Recommending Green Routes for Pedestrians to Reduce the Exposure to Air Pollutants in Barcelona

Demonstration Track

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ABSTRACT

We demonstrate our prototype that recommends *green routes* for pedestrians that minimize the exposure to harmful air pollutants in a city (in our case, Barcelona). Our prototype allows potential users (including public administrations concerned with the population's health) to visualize and compare the *green route* computed by our method with the *shortest route* (analogous to those computed by widely used tools such as Google Map, which disregard air quality data), quantifying the reduction in terms of exposure to air pollutants. Results on real Air Quality Index data from the Open Data BCN portal show a median NO_2 exposure reduction of -7.82%, along with only a $+4.54\%$ median increase in terms of route length.

KEYWORDS

Air Quality Index; Routing; Graph Neural Networks

ACM Reference Format:

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1 INTRODUCTION

In this work, we address the pressing issue of air quality in urban areas, which can lead to various negative health outcomes such as respiratory and cardiovascular diseases [5]. This is particularly true for pedestrians, the most exposed individuals among those who commute in a city [2]. Along these lines, we provide a solution to the question "Can the exposure to harmful pollutants —such as NO_2, $PM_{2.5}$, and PM_{10}— be reduced by walking along *greener* routes, instead of the shortest ones usually recommended by widely used tools such as Google Maps?" Specifically, the main contribution of this article is to demonstrate a prototype that recommends *green routes* for pedestrians that minimize the exposure to the pollutants mentioned above, showcasing it in the case of Barcelona (e.g., see Figure 1). Results on real Air Quality Index (AQI) data provided by Barcelona's city council show promising benefits in reducing the exposure for pedestrians, corroborating the indication that our tool could be of great interest both for individual and public administrations concerned with the citizens' health.[1]

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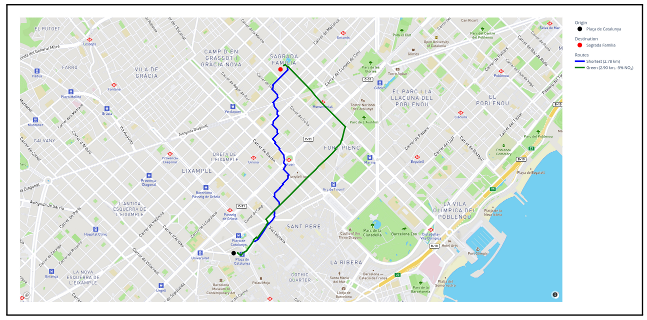

Figure 1: Green route from Plaça de Catalunya to Sagrada Familia, resulting in a NO_2 exposure reduction of -5.14% and a route length increase of $+4.35\%$ *wrt* the shortest route (blue).

2 RECOMMENDING GREEN ROUTES

We solve the problem of computing green routes as a "shortest" path problem on a weighted graph representing the city's road network, where the weight of each edge represents the exposure to a given pollutant when walking along that edge. Following the definition in the literature [7, Section 19.3], we define the exposure along each edge as proportional to the AQI (e.g., NO_2 concentration) measured on such an edge multiplied by its length. We then solve the shortest path problem within seconds with the bidirectional Dijkstra algorithm, as implemented in the Python `networkx` library.

Our prototype employs both historical AQI data from the Open Data BCN portal [4], as well as real-time data from air quality sensors in Barcelona.[2] The main difference between these data sources is that historical data has a high spatial resolution (one value for each edge/road) but a low temporal resolution (updated once per year, in the case of Open Data BCN). In contrast, real-time data has a high temporal resolution (updated every hour) but a low spatial resolution (only 7 sensors in the entire Barcelona).

To account for this heterogeneity, our prototype incorporates the technique we recently proposed in [3] to interpolate data with low spatial resolution from real-time sensors with a Graph Neural Network (GNN) trained on the high-resolution historical data. This aspect is fundamental as real-time data can differ significantly from historical data in a certain location. Therefore, accounting for real-time data allows us to recommend green routes with more accurate, hence lower, exposure (see example in Figure 2).

[1] https://www.theguardian.com/environment/2017/jun/14/side-street-routes-avoid-city-pollution-cut-exposure-by-half.

[2] https://ajuntament.barcelona.cat/qualitataire.

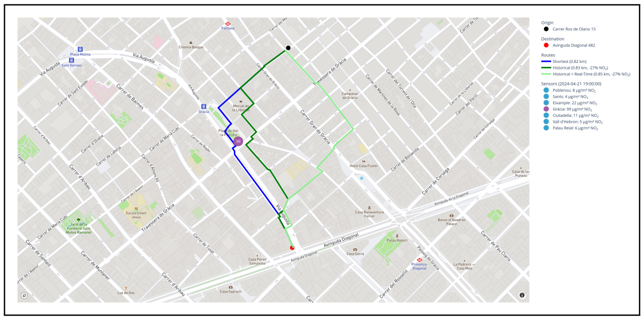

Figure 2: Green route based on both historical and real-time AQI data (light green), resulting in a NO_2 exposure reduction of -27.08% and a route length increase of $+3.68\%$.

To the best of our knowledge, this is Barcelona's first study of this kind. Similar studies have been conducted in London (UK),[1] Riverside (California, USA) [6] and Melbourne (Australia) [8], confirming that *green* pedestrian routes can lead to a reduction of exposure to air pollutants from 11% to 60%, depending on the city and the time of the day. While we adopt the same optimization approach (i.e., computing the "shortest" path on a graph weighted with AQI data), in contrast with [6, 8], we employ a more advanced AQI prediction method based on GNNs [3], which has been shown to outperform alternative approaches [1, 9] to solve the same task.

3 EXPERIMENTS ON BARCELONA'S POIS

We quantify the benefits of our method on routes commonly walked in the city of Barcelona. Specifically, we consider the following 10 touristic Points of Interest (POIs) shown in the map in Figure 3:

(1) Casa Batlló
(2) Plaça de Catalunya
(3) Platja del Bogatell
(4) Sagrada Familia
(5) Parc de la Ciutadella
(6) Platja de la Barceloneta
(7) Camp Nou
(8) Estadi Olimpic
(9) Recinte Modernista
(10) Turó de la Rovira

We then consider all possible $\binom{10}{2} = 45$ couples of starting and destination points among such POIs, computing the corresponding green and shortest routes. Even though our prototype is prepared to account for any available AQI data, we only consider NO_2 concentration for simplicity. Furthermore, we only consider historical data of 2023 (the most up-to-date data currently available) [4], as we deem it more representative than real-time data for this experiment.

Results in Figure 4 show that the green routes computed with our method produce a median exposure of NO_2 reduction of -7.82% compared to the shortest ones, while only being $+4.54\%$ longer. Notably, the maximum exposure reduction in our experiments reaches -29.08%, corresponding to a route length increase of $+12.65\%$. Overall, we observe that, in the realistic scenario considered here, the benefits of walking a green route generally outweigh the inconvenience of taking a possibly longer (but less polluted) detour.

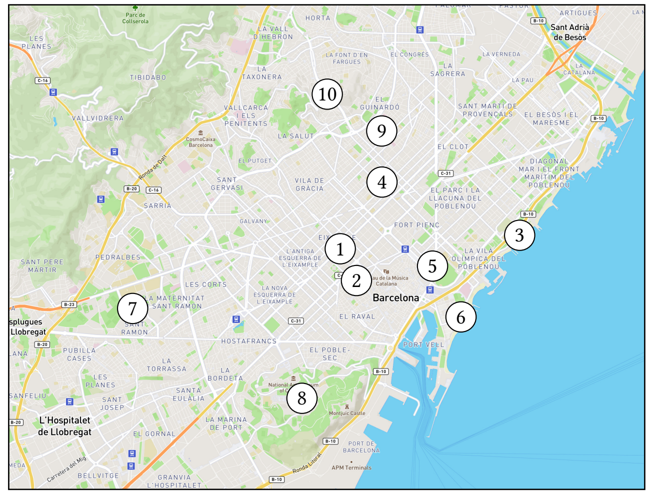

Figure 3: Map of considered POIs in Barcelona.

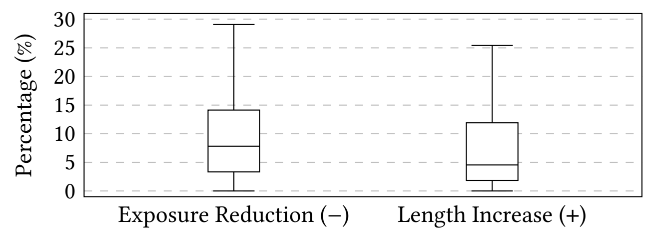

Figure 4: Boxplot of exposure reduction (%) and route length increase (%), outliers not shown for better clarity.

4 CONCLUSIONS

We demonstrated a prototype to recommend green routes to pedestrians and showcased it for the city of Barcelona. Our prototype considers publicly available AQI data from Barcelona's city council (both historical and real-time data). Nonetheless, our prototype could be easily adapted to other cities with analogous AQI data.

Our experiments on a realistic scenario in Barcelona align with previous findings for other major cities, confirming that walking routes optimized for minimizing exposure to pollutants can produce significant health benefits for citizens while causing only minimal inconveniences in terms of increased walking length.

DEMONSTRATION VIDEO

https://youtu.be/qX1-2WjZOGE

ONLINE PROTOTYPE

https://greenroute.filippobistaffa.com

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