Feasibility study for using the CNOSSOS-EU road traffic noise prediction model with low resolution inputs for exposure estimation on a Europe-wide scale.

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Summary

A noise model based on the CNOSSOS-EU method was developed to estimate exposures to road traffic noise at individual address locations for studies of noise and health in European cohorts in the EU FP7 BioSHaRE project. We assessed the loss in model performance from necessarily (i.e. at national scale) using low resolution data on traffic flows, road geography and land cover. To assess the feasibility of this approach in terms of the loss of model performance, we applied CNOSSOS-EU with different combinations of high- and low-resolution inputs (e.g. high resolution road geography with low resolution land cover) and compared noise level estimates with measurements of L_{Aeq1hr} from 38 locations in Leicester, a medium sized city in the UK. The lowest resolution model performed reasonably well in terms of correlation [r_s = 0.75; p = 0.000)] but with relatively large model errors [RMSE = 4.46 dB(A)]. For a sample of postcode (zip code) locations (n=721) in Leicester, in comparing output from Model A (highest resolution) and Model F (lowest resolution), 81.8% and 72.8% of exposure estimates remained in the lowest and highest of three equal exposure categories, respectively.

1. Introduction

Key to studies of road traffic noise and health is the estimation of an individual's noise exposure. This has been applied with some success [1, 2, 3]. These noise prediction models often operate on a city-wide or municipality level; at a scale which precise road traffic and land cover data are often both affordable and readily obtainable. Although strategic noise maps do exist for countries in Europe, these are often only for urban areas (e.g. DEFRA[1]) or generalised exposure figures mapped at country level (e.g. EEA[2]). Both of these are unsuitable for regional or national-scale epidemiological studies as suburban and rural areas need to be considered along with major urban centres. Broadening the geographical area under investigation introduces limitations on computer processing time and on data availability (e.g. costs, geographical coverage). For comparable estimates between countries it is important that input data are standardised and harmonised. Therefore, it is often necessary to use data available on a much broader geographical scale, which may be less detailed as a result.

CNOSSOS-EU has been formulated as a strategic noise mapping tool both to assess environmental noise levels and for noise exposure assessment over the whole European Union. Therefore, it fits with the needs of noise modelling for epidemiological studies, as it focuses on spatial variability in noise levels over broad geographical

[1] http://services.defra.gov.uk/wps/portal/noise
[2] http://noise.eionet.europa.eu/viewer.html

areas rather than adopting a more focused engineering or site-specific approach.

We have implemented a version of the CNOSSOS-EU noise modelling framework [4] to provide noise exposure estimation for a number of European countries as part of the EU funded BioSHaRE (Biobank Standardisation and Harmonisation for Research Excellence in the European Union) project[3]. In this study, we investigate the feasibility of applying CNOSSOS-EU with relatively low resolution inputs to undertake harmonised noise exposure assessment for large cohort studies operating on a national or continental scale. Fundamental to this is to obtain associated noise exposure estimates that are comparable between countries. We assess the feasibility of the CNOSSOS-EU in this context by comparing noise levels estimates made from various combinations of high and low resolution data on traffic flows, road geography, land cover, and terrain, with noise level measurements.

2. Methods

For the purposes of this study, the CNOSSOS-EU model algorithms were implemented in PostGIS[4] v2.1 according to the protocol described the methodology document [4]. PostGIS is a geographical information system (GIS) and is the spatial extension of the PostgreSQL[5] database. This was chosen because it is open-source (i.e. freely available) software and efficient in handling the large volumes of spatial vector data required as model inputs.

The present study aims to investigate the effect of input data resolution on model output rather than present an evaluation of the model's use on a European scale. Therefore, we focussed on a specific area in which previous noise monitoring and modelling work had taken place. We used measurements from 38 road traffic noise monitoring sites collected in the EU funded FP5 HEAVEN (Healthier Environment through the Abatement of Vehicle Emissions and Noise, in 2002) and HEARTS (Health Effects and Risks to Transport Systems, in 2005) projects covering the south west area in the city of Leicester, UK (Figure 1).

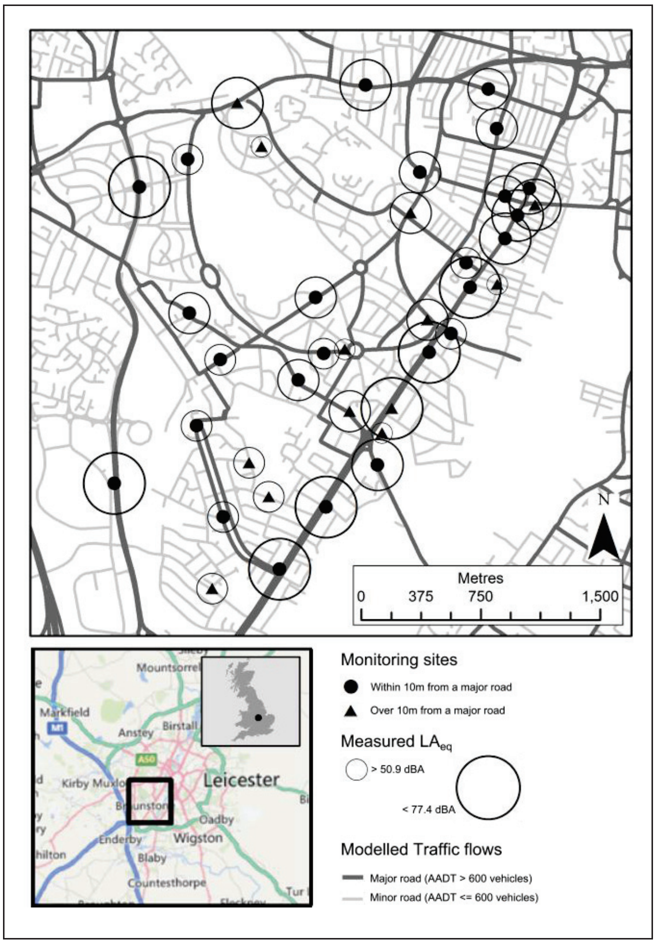

Figure 1. Location of and measured hourly L_{Aeq} from the 38 monitoring sites in Leicester, UK. Sites are distinguished as roadside locations (those within 10m of a major road) and background/residential locations (those over 10m from a major road). The high resolution road network shown is from the OS Land-Line®. Inset map from Microsoft® Bing™ Maps.

The main source of environmental noise is from road traffic with little effect from surrounding areas from railways and very occasional light aircraft [5]. Noise measurement locations were chosen to capture a range of noise conditions with sites located along main 'A' and secondary 'B' roads, but also on minor roads in residential areas. Noise measurements were based on single average continuous measurements (for either 30 or 60 minutes) at each site and during the period outside of the morning and evening rush hours: in HEAVEN between the hours of 10.00 and 15.00 during August 2002 and in HEARTS between the

[3] https://www.bioshare.eu/

[4] http://postgis.refractions.net/

[5] http://www.postgresql.org/

hours of 09.00 and 16.30 during February 2005 [6, 7].

For the purpose of this feasibility study, a low resolution or generalised version of each data set was obtained in order to compare with the highest resolution available (Table I). In total, six test models were parameterised (Table II). Model A used the highest resolution and most detailed data available for each input, which would typically be used for city-scale modelling, while model F used the least detailed data for each input which is comparable to the data to be used in BioSHaRE study of noise and health in European cohorts (i.e. regional and national scale). Models B, C, D and E demonstrate the continuum between models A and F with a gradual shift to coarser input resolution by degrading the resolution of one data set at a time. By changing the resolution of model inputs, in turn, it was possible to understand which data types have the greatest relative importance on the accuracy of predictions made by the noise model.

Input	High Resolution	Low Resolution
Land cover	OS MasterMap® Topography (~1m precision)	CORINE 2006 v16 (~100m precision)
Building heights	Landmap LiDAR	1) 50m grid generalised Landmap LiDAR 2) Constant value according to CORINE urban extent
Road network	OS Land-line	OS Meridian 2®
Traffic flow	HEARTS modelled traffic flow	ESCAPE/UK Department of Transport modelled traffic flow
Topography	2m LiDAR DTM (Digital Terrain Model)	Flat plane
Meteorological data	Annual average of 2003-2010 UK Met Office air temperature and wind direction	Annual average of 2003-2010 UK Met Office air temperature and wind direction

Table I. Summary of the high and low resolution data sets used as inputs to CNOSSOS-EU to investigate the role of spatial scale on model performance.

Resolution	Model	Terrain	Land cover	Buildings	Traffic	Roads
Highest	A	LiDAR DTM	OS MasterMap®	Landmap	HEARTS local traffic model	OS LandLine®
	B	None	OS MasterMap®	Landmap	HEARTS local traffic model	OS LandLine®
	C	None	CORINE	Generalised Landmap	HEARTS local traffic model	OS LandLine®
	D	None	OS MasterMap®	Landmap	ESCAPE national traffic model	OS LandLine®
	E	None	CORINE	Generalised Landmap	ESCAPE national traffic model	OS Meridian 2®
Lowest	F	None	CORINE	CORINE urban extent	ESCAPE national traffic model	OS Meridian 2®

Table II. Summary of input data used in CNOSSOS-EU models A to F (highest to lowest resolution).

The following high and corresponding low resolution data were collected for input to the CNOSSOS-EU model (Table II). For traffic flow, the high resolution input was gathered as part of the HEARTS project and used Leicester Council's Airviro model [8], which in turn received data from the city's SCOOT (Split, Cycle, Offset, Optimisation Technique) [9] system. The detailed road network geography was Ordnance Survey (OS) Land-line® (now obsolete). The low resolution traffic data used is a national data set derived in the EU 7th Framework ESCAPE (European Study of Cohorts for Air Pollution Effects) project [10]. The traffic data were attached to a road network extracted from the OS Meridian 2® product, while flow data for major roads were obtained from the UK Department for Transport. Counts for all roads were not available so missing data were estimated based on the flow data of nearby roads [10]. In terms of the spatial representation of the road network, detailed curved road segments are generalised to straight lines by vertex removal in the Meridian 2® layer and not all minor roads or slip roads are included. The Land-Line® road network provides a much more precise representation of the true road layout with detailed curved road segments, separate lanes on primary roads and motorways, roundabouts, and full inclusion of all local authority maintained roads.

High resolution land cover data for the UK are available from the OS MasterMap® topography layer which is precise to ±1m in urban areas and to a level of individual buildings, paths, roads, gardens and areas of vegetation. Low resolution data come from the freely available pan-European scale CORINE 2006 v16 land cover product at a precision of 100m. This includes only two classes of urban fabric (continuous and discontinuous). To provide barrier information from the built environment, individual building heights from LiDAR measurements obtained by Landmap[6] were also included. In order to provide a comparable low resolution input, two additional datasets were derived. Firstly, the individual building heights were averaged over a 50m grid to provide a generalised surface while still being based on real height data. Secondly in the absence of all other height data, areas identified in CORINE as urban fabric were assigned a height of 9.5m based on the average height of a two-storey building (i.e. typical dwellings) in the UK. In areas within 75m of a major road (where it may be assumed that higher buildings could be found) buildings were given a higher value of 10.5m based on the distribution of buildings and associated heights near major roads from the Landmap dataset.

3. Results

Table III shows model performance for CNOSSOS-EU models A to F (highest to lowest resolution) when compared to measured noise levels in Leicester. Figure 2 shows changes in performance of the CNOSSOS-EU models B to F over declining resolution of inputs when compared to measured noise levels in Leicester.

[6]http://www.landmap.ac.uk/index.php/Datasets/Building_Heights/Key-Facts-Building-Heights

Resolution	Model	r_s	R^2	RMSE	Median Residual	ρ_c (95% CI)
Highest	CNOSSOS-EU A	0.94	0.89	1.63	-1.61	0.90 (0.83 – 0.94)
	CNOSSOS-EU B	0.94	0.87	1.66	-1.47	0.88 (0.80 – 0.93)
	CNOSSOS-EU C	0.91	0.87	1.91	-1.61	0.89 (0.80 – 0.91)
	CNOSSOS-EU D	0.71	0.60	5.29	-3.62	0.67 (0.49 – 0.79)
	CNOSSOS-EU E	0.76	0.66	4.44	-4.56	0.66 (0.49 – 0.78)
Lowest	CNOSSOS-EU F	0.75	0.66	4.46	-4.62	0.66 (0.49 – 0.78)

Table III. Model performance for CNOSSOS-EU models A to F (highest to lowest resolution) when compared to measured noise levels in Leicester. r_s is the Spearman's rank and ρ_c is the concordance correlation coefficient with 95% confidence intervals.

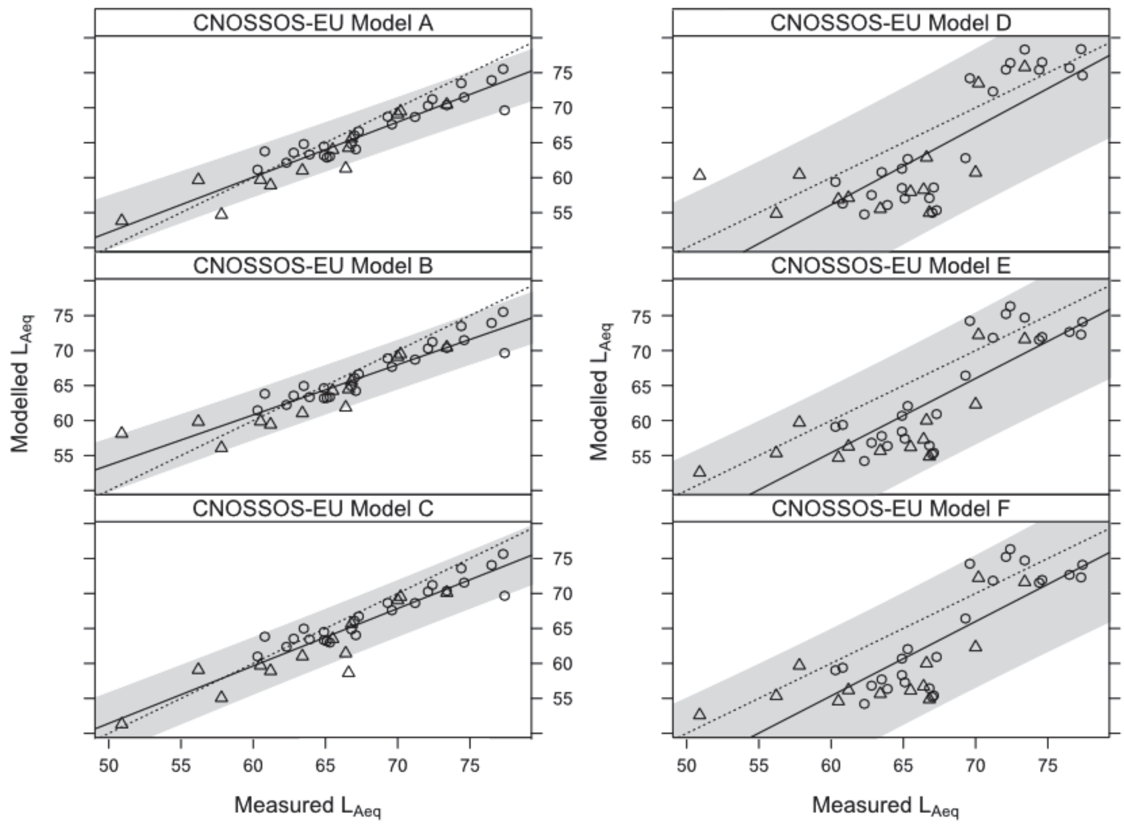

Figure 2. Scatterplots with shaded 95% prediction interval (left column) of modelled against measured L_{Aeq} for CNOSSOS-EU models A-F to illustrate relative performance. The identity line (where measured = modelled) is shown by the dotted line; the solid black line is the linear regression. Triangle symbols indicate background sites, circles are roadside sites.

Figure 2 and Table III show that models B (DTM removed) and C (switch to low resolution land cover), have almost identical predicted L_{Aeq} to model A. Overall, r_s were all above 0.91 and concordance correlation coefficients at 0.88 or above. There is slight loss of performance as a result of the transition from the high resolution land cover with representation of individual buildings to generalised CORINE land cover classes where no individual buildings are included (Model C).

The introduction of low resolution traffic data (models D-F) gives the most marked change in model performance. Model D has the worst overall performance. For this model, the low resolution traffic data had to be forced to match the high resolution geography which may have resulted in possible errors in matching corresponding road segments and traffic flows.

Table IV shows the contingency table for predictions from model A and model F for the 721 postcode centroid locations in the Leicester study area for the daytime average noise level (L_{Aeq16}). There is high agreement between the models A and F when classifying the lowest (81.8%) and highest exposure sites (72.8%). For the mid-range class, only 20.2% are correctly classified with the low resolution model tending to under-predict noise levels in these locations with 77.4% of these sites classified as low exposure.

Model F

	Low <57.9 dB(A)	Middle 57.9-64.9 dB(A)	High >64.9 dB(A)	
Low	422 (81.8%)	96 (77.4%)	9 (11.1%)	527
Middle	94 (18.2%)	25 (20.2%)	13 (16.0%)	132
High	0 (0.0%)	3 (2.4%)	59 (72.8%)	62
	516	124	81	721

Table IV. Contingency table of model A (high resolution) and model F (low resolution) noise predictions for the 721 postcode centroid locations within the Leicester study area. These are split into three equal width exposure categories based on L_{Aeq16}. Percentages of locations classified by model F in accordance to model A are given in brackets.

4. Conclusions

Our study promotes the application in an epidemiological context, by showing that the existing road traffic noise component, in its current iteration, may be viably parameterised with lower resolution, and therefore more readily available data sets. Most importantly, it has been shown here that the representation of traffic flows is critical in model performance. When applying this model to cohorts within individual European countries, differences in noise estimations will most likely be explained by disparities in how traffic flow data were collated.

Acknowledgement

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