Modeling commuter bicycle route choice in a dense urban network

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Introduction

This paper focuses on bicycle route choice in urban areas, in particular commuter bicycle trips. The paper investigates bicycle route choice characteristics, using a dataset from a GPS-assisted household survey, and estimates route choice models accounting for different network characteristics and land use variables.

Bicycle route choice models based on revealed preference surveys, such as the dataset in this research, consider separately the individuation of alternative paths, which are added to form the choice set for estimation of the model parameters. The probabilities of choosing the observed routes are then estimated from the generated choice sets.

Several methods were proposed to generate a route choice set. The methods developed for motorized travel modes are generally based on variations of the shortest path search. For example, the labeling approach, which minimizes generalized cost functions according to link attributes; link penalty, which gradually increases the impedance of all links on the shortest path; link elimination, which removes shortest paths from the network in sequence to generate new routes; simulation method, which produces alternative paths by drawing link impedances from probability distributions.

Model specifications that account for correlation among alternatives are preferable than the Multinomial Logit (MNL) model to represent route choice behavior. MNL modifications, such as C-Logit and Path Size Logit (PSL), include a correction term in the deterministic part of the utility function and maintain a simple logit structure. Generalized Extreme Value (GEV) specifications, such as Cross-Nested Logit (CNL), relate the network topology to model parameters in the stochastic term of the utility function and present a more complex structure.

Methodology

In the context of bicycle route choice, most existing studies focused on methods to create a route choice set for private vehicles or public transport. The studies that applied methods to generate routes for bicycle route choice generally collected data from GPS devices in convenience samples (such as faculty students). This study makes use of a household survey that was carried out in 14 major cities of the Tel Aviv metropolitan area between the December 2013 and June 2014.

The sample included 2,896 households with 8,515 household members who performed 12,731 and 23,222 travel tours (out of them, 1.7% were bicycle tours). The GPS device recorded the position every 3 seconds on average, and the raw data file included over 45 million readings. After performing logical checks and deleting observations with gross errors in GPS, there were 151,392 points relating to 618 bicycle trips.

Path generation techniques are applied to the detailed network of the Tel Aviv metropolitan area, which contains 92,670 nodes and 127,053 links, with a total length of 8384 km. In this paper, bicycle routes are generated by three main methods: link elimination, link penalty, and simulation method.

All three methods above were independently run in the network. After removing routes with less than 80% overlap, a total of 20 routes per each origin-destination pair formed the path set for model estimation.

Model estimation was performed for different model structures. The best results were obtained for the PSL and CNL models.

Choice Set Generation Results

The overall coverage for the 3 methods together, for an overlap threshold of 80% of the route length, is 72%. If a strict threshold of 100% overlap is imposed, the coverage drops to 56%. It is noticeable that with only 5 routes generated by the simulation method, the coverage is superior in comparison to both link penalty and link elimination methods.

The ratio of the observed route to the shortest route is 1.13, which is close to results found in the literature. Further inspection on the results indicate that this ratio increases to 1.19 in the city of Tel Aviv, which has a higher proportion of bicycle facilities relative to other cities, for which the ratio is equal to 1.07.

About 11% of all the distance of bicycle travel recorded by the GPS units occurred on roads with bicycle lanes, paths, or bicycle boulevards in Tel Aviv, compared with 3% in other cities. Although cyclists prefer to travel along the bike path, the results are quite low in comparison to other studies. One possible reason is the lack of connectivity between the bicycle links and dedicated lanes.

Model Estimation Results

Several variables were tested and the paper reports selected model estimation results. The explanatory variables that were found significant in most estimation runs were route length, the street category, average link length (the ratio between the route length and the number of intersections), dwelling units along the link (number of dwelling units divided by link length), and an interaction variable: age between 16 and 50 multiplied by route length.

As indicated in the previous section, the choice set generation methods applied in this paper created up to 20 different routes for each observation. In order to examine the sensitivity of the parameters with respect to the choice set, we estimated models according to a variable choice set size. The reference case is the "original" set composed of 20 routes, and two alternative choice sets were tested. The first was formed by drawing 10 routes from the 20 set, and the second by including 10 routes that generated by link penalty and simulation methods only (that is, not including the routes generated by elimination).

The results (not presented here) indicate that the coefficients do not significantly differ between the models, which indicate the robustness of the results with respect to different choice sets.

Conclusions

The choice set created with up to 20 routes per observation achieved high coverage, compared with reported results from the literature. The high-resolution network provides rich information about street characteristics (including pedestrian and bike paths), which enables the formation of alternative routes that cover in a more realistic way the chosen routes.

The model estimation results indicate that the utility of a bike route is equivalent to a route 67% longer than the shortest route. Similarly, the cyclist is willing to ride a route 47% longer than the shortest path to avoid riding routes with high level of stress.