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Annoyance due to vibrations caused by metro trains in Oslo

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The annoyance caused by vibrations from metro trains in Oslo has been investigated by means of a questionnaire sent to persons living along the metro lines in Oslo. The questionnaire has been sent to households where vibration measurements had been made. The paper will present the correlation between degree of annoyance and measured vibration level. The novelty of the paper is the level of detail in determining the physical vibration level. Vibration measurements were made using 3 to 6 vibration transducers, in most cases 5 triaxial transducers (geophones or accelerometers) were used. The measured vibration level has been defined as the vw,95 level measured in the direction with the highest level in the room with the highest level. Normally the vw,95 level is based on measurements during 20 metro train passages. The annoyance is graded from 0 ("do not notice") to 4 ("highly annoyed"). A SurveyMonkey questionnaire has been distributed to the households where measurements had been made. 55 respondents have completed the form so far. The results indicate that the threshold of annoyance for vibrations from metro traffic may be lower than previously assumed

1 Introduction

Investigations about the way neighbours perceive vibrations from metro trains started as a student assignment [1]. There was a definite impression that the threshold of annoyance from vibrations in the house due to metro trains was lower than previously reported. This impression originated from what the residents said when we visited their house to measure vibration levels. These statements must be considered anecdotic evidence, but closer investigation both by qualitative [2] and quantitative research was thought justified. The field measurements were made with transducers covering a reasonable cross-section of the property.

The method of sampling should be classified as a convenience sampling. The questionnaire has only been sent to households where comprehensive measurements of vibration had been made. 23 respondents completed the questionnaire in the original campaign. For these cases a short message was sent by e-mail in advance of the questionnaire. As the results were quite interesting, it was decided to continue the survey after completion of the original assignment.

2 Method

The continuation of the survey was performed by sending the questionnaire to those we had visited in order to measure vibrations in their house. The vibration measurements are described in the companion paper [3]. For the continued survey we asked during our visit whether they would like to answer some questions about perceived vibration. A summary of results after 36 cases has been briefly reported earlier [4]. The questionnaire contains 10 questions. Out of these questions the main part of the analysis was to compare the results of the questions about annoyance from vibrations with the measured vibration level. There were two questions directly concerned with perceived vibrations. The texts below are approximate translations. The original questionnaire was in Norwegian language. The questions may be divided into two groups: The main group that has been analysed in detail was about annoyance due to vibrations. The other group consists of questions that gave inconsistent or obvious results.

2.1 Main questions – annoyance due to vibrations

This group consists of the two main questions:

Question 3: Do you perceive vibrations in your house? (coded as 0)

Question 4: If you answered YES to question 3, are you:

- Highly annoyed by vibrations (coded as 4)
- Annoyed by vibrations (coded as 3)
- Somewhat annoyed by vibrations (coded as 2)
- Not annoyed by vibrations (coded as 1)

2.2 Remaining questions – results not analysed in detail

Other questions in the survey include:

1. Frequency of use of the metro for transportation
2. Purpose of use of the metro for transportation
5. How do you notice vibrations
6. Changes in vibrations with weather and season
7. Changes in vibration with driving speed of the metro train
8. Damages to the residence
9. Changes in market value of the house due to the metro
10. Free text for comments

3 Results

In the following the results are shown first for the main questions, the ones related to direct quantification of annoyance due to vibrations. The other questions are discussed briefly.

3.1 Annoyance due to vibrations

The annoyance due to vibration levels are shown in figure 1. Annoyance is considered a categorical variable, while the vw,95 is shown as a continuous variable. The vibration level presented is the level in the direction with the highest vibration level in the room with the highest vibration level. Some people report that they are annoyed at vibration levels well below current Norwegian guidelines [5].

All the respondents report that they are “annoyed” or “highly annoyed” when vibrations exceed $v_{w,95}$ = 0,3 mm/s. The Norwegian regulations and guidelines about noise and vibrations are meant to ascertain that 80% of persons affected will find conditions satisfactory.

According to the present results this seems not to be the case for the metro lines of Oslo. There are several possible reasons for why our survey gives results different from those that form the basis of current guidelines.

1) The metro runs frequently. At all the sites we have considered there are at least 8 trains per hour in daytime, in some places even more than this. Earlier investigations were made at a time when traffic was lighter, so it may well be that trains running more often are more annoying.

2) Our survey is based on measured values inside the house. Earlier investigations are based on outdoor measurements and a standard factor of multiplication to find indoor level. As the companion paper shows [3] the vibration levels in the house are normally lower than those on the ground outside.
3) We have only sent the questionnaire to households where we have measured vibrations. There has been an appointment in advance, we have of course talked with the residents during the measurements, and the residents have seen the instruments used. This could have some effect on the responses.

These factors will be considered in more detail in section 4.

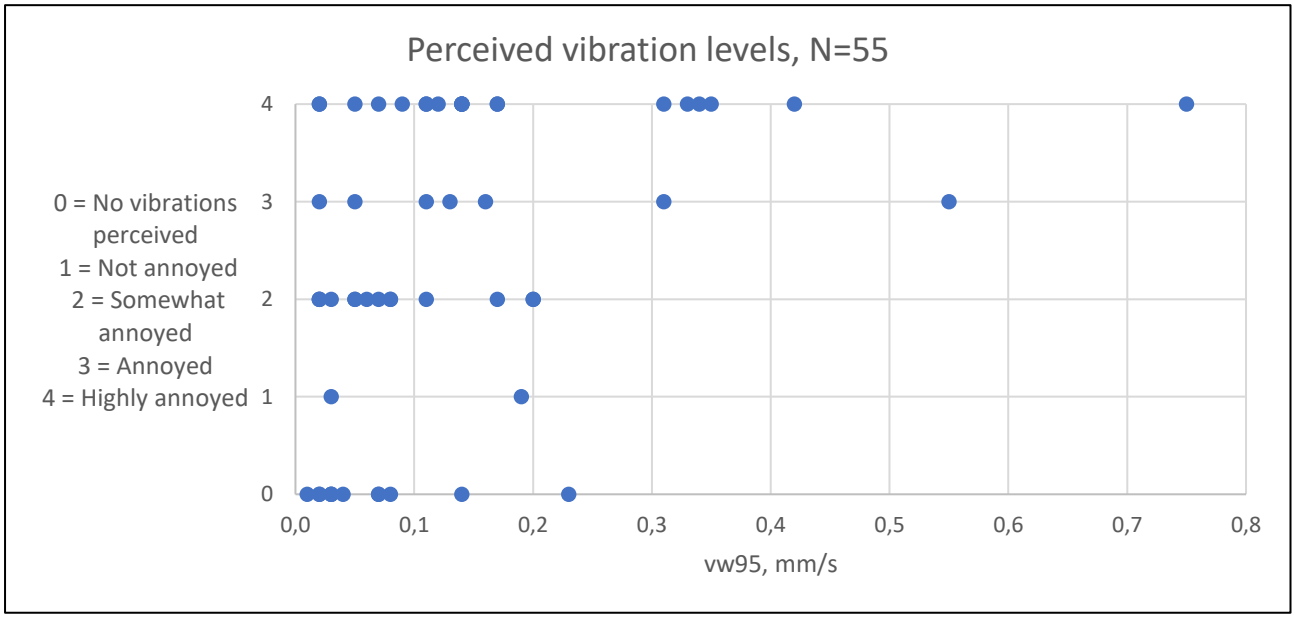

Figure 1, annoyance due to vibrations

3.2 Other questions

The correlation between other questions and vibration levels has not been investigated further. This is partly because the data set is too small, partly because the sample is not representative. The answers to other questions are only mentioned briefly.

3.2.1 How often and for what purpose do you travel with the metro?

This is question 1 and 2 in the survey questionnaire. Almost all the respondents answered that they use the metro regularly, 28% on a daily basis, 78% at least once a week. 42% use the metro to commute to work.

3.2.2 How do you notice vibrations?

This is question 5 in the survey questionnaire. The largest percentage reported that they can sense the vibrations directly (32 respondents). The next most important sign of vibrations is rattling in glass (27 respondents). 11 respondents claim that vibrations from the metro has led to damage in their house, see also section 3.2.5 below. It is very difficult to verify or refute this claim. Vibration levels are lower than those that are expected to result in building damage. However, the metro runs 8 or more times per hour, and the frequency of occurrence of vibrations in other cases is not well known. Somewhat unexpectedly only 3 respondents have noticed plants swaying, which is sometimes cited as a first indicator of vibrations.

3.2.3 How do vibrations change with weather and seasons?

This is question 6 in the survey questionnaire. There is only one common factor in the answers: Vibrations increase in winters with deep frost. This corresponds with the reaction we got in one house where we measured vibrations. The residents exclaimed: "January 17th" when we asked on site if vibrations changed with the seasons. Apparently something happened that increased the vibrations substantially on that date. A probable cause could be that the frost went down to a sufficient depth to suddenly change the pattern of vibrations that day.

Apart from an increase in vibrations in winters with deep frost, the answers give no detectable clue as to variations with weather or seasons. There is insufficient evidence in terms of long term measurement of vibrations to verify the claimed increase in vibrations.

3.2.4 Do the vibrations change with the speed of the metro train?

This is question 7 in the survey questionnaire. The majority of those who have noticed report that vibrations increase with increasing speed of the metro train. This agrees with the general result from the environmental monitoring program for Oslo's metro [6].

3.2.5 Have you noticed damage in your residence?

This is question 8 in the survey questionnaire. 19 respondents report minor damage to their house which they suspect to be due to metro vibrations.

3.2.6 Do you think the metro changes the market value of your residence?

This is question 9 in the survey questionnaire. 45 respondents believe the metro reduces the value of their residence, while 3 respondents believe the metro increases the value of their residence.

3.2.7 Free text field

The free text field permits the respondents to write whatever comments they wish. It can be summed up in a simple way. They think the metro is a great way to transport people, but they do not like the noise and vibration it produces.

4 Discussion

Our results seem to indicate a lower threshold of annoyance due to transport vibrations than has previously been reported.

There are several possible reasons for this apparent discrepancy. They shall be discussed in the following. Those explanations for this apparent discrepancy that we have considered so far, are as follows:

- The metro runs often, and vibrations comparable to the reported vw,95 occur several times per hour
- A different physical parameter is compared to the reported annoyance
- Our sample may not be representative

4.1 Frequency of metro trains

At the time when the research leading up to NS 8176 [5] was performed most metro lines ran 4 times per hour in each direction with trains having 2 or 3 cars. Currently 3 or 6 cars is the norm, and there are several lines with 8 departures per hour in daytime. The daytime schedule is maintained longer into the evening, and the last train runs later and the first train earlier than before. On some lines there is only a 3 hour pause between the last and the first train. It is quite conceivable that annoyance due to vibrations increases with the frequency of events as well as with the level of vibrations.

4.2 Physical parameter that is compared to annoyance

The research leading up to NS 8176 was based on measurements outside the building. The indoor vibration level was based on multiplication with a calculated factor. This current paper is based on actual measured indoor vibration level. Our experience has shown [3] that the indoor vibration level from metro trains is almost always lower than outdoor levels, sometimes much lower. It is quite possible that we have compared a lower nominal level with the annoyance than NS 8176 is based on. This means that earlier surveys may have compared the same annoyance to a higher nominal vibration level than the current paper. It is quite possible that earlier surveys have been based on experience from mainline railways. It may well be that mainline railways excite vibrations in houses in a different way than metro trains.

4.3 Representative sample

There are three main sources of our data:

- Kolsåsbanen after reopening
- Østensjøbanen before being closed and after reopening
- Households where measurements have been made due to complaints

Kolsåsbanen was an old tram line that was deemed unsafe and closed in 2006. It was gradually rebuilt as a metro line and reopened, the latest part in 2014. This means that many respondents had experienced a lengthy period of no railbound traffic before new trains with 6 cars were introduced. It would be reasonable to believe that residents close by were taken by surprise and disliked the new trains from the beginning.

Østensjøbanen had a long history as a metro line, but traffic was doubled after reopening. Although the shutdown period was much shorter than Kolsåsbanen, it was still long enough for people to get used to a silent track.

Those who complain are probably the ones most annoyed and at the same time the most resourceful neighbours.

It is likely that the answer from each individual respondent is influenced by the fact that measurements have been made in their home. This influence may be different from respondent to respondent.

All this means that the sample may not be representative. This should be investigated further.

5 Further work

It would be desirable if investigations could be carried out with a more representative sample of respondents. There is, however, the problem of practical feasibility. The comprehensive measurements required to obtain a sufficiently accurate vibration value are time-consuming and costly.

It is not known whether our results can be applied to other types of vibration sources like road traffic, trams or mainline railways. It is quite possible that the perceived annoyance from other sources is different from that pf metro trains.

6 Conclusion

The presented survey appears to indicate that neighbours are more sensitive to metro vibrations than indicated in current Norwegian guidelines [5]. This does not mean that this current paper contradicts earlier research. The discrepancy is to be expected. There is a larger number of longer metro trains running than 20 years ago. The vibration level that the annoyance is compared to is lower in our study. The sample behind the current paper is not representative and may be quite skewed. All these factors mean that there is not necessarily a conflict between this investigation and earlier investigations.

7 Acknowledgements

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