Context-Aware Bicycle Route Planning

Damianos Gavalas¹,4, Theofanis Gerodimos², and Christos Zaroliagis³,4

Abstract. Cycling represents a fundamental link in the sustainable urban mobility chain. Besides time and distance, cyclists consider a multitude of criteria when planning their route towards a destination, such as safety, road inclination, road surface, etc. Finding routes that properly take such criteria into account is particularly challenging. Therefore, intelligent route planning services are important to assist cyclists in scheduling routes that address their preferences. Our key research objective has been to develop a wayfinding service tailored to the specific requirements of cyclists (including delivering services) using analytical models which capture various practical aspects that affect the cycling experience. We investigate the use of OpenStreetMap (OSM) to obtain geospatial data relevant to bike routing. Those map data are combined with contextual data (such as wind speed/direction) to derive optimal multicriteria, context-aware bike routes. A preliminary qualitative evaluation has demonstrated the effectiveness and utility of our approach in realistic bike route planning scenarios in urban environments.

Keywords: Sustainable urban mobility · Urban transportation · Bicycle · Route planning · Context awareness · OpenStreetMap

1 Introduction

Cycling comprises a fundamental link in the chain of sustainable mobility, while also having a positive effect on personal health and well-being [1, 9]. Unlike car drivers, cyclists take into account a multitude of criteria, besides time and distance, when planning their route towards a destination. Recent research has shown that cyclists consider safety (e.g., the existence of continuous road infrastructure for cyclists), road inclination (slope), road surface type and condition, environmental pollution, traffic characteristics (e.g., the intensity of motorized wheel traffic), number of intersections with traffic lights, bike parking infrastructure, etc. [4, 16]. In addition, cyclists also consider several context-dependent factors such as the weather (wind, rainfall, etc.) but also the purpose of the transfer (commuting, exercise, recreation, delivering services, etc.). Finding routes that take all the above factors into account is not straightforward, especially when cyclists are called upon to make route planning decisions on a complex or unknown

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
E. G. Nathanail et al. (Eds.): CSUM 2022, 2023.
https://doi.org/10.1007/978-3-031-23721-8_65
urban environment. Therefore, cyclists can benefit from e-services deriving origin-to-destination optimal route plans that help them discover routes tailored to their needs and preferences [13].

Notwithstanding the rich literature in multi-criteria journey planning both in transport networks and transit networks [3, 6], bicycle route planning has not received much attention. So far, existing approaches either consider a single (among the many) criterion to optimize bike routes [11, 17] or enable multi-criteria shortest path search at the expense of calculating lower quality solutions [13]. Even the latter consider only a few criteria (among the many which are important to cyclists) so as to make the problem efficiently tractable [10] thus suitable for real-time bicycle route planners. Besides, previous research takes into account solely static spatial data (such as length and inclination of road segments, terrain type, etc.) neglecting real-time information regarding traffic, environmental and weather conditions.

To address the abovementioned issues, we propose a pseudo-multi-criteria approach whereby a weighted combination of all known cyclist-relevant criteria (including those depending on real-time data) is employed to derive optimal bike routes while achieving high performance on city-wide transport network scales. Our algorithmic approach builds upon a detailed modelling of the multi-criteria bicycle routing problem which incorporates realistic route choice aspects considered by cyclists. We also investigate the use of the OpenStreetMap (OSM) platform for geospatial data mapping. We undertake a systematic mapping of the OSM annotation elements (tags) which convey information relevant to bike routes and cyclists. We then create a dynamic weighted cycleway graph based on OSM and real-time data upon which we execute our route planning algorithm. The key end-product of our research is a wayfinding tool tailored to the specific requirements of cyclists.

Our bike route planning prototype has undergone a preliminary qualitative evaluation to assess its performance and utility in realistic scenarios. Our pilot study has been undertaken in the city of Ioannina, Greece, chosen mainly due to its diverse geomorphological characteristics and fragmented cycling infrastructure.

The remainder of this article is structured as follows: Sect. 2 provides an overview of the state-of-the-art in our field of research. Section 3 presents our modelling approach in the bike route planning problem. Section 4 discusses the implementation aspects of our web framework, while Sect. 5 presents preliminary test results. Last, Sect. 6 concludes our work and draws directions for future research.

### 2 Related Research

Several research projects investigated the human factors influencing the route choices of bikers. Hochmair [11] proposed a scheme which incorporated the classes ‘fast’, ‘safe’, ‘simple’ and ‘attractive’, each associated with a number of lower-level criteria; for instance, the ‘fast’ class better suited cyclist who valued short routes, with few traffic lights, bypassing pedestrian areas. Hence, a decision-making system must have all the evaluation criteria and cover all the important aspects of the problem without adding unnecessary complexity to the end user [14].

In the algorithmic domain, multi-criteria journey planning for motorized vehicles (private cars, taxis, motorbikes, etc.) as well as multimodal route planning represent
well-studied fields of research [3, 6]. Existing solutions typically optimize routes with respect to travel time, distance, number of transfers, and walking distance criteria. On the contrary, route planning for bicycles represents a largely unexplored research subject, despite the proliferation of commercial web and mobile bicycle route planners\(^1\), the majority of which (like Google Maps) only accept safety (e.g., dedicated cycling lanes or bike-friendly roads) as an optimization criterion and do not allow users to denote other criteria.

As regards the scientific literature, most existing approaches considered a single (among the many) criterion to optimize bike routes: safety, distance, complexity, aesthetic value [8, 12]. Su et al. [17] implemented a similar system for cyclists in Vancouver, Canada, with emphasis on sustainable urban mobility. The criteria they introduced emerged after interviews with cyclists and literature research [2]. The most important ones, which had not appeared until then in the relevant literature, have been the slope (inclination) of the route (this affects the calories consumed by the cyclist), air pollution and links to transit.

The vast majority of existing approaches to bicycle routing, however, do not use multi-criteria search methods and they thus cannot produce diverse sets of suggested routes properly accounting for cyclists’ multiple route-choice criteria. Hrncir et al. [13], have proposed speedup heuristics over standard multicriteria label-setting algorithms to approximate the full set of Pareto optimal routes. In order to reduce the run time and space consumption, the authors limit the total number of Pareto optima to three: travel time, comfort (good-quality surfaces and low traffic) and elevation gain (preference on flat routes over routes with long uphill sections); thus, they neglect other important criteria like safety, scenic value, number of intersections across the route, etc. This approach indicates a trade-off between considering the whole range of optimization criteria which are important to cyclists, the efficiency and the quality of route planning solutions. Namely, it is hard to provide real-time response without compromising the quality of derived routes, especially when considering city-wide problem spaces.

The state-of-the-art overview indicates that existing approaches in bike route planning still lack services that balance well between taking into consideration all the criteria which are relevant to cyclists (e.g., preference on including relatively short and flat road segments with high safety standards, small number of turns and crossings with traffic lights, etc.) and deriving high quality route plans in reasonably short time so as to be suitable for real-time applications. Moreover, it is crucial to leverage open map data platforms with cycling-relevant path annotations so as to enable a universal solution, applicable to any urban environment. Last, it is important to take into consideration real-time information regarding traffic, environmental and weather conditions, which are particularly relevant to cycling, e.g. traffic conditions, wind speed and direction, temperature or raining (which affects the slipperiness of road segments for certain surface types).

3 Problem Definition and Formalization

3.1 Requirements Analysis

In order to elicit the end-user requirements, we have conducted a user survey with 52 participants. The participants list included occasional cyclists (typically using bike for short rides or for recreation), frequent users (individuals commuting by bike or athletes) and professionals (employees of delivery services). Most of them have been members of a Cycling Sports Association (in Ioannina, Greece) and relevant Facebook groups. The participants have been invited to answer a questionnaire which, further to demographic data, included questions about their relationship with cycling (their most common type of bike use) and a long list of criteria they typically consider when selecting a particular bike route over alternatives.

Apart from safety-related criteria (dedicated cycling lanes, pedestrian roads, avoidance of motorized traffic, etc.), distance, and scenic value of the route (e.g., preference on taking longer lakeside routes), many respondents consider aspects related to convenience, for instance the streets’ slope and the wind direction (some routes are more exposed to air gusts). In contrast, route complexity (e.g. number of turns) or air pollution has not been an issue for most responders. The results of our requirements analysis as well as those of previous studies have dictated the need to offer users a limited number of options (to avoid cognitive overload), however, to allow them to configure route planning in accordance with their personal needs. Keeping only the route planning criteria which have received high average score, we have grouped the criteria under four basic categories: safety, comfort, distance and scenic value.

3.2 Cycleway Graph

We model the cycleway network as a bidirectional weighted graph \( G = (V, E) \) where \( V = \{v_i\} \) is the set of all vertices in graph \( G \) and \( E = \{e_{i,j}\} \) where \( e_{i,j} = (v_i \rightarrow v_j) \) with \( v_i, v_j \in V, i \neq j \) is the set of directed edges of our structure. Each vertex represents a point (node) on the map that belongs to the city road network. For each vertex, we store its geo-coordinates (longitude, latitude, altitude). Each edge represents a road segment that connects map points (vertices) and has a weight value depending on the user-defined optimization criterion. The edges are bidirectional, hence, the weights \( c_{i,j} = c(e_{i,j}) \) and \( c_{j,i} = c(e_{j,i}) \) may differ: \( c_{ij} \neq c_{ji} \), where \( c_{i,j} \) the weight of the edge \( e_{i,j} \). An example graph representation is shown in Fig. 1.

To compute the weight \( c \) of edges, we define a multivariable function \( c(E) : S \rightarrow \mathbb{R} \), where \( S = (d, \vec{g}, \vec{a}, \vec{t}) \) the vector space, which includes: the distance \( d \), the inclination \( \vec{g} \), the weather \( \vec{a} \) (wind speed and direction) and other road features \( \vec{t} \) extracted from OSM annotations (tags).

Slope Contribution

To define the inclination contribution \( \vec{g} = (g_\phi, g_E) \) we worked as follows: each section of a road is characterized by two nodes \((v_1 \rightarrow v_2)\), namely \( v_1 \) the starting and \( v_2 \) the destination point, \( d(v_1, v_2) \) the distance and \( h \) is the altitude difference between nodes \( v_1 \) and \( v_2 \).
Thus, the sin of the angle of slope $\varphi$ is calculated by the formula $\sin \varphi = \frac{h_2 - h_1}{d}$, with $-1 \leq \sin \varphi \leq 1$. Then we defined the slope’s contribution through the function $g_\varphi : [-\frac{\pi}{2}, \frac{\pi}{2}] \rightarrow [0, e]$ as follows:

$$g_\varphi = g(\varphi) = \begin{cases} e^{\sin \varphi}, & \sin \varphi > 0 \\ 0, & \sin \varphi \leq 0 \end{cases}, \quad 0 \leq g(\varphi) \leq e \quad (1)$$

When $\sin(\varphi) \leq 0$ then the road segment is flat or downhill, so the inclination of the segment does not contribute to the weight of the edge. Otherwise, it is uphill and the slope contributes exponentially to the edge cost.

**Weather Contribution**

The weather conditions $\vec{\alpha}$ represent a crucial contextual (time and location-dependent) factor taken into account by bikers when planning their routes. Wind speed and direction largely affect the aerodynamic drag power losses of cyclists. User research has indicated that intense wind opposite to the cyclist’s direction, makes steep road segments less appealing. Therefore, they significantly add to the route cost, when the optimization criteria are the most comfortable or the fastest route [15].

In order to define the wind’s contribution, for each route segment, we need to estimate: (a) the angle $\varphi$ (in degrees) of the route segment as to the magnetic north; (b) the angle $\theta$ referring to the wind’s direction. Based on the abovementioned angles, we calculate the angle $\theta'$ of the wind as to the biker’s direction for each road segment:

$$\theta' = \theta - \varphi \quad (2)$$

Suppose that the endpoints of a route segment are the point $V_1$ with coordinates $(x_1, y_1)$ and point $V_2$ with coordinates $(x_2, y_2)$. The tangent of angle $\varphi$, which forms the route segment $V_1 \rightarrow V_2$ is given by the formula: $\tan \varphi = \frac{\Delta x}{\Delta y}$, so:

$$\varphi = \arctan \left( \frac{\Delta x}{\Delta y} \right) \quad (3)$$

Thus, the angle of the section in combination with the wind (normalized) speed contributes to the shaping of the weight of the edges, if the wind direction is opposite
to the direction of movement of the cyclist with \( a_w = w(\theta') \cdot \frac{b}{6}, 0 \leq a_w \leq 2 \), because

\[
0 \leq b \leq 12 \text{ in the Beaufort scale and } w(\theta') : [0, \pi] \rightarrow [0, 1], \text{ with }
\]

\[
w(\theta') = \begin{cases} 
1 - \frac{\theta'}{\pi/2}, & -\frac{\pi}{2} < \theta' < \frac{\pi}{2} \\
0, & \pi \leq \theta' \leq 2\pi 
\end{cases}
\]

**OSM-Extracted Road Features**

OSM\(^2\) data is distributed in XML format. OSM data are organized into three core entities: nodes (which define points with a geographical position), ways (which define linear features and areas through ordered lists of nodes), and relations (relationships between existing nodes and ways). Each way may be annotated by a number of tags; among them, several are highly relevant to cycling (for instance, the \(<\text{highway}=\text{cycleway}>\) tag indicates a separate way for the use of cyclists).

From the OSM data we extracted information related to cycling, based on the findings of the requirements analysis (see Sect. 3.1): road type and surface, points of interest, scenic value, speed limits and indications about traffic lights and lighting. The geometric and topologic attributes of each way segment (derived by the OSM tags and the nodes’ geo-coordinates) affect the edge weights in our weighted graph.

Specifically, we have extracted the values of the following keys:

- **highway** is used to identify the type of each road section; the key value indicates the importance of the highway within the road network as a whole.
- **smoothness** describes the surface regularity/flatness; road segments with smoothness value equal to bad (or below) have been excluded since those typically refer to countryside roads.
- **surface** provides additional information about the physical surface of roads and some other features, especially in terms of material composition and/or structure which affects the bike’s rolling friction [13].
- **scenic** whether a road segment is of high scenic value.
- **maxspeed** indicates the maximum speed limit on a particular road.
- **traffic_calming** consists of engineering and other measures put in place on roads for reducing motor-vehicle traffic as well as to improve safety for cyclists.
- **bicycle** is used in combination with the value of the key highway to indicate the existence of bike tracks or lanes.

The contribution of the above listed keys (road segment aspects) to the corresponding edge’s weight appears in Table 1.

As shown in Table 1, key values which mostly contribute to the suitability of a road segment for biking, with respect to one of the four optimization criteria, correspond to lower weight values. For instance, road segments with high maxspeed values are mostly inappropriate when the route planning criterion is safety, while they are suitable for fast journeys.

\(^2\) https://www.openstreetmap.org/.
Table 1. OSM key/values contribution to edges’ weight.

<table>
<thead>
<tr>
<th>Key</th>
<th>Value</th>
<th>Comfort</th>
<th>Fast</th>
<th>Scenic</th>
<th>Safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway</td>
<td>Motorway</td>
<td>0.89</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Trunk</td>
<td>0.89</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>0.89</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>0.25</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>0.25</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Unclassified</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Residential</td>
<td>0.12</td>
<td>0.62</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Living_street</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Pedestrian</td>
<td>0.5</td>
<td>1</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Track</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Footway</td>
<td>0.12</td>
<td>1</td>
<td>0.62</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Steps</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Path</td>
<td>0.38</td>
<td>0.89</td>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Cycleway</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Traffic_signals</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Street_lamp</td>
<td>0</td>
<td>0</td>
<td>0.38</td>
<td>0</td>
</tr>
<tr>
<td>Smoothness</td>
<td>Excellent</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>0.12</td>
<td>0.12</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Intermediate</td>
<td>0.89</td>
<td>0.75</td>
<td>0</td>
<td>0.25</td>
</tr>
<tr>
<td>Surface</td>
<td>Gravel</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grass</td>
<td>1</td>
<td>1</td>
<td>0.12</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Paved</td>
<td>0</td>
<td>0</td>
<td>0.38</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Asphalt</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Paving_stones</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Cobblestone</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.62</td>
</tr>
<tr>
<td>Scenic</td>
<td>Yes</td>
<td>0.12</td>
<td>1</td>
<td>0</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0.89</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bicycle</td>
<td>Yes</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1</td>
<td>0.38</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Traffic_calming</td>
<td>Bump</td>
<td>0.85</td>
<td>0.38</td>
<td>0.12</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Table</td>
<td>0.85</td>
<td>0.25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Island</td>
<td>0</td>
<td>0</td>
<td>0.12</td>
<td>0.38</td>
</tr>
</tbody>
</table>

(continued)
Table 1. (continued)

<table>
<thead>
<tr>
<th>Key</th>
<th>Value</th>
<th>Comfort</th>
<th>Fast</th>
<th>Scenic</th>
<th>Safe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxspeed</td>
<td>50</td>
<td>1</td>
<td>0</td>
<td>0.62</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.12</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### 3.3 Weighted Graph

The cycleway graph is built as a weighted graph where, similarly to existing approaches [5, 13], edge weights (costs) are calculated based on a weighted function which takes into account the four parameters of the multiparametric function $c(E) : \tilde{S} \rightarrow \mathbb{R}$ (distance, inclination, wind and cycling-related road characteristics). The overall route cost equals the sum of costs $c_{i,j}$ of its individual road segments:

$$c_{i,j} = w_d d_{i,j} + w_g \|\tilde{g}_{i,j}\| + w_a \|\tilde{a}_{i,j}\| + \|\tilde{t}_{i,j}\|$$  \hspace{1cm} (5)

Of course, the weight coefficients $w_d$, $w_g$ and $w_a$ (corresponding to distance, inclination and wind vectors, respectively) are adjusted based on the optimization criterion selected by the user. For instance, when optimizing bike routes so as to be ‘fast’, $w_d$ receives higher value than the other two coefficients, while $\|\tilde{t}_{i,j}\|$ that represents the contribution of road features is calculated based on the values corresponding to the ‘fast’ column of Table 1.

### 4 Implementation

Our software architecture comprises three layers:

- The front-end has been developed in HTML5 and the Leaflet\(^3\) JavaScript library to handle the map interface.
- The backend system has been developed using the Java Spring\(^4\) framework to implement a RESTful API.
- The data layer comprises the XML-formatted OSM data and a MySQL database.

The backend consists in 6 modules and 14 classes with their dependencies as shown in Fig. 2.

Our framework also makes use of external services:

- Since the OSM data in our test area does not include node elevation information, we use the Open Topo Data elevation API\(^5\) to automatically populate our graph data accordingly.

---

3 https://leafletjs.com/.
4 https://spring.io/.
5 https://www.opentopodata.org/.
• Wind speed / direction data are periodically retrieved at runtime through invoking the OpenWeatherMap⁶ web service.

In order to solve the optimization problem, we used Dijkstra’s algorithm [7] which calculates the shortest path (practically, the lowest cost path) between an origin and a destination vertex of the weighted graph.

5 Preliminary Evaluation

As a test case area, we have chosen the center of Ioannina, Greece. Ioannina has been chosen due to its variable weather conditions (frequent rainfalls and strong winds); diverse geomorphological characteristics (hills with steep slopes, but also relatively large flat areas); limited bike infrastructure, however, existence of a large network of pedestrian streets; diverse road surface.

The main objective of our preliminary evaluation has been to validate the appropriateness of derived routes from a cyclist viewpoint, thus, providing insights on whether a bike route planning application would indeed motivate an attitude change of citizens from motorized means of transport towards cycling.

We recruited 5 users (experts and amateur cyclists) which have been invited to use the application to derive optimal bike routes (of approximately 10 min) between two

⁶ https://openweathermap.org/.
specific start/end locations in Ioannina using three of the available optimization criteria: fastest, safest, most comfortable (see Fig. 3 for an illustration of the safest vs the fastest route). The evaluators have then been asked to follow those routes by bike and then have had a short interview.

![Fig. 3. Safest vs. fastest route.](image)

Notably, the faster route has been slightly longer than the shortest one as the algorithm favors road segments without traffic lights which add to the journey’s duration. The safest route is in fact longer (2.5 km long, while the shortest has been 1.82 km long), as the system did not choose any of the main roads. However, the algorithm favored mostly pedestrian streets or roads with low speed limits (where no bike lanes were available) to increase safety. It is noted that at night, the safest route changes to incorporate road segments with sufficient lighting. As regards the most comfortable route, it has been the flattest (i.e. the one with the least overall elevation gain) at the expense of longer trip distance; the algorithm avoided uphill roads with opposite wind direction. Moreover, segments traversing parks have been preferred over main roads with motorized traffic to increase comfort.

The evaluators have verified that the three routes have been indeed well-planned with respect to their corresponding optimization criterion. They also expressed their appreciation for the integration of contextual parameters in our route planning system, such as time of day and wind speed/direction for specific criteria such as comfort and safety, respectively.

6 Conclusion and Future Research

This study presents a practical approach in deriving bike-friendly route plans. Our proposed problem modeling considers various practical aspects (road inclination, friction
due to terrain type or wind, etc.) as well as a wide range of criteria to estimate the bike friendliness of specific routes. The proposed criteria far exceed those taken into account by commercial route planning services as well as by existing research prototypes; notably, those include context-dependent aspects, such as time and wind speed/direction.

Our route planning engine is based on tagged OSM data, exploiting the richness of cycling-related layers. We focused on planning routes that are safe, comfort, fast and scenic for cyclists. To date, no solution enables the combination of OSM map data relevant to cyclists with weighted network graphs to apply multi-criteria optimization algorithms upon and derive (sub-)optimal bike routes.

The end-product of our research is a wayfinding tool deriving context-aware routes tailored to the specific requirements of cyclists. Our service has undergone qualitative evaluation wherein we involved volunteer cyclists (knowledgeable of the urban area) to assess its utility to realistic scenarios. Preliminary results revealed that the derived routes were more effective for cyclists, and the criteria used for route planning were practical and relevant. It is foreseen that the deployment of our service and supporting applications would motivate the use of bicycle for urban transfers, thus promoting sustainable urban mobility.

Our future research plans involve the following action points: development of a mobile application for visualizing the bike route plan and providing real-time navigation assistance along the route; extension of our algorithmic engine so as to derive optimal multi-stop routes tailored to the needs of tourists or bikers engaged in goods delivery tasks; large-scale field trials to thoroughly evaluate our proposed system in several urban and sub-urban environments with diverse cycling infrastructure characteristics.

Acknowledgment. This work was supported by the Operational Program Competitiveness, Entrepreneurship and Innovation (call Research – Create – Innovate, co-financed by EU and GR) under contract no. T2EDK-03472 (project iDeliver).

References