# Pedestrian Route Planning based on an Enhanced Representation of Pedestrian Network and Probabilistic Estimate of Signal Delays

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**Summary**

The paper proposes an enhanced representation of the pedestrian network that provides benefits for pedestrian route planning over a network representation that is used by a majority of existing route planning services. The pedestrian network is represented in the proposed methodology by pavements and crossings between them. Route planning is based on the travel time derived from distance and average walking speed. Additional delays calculated using probabilistic method are applied for signal crossings. This allows more accurate pedestrian route choice by accounting for signal delays and pavement closure, which is not possible under a usual network representation used for vehicles.

**KEYWORDS:** pedestrian, network, routing, representation, probabilistic estimate

## 1. Introduction

Most popular route planning services use the same representation of the road network when planning routes for pedestrians as they use for vehicles. Roads in this case are represented as single edges, their junctions as nodes. This however leads to a simplified modelling of pedestrian movement, as it does not account for the need to cross the roadway to get to the opposite side of the road, a possible lack of pavement on any side of the road, and the fact that not all roads can be crossed at any position on them. The project aims to develop a representation of the pedestrian network that would allow modelling pedestrian movement in the most realistic way, and to plan pedestrian routes based on it.

## 2. Background

The widely used route planners such as GoogleMaps[2] and OpenStreetMap[3] offer options for pedestrian routing, among other transport modes. While the level of detail they offer can be sufficient for vehicle routing, its capacity to ensure an effective pedestrian route choice is quite limited. Differences between pedestrian and vehicle navigation have been highlighted in a number of works. Zielstra & Hochmair (2012) assessed several open-access, commercial and government datasets for pedestrian navigation and found the biggest constraint in inaccuracies or incompleteness of data related to minor pedestrian ways. Pedestrian navigation can also be improved by accounting for paths within large public buildings, as well as open areas such as parks that might lack a path network but are traversable by pedestrians (Elias, 2007). Incorporating the data on obstructions, pavement quality and terrain slope can be especially important for selecting routes for pedestrians with different abilities (Sobek & Miller, 2006). Overall, availability of sources that could provide comprehensive data for an accurate pedestrian route planning can be recognized as a gap.

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[2] https://maps.google.com
[3] http://www.openstreetmap.org

## 3. Methodology

The current section discusses a proposed geometric representation of a pedestrian network, and routing criteria.

### 3.1 Representation of a pedestrian network

The Highway Code (Department for Transport, 2015) advises pedestrians to cross roads at designated crossings if there are any nearby; otherwise, they are advised to choose a safe place where to cross. There are two broad categories of designated crossings: 1) signalized that include pelicans, toucans and puffins, and 2) non-signalized represented by zebras. Considering this, roads are depicted in this study in two different ways, depending on the extent to which they represent an obstacle for pedestrians to cross them.

The study area with the size of 0.4 $km^2$ is located in the Greenwich borough of London (Figure 1). OpenStreetMaps (OSM) dataset containing roads and pedestrian ways is used as a basis[4].

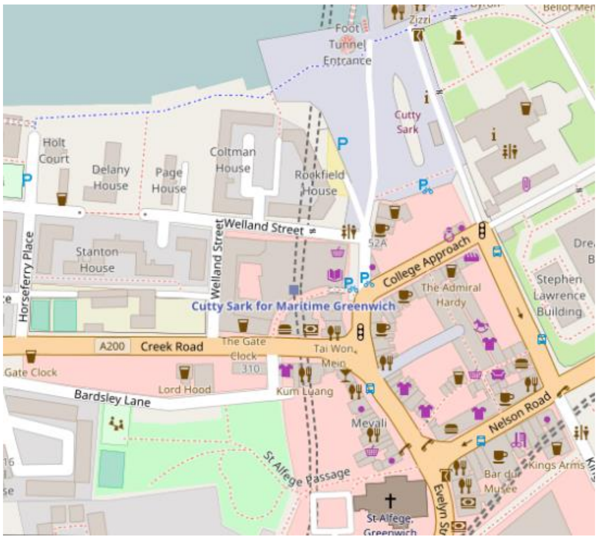


**Figure 1** Study area

1) *Major roads* are roads with relatively high volumes of traffic, that have designated crossings and where it is usually hard to find a safe place to cross outside these crossings. These roads are depicted as two edges, each corresponding to pavements on the road side, except for cases when there is no pavement on any of the sides. Links between pavements are drawn at designated crossings. This category includes OSM road classes that receive the most intense traffic: motorway, motorway link, trunk, trunk link, primary and primary link (OpenStreetMaps Wiki, 2016).

2) *Minor roads* are roads with no or low motorized traffic, so pedestrians can cross at any position on them without significant safety concern. These roads usually lack designated crossings. This category includes all of the rest OSM road classes not included into the major roads category.

[4] http://download.geofabrik.de/europe/great-britain/england/greater-london.html

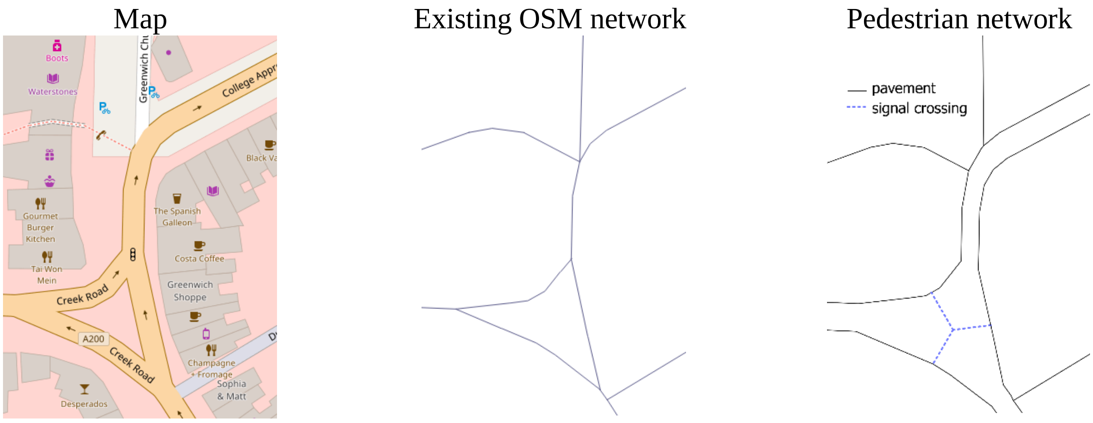


**Figure 2** Comparison of the existing OSM network with the developed pedestrian network on a fragment of the study area

The highest road class within the study area is ‘primary’, so this is the only one that got its representation modified. Based on a ground survey, all roads in the study area have pavement on each side although there are pavements that are closed due to construction works. The area has 10 signalized crossings also mapped based on a ground survey, and no zebra crossings.

### 2.2 Probabilistic estimate of signal delays

For routing purposes, edges are assigned with costs equal to their travel time. Pavements have the travel time derived from the edge length and an average speed of walking, whereas crossing links in addition to travel time get assigned the amount of delay caused by signal.

Average waiting time on the signal ($t_w$) is calculated based on the ground measurements shown in Table 1, using Equation 1.

$$t_w = t_r/c * t_r/2 \tag{1}$$

where

$t_r$ – average time of the red signal,
$c$ – average cycle, time of the red plus green signal,
$t_r/c$ – probability of the red signal within the cycle,
$t_r/2$ – average waiting time within the red signal.

**Table 1** Times of signal delays measured within the study area

| Signal # | Time of green signal (sec.) | Time of red signal (sec.) (time between green signals if the button is pressed immediately after the previous green signal goes off) |
|---|---|---|
| 1 | 15 | 43 |
| 2 | 12 | 33 |
| 3 | 14 | 46 |
| 4 | 8 | 21 |
| 5 | 13 | 50 |
| 6 | 15 | 64 |
| **Mean** | **13** | **43** |

Signal delay according to the Equation 1 is *43/56 * 43/2 = 16.5 sec.*
Average walking speed is assumed to be 5 kph (Franěk, 2013).

## 4. Results and discussion

A range of pedestrian routes are computed within the study area using the A* shortest path algorithm powered by the PostgreSQL extension pgRouting. To clearly see the benefits of the pedestrian network representation developed for the project, the routes computed on it (P-routes) are compared to those generated on the existing OSM network (E-routes).

E-route 1 ignores the need to cross four signals, whereas the P-route avoids all of them and crosses only one on Romney Road (Figure 3).

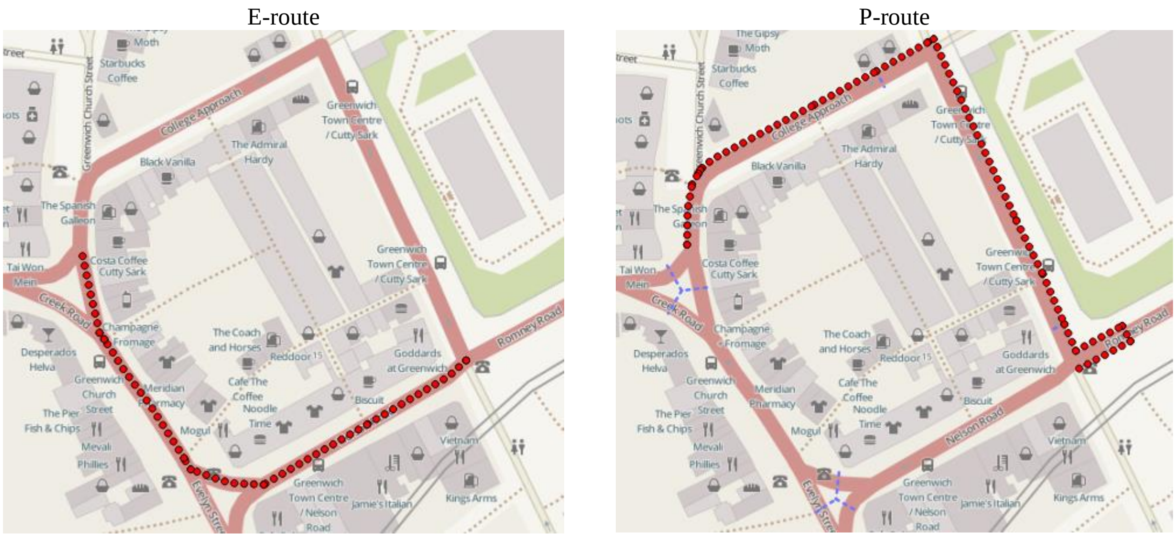


**Figure 3** Route 1

Route 2 has two modifications (Figure 4). One of them starts on the *western* side of Evelyn Road, another one has the same start location but across the road - on the *eastern* side of Evelyn Road. The E-route results the same for both cases. While the P-route that starts on the western side shows no difference with the E-route, the P-route starting on the eastern side is different as it avoids four signals.

Route 3 also has two modifications - one with temporary restriction due to pavement closure, another without restriction (Figure 5). As in route 2, the E-route here results the same for both modifications, because there is no way to reflect pavement closure on the existing network, as the corresponding road section cannot be totally excluded from routing. While the unrestricted P-route is similar to the E-route, the restricted P-route differs, resulting more than twice as longer as the E-route.

E-route

P-route starting on the *western* side of Evelyn Road

P-route starting on the *eastern* side of Evelyn Road

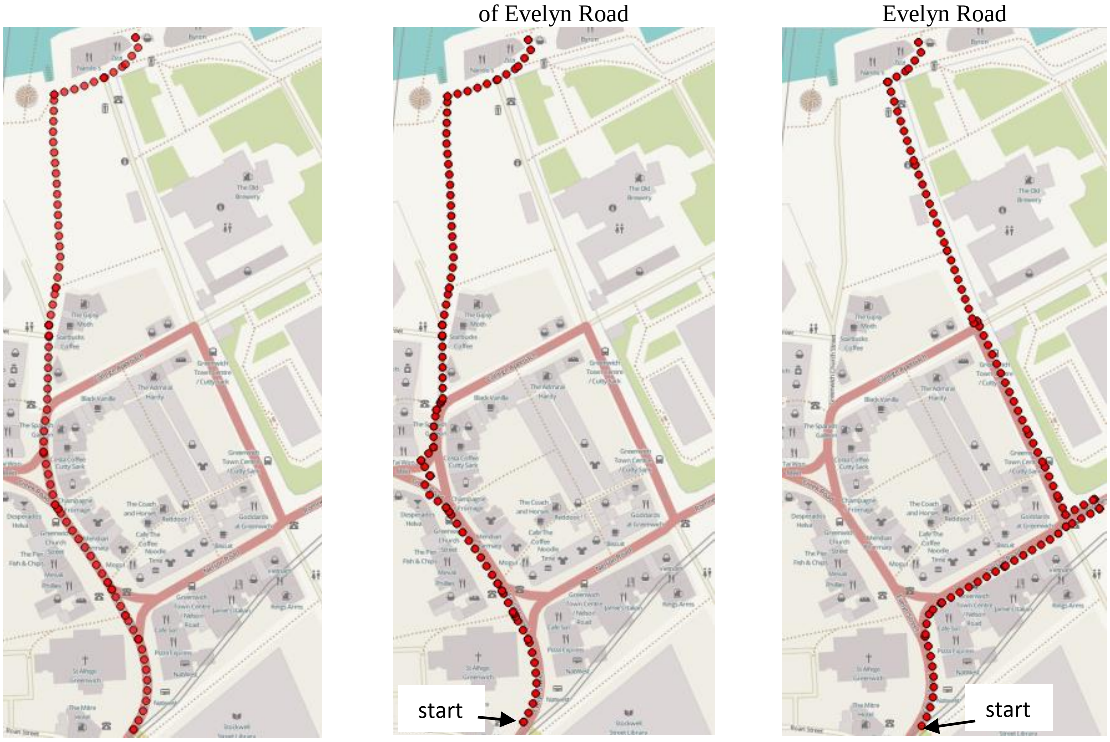


**Figure 4** Route 2

E-route

P-route without restriction

P-route with restriction

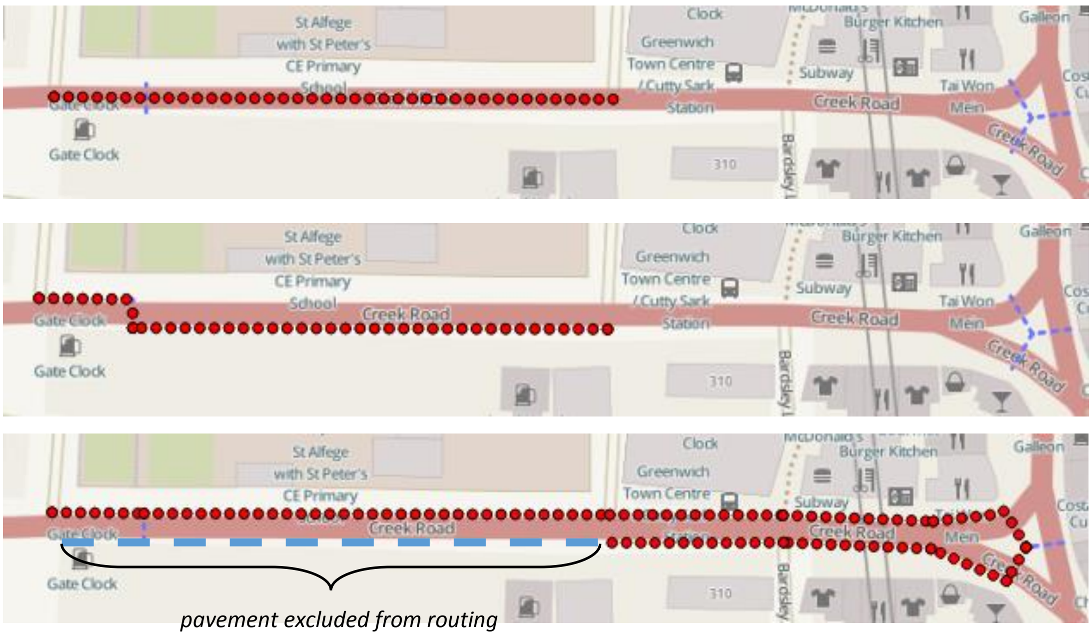


**Figure 5** Route 3

## 5. Conclusions and future work

The current paper proposed an enhanced representation of a pedestrian network that consists of pavements and the crossings between them. This allowed more accurate pedestrian routing by accounting for signal delays, side of road where a route starts or ends, and lack or closure of pavement, which is not possible under an existing representation of the road network.

To ensure the scalability of the present research, several things have to be accounted for. If OSM road dataset is used for reconstruction of pedestrian network, it can be area-specific which road classes should be included into major roads and which into minor roads category. OSM provides general description of each road class that is supposed to be adhered globally, but levels of traffic each road class receives depend on the local context. Therefore, a ground survey is likely to be needed to decide to what extent each class affects pedestrian movement in different areas.

While this methodology used a probabilistic estimate of delays on signal crossings, zebra crossings were not present within the study area. Although waiting times on zebras measured in other locations across London were very small and thus can be recommended to be neglected, this may not be the case in other areas.

Future work on this topic includes incorporation of other parameters into pedestrian routing rules, such as pedestrian flows, time restrictions (e.g., closure of green areas after dusk) and terrain slope.

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## Author's biography


Olena Klochkova has degrees in GIS with Remote Sensing, and in Geography, both Master's level. Her past work includes development of a web-based multi-criteria cycle route planner for Greater London. Currently she is involved in development of a pedestrian routing system.