



**NTNU – Trondheim**  
Norwegian University of  
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# Residents' perceived impact of noise reducing measures implemented on habitations located nearby heavy traffic roads

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## **Problem Description**

Road traffic noise is the biggest source of noise nuisance in Norway and can be counted responsible for around 80% of the noise nuisance in 2007. The task is to do a literature study on noise nuisance and to conduct a social survey on a large amount of households having had noise control measures performed to understand their experience with noise nuisance before and after the amelioration. Statistical treatment of the answers will be done.

Assignment handed out: 22. January 2012

Supervisor at NTNU: Ulf Kristiansen

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# Preface

This master thesis is the result of the work done during the 10<sup>th</sup> semester of the Master's program Communication Technology at the Department of Electronics and Telecommunications, NTNU. The work has been carried out between February and July 2012 with Professor Ulf Kristiansen as supervisor and engineer Eivind Thoresen Skarpaas at Sweco as external supervisor. This report is written after a project proposal from SWECO and is part of their research into noise control connected to road traffic.

Being involved in this project has given me further insight into the interesting subject of noise control and especially into the various health consequences noise exposure can lead to.

The project is submitted to the Department of Electronics and Telecommunication at the Faculty of Information Technology, Mathematics and Electrical Engineering, NTNU, as part of my M.Sc. degree.

## Acknowledgments

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Frederik Strand Sardinoux



# Abstract

Road traffic has seen a constant augmentation these last decades. The noise it generates has grown more or less linearly with the traffic and has created a major environmental problem. It affects the human body in negative ways by engendering sleep disorders, stress and even cardiovascular diseases. The Norwegian government came with regulations to reduce the number of people exposed to high noise levels and many people have now had their habitation supplemented with noise-reducing measures.

There is however a lack of researches made on these noise control measures in the indoor noise; especially on how the residents experience these modifications. A telephone-based survey is done in this research where 76 households have been selected on the parcel from Gardemoen to Biri on the new E6 in Norway. Between these habitations, the average outdoors and indoor noise levels are, respectively, 61dB and 34dB prior the installation of any noise reducing measures.

The results, treated statistically using the software SPSS, are showing the nuisance degree experienced by the habitants for different noise levels both outdoors and indoors. Additionally, the subjective improvement of the noise situation felt by the habitants after the measures shows a rather different picture outdoor and indoor, as the amelioration is generally bigger inside the habitation.

Indeed, while nearly 90% of the respondents felt annoyed to extremely annoyed outdoors only 50% showed the same nuisance levels after the noise control measures were installed. For the indoors situation 40% of the participants of the survey felt annoyed to very annoyed prior the measures while only 5% of them felt the same degree of annoyance after. Furthermore, while 42% were sleep disturbed and 50% experienced stress and 66% felt a reduction of their well-being only 13%, 20% and 18% felt the same health issues after the noise-measures were installed.

Around half of the interviewees declared they were satisfied with both Sweco and Statens Vegvesen which were key firms for the planning and building of the measures along the chosen parcel. Finally, taking all this into account, it appears that 40% of the 76 selected residents are satisfied with the noise-reducing measures, 10% are unsatisfied and the rest is neutrally satisfied.





# Sammendrag

Veitrafikk har økt betydelig de siste tiår. Støyen den genererer har vokst mer eller mindre lineært med trafikken og har skapt et stort miljøproblem. Det påvirker menneskekroppen på negative måter ved å skape søvnforstyrrelser, stressøkning og til og med hjerte- og karsykdommer. Den norske regjeringen kom med forskrifter for å redusere antall personer som utsettes for høye støynivåer, og mange har nå fått sin bolig supplert med støyreducerende tiltak.

Det er derimot mangel på forskning utført på disse tiltakene som kjemper mot innendørs støy, spesielt på hvordan beboerne opplever disse endringene. En telefonbasert spørreundersøkelse ble gjort i denne forskningen der 76 husstander ble valgt på parsellen fra Gardermoen til Biri på den nye E6 i Norge. Blant disse boligene lå gjennomsnittlig utendørs og innendørs støynivå på henholdsvis 61dB og 34dB før installasjon av tiltakene ble gjort.

Resultatene, som ble statistisk behandlet ved hjelp av programvaren SPSS, viser plagegraden opplevd av beboerne for ulike støynivåer både ute og inne. I tillegg forbedringen av støysituasjonen etter at tiltakene ble utført viser et ganske annerledes bilde utendørs og innendørs.

Da nesten 90% av respondentene var plaget til ekstremt plaget utendørs, viste bare 50% samme plagegrad etter tiltakene ble installert. For innendørssituasjonen var 40% av deltakerne i undersøkelsen plaget til meget plaget før tiltakene, mens bare 5% av dem følte den samme plagegraden etterpå. Videre viser resultatene av undersøkelsen at 42% av beboerne hadde søvnforstyrrelser, 50% opplevde stress, og 66% følte en reduksjon av egen velvære. Etter støytiltakene ble installert ble prosentene redusert til henholdsvis 13%, 20% og 18% på de nevnte helsemessige problemene.

Rundt halvparten av de intervjuede sa de var fornøyde med både Sweco og Statens Vegvesen som var viktige aktører for planleggingen og byggingen av tiltakene langs den valgte parsellen. Til slutt oppsummeres undersøkelsen med at 40% av de 76 utvalgte beboerne er fornøyd med de støyreducerende tiltakene, 10% er misfornøyd og de resterende prosentene stiller seg nøytralt.



# Table of content

<b>PREFACE</b> .....	<b>III</b>
<b>ABSTRACT</b> .....	<b>V</b>
<b>SAMMENDRAG</b> .....	<b>VII</b>
<b>TABLE OF CONTENT</b> .....	<b>IX</b>
<b>LIST OF FIGURES</b> .....	<b>XIII</b>
<b>LIST OF TABLES</b> .....	<b>XV</b>
<b>INTRODUCTION</b> .....	<b>1</b>
1.1 MOTIVATION .....	1
1.2 RESEARCH QUESTION .....	2
1.3 STRUCTURE OF THE REPORT .....	3
<b>NOISE</b> .....	<b>5</b>
2.1 DEFINITION AND MEASURABILITY .....	5
2.2 TRENDS AND EVOLUTION OF NOISE .....	6
2.3 LAWS AND ACTION PLANS AGAINST NOISE .....	8
2.4 THE EFFECT OF NOISE ON HUMANS.....	10
2.4.1 <i>Noise annoyance</i> .....	10
2.4.2 <i>Hearing loss</i> .....	10
2.4.3 <i>Communication disturbances</i> .....	11
2.4.4 <i>Stress related effects</i> .....	11
2.4.5 <i>Sleep disturbance</i> .....	11
2.4.6 <i>Effects of road traffic noise</i> .....	11
2.4.7 <i>Still a way to go</i> .....	12
2.4.8 <i>Calculation procedure</i> .....	13
2.4.9 <i>Indoor Noise measures</i> .....	13
<b>RESEARCH METHOD</b> .....	<b>15</b>
3.1 QUANTITATIVE AND QUALITATIVE RESEARCH METHOD .....	15
3.1.1 <i>Quantitative research method</i> .....	15
3.1.2 <i>Qualitative research method</i> .....	16
3.2 OTHER METHODS.....	16
3.2.1 <i>Experimental study</i> .....	16
3.2.2 <i>Transversal and longitudinal studies</i> .....	16
3.2.3 <i>Case study</i> .....	16
3.2.4 <i>Pairwise comparison</i> .....	17
3.3 DATA COLLECTION TECHNIQUES .....	17
3.3.1 <i>Surveys</i> .....	17
3.3.2 <i>Interviews</i> .....	18
3.3.2 <i>Observation</i> .....	19
3.4 CHOICE OF METHOD .....	20
3.4.1 <i>Research method chosen</i> .....	20

<b>SURVEY .....</b>	<b>23</b>
4.1 BACKGROUND.....	23
4.1.1 Statens Vegvesen.....	23
4.1.2 Sweco.....	24
4.1.3 Procedure experienced by the residents.....	24
4.1.4 Reports.....	25
4.2 POPULATION SAMPLE .....	26
4.2.1 Where?.....	26
4.2.2 Why? .....	27
4.2.3 Who?.....	27
4.2.4 What is the noise situation? .....	28
4.3 STRUCTURE OF THE SURVEY.....	28
4.3.1 Structure.....	28
4.3.2 Questions.....	29
4.4 PROCEDURE.....	30
4.4.1 Personal data.....	30
4.4.2 Telephone interviews.....	30
4.5 ANALYSIS USING SPSS.....	30
<b>RESULTS .....</b>	<b>33</b>
5.1 IMPLEMENTED NOISE MEASURES .....	33
5.2 NOISE LEVELS BEFORE AND AFTER THE MEASURES.....	36
5.2.1 Noise source experienced by residents.....	37
5.2.2 Outdoor noise levels.....	37
5.2.3 Indoor noise levels .....	38
5.3 EFFECT OF THE NOISE-REDUCING MEASURES .....	40
5.3.1 Outdoor noise improvements.....	40
5.3.2 Indoor noise improvements.....	42
5.4.1 Sleeping disturbance .....	44
5.4.2 Illness.....	44
5.4.2 Illness.....	45
5.4.3 Muscle tension and muscle pain .....	46
5.4.4 Stress.....	47
5.4.5 Reduced well-being .....	48
5.5 RESPONDENTS SATISFACTION.....	49
5.5.1 Satisfaction with the information received .....	49
5.5.2 Satisfaction with Statens Vegvesen and Sweco.....	50
5.5.3 Satisfaction with the noise measures .....	51
<b>DISCUSSION .....</b>	<b>53</b>
6.1 AMELIORATION OF THE SURVEY .....	54
6.2 VALIDITY OF THE SURVEY .....	55
6.3 OUTDOOR.....	55
6.4 INDOOR.....	55
6.5 HEALTH .....	56
6.6 SATISFACTION WITH THE PROCESS.....	56
6.7 RESEARCH QUESTIONS .....	57

<b>CONCLUSION .....</b>	<b>59</b>
<b>APPENDIX A – HOW TO CALCULATE THE NOISE NUISANCE INDEX (SPI) .....</b>	<b>63</b>
<b>APPENDIX B – HABITATION NOISE REPORT EXAMPLE (MADE BY SWECO).....</b>	<b>65</b>
<b>APPENDIX C – TIMELINE E6 GARDEMOEN - BIRI.....</b>	<b>69</b>
<b>APPENDIX D – CONVERSATION TEXT (SURVEY).....</b>	<b>71</b>
<b>APPENDIX E – QUESTIONNAIRE .....</b>	<b>73</b>
<b>APPENDIX F – ANSWER SHEET (EXCEL) .....</b>	<b>77</b>



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# List of Figures

---

<b>Figure 1:</b> Overview over the noise nuisance index (SPI) from different noise sources (numbers are from 2007, <i>source: SSB</i> ) .....	1
<b>Figure 2:</b> Change in noise nuisance from road traffic between 1999 and 2007, classified by cause [1] .....	7
<b>Figure 3:</b> Number of persons bothered by noise in Norway in 2006. <i>Source: Handlingsplan mot støy [4]</i> .....	8
<b>Figure 4:</b> Day distribution of traffic as a function of the day of the week.....	12
<b>Figure 5:</b> Location of the parcel Gardemoen - Biri .....	28
<b>Figure 6:</b> Details of the parcel E6 Gardemoen - Biri.....	29
<b>Figure 7:</b> Response confidence of the survey participants .....	34
<b>Figure 8:</b> Noise reducing measure costs .....	35
<b>Figure 9:</b> Type of noise reducing measure installed on the four parcels .....	39
<b>Figure 10:</b> Outdoors noise levels, statistical view .....	37
<b>Figure 11:</b> Outdoors noise levels .....	37
<b>Figure 12:</b> Indoors noise levels, after the noise reducing measures .....	39
<b>Figure 13:</b> Indoors noise levels, before the noise reducing measures .....	42
<b>Figure 14:</b> Noise situation improvements outdoors.....	43
<b>Figure 15:</b> Outdoors noise nuisance before the noise-reducing measures.....	44
<b>Figure 16:</b> Outdoors noise nuisance after the noise-reducing measures.....	44
<b>Figure 17:</b> Noise situation improvements indoor .....	45
<b>Figure 18:</b> Indoor noise nuisance before the noise-reducing measures .....	46
<b>Figure 19:</b> Indoor noise nuisance after the noise-reducing measures.....	46
<b>Figure 20:</b> Sleep disorder before the noise-reducing measures .....	47
<b>Figure 21:</b> Sleep disorder after the noise-reducing measures .....	47
<b>Figure 22:</b> Illness due to noise after the noise-reducing measures .....	48
<b>Figure 23:</b> Illness due to noise before the noise-reducing measures .....	48
<b>Figure 24:</b> Muscle soreness due to noise before the noise-reducing measures .....	49
<b>Figure 25:</b> Muscle soreness due to noise after the noise-reducing measures .....	49
<b>Figure 26:</b> Stress due to noise before the noise-reducing measures .....	50
<b>Figure 27:</b> Stress due to noise after the noise-reducing measures .....	50
<b>Figure 28:</b> Well-being effect before the noise-reducing measures .....	51
<b>Figure 29:</b> Well-being effect after the noise-reducing measures.....	51
<b>Figure 30:</b> Degree of satisfaction with the information provided by vegvesenet.....	52
<b>Figure 31:</b> Degree of satisfaction with the information provided by Sweco .....	52
<b>Figure 32:</b> Degree of satisfaction with Sweco .....	53
<b>Figure 33:</b> Degree of satisfaction with Statens Vegvesen .....	53
<b>Figure 34:</b> Degree of satisfaction with the noise-reducing measures .....	54





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# List of Tables

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<b>Table 1:</b> Criteria for zone classification.....	9
<b>Table 2:</b> Number of people exposed to road traffic (2000). <i>Source:SSB</i> .....	12
<b>Table 3:</b> Details of the parcels actual for the survey.....	28
<b>Table 4:</b> Actual effect of change in dB(A).....	36
<b>Table 5:</b> Indoors noise levels before after the noise reducing measures (statistical view) .....	41



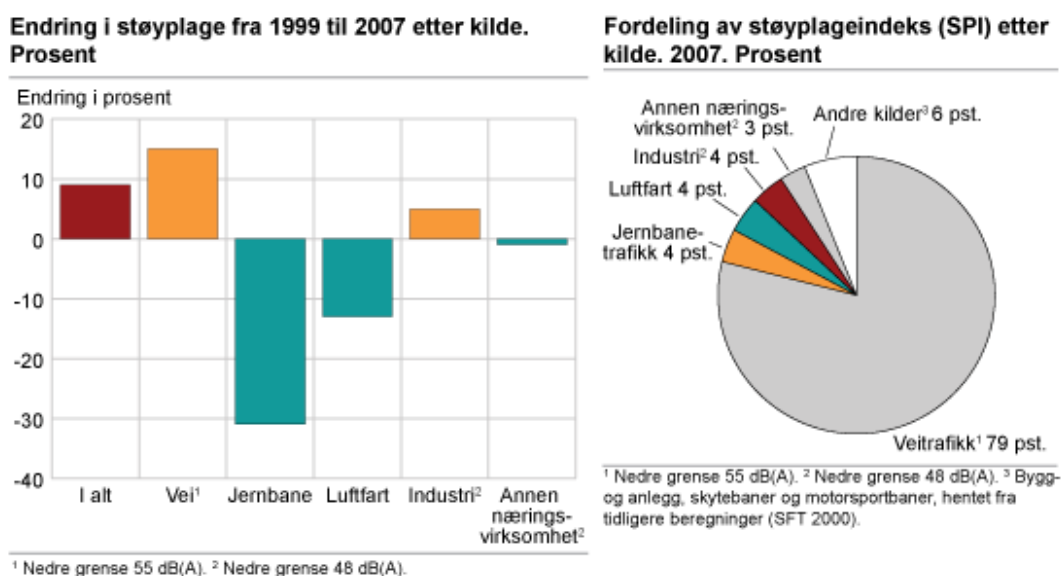
# CHAPTER 1

## Introduction

This report is a master thesis written at the Norwegian University of Science and Technology (NTNU) at the department of Electronics and Telecommunications, a part of the faculty of Information Technology, Mathematics and Electrical Engineering. The main task is to evaluate the experienced effect of noise control measures on households located nearby heavy road traffic. In this introduction, the motivation for writing this report will be presented (1.1), and then the main research question will be defined (1.2). Lastly, an overview of the structure of the report will be listed.

### 1.1 Motivation

Noise, caused by traffic, industrial and recreational activities, is one of the main local environmental problems in Europe. In Norway, noise can be considered at the biggest pollution problem since 1 out of 3 inhabitant is exposed to outdoor noise levels higher than the legislation says is recommended. Furthermore, traffic noise is definitely the largest source leading to noise nuisance in Norway as indicated by the number of *Statistics Norway, SSB [1]*.



**Figure 1:** Overview over the noise nuisance index (SPI) from different noise sources (numbers are from 2007, *source: SSB*)

As seen on Figure 1, it is obvious that road traffic is the biggest source leading to noise nuisance in Norway as it represents almost 80% of the total noise nuisance. Actions have been taken to counter this alarming development and noise control measures are more and more common as it will be discussed throughout this report. Most of the researches leading to these conclusions are based on the outdoor situation, which is very different from the indoor situation. The researches conducted gave information on the number of persons being annoyed by high noise levels due to traffic, on the consequences of being exposed to noise and more. However, there is little to no research made on the indoor noise nuisance and especially on the experienced effect of noise control measures on inhabitants, which endured high noise levels due to heavy road traffic.

## 1.2 Research question

The Norwegian government has developed an action plan against noise for the period 2007 – 2011; in summary it focuses on two main goals:

- The noise nuisance shall be reduced with 10% in 2020, compared to the results in 1999
- The number of persons exposed to indoor noise levels above 38dBA shall be reduced with 30% by the end of 2020 compared to 2005

These numbers are and will be challenging to follow and to respect as the time frame is small. Besides, we know very little on the experienced noise nuisance indoor and especially after noise reductions measures have been installed. How are the households reacting to these reductions? Do they feel an improvement has been made? Has their health been improved? It could be that the national measures are not in adequacy with what the population actually needs.

The final research questions can be formulated as the following:

- *How satisfied are residents with the process behind the execution of the measures?*
- *How do the residents experience the noise levels both before and after the noise measures?*
- *What is the perceived noise nuisance improvement due to the measures?*

### **1.3 Structure of the report**

Considering what has been said earlier, this report will only focus on the noise coming from road traffic, as it is the largest noise source and directly affects the indoor noise levels of households. A noise sound source can also vibrate heavily which can be already annoying in itself but can especially be deranging if it generates vibrations on the structure inside the house. Vibrations and structure vibrations are part of the noise policy in the same position as air carried noise. The scope of the report will however not include these aspects and will mainly focus on air carried noise.

This report will first look into the definition of noise and what consequence it has on the health of the exposed population. Then, it will go into the different methods one can use to minimize the noise levels. Following, the noise situation in Norway and the actions taken so far to fight against it will be presented. The research method will be presented together with the found results. Finally, a discussion will take place summarizing all the interesting results having in mind today's situation. References and appendixes can be found at the end of the report.



# CHAPTER 2

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## Noise

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Noise is unwanted sound. How unwanted or annoying sound is depends on the noise levels and noise characteristics. Moreover, the degree of noise annoyance felt by those who are exposed depend on a variety of individual circumstances and factors related to the situations and activities at the time of the noise disturbance.

### 2.1 Definition and measurability

Noise generally refers to unwanted sounds. It doesn't necessarily need to be a random sound; it can be loud sounds that disturb people or make it difficult to hear the original wanted sound. The sound of a weak radio transmission, the sound of neighbors playing music, road traffic sounds or even dogs barking can all be categorized as noise. Acoustic noise can refer to any sounds; from quiet but annoying to loud and harmful. This can be a problem when trying to scale the amount of noise one experiences. Indeed, how can we measure the degree of annoyance when this notion is so subjective? Also, does the intensity of two different noise sound sources give out the same perceived noise effect?

How annoying or unwanted a sound is depends mostly on the noise sound pressure level and the noise characteristics:

- frequency content
- duration
- predictability

The physical strength of sound – sound pressure level- is expressed in dB, which is a logarithmic unit used to describe a ratio. The ratio may be composed of power, sound pressure, voltage or intensity. An increase of about 10dB represents a perceived doubling of loudness. 0dB indicates the lowest sound humans can hear and 120dB is the loudest sound one can hear without pain. Humans perceive sound differently on the frequency range 20Hz – 20kHz; which are the tones our auditory system can perceive. This is why we often talk about dBA where a weighting filter has been applied to adapt the loudness perceived adequately to our ear.

For many purposes, including noise measurements it is common to use:

- the equivalent noise level  $L_{Aeq}$  which is the average value (mean energy) of the sound level during a period of time.
- $L_{Amax}$  represents the highest peaks in the varying sound level and can also be used
- $L_{den}$  (day-evening-night level) is a A-weighted equivalent level for the day with a time weighting factor that varies. Noise in the evening period (4hours) gets an additional 5dB and noise at night (8hours) 10dB. This is a EU developed indicator as specified on the paper made by the European Commission [2].

$$L_{den} = 10 \log \left[ \left( \frac{12}{24} \right) \cdot 10^{\frac{L_{day}}{10}} + \left( \frac{4}{24} \right) \cdot 10^{\frac{L_{evening}+5}{10}} + \left( \frac{8}{24} \right) \cdot 10^{\frac{L_{night}+10}{10}} \right]$$

where  $L_{day}, L_{evening}, L_{night}$  are the A-weighted long term  $L_{Aeq}$  as defined in ISO 1996-2 [3] for the day (7-19h), evening (19-23h) and night (23-7h).

- $L_{night}$  is an A-weighted equivalent level for the night period (8hours).

An internationally recognized academic group managed to develop a commonly applied scale; the noise annoyance index (SPI) [4].

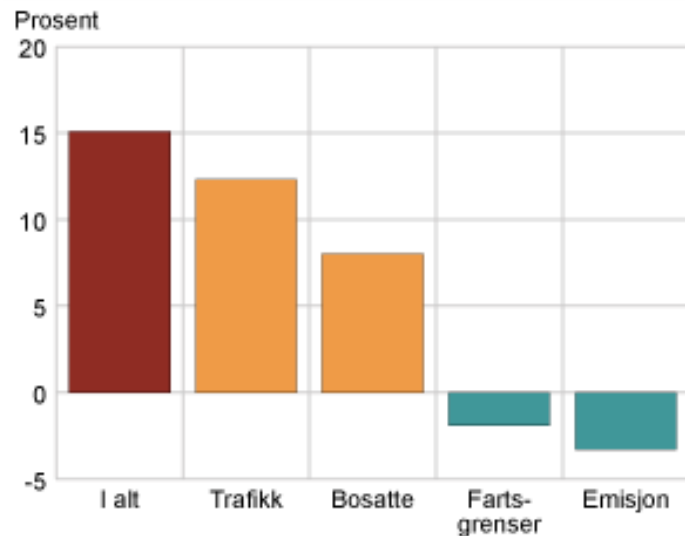
The SPI index value is calculated by multiplying the number of exposed people in every sound level (with 5dB increments) with its respective average annoyance level. The indicator allows the comparison of the annoyance level of noise sources as different as they can be from one another. Appendix A – How to calculate the noise nuisance index (SPI) shows an example on how to calculate the SPI. Despite the common use of the SPI for noise assessments it will not be used in this research as they are no noise sources to compare to each other; noise from road traffic is what is assessed here.

## 2.2 Trends and evolution of noise

On a national scale there are different noise sound sources that can be considered as annoying. Most of these noises provide from the sound emitted by transportation means: planes, trains, cars, trucks and busses but the industry is also a noise source. Figure 1 shows the main sources responsible for noise nuisance. As one can see, road traffic represents 79% of the total noise nuisance while railroad traffic, and aviation only represent 4% each. Industries and other commercial activities contributed a total of 7%. The rest of the estimated noise problems are caused by construction, shooting range and racetracks, which together accounted for 6% of the estimated noise complaints.



**Endring i støyplage fra veitrafikk fra 1999 til 2007, etter årsak. Prosent**



**Figure 2:** Change in noise nuisance from road traffic between 1999 and 2007, classified by cause [1].

Looking at Figure 2 one can see that noise from road traffic increased by about 15% from 1999 to 2007 (there are no more recent numbers than these from Norway); traffic growth is the main cause of this increase. Additionally, there were more people living in noise sensitive areas in 2007 than in 1999. Sensitive areas refer to living areas where the households are located close to major roads.

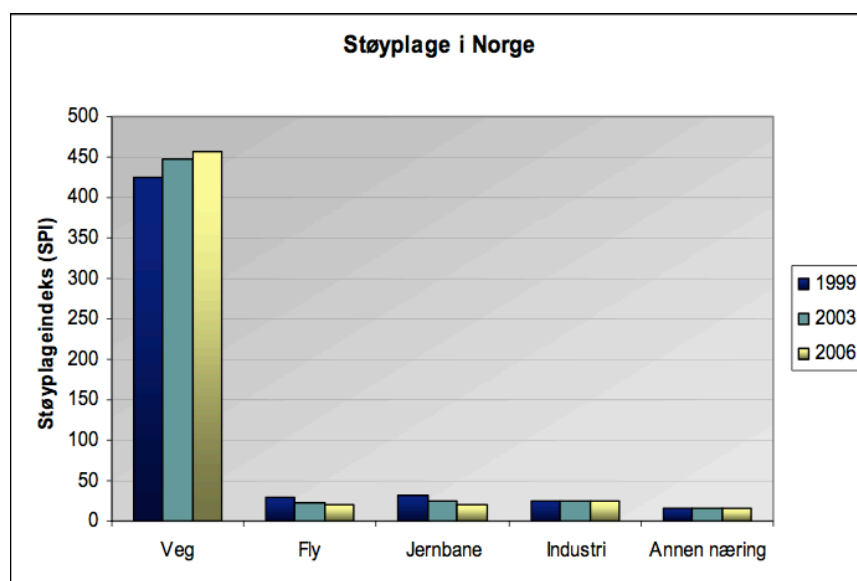
These areas are more and more populated because of an ongoing trend since 1900 that the population is moving towards highly density populated areas as Sørliie clarifies [5]. The improvements made to the vehicle engines and tires have helped reducing the rise in noise nuisance during the same period. On the other hand, a growing use of wider tires have led to slightly higher noise so the final gain is probably less than assumed in the calculations [1]. Changes to speed limits on road network has resulted in a slight reduction in noise nuisance also.

Noise annoyance caused by railroad declined by 31% from 1999 to 2007 (Figure 1). An increase in the densification of houses near the railway line network contributed to a rise in noise nuisance, while the reduction in traffic volumes, replacement of trains to quieter ones and rail grinding led to an important noise reduction.

Noise annoyance from air traffic went down about 13% in the same period and is now just over 25.000 SPI [4]. This is related to the replacement of less noisy aircraft types and changes in landing and take-off patterns at certain airports. These are very pleasant results as the overall air traffic has increased during the same period.

Although the calculations show a decrease in noise from rail and air transports from 1999 to 2007, the total noise exposure of Norway has increased by approximately 3%

during that period. This is because the noise from noise traffic, which accounts for most of the noise nuisance, has increased by approximately 8% in the period.



**Figure 3:** Number of persons bothered by noise in Norway in 2006. *Source: Handlingsplan mot støy [4]*

As mentioned before it appears on Figure 3 that road traffic noise is the only sound source that leads to an increase in the amount of people noise annoyed. Norwegian government is concerned by the problem and has come up with an action plan for the years 2007 to 2011 where the main focus is developing new road materials and vehicle tires that would minimize the outputted noise [6].

### 2.3 Laws and action plans against noise

The Norwegian government has put forward new national goals for noise reduction. They cover both the noise annoyance on humans and the needed general noise reduction.

The government's proposals for new national goals are:

- Noise annoyance will be reduced by 10% by 2020 compared to 1999
- The number of persons exposed to indoor noise levels of 38dB or over will be reduced by 30% by 2020 compared to 2005

The action plan for 2007 to 2011 [6] is the first stage towards achieving the national goals. During that period, much of the focus will be concentrated on research work and development of instruments. There is also a great need for research and testing on

low noise road surfaces. Good and practical ways to encourage the use of low noise tires and vehicles should also be established.

To sum up, in the period 2007 – 2011 the focus is on measures to reduce noise nuisance for those who are exposed to the highest noise levels, and on research and development related to noise source measures.

When it comes to laws and recommendations for noise issues, the government has a document for the communes: guideline for the treatment of noise in land planning (T-1442) [7]; which has been made in line with EU regulatory methods and measurement units. The guidelines are advisory and not legally binding.

The guidelines recommend that the owner (of the new construction) calculates two noise zones around major noise sources: a red and a yellow one. The red zone indicates that noise sensitive buildings shall be avoided, while the yellow zone is an assessment area where new buildings can be listed if there is evidence that the migration measures provides satisfactory noise conditions.

**Table 1:** Criteria for zone classification

Støykilde	Støysone			
	Gul sone		Rød sone	
	Utendørs støynivå	Utendørs støynivå i nattperioden kl. 23 – 07	Utendørs støynivå	Utendørs støynivå i nattperioden kl. 23 – 07
Vei	55 L <sub>den</sub>	70 L <sub>5AF</sub>	65 L <sub>den</sub>	85 L <sub>5AF</sub>
Bane	58 L <sub>den</sub>	75 L <sub>5AF</sub>	68 L <sub>den</sub>	90 L <sub>5AF</sub>
Flyplass	52 L <sub>den</sub>	80 L <sub>5AS</sub>	62 L <sub>den</sub>	90 L <sub>5AS</sub>
Industri, havner og terminaler	Uten impulslyd: 55 L <sub>den</sub> Med impulslyd: 50 L <sub>den</sub>	45 L <sub>night</sub> , 60 L <sub>5AF</sub>	Uten impulslyd: 65 L <sub>den</sub> Med impulslyd: 60 L <sub>den</sub>	55 L <sub>night</sub> , 80 L <sub>5AF</sub>
Motorsport	45 L <sub>den</sub> , 60 L <sub>5AF</sub>	Aktivitet bør ikke foregå	55 L <sub>den</sub> , 70 L <sub>5AF</sub>	Aktivitet bør ikke foregå
Skytebaner	30 L <sub>den</sub> , 60 L <sub>Almax</sub>	Aktivitet bør ikke foregå	35 L <sub>den</sub> , 70 L <sub>Almax</sub>	Aktivitet bør ikke foregå
Vindmøller	45 L <sub>den</sub>	-	55 L <sub>den</sub>	-

Noise limits are important in relation to both new construction and the establishment of new facilities or businesses that output noise.

In addition, “Forurensingsloven” sets the general prohibition against pollution, including noise emissions. It includes limitations for the values of indoor noise levels for existing habitations, schools, health institutions, and the mapping and action plans in accordance with the provisions of the EU framework against noise.

The relevant part of the text for this report is *chapter 5* and especially the part on indoor noise levels [8].

*“When the average indoor noise level during a day exceeds 42dB  $L_{pAeq,24h}$  in existing buildings, noise measures shall be implemented.”*  
(§5-4.Tiltakgrenser for innendørs støy [8])

However, for the study following in this report an indoor noise level limit of 30dB was used; passed this limit a noise measure was installed. For outdoor noise the limit was 55dB.

## **2.4 The effect of noise on humans**

It is now undeniable that noise has a negative effect on humans. It may just be being annoying sounds occurring during conversations, quiet activity or sleep; it is easily understandable that it causes increases of the stress level of the offer. Many different studies have been done, both in laboratories and via large surveys presenting more or less the same results as specified in the article from the European Commission [9]. It has been estimated that around 20% of the European Union’s population (ca. 80 million people) suffer from noise levels that scientists and health experts consider to be unacceptable.

The effect of noise exposure can be divided into two categories, the direct effects arising when the hearing system and the brain receive auditory impulses and indirect effects arising due to reflex mechanisms and the subjective interpretation of the noise, as specified by K. Kaneko and I. Yamada [10].

### **2.4.1 Noise annoyance**

Loud noises can be very annoying. To be interrupted during a rest, a conversation, when listening to the radio or TV or in a work context contributes to a reduced well-being and affects people’s behavior. A number of foreign and Norwegian studies document a clear relationship between the noise level and the proportion of the exposed population that is highly bothered [11]. The fact that people report their noise troubles to the authorities is also a good indicator of the aspect of health risk they are exposed to; they clearly experience displeasure.

### **2.4.2 Hearing loss**

The primary problem of hearing loss is a diminution of a person’s ability to understand speech as D.R Raichel [12] specifies. Loud noises can lead to permanent hearing damage. This arises when the sensory cells of the inner ear are destroyed. Briefs and intense sounds are especially harmful together with recreational activities such as discotheques and concerts. However, the noise levels one can find in the environment will rarely lead to permanent hearing loss.

### **2.4.3 Communication disturbances**

Noise has the annoying property to cover or mask other sounds; conversations or listening to radio and TV where concentration is needed are highly subjective to be disturbed if noise occurs. Masking of sound signals may indirectly pose a severe problem when warning signals or shouts cannot be heard. In schools and other institutions, noise will reduce the quality of the learning process. Children, elderly and people conversing in a language other than their mother tongue require a better signal-to-noise ration in order to understand what is being said.

### **2.4.4 Stress related effects**

Studies have linked stress with stomachaches, cancer, hypertension, cardiovascular disease, muscle pain, immune disorders, depression and anxiety as A. Baum, T. A. Revesnon [13] describe as well as D. Krantz and S. Raisen [14]. It is not clearly shown that noise exposure provides a significant risk to health but research results provide evidence that noise leads to stress and may contribute to increase health disorders as pointed by Carskadon M.A [15].

### **2.4.5 Sleep disturbance**

According to SSB's (Statistisk Sentralbyrå) surveys (done in 1997 and 2004) 5% of the population in Norway have sleep disturbances due to noise. Much of the knowledge about sleep disturbances caused by noise has been from laboratory studies. The surveys have been done on basis of road traffic or/and aircraft noise.

Noise interferes with sleep patterns by affecting the deepness of the sleep and the number of awakenings as specified by K.S.Pearsons, D.S.Barber, B.Tabachnick and S.Fidell [16]. Noise disturbed sleep can lead to poorer performance and reduced productivity the following day. It is likely that sleep deprivation leads to health effects especially in the long run.

### **2.4.6 Effects of road traffic noise**

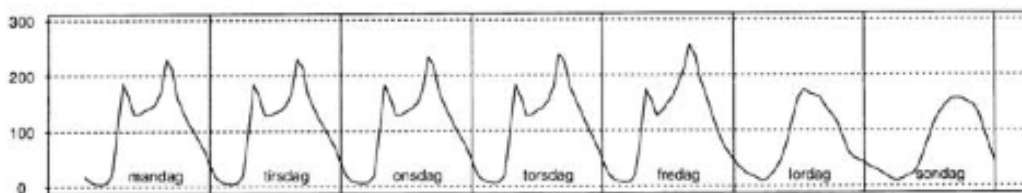
It has been said that the biggest source of noise in Norway is road traffic. Those who live in the vicinity of heavy traffic roads will experience the noise as a constant disturbance. The background noise created can cause fatigue, headaches and other similar symptoms. At short distances from the road it is often the noise peaks that are perceived most annoying as explained in the STF report [4]. In cities or by crossroads it is the accelerations and slowing downs that are the most annoying. Noise peaks usually affects the concentration and/or the flow of a conversation. Traffic of large vehicles during the night is very disturbing in residential areas both because of the

sound level but also because they tend to generate vibrations in the buildings, which amplifies the experiences noise.

**Table 2:** Number of people exposed to road traffic (2000). *Source:SSB*

Intervall, dBA	55-60	60-65	65-70	>70	Sum	SPI
Antall personer	411.900	385.800	204.460	57.040	1.059.200	411.413

Table 2 gives an overview over the amount of people exposed to road traffic in Norway. The majority of people are exposed to levels right above the recommended limit; and approximately 5% of the people exposed are subject to noise levels of over 70dB.



**Figure 4:** Day distribution of traffic as a function of the day of the week

When observing **Figure 4**, one can understand when the noise is the most intense. It is however during the evening and the night that it is the most annoying.

### 2.4.7 Still a way to go

The data available on noise exposure is generally poor in comparison to that collected to measure other environmental problems and often difficult to compare due to the different measurement and assessment methods. There is little knowledge about sleep disorders due to railway noise. It is stated in the action plan 1997 to 2011 [6] that there is a need for surveys, which are carried out where people actually live. The survey made in this master thesis is therefore very relevant. Through EU framework directive it has been decided that  $L_{night}$  is to be an indicator of noise caused sleep disturbances. However, the knowledge about the effect of different  $L_{night}$  levels on the sleep quality is very low. It is not certain what type of sleep disturbance the indicator predicts: is it awakenings, subjectively experienced sleep or physiologically measured sleeping stage changes?

When it comes to the health effects; it is difficult to correlate them with either pollution, noise or a combination of both, as road traffic is a source of both noise and air pollution. Could it be that the increased risks for heart diseases and other health effects are due to the air pollution and not of the noise?

### **2.4.8 Calculation procedure**

Sound propagation is calculated using the Nordic calculation method for road traffic noise (based on Håndbok 47 [17]). There is established a digital computational model on the basis of the available digital maps. The calculations are performed with Cadna / A version 3.6.

### **2.4.9 Indoor Noise measures**

It can be useful to understand how noise can be reduced at the facades of buildings; a quick overview of amelioration of walls, windows and ventilation will be presented, with the help of Håndbok 47 [17].

Factors that reduce sound transmission through the outer wall:

- Increased surface mass
- Bigger cavity distance
- Better sealing
- Better insulation and absorbing
- Fewer structural connections between wall surfaces

Factors that reduce sound transmission through the window:

- Better sealing between the casement and window frame
- Better sealing between wall and frame
- Gas filling, absorbent material in the cavity
- Less connections between the glass surfaces
- Use of laminated glass

Ventilation ensures a good air quality and limits the humidity in the building. There are many different forms of ventilation systems; from ventilation valves to balanced ventilation systems. The better the ventilation system, the fewer windows need to be opened and the less noise penetrates the building.





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## Research method

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Following, an overview over the different methods that can be used for research. Based on that and on the research question of this thesis the appropriate method will be chosen.

### 3.1 Quantitative and qualitative research method

For many problems where the human is the subject there are no easy solution. Surveys can gather the feedback from many different persons giving a more complete aspect of the problem and can therefore lead to a more appropriate solution. In this report it is wished to collect the voice of inhabitants of noise-exposed areas. A choice has therefore to be made considering the approach to use for collecting this data.

Research strategy is handling about which research method is to be used to obtain the wanted results. There are mainly two different strategies one can choose between, quantitative or qualitative research. The choice made depends on the problem to be assessed and the practicalities proper to each method for that situation. It is common today to consider the methods as complementary. The next chapter will go deeper on the definition on each of them.

#### 3.1.1 Quantitative research method

Quantitative research strategy, by collecting data, aims at proving or refuting a hypothesis or question, which is made on the background of an appropriate theory. It gives a wide range of liberty concerning the type of responses for the survey. Quantitative data is data that is in numerical form, such a statistics, percentages, etc. This means that the questions on the questionnaire have to be specific, narrow and precise giving the subject a list of choices. This makes the statistical work much easier and accurate for the analyzing of the data.

### **3.1.2 Qualitative research method**

Quantitative research on the other hand asks broad questions and collects word data from participants. This research method aims to gather an in-depth understanding of a problem. It is about understanding situation and actions and to discover new information. This requires an in-depth conversation with the subject and only requires a group of participants rather small. The answers are analyzed in text form without use of mathematical tools.

## **3.2 Other methods**

A research method describes how the researcher is going to conduct this survey. According to K. Ringdal [18], they can be classified in different categories. A quick overview over those is presented below.

### **3.2.1 Experimental study**

An experiment is a study of cause and effect. It differs from non-experimental methods in that it involves the deliberate manipulation of one variable, while trying to keep all other variables constant. This method is usually taken to be the most scientific of all methods as J. H. McMillan stipulates [19]. Laboratory experiments, field experiments are examples of such a method.

### **3.2.2 Transversal and longitudinal studies**

A longitudinal approach is where a group of participants are followed up after a period of time. A longitudinal study is usually found in the area of developmental psychology because it is a way of studying a change over time. It is important to recognize that longitudinal studies represent an approach and not an actual method of collecting data.

A transversal approach is where the research is done at a specific point of time. The survey is only done once and it is wished to describe the analysis as it was at the time the research was done.

### **3.2.3 Case study**

A case study is a detailed and intensive study of an individual or small group of people. Case study methods involve an in-depth, longitudinal (over a long period of time) examination of a single instance or event: a case [19].

### **3.2.4 Pairwise comparison**

Pairwise comparison is used when one has to compare two cases and choose which one is preferred.

## **3.3 Data collection techniques**

When both the research strategy and method are decided one has to choose how to collect the data. Indeed, there are several ways of doing so which will be described in the following sections. There are mainly three types of data collection techniques: surveys, interviews and observations [19].

### **3.3.1 Surveys**

According to K. Ringdal [18] a survey can be defined as a systematic method for collecting data from a number of people in order to give a statistical description of the population the sample is taken from. A survey is standardized, meaning that all participants get the same questions where the results will mainly be used for quantitative use. Since survey research is always based on a sample of the population, the success of the research is dependent on the representativeness of the population of concern.

How to gather the responses is to the choice of the researcher. He/she can send it by different communication means (email, mail, etc) or ask the questions over the telephone or face-to-face by visiting the participants. Each of these procedures has its advantages and disadvantages.

A questionnaire is, for example, inexpensive, it can be distributed over a large sample, which may be geographically dispersed and guarantees the anonymity of the respondents. However, one has little control over the quality and accuracy of the answers. One reason to that can lie on the difficult of the questionnaire and the inability of the participant to ask advice to the researcher. Also, the researcher can experience that many of the participants choose not to respond to the survey. This can be explained with the lack of responsibility they feel to respond to they survey because of the manner they received it in the first place.

Telephone surveys or personal visits will guaranty a higher quality of the survey. A higher rate of response will be achieved and the participant will feel more taken care of since the researcher may lead the respondent in case of misunderstanding of the question. However, this method is more time-and resource demanding and it reduces the anonymity of the research.

When conducting a survey, there are two important steps one must go through before collecting the data.

The first is to decide who to ask; or in technical words choosing the sample. Who are

the persons that will be able to provide you with valuable data for your research? And how many respondents do you need? To answer that last question it is important to decide how your sample should look like? Are the gender, age, income, profession, marital status (to name a few) important for the survey? Will the factors have an impact on the results?

The second is to create a good questionnaire and to test it. Indeed, there are several ways of asking questions; one can ask open questions, closed questions or assessment questions [18]. An open question lets the respondent formulate his own answer while a closed question lets him choose between several possible answers. Assessment questions give a claim that the respondent can grade how he agrees with the statement.

Closed and assessment questions are easier to analyze as statistical tools can be used. Open questions gives a more personal response which allows the researcher to understand the background for the respondent's response but is more demanding for the post-processing of the answers.

### 3.3.2 Interviews

For Kvale [20] "the qualitative interview seeks to describe the meanings of central themes in the life world of the subjects. The main task in interviewing is to understand the meaning of what the interviewees say."

Naturally enough, an interview is a type of data collection that is a widely used method for qualitative research and for case studies. It can also be simply defined as a conversation between two people where the one asking the questions is referred as the interviewer and the responding person is referred as the interviewee with the particularity that the interviewer has the ability to lead the discussion in the way he intend to. McMillan [19] states that the interview technique is useful when information that is too complex to formulate in a questionnaire is needed. The open questions can also be adapted to each interviewee. Interviews may have the ability to capture feelings and experiences unlike the closed question type of surveys.

Interviews can be classified in three categories.

- *Structured interviews*: the interviewer has made all the questions in advance and keeps to this manuscript under the conversation. This method can be considered as quite similar to open questions in surveys since the interviewer only wants answers to the premade questions.
- *Semi-structured interviews*: the interviewer has an agenda to refer to during the interview with topics to be taken up with the interviewee. However, the conversation can progress to a certain direction if the interviewer feels there is some interesting information to gather along the way. It gives the interviewer some liberty of action and he may find information he wouldn't have thought of prior the interview.

- *Unstructured interviews*: the interviewer starts and gives the theme for the following discussion. There are however no more pre-made questions from the interviewer's side. The discussion follows its course without the interviewer taking it in a special direction.

Both the semi-structure and unstructured interview techniques are used when the researcher wants to discover new information he didn't know prior the conversation. Structured interviews on the other side works more as checklist where the researcher gets the answers he planned on having prior the conversation.

### **3.3.2 Observation**

Observation is a data collecting technique that can be used both in the qualitative and quantitative methods. This method came when it has been shown that both interviews and surveys can give the wrong picture of the reality. Indeed, it is quite easy for the participants of the research to modify the truth and not answering according to the reality. There can be several reasons for this; the subject of the survey or discussion can be sensitive for the participant and it may cause him to modify the answers. Another reason could be that the interviewee may not recall at all or exactly the information the interviewer is after. Humans have a tendency to recall what they want to recall or important happenings while the rest can be easily forgotten. These facts make the two previous data collecting techniques less accurate.

This is where the observation technique can avoid these problems by observing what the population sample is doing instead of listening to what they say they are doing [18]. Marshall and Rossman (1989) [21] define observation as the "systematic description of events, behaviors and artifacts in the social setting chosen for study". Participant observation is the process enabling researchers to learn about the activities of the people under study in the natural setting through observing and participating in those activities according to DeWalt (2002)[22]. Schmuck (1997) [23] states that observation methods provide researches with ways to check for nonverbal expression of feelings, determine who interacts with whom, grasp how participants communicate with each other and check for how much time is spent on various activities.

Observation techniques are often divided in open and hidden categories. In an open observation, the person being observed knows about it. This may have some disadvantages because the person concerned might then be more aware of their own actions and therefore the research may lose some of its authenticity. In a hidden observation, the person being observed doesn't know about it. This on the other hand, may present some ethical issues.

### **3.4 Choice of method**

Now that an overview over the possible research techniques have been presented, the research procedure used for this thesis will be described.

#### **3.4.1 Research method chosen**

Considering the three research questions described in 1.2 Research question which are specific and where the researcher knows exactly what type of information he is after it is logical to use a quantitative method to do the research.

Since the researcher got into the problem of noise prior the research he knew well what kind of information he was out after. Therefore, a qualitative research method was not needed. Further, it was decided that the most appropriate way to collect the data was to execute a survey using closed questions. Several factors led to that choice.

Firstly, the size of the population sample is big enough for such a procedure.

Secondly, for statistical analysis, which is the most appropriate way for answering such research questions, survey results are best suited because the participants' answers can be treated as numbers. Indeed, if a question is of the assessment type (3.3.1 Surveys), that is, a close-ended question that limits the respondent with a list of answer choices ordered in scale format where the respondent should decide to rate the situation, the result can easily be used for statistics purposes. One can convert the scale vocabulary into numbers. An example of the this survey could be when asking how the residents are annoyed by the noise the following list of answers is given:

1. Extremely annoyed
2. Very annoyed
3. Moderately annoyed
4. Slightly annoyed
5. Not at all annoyed

Converting this list each individual answer with a number can easily be done where 10 corresponds to the answer "extremely annoyed" and 0 to "not at all annoyed".

The previous response scale is taken from the ISU standard ISO/TS 15666 [24] providing specifications for socio-acoustic surveys and social surveys that include questions on noise effects.

This method is applied for all research questions since they are of the same nature and requires the same type of answer and statistical analysis.

Further, it was decided that the most appropriate way of getting in contact with the chosen population sample for this survey is by telephone. Since the reports received from Sweco gave most of the personal information it was easy to contact them this

way. Besides, as the total number of participants is found to be 84, which is a satisfactory number for this specific survey. However, it is primordial that the response rate is high. The survey won't be representative enough if the population sample is small. Therefore, it was decided to perform the survey by contacting the participants by telephone; it gives a higher response rate than by sending the questionnaire by mail or email where the response rate can be as low as 50% as the articles (C.B.Alan, 2008) [25] and (D.A.Dillman, G.Phelps, R.Tortora, K.Swift, K.Kohrell, K.Berck, B.J.Messer, 2009) [26] specifies. Furthermore, it takes less time to perform a survey by telephone than by mail. And in the time frame of this study was to perform a survey by mail would not have been possible. The email addresses were not included in the reports given by Sweco so in any case it would have been necessary to call each household to get hold on their email address for so sent the questionnaire via the Internet. It made more sense to just interview the residents by phone.





# CHAPTER 4

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## Survey

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The topics to be included in the survey were first brainstormed between the author and the supervisor in Oslo, at Sweco's headquarters. There it was decided to focus more on the residents' experienced change in noise nuisance before and after the measures were installed. The questionnaire was first drafted by the author of the thesis and was then sent to the supervisor for feedbacks. The final version was sent to Statens Vegvesen for approval as well since all the participants of the survey were first affected by the creation of the new E6, a project of Statens Vegvesen. Indeed, Statens Vegvesen is responsible for the noise nuisance caused by road traffic and is therefore obliged by law to respect the noise limits specified earlier (2.3 Laws and action plans against noise).

A more detailed description of the survey and the procedure for the data collecting part will be presented below.

### 4.1 Background

#### 4.1.1 Statens Vegvesen

Statens Vegvesen, or in English, the Norwegian Public Roads Administration is the government agency responsible for the state and county public roads in Norway. This includes the planning, construction and operation of the national and county road network, vehicle inspection and requirements, driver training and licensing [27].

Its role fighting the noise situation is quite important. Indeed, for existing homes, schools, kindergartens and health institutions the regulations relating to pollution are to be applied. *Section 2.3* Laws and action plans against noise gave an overview over the noise levels to respect; if this limit exceeds, the facility owner (i.e. the Public Road Administration) is in the duty to make the necessary noise reduction measures.

A quick summary of the laws: if the indoor noise level exceeds 42dBA averaged over a day then the building is entitled for noise reducing measures. For new buildings and new roads construction the guidelines for the treatment of noise should be respected [7].

The residents interviewed in this survey have had their habitations noise affected by the construction of a new road. Therefore, Statens Vegvesen was entitled to do noise level measurements and simulations to find out if the expected noise levels were to exceed the limits both indoor and outdoor the habitations.

#### **4.1.2 Sweco**

Sweco is an international company providing multi-disciplinary engineering and environmental professional service for planning and building design, sustainable urban and land development, energy, industry, infrastructure, offshore, water and environment.

Further, Sweco performs assessment, planning and monitoring in relation to sound and vibrations. In the field of transport and noise, Sweco has been active creating noise maps of all railroads in Norway. Also, the acoustical consultants of Sweco Norway have designed noise measures and worked closely with the Norwegian Public Road Administration (4.1.1 Statens Vegvesen).

#### **4.1.3 Procedure experienced by the residents**

From the moment the government and the Public Road Administration agreed on building a new road, the affected habitations and residents are part of the project. Indeed, a dialogue is then created which may lead to noise reduction measures. The typical procedure is made in five steps:

1. After that an acoustic consultant company has been chosen to perform the noise measurements, in this case Sweco; the residents receive a letter informing them about the new planned road. Also, the letter states that some engineers from Sweco will come by their homes to make some measurements in order to assess the habitation for both indoor and outdoor noise levels.
2. An acoustician, after having decided the time with the residents, visits the habitation. There, he measures the dimensions of the living areas (living room, kitchen, rooms), the dimensions and thickness of the windows and the type of isolation. He also notes the type of ventilation used in the different rooms.
3. A certain period of time passes where Sweco using the data collected simulates the experienced noise for each habitation. This procedure has been explained previously (2.4.8 Calculation procedure). Noise levels for each room are computed stating if it exceeds the noise limits. The outdoor noise level is also simulated using CadnaA. Sweco is also proposing noise-reducing measures for each area where the noise limit is exceeded. These can be of various types.
4. Statens Vegvesen is then responsible for the rest of the work. They first make a plan for how to install the noise reducing measures. The residents will

receive a letter informing them about the following steps related to the new road. They may get the message that the new road won't affect their habitation, or it may be the opposite so that noise-reducing measures are needed. In that case the letter will stipulates that workers will come to install some noise reducing measures.

5. The workers effectuate the work, which will then mean that the Public Roads Administration has followed the regulations and taken the consequences of building the new road.

There is, however, no more dialogue between either Sweco or Statens Vegvesen and the residents. This means there are no possibilities for feedback and the residents don't have the opportunity to express their feelings about the whole process. Also, from the simulations it is known that the measures will reduce the experienced noise, but does that coincide with what is the residents experience? Do they experience the same improvements as they are supposed to?

This is where the survey done in this master thesis can elude these questions.

#### **4.1.4 Reports**

Reports for every single visited habitation are made by the consultant company, which include information about the noise levels, the eventual recommended noise reducing measures and the costs. These reports are then sent to the facility owner (4.1.1 Statens Vegvesen) for approval.

## 4.2 Population sample

The population sample chosen for the survey is a determining factor on the quality of the research. Indeed, one wants to gather a representative group that will most probably give satisfactory results and thus an answer to the research questions. The following sections will give a complete picture of the participants of the survey.

### 4.2.1 Where?



The chosen areas for this research have been decided together with Sweco. Indeed they have worked on a few roads together with Statens Vegvesen over the years and have accumulated quite useful data for the purpose of this research. E6 Gardemoen – Biri is the main parcel this research is based on and is located close to Oslo as shown on Figure 5.

**Figure 5:** Location of the parcel Gardemoen - Biri

The national road E6 in Norway stretches from Svinesund to Kirkenes and is the main link between North and South. E6 Gardemoen – Biri is a part of this main national road. The road is important for the industry and commerce because there are major transports of goods between the North and South of Norway but also from and towards Europe.

On request from the Parliament, the Public Roads Administration is expanding the E6 north from the airport to a four-lane road. Initially it was just planned to expand it from Gardemoen to Kolomoen, but it was found later that the expansion should go up to Biri. The work plan for the parcel can be found in Appendix C – Timeline E6 Gardemoen - Biri. The road is supposed to be totally finished 2015 and it is so far in time with the plan.

The parcel from Gardemoen to Biri can be divided in four smaller parcels as following, from South to North:

- E6 Dal - Minnesund
- E6 Minnesund - Labbdalen
- E6 Skaberudkrysset
- E6 Skaberud – Kolomoen



**Figure 6:** Details of the parcel E6 Gardemoen - Biri

#### 4.2.2 Why?

These four parcels were chosen because Sweco has been appointed the acoustical responsibility for those areas and has already made the measurements needed for simulating the noise situation at each household. Besides, since the project started in 2005 and the measurement happened some time after that, the residents are susceptible to remember the process and even the noise situation before the eventual noise measures. Thus it fits perfectly to the survey planned and it is expected that it will give satisfactory results. The choice of population sample is very important in these kinds of surveys where it clear what kind results are expected.

#### 4.2.3 Who?

The reports (4.1.4 Reports) made by Sweco contained lots of information on the habitations and residents of the different parcels. These were very useful for the planning of the survey and 84 out of the 283 households investigated were chosen for the survey, Table 3. The main factors that decided if a household qualified for the survey or not was if the noise level limit was exceeding the indoor noise limit of 30dB. Since the main goal of the research is to determine whether noise measures are doing the effect it is supposed to do, households having had those types of sound amelioration are the most relevant. Habitations where the new road doesn't generate noise level of over 30dB are thus not interesting in this case.

**Table 3:** Details of the parcels actual for the survey

Parcel	Location	Length	Number of habitations in the noise zone	Number of habitations selected for the survey
Dal - Minnesund	Eidsvoll, Akershus	21,6km	180	29
Minnesund - Labbdalen	Eidsvoll, Akershus –Stange, Hedmark	22km	68	34
Skaberudkrysset	Stange, Hedmak	>1km	15	8
Skaberud – Kolomoen	Stange, Hedmark	12,7km	20	13

#### **4.2.4 What is the noise situation?**

The households examined, located nearby the new E6 may be exposed to high noise levels. Simulation using the measurements Sweco's employees made together with the expected traffic on the new E6 give a picture over the noise levels both outdoor and indoor the selected households which will be presented in *Chapter 5*.

### **4.3 Structure of the survey**

#### **4.3.1 Structure**

The survey is divided in five parts. The survey can be found on the Appendix E – Questionnaire. The last three parts are more or less each corresponding to one of the research questions presented in the introduction (1.2 Research question).

- The first part of the questionnaire resumes the hard facts about the habitation in order for the interviewer to have some background information when doing the survey. This contains contact information of the resident, the construction year of the building and the respective noise levels indoor, outdoors and on the façade simulated before hands.
- The second part focuses on the respondent basic information, the type of building (villa, apartment, etc) and the different noise sources the resident is affected by.
- The third part concentrates on the experienced process of the entire project; from the first contact made by Statens Vegvesen to the installation of the noise measures.

- The fourth part is simply asking residents about the improvements the noise measures may have led to.
- The last part focuses on the health of the resident and especially if the noise measurements have led to any changes on the annoyance level and/or on their health.

### 4.3.2 Questions

Following is a summary of the most important questions and the type of answers the participant can choose between.

As evoked in 3.4.1 Research method chosen, an ISO standard [24] has been introduced for socio-acoustic surveys. This standard is applied here as well. However, since the survey is done in Norwegian the following translation has been used:

1. Extremely annoyed ⇔ Ekstremt plaget
2. Very annoyed ⇔ Veldig plaget
3. Moderately annoyed ⇔ Plaget
4. Slightly annoyed ⇔ Litt plaget
5. Not at all annoyed ⇔ Ikke plaget

The survey is focusing both on the experienced process by the resident from the moment they were informed of the new E6 road to the last visit of the workmen installed the eventual noise reducing measures. *“How satisfied were you when you first heard your habitation would undergo a noise assessment?”* or *“How satisfied are you with the newly installed noise reducing measures?”* are examples of questions focusing on that part of the survey.

Besides, *“How do you feel the noise situation has changed after the noise reducing measures”* is a question of part 4 where the participant has the choice between the following answers: betydelig forverring, forverring, ingen bedring, forbedring, betydelig forbedring, vet ikke.

The majority of the questions give the participants a chance to scale their response between five different answers fitting best their situation.

The last part of the survey asks specifically the annoyance level before and after the measures: *“How annoyed do you feel in this room, both before and after the noise reducing measures?”*

The survey was first sent to Sweco and Statens Vegvesen for feedback. Then the researcher tested it on persons who didn't have the same technical background as him or the supervisors. This allowed the researcher to know how long the interview took and if adjustments were needed.

These questions will permit statistical treatment of the responses collected and will hopefully give a broad picture of the noise situation.

## **4.4 Procedure**

### **4.4.1 Personal data**

The reports 4.1.4 Reports made by Sweco gives information about the residents to be interviewed. At first the report of each household was individually analyzed in order to find the most relevant cases for the survey. Having noise levels above the limit set to 30dB indoors was the main criteria; levels above 55dB outdoors was preferable as well. This, in order for the survey to be able to answer to the research questions asked in the report.

Some of the selected reports, 84 were finally selected (4.2 Population sample), were missing the contact information or contained the wrong information. It was then needed to search on the yellow pages the correct information.

### **4.4.2 Telephone interviews**

Out of the 84 relevant households, only 76 were possible to contact. The missing 8 households were either not willing to answer the survey, were not possible to contact either because they were not at home or because the contact information was outdated and was not possible to find on the Internet.

Most of the contacted residents were willing to answer to the researcher's survey (which can be found in *Appendix D*). The average time used per call was 12 minutes. It could sometimes be done in 6 minutes when the participant didn't explain its answers nor asked questions around the survey. It could also take up to 25 to 30 minutes when the person called was talkative and wanted to know more about the survey, the results so far, etc. A standard text was written in order to ease the job of the researcher and can be found in *Appendix E – Questionnaire*. This text was slightly modified after the first couple of interviews as it was then seen what kind of information the residents wanted to know and for which questions they needed more detailed explanations. During the conversations some interesting aspects of the noise situation was discussed and some of these aspects will be integrated throughout this report.

The survey was started in April 2012 and ended 3 weeks later. Some residents were very busy and the researcher had to call several time or even plan the call in advance in order to be able to interview them.

## **4.5 Analysis using SPSS**

The results of the survey were stored in individual excel sheets (see *Appendix F*). These sheets included some personal data, the type of household, and the answers to each question asked. Some comments could also be written if the researcher needed to note some interesting answers during the interviews.



Once all the interviews were performed, a statistical tool, SPSS, was used for the post-processing of the answers.

SPSS (Statistical Package for the Social Sciences) is a data management and analysis product produced by SPSS, Inc. in Chicago, Illinois. Among its features are modules for statistical data analysis, including descriptive statistics such as plots, frequencies, charts, and lists, as well as sophisticated inferential and multivariate statistical procedures like analysis of variance (ANOVA), factor analysis, cluster analysis, and categorical data analysis. SPSS is particularly well suited to survey research, though by no means is it limited to just this topic of exploration.

SPSS can take data from almost any type of file and use them to generate tabulated reports, charts, and plots of distributions and trends, descriptive statistics, and conduct complex statistical analyses.

IBM SPSS Statistics has been the leading desktop statistical analytics and reporting tool for over thirty years now, and currently in its version 20 and I the one used in this research.



# CHAPTER 5

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## Results

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The survey described in *Chapter 4: Survey* and executed as explained 4.4 Procedure gave 76 unique responses on a various range of questions. These questions can be examined in Appendix E – Questionnaire. They are primarily oriented towards the indoor noise situation and the noise annoyance levels experienced by the residents after the noise reducing measures have been applied. Being in contact with the selected people (4.2 Population sample) will help the researcher to answer the questions addressed in this report (1.2 Research question).

This chapter will first do a quick overview over the amount of responses the survey gave and the kind of noise reduction measures the households got installed. Then, a quick comparison between the before and after state of the noise levels in the exposed rooms of the different households will be presented. Further, the experienced noise annoyance by the residents is described and will especially focus on the improvements the noise reduction measures might have led to. Lastly, the participants of the survey were given the chance to give their feedback to the two main actors they were in contact with; that is the Norwegian Public Roads Administration (4.1.1 Statens Vegvesen) and the consultant company Sweco (4.1.2 Sweco). Also a general question on the noise reducing measures was asked to the participants of the survey and the results will be presented at the end of this chapter.

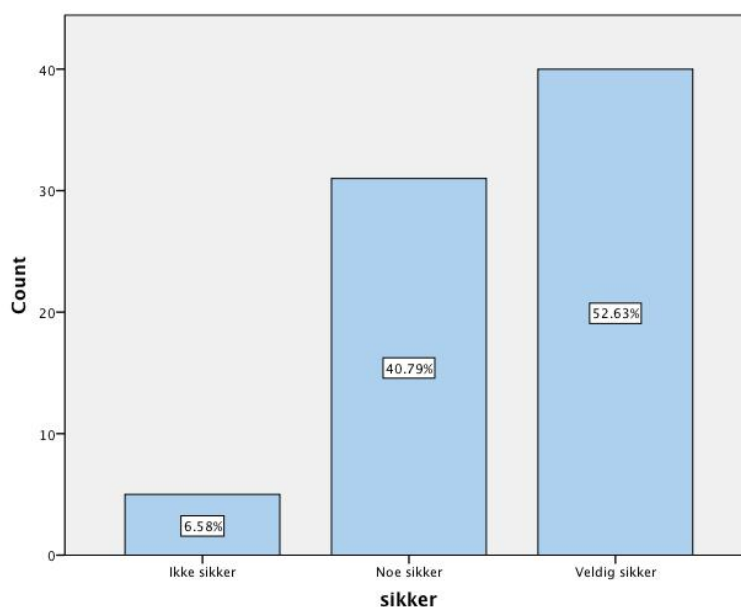
### 5.1 Implemented noise measures

As previously mentioned, the survey reached 76 participants and the researcher was able to gather complete responses for all of them. The population sample was originally composed of 84 households but due to outdated contact information or non-willing participation it was reduced to 76.

Therefore, most of the questions had 76 responses, which gave a reasonable overview over the situation. Some questions which either didn't apply for all households or where some participants didn't wish to answer had lower responses. The lowest amount of responses was still up to 50. On the other hand, questions that had to do with the noise situation in the different rooms of the households had as many as 245 responses. This is because, the majority of the households had noise reducing

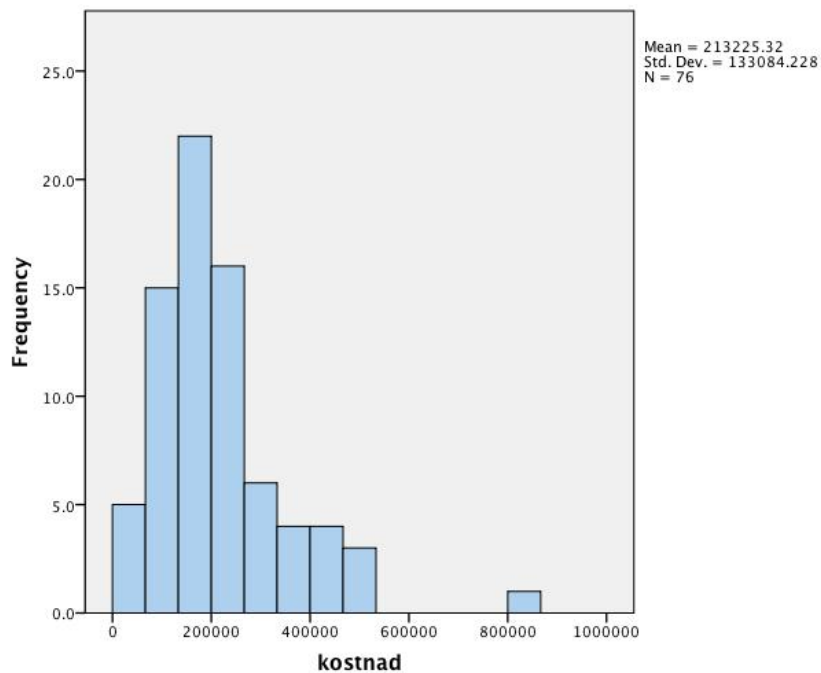
measures installed on several rooms of the habitation. To have a complete overview the situation in each of these rooms was included in the survey.

The survey was made during the spring of 2012. However, the noise reducing measures of the parcels chosen may have been installed as early as 2008 (see Appendix C – Timeline E6 Gardemoen - Biri). It is thus plausible that the participants don't recall exactly how the noise situation was before the measures. In order, to check this hypothesis the researcher directly asked the respondents how sure they felt about the accuracy of the responses they gave throughout the questionnaire. Figure 7 shows that over 90% of the respondents feel either very sure or quite sure about their responses. The researcher has therefore chosen to consider the survey as a good representation of the noise situation the population sample experiences.



**Figure 7:** Response confidence of the survey participants

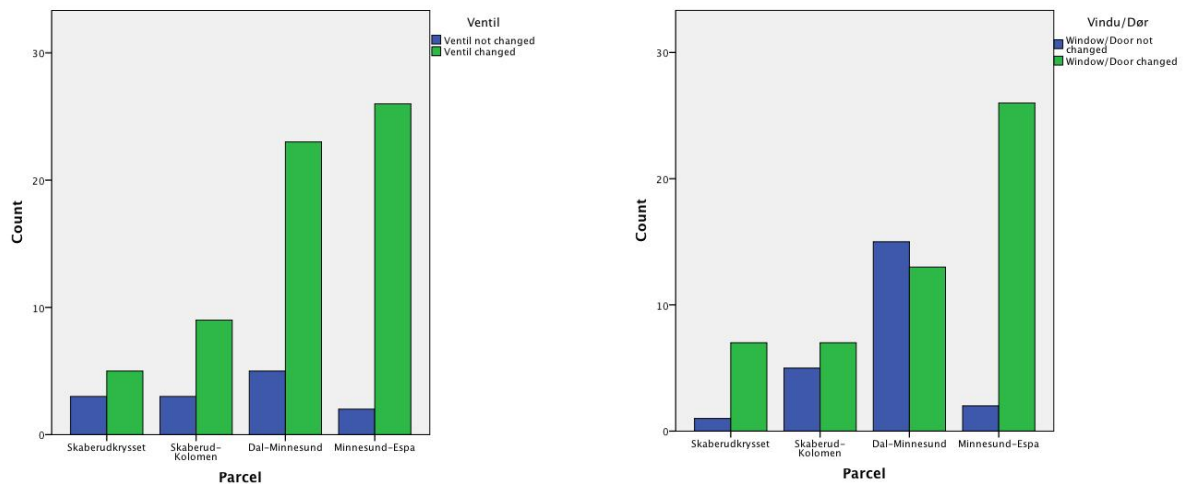
In average, the noise reducing measures installed on the 76 households participating in the survey is costing the owner of the new road (4.1.1 Statens Vegvesen) over 200.000 NOK per habitation. Figure 8 shows the total costs for all the households studied in this report.

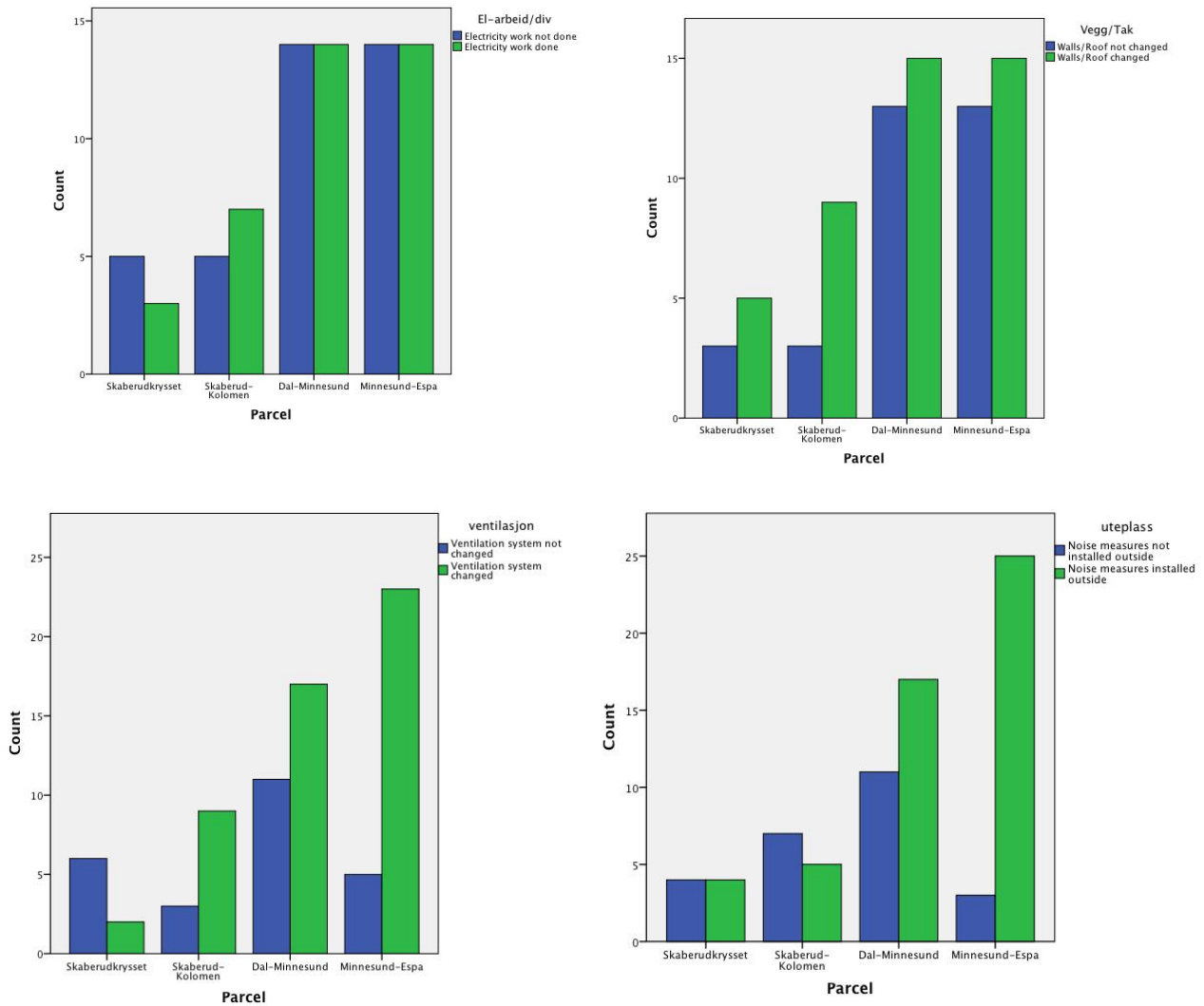


**Figure 8:** Noise reducing measure costs

Various noise-reducing measures have been installed on the households included in this survey. Indeed, as seen on Figure 9 air vents have been changed, walls and roofs may have been replaced or isolated, windows and doors could have been changed, ventilation systems replaced and isolating walls for the outdoor situation can have been installed.

From the graphs on Figure 9, it is noticeable that air vents and windows are the most common changes in the households in order to reduce the indoor noise levels.





**Figure 9:** Type of noise reducing measure installed on the four parcels

## 5.2 Noise levels before and after the measures

Before going into details in the improvements the noise-reducing measures may have led to it is useful to know how a reduction of the noise actually feels like. The following table can illustrate this thought.

**Table 4:** Actual effect of change in dB(A)

Change	Actual effect
1 dB(A)	Improvement is just noticeable
2 - 3 dB(A)	Improvement is noticeable
4 - 5 dB(A)	Improvement is well noticeable
5 - 6 dB(A)	Improvement is important
8 - 10 dB(A)	Improvement feels like a half of the original noise

### 5.2.1 Noise source experienced by residents

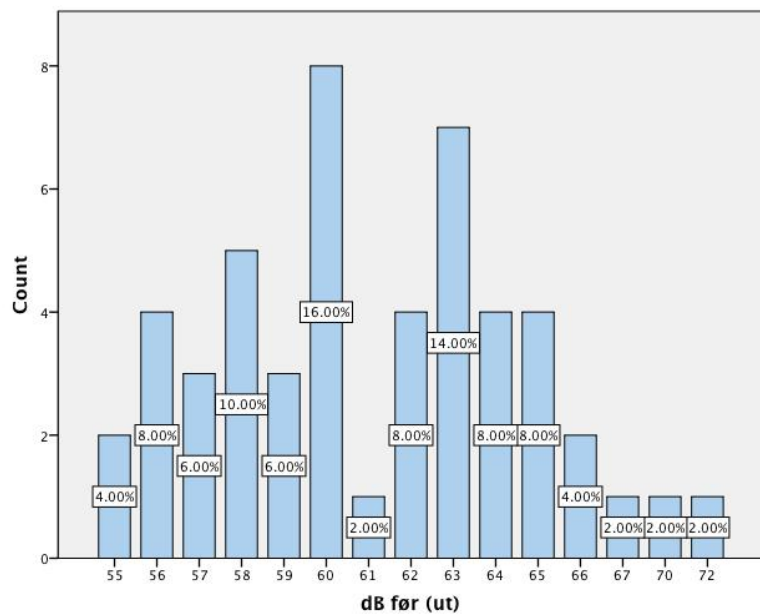
After having talked to 76 different residents it was striking for the researcher how the common noise nuisance had its origins from the road traffic. The question “*What type of noise are annoying you in your home*” was asked and only a minority mentioned, additionally to road traffic noise, neighbors, railroad noise or air traffic. The researcher has thus concluded that the population sample is adequate for this research since it focuses on the indoor noise caused by road traffic. It was also asked to the participants mentioning other annoying noise sources to only consider road traffic when giving their answers. The researcher believes this rule was respected and considers all the responses to be valid and representative.

### 5.2.2 Outdoor noise levels

The simulations made by Sweco using the technique described in 2.4.8 Calculation procedure gave, the selected population sample, the following noise situation outside the habitation.

N	Valid	50
	Missing	195
Mean		61.18
Std. Deviation		3.789
Variance		14.355
Range		17
Minimum		55
Maximum		72

**Figure 10:** Outdoors noise levels, statistical view



**Figure 11:** Outdoors noise levels

Figure 10 and Figure 11 depicts the noise situation outside the households chosen for the survey. Only 50 of the 76 residents are experiencing noise levels superior than 55dB, which is the limit specified in T-442 [7] and explained in the following chapter: 2.3 Laws and action plans against noise. The resting 26 are experiencing lower outdoor noise levels and are therefore not included in this results presented above. Those 50 habitations have had outdoor noise measures installed, which is usually

consisting of a noise wall shielding from the road traffic and is placed at places where the residents are spending time. This could for example be at the terrace.

From Figure 10, one can see that the mean noise level experienced by the selected population sample is 61dB and can reach up to 70dB for certain households.

The noise levels after the noise reducing measures have been installed were not measured nor simulated so it is difficult to observe the effect of those. However, as described later in this report, it will be possible to draw conclusions on the necessity of the measures from the potential improvements the residents experienced.

### 5.2.3 Indoor noise levels

The simulations made by Sweco using the technique described in 2.4.8 Calculation procedure gave, the selected population sample, the following noise situation inside the habitation.

**Table 5:** Indoors noise levels before after the noise reducing measures (statistical view)

		dB før (inn)	dB etter (inn)
N	Valid	245	245
	Missing	0	0
Mean		33.67	28.55
Std. Deviation		2.893	2.440
Variance		8.370	5.953
Range		19	18
Minimum		23	14
Maximum		42	32

Table 5 shows the statistical interpretation of the noise levels experienced inside. It is important to note that only the levels of approximately 30dB and higher are considered here. To be more precise, only the levels in the rooms where noise-reducing measures have been applied are considered. This is because this research focuses on the effect of the measures on the indoor noise levels. It is thus not interesting to consider all the noise levels.

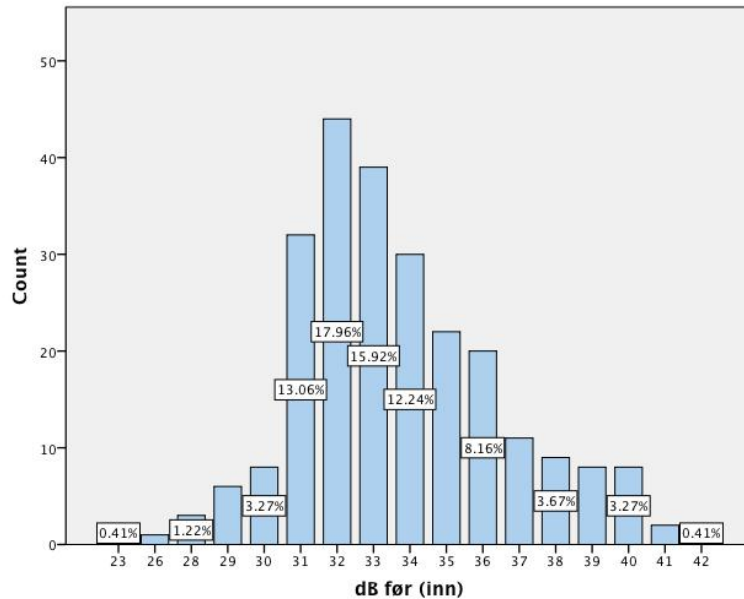
According to Table 5 these levels are ranging between 23 and 42dB with a mean of nearly 33.5dB before any noise measure has been installed. These levels are actually quite low considering the guidelines mentioned in 2.3 Laws and action plans against noise where the national indoor noise limit is set to 42dB before it is considered not healthy. Here, the Norwegian Public Roads Administration chose to apply noise-reducing measures for levels of 30dB and higher. And as many as 245 different rooms, in the habitations chosen for this research, have had noise-reducing measures.

Simulations were made both before and after the measured were installed. We mentioned that the mean noise indoor level is 33.5dB before any modifications to the

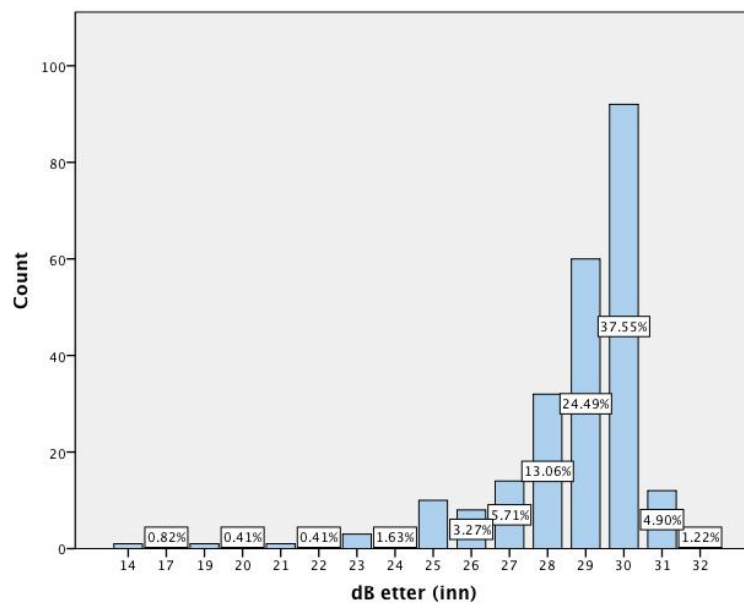


household has been done. As seen on Table 5, the mean noise level is reduced to 28.5dB. This means that the noise reducing measures are in reality reducing approximately 5dB and according to Table 4 this is a very well noticeable improvement. An average of 28.5dB is very satisfactory and noise shouldn't cause the inhabitants much nuisance when only considering these numbers. The following sections will discuss the noise nuisance more in depth.

**Figure 12** may give a better representation of the improvements made when it comes to the experience noise levels inside the habitations.



**Figure 12:** Indoors noise levels, before the noise reducing measures



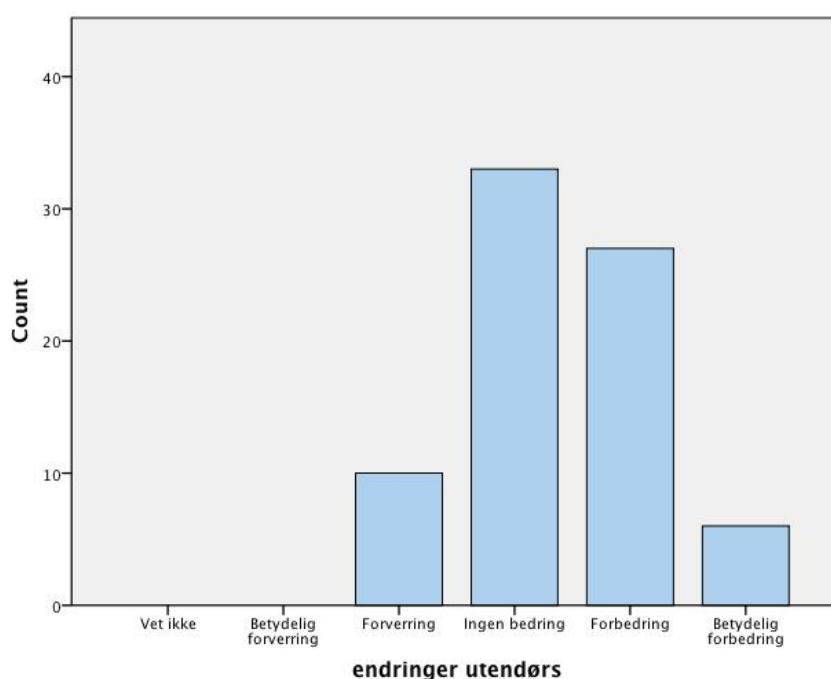
**Figure 13:** Indoors noise levels, after the noise reducing measures

## 5.3 Effect of the noise-reducing measures

When asked about the improvements concerning the noise situation both inside and outside the habitation, the participants of the survey answered differently. The result of these series of questions together with the degree of annoyance the residents' perceived both before and after the measures are presented below.

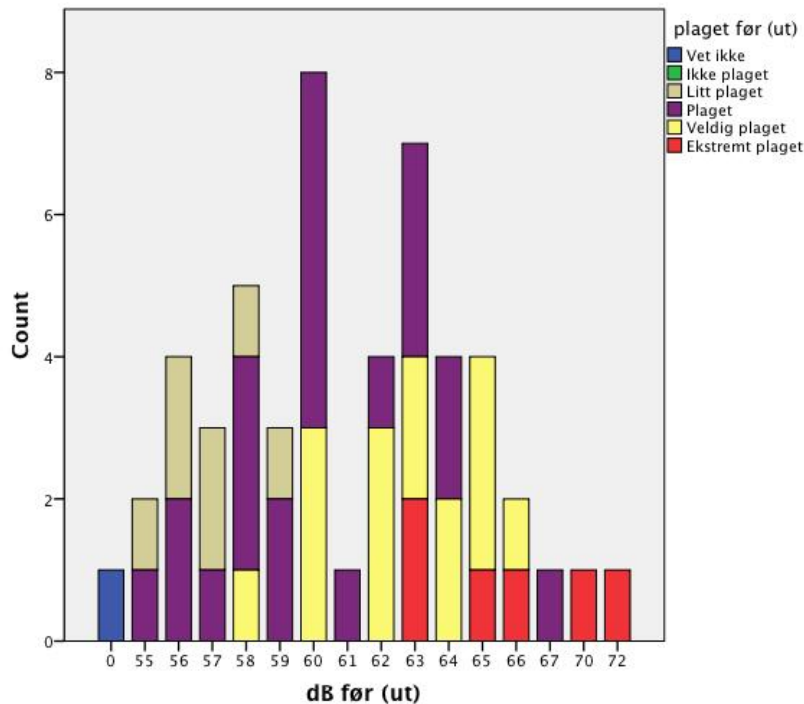
### 5.3.1 Outdoor noise improvements

The participants had during the interview, to give their feedback on the improvements the noise reducing measures may have made. Figure 14 shows the improvements on the outdoor situation.



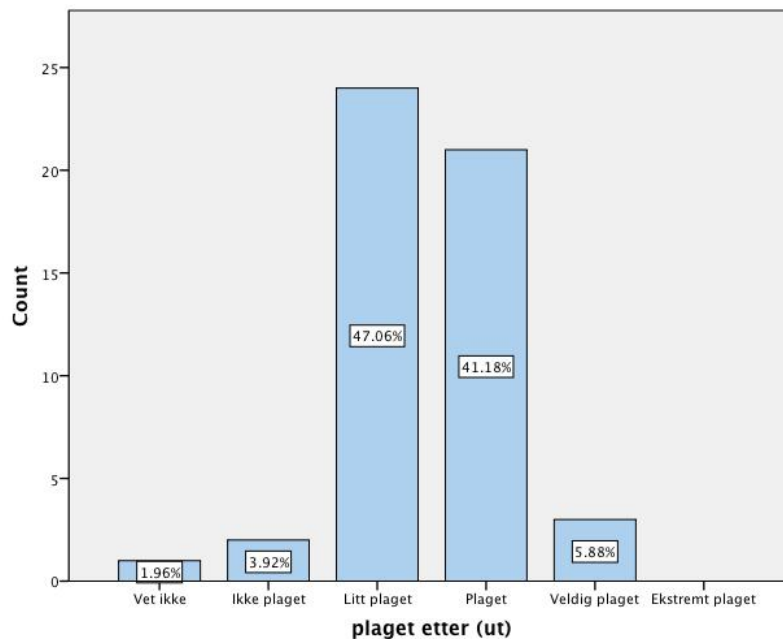
**Figure 14:** Noise situation improvements outdoors

It shows that the majority of the respondents are experiencing “no” to “some improvements”.



**Figure 15:** Outdoors noise nuisance before the noise-reducing measures

The figure above is depicting the degree of annoyance in relation with the noise level outside the habitation before any reduction measures has been installed. It is clear that the inhabitants are annoyed already at levels above 55dB and they tend to be “extremely annoyed” at levels of 65dB. Only a minority is disturbed “a little” by the road traffic.

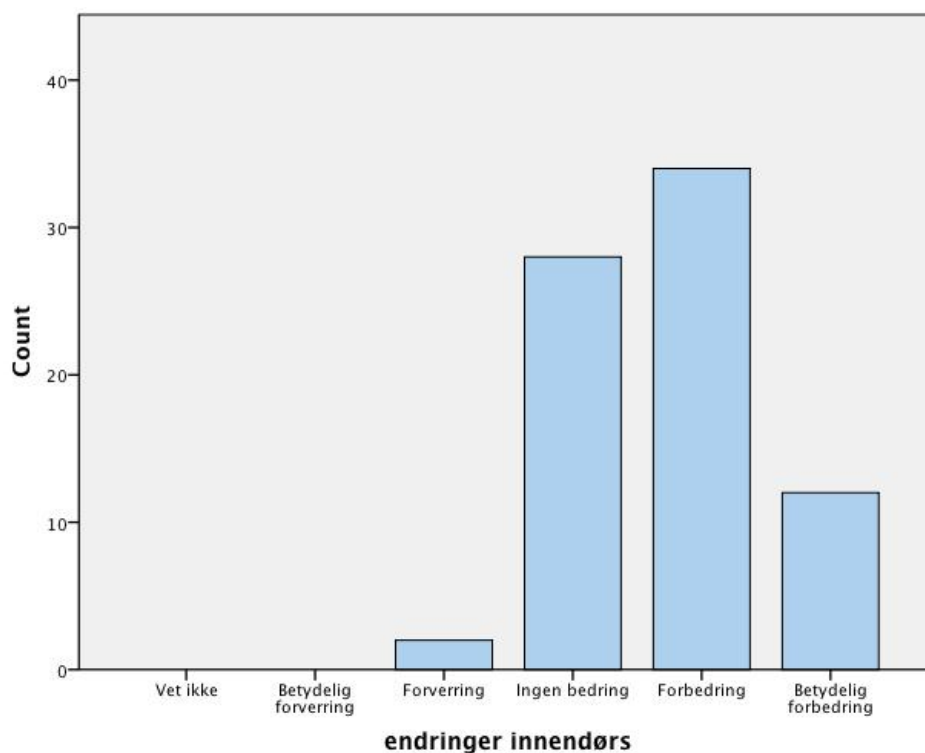


**Figure 16:** Outdoors noise nuisance after the noise-reducing measures

The noise reducing measures seem to have improved the outdoor noise nuisance. Almost 50% of the respondents are still annoyed or very annoyed by the outdoor noise situation but it is considerably better than before the installations since nearly 90% experienced the same degree of annoyance then.

### 5.3.2 Indoor noise improvements

Concerning the indoor situation the response was a bit different. Indeed, as can be seen on Figure 17, most of the respondents admit that the noise-reducing measures had a positive effect on the noise situation inside their habitation. More than 65% experienced an improvement or a major improvement on the noise perceived inside.



**Figure 17:** Noise situation improvements indoor

When looking at the details for each noise level, it appears that the residents start to be “annoyed” and “very annoyed” by the noise generated by road traffic at around 32dB. This can be seen on Figure 18 below. Only a few interviewees expressed their feeling of “being extremely” annoyed by road traffic noise; this occurred when the noise was reaching 40dB.

When looking at Figure 19, it appears that the noise levels have been strongly reduced (5dB according to Table 5). Respectively, the noise nuisance degree has also decreased. None of the residents are still “very” or “extremely annoyed” and only a few are still “annoyed”. The majority is now “not annoyed” or “slightly annoyed”.

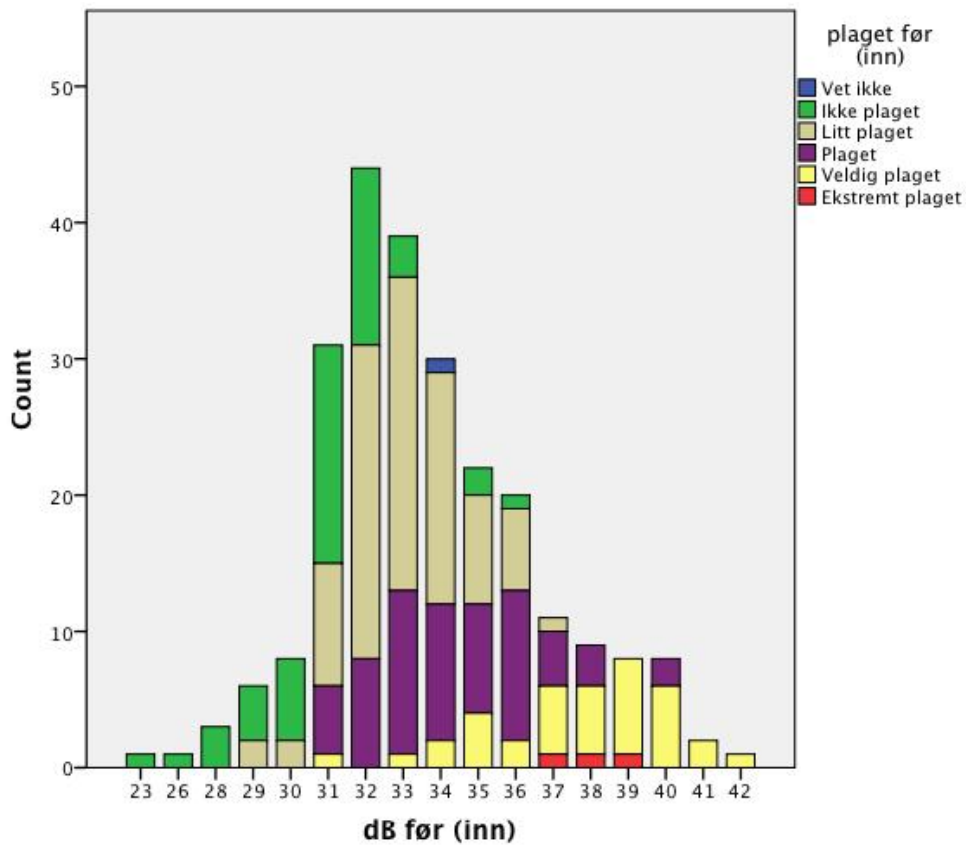


Figure 18: Indoor noise nuisance before the noise-reducing measures

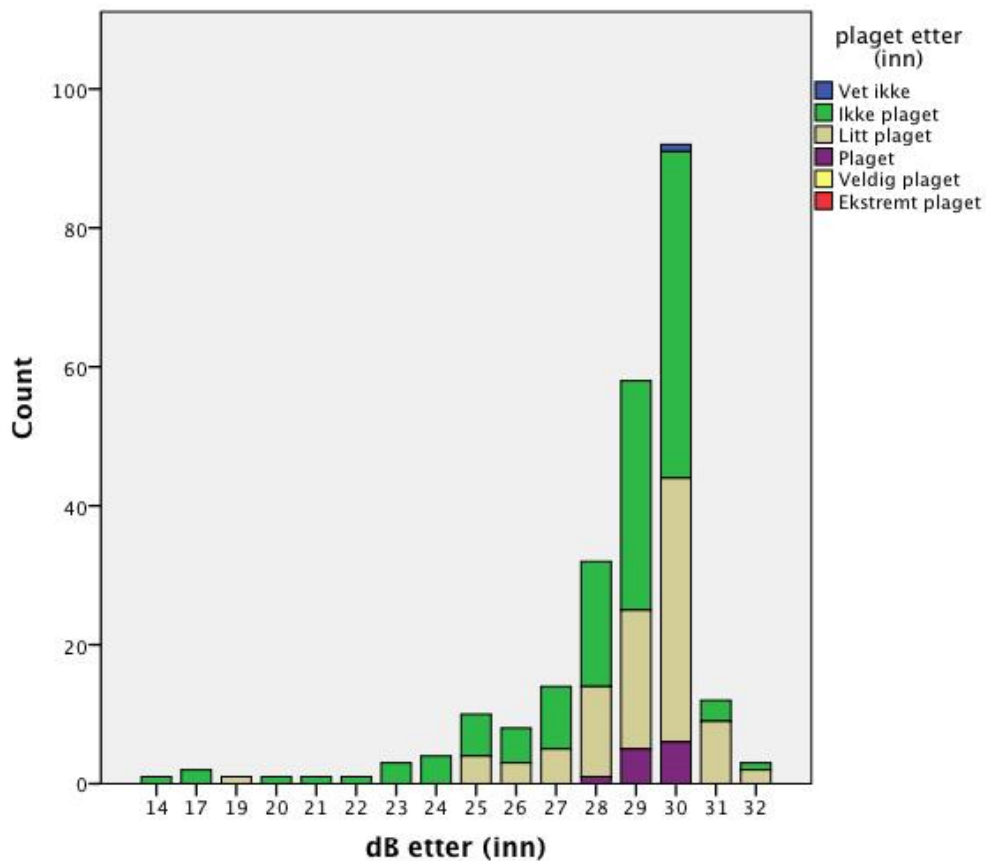


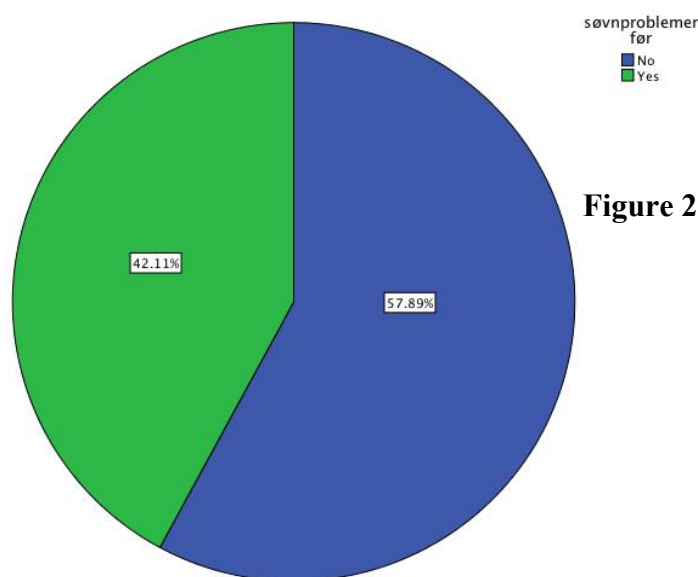
Figure 19: Indoor noise nuisance after the noise-reducing measures

## 5.4 Noise effect on life quality

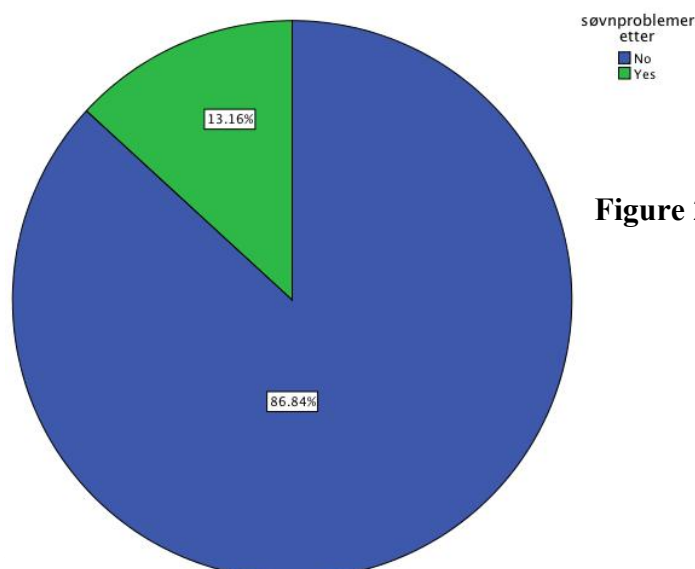
After having described all the possible effects exposure that noise can have on the human body, see earlier in the report (2.4 The effect of noise on humans), several questions during the interviews were concerning this topic. Simple questions were asked where the respondents could answer by yes or no were asked. The researcher has focused the health related questions on the difference between before and after the noise reducing measures were installed. The following sections are describing five different effects noise can have.

### 5.4.1 Sleeping disturbance

Road traffic is usually at its highest during peak hours (**Figure 4**) but can also be annoying at other times. During the night, road traffic is particularly annoying as quiet is usually required for a good night of sleep. When asked the participants of the survey, around 42% of them said they experienced sleep disorder before the noise-reducing measures were installed. Whereas it was reduced to 15% after, see Figure 21.



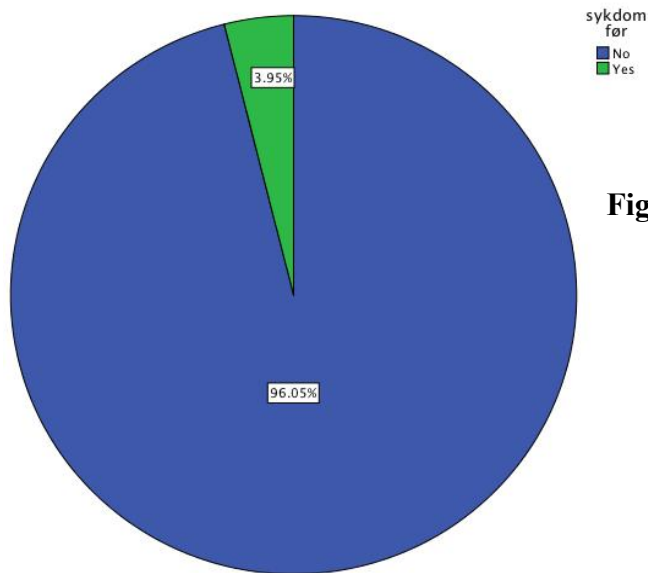
**Figure 20:** Sleep disorder before the noise-reducing measures



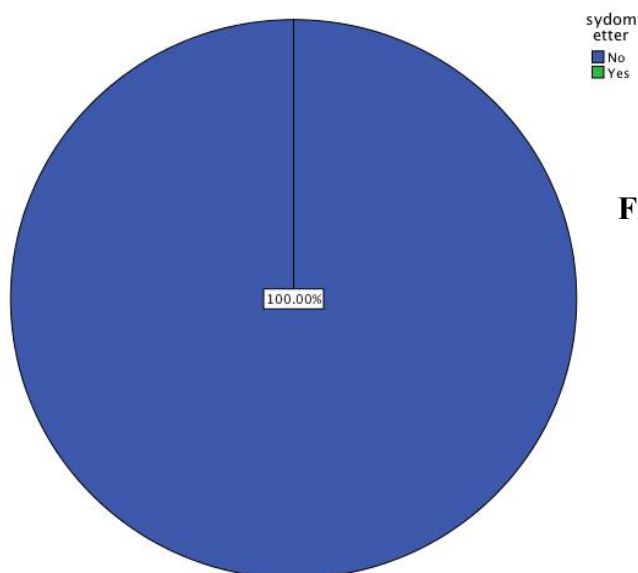
**Figure 21:** Sleep disorder after the noise-reducing measures

### 5.4.2 Illness

It appears on Figure 23 that only a very limited number of the residents chosen for the survey have experienced illness of any kind that could be related to noise. After the measures, none of the respondents responded yes to that question.



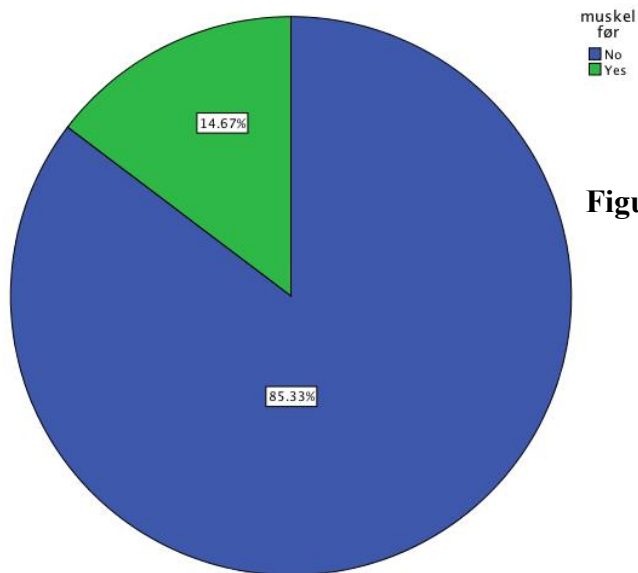
**Figure 23:** Illness due to noise before the noise-reducing measures



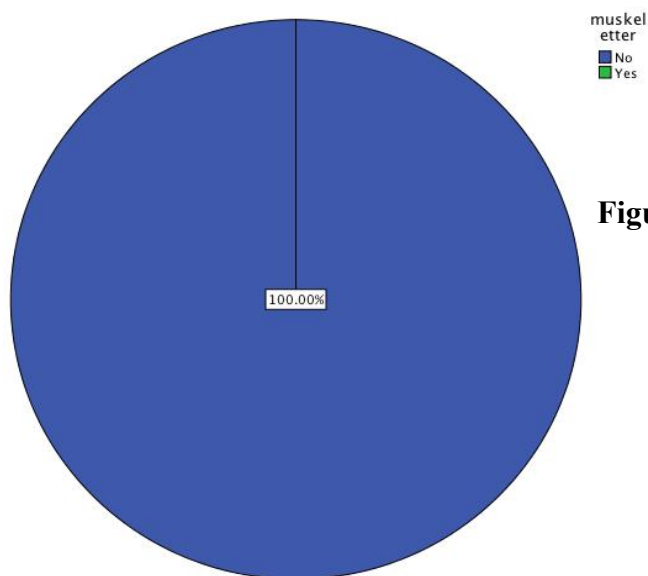
**Figure 22:** Illness due to noise after the noise-reducing measures

### 5.4.3 Muscle tension and muscle pain

Less than one fifth of the participants of the survey complained about muscle tension or muscle pain that could be related to the noise perceived indoors. Comparing Figure 24 and Figure 25 one can easily see that the noise-reducing measures decreased that percentage to 0.



**Figure 24:** Muscle soreness due to noise before the noise-reducing measures



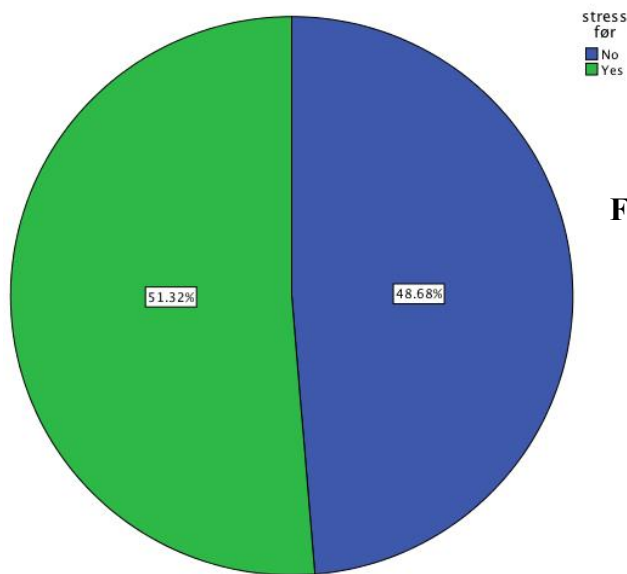
**Figure 25:** Muscle soreness due to noise after the noise-reducing measures



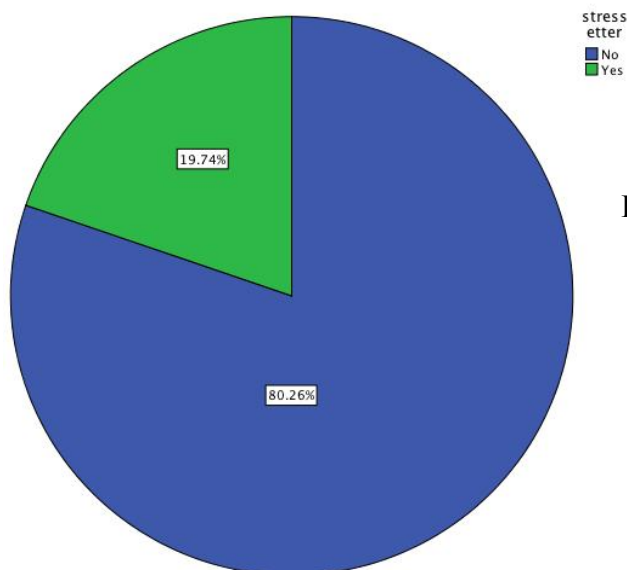
### 5.4.4 Stress

Stress is a physical state that is hard to describe and also hard to know what it is due of. Still, over 50% of the respondents (Figure 26) were positive about the fact that the noise situation in their home was increasing their stress level.

The number was reduced to 20% after the noise reducing procedure.



**Figure 26:** Stress due to noise before the noise-reducing measures

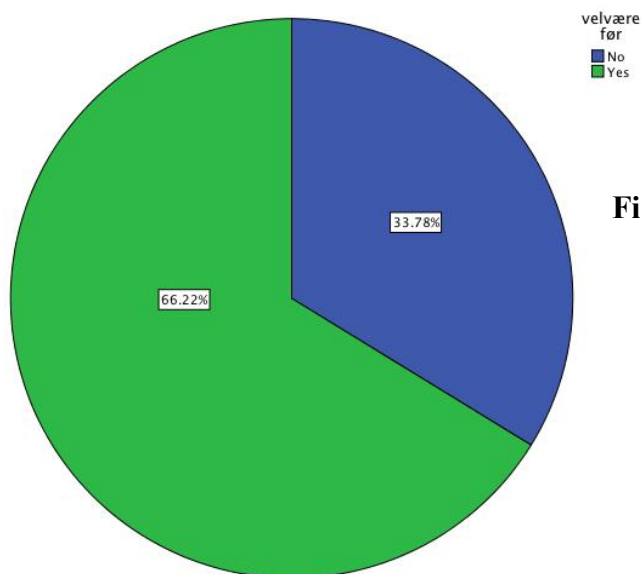


**Figure 27:** Stress due to noise after the noise-reducing measures

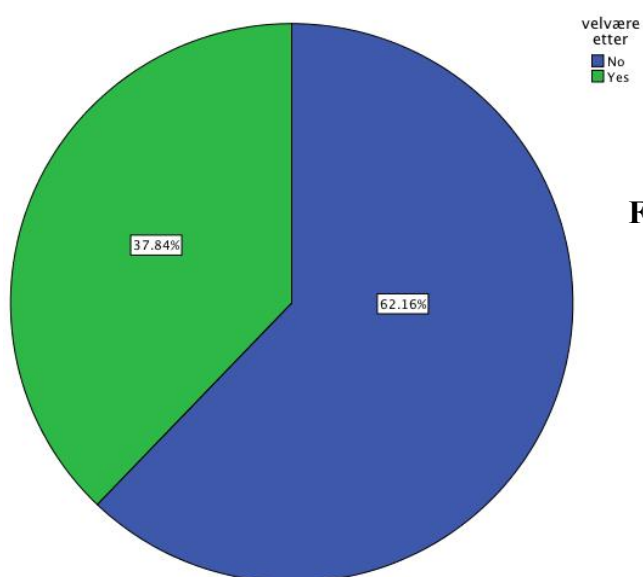
### 5.4.5 Reduced well-being

Noise can be very intrusive in the personal life when it's affecting the indoor climate. This can then lead to a reduced well-being and was the most common consequence together with sleep disorders.

As many as 66% felt a general reducing in their well-being that could be linker to the noise situation both indoors and outdoors. After the measures, this percentage got reduced to around 40%, which is still quite high.



**Figure 28:** Well-being effect before the noise-reducing measures



**Figure 29:** Well-being effect after the noise-reducing measures

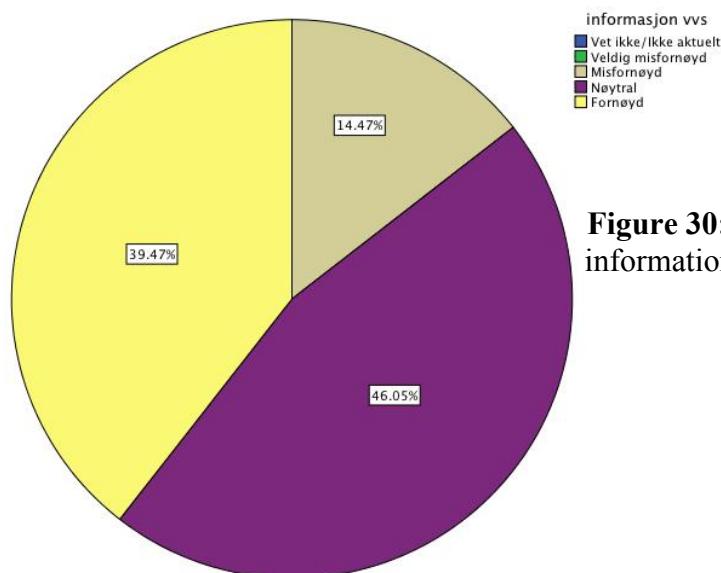
## 5.5 Respondents satisfaction

As this master thesis was written in cooperation with Statens Vegvesen and Sweco, a few questions were introduced to hear about the residents' opinion on the contacts with those two companies.

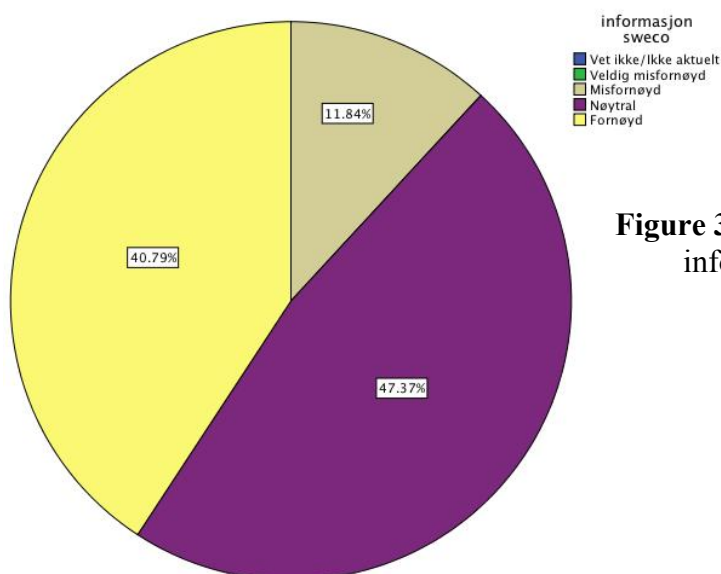
### 5.5.1 Satisfaction with the information received

Both Statens Vegvesen and Sweco were in contact with the residents in order to provide important information. This could be done by mail, telephone, or face-to-face interaction. The two statistical distributions below present the degree of satisfaction the residents felt about the information provided by, first, Statens Vegvesen, and second, with Sweco.

Both distributions are quite similar. Around half of the respondents were neutrally satisfied with the information they received both by Statens Vegvesen and Sweco.



**Figure 30:** Degree of satisfaction with the information provided by Statens Vegvesen



**Figure 31:** Degree of satisfaction with the information provided by Sweco

### 5.5.2 Satisfaction with Statens Vegvesen and Sweco

In general, the participants were quite satisfied with both Statens Vegvesen and Sweco as can be seen on Figure 33 and Figure 32. The idea was to get the general feedback from the residents on the work done by these two actors. From the first contact, the residents have made up an opinion about how the cooperation with both these companies has been. Less than 5% of the respondents are unsatisfied with Statens Vegvesen and Sweco.

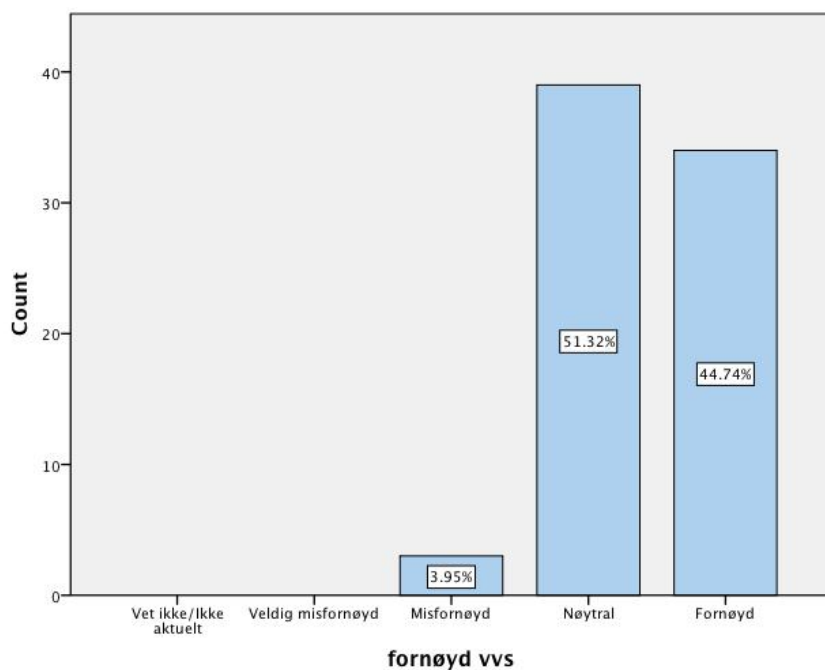


Figure 33: Degree of satisfaction with Statens Vegvesen

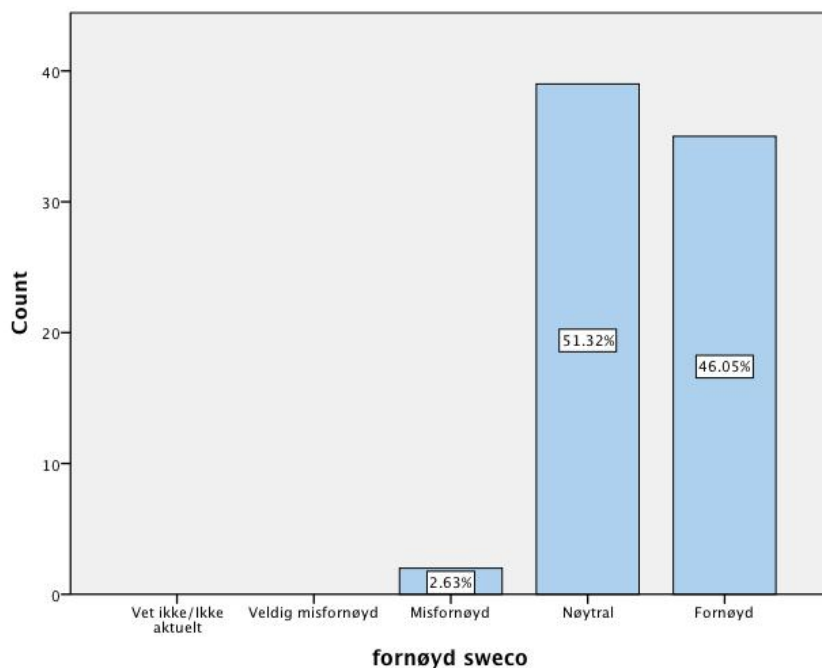


Figure 32: Degree of satisfaction with Sweco

### 5.5.3 Satisfaction with the noise measures

In general, the residents felt quite satisfied with the noise-reducing measures they got installed. From the responses collected, around 10% of those described dissatisfaction. Half of the residents were neutrally satisfied with the work done by Statens Vegvesen and Sweco and around 40% expressed their satisfaction with the total process and the noise situation after the noise-reducing measures got installed.

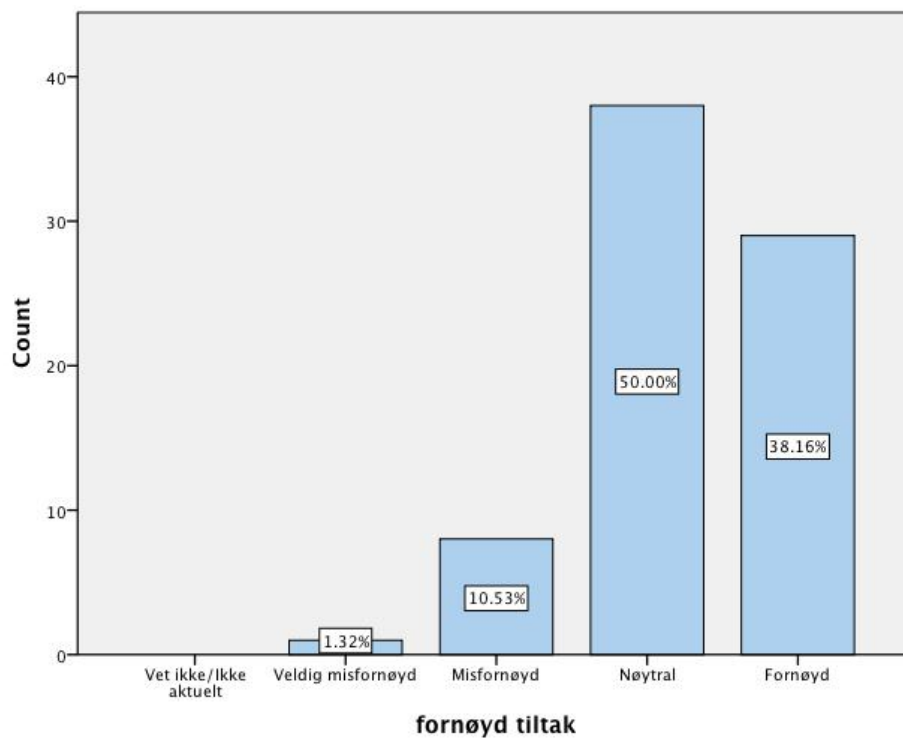


Figure 34: Degree of satisfaction with the noise-reducing measures



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## Discussion

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The region office for Europe of the World Health Organization published a report [28] indicating that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe. This number is alarming. As discussed in Chapter 2 (2.4 The effect of noise on humans) there can be many consequences for humans when exposed to noise for longer periods. Noise intruding in the households is particularly annoying as home is a place where it is supposed to be quiet for us to relax. Long noise exposure can cause as wide health effects as stress increase, cardiovascular disease, cognitive impairment, muscle tension, sleep disturbance and tinnitus. Of course it is hard to directly link noise exposure and these diseases as road traffic noise may often come with air pollution. But it is undeniable that noise causes sleep disorders and impairs the well-being of the offers. Exactly how much and at what decibel levels is described in the results chapter and will be discussed further down.

Many studies have been done on the outdoor noise situation since it is in the open air that the noise levels are the more important. And the louder the noise, the bigger the health consequences are. Indoor, however, little research has been done even though noise disturbance there is a growing problem. There is especially a lack of study on the effect of noise control measures that are supposed to reduce the indoor noise. These measures are often focusing on isolating the habitation from the outdoor disturbances. Replacement of the ventilation system, amelioration of the windows and doors, thicker isolation of the wall and roof and replacement of the air vents are common noise reducing measures that are applied and have been applied in the households chosen for this research.

The selected population sample is a good selection of households that allows the researcher to ask in depth question about the perceived amelioration of the noise situation before and after noise control measures have been installed. Indeed, the time lapse between the moment the noise reducing measures have been constructed and the moment the interviews took place was still short enough for the residents to remember the previous noise situation. Figure 7 is proof of that statement.

## 6.1 Amelioration of the survey

It would have been more accurate of course to perform two rounds of interviews: one before the noise reducing measures have been installed and one after. But due to time limitation this was not an option.

Further, it could have been possible to perform two surveys in parallel: one with the selected population sample and another one with a control group. This control group would consist of households of the same neighborhood, but exposed to noise levels just under the regulation so that noise-reducing measures would not be obligatory. Choosing households of the same neighborhood would not alter the quality of the results, as both population samples would have been exposed to the same type of noise but at different intensity levels. Having two sets of results would have allowed the researcher to compare them and thus assess more accurately the effect of the noise control measures.

Another modification that could have been done regarding the survey was to choose a population sample being exposed to higher indoors noise levels. Indeed, a mean noise level of 33dB before modifications like the households used in this survey is quite low. This statement was confirmed by several of the residents during the interviews as some of them were surprised their habitation even needed noise control measures. This reaction often came when the simulated noise level was right above 30dB and thus over the limit. A higher initial noise level would probably give more interesting results especially concerning the health of the residents.

Furthermore, it would have been interesting to interview households that are going to have noise control measures to see what kind of expectations they have. Indeed, it may be that the expectations towards noise reducing measures are very low or very high and would thus affect the final response. If the residents were expecting the control measures to reduce greatly the noise levels, their experience once they are installed may be influenced by these expectations; and inversely. Also, these interviews would give information about whether the expectations are in correlation with the reality. Are people's expectations towards the noise reduction in accordance with what the measures actually provide as reduction?

Lastly, a few individual in depth interviews could have elucidated the researcher with more information about the possible living improvements the noise reduction measures may have led to. Also, side information which maybe may not have been asked through the standard questionnaire could have come through and instruct the research.

The questions the researcher chose to ask to the population sample were satisfying. Indeed, the residents were responding without having doubts on what the interviewer was asking about and the responses were easy to treat statistically. It only happened a couple of times where the interviewer had to explain thoroughly what was meant with



the question. A good indicator of the quality of the questions is the rate of the type of response “I don’t know” which is very low.

## **6.2 Validity of the survey**

Both the quality of the questions and the fact that the residents felt quite confident about answering questions regarding the noise situation before the noise-control measures were installed (Figure 7) led the researcher to consider the survey as valid and as a good base for answering the research questions.

However, it could be that the respondents were answering approximately as fast as possible to be done with the questionnaire or that didn’t want the researcher to think they didn’t know what to reply. The interviewer didn’t get that feeling from talking to 76 different habitants; he feels they answered honestly and chose the most suitable response that described their situation.

## **6.3 Outdoor**

Only 50 out of the 76 chosen households had outdoor noise reducing measures. These usually consist of a wall of a strategic size placed to shield the area behind it.

However, it is clear that this kind of noise reducing measures is very local and only works for reducing the noise exposure at certain strategic places, like a terrace for example. So it is with no surprise that Figure 14 shows that the majority of the respondents have not noticed any change on the outdoor noise situation even after the noise-reducing measures were installed. The term “outdoor” is too vast of a term for this use as the noise reduction is rather happening locally behind the new installed wall.

Also, it is difficult to really understand how effective the outdoor noise reducing measures are as the noise levels post-modifications were not calculated. Thus, it may be that the measures are ineffective.

## **6.4 Indoor**

Figure 9 displays the type of local noise reducing measures the selected households had installed. The main goal of these measures for reducing indoor noise is to isolate the household in order to block the noise from coming into the habitation.

Replacement of air vents and ventilations will lead to a reduced need to open the windows in order to air the household and thus less noise penetrates the habitation. Measures that have to do with the windows, doors, roof and walls are increasing the insulation of the habitation and let less noise penetrate.

As mentioned earlier the indoor noise levels before any noise-reducing measures were installed were rather low. Still, it appeared that around 70% of the respondents were

at least a little annoyed by the indoor noise situation. A few respondents were even very annoyed at levels right below 40dB. Still, some respondents told the researcher they were surprised the question of noise annoyance even came in the first place. They told the interviewer they never though the experienced noise as a problem even though they had levels of 30dB or more.

Most of these residents experienced an improvement after the noise-reducing measures were installed even though they did not feel the need for them.

According to Figure 17, close to 70% of the participants of the survey felt the noise control measures installed have led to improvements in the living situation indoors. The measures have approximately reduced the noise levels by 5dB indoors, which is a reasonable achievement. So even though the noise levels were not very important to start with, the residents still feel a noticeable change in the positive direction.

A few respondents, mostly the ones with the highest noise levels, used the discussion with the researcher to complain about the noise situation in their homes and outside. They were very negative to the whole process and even though improvements were made, the situation was still critical. From the tone the respondents took, as they were mostly negative in all their responses, it became obvious for the researcher that high levels of noise can effect greatly the well-being and mood of the persons exposed.

## **6.5 Health**

Figure 20 to Figure 29 show five different aspects of health consequences noise can engender. The most common problems are sleeping disorders, stress increase and impairment of the well-being. These three aspects affect more than 50% of the respondents before the noise-reducing measures. After, it only affects around 20% of them. This reduction is a big achievement and shows how reduction of noise can improve the life of noise-exposed persons.

The two other aspects included in the survey were not as big concerns. Indeed less than 10% were annoyed by muscle tensions or have developed diseases like cardiovascular diseases, which has been found to be one of the consequences to the extended exposure to high level of noise. Many of the respondents were surprised these were even asked; they did not know and did not think that noise could have such negative and dramatic effects.

## **6.6 Satisfaction with the process**

The researcher worked on this project with the cooperation of Statens Vegvesen and Sweco in the terms that Statens Vegvesen gave the approval to use the contact information of the residents and Sweco provided the necessary reports and theoretical help. It was decided to use the survey to ask the respondents about how satisfied they are with the information provided and the dialogues made with those two firms. The

researcher got the feeling that most of the participants did not necessarily know how to differentiate the two companies and were not familiar with the work distribution between the two. The interviewer explained briefly the difference when it was needed, but this confusion can explain why the results are so similar (see Figure 30, Figure 31, Figure 32 and Figure 33). The residents usually replied with the same answer for both Statens Vegvesen and Sweco, and they are in general “neutral” to “satisfied” with both the information provided and the companies in general.

## 6.7 Research questions

The research questions asked in the introduction will now be answered with the information gained throughout the report.

- *How satisfied are the residents with the process behind the execution of the measures?*

The two main actors for the noise-reduction measures are Sweco and Statens Vegvesen. It seems the residents are generally satisfied with their work. Indeed, over 50% are satisfied and around 45% are neutrally satisfied. This should be encouraging as the contact is rather scarce and noise is a delicate subject and thus hard to improve; the feeling of being annoyed by noise can be very subjective and personal.

Furthermore, Figure 34 shows that, overall, 40% of the households are satisfied with the noise-reduction measures while 50% are neutrally satisfied and 10% are a little unsatisfied. The researcher believes that the reason there are not more people satisfied is their lack of knowledge on noise. Indeed, none knew what degree of noise reduction they could benefit from the measures and probably many had their hopes too high. Also, since the noise levels were quite low from the beginning, the noise improvements are not very important and could explain the rather low satisfaction rate of the residents.

- *How do the residents experience the noise levels both before and after the noise measures?*

The indoor noise level before the noise-reducing measures was in average 34dB and was reduced to 29 after (Table 5). Figure 18 and Figure 19 are very informative graphs where one can observe the nuisance degree experienced by the residents for each noise level. It appears that there are many of them experiencing high degrees of nuisance from 34dB and up to 42dB. After the measures, the indoor noise levels only annoy a few.

- *What is the perceived noise nuisance improvement due to the measures?*

Figure 14 and Figure 17 are showing the improvement degree experienced by the residents outdoors and indoors respectively. It appears, that the improvement indoors is much more noticeable than outdoor. It is much easier to reduce the indoor noise than the outdoor noise so this result is justified.

- *What are the health consequences of long exposures to noise indoors?*

As described in 6.5 Health, the main consequences of long exposures to noise indoors are an increase of stress, sleeping disorders and a general reducing of the well-being. Since these consequences are reduced together with the noise levels, one can easily see the connection between noise and these health effects. There are, however, almost none of the 76 interviewed residents that complained about muscle tension nor diseases provoked by noise.

# CHAPTER 7

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## Conclusion

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The 76 residents participating in the survey gave interesting insight in the improvements noise control measures can lead to. The results of the interviews enlightened the researcher with the following:

- The majority of people exposed to noise of 60dB or higher outdoors, are feeling annoyed, very annoyed or extremely annoyed
- Around half of the investigated habitants feel annoyed or very annoyed by the indoor noise when it is above 32dB
- It doesn't require a big reduction in the indoor noise situation for people to feel less annoyed but also to reduce the stress, sleep disorders and various health problems they might suffered prior the noise control measures
- More and clearer information could be given by both Sweco and Statens Vegvesen; this for the inhabitants to understand in detail the situation

The survey could have been more complete by comparing it with an identical survey made on a control group and by having done a similar questionnaire prior before the noise-reducing measures were installed to observe the expectations of the residents.

This survey is a good sign for reaching by 2020 the national goals set by the Norwegian government:

- reduce the noise nuisance by 10%
- reduce by 30% the number of persons experiencing noise of 38dB and higher

However, as road traffic is increasing, the government will need to reduce the noise generated by road traffic at the source by developing new types of roads and tires and continue installing noise-reducing measures like the ones studied in this report.



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## Appendix A – How to calculate the noise nuisance index (SPI)

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For road traffic, the equation linking the average nuisance index and sound level is:

$$GP = 1,55(L - 37)$$

where GP is the average nuisance index and L is the equivalent sound level (including the 3dB façade reflection).

The distribution of people exposed to road traffic “today” is the following, with 5dB steps:

$L_{den}$	55-60	60-65	65-70	>70	Sum
Amount of people	821.200	402.400	181.100	41.000	1.445.700

The SPI for the interval 50 -60dB is calculated as follows:

$$L = 57.5dBA \text{ (median of the interval) gives } GP = 31.775\%$$


And,  $SPI = GP \times \text{amountofpeople} = 0.31775 \times 821200 = 260936$  in that interval.

The SPI for all the intervals can be found on the table below.

$L_{den}$	55-60	60-65	65-70	>70	Sum
Amount of people	821.200	402.400	181.100	41.000	1.445.700
SPI	260.936	127859	57545	13028	459368



# Appendix B – Habitation noise report example (made by Sweco)

3  
 Gnr/Bnr: 121/13  
 Eier:   
 Byggeår:   
 Tiltak:  Ja  Nei  
 Fasadetilak  
 Lokal skjerming  
 Balansert ventilasjon  
 E6 Skarerd-Kolomoen  
  
 Statens vegvesen

## Utendørs lydforhold



Beregnet frittfelt lydnivå [dBA] på fasade: (Se merknad)

Fasade	Etg	Høyde [m]	LdenA prim* [dBA]	LdenA sek* [dBA]	Total [dBA]
1) Nordvest	1	5,5	68	6	68
	2	2,4	69	6	69
2) Nordøst	1	2,4	65	5	65
	2	5,5	65	4	65
3) Sørvest	1	2,4	67	5	67
	2	5,5	67	6	67
4) Sørøst	1	0,0	57	0	57
	5) Nordvest	1	2,4	66	6
Høyeste for bygning			69	6	69

Kun lydnivåer over 45 dBA er vist

\*) LdenA - "Dag-kveld-natt nivå".  
 Beregnet gjennomsnitt for kveld og natt er gitt et tillegg på 5 og 10 dB før gjennomsnitt er beregnet.

prim - Primær veg (nye veganlegg)  
 sek: Sekundær veg (andre eksisterende veganlegg)



### Utendørs oppholdsplass

Estimert LdenA på uteplass:  Estimert lengde lokal skjerm:

**Merknad:** Treplattning etableres på baksiden av boligen

- (ikke vurdert)
- Beregnet lydnivå på utendørs oppholdsareal er under grenseverdi
- Lokal skjerming forventes å ha liten virkning og anbefales ikke
- Lokal skjerming anbefales
- Lokal skjerming anbefales ikke, beboer har alternativt utendørs oppholdsareal
- Beboer ønsker ikke skjerming av uteplass
- Annet, se kommentar

3	Gnr/Bnr: 121/13	Tiltak: <input checked="" type="radio"/> Ja <input type="radio"/> Nei	E6 Skarvud-Kolmoen
Eier: ██████████	Byggeår: ██████	<input checked="" type="checkbox"/> Fasadetiltak	
		<input checked="" type="checkbox"/> Lokal skjerming	
		<input checked="" type="checkbox"/> Balansert ventilasjon	

### Innendørs lydforhold

#### Beregnet døgnekvivalent lydnivå [dBA]

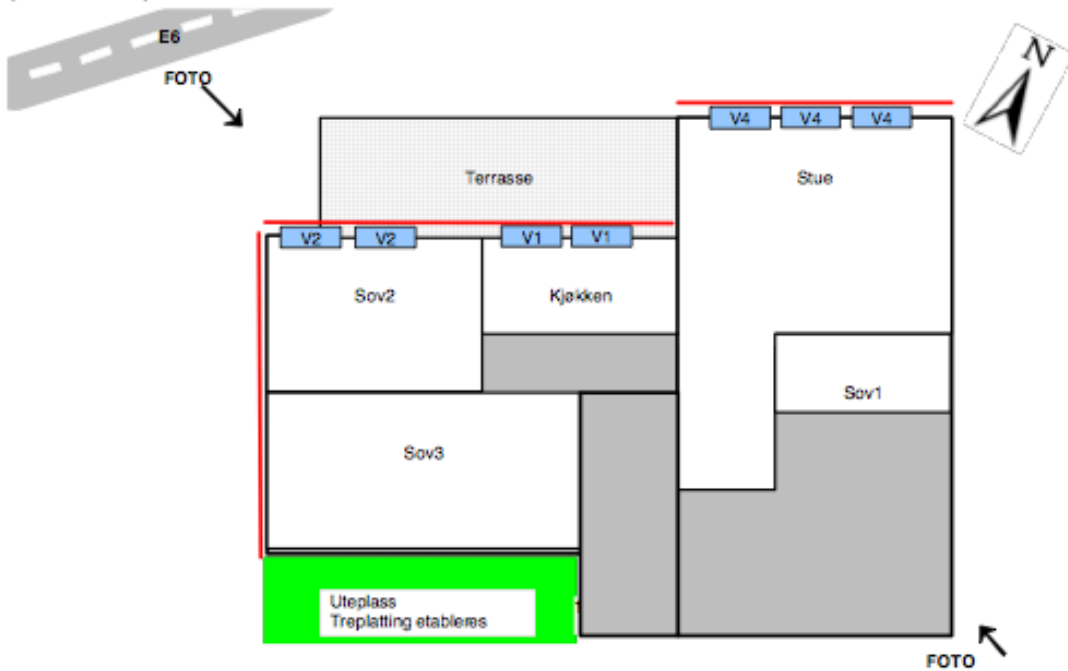
L1=Primær veg, L2=Sekundær veg, Ltot>Totalt lydnivå, Luv>Totalt lydnivå uten ventil  
 \*) Ingen ventil

Etg	Rom	Før tiltak				Etter tiltak				
		L1	L2	Ltot	Luv	Krav	L1	L2	Ltot	Luv
1	Kjøkken	41	-	41	36	30	29	-	29	29
	Sov 3	31	-	31	30	30	29	-	29	29
	Sov 2	39	-	39	35	30	29	-	29	29
	Sov 1	38	-	38	29	30	29	-	29	29
	Stue	37	-	37	34	30	29	-	29	29
Høyeste for bolig				41					29	




### Plantegning

(ikke i målestokk)



Balansert ventilasjon monteres i hele boligen

3	Gnr/Bnr: 121/13	Tiltak: <input checked="" type="radio"/> Ja <input type="radio"/> Nei	E6 Skarverud-Kolomoen
Eier: [REDACTED]	Byggeår: [REDACTED]	<input checked="" type="checkbox"/> Fasadetiltak <input checked="" type="checkbox"/> Lokalskjerming <input checked="" type="checkbox"/> Balansert ventilasjon	

## Fasadetiltak

### Stue, 1. etg

\*) Rw+C2 (Veg, 50 km/t)

Element, Fasade	A	B x L(H)	Tiltak	Rw+Ctr*	Kostnad
V4, 1	1,72	1,15 x 1,5	1 fag, fast, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Fast karm. Stapelaminat. Rammekarm i tre. (Kost=1fag+fast). Hb47, nr. 145	38	13 760
Vegg, 1	14,40	6 x 2,4	Ekstisterende kledning fjernes, (ev. vindtett pl. beholdes) 50mm utforing med med stendere av tre og 13mm gips, Asfalt vindtett + Luftet yttervegskledning. Hulrom fylles med mineralull.	46	15 120
V4, 1	1,72	1,15 x 1,5	1 fag, fast, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Fast karm. Stapelaminat. Rammekarm i tre. (Kost=1fag+fast). Hb47, nr. 145	38	13 760
V4, 1	1,72	1,15 x 1,5	1 fag, fast, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Fast karm. Stapelaminat. Rammekarm i tre. (Kost=1fag+fast). Hb47, nr. 145	38	13 760
Ventil, 2	1,00	-	- Ventil dyles m mineralull og stenges	99	50
Ventil, 5	1,00	-	- Ventil dyles m mineralull og stenges	99	50

### Sov 1, 1. etg

\*) Rw+C2 (Veg, 50 km/t)

Element, Fasade	A	B x L(H)	Tiltak	Rw+Ctr*	Kostnad
Ventil, 2	1,00	-	- Ventil dyles m mineralull og stenges	99	50

### Sov 2, 1. etg

\*) Rw+C2 (Veg, 50 km/t)

Element, Fasade	A	B x L(H)	Tiltak	Rw+Ctr*	Kostnad
Vegg, 1	8,16	3,4 x 2,4	Ekstisterende kledning fjernes, (ev. vindtett pl. beholdes) 75mm utforing med med stendere av tre og 13mm gips, Asfalt vindtett + Luftet yttervegskledning. Hulrom fylles med mineralull.	48	8 976
Spalteventil, 1	1,00	-	- Spalteventil fjernes når vindu skiftes	100	0
Spalteventil, 1	1,00	-	- Spalteventil fjernes når vindu skiftes	100	0
V2, 1	0,97	0,85 x 1,15	1 fag, åpringsbart, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Stapelaminat. Rammekarm i tre. Hb47, nr. 146.	39	8 730
Vegg, 3	8,16	3,4 x 2,4	Ekstisterende kledning fjernes, (ev. vindtett pl. beholdes) 50mm utforing med med stendere av tre og 13mm gips, Asfalt vindtett + Luftet yttervegskledning. Hulrom fylles med mineralull.	46	8 568
V2, 1	0,97	0,85 x 1,15	1 fag, åpringsbart, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Stapelaminat. Rammekarm i tre. Hb47, nr. 146.	39	8 730

### Sov 3, 1. etg

\*) Rw+C2 (Veg, 50 km/t)

Element, Fasade	A	B x L(H)	Tiltak	Rw+Ctr*	Kostnad
Vegg, 3	7,44	3,1 x 2,4	Ekstisterende kledning fjernes, (ev. vindtett pl. beholdes) 50mm utforing med med stendere av tre og 13mm gips, Asfalt vindtett + Luftet yttervegskledning. Hulrom fylles med mineralull.	46	7 812
Spalteventil, 4	1,00	-	- Spalteventil dyles med min.ull og stenges	91	50
Spalteventil, 4	1,00	-	- Spalteventil dyles med min.ull og stenges	91	50
Spalteventil, 4	1,00	-	- Spalteventil dyles med min.ull og stenges	91	50

### Kjøkken, 1. etg

\*) Rw+C2 (Veg, 50 km/t)

Element, Fasade	A	B x L(H)	Tiltak	Rw+Ctr*	Kostnad
Vegg, 1	9,36	3,9 x 2,4	Ekstisterende kledning fjernes, (ev. vindtett pl. beholdes) 75mm utforing med med stendere av tre og 13mm gips, Asfalt vindtett + Luftet yttervegskledning. Hulrom fylles med mineralull.	48	10 296
Spalteventil, 1	1,00	-	- Spalteventil fjernes når vindu skiftes	100	0
V1, 1	1,25	1 x 1,25	1 fag, åpringsbart, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Stapelaminat. Rammekarm i tre. Hb47, nr. 146.	39	11 250
V1, 1	1,25	1 x 1,25	1 fag, åpringsbart, 2-lags isolermute. Laminert glass en side. 8-18-4/1/4. Luft i hulrom. Stapelaminat. Rammekarm i tre. Hb47, nr. 146.	39	11 250
Spalteventil, 1	1,00	-	- Spalteventil fjernes når vindu skiftes	100	0

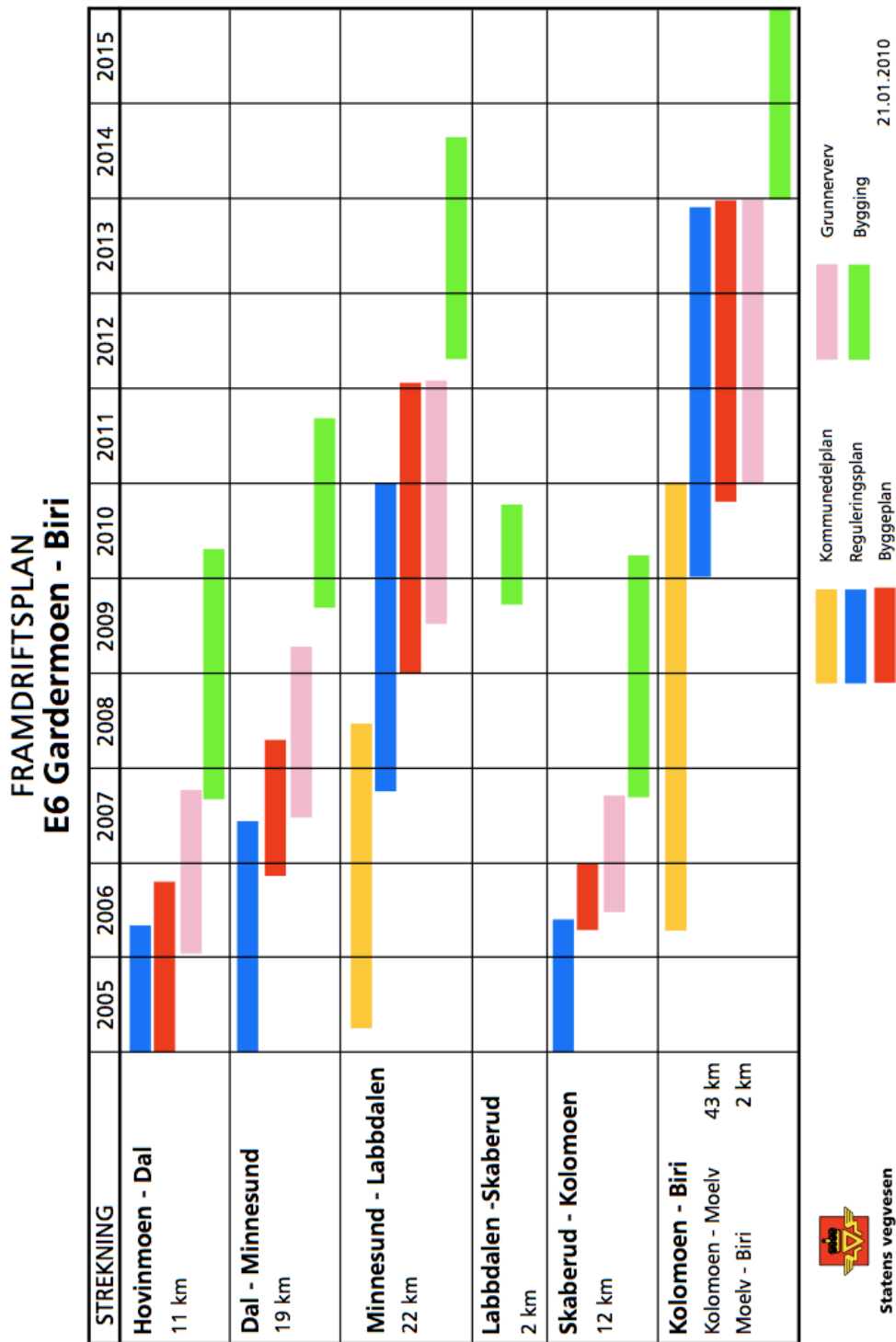
3	Gnr/Bnr: <b>121/13</b>	Tiltak: <input checked="" type="radio"/> Ja <input type="radio"/> Nei	E6 Skaberud-Kolmoen
Eier: [redacted]	Byggeår [redacted]	<input checked="" type="checkbox"/> Fasadetiltak <input checked="" type="checkbox"/> Lokal skjerming <input checked="" type="checkbox"/> Balansert ventilasjon	 Statens vegvesen

**Alle tiltak og kostnader for 121/13 Fjellstad:**

Fasadetiltak	132 312
Skjerming uteplass	0
Ventilasjonsanlegg. 2 soverom (Sov 1, Sov 2) har lydnivå over Lden 60 dBA utenfor vindu. Balansert ventilasjon i hele boligen anbefales.	100 000
Overflater innvendige vegger	0
El-arbeider (5 vegg(er))	3 750
Treplattling på baksiden av boligen 2.5m*6m*kr.1000	15 000
Rigg, drift, uforutsett (10%)	25 106
<b>Sum kostnader eks MVA</b>	<b>276 168</b>



# Appendix C – Timeline E6 Gardemoen - Biri







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## Appendix D – Conversation text (survey)

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Mitt navn er Frederik Strand og jeg er masterstudent ved Universitet i Trondheim, ved NTNU. Jeg har valgt å skrive masteroppgave om støytiltak og støyplage og har dermed vært i kontakt med både vegvesenet og konsulentfirmaet Sweco.

Det jeg spesielt forsker på er den opplevde virkningen av støytiltak som blir utført for å redusere støy fra vegtrafikk.

Jeg vil gjerne spørre deg noen spørsmål angående dette og du har blitt utvalgt fordi tiltak har blitt utført i ditt nærområde.

Undersøkelsen kommer til å ta 12 minutter og vil hjelpe meg i forhold til oppgaven min, men vil samtidig også hjelpe fremtidens støytiltakløsninger.

Undersøkelsen består av 4 deler. Du må gjerne komme med kommentarer hvis du føler at det er nødvendig.

### **DEL 1.**

Jeg vil først spørre deg noen personlige spørsmål.

Jeg vil minne deg på at for resten av undersøkelsen vil jeg at du skal fokusere på veitrafikken og hvordan det oppleves i hjemmet ditt.

### **DEL 2.**

Jeg vil nå spørre noen spørsmål om hvordan du selv har opplevd selve prosessen av hele prosjektet.

### **DEL 3.**

Jeg vil nå spørre deg om hvordan du har opplevd endringene generelt sett.

### **DEL 4.**

Jeg vil nå gå i detalj på hvor du opplever støy og hvordan dette plager deg både før og etter at tiltakene ble utført.



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## Appendix E – Questionnaire

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### DEL 1 – Personalia + bolig

Fullt navn:

Alder:

*Kjønn:*

*Type bolig:*

- *Rekkehus*
- *Enebolig*
- *Blokkleilighet*
- *Fritidsbolig*

Hvilken type støy er du plaget av (flere svar er mulige):

- Jernbane
- Fly
- Naboer
- Veitrafikk
- Annet? Hva?

## DEL 2 – Prosessen

	Veldig misfornøyd	Misfornøyd	Nøytral	Fornøyd	Vet ikke/ikke aktuelt	Kommentar
Hvor fornøyd var du da du først ble kjent med at din eiendom skulle undersøkes for støytiltak?						
Hvor fornøyd var du når du hørte at du fikk/ikke fikk dekket kostnadene til utbyggingen av støytiltak?						
Hvor fornøyd er du med informasjonen du fikk i forkant, under og etter utføringen av støytiltakene?						
- Fra vegvesenet						
- Fra konsulentfirmaet Sweco						
Generelt sett, hvor fornøyd er du med?						
- Statens Vegvesen						
- Konsulentfirmaet Sweco						
Hvor fornøyd er du med utførelsen av støytiltakene?						

## DEL 3 – Hvordan oppleves endringene?

	Betydelig forverring	Forverring	Ingen bedring	Forbedring	Betydelig forbedring	Vet ikke	Kommentar
Hvordan føler du situasjon har endret seg etter tiltakene?							
- Innendørs							
- Utendørs							

## DEL 4 – Opplevd støyplage

Hvor plaget føler du deg i disse rommene:	Ikke plaget		Lite plaget		Plaget		Veldig plaget		Ekstremt plaget		Vet ikke	
	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER
Soverom 1												
Soverom X												
Stuer 1												
Stue X												
Kjøkken												
Uteplass												

	Ikke sikker	Noe sikker	Veldig sikker
Hvor sikker føler du deg når du uttaler deg om forholdene før og etter tiltak? (mao. <i>Husker du hvordan det var før?</i> )			

	Søvnproblemer		Påvirker utvikling av sykdom		Økende Stress		Muskelspenning er og muskelsmerter		Redusert velvære og mistrivsel	
	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER
Kjenner du på plager som kommer av støyen opplevd innendørs?										



# Appendix F – Answer sheet (Excel)

## DEL 0 - Generell info.

Parselle	Eier	Kontaktinfo	Enh.nr.	Byggeår	LeqA fasade	LeqA innendørs (FØR)	LeqA innendørs (ETTER)	LdenA uteplass

Tiltak				Total kostnad
Fasadetiltak	Vegg/Tak	Ventilasjon	Uteplass	
Vindu/Dør	El-arbeid/divers			

## DEL 1 - Info om undersøkt person

Navn på undersøkt	Alder	Kjønn	Type Bolig	Opplevd støy
			Bekkehus	Jernbane
			Enebolig	Flv
			Blokkleilighet	Naboer
			Fritidsbolig	Veitrafikk
			Annet	Annet? Hva?

## DEL 2 - Processen

	Veldig misfornøyd	Misfornøyd	Nøytral	Fornøyd	Vet ikke / Ikke aktuelt	Kommentar
Hvor fornøyd var du da du først ble kjent med at din eiendom skulle undersøkes for støytiltak?						
Hvor fornøyd var du når du hørte at du fikk/ikke fikk dekket kostnadene til utbyggingen av støytiltak?						
Hvor fornøyd er du med informasjonen du fikk i forkant, under og etter Generelt sett, hvor fornøyd er du med?						
Hvor fornøyd er du med utførelsen av støytiltakene?						

### DEL 3 - Hvordan oppleves endringene

	Betydelig forverring	Forverring	Ingen bedring	Forbedring	Betydelig forbedring	Vet ikke	Kommentar
Hvordan føler du situasjon har endret seg etter tiltakene?	Innendørs Utendørs						

### DEL 4 - Opplevd støypplage

Hvor plaget føler du deg i disse rommene:	Lydforhold (FØR)	Lydforhold (ETTER)	Ikke plaget	Litt plaget	Plaget	Veidig plaget	Ekstremt plaget	Vet ikke
Soverom 1			FØR	FØR	FØR	FØR	FØR	FØR
Soverom 2								
Soverom 3								
Kjøkken								

Hvor sikker føler du deg når du uttaler deg om forholdene før og etter tiltak? (m.a. Husker du hvordan det var før?)	Ikke sikker	Noe sikker	Veidig sikker

Kjenner du på plager som kommer av støyen opplevd innendørs?	Søvnproblemer		Utvikling av sykdom		Økende stress		Muskelspenninger og		Redusert velvære og	
	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER	FØR	ETTER



