University Transportation Research Center - Region 2

Final Report

Automating Web Collection and Validation of GPS Data for Longitudinal Urban Travel Studies

Performing Organization: Hunter College/CUNY

August 2012

Sponsor:
Research and Innovative Technology Administration / USDOT

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

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16. Abstract

Traditional paper and phone travel surveys are expensive, time consuming, and have problems of missing trips, illogical trip sequences, and imprecise travel time. GPS-based travel surveys can avoid many of these problems and are becoming increasingly popular in major cities worldwide. However, methodologies have not been developed to catch up with the enormous amount of data generated by the GPS. This project established a Web-based GIS prototype to speculate travel modes and trip purposes from GPS data and to validate the results from the survey participants. The prototype has the functions to collect GPS data from participants through the Web, run algorithms to speculate travel modes and trip purposes from the GPS data and other transportation and land use data, send back the results to participants for verification or modification, and finally update the data. While reducing the burdens on participants by using GPS, this Web-based GIS prototype has the potential to provide accurate and validated travel information for transportation modeling and planning.

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1. Introduction

Traditional paper and phone travel surveys are expensive and time consuming. As a result of the burdens on survey participants, response rates in travel surveys have been dropping (Wilson, 2004). Studies have revealed reporting problems such as a significant number of missing trips (Wolf et al., 2003), illogical trip sequences (Lawson et al., 2008, 2009), and imprecise travel time (Stopher et al., 2005). GPS(Global Positioning Systems)-based travel surveys can avoid many of these problems and are becoming increasingly popular in major cities in the U.S. and other developed countries. However, methodologies and data processing tools have not been developed to catch up with the enormous amount of travel data generated by the GPS (Li and Shalaby, 2007).

This project established a Web-based GIS prototype to speculate travel modes and trip purpose from GPS data and to validate the results from the survey participants. The prototype will have the functions to collect GPS data from participants through the web, run algorithms to speculate travel modes and trip purpose from the GPS data and other transportation and land use data, send back the results to participants for verification or modification, and finally update the data. While reducing the burdens on participants by using GPS, this Web-based GIS prototype has the potential to provide accurate and validated travel information for transportation modeling and planning.

2. Literature Review

There has been an increase demand for higher quality and cost effective travel survey data to "feed" more advanced forms of transportation models (*see Transportation Research Board 2007*). Recent research in the usefulness of GPS technologies in dense urban areas has demonstrated the opportunity to move quickly to the collection of GPS data for travel survey data (see Lawson et al. 2007, 2008, 2009). GPS was originally considered a supplement for traditional paper and phone travel surveys with the "discovery" of missing trips when comparing GPS to survey responses (Wolf et al. 2002). However, as research and practice advanced, it became clear that GPS should be the primary data collection mode, with survey respondents participating only when data was ambiguous.

Two recent travel surveying efforts are planning to use GPS as the primary data source, putting pressure on the data analysis and modeling community to also improve their operations to accommodate this rich data source (PRNewswire 2008; Ohio Department of Transportation 2008; Vovsha 2009). The implications of a full GPS sample are enormous with respect to data storage, manipulation and long-term data asset management. As the trend towards using GPS for its superior performance advantages increases, the need for practice-ready applications grows.

From a processing perspective, the key step is to convert the raw GPS data to interpretable information (e.g., origin and destination). Research has been conducted on the possibility of detecting travel modes and determining trip purpose using only the GPS traces by implementing a post-processing technique (Wolf et al. 2004, 2001; Chung and Shalaby, 2005; Tsui and Shalaby, 2006; Stopher et al., 2008a, 2008b, 2007a, 2007b; Bothe and Maat 2008; Du and Aultman-Hall 2007; Zheng et al. 2008). In many cases, researchers have learned to combine

GPS with GIS data to improve handling and management. At the same time, it has demonstrated that Google technologies can be used to display GPS data, yet there are few examples (with the exception of Li and Shalaby, 2007) of using web-based GIS to not only display the GPS data, but to use it for analysis and editing purposes. This combination of three technologies, GPS, GIS and the Web uses the best features of each, while being able to compensate for the short-comings of any one technology.

Other than allowing analysis and editing, there are additional advantages of using Web GIS in travel surveys. Lee and Pino (2012) noted the time convenience of Web-based surveys for respondents so that they are not "bombarded with a phone call at an inconvenience time" and this convenience "may have induced more people to take it" (p. 10). Web-based surveys, like the one we proposed, can also avoid the costs of collecting GPS loggers back in a time soon enough before the survey participants forget about the trips (Chiao et al. 2012).

3. Data and Algorithm Development

Figure 1 outlines the major components of the prototype we developed from this project. In this section of the report, GPS data from travel surveys and the algorithms for detecting travel modes and trip purpose are briefly discussed. The Web GIS component will be discussed in the next section.

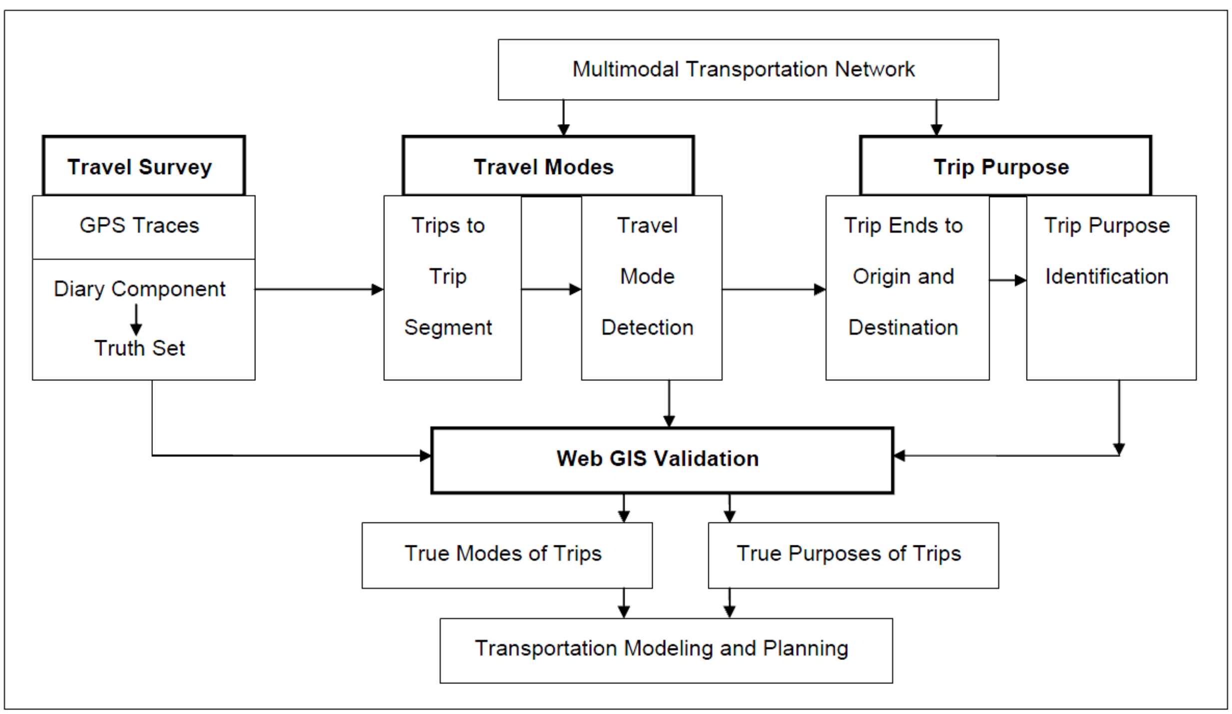


Figure 1. Major Components in the Prototype

GPS data from two small GPS-based travel surveys were used for the development of the prototype. One set of the GPS survey data is a one-weekday GPS-based travel survey of 25 people in the Tri-State metro region. There are GPS traces collected at 1-second interval and a traditional travel diary in each data set. Another set of GPS data is a five-weekday GPS-based travel survey of 24 people in NYC with one-day travel diary. The GPS was set at 5-second interval for five-day traces. In the one-day travel diary, survey participants reported number of automobiles owned by the household, frequently visited locations, activity nodes for that day, and for each activity node, the travel modes taken, transfer points, arrival time, departure time, and trip purpose. This one-day travel diary was verified and used as the "truth set" to test the success rates of the algorithms for travel mode detection and trip purpose speculation.

In addition to GPS traces, we used other data available for speculating travel modes and trip purpose. We built a multimodal transportation network for NYC, incorporating all streets and highways as well as their directions, bus routes and stops, subway lines and stations, commuter rails and stations. We obtained the MapPLUTO data from NYC Department of City Planning, with land use information at the tax lot level. We also used the locations, SIC/NAICS codes, and many other information of all businesses in the Tri-State metro region, a data set published by InfoUSA.

We developed algorithms to identify travel modes and trip purposes from these data. Methodologies used to develop these algorithms have been discussed in detail in our publications and conference presentations (Gong et al. 2012; Chen et al. 2010; Muckell et al. 2009). Table 1 summarizes the success rates of our mode detection algorithm. For trip purpose, we achieved 67% success rate for home-based trips and 78% for non-home-based trips (Chen et al. 2010).

Table 1. Success Rates of Travel Mode Detection

	Identified by algorithm as						Success rate
	Walk	Subway	Rail	Car	Bus	Unknown	
Walk	182	0	0	11	4	0	92%
Subway	0	40	0	3	3	15	66%
Rail	0	1	5	8	0	0	36%
Car	2	0	0	37	5	0	84%
Bus	2	0	0	7	15	0	63%
Total	186	41	5	66	27	15	83%

Source: Gong et al. 2012.

Although we are able to achieve good success rates in detecting travel modes and trip purposes, we realize that without feedbacks from the participants, it would be almost impossible to obtain accurate travel information in a complex urban environment such as New York City where urban canyon effect is obvious, transportation network is sophisticated, and mixed land use is common. A Web GIS component was therefore developed to allow survey participants to validate the results from the algorithms for travel mode detection and trip purpose identification.

4. A Web GIS Prototype

A Web GIS was created in the geopublic server at Hunter College for the public to upload GPS data and verify/modify travel information derived from the GPS data. The data flows between Web-interface and server in the prototype is described in Figure 2.

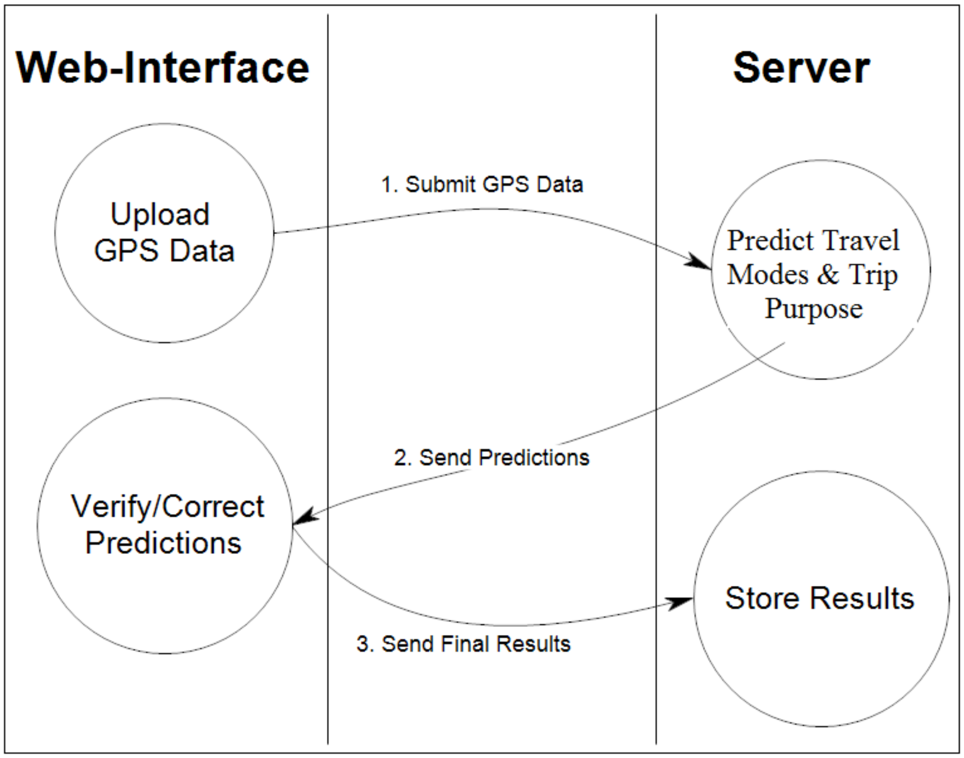


Figure 2. Data flows between Web-Interface and Server

Figure 3 below is the login/register web page in the Web interface for anyone to register and then login to access the Web GIS prototype.

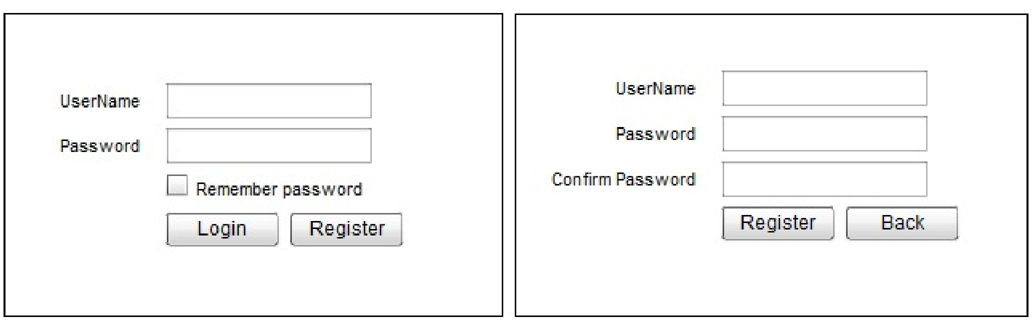


Figure 3. Login/Register Web Page

After login, the Web GIS prototype will display a base map of New York City (Figure 4), with basic map functions such as Pan, Zoom in, Zoom out, etc.

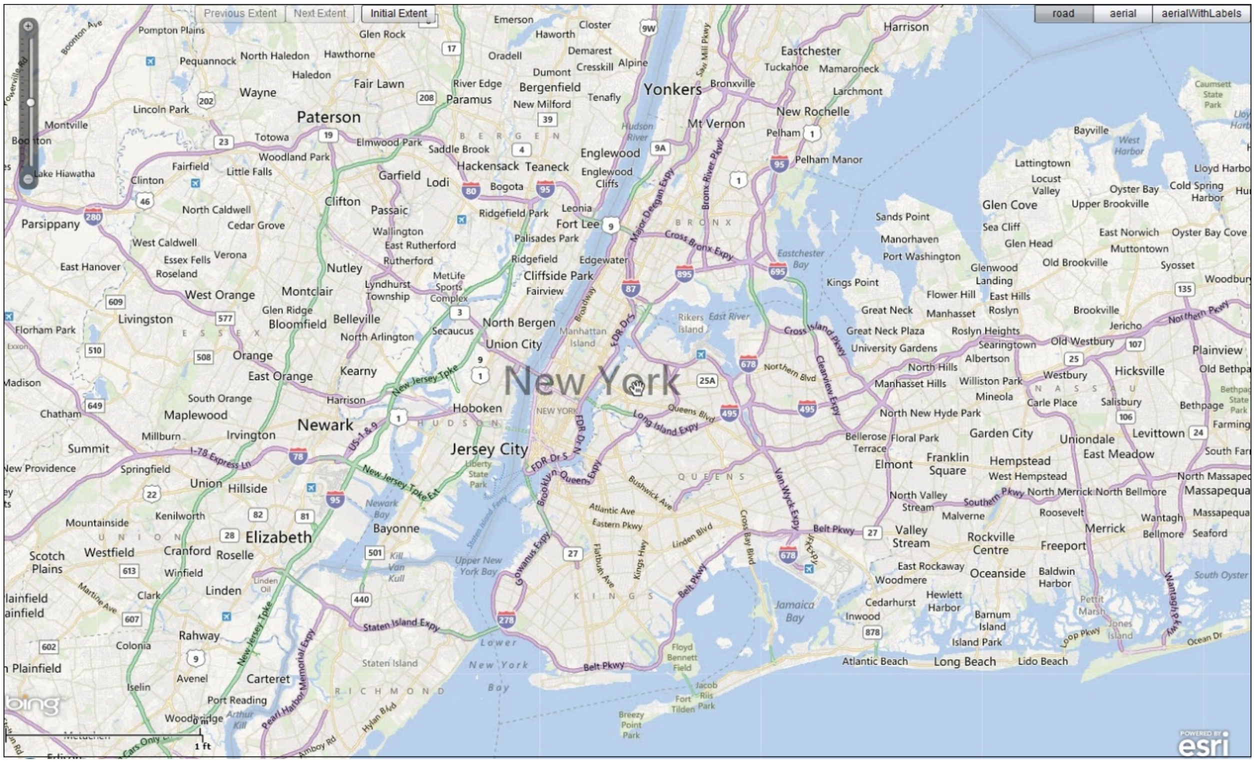


Figure 4. Base Map of New York City

On the right side of the map, the prototype provides two sets of tools. The first set of tools allows a registered user to upload GPS data in .csv format, run the data through our algorithms for trip purpose and mode detection, view the results, made changes to the non-spatial data such as trip purpose and travel mode (Figure 5), and save the changes.

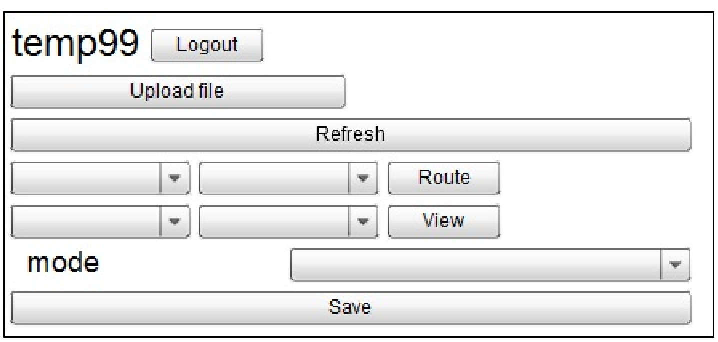


Figure 5. Tools to Upload GPS data and Change Non-spatial Data

The second set of tools allows a user to modify spatial data when necessary and save the changes (Figure 6). A user may edit a selected trip or segment, add a trip or segment, and merge two trips or segments. Because we use a multimodal transportation network in our GIS, the prototype can also accommodate multiple modes in a trip. We use the following four examples to illustrate the characteristics of the prototype.

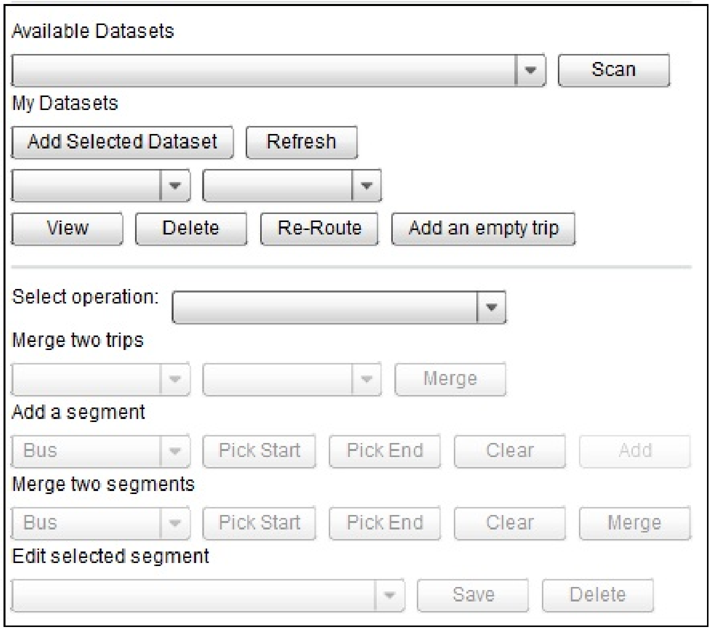


Figure 6. Tools to Change Spatial Data

(1) Example: Multiple travel modes

Better than Google Map or Bing Map that allows only single mode (by car, by public transit, walking, or bicycling), this prototype allows multiple travel modes in a trip to fit the situation of New York City. Figure 7 shows a home to work trip by car, walking to a subway station, by subway, and then walking from the subway station to work place.

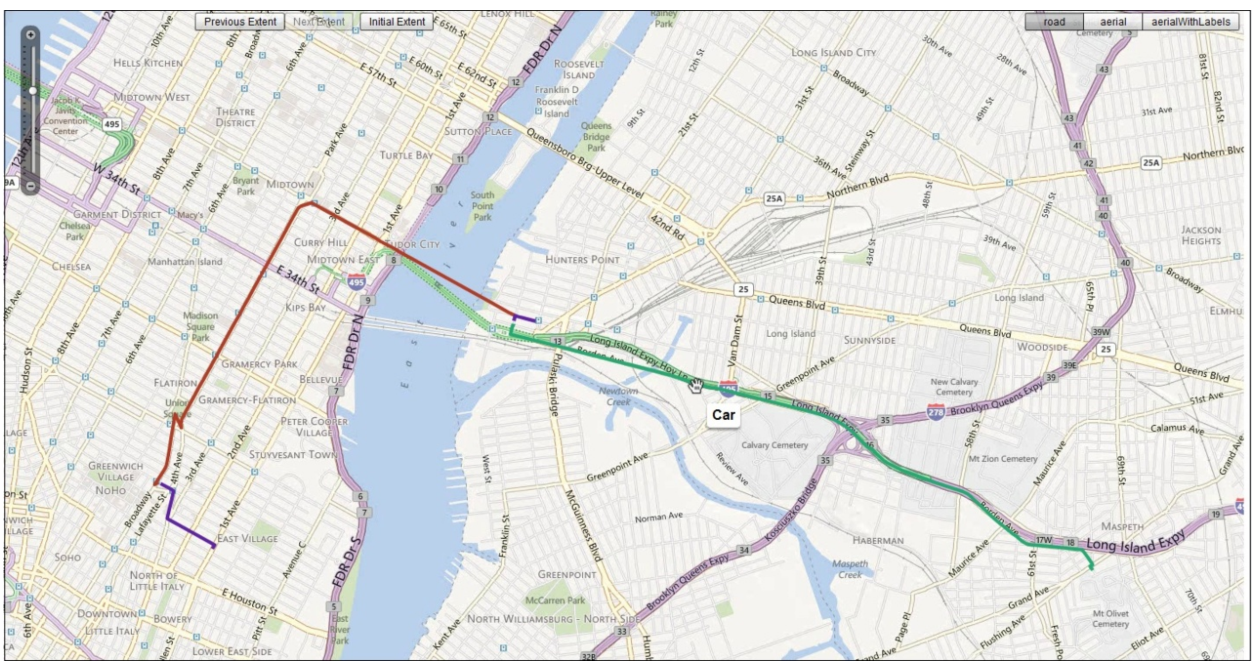


Figure 7. Example of a Trip with Multiple Travel Modes

The different colors of the trip display different modes of travel (Figure 8). When the mouse is hovered onto the first trip segment in Figure 7, a label appears to show the car mode.

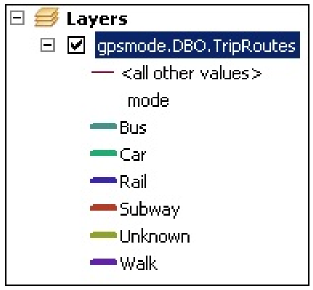


Figure 8. Legend to Represent Travel Modes

If the user wants to change the subway segment to be a bus segment, the user can click on the subway trip segment on the map to select it (Figure 9), choose "Select Operation" from the second tool set and "Edit Select Segment" from its drop down menu. When the "Edit Select Segment" submenu becomes available (not dim out), choose "Bus" from the drop down menu, then click "Save" to save the change.

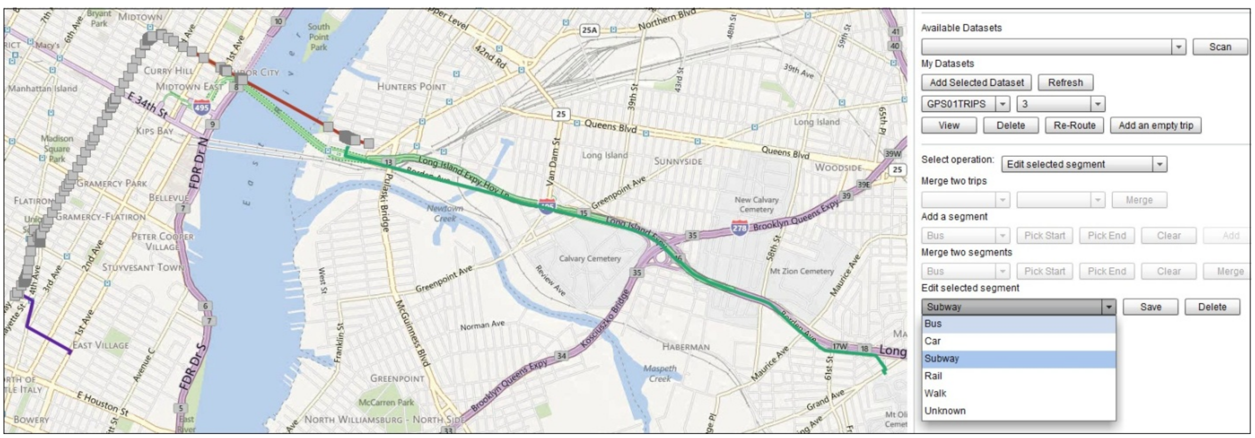
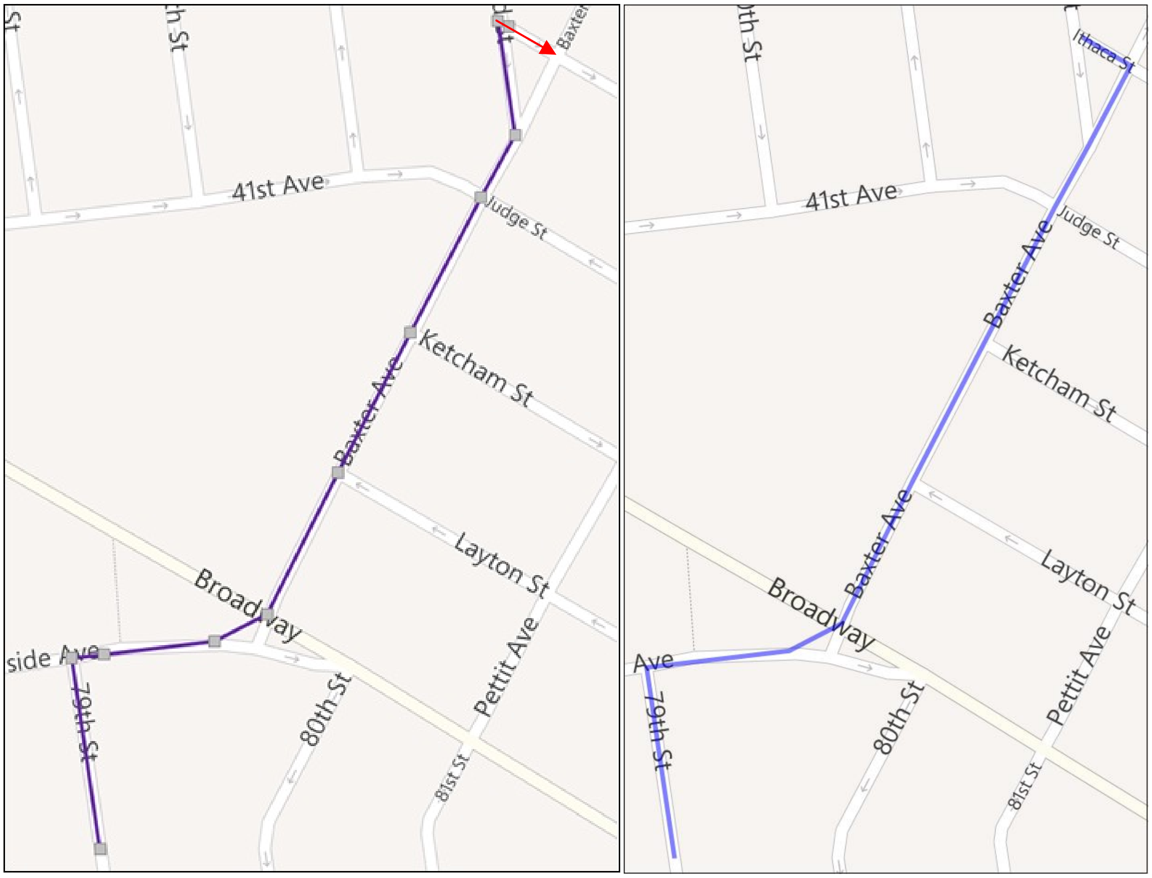


Figure 9. Selecting a Trip Segment and Changing the Mode

(2) Example: Spatially editing a trip

Figure 10 shows how a user may click and drag to change a trip. After the user click on the trip, gray squares will appear to represent vertexes of the trip (Figure 10a). The user can click on the top vertex and drag it to a street corner on the right (see the red arrow added for illustration) to represent the fact that the user walked around the corner on the right (Figure 10b) instead of the corner on the left.



(a) (b)

Figure 10. Example of Spatially Editing a Trip

(3) Example: Adding a trip segment

Because of the urban canyon effect, the cold start of a GPS logger may take longer than usual and may therefore cause the first trip segment being not recorded in the morning. Figures 11-13 show how the user can pick the start location of the missed trip segment and the end location of the segment and add a new trip segment.

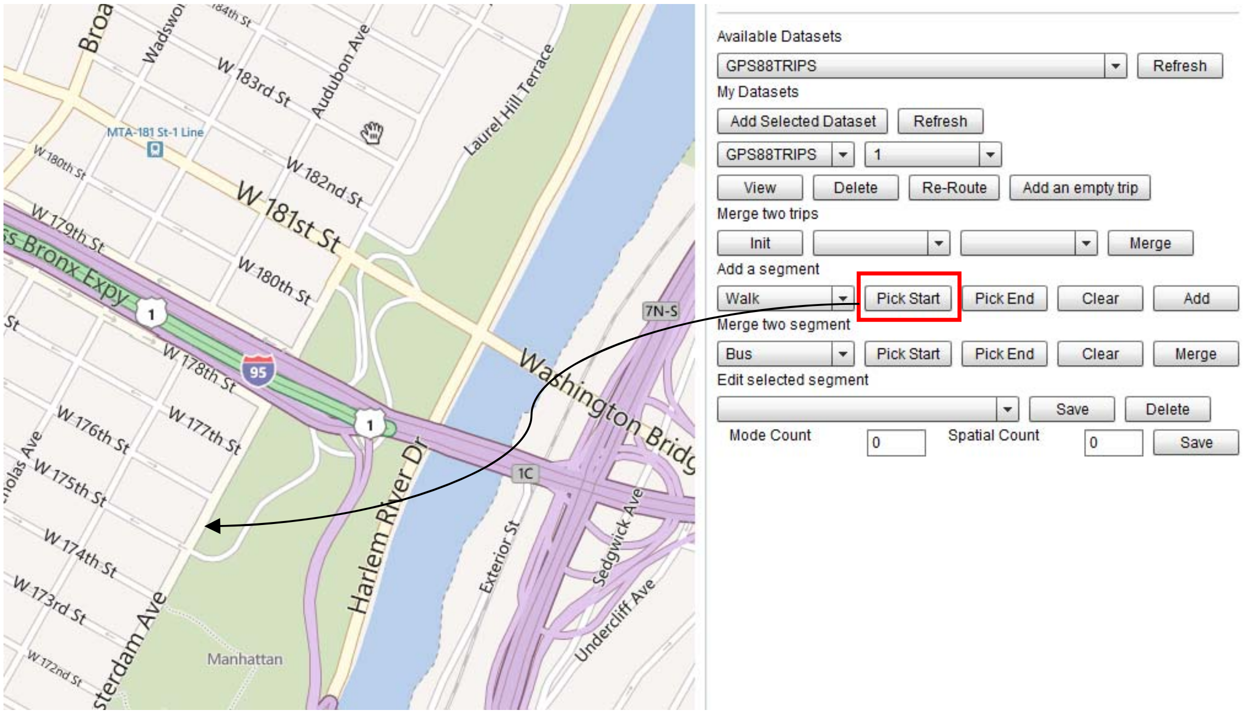


Figure 11. Picking the Start of a New Trip Segment

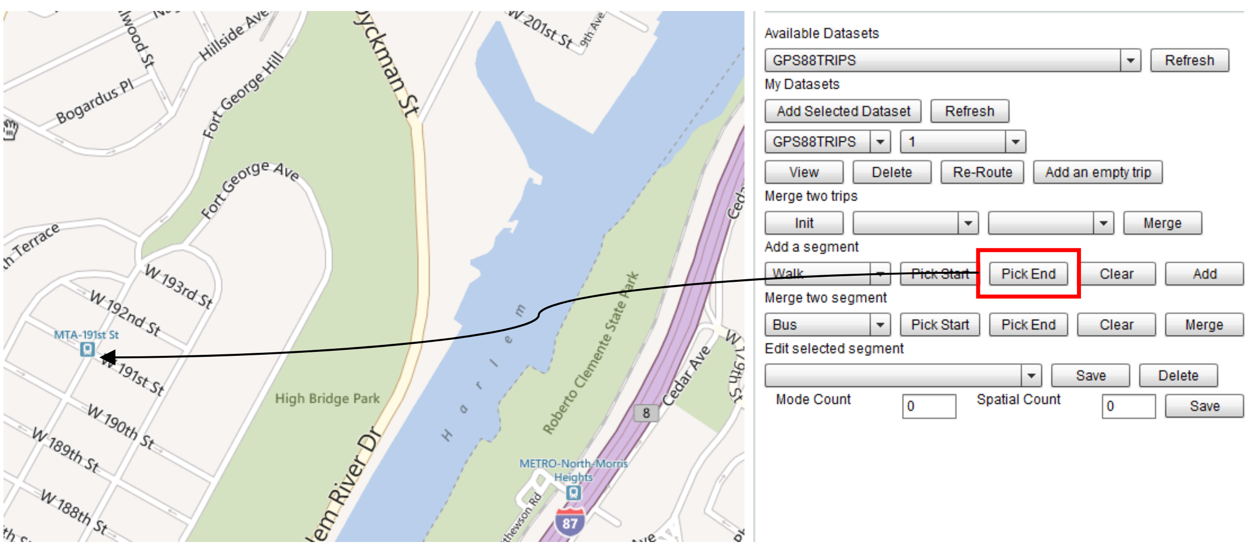


Figure 12. Picking the End of a New Trip Segment

After the user clicked the "Add" button and confirmed adding the new trip segment, a new walk trip segment from home to a subway station on the "W 191st St" was added using the shortest path function in ArcGIS (Figure 13). If the user did not walk by the shortest path, he or she can click and drag the vertexes of the segment (as shown in example 1) to reflect the actual walk path.

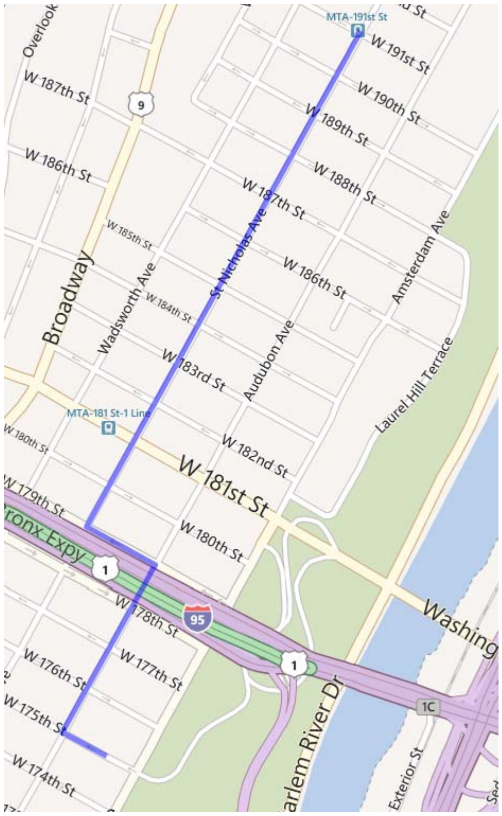


Figure 13. A New Trip Segment Was Added

(4) Example: Merging two trip segments

Sometimes a bus ride may be partially misidentified as subway because no GPS signal was recorded for some part of the trip. In this case, the prototype provides functions to first change the subway segment to have a bus mode (Figure 14). Then, two bus segments are selected separately (Figures 15-16) and merged to represent one bus ride.

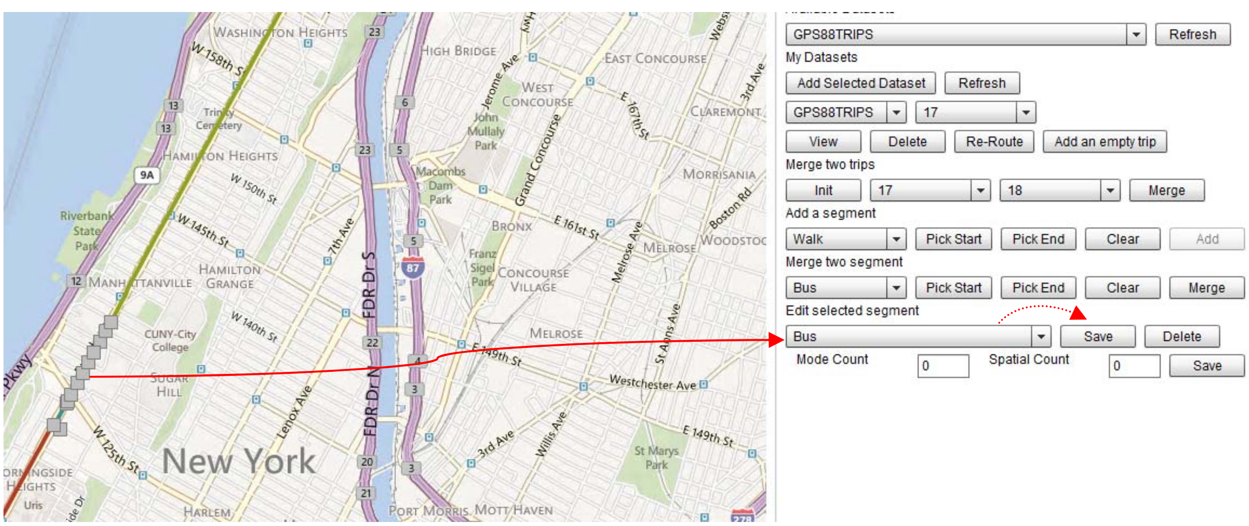


Figure 14. Making the Modes Consistent before Merging Two Trip Segments

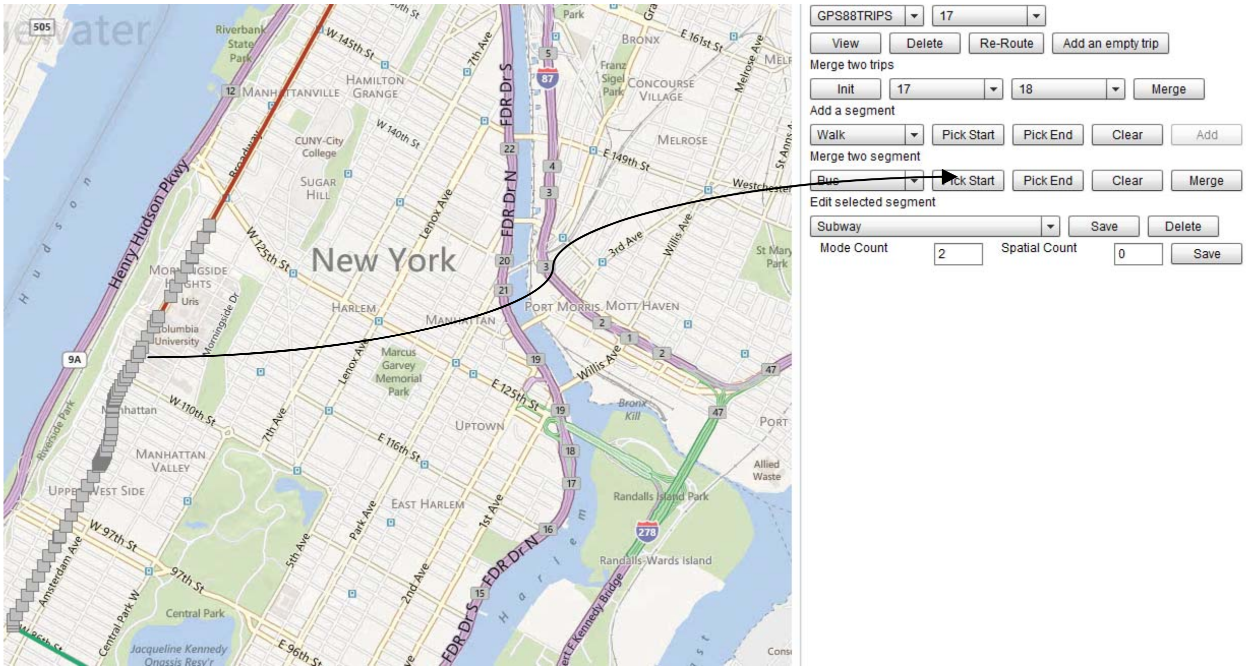


Figure 15. Picking the First Bus Segment for the Merging

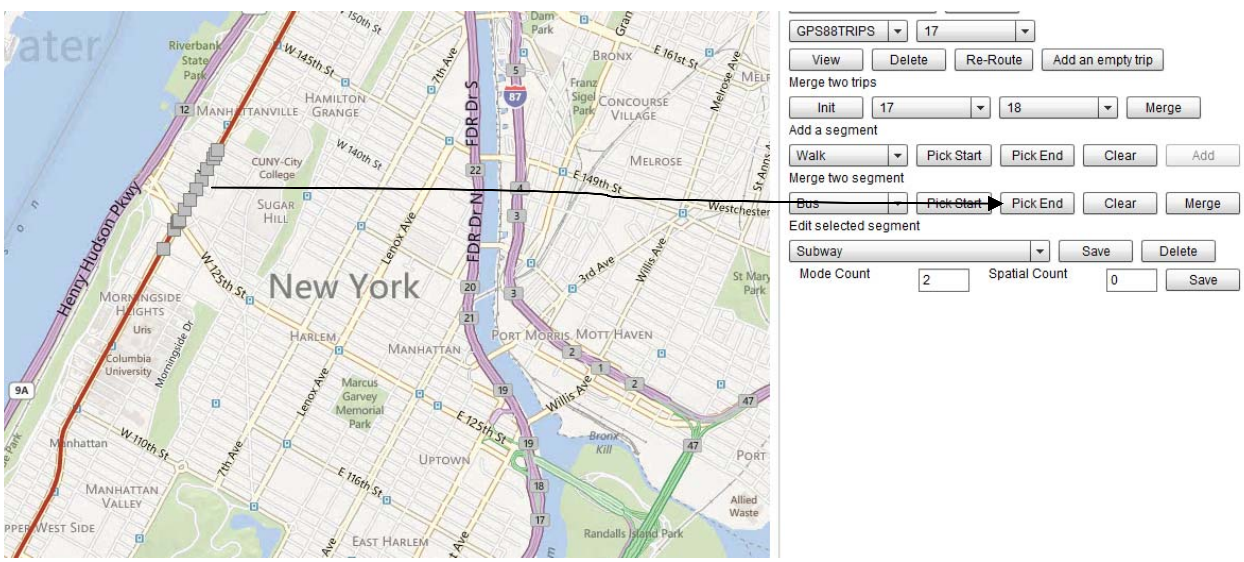


Figure 16. Picking the Second Bus Segment for the Merging

With these functions, the prototype basically allows users to do all the necessary modifications to eventually provide accurate travel mode and trip purpose information for transportation modeling and planning.

5. Conclusions

While reducing the burdens on survey participants by mining GPS data and providing the flexibility of spatial editing in a Web GIS, we established a prototype in this project that has the potential to provide accurate and validated travel information for transportation modeling and planning. We are currently improving the prototype by incorporating the mobile technology so that smartphones instead of separate GPS loggers are used as the device for travel surveys. We will also implement this prototype in a case study of Queens College of City University of New York in New York City. When this prototype becomes practice-ready, it could be expanded from a small group of participants to larger scales of travel surveys in the future, from one-day surveys to multiple-day surveys, and from one-time survey to year after year survey of the same cohorts. This longitudinal aspect and the goal of providing accurate travel information for transportation modeling and planning fit the prototype well in UTRC's theme of "Planning and Managing Regional Transportation Systems in a Changing World."

6. Dissemination of the Project Results

We disseminated the results of this project in three publications, five conference presentations, and one research brief.

(1). Publications

Chen, C., H. Gong, C. T. Lawson, E. Biolostozky. 2010. Evaluating the feasibility of a passive travel survey collection in a complex urban environment: Lessons learned from the New York City case study. *Transportation Research Part A* 44:830-840.

Gong, H., C. Chen, E. Biolostozky, C. T. Lawson. 2012. A GPS/GIS method for travel mode detection in New York City. *Computers, Environment and Urban Systems* 36(2):131-139.

Gong, H. 2012. Jobs-housing balance, transit-oriented development, and commute Time: Integrating GPS and GIS, in *Economic Development and GIS*, eds. J. M. Pogodzinski and R. M. Kos. Redlands, ESRI Press.

(2). Conference Presentations

Gong, H., C. Chen, C. T. Lawson, E. Bialostozky. A GPS/GIS method to understand people's travel modes in New York City. Presented at the annual meeting of the Association of American Geographers, DC, April, 2010.

Chen, C. Gong, H., T. Lawson, E. Bialostozky. Evaluating the feasibility of a passive travel survey collection in a complex urban environment: A case study in New York City. Presented at the 89th Annual Meeting of the Transportation Research Board, DC, January, 2010.

Gong, H. and C. Chen. Combining GPS/GIS/Internet/mobile technologies to understand people's travel. Presented at the annual meeting of the Association of American Geographers, Seattle, April, 2010.

Chen, C. and H. Gong. Using mobile phones for location tracking and activity monitoring. Presented at the annual meeting of the Association of American Geographers, Seattle, April, 2011.

Muckell, J., C. Lawson, H. Gong, and C. Chen (2009). Detecting Trip Purposes from a GPS Data Streem Using ArcObjects. Presented at 2009 Northeast Arc Users Group conference, Nashua, NH, Oct. 4-7.

(3). Research Brief

One-page research brief for UTRC2 Newsletter summarizing the methods, findings, and significance of this project.

7. Acknowledgements

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