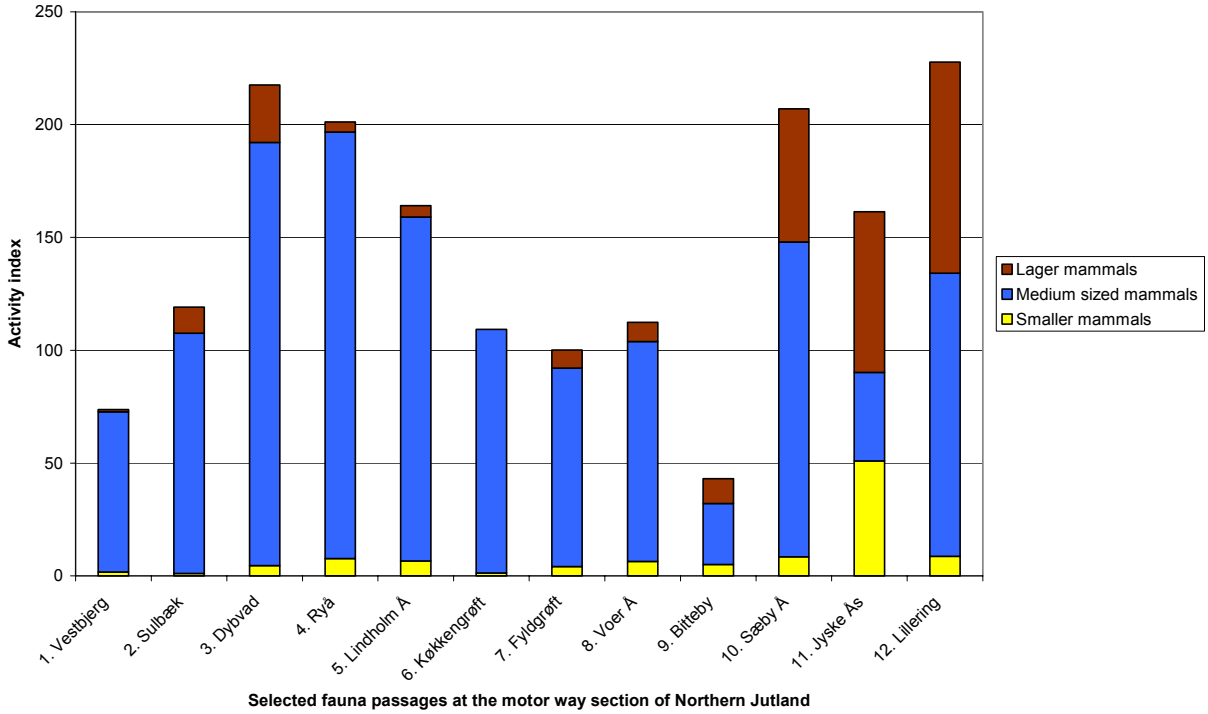

Figure 10 - The mammals' use of selected fauna passages. Dry passages 1-3; wet passages 4-10 (no. 10 is a landscape bridge); overpasses 11-12.

There is no indication that the normal underpasses will be used more frequent by roe deer, even if the dimension of the entrance is enlarged or the total tunnel effect is increased. When landscape bridges and overpasses are taken into consideration the activity level of the fauna passages of the roe deer is markedly increased. The cause might be that roe deer do not regard the landscape bridge and the overpass as obstacles. Another fact might be that such fauna passages are established on locations where the density of roe deer is higher. In addition the barrier effect of the presence or absence of wire fence along the motorway systems should be taken into consideration.

3.4. Are the needs for natural dispersal met for most of the species?

In general, the fauna passages at the motorway systems in Northern Jutland have been placed in connection with the natural corridors of the mammal species as the species have started to use them. Most of the passages have dimensions that roe deer can use them, too. Except from the landscape bridges and the overpass at Jyske Ås, the main part of the fauna passages are not dimensioned for red deer *Cervus elaphus*. Besides, the frequency of red deer is probably increasing in Northern Jutland.

Proposals for changes of specific fauna passages in Northern Jutland are given in a report worked out by NERI for the Road Directorate. However, neither changes of dimensions of specific fauna passages, nor improvements of corridors in the surroundings nor changes

of fences along the motorway system are treated. It has not been a task of NERI to map the distribution of red deer, thus no recommendations are given for fauna passage connection for this species.

4. NORD2000, THE NEW NORDIC PREDICTION METHOD FOR ROAD TRAFFIC NOISE

In 1996 the Nordic Council of Ministers decided to initiate the development of a new generation of prediction methods for environmental noise using the scientific development that has taken place since the first Nordic methods were published in the 1970s.

The idea was to develop a general sound propagation model and to establish source-specific prediction methods for road and rail traffic and other types of environmental noise sources. All prediction methods should be based on the same general propagation model. The sound propagation model should be applicable for computing the sound pressure level caused by a point source, in ⅓ octave bands, in every normal type of weather.

The new source model distinguishes between tyre/road noise and propulsion noise, and the new propagation model allows computations for a variety of weather conditions. Nord2000 is significantly better than the present method. It can handle computation in situations where the present model is not applicable, it gives results in frequency bands, and noise levels can be computed for various weather conditions, and thus yearly average noise levels can be accurately computed.

Subsequent to the completion in 2001 of the original work on Nord2000 the source and propagation models have been adjusted in a few places. Features have been taken over from the source model of the European Harmonoise project which demonstrated that it was possible to separate tyre/road noise and propulsion noise and that it was good enough to work with two point sources to describe a road vehicle.

This new source model has been adapted and fitted to available Nordic source data. Nord2000 Road is the first official Nordic prediction method applying the new generation of methods. The easiest way to get familiar with its behaviour is to exercise the type case software developed by SINTEF. The software can be downloaded from www.sintef.no/n2kr free of charge.

Work on the original Nord2000 was funded by the Nordic Council in collaboration with Nordic national environmental and road authorities and carried out by a cooperation of Nordic acoustic institutes. In 2005 Nordic road authorities decided to implement this new model in road traffic noise prediction. NordFoU, a co-operation between the Nordic road administrations, funded the project in which the original model was adjusted and corrected - among other things in the light of experience obtained in the European Harmonoise project - and supplemented with statistics on weather conditions.

4.1. Prediction method

Nord2000 Road can be used to calculate L_{eq}, overall A-weighted or in frequency bands, for any combination of road vehicles provided input data are available.

The maximum sound pressure level corresponding to time weighting F can be calculated, from individual vehicles or combinations of vehicles at specified positions. However, the prediction method does not give statistical methods to calculate maximum levels from

passing groups of vehicles. The assessment points should be chosen in accordance with the recommendations in *Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure* from the European Commission.

The prediction method separates tyre/road noise from propulsion noise. Thus, the method can be used to estimate the effect of changing road surface or tyres. For the most common types of road surfaces default values are given. It is also possible to calculate the effect of studded tyres and of vehicle acceleration and to correct the tyre/road noise generation for variation in air temperature.

The method distinguishes between medium heavy and heavy vehicles and introduces the number of axles of heavy vehicles as an input parameter.

The prediction method can handle various uncomplicated weather conditions whereas very strong or varying wind gradients as well as layered atmospheric conditions have been excluded. By combining results from different weather conditions, it is possible to calculate yearly average noise levels such as the L_{den} and L_{night} prescribed in the European directive on environmental noise.

The prediction method can handle any number and any combination of varying ground conditions with and without screens. The algorithms have been limited to two screens. The screens can be thin or thick with any shape.

The prediction method does not specifically deal with indoor noise. No special guidelines or data on the sound insulation of windows or facades are given. However, provided that sound insulation data are known, indoor sound pressure levels can be calculated from standard building acoustic formulae because all calculations in Nord2000 are carried out in ⅓ octave bands.

4.2. Source model

The source model distinguishes between 1) light, 2) medium and 3) heavy vehicles. A vehicle is represented by a number of noise sources at different heights (0.01 m, 0.30 m, 0.75 m or 3.5 m) at 1 m from the vehicle centre line, towards the receiver.

The ⅓ octave-band sound power level of each source is calculated from input parameters selected by the user, determining the sound power of tyre/road noise and propulsion noise, respectively.

The Danish emission data are based on measurements 1999-2000 during 4,000 vehicle pass-bys at 21 sites with speed limit 30- 110 km/h and dense asphalt concrete or stone mastic asphalt with aged 2 – 18 years with 8-12 mm maximum aggregate.

Figure 11 compares vehicle noise emission in Nord2000 and in the present model. The levels are higher in the new model, particularly L_{AFmax} at high speed. In the present model heavy vehicles are a mix of category 2 and 3 with category 2 dominating at low speed and category 3 at high speed.

There is a trend for noise emission to be higher than in the present method. The higher emission values might be caused by changes in vehicle fleet or wider tyres, but the reasons are still unknown. Emission data from Finland, Norway and Sweden are 1-2 dB higher than the Danish data.

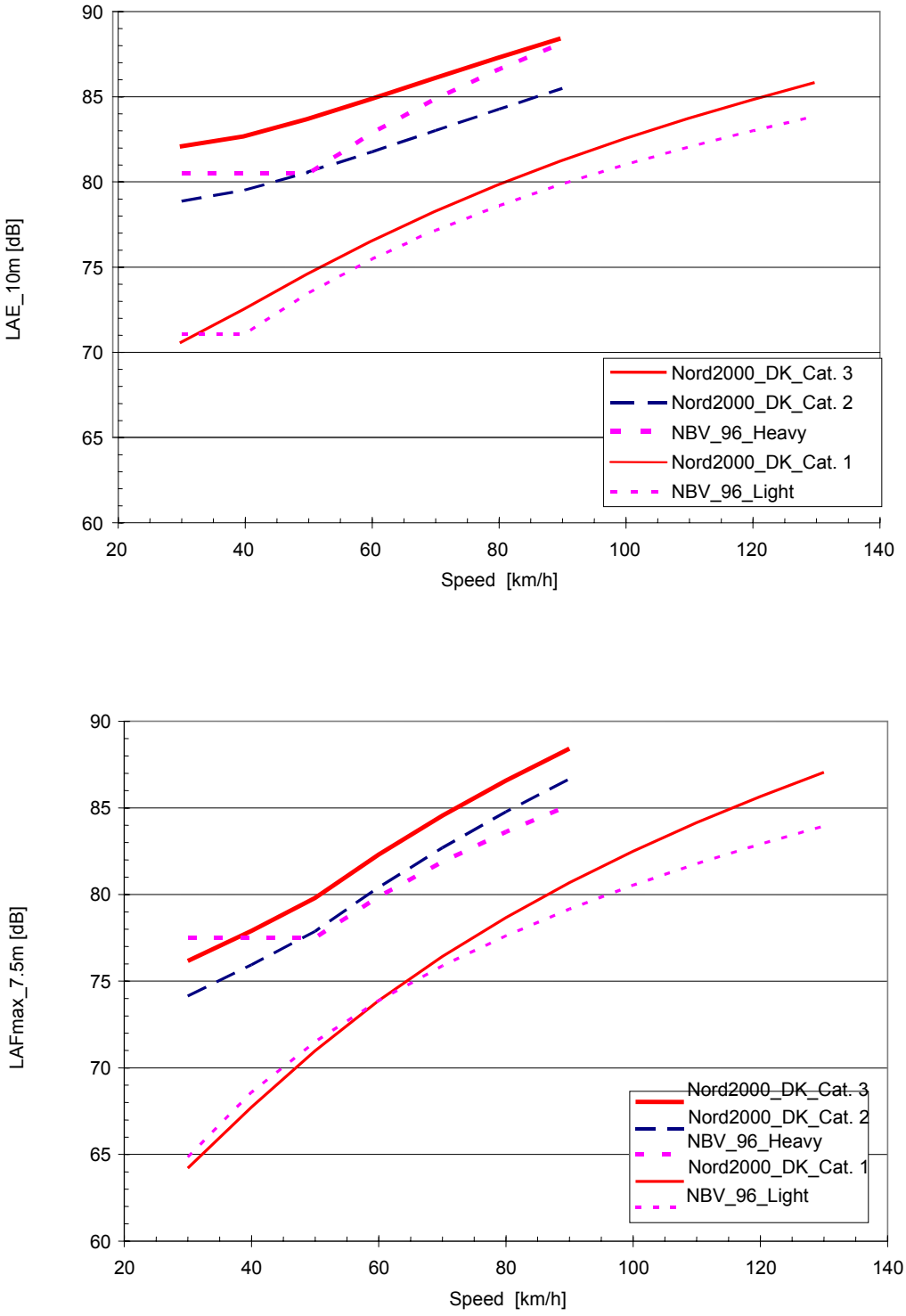

Figure 11 - Noise emission in the present and the new method.
Top: L_{AE} at 10 m.
Bottom: L_{AFmax} at 7.5 m.
Nord2000 data are for Danish vehicles
Cat. 3 are trucks with 5 axles.

4.3. Propagation model

The propagation model is based on geometrical ray theory and gives algorithms for computing ⅓ octave band sound attenuation along the path from source to receiver taking into account the terrain shape as well as ground type (impedance) and roughness. The vertical terrain cross-section is simplified to consist of a chain of straight-line segments and the model combines the contributions from all segments to the resulting ground and screen effect.

Eight classes of ground surface have been defined, from very soft (moss-like) to very hard (dense asphalt), although for noise mapping probably only the classes “soft” and “hard” will be used. Data may be entered “manually” in single-receiver software or imported from digital terrain models into “automatic” mapping software. With the complexity of the model “manual” calculation is out of the question.

Nord2000 deals with attenuation under different weather conditions and is suited for computing yearly average noise levels. Various classes of weather have been defined and their frequency of occurrence has been determined based on data from meteorological observations. The yearly average is obtained by computing the noise level for each weather class and then combining these levels weighted with their occurrence.

At 300 m from a road with direction North-South the yearly average noise level in Denmark is 2 dB higher at receivers east of the road than at receivers west of the road.

4.4. Fresnel-zones

Fresnel-zones introduced in Nord2000 have lead to essential improvement compared to earlier methods and among other things solved problems of discontinuity in computation results.

Their use was inspired by an approximate solution to predict sound propagation over flat terrain with varying surface types. In this model the sound field at the receiver is assumed to be determined by the surface conditions in a region around the reflection point denoted the Fresnel-zone.

When the sound field is reflected by a plane surface, the elliptically shaped Fresnel-zone is defined by the intersection between the plane and the Fresnel ellipsoid, which is shown in Figure 12.

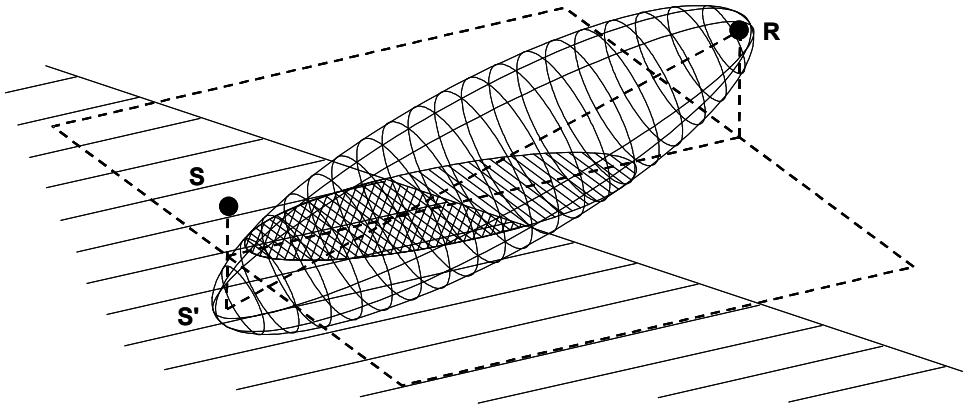

Figure 12 - Definition of Fresnel ellipsoid and Fresnel-zone.

4.5. Nord2000 in relation to the present model

The propagation attenuation has been compared in a number of cases (8 with a screen and 4 without a screen; distances 25-300 m; receiver heights 2 m, 4 m and 10 m). In lack of an exact definition the present model was presumed to be valid for 1 m/s downwind and no temperature gradient (overcast). The uncertainty introduced by the lack of definition is 1 dB or less.

For the un-screened cases Nord2000 on the average gave 1-2 dB more attenuation (lower noise level) than the present model. For the cases with a screen Nord2000 gave on the average 4 dB more attenuation than the present model. In cases with a road in a cutting Nord2000 yields significantly more attenuation than the present method.

4.6. Type cases

The present model allows fast and accurate calculation by means of diagrams for 22 selected cases. These diagrams have been replaced by software with pre-calculated transfer functions for 30 selected cases. Default traffic data for 5 types of road can be edited by the user to fit any case.

5. REDUCTION OF HIGHWAY NOISE, TEST OF NOISE REDUCING THIN LAYERS

The Danish Road Institute (DRI) and Road and Hydraulic Engineering Institute in the Netherlands (DWW) are carrying out a research work under the title : DRI-DWW Noise Abatement Programme, which includes a project on Thin Layer Pavements. The DRI-DWW Noise Abatement Programme is a part of the Dutch Noise Innovation Program for Road Traffic. An important part of this Thin Layer Pavements project is to carry out a full scale test of different types of noise reducing thin layers on a highway in Denmark. The test site is located on highway M10 at ‘Køge Bugt Motorvejen‘ near Solrød where the speed limit is 110 km/h.. The purpose of this experiment is to document the noise reducing effect, and on the long term to document the acoustical and the structural lifetime of the thin layers.

Figure 13 – Typical microphone setup at the SPB noise measurements at the test sections at M10.

In the summer 2004 - 5 different pavements including a reference pavement were laid. In the last part of 2004 (year 0) when the mentioned pavements only were a few months of age, the DRI performed a series of detailed noise measurements. A sixth pavement section was laid in August 2005. A new series of measurements were conducted in December 2005 (year 1) in order to monitor the development of the noise emission at these pavements. The measurements were performed according to the international standard ISO 11819-1 characterizing road surface influence on traffic noise the so called "SPB" method (Statistical Pass By method). Furthermore, a series of CPX (Close Proximity) measurements were performed in year 0 (not repeated in year 1) as a part of the project on acoustical characteristics in the DRI-DWW Noise Abatement Program. To describe the surface texture of the pavements on the 5 sections DRI has performed detailed texture measurements by using laser equipment also in year 0 (not repeated in year 1). And finally, the friction of the 5 pavements has been measured.

5.1. Results on noise

The completed SPB measurements, which are highly reliable and detailed, are used to evaluate the noise reduction of the tested pavements relative to the reference pavement. When the actual traffic distribution is used as it was in the noise mapping of the M10 at 'Solrød' with 90 % passenger cars, 5 % dual-axle trucks and 5 % multi-axle trucks. The results expressed by the modified SPB index ($SPBI_{M10}$) for each tested pavement is as shown in the table below.

		AC11d		**SMA8**		**AC8o**		**TP8c**		**SMA6+**		**SMA8+***	
Year 0	Year 1	0	1	0	1	0	1	0	1	0	1	0	1
$SPBI_{M10}$		84.0	84.1	83.2	84.1	81.2	81.8	81.8	83.1	82.6	82.6	81.6	-
Difference re. AC11d [dB]		0	0	-0.8	0.0	-2.8	-2.3	-2.2	-1.0	-1.4	-1.5	-2.4	-

Table 2 - Modified SPB indices for each pavement and difference re reference pavement, when the actual traffic distribution was used. Year- 0 / 1.

There was an increase in the noise emission of 0 to 1 dB from year 0 to year 1. At the dense reference pavement there was no increase in the noise emission. This is the main reason that the year 1 measurements showed a less effective noise reduction compared to year 0 noise reductions. It can be seen that relative to the reference pavement there was a reduction in the modified SPB index for the tested pavements of 1 to 3 dB's in year 0 and year 1, even though the tendency was a lower noise reduction in year 1. The noise reduction at the SMA8 pavement turned out to be of no significance. The noise reduction was around 1.5 dB at the SMA6+ pavement, while the initial noise reduction at the two thin layers (TP8c and AC8o) was 2-3 dB's, in year 1 this is reduced to 1-2 dB's. The noise reduction at the SMA6+ is the same for both years. At the SMA8+ the measured noise reduction was of 2.4 dB in year 0. The uncertainty for the $SPBI_{M10}$ was calculated to be 0.4 dB.

5.2. Surface texture measurements

The surface texture measurements are represented by an MPD value. The MPD value for the layers SMA8, AC8o and TP8c was around 0.9 mm, this is significantly a higher MPD value compared to the reference pavement and SMA6+ which was around 0.4-0.5 mm. All

pavements fulfilled the requirements for the friction as stated in the highway standards. The measured values for the surface texture (expressed by the MPD value) and friction were uniform in the longitudinal direction for all pavements. The results of the friction measurements showed that these pavements have a very good friction.

5.3. Perspective

DRI will continue the noise measurements in the coming years. The object is in principle to follow the pavements over their total lifetime. In the DRI-DWW Noise Abatement Program work is ongoing to make further optimization of the noise reduction of thin layers for highways. In the autumn of 2006 11 new test sections with optimized mixes were constructed on a highway near Herning in Denmark and a new measurement program will be conducted.

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