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Assessment of Road Traffic Noise in a Danish City Using Mobile Monitoring and Statistical Modelling Approaches

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ABSTRACT

This research work assesses road traffic noise in the Danish city of Roskilde via mobile monitoring. A bicycle measurements campaign using portable sensors was conducted during September – October 2020. Results of the measurements showed an overall median value of 69 dBA and no statistically significant difference between the mornings (51 – 88 dBA) and evenings (51.3 – 91.4 dBA) rush hours' noise levels (per-minute, $L_{Aeq,1min}$). Land-use Regression (LUR) and Mixed-effects Models (MEM) are being tested and developed using this measured data. This short article summarizes LUR model development. The oral presentation will reflect more results and analyses.

Keywords: *Road traffic noise, mobile monitoring, exposure assessment, portable sensors, statistical modelling*

1. INTRODUCTION

Noise is a nuisance. Its exposure leads to several harmful diseases, such as dementia [1] and heart diseases [2]. Thus, assessing noise levels to protect public health and inform urban planners is indispensable. LUR modelling is a valuable approach to assessing and predicting noise levels in urban settings. This method leverages land use and other spatial variables to model the relationship between noise and the surrounding environment [3]. Researchers have applied LUR modelling to mobile monitoring data to explore the impact of land use characteristics on noise levels. For example, Xu and colleagues [4] developed LUR models to assess traffic noise in Shanghai, China. The same has been done in European cities as well. However, such assessments are scarce in Denmark. This leaves a significant research gap about the unexplored potential of LUR modelling for noise assessments in the Danish context. Therefore, this study aims to address the abovementioned research gap using statistical modelling approaches (LUR, MEM). In this short article, only LUR testing and development are presented.

2. MATERIALS AND METHODS

A bicycle measurements campaign was conducted in Roskilde from 18 September – 20 October 2020. See Figure 1 for the study area. Six employees of Aarhus University (ENVS-AU) volunteered to measure the noise (six different routes) while bicycling to work in the morning (between 07:00 – 09:00) and on the way back home in the evening (between 15:30 – 17:30). In total, 771 km (51.4 hours, GPS trace) were travelled without any stopovers, e.g. a visit to a supermarket.
Data was collected using HBK's Personal Noise Dose Meter (Type 4448, class 1), recording per-minute A-weighted sound pressure levels ($L_{Aeq,1min}$). Each volunteer carried two sensors attached to the backpack and was requested to maintain a mean speed of 15 km/h. The sensors were calibrated once a day using the sound calibrator per the manufacturer's recommendation. We also performed colocation tests of the sensors, which showed good agreement. The per-second GPS data was collected using a freely available Android app, OSMTracker for Android™.

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This paper presents analyses of route 1 (volunteer 1, example route).

The abovementioned measured data was analyzed, including an ANOVA assessment. Then, this data was used to test and develop LUR models. The process summary is as follows. As a first experiment, we included the most significant predictor variables. Namely, Annual Average Daily Traffic (ADT) (vehicles/day) for the road next to the bicycling route. Additionally, traffic speed (km/h) and building polygon estimated heights (meters). All these parameters were based on aggregation in a 100-meter buffer. We also included land use variables, the percentage of built-up, trees and grassland, cropland, wetland and water bodies within the same buffer. ESA's freely available 10 m land use land cover dataset was used to retrieve land cover information.

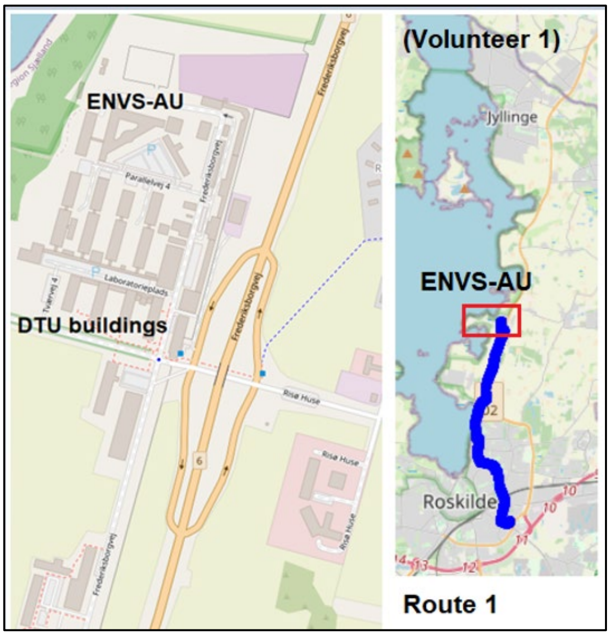

Figure 1. The study area, ENVS-AU (left), and the route of volunteer 1 (right).

We developed LUR models for all measuring routes in R software. A supervised, forward, stepwise regression approach was used, and the best-performing model based on RMSE and R^2 was chosen for each route. To supplement this, we also tested developing LUR models using machine learning (ML). We R's caret package to develop ML-based LUR models and carried out their 10-fold cross-validations. All LUR predictions were compared with the measured data and subsequently visualized and mapped. The predictions for one sample day, i.e. 12 October 2020 (Monday), are shown in the results and discussion section of this paper. More results will be presented and discussed in the oral presentation.

3. RESULTS AND DISCUSSIONS

Table 1 shows the summary statistics of the measured noise ($L_{Aeq,1,min}$) from 18 September – 20 October 2020. For the morning trips (N = 1094), the measured noise was in the range 51 – 88 dBA, whereas for the evening trips (N = 844), the upper limit was slightly higher, i.e. 91.4 dBA. 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 in 2020. This was also confirmed by the ANOVA analysis (see Table 2), F-value = 0.42 and p-value = 0.52 within groups.

Table 1. Summary statistics of the measured noise from 18 September – 20 October 2020.

	$L_{Aeq,1min}$ (dBA)		
	Morning	Evening	Overall
N	1094	844	1938
Min	51.0	51.3	51.0
Max	88.0	91.4	91.4
Median	68.7	69.1	69.0
Variance	57.8	52.0	55.2
SD	7.6	7.2	7.4

Table 2. ANOVA analysis of the measured noise. Note: BG = Between groups, WG = Within groups, T = Total, DF = Degrees of freedom, SS = Sum of squares, MS = Mean of squares, F = F-value via F-test, pr = p-value (> F).

	DF	SS	MS	F	pr
BG	1	23	23.2	0.42	0.52
WG	1936	106935	55.2		
T	1937	106958			

Figure 2 shows the LUR model predictions for an example day, 12 October 2020 (Monday), morning trip only. Let us recall several traffic and land use predictor variables were used in LUR model development. In conjunction, the predicted noise ($L_{Aeq,1min}$ in dBA) reflects their influence. That is, the noise was relatively higher (~ 65 dBA) at the start of the bicycling (bottom of the Figure 2). This part is close to

the Roskilde city centre and usually contains moderate to heavy traffic and buildings on both sides.
Similarly, the highest noise levels were observed close to the ENVS-AU (the yellow part). This part is the heavily trafficked highway just before the ENVS-AU campus. The LUR predicted noise was in good agreement (not shown here) with the measured noise patterns. The prediction R^2 and RMSE were 0.73 and 3.9 dBA, reflecting Pearson's correlation, r = 0.85.

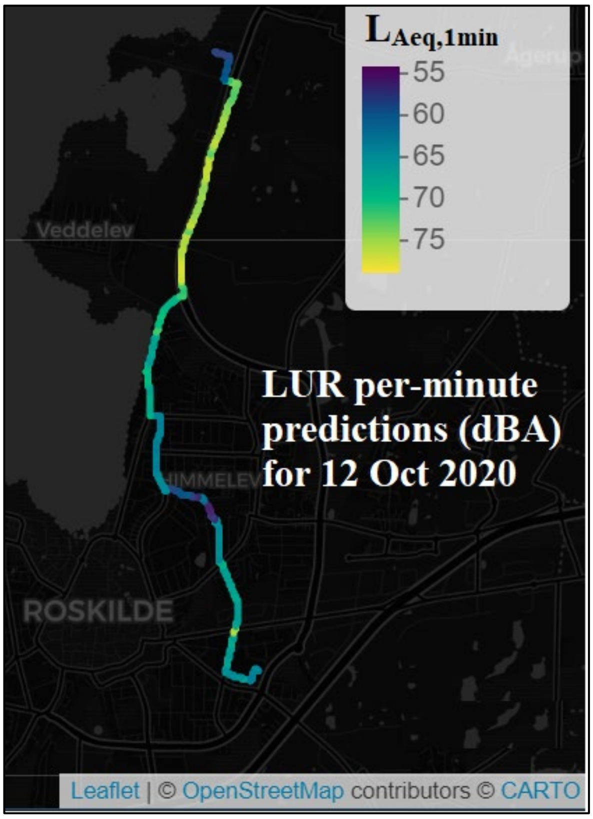

Figure 2. LUR model predictions ($L_{Aeq,1min}$ in dBA) for an example day, 12 October 2020. The road segments are divided into 10-meter segments.

4. CONCLUSIONS AND OUTLOOK

In this paper, noise exposure of individuals, bicycling to work in the Danish city of Roskilde (September – October 2020) has been briefly 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). LUR model predictions were found to be in good agreement with the measured data, showing its great potential to assess noise levels.
One strength of this work is the investigation of LUR modelling for noise assessment. One limitation is that the present work mainly focuses on the spatial patterns of noise levels, not the temporal ones.
Future work will reflect an in-depth analysis of statistical modelling, both LUR and MEM, to explore spatiotemporal patterns of noise levels.

5. ACKNOWLEDGMENTS

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