Appendix E
Trip Planning Technologies

May 2015

IBI Group
5th Floor – 230 Richmond Street West
Toronto ON M5V 1V6 Canada

tel 416 596 1930
fax 416 596 0644

Memorandum

To/Attention	Halton Region	**Date**	June 12, 2012
From	Gregory De Santis	**Project No**	31898
cc	Dylan Passmore Norma Moores		

Subject Halton Region Active Transportation Master Plan: Review of Trip-planning Technologies

1 Introduction

Online trip-planning tools use a variety of criteria to recommend travel routes that connect an origin and destination provided by users. Such systems use a network representation of the municipality's roadways (and possibly trails, sidewalks, etc.) to determine an "ideal" path from the origin to the destination. Traditionally, these tools were developed for automobile and transit trips. However, increasingly, they are incorporating the nuances of non-motorized travel. This memorandum will examine five current active transportation trip-planning options, some typical requirements associated with these systems, and provide a brief comparison between a Google's system and systems developed in-house.

2 Active Transportation Trip-Planning Options

There are multiple active transportation trip-planning tools for users to choose from. The sections below will look at the features of Google's system as well as four systems developed in-house.

2.1 Google's Trip-Planning Tool

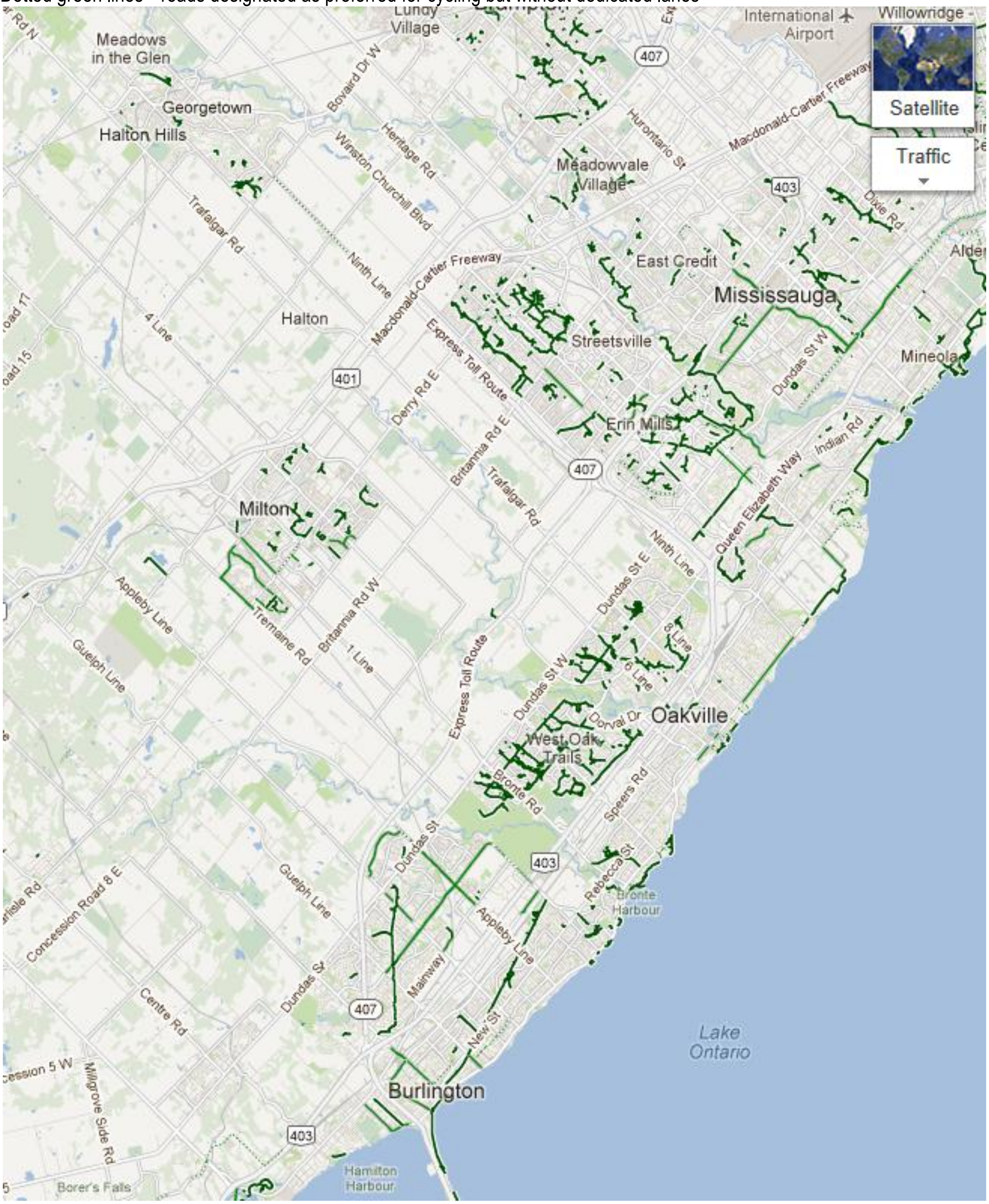
In July 2008, Google announced it was adding a walking directions feature to its Google Maps tool. Later, in March of 2010, Google announced it was adding cycling directions as well. As is typical of many Google products, these features have been in the beta testing stage for several years. For the cycling trip-planning tool, Google has updated its system to include three types of bikeways:

- Multi-use trails
- Roads with dedicated bike lanes
- "Roads that are designated as preferred for bicycling, but without dedicated lanes"

Halton Region provided bikeway data to Google, as illustrated in Exhibit 1.

Exhibit 1: Google Maps Image showing Bikeways in Halton Region

Dark green lines—multi use trail
Light green lines—roads with dedicated bike lanes
Dotted green lines—roads designated as preferred for cycling but without dedicated lanes



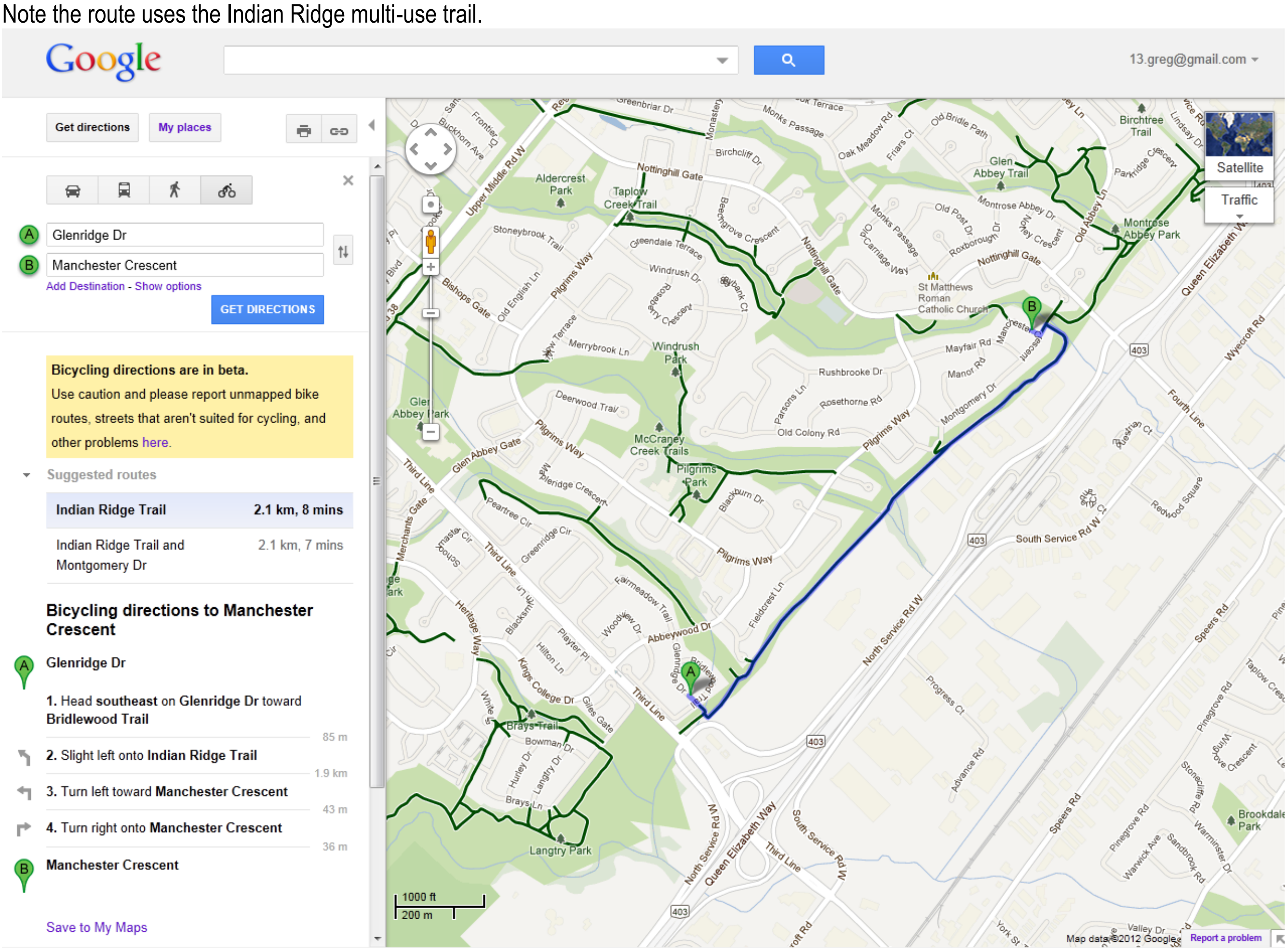
The Google Trip Planner receives trip origin and destination (O-D) information from the user either through an address search or by clicking on the map interface. Following O-D selection, multiple route options are presented to the user. Each route is shown on the map, with turn-by-turn directions provided beside the map. The system also provides the distance and estimated travel time for each proposed route based on an average travel speed of 9 mi/hr or 14.4 km/h.

Apparently Google's trip-planning algorithm does take into account issues such as topography, however it is a "black box" as the system does not allow the user to input any preferences for route planning, such as topography or tolerance for mixing with traffic. As a result, the system simply generates multiple routes for the user to choose from. Google's tool also allows the user to add multiple destinations and waypoints to the route. Exhibit 2 illustrates a sample trip planned in Oakville using the Google bike trip planning system.

Google Maps is an integrated system which supports the planning of trips not only in Halton Region but throughout Canada and the United States.

Exhibit 2: Sample Route Planned in Oakville using Google Maps Trip Planner for Cyclists

Note the route uses the Indian Ridge multi-use trail.



2.2 Examples of In-House Trip-Planning Systems

Developing the system either in-house or through contracting a third party would provide Halton Region with a greater level of control over system functionality. Two well-established systems developed in-house are the Cycling Metro Vancouver system and the BiKE Broward Interactive Trip Planning System (Florida). These systems focus on trip planning for cyclists; however, their routing algorithms could theoretically be applied to other modes of active transportation. Vélo Québec has developed a system completely in-house and offered some insight into their experience and lessons learned. Walkit.com is a pedestrian trip-planning tool developed for cities in the United Kingdom.

2.2.1 Cycling Metro Vancouver System

The Cycling Metro Vancouver system was developed at the University of British Columbia with cooperation from the City of Vancouver. Funding for the project came from various sources including Translink and the Heart and Stroke Foundation. The system provides cycling trip-planning capabilities for the Metro Vancouver Area.

Similar to Google, the origin and destination of these routes are determined through an address search or by clicking on the map interface. However, the system does not support additional waypoints or destinations. The user is provided with the following information about their route:

- Route length
- Estimated travel time
- Green house gas emissions prevented (versus driving the route)
- Calories burned
- Mean atmospheric NO_2 level
- Elevation gains
- Mean vegetation cover

The Cycling Vancouver system allows users to select a route based on their riding preferences. Riders can choose to restrict their route from major roads or include them in addition to the following options:

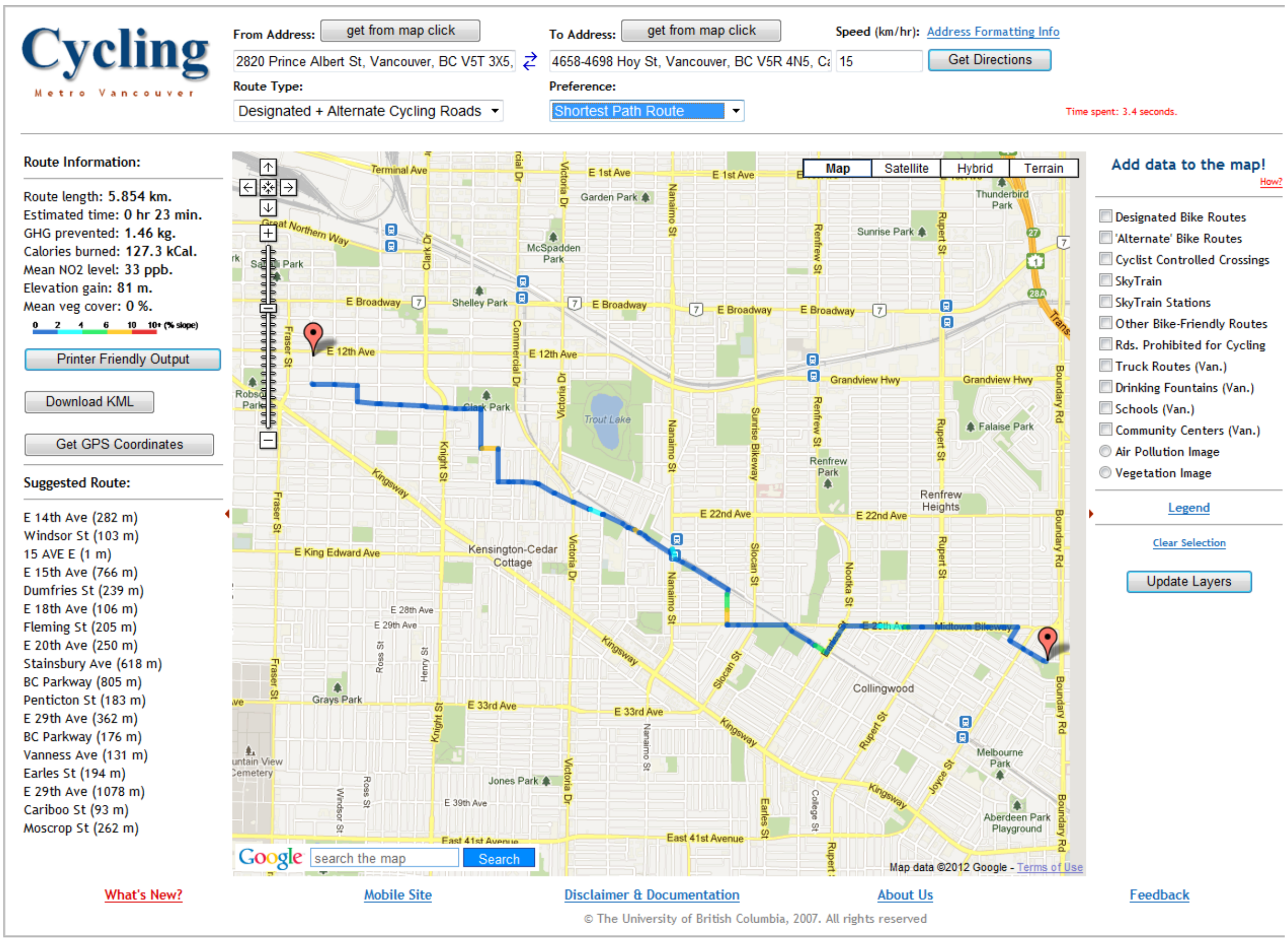
- Shortest distance
- Restrict the maximum slope
- Minimum traffic pollution
- Minimum elevation gain
- Maximum tree coverage

Once the route has been created it is displayed on the map interface, with turn-by-turn text directions beside the map. The route can also be exported to Google Earth or a GPS device. A sample route generated by this system is shown in Exhibit 3.

The system allows the user to overlay various layers onto the map interface. Generally these are locations that would be of interest to people using active transportation; including, but not limited to:

- Designated bike routes
- Cyclist controlled crossings
- Public transit stations
- Roads where cycling is prohibited
- Drinking fountain locations

Exhibit 3: Sample Route Generate by the Cycling Metro Vancouver System



2.2.2 BiKE Broward System

The BiKE Broward system was developed though a joint effort from the Florida International University GIS Center and the University of Florida Geomatics Program. The system provides cycling trip-planning capabilities for Broward County, Florida, and funding for the project came from the Broward Metropolitan Planning Organization.

Similar to Google, the system allows users to enter their origin and destination through a location search or by clicking on the map interface. The system allows users to choose multiple destinations by adding waypoints to the route. The system also tracks the routes generated to estimate the high bicycle traffic corridors. When a route is generated, the user is provided with the route distance and the estimated travel time.

Users of the system are able to instruct the route planner to generate their route based on one of the following preferences:

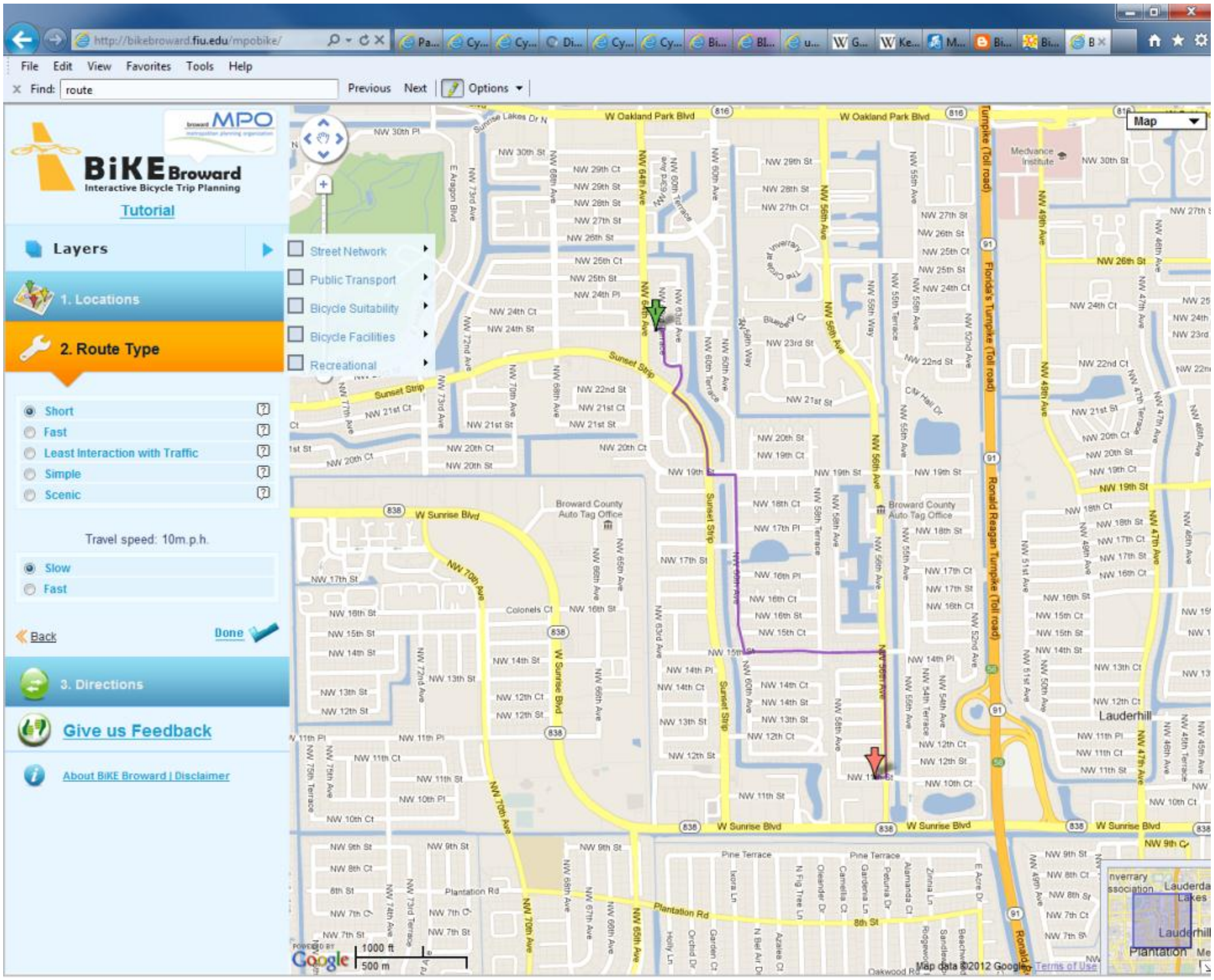
- Shortest distance
- Fastest route (taking into consideration time spent waiting at intersections, in addition to the distance travelled)
- Least interaction with traffic
- “Simple” (the route with the fewest turns)
- Scenic route (a higher preference for routes going past lakes and parks)

Once the route is defined it is displayed on the map interface with turn-by-turn text directions beside the map. The route can be exported to a GPX or KML file for use on a GPS device or Google Earth. Another interesting feature is the ability for users to “walk-through” their route using the Google Street View application. A sample route generated by the BiKE Broward system is shown in **Error! Reference source not found.**.

The system allows users to update the visible layers of the map interface to include:

- Street information (e.g. traffic lights)
- Recreational activity locations
- Bicycle facilities
- Public transportation routes and stops
- A bicycle suitability (i.e. level of interaction with traffic)

Exhibit 4: Sample Route Generated by the BiKE Broward System



2.2.3 La Route verte System

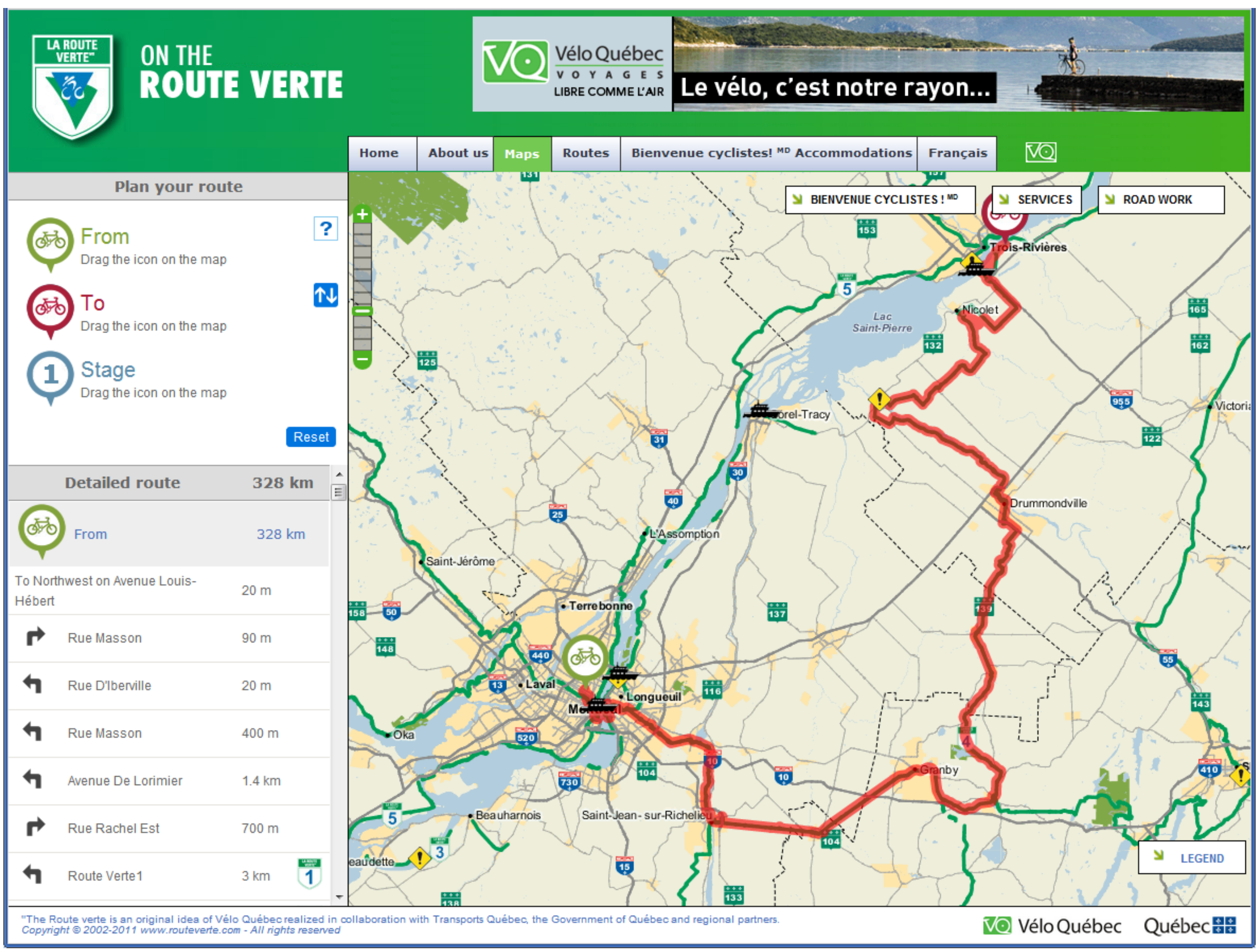
Vélo Québec has been developing a trip-planning tool for cyclists in-house for the past year. This project was broken up into two stages: Firstly, the creation of a "zoomable" map covering the entire *La Route verte* network, including multi-use trails. Secondly, the development of the trip planning tool itself.

The tool simply involves dragging the origin and destination onto the system's map (see Exhibit 5). Detailed text route instructions appear on the left, which include turn-by-turn information. Some point layers can be added to the map: tourism offices, rest areas, train & bus stations, and ferry ports. The map also includes tips for getting through tricky segments, and links to ferry schedules. The system supports breaking up the route into stages.

The main challenge in developing the tool was coding the cycling network. That is, simply having a bikeway GIS layer is not sufficient. The GIS layer has to be made into a network, with nodes in the right place (consistent with the road network), ensuring that crossing restrictions for cyclists & pedestrians are properly coded, turn restrictions are properly coded, pedestrian and bike-only facilities are included (e.g. crosswalks), etc. In many cases the bikeway is not on-road, which can create complications at the intersections. A further problem with network coding involves integrating the coding of bikeway types from various sources as this is not yet a standardized practice. Vélo Québec's experience is that the primary distinction in labeling bikeway types is to identify whether a facility is on-road or not since, and from their experience, this is the primary concern of cyclists. Regardless of what the standard is some harmonization of data sources and maintenance as data change will be required.

Vélo Québec decided to develop the tool entirely in-house. This decision was made because they have a contractual obligation with the Ministry of Transports of Québec (MTQ) to maintain a bikeway database. Providing a trip planning service added some complexity to the way these data were coded, but it was seen as efficient to fold it into their on-going efforts.

Exhibit 5: Sample Route Generated by Vélo Québec's *La route verte* System



2.2.4 Walkit.com: The Urban Walking Route Planner

Walkit.com is a trip planner that focuses specifically on routing for pedestrian trips. Currently this system is only available to some cities in the UK. The system allows users to plan their route based on:

- The shortest distance
- The least busy
- The least air pollution (this is only available for some areas where average NO_2 levels are known)

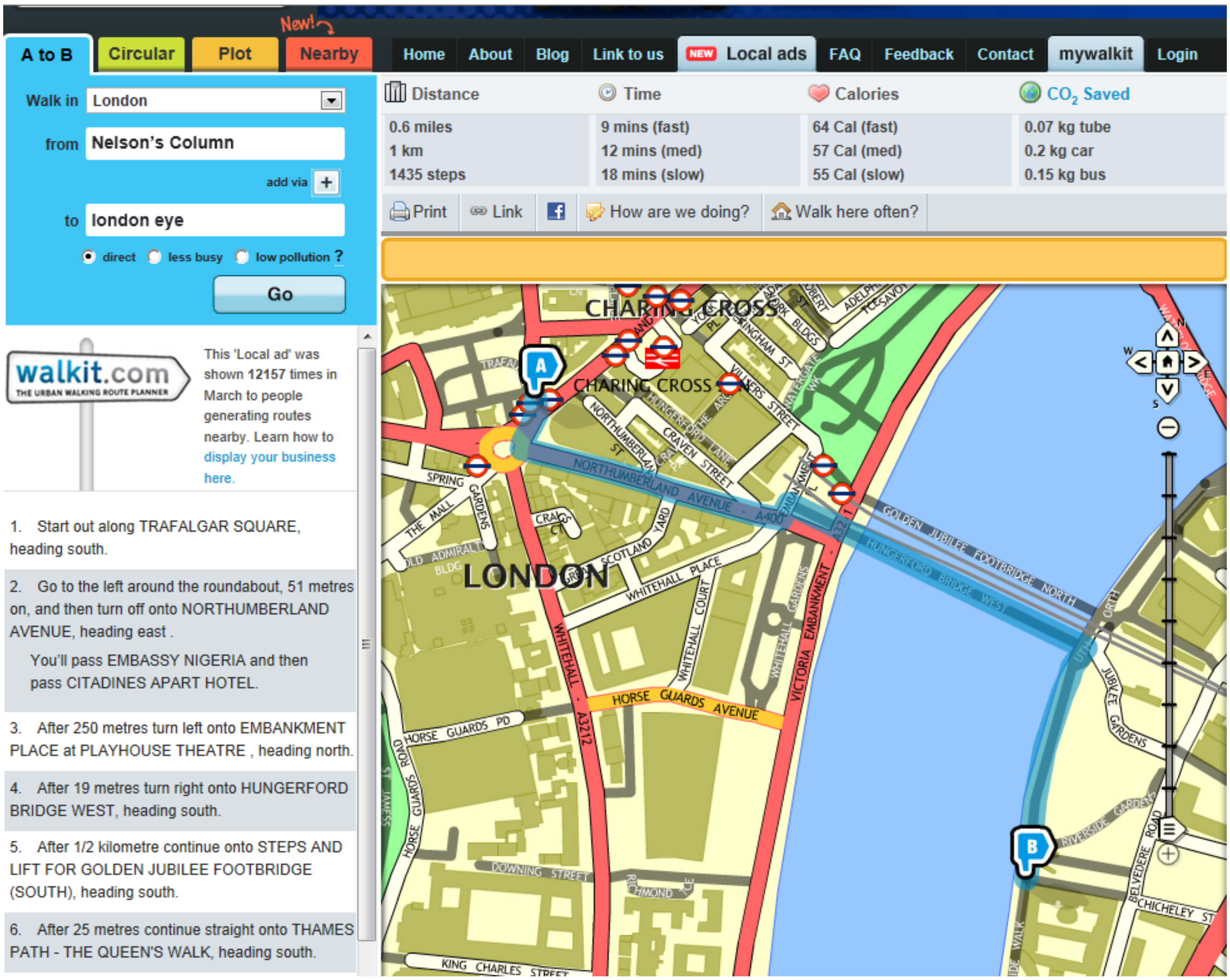
Users are able to plan circular routes by providing the system with a starting point, duration for the walk, and the average walking speed.

The system interface is somewhat cumbersome as users are not able to enter origin and destination information through the online map. Rather, they must know the address or the name of the location (e.g. London Eye). The system supports the insertion of waypoints, but again, these cannot be added through the map interface. Once a route has been created the user is presented with the following information (see Exhibit 6):

- A map with the route highlighted
- Turn-by-turn text directions beside the map
- Profile (elevation) of the route
- Route distance
- Estimated route time
- Calories burned on the route
- CO_2 saved by walking

This system also allows users to create a profile on the site to save their preferred walking routes, their preferred walking pace, and their stride length for more accurate time and calorie burning estimates.

Exhibit 6: Sample Walking Route Generated by the Walkit.com System



3 Typical Requirements

The requirements of an active transportation trip planning tool can be loosely defined into three main categories: trip routing considerations, data and development requirements, and data privacy and control considerations.

3.1 Trip Routing Considerations

Basic active transportation trip planning services generate a suggested travel route for users. Some systems go further and take user preferences into account when generating the route. Some of the typical preferences supported are discussed below.

3.1.1 Shortest Distance

The shortest path route is simply the route with the shortest network-based distance between the origin and destination, irrespective of the conditions along that route.

3.1.2 Fastest Route

In addition to the simple conversion of trip distance to travel time based on an assumed average travel speed, when intersection data is available, some systems can incorporate a time "impedance" wherever the route must cross through a major intersection. This would depend partly on the turning movement at the intersection node since right-hand turns by bike or on foot would not be expected to incur any extra time.

3.1.3 Route with Least Traffic Interaction

Where traffic volumes and/or traffic speeds are available, the trip routing algorithm can be optimized to favour streets with less intense traffic. In other words, the routing will tend to favour local streets and paths, despite their tendency to increase the overall trip distance.

3.1.4 Elevation Restrictions

There are two main types of elevation restrictions employed by active trip planners: maximum grade restrictions and minimal total elevation gain. A maximum grade restriction will prevent the route from taking any hills with a slope greater than a specific threshold. A minimal total elevation route will reduce the total number of hills along the route.

3.1.5 Scenic Route

The City of Vancouver has extensive data on its tree canopy (derived from satellite images). Thus, their routing algorithm favours routes with better tree coverage. As well, it is our understanding that the system favours routes that pass along lakes and parks.

3.1.6 Air Pollution

It appears that many U.K. towns and cities have extensive localized NO_2 data that allows the trip routing algorithm to avoid areas with high-levels of such air pollution. One could also estimate general air pollution from proxy data such as daily truck and car volumes.

3.2 Data and Development Requirements

3.2.1 Integration of Cycling/Walking Network

A requirement for all active transportation trip-planning systems is to develop separate cycling and walking networks, which is typically based on existing GIS data that will likely require supplemental information. A significant issue is overlaying walking and cycling networks with street and road networks in a consistent manner:

- Turning restrictions are not the same (direction of travel, turn movements)
- Trails and trail intersections with streets need to be added

- Connectors, i.e. short-cut path between two streets, staircases between bridge/overpass and ground level street, pedestrian only bridges, etc., need to be added
- Must exclude road segments that prohibit use by pedestrian or cyclists (generally freeways)

Turning movements for pedestrians and cyclists can be less of a constraint than turn restrictions for motorists. Pedestrians can turn in all directions. Even in the few cases where a pedestrian crossing is prohibited on one leg of an intersection, it is almost always possible to make a turn by using the crosswalk on the opposing leg. The same applies to cyclists, who can turn left in two stages, if necessary, and can dismount if the only legal option is to walk or use a crosswalk.

The amount of effort required to integrate the cycling / walking network will depend largely on how much of this work on the database has already been completed by Halton Region.

3.2.2 Integration of Data from Multiple Municipalities

Integrating the databases from multiple municipalities is time consuming work since the definition of one type of bikeway in one municipality may not be consistent with their neighbouring community. This means that the development team would be required to harmonize the sources to include them in the same system.

3.2.3 Integration with Third Party Services

Most in-house systems are not developed from scratch, but, rather, add additional layers to existing mapping services. Two notable third party maps are OpenStreetMap and Google Maps.

3.2.3.1 Google Maps

The Vancouver Cycling and BiKE Broward systems highlighted above work as additional layers to the Google Map system. They have essentially overlaid upon the Google Map their own cycling network and other available information (e.g. elevation information for the Vancouver system). However, they also developed their own algorithms that generate trip routes based on user preferences.

3.2.3.2 Open Street Map

OpenStreetMap is a free open source worldwide map. The maps are free to download, transmit, and adapt provided they and their contributors are credited for their work. The map is provided in XML format, with an updated version provided weekly. OpenStreetMap is another option to use as a base layer for the creation of a trip planning system. Using OpenStreetMap would avoid the copyright issues inherent with using a database which is not freely accessible to the public.

3.2.4 Funding

The funding requirement for this type of system varies depending on the level of development required. It can be divided into two expenditures: the initial development cost, and the annual operating cost.

3.2.4.1 Development Cost

Based on the experience of Vélo Québec, the development of a system entirely in-house would likely cost between $50,000 and $100,000. This represents the cost of:

- Developing a custom trip-planning web interface
- Collecting and merging the GIS data from multiple municipalities
- Adapting existing GIS data sources to code distinct walking and / or cycling networks, including the necessary data to be incorporated as routing criteria (e.g. tree canopy or air pollution)
- Developing the algorithms to generate routes based on user-selected preferences

3.2.4.2 Annual Cost

Based on Vélo Québec's experience, the annual operating cost for maintaining an in-house tool is estimated to be between $5,000 and $10,000. This includes the cost of hosting the website, maintaining and updating network coding, and re-computing cached tiles annually.

3.3 Data Privacy and Control Issues

3.3.1 Base Layer Copyright Issues

When using third party GIS base layers, it is important to be careful of copyright infringements. Some important considerations include:

- Any data that the Region uses that is not open source would likely require that the cycling and pedestrian data that are generated be completely decoupled from proprietary data in order to avoid infringement. This condition would hold for the information provided to Google as well.
- If using OpenStreetMap, the service would have to be credited.
- Using a Google Map base would require agreeing to the Google Terms of Use. This policy could include providing Google with some advertising space where their maps are shown.
- Using the Google Maps API is free of charge up to 2,500 map loads per day, going above this limit costs $4 USD per 1000 excess map loads.

Using Google's or an open source base layer would reduce the effort associated with coding points of interest on the map (e.g. transit stations) if this is desired.

3.3.2 Control Issues Related to Using Google's System

Developers at Google have created their own trip-planning algorithms. An organization relying on this service to host their trip-planning needs is not likely to have much influence on how these algorithms work. Furthermore, relying on the Google Maps active trip planner gives Google complete control over the service. Google is responsible for all updates to their system and will incorporate new information at their discretion. This means that:

- Google may not incorporate all content submitted to them into their service[1]
- The time taken to incorporate new data varies and is determined by Google[2]

Map information provided to Google becomes the property of Google. This means that:

- Google will not provide direct access to the data provided to them[3]
- Google retains the right to add or remove content provided at their discretion[4]

Providing content to Google requires an organization to enter a content licensing agreement that grants Google the authorities indicated above.

4 Options Analysis

A summary of the comparison of the characteristics of the Google Maps systems and in-house systems is provided in Exhibit 7.

Exhibit 7: Summary of Trip-planning Systems

Potential Requirement	Google Maps	In-House
Trip routing criteria	Routing algorithm is fixed and determined by Google. Individual user preferences not currently supported. The trip planning algorithm is developed by Google and cannot be altered.	Can support custom route-selection criteria, including but not limited to: ▪ Shortest distance ▪ Fastest route ▪ Least traffic interaction ▪ Scenery ▪ Elevation changes ▪ Air pollution
Support for waypoints	Yes	Yes: BiKE Broward, walkit.com No: Cycling Metro Vancouver, *La Route verte*
Support for pedestrian trip planning	Yes	Yes: walkit.com No: BiKE Broward, Cycling Metro Vancouver, *La Route verte*
Data and Development Requirements	All development done by Google. Data collected by Google or provided to Google by third parties through a content licensing agreement.	Development and data collection done in-house or tendered to a third party.

[1] http://support.google.com/mapcontentpartners/bin/answer.py?hl=en&answer=162381&topic=21609&ctx=topic (June 2012)
[2] http://support.google.com/mapcontentpartners/bin/answer.py?hl=en&answer=143995&topic=21609&ctx=topic (June 2012)
[3] http://support.google.com/mapcontentpartners/bin/answer.py?hl=en&answer=143992&topic=21608&ctx=topic (June 2012)
[4] http://support.google.com/mapcontentpartners/bin/answer.py?hl=en&answer=143996&topic=21609&ctx=topic (June 2012)

Potential Requirement	Google Maps	In-House
Integration of Cycling Network(s)	Google requires data to be provided in a specific format, thus setting up the various cycling networks to meet Google's standards would have to be done in-house.	In-house
Integration with a third party base layer	Not required	May be required to reduce development costs
Initial Cost Estimate	Not required	$50,000 to $100,000
Annual Cost Estimate	Not required	$5,000 to $10,000
Data Privacy and Control Issues	Data sent to Google become their property. The Region would lose control over timelines for updating the data. As well, the trip routing algorithm is controlled by Google.	Data are owned and controlled in-house, but care should be taken to ensure there are no complications with the base map data. The routing algorithm would be entirely at the discretion of the Region.