2013

Web Based Bicycle Trip Planning for Broward County, Florida

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Abstract

To promote the use of bicycle transportation mode in times of increasing urban traffic congestion, Broward County Metropolitan Planning Organization funded the development of a Web-based trip planner for cyclists. This presentation demonstrates the integration of the ArcGIS Server 9.3 environment with the ArcGIS JavaScript Extension for Google Maps API and the Google Local Search Control for Maps API. This allows the use of Google mashup GIS functionality, i.e., Google local search for selection of trip start, trip destination, and intermediate waypoints, and the integration of Google Maps base layers. The ArcGIS Network Analyst extension is used for the route search, where algorithms for fastest, safest, simplest, most scenic, and shortest routes are imbedded. This presentation also describes how attributes of the underlying network sources have been combined to facilitate the search for optimized routes.

1 Introduction

In the early 90's, Broward County Metropolitan Planning Organization (MPO) developed a bicycle suitability map[1], which has since then been permanently updated. The ratings in the suitability map are based on a Bicycle Safety Index Rating (BSIR) developed in the late 80's (Davis 1987). This rating, which is called Road Condition Index (RCI) by Broward County Planners, takes into account 20 factors that affect bicycling. High ratings indicate a high level of bicycle car-interaction, where as a low level indicates the least amount of interaction with car traffic. Ratings in the map are provided for arterial roads. The suitability map also shows the type of bicycle facilities along Broward streets, including multi-purpose paths, marked bike lanes, wide curb lanes, or paved shoulders (Fig. 1).

[1] http://www.broward.org/transportationplanning/

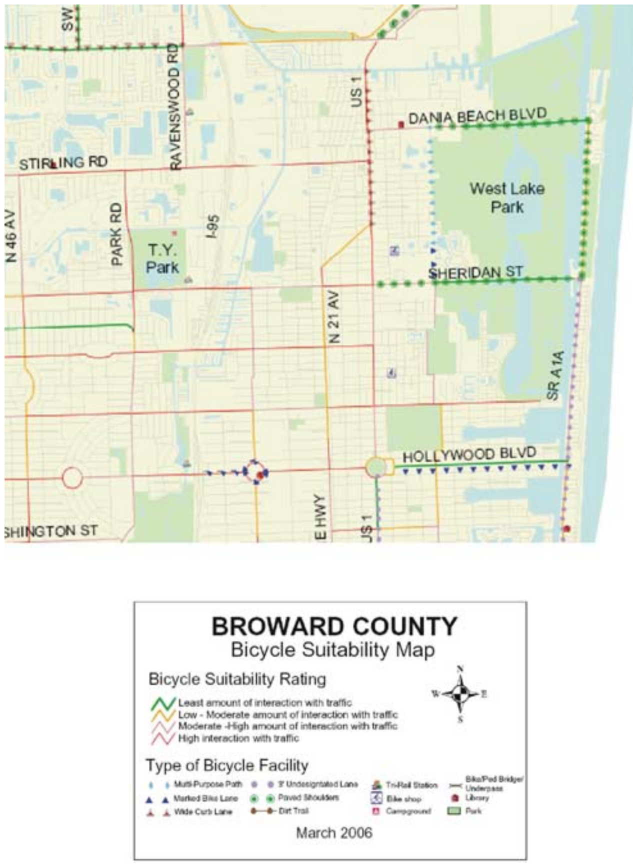

Fig. 1: Bicycle suitability map showing the amount of interaction with car traffic, and type of bicycle facilities (source: Broward County MPO).

Since this bicycle related information exists in a GIS format, this valuable data source facilitated the implementation of a Web based bicycle route planner for Broward County. Whereas numerous bicycle route planners have been developed in Europe, they are rarities in North America. Bicycle routing applications have, for example, been developed for the Portland and Milwaukee area (byCycle 2007) and Vancouver (Cyclevancouver 2009). Each uses the Google base maps as a mashup. Trip origin and destination are either defined through a mouse click on the map (byCycle 2007), or entered as an address (Cyclevancouver 2009). The first route planner allows the user to selected between normal and safe route, whereas the latter application offers selection between restricted maximum slope, least traffic pollution, least elevation gain, most vegetated route, and shortest path route.

The bicycle route planner for Broward county[2] provides additional functionalities compared to other existing online applications. It allows to

- visualize bicycle related feature layers, such as bicycle facilities, traffic lights, or parks;
- use a Google location search for identifying trip start and destination in addition to pinpointing locations on the map;
- add additional waypoints along the planned route;
- choose between additional route optimization criteria.

To identify meaningful route optimization criteria that should be implemented, results from previous research studies are utilized. User responses in an earlier desktop survey with 42 participants identified a total of 36 route choice criteria that might be considered when planning a bicycle trip in an urban environment. The most prominent criterion identified was bike lane, followed by short distance, sights, and avoidance of heavy traffic (Hochmair 2004a). In a subsequent study (Hochmair 2004b) participants were asked to group the previously identified 36 criteria into three to six more general higher-level criteria, whatever number of classes was considered most appropriate. Most participants, suggested that a classification into "fast", "safe", "simple", and "attractive" criterion classes was most preferred. Therefore, a user interface that offers these four optimization criteria should be a good starting point for the design of a Web based cyclist trip planner. In addition to this, we provide a fifth option, which is search for the shortest route, since this is one of the most common criteria in trip planners in general.

Fig. 2 through Fig. 4 show some screen shots of the user interface of the prototype, including defining trip origin and destination, setting the search criterion, and visualization of search results.

[2] http://maps.fiu.edu/mpobike/index.html

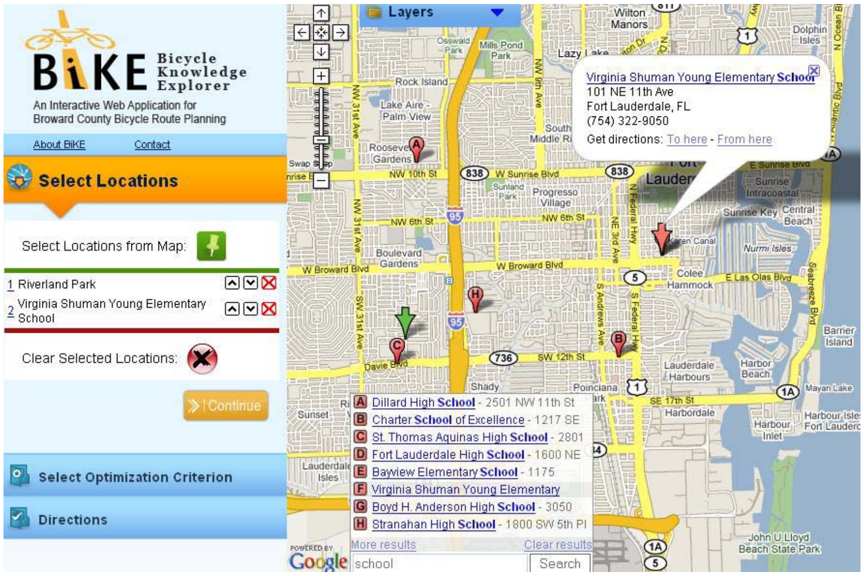

Fig. 2: Setting trip origin and destination via Google search bar .

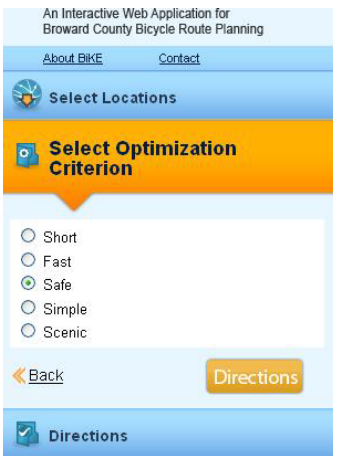

Fig. 3: Selecting the route optimization criterion: safest route

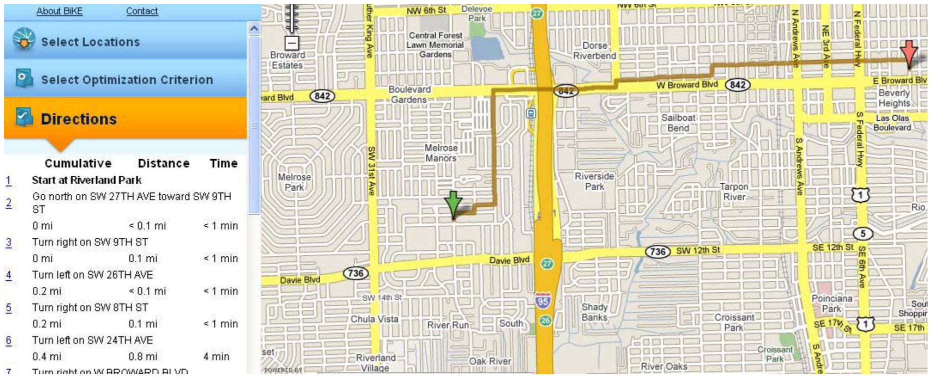

Fig. 4: Visualization of safest route and route directions.

2 Implemented System Architecture

The application is built upon ESRI's ArcGIS server framework, and uses a geoprocessing model which involves the Network Analyst solver to find the best route according to the user selected optimization criterion. The application design represents a 3-tiered architecture, i.e., the client, application and database tier (see Fig. 5). In the client tier, the Web browser requests ArcGIS JavaScript extension for Google Maps API, Google Local Search control for Maps API, and Google Maps API upon initial page loading. The Google Local Search Control for Maps API provides access to local search results from Google Maps which can be used for identification of trip origin and destination. It allows the user to locate among others businesses, addresses, roads and intersections, political entities (e.g., cities, provinces), and geographic coordinates. Upon the initial page load, additional map resources, such as images and CSS are loaded from the IIS (Internet Information Services) Web server, and the layer symbology and structure is retrieved from ArcGIS Map services via internet http protocol. When panning or zooming in the Web browser, a request for tiled layer images is also sent to the ArcGIS server and retrieved via IIS (application tier). Client requests are forwarded through a proxy server to the IIS and ArcGIS servers, which separates the Internet from the private net. The proxy server is the only service within the demilitarized zone (DMZ).

When selecting trip origin and destination the WGS84 geographic coordinates for trip origin, destination, and waypoints in-between are retrieved from marker positions through Google Maps API. They can either be set per mouse click on the map or through Google Local search. When clicking the route search button, a request for the computation of the optimized route is sent to the ArcGIS server. This triggers a geo-processing service on ArcGIS server, which is a published routing model (see Fig. 6). The original model is part of an mxd document. The input for the routing model consists of a string describing the optimization criterion, and an array of WGS84 geographic coordinates of waypoints (called stops in ArcGIS language). The result is a route geometry object expressed in JSON (JavaScript Object Notation), and the URL of an XML document with generated route directions. This XML file is then retrieved through IIS from ArcGIS server, then parsed by the client using JavaScript to finally output directions within the browser.

On the database tier, two File Geodatabases are used. The first database hosts feature classes that are used for layer visualization and thus independent from the routing process (e.g., traffic signals, recreational facilities, bicycle facility layer, etc.). The ArcGIS JavaScript Extension for the Google Maps API makes GIS resources available on an ArcGIS Server so that they can be used on top a Google Maps base map. This combination of information from two different Web sources is called a "mashup". Since the Google base maps are projected in Web Mercator, the feature dataset in the first File Geodatabase is using the Web Mercator projection as well. The data sources supporting the geoprocessing services are stored in a second File Geodatabase, the coordinate system of which is set to WGS84, since the Google Maps API provides waypoint coordinates in WGS84 geographic coordinates that are used as input in the routing model.

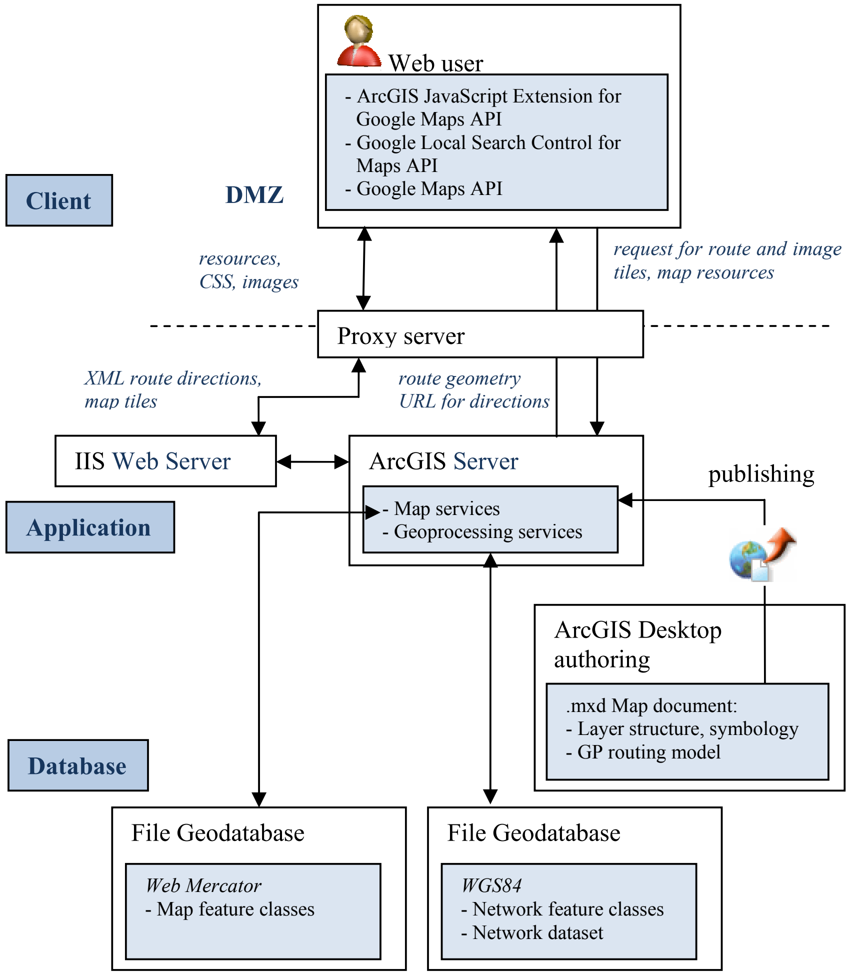

Fig. 5: System architecture of the BiKE application

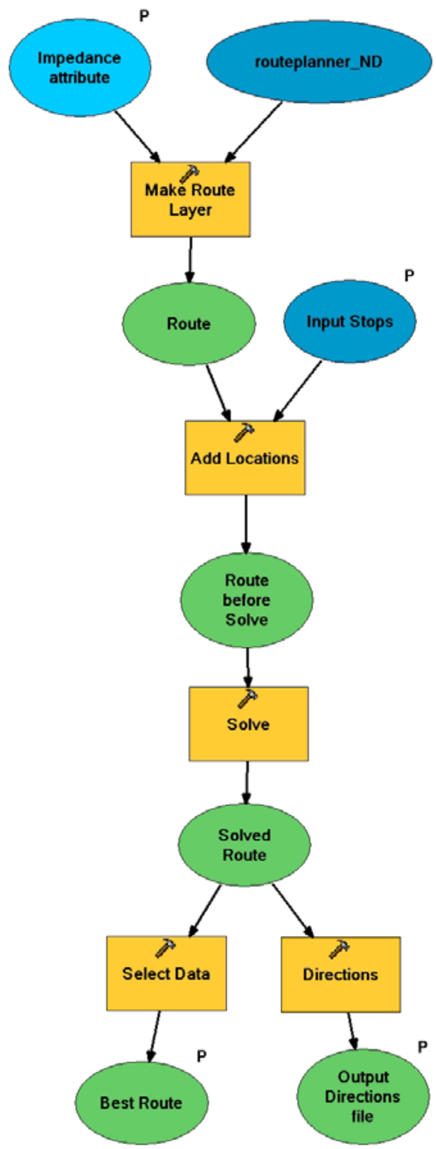

Fig. 6: Routing model in model builder

3 Route Optimization Criteria

The optimal bicycle route is computed within a geoprocessing model which calls the Network Analyst solver function. To materialize the five optimization criteria in route search, a Network Dataset with five cost criteria was built based on two participating feature classes. The first participating feature class is the Broward County street network, where all interstates and other streets that do not permit cycling were removed. The second feature class is a turn feature class built from the street Network Dataset using ArcObjects scripting in VBA that contains turn cost and waiting times for all turn types at controlled intersections. Results of an earlier desktop study (Hochmair 2004a), and analysis of bicycle route choice behavior in the field (Aultman-Hall et al. 1997; Harvey et al. 2008) suggest that cyclists take into account more than one optimization criterion at a time. For example, commuter cyclists give high importance to short trip distance, but their chosen routes partly deviates from the shortest route. This may be based on the preference to use bicycle facilities along a route (e.g., to reach a higher level of cycling comfort) where it does not cause too much detour. Because of this compromise behavior, most of the five cost criteria were implemented using a weighted linear combination of street and turn related network attributes in the Network Dataset. In addition to these attributes, one-way restrictions, and turn restrictions (to prevent cyclists from crossing medians where no openings exist) were included in the list of attributes in the Network Dataset as well. The following overview provides more information on the structure of implemented cost attributes. The used weighting and trade-off values are only first estimates and need to be refined after receiving feedback from users of the application.

<u>Shortest route:</u>
This criterion is solely based on the segment length.

<u>Fastest route:</u>
This criterion is based on the segment length and waiting times for turns at controlled intersections. Travel time on segments is computed as segment length over travel speed, where a default travel speed of 16 km/h was assumed. Turn time at controlled intersection depends on the type of turn, i.e., left, right, U, or going straight. Based on information provided by Broward County engineers, the average waiting time at traffic lights was derived at 40 seconds. This value was multiplied by correction factors for going straight or making left turns, where the waiting time for left turns was presumed longer, since the green light phase for left turns is generally short. Right turns were given no time penalty since there is no need to wait for the next green phase. Further, the hierarchical levels of streets and the geometry of the intersection were included in the correction factors as well. For example, it makes a difference whether the route enters an intersection from a local street or from an arterial street. Factoring all this in, the waiting time ranges between 10 and 70 seconds. In addition to this, to avoid extremely meandering routes, an additional cost of 6 seconds per left/right/U turn was included in the cost function.

<u>Simplest route:</u>
This criterion minimizes the number of all turns along a route (left/right/U turn). In order to get a reasonable compromise and avoid extreme detours for the simplest route, an

additional cost of 1 turn per 2000m trip length was included. That is, an additional 2000 meters in trip distance counts as one additional turn.

Scenic route:
Computation of scenic (attractive) routes follows a method developed earlier (Hochmair & Navratil 2008). The core idea is that the experiential length of a segment, i.e., the effort to traverse this segment as perceived by a cyclist, is smaller when the segments runs within attractive areas. Thus, it is assumed that attractive areas reduce the perceived travel impedance. As a first criterion, all route segments within a 25 m buffer from water bodies (lakes, canals) or parks were marked as such in the dataset in a binary route attribute (1…within 25m buffer, 0…not within 25m buffer). See Fig. 7 for an example. Second, all segments that run on major roads are modeled to be perceived less attractive due to a higher traffic volume, and were marked as such in a similar manner through a binary attribute. Third, some bike-pedestrian-only segments, such as paths through parks, also increase the attractiveness of a route, and are marked as such. Finally, the scenic length of a route segment, which was minimized in the Network Analyst solver for finding the most scenic route, was computed as follows:

scenic length = [length_meter]*(1+ [mult_bigroad]*0.7)*(1- [mult_scenic]*0.5)*(1- [bikeonly]*0.7)

The equation causes for travel along big roads increased travel cost, and for travel within the buffer around water bodies or parks, and travel on bike-pedestrian-only segments reduced travel cost.

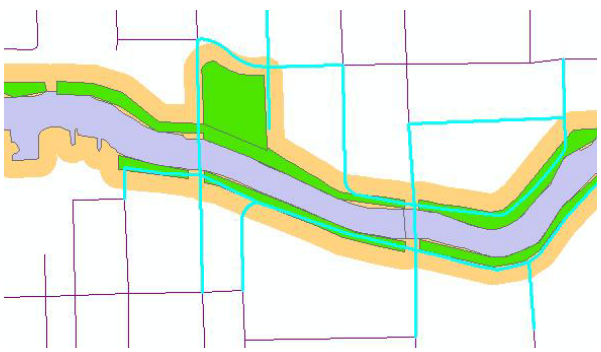

Fig. 7: Highlighted segments intersect with a 25m buffer around a canal and adjacent parks

Route with least bicycle-car interaction:
This criterion is primarily based on the Road Condition Index (RCI) provided by Broward County MPO. The range of the RCI was converted to a range between 1 and 2 for all street segments, where 1 means minimum bicycle-car interaction, and 2 means maximum exposure to cars. Values for local roads were by default set to 1. The RCI takes into account factors, such as average daily traffic, number of traffic lanes, speed limit, width of outside traffic lane, pavement factors, and location factors (angled parking, parallel parking, right-

turn lanes, raised median, etc.). The travel impedance of a segment was then computed as the segment length multiplied by this scaled RCI value. In addition to this, the cost of crossing an arterial street at an uncontrolled intersection was set to 1000m, i.e., the route is somewhat diverted towards controlled intersections. This information is included as attribute in the customized turn feature class. To avoid meandering routes, a cost per turn was set to 50m. All these cost together are minimized in the Network Analyst solver for finding the safest route.

4 Conclusions

This paper describes the implementation of an online bicycle route planning application within the ArcGIS Server framework. The integration of various Google APIs gives a mashup where information from different Web sources is utilized. Once fully functioning, the logged trip origin and destination requests of application users may be used as useful resource for the estimation of bicycle demand on the streets network and for the identification of network segments where improvement of bicycle facilities would be beneficial to a high number of cyclists (Landis & Toole 1996; Hochmair 2009a; Hochmair 2009b).

Acknowledgement

The authors thank Dan McGillicuddy and Daniel Kirsch for their valuable input in describing the implemented system architecture.

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