DOI: 10.61782/fa.2025.0456

IMPACT OF THE CHOICE OF ROAD TRAFFIC SPEED DATA ON MODELLED ENVIRONMENTAL NOISE

Annalisa Sheehan[1*] **Sean Beevers**[2,3,4] **Andrew Beddows**[2,3] **John Gulliver**[1]

[1] Population Health Research Institute, School of Health and Medical Sciences, City St George's, University of London, London, United Kingdom.

[2] Environmental Research Group, School of Public Health, Imperial College London, United Kingdom.

[3] MRC Centre for Environment and Health, School of Public Health, Imperial College London, United Kingdom.

[4] NIHR HPRU in Environmental Exposures and Health, School of Public Health, Imperial College London, United Kingdom.

ABSTRACT

Accurate road traffic speed data is a key requirement for noise mapping. Speed datasets are however not routinely available, often resulting in the use of crude estimates by road type. In the EU-funded Equal-Life project, studying the relationship of environmental noise and mental health, we investigated the impact of varying traffic speed on modelled noise levels via three different approaches: 1) national speed limits (NSL), 2) half the national speed limit (HNSL) (i.e., to reflect the likely lower speed levels in built-up areas), 3) a novel approach using satellite imagery (SAT) (i.e., spatial displacement of detected vehicles between two images taken <1s apart) to derive average vehicle speeds by road type. We compared changes in applying different speed data via CNOSSOS-EU modelling for 4394 cohort residential addresses in Barcelona. We found differences of up to 13 dB(A) depending on the choice of speed data. Switching from NSL to SAT speeds resulted in a median decrease of 9.3 dB(A). Switching from HNSL to SAT speeds ranged between -2.2 dB(A) and 4 dB(A) with a median decrease of 1.7 dB(A) depending on road type and time-period. The choice of speed data therefore can have a substantial impact on estimated residential noise levels.

[*] ***Corresponding author***: asheehan@sgul.ac.uk.

Keywords: *road traffic noise, noise modelling, CNOSSOS-EU, vehicle speed.*

1. INTRODUCTION

Road-traffic noise pollution is a widespread problem, with more than 100 million people (approximately 1 in 5) across Europe exposed to harmful levels [1]. To understand the broad-scale, long-term impacts of road traffic noise on health and well-being, noise modelling is required to quantify population/individual noise exposure. Key data inputs for characterising road-traffic noise emissions include traffic flows, usually expressed as annual average daily traffic (AADT), traffic composition (i.e., the number of cars, heavy goods vehicles, motorcycles, etc.) and traffic speed. However, rarely do complete datasets exist for the connected road network. Traffic flow data is often limited to vehicle counts for major roads from measurements (i.e., automatic or manual counts). Assumptions based on measurements by road type may be used to represent traffic composition. Seldom is traffic data available for minor roads (i.e., secondary, tertiary, residential), which typically carry lower flow but may still account for thousands of vehicles per day (AADT). Data for traffic speed may be limited to fixed values (e.g., national speed limit values) for each road type (e.g., motorway/highway, residential, etc.). In many situations, especially within urban areas, values based on national speed limit (i.e., maximum speed values) would result in an overestimation of noise levels.

For this paper we assessed the impact of limited choices and assumptions for traffic speed based on road type. We did this, firstly, by estimating traffic speeds from satellite data (SAT) using a novel methodology to detect vehicles determine their speed [2-3] and then comparing the differences in modelled noise levels from applying SAT versus different default values for speeds. Our motivation was to assess the likely uncertainty in noise levels associated with crude estimates for speed. This information is being used to understand uncertainties propagated in exposure assessment in an epidemiologic context, as part of the EU-funded H2020 Equal-Life project looking at the relationship between environmental noise and mental health in childhood and adolescents.

2. METHODS

To compare the impact of the choice of traffic speed data on estimated noise levels, we modelled noise exposure for 4394 cohort residential addresses in Barcelona using the CNOSSOS-EU algorithms implemented in the 'NoiseModelling' software [4].

We developed a geographical information system (GIS) for Barcelona, Spain, including the connected road network (OpenStreetMaps; OSM [5]) and attributed traffic flows (AADT), modelled for each road link using a methodology under development and to be reported elsewhere. We made an assumption on vehicle composition, differentiating only between major and minor roads in terms of the proportion of cars, heavy goods vehicles, etc. We used a single diurnal profile, varying hourly, of traffic flows/composition (% heavy vehicles) based on data from a study in the UK [6], as we could not obtain the equivalent information for Barcelona.

Three speed data sets were used in the analysis 1) national speed limits (NSL), 2) half the national speed limit (HNSL) (i.e., to reflect the likely lower speed levels in built-up areas), 3) a novel approach using satellite imagery (SAT). Table 1 shows the speeds by road type for each speed data set. Standard national speed limits (NSL) were used as the default (e.g. 112 km/h (70 mph) on motorways, 96 km/h (60 mph) on primary, secondary and tertiary roads, 48km/h (30 mph) on residential roads.

The SAT data set was created from high-resolution WorldView 2/3 satellite imagery in three steps.

1) Vehicles were detected in the imagery using the Deep Learning Object Detection model 'You Only Look Once' (YOLOv3), which was trained on a manually created data set of vehicles in 5% of the satellite imagery across Barcelona [7]. The Object Detection model had a precision of 0.69, a recall of 0.79 and a F1 score of 0.74 [2].

2) The speed for each of the detected vehicles was estimated by utilising the fraction of a second gap between capture of each of the multi-spectral sensors on the satellite (e.g. there is a 0.29 second gap between capture of the Red and Coastal Blue bands) [3]. For each vehicle, the OSM road network was shifted to vehicle centroid, and the imagery was subset to 5m in each direction from the vehicle centroid and to the road lane. The pixel values were then extracted for five different spectral bands (Coastal Blue, Blue, Green, Yellow and Red) at 1m intervals along the road lane. The peaks in values for each spectral band were identified. The distance was then calculated between the peak values for different spectral band combinations (Red and Coastal Blue, Green and Coastal Blue, Blue and Coastal Blue, and Blue and Yellow) and the average vehicle speed from the different band combinations was estimated. Figure 1 shows the identified pixels in each spectral band and the estimated speed for each vehicle.

3) The average vehicle speed for each road type in Barcelona was calculated (shown in Table 1). The satellite method (SAT) did not provide speed estimates for vehicles on residential or unclassified roads, therefore, the average percentage decrease of speed from the NSL to SAT data sets for the 5 road types was estimated and used to estimate a penalised average speed estimate of 21 km/h on residential and unclassified roads.

The satellite-derived vehicle speed estimates from step 2 were compared with Google's Directions API route request average speeds on 40 road segments in Barcelona [8]. The Directions API data set covered 40 segments on 14 different roads across the city of Barcelona. To create the Directions API data set, route requests for all road segments were sent at 11am every day for a 7-month period (August 2021 until February 2022 inclusive) and the median speed of the route requests was calculated. The satellite median vehicle speeds were calculated for each of the 40 road segments, using the number of vehicles in each image to calculate a weighted median. The Mean Gross Error (MGE) was 8.4 km/h, the RMSE was 13.4 km/h and the R^2 was 0.71 [3].

Table 1. Vehicle speed (km/h) by road type in Barcelona for the three speed data sets.

Road type	National speed limit – NSL (km/h)	Half national speed limit – HNSL (km/h)	Satellite-derived average vehicle speed – SAT (km/h)
Motorway	112	56	69
Trunk	112	56	58
Primary	96	48	35
Secondary	96	48	33
Tertiary	96	48	31
Residential	48	24	21
Unclassified	48	24	21

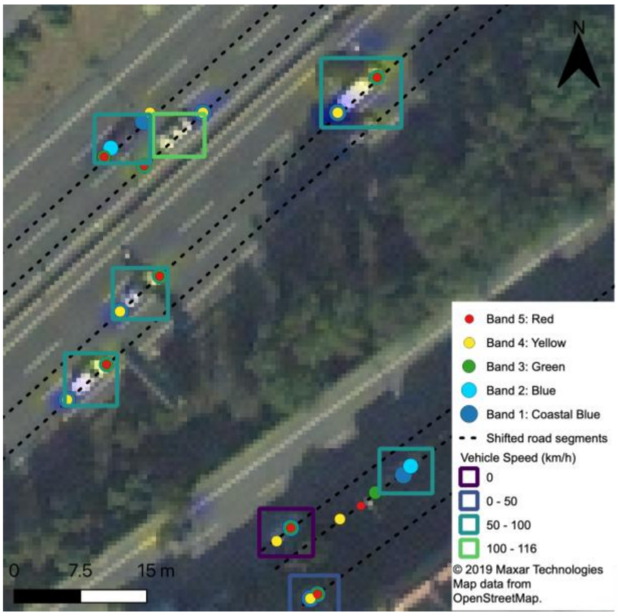

Figure 1: The spatial displacement in vehicles detected in different multi-spectral bands, given the time-lapse between spectral band capture (e.g. < 1s), determines vehicle speed. The example shows detected vehicles and their speed (km/h) on trunk (top) and tertiary (bottom) roads.

As a basis for modelling noise propagation, we integrated the following datasets.

1) **OSM roads and buildings** data sets were used in this study [5]. OSM roads were used to model traffic on a subset of 12 road types: trunk, trunk link, motorway, motorway link, primary, primary link, secondary, secondary link, tertiary, tertiary link, residential and unclassified. OSM buildings were used in the noise modelling.
2) **Building height** was estimated from two data sets. Firstly, the Urban Atlas Building Height 2012 10m data set [9] was intersected with the OSM buildings data set to calculate height of each building. Secondly, the Global Human Settlement Average of the Net Building Height 2018 100m data set [10] was used to calculate height of any remaining buildings.
3) **Acoustic Ground Absorption** was represented using the CORINE Land Cover 2018 vector data set [11]. The G coefficients [12] for different ground cover types were joined on to the CORINE land cover data set and ranged from 0 for hard surfaces such as water, concrete and asphalt, to 1 for soft vegetated surfaces such as grassland and forest.
4) **Digital Elevation Model:** The EuroDEM 2023 which has a 2 arc second (~60m resolution) [13].
5) **Meteorology:** Wind speed data for Barcelona airport was downloaded from the NOAA Integrated Surface Database via the worldmet R package [14]. The proportion of hourly wind direction measurements in each 22.5° segment of a wind rose was calculated for 2023.
6) **Receivers for the addresses:** Receivers were placed at a 5 m spacing around the cohort address buildings to enable quantification of the quietest and loudest façade.

Noise modelling was undertaken for each speed variable, only varying the data on traffic speeds by road type each time, as per the values in Table 1 (NSL, HNSL, SAT). Noise estimates were made for Lden (A-weighted integral of Lday, Levening and Lnight; 5 dB penalty for evening and a 10 dB penalty for nighttime), for the loudest and quietest façade associated with each address location in the sample (N = 4,394).

3. RESULTS

Table 2 shows the average differences in Lden noise estimates resulting from comparison of the application of each of the speed variables (NSL-SAT; NAT-HNL; HNSL-SAT), by road type and differentiating for the loudest and quietest façade. Figure 2 shows the full distributions that the average differences in Table 2 were based on, for the sample of address locations, separately for the loudest and quietest façades.

As shown in Table 2, the greatest average differences in estimated noise levels were between NSL and SAT, up to 12.2 dB(A) (tertiary roads). Lower differences between 5.9 dB(A) and 9.0 dB(A), across both types of façade location, were seen for trunk, primary, residential and unclassified roads. The differences between HNSL and SAT were three-to-four-fold lower than between NSL and SAT, with the largest difference of 3.6 dB(A) (tertiary roads). Differences of <1 dB(A) were obtained for trunk, residential and unclassified roads in comparing HNSL with SAT, suggesting that HNSL may be a good basis for estimating traffic speed for these road types. For the other road types (primary, secondary and tertiary) average differences were between 1.9 and 3.6 dB(A).

In relation to Figure 2, for Lden on the loudest façade 100 % of addresses had a greater than 4 dB(A) difference between NSL and SAT. For Lden on the quietest façade 99.9 % had a greater than 4 dB(A) difference between NSL and SAT. These results were similar for the difference between NSL and HNSL.

For the loudest façade and Lden, 42 % of addresses had a greater than 2 dB(A) difference between HNSL and SAT, and 34.6 % had a greater than 3 dB(A) difference. For LDEN on the quietest façade the corresponding values were 32.2 % and 13.4 %. All noise estimates were <5 dB(A) for the difference between SAT and HNSL, with differences commonly in the range of 1 to 3 dB(A).

4. DISCUSSION

Our analysis suggests that traffic speeds based on national speed limits (NSL) will result in relatively large errors in estimated noise levels. Taking speed values as half the national speed limit (HNSL) would likely reduce errors in estimated noise levels. In this study, we benchmarked the noise levels estimates for NSL and HNSL against those yielded by estimating traffic speed from a novel method using satellite data (SAT). We presented noise estimated for Lden only, because the noise estimates for the other customary periods (Lday, Leve, Lnight) are highly correlated with Lden.

Table 2: Average differences in noise level (dB(A)) estimates between each of traffic speed data sets: (National Speed Limit (NSL), half the national speed limit (HNSL), satellite imagery (SAT)) for Lden estimates at the loudest and quietest façade.

	Traffic speed data set					
	Loudest façade			Quietest façade		
Road type	NSL – SAT	NSL – HNSL	HNSL – SAT	NSL – SAT	NSL – HNSL	HNSL – SAT
Trunk	7.4	7.6	-0.3	7.6	7.6	-0.1
Primary	9.0	7.1	1.9	8.9	7.1	1.9
Secondary	11.9	8.6	3.3	11.1	8.2	2.8
Tertiary	12.2	8.6	3.6	10.2	7.9	2.5
Residential	6.4	6.0	0.5	7.5	6.6	1.0
Unclassified	6.3	6.2	0.0	6.2	5.9	0.1

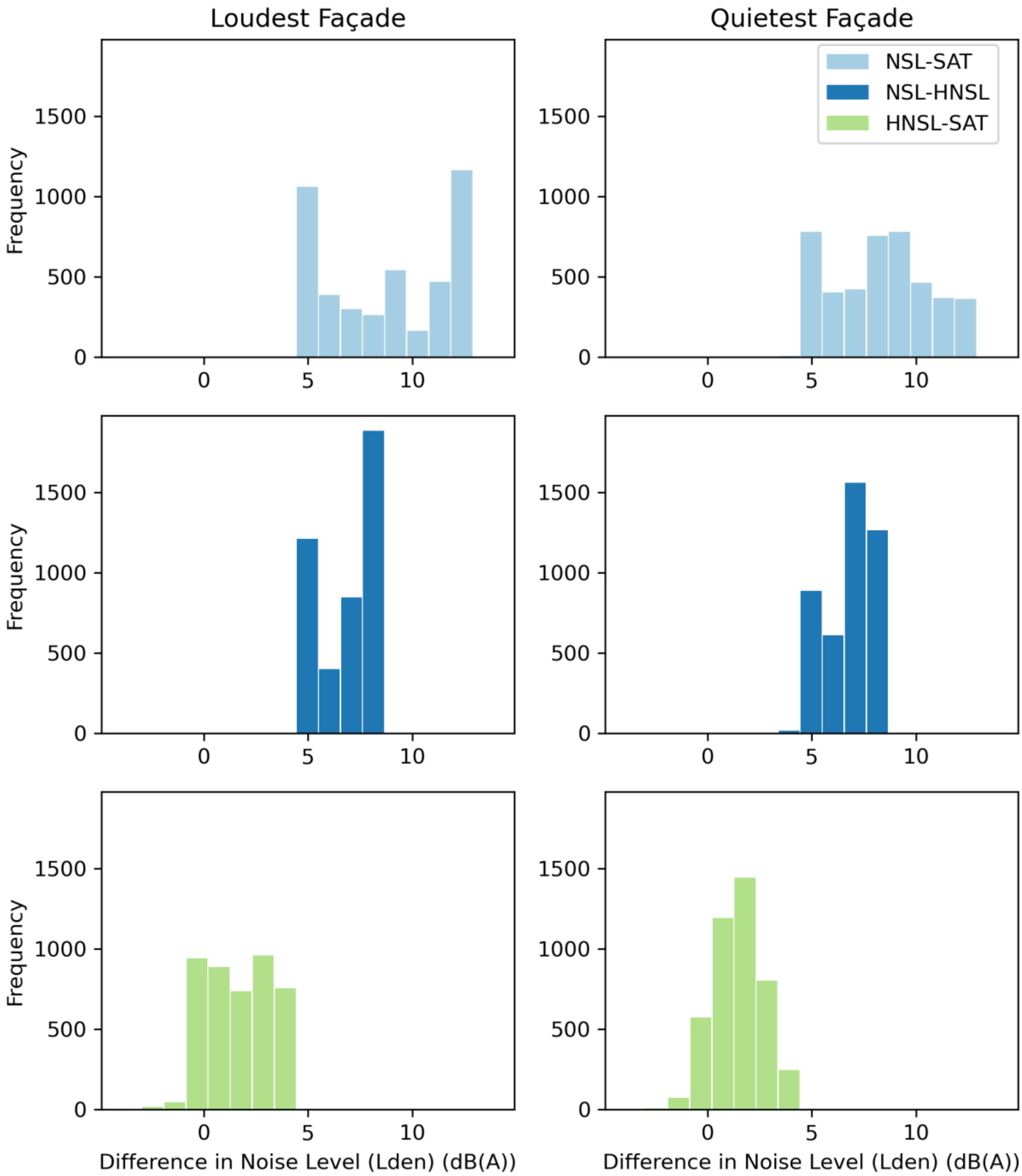

Figure 2: Differences in Lden dB(A) between the three traffic speed data sets for the loudest and quietest façade: (NSL-HSNL: difference between National Speed Limit (NSL) and half the national speed limit (HNSL), NSL-SAT: difference between NSL and satellite imagery (SAT), HNSL-SAT: difference between HNSL and SAT).

It is important to note that the SAT method is based on limited data for a small selection of road links/types. It must also be noted that the values in Table 1 for SAT were evaluated using Directions API data from Google, which is based on a model rather than measurements. This means that the method is not likely to be robust and has not been stringently evaluated at this stage.

Given our results, it may be considered appropriate to use HNSL by road type as the basis for traffic speeds.
The results presented here – allowing SAT to be the basis for benchmarking – show, however, that for some road types errors in estimated noise levels due to speed represented by HNSL may still be equivalent to errors from very large differences in traffic flows. For context, a doubling/halving of AADT flows would result in a modelled change of +/- 3 dB(A).

Furthermore, in this paper we only considered average speeds for each road link. In many situations speed may vary considerably between "mid-block" and the approach to junctions. Ideally, a more detailed speed profile, varying along each link, would be used.

More work needs to be done on developing and evaluating the SAT methodology. Ideally the evaluation would be based on measured traffic speed rather than Directions API data. It may be practical to use the SAT methodology to estimate traffic speed for whole cities but it likely to be prohibitive to extend this to regions/countries due to cost. There is also the challenge of processing the very large amount of imagery involved and undertaking speed measurements to calibrate and then evaluate a model.

Directions API data could be used as an alternative route to estimating traffic speed. It is theoretically possible to generate traffic speeds for each road link from Directions API data, but this approach would be time consuming, as each request must be made independently for each road link. Moreover, Directions API data is modelled and has received little evaluation against data on measured traffic speed, with one study in Germany identified, which evaluated Directions API data against real test drive GPS for one street in Krefeld [15].

Until SAT-based and/or Directions API methods become more accessible/viable, HNSL may be a practical solution, with the magnitude of errors in noise estimates related to traffic speeds defined by road type.

5. ACKNOWLEDGMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 874724. This research was funded by the Natural Environment Research Council via the London NERC Doctoral Training Partnership, grant number NE/L002485/1. The authors thank the NERC Earth Observation Data Acquisition and Analysis Service (NEODAAS) for access to compute resources for this study.

6. REFERENCES

[1] World Health Organisation, "Environmental Noise Guidelines for the European Region", available online: https://www.who.int/europe/publications/i/item/9789289053563, accessed on 5 February 2024, 2018.

[2] A. Sheehan, A. Beddows, D.C. Green, S. Beevers, "City scale traffic monitoring using worldview satellite imagery and deep learning: A case study of Barcelona", *Remote Sens*, 15, doi:10.3390/rs15245709, 2023.

[3] A. Sheehan, A. Beddows, J. Gulliver, D.C. Green, S. Beevers, "Estimating road vehicle speed from high-resolution satellite imagery for environmental applications: a case study of Barcelona", *Remote Sensing Applications: Society and Environment*, 37, doi:10.1016/j.rsase.2025.101507, 2025.

[4] E. Bocher, G. Guillaume, J. Picaut, G. Petit, N. Fortin, "NoiseModelling: An Open Source GIS Based Tool to Produce Environmental Noise Maps", *ISPRS International Journal of Geo-Information*, 8 (3), pp.130, 10.3390/ijgi8030130, 2019.

[5] OpenStreetMap Contributors, "OpenStreetMap data extracts", Available online: http://download.geofabrik.de/; accessed on 16 March 2020, 2020.

[6] D.W. Morley, K. de Hoogh, D. Fecht, F. Fabbri, M. Bell, P.S. Goodman, P. Elliott, S. Hodgson, A.L. Hansell, and J. Gulliver, "International scale implementation of the CNOSSOS-EU road traffic noise prediction model for epidemiological studies", *Environmental Pollution*, 206, pp.332-341, 2015.

[7] G. Jocher, "Ultralytics xview-yolov3", Available online: https://github.com/ultralytics/xview-yolov3 accessed on 16 March 2020, 2019.

[8] Google, "Google Directions API", Available online: https://developers.google.com/maps/documentation/directions, accessed 1 March 2021, 2022.

[9] European Union's Copernicus Land Monitoring Service information, "Urban Atlas – Building Height 2012, version 2" Available online: https://doi.org/10.2909/42690e05-edf4-43fc-8020-33e130f62023, accessed on 17 April 2024, 2020.

[10] M, Pesaresi, P. Politis, "GHS-BUILT-H R2023A - GHS building height, derived from AW3D30, SRTM30, and Sentinel2 composite (2018)", *European Commission, Joint Research Centre (JRC)*, Available online: http://data.europa.eu/89h/85005901-3a49-48dd-9d19-6261354f56fe, doi:10.2905/85005901-3A49-48DD-9D19-6261354F56FE, accessed on 18 April 2024, 2023.

[11] European Union's Copernicus Land Monitoring Service information, "CORINE Land Cover 2018 (vector), Europe, 6-yearly, version 20.1.", Available online: https://doi.org/10.2909/71c95a07-e296-44fc-b22b-415f42acfdf0, accessed on 14 March 2024, 2020.

[12] S. Kephalopoulos, M. Paviotti, F. Anfosso-Lédée, *Common Noise Assessment Methods in Europe (CNOSSOS-EU)* EUR 25379 EN. Publications Office of the European Union, Luxembourg, 2012.

[13] EuroGeographics AISBL, "EuroDEM: Pan-European Height Dataset at Medium Scale", Available online: https://ome-download-data.s3.eu-west-1.amazonaws.com/euro-dem/documents/EuroDEM_2023_Specification.pdf, accessed on 14 March 2024, 2023.

[14] D. Carslaw, "worldmet: Import Surface Meteorological Data from NOAA Integrated Surface Database (ISD)", Available on: https://github.com/openair-project/worldmet, accessed on 4 April 2024, 2025.

[15] J.M.S. Wagner, M. Eschbach, K. Vosseberg, M. Gennat, "Travel time estimation by means of Google API data", *IFAC-PapersOnLine*, 53–2, pp. 15434-15439, 10.1016/j.ifacol.2020.12.2365, 2020.