Cyclists' Road Traffic Noise Exposure: Highlights of Bike-to-Work Noise Measurements Campaign under Corona Lockdown in a Danish City

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Abstract
Exposure to high levels of road traffic noise is associated with adverse health outcomes. Whereas cyclists' exposure to noise could substantially vary according to their route choice, the literature suggests that cyclists, in general, are exposed to higher noise levels than other transport mediums, e.g. cars. This work, therefore, aims to assess cyclists' exposure to noise in the Danish city of Roskilde. A bike-to-work noise measurements campaign at a University Campus was conducted in September – October 2020 under Corona lockdown. The measurements were performed using portable noise sensors and mainly covered morning (07:00 – 09:00) and evening (15:30 – 17:30) rush hours. Overall, the measured noise levels ($L_{Aeq,1min}$) varied in the range, 51 – 91.4 dBA (Median: 69 dBA). The ANOVA analysis revealed no statistically significant difference in the recorded noise levels of morning and evening trips. The presentation will provide more insights into the results.

Keywords: Road traffic noise, cyclists' exposure, health outcomes, COVID-19, lockdown.

1 Introduction

Noise is an unwanted sound and invisible danger. According to the World Health Organization (WHO), hearing loss is the fourth highest cause of disability globally, having an estimated annual cost of over 750 billion dollars [1]. In Denmark, approximately 800,000 Danes have a hearing problem, and about every 3rd Dane is bothered by noise [2]. Exposure to higher, unsafe levels of noise (WHO limit: > 55 dB) is a significant cause of hearing impairment, which is often referred to as "noise-induced hearing loss" [3, 4]. Workplace and commuting, among others, are the two main environments, where individuals are exposed to harmful noise levels.

To evaluate the influence of workplace noise exposure on individuals' health, it is indispensable to take into account not only work-related noise exposure, but also non-occupational exposure, such as travel to work and back [5]. Nevertheless, the majority of workplace safety laws, e.g. [6, 7], are focused on protecting workers from noise-related hazards at work, and a complete noise exposure assessment by taking into account non-occupational activities, e.g. commuting, is often ignored. Therefore, there is a dire need to address this issue.

Bicycling is one of the primary modes of transportation in Denmark, which roughly accounts for 33% of trips to the workplace [8]. There is a growing body of evidence that bicyclists and pedestrians are exposed to relatively higher noise levels, on average, > 75 dBA, compared to other transportation modes [9]. In particular, exposure longer than four seconds of 114 dBA may lead to a greater risk of noise-induced hearing loss [10]. However, noise exposure of individuals who bicycle to work is under-studied, particularly in the Danish context. To the authors' knowledge, there are only a few scientific articles on this subject.

Recently, Apparacio and Gelb [11] studied bicyclists' exposure to road traffic noise in Copenhagen, Denmark, and compared it with noise levels in Paris (France) and Montreal (Canada). Their work, however, was based on six days of measurements (3 sensors), focused on evaluating bicycling infrastructure of the cities in question, and did not distinguish between work and other commuters. Thus, the research gaps concerning noise exposure of bike-to-work commuters persist and need to be addressed.

The recent Corona virus pandemic (COVID-19) has influenced humanity across the globe, via societal closures and lockdowns. Whereas all institutions and organizations were closed down during the pandemic in Denmark, some government employees performing critical functions (daily laboratory work, management, etc.) were allowed to work. At the same time, the associated lockdowns and restrictions also provided experimental environments to study noise levels under reduced traffic volumes.

Therefore, this paper aims to study noise exposure of bike-to-work commuters under Corona lockdown at a University campus in the Danish city of Roskilde.

2 Materials and methods

This section reflects on the study site and bike-to-work campaign under Corona lockdown. Data collection and analysis are also summarized.

2.1 Study site and bike-to-work campaign

The study site is the Department of Environmental Science, Aarhus University (hereafter, ENVS). The ENVS is located at the DTU Risø campus, which is home to several research centres. The campus is located in the north of Roskilde, a Danish city with relatively less busy roads, compared to, for example, Copenhagen. Figure 1 shows the study site, its surroundings, and the city of Roskilde. The landscape surrounding the study site is mainly bounded by dense and sparse vegetation and water bodies. In addition, there is a highway nearby, namely, Frederiksborgvej, which connects the DTU Risø campus with the different parts of the city (Figure 1).

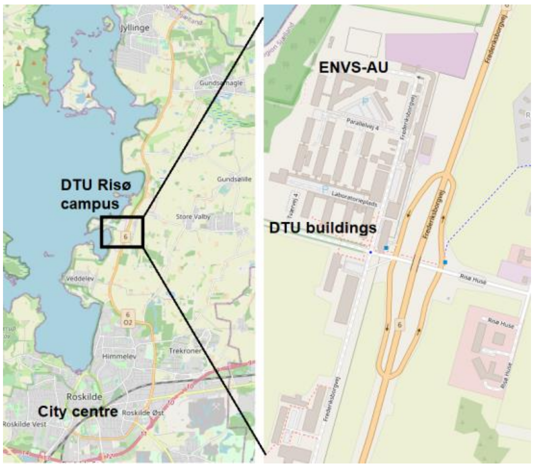

Figure 1 – The city of Roskilde and the study site. Note: only relevant areas of Roskilde are shown in the left panel. Background map © OpenStreetMaps.

Every year ENVS organizes a bike-to-work campaign to motivate its employees towards a healthy lifestyle. In conjunction, a similar campaign was organized in September – October 2020, which was disrupted due to Corona lockdown. However, a few employees performing daily-basis, critical laboratory and maintenance tasks were allowed to come to the ENVS. Thus, bike-to-work participants were requested to help with the noise measurements. Of which, six participants, bicycling from different parts of the city to the ENVS, were chosen. The aim was to maximize the coverage of different areas of Roskilde (e.g. city centre, remote area) as much as possible. The measurements protocol is described in the next section.

2.2 Data collection

As stated above, six volunteers were involved in the data collection. The measurements were performed from 18 September – 20 October 2020 and on dry days only. During data collection, volunteers bicycled from their residential locations to ENVS and back during morning and evening rush hours. The morning trip was made between 07:00 – 09:00 hours, whereas the evening trip was covered between 15:30 – 17:30 hours. The same route (both ways) was covered each day without any stopovers, e.g. a visit to a supermarket on the way back home. In total, 771 km (51.4 hours, GPS trace) were travelled through the city of Roskilde. Figure 2 shows the routes of six volunteers.

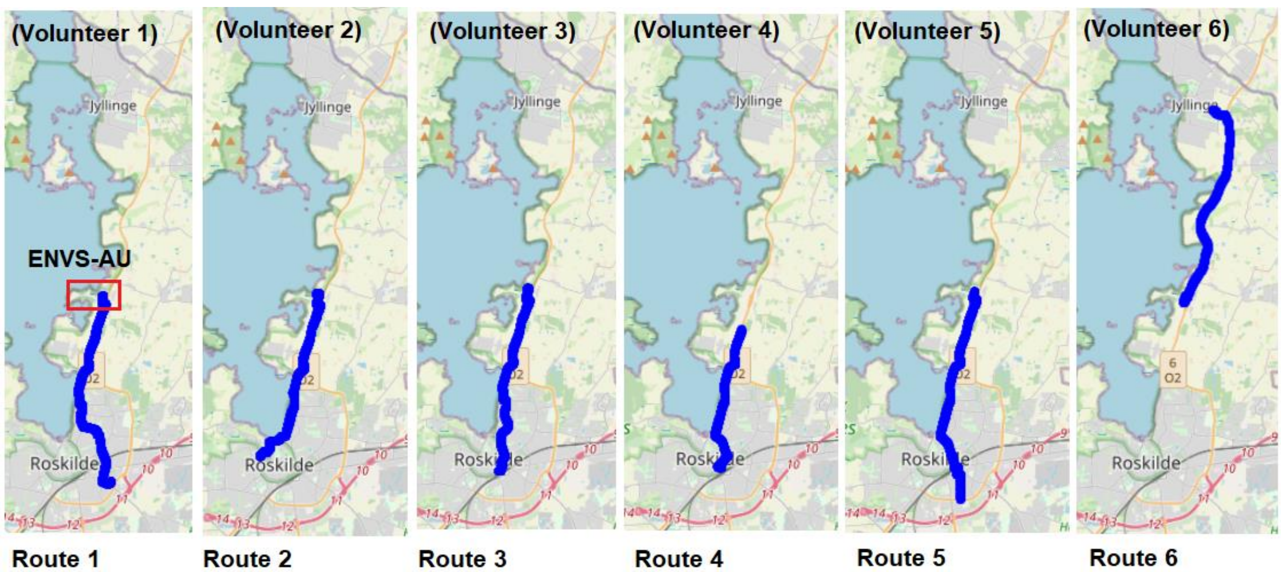

Figure 2 – The routes of volunteers during the noise measurements campaign under Corona lockdown in Roskilde from 18 September to 20 October 2020. Background map © OpenStreetMaps.

The data was collected using HBK – Hottinger Brüel & Kjær's A/S Personal Noise Dose Meter (Type 4448, class 1) (HBK, Nærum, Denmark). The HBK's noise dose meter recorded A-weighted equivalent sound pressure level every minute, namely, $L_{Aeq,1min}$, in dBA. We believe the temporal resolution of one minute is sufficiently detailed, since bicyclists were requested to maintain a mean speed of 15 km/h. At this speed, a cyclist can only ride 250 m in one minute. This was in line with the measurements strategy adopted by Apparacio and Gelb [11], who used 3 similar sensors to investigate cyclists' noise exposure in Copenhagen.

However, in our study, each volunteer carried two sensors attached to the backpack (not shown here, the presentation will reflect on all relevant figures). The aim was twofold. First, to minimize the wind-induced noise affecting the noise measurements. Second, to double the amount of data collected. In total, 12 sensors were used. The sensors were calibrated once a day using the sound calibrator, Type 4231, per the manufacturer's recommendation. In addition, colocation tests of the sensors were also performed, where sensors were placed in a quiet room, and their measured noise levels were compared.

The GPS data was collected using a freely available Android app, OSMTracker for Android™. The app recorded the GPS coordinates every second. Due to General Data Protection (GDPR) issues, the GPS data of bicyclists' homes was discarded, and while bicycling to work in the morning, the nearest street to the house was assumed as the starting point. The GPS points were first map-matched with the OpenStreetMaps®, and then merged with the data collected by noise sensors.

We also obtained meteorological data from the meteorological mast at the DTU Risø campus. The data, for the relevant measurements hours, 07:00 – 09:00 and 15:30 – 17:30, contained ten-minute averages of air temperature (^{0}C), wind speed (m/s), wind direction (degrees), and relative humidity (%).

2.3 Data analysis

We conducted the descriptive and statistical analysis of the collected data ($L_{Aeq,1min}$). Several measures were computed, including minimum, maximum, variance, standard deviation and percentiles (i.e. 5th, 10th, 25th, 50th, 75th, 90th, 95th), all given in dBA. In addition, we also performed a one-way Analysis of Variance (ANOVA) to determine, whether there was a statistical difference between noise levels of morning and evening trips. Box plots were used to illustrate the differences graphically.

In the following sections, we present and subsequently discuss the selected results. The presentation will reflect on more results and associated discussions.

3 Results and discussions

Table 1 shows summary statistics of the measured noise per minute, $L_{Aeq,1min}$ (dBA), from 18 September to 20 October 2020 under Corona lockdown in Roskilde, Denmark. An overview of the recorded noise (morning, evening, overall) is presented (Table 1). For the morning trips (N = 1094, per minute values), the measured noise varied from 51 – 88 dBA, whereas for the evening trips (N = 844), the upper limit was slightly higher, i.e. 91.4 dBA. The summary statistics shown in Table 1 revealed that there was no significant difference in the recorded noise levels of the morning (07:00 – 0900) and evening (15:30 – 17:30). This is most likely due to reduced, somewhat similar traffic conditions, particularly in morning and evening rush hours, under COVID-19 restrictions.

Similar noise levels prevailed during the whole measurements campaign (see Table 1), with the overall median value found to be 69 dBA. In addition, the ANOVA analysis confirmed no statistically significant difference in the measured noise during morning and evening trips, that is, $F(1, 1936) = 0.42$, p-value = 0.52, between the groups (morning and evening trips) (see Table 2 and Figure 3). Furthermore, the noise levels were relatively higher along intersections and busy roads, and varied rather smoothly along minor/less-busy roads (Figure not shown here).

Several researchers have studied noise levels in terms of the COVID-19 perspective. For example, Sakagami [12] evaluated recorded noise levels after the COVID-19 state of emergency in Kobe, Japan. They divided noise levels into the morning (07:00 – 11:00) and evening (17:00 – 19:00) with several measurements per day for each time period. The author did not notice a significant difference in morning and evening noise measured data, similar to our finding (Figure 3).

In addition, several studies have compared pre- and post-lockdown noise levels, Hornberg et al. [13] in Germany and Mishra et al. [14] in India, to name a few. A similar comparison will be the logical next step of the noise measurements experiments discussed in this paper.

Table 1 – Summary statistics of the measured noise per minute ($L_{Aeq,1min}$) (dBA) from 18 September to 20 October 2020 in Roskilde, Denmark. Note: N = number of per minute L_{Aeq} values in dBA.

	L_{Aeq} (dBA)		
	Morning	Evening	Overall
N	1094	844	1938
Percentiles			
5	56.4	55.4	55.9
10	58.5	58.2	58.4
25 (first quartile)	63.2	63.6	63.5
50 (median)	68.7	69.1	69.0
75 (third quartile)	74.2	73.9	74.1
90	79.5	78.2	78.9
95	81.2	79.3	80.5
Min	51.0	51.3	51.0
Max	88.0	91.4	91.4
Variance	57.8	52.0	55.2
Standard deviation	7.6	7.2	7.4

Table 2 – The Analysis of Variance (ANOVA) of the measured noise, $L_{Aeq,1min}$ (dBA), for morning and evening trips. DF = Degrees of freedom, SS = Sum of squares, MS = Mean of squares, F-value = F-test statistic, Pr = p-value.

	DF	SS	MS	F-value	Pr (> F)
Between groups	1	23	23.2	0.42	0.52
Within groups	1936	106935	55.2		
Total	1937	106958			

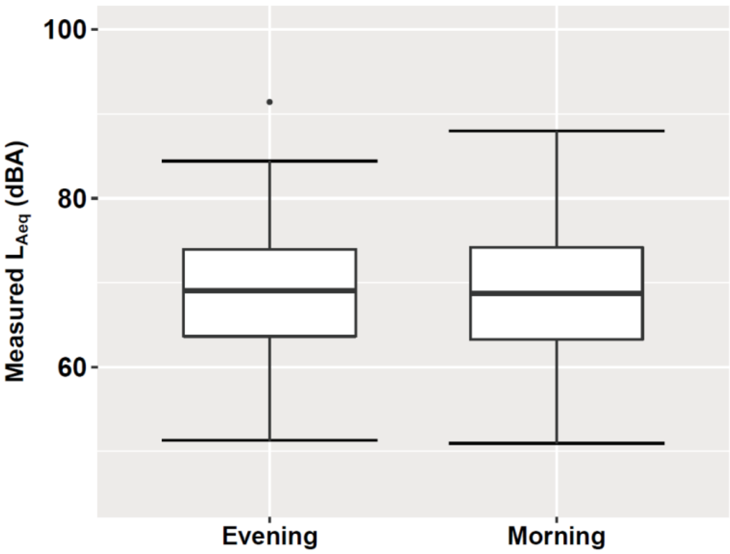

Figure 3 – Box and Whisker plots of the measured noise level, $L_{Aeq,1min}$ (dBA), for the morning and evening trips from 18 September – 20 October 2020.

4 Conclusions

In this work, noise exposure of individuals, bicycling to work under Corona lockdown in the Danish city of Roskilde (September – October 2020) has been studied. Overall, the measured noise levels, $L_{Aeq,1min}$ (N = 1938), varied in the range, 51 – 91.4 dBA, with a Median value of 69 dBA. There was no statistically significant difference in the recorded noise levels of morning and evening trips (N = 1094 and 844), which was further confirmed by the ANOVA analysis (F-value = 0.42, p-value = 0.52).

Since Corona restrictions have almost ended, repeating the same experiments and comparing pre- and post-lockdown noise levels is a logical next step of the work described in this paper.

Acknowledgements

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