People are not “rational”: An empirical study of the deviation between actual and shortest travel time paths

Wenyun Tang∗  David M. Levinson†

August 1, 2014

Abstract

Few empirical studies of revealed route characteristics have been reported in the literature. This study challenges the widely applied shortest path assumption by evaluating routes followed by residents of the Minneapolis - St. Paul metropolitan area, as measured by the GPS Component of the 2011 Twin Cities Travel Behavior Inventory. It finds that most travelers used paths longer than the shortest path. Some reasons for this are conjectured.

1 Introduction

Few empirical studies of revealed route characteristics have been reported in the literature. Previous research by the authors [27] found fewer than 40% of commuters took the shortest paths, though 90% of subjects took routes which were within 5 minutes of the shortest paths.

∗Visiting Scholar: University of Minnesota, Department of Civil, Environmental, and Geo- Engineering, Ph. D. candidate, Southeast University, 2# Sipailou, Nanjing, Jiangsu, China, wtang@umn.edu
†RP Braun-CTS Chair of Transportation Engineering; Director of Network, Economics, and Urban Systems Research Group; University of Minnesota, Department of Civil, Environmental, and Geo- Engineering, 500 Pillsbury Drive SE, Minneapolis, MN 55455 USA, dlevinson@umn.edu http://nexus.umn.edu
Other researchers have found similar results [1, 13, 16]. The reasons for this are several, but foremost people care about things other than average travel time.

They care about monetary cost [3], they care about avoiding stops [25], they care about travel time reliability [2], they care about aesthetics [24]. They might misperceive travel times [15]. They might not want to engage in route search, and instead still to habitual routes. We might also acknowledge mismeasurement on the part of the analyst in what is the shortest path as a possibility, though we discount it as the dominant reason.

This study tests the widely applied shortest path assumption by evaluating routes followed by residents of the Minneapolis - St. Paul metropolitan area, as measured by the GPS Component of the 2010 Twin Cities Travel Behavior Inventory.

2 Data

There are several sources of data. The first comes from the 2010 Travel Behavior Inventory, conducted by the Metropolitan Council for the Twin Cities (Minneapolis-St. Paul region). A GPS component of the survey is used in this analysis, which for a subset of 250 households, issued pendant GPS units to wear for a seven day period, in addition to the one (weekday) the same subjects also filled out a travel survey. This is detailed in [14].

The second is TomTom road speed network data for 2010 acquired by the Metropolitan Council [6]. From ??, we can see that TomTom data are largely consistent with GPS data for the same links, though TomTom’s times are a bit lower (speeds higher) on average. Causes for this include differences in definition, differences in sampling, differences in treatment of traffic signals, and the possibility that some subjects made small stops without being identified as distinct trips, among others.

The third is the TLG base network, with 290,231 links, described in previous studies by the author [4], maintained by the Metropolitan Council and The Lawrence Group (TLG).
It covers the seven-county metropolitan area and is considered the most accurate GIS street map of this network to date.

3 Methodology

Mode classification is an important assessment in the use of GPS data [5, 9, 26] set of mode identification rules were developed and used.

1. Walk:
   
   (a) Max speed of all points $\leq 20 \text{km/h}$;
   
   (b) Duration $> 60 \text{s}$;
   
   (c) 85th percentile of speed of all points $\leq 10 \text{km/h}$;
   
   (d) Average speed of all points $\leq 6 \text{km/h}$.

2. Off-network public transport modes:

   (a) Distance from first point of speed accelerates to $10 \text{km/h}$ to the nearest rail station $< 150 \text{m}$;
   
   (b) Distance from last point that speed is greater than $10 \text{km/h}$ to the nearest rail station $< 150 \text{m}$;
   
   (c) Average speed of all points $> 10 \text{km/h}$.

3. Bus:

   (a) Distance from first point of speed accelerates to $10 \text{km/h}$ to the nearest bus stop $< 50 \text{m}$;
   
   (b) Distance from last point that speed is greater than $10 \text{km/h}$ to the nearest bus stop $< 150 \text{m}$;
(c) Average speed of all points > 10\textit{km/h}.

4. Bicycle:

(a) 85th percentile of speed of all point ≥ 10\textit{km/h} and < 20\textit{km/h};

(b) Max speed of all points ≤ 30\textit{km/h}.

5. Car: the remaining trip segments with average speed of all points > 10\textit{km/h}

Visual inspection of the individual trip records suggests they plausibly reflect the actual modes taken (though, e.g. a fast bike and a slow car remain undifferentiable from this method). From the perspective of this study, focusing on automobile users, the most important task was to avoid “false positives” (non-auto trips showing up as auto), rather than worrying about “false negatives” (auto trips excluded from the sample set). Other studies may have different objectives with regard to modal classification, and typically identifying transit is more difficult.

Trip purposes are identified based on the relative location of the GPS trip origin and destination (start and stop point) and the subject’s known home and work locations, as detailed in Table 1. Again, avoiding false positives (mis-identifying non-work trips as work trips) was more of a concern than the converse.

After being divided into trips, modes, and trip purposes, auto commute trips were separated out. As shown in Table 2, the GPS Data contains 232 drive commute trips (142 Home to Work (H2W) and 90 Work to Home (W2H)) belonging to 58 different travelers from 51 households. Note, no Work to Work (W2W) trips were identified, so those are excluded. Several round trips from home without stops (H2H) trips were identified. Persons with no work address were identified as non-workers. Trips to destinations other than the main work address were classified as non-work (Other) trips, even if the function of the trip was for work, as that could not be determined from the GPS data.
Auto commute GPS data were then matched to The Lawrence Group (TLG) Twin Cities network. The method that was applied to ensure all points have been snapped to the nearest (by distance) link, ensuring the link was a through link with no broken ends except for origin and destination links, and ensuring the link was in the same travel direction as the GPS data, and eliminating cycles in the network route.

Then shortest distance route is developed on TLG network, while shortest time route on TomTom network. TomTom speed data include seven periods in 24-hour day (Early Morning (AM1), Late Morning (AM2), Mid Day (MD), Early Afternoon (PM1), Late Afternoon (PM2), Evening (EV), Night (NT)). Link travel speed is chosen based on trips start time in GPS data. Then we compare the total distance between actual route and shortest distance route as well as shortest time route, and also total travel time between actual route and shortest time route. The total overlap distance are found between actual route, the TomTom shortest travel time path route, and the shortest distance path route.

An example for one subject’s shortest travel time path (using TomTom data), shortest distance path, and actual path is given in Figure 1.

4 Results

Figure 3 compares (in percentage terms) actual GPS travel times with estimated TomTom times on the shortest path. As can be seen, almost all trips had travel times longer than the TomTom shortest path (a few are shorter because the TomTom network does not have speeds on some local roads). This is in part because end of trip details (e.g. parking) are not going to show up on the TomTom network. More than half the trips were 30% or more longer than the estimated shortest travel time path.

Figure 4 looks at the absolute difference in minutes. More than half of all auto commute trips in the sample are more than five minutes longer than the shortest path,
In Figure 5, the horizontal axis is distance overlap rate between actual route and the estimated shortest travel time route using TomTom data. The vertical axis is the time comparison between them ((actual time-shortest time)/shortest time). We find that the highest travel time differences occur for trips with low overlap. While for trips with a high overlap rate the time differences are not as large, but far from zero. Although in comparison with the shortest distance route (Figure 6), the percentage of overlap between actual route and shortest time route (Figure 7) is higher. However, only about a quarter (37 of 142) choose a route that have a very high overlap (>90%) with the shortest travel time route.

5 Discussion and Conclusions

Using empirical data from a GPS-based study of some 250 households, and focusing on auto commuters in that dataset, this paper tests a crucial assumption in transportation planning practice, embedded in the principle of user equilibrium due to Wardrop [21], that travelers choose the shortest travel time path. It finds most travelers do not choose such a path, and the overlap between their actual path and the analysts best estimate of the shortest path is well below 100 percent.

Why aren’t people taking the shortest path? Here are a few conjectures:

Selflessness: Wardrop’s principle [21] assumes that people are selfish, but perhaps they are selfless. We assume they aim to minimize their own travel time rather than society’s. Suffice to say that people cannot know what decision will minimize society’s travel time, because of computational and informational issues, discussed below. Perhaps if they had that information, they might selflessly choose a different route. In the absence of that information, they are, at best, left guessing whether what they are doing is best for everyone else, even if at some self-sacrifice. (This assumes they are still making the trip at that time. In general, if there is congestion, it would be better for everyone else from a travel time
perspective to avoid the trip altogether).

Rationality: Wardrop’s principle assumes that people are rational, but maybe people aren’t rational, or at least not rational all the time. In one sense that is of course true, people react emotionally and intuitively, employing what Nobel Prize winner Daniel Kahneman [10] calls System 1 in *Thinking Fast and Slow*, based on heuristic rules. They don’t have time for rational assessment. In another sense, for a repeated decision like commuting back and forth to work daily, it costs a significant amount of travel time, a scarce resource, to systematically behave irrationally. We thus assume people are behaving rationally (engaging Kahneman’s System 2) when they can. The idea of Bounded Rationality, developed by Herbert Simon [18], has been applied to route choice problems by many researchers, see e.g. [7, 8, 12]. We can build models with bounded rationality assuming or estimating the bounds to this rationality due to information, cognitive limits, and time available to make a decision.

Perception: It might be that people think they have the shortest travel time on their route, but they misperceived the travel time on the network. There are perception or cognition limits. On a 24 minute trip, few travelers will know the travel time to the nearest 30 seconds or minute. Reported travel times in surveys are typically rounded to 5 minutes and sometimes they round to the nearest 15 minutes. If people are only dealing with time perception in 5 or 15 minute chunks, saving a minute or two isn’t going to show up on their radar as something that is important to them [15].

Computation: Travelers cannot accurately add travel times across different road segments, they can’t systematically compare the travel times over alternative routes even if they had a complete data set.

Information: Not only are people not computers, they are not GPS systems either. People don’t have complete maps of the network; people often have good mental maps of the local street network around where they live and a little bit around where they work and where they travel frequently, but if they live far from where they work, they tend not to know
the detailed network in-between. There are limits to people’s ability to navigate. People’s
cognitive or mental maps are far from complete. They only have the experience of the routes
they have actually used. They can test other routes to gain experiences but they don’t have
those innately.

Valuation: Maybe people are minimizing the weighted sum of travel time, where time
spent in different conditions is valued differently. We know, for instance, from the transit
literature that time spent waiting for a bus is much more onerous than time while on-board
a vehicle in motion making progress towards its destination, especially if the arrival time of
the bus is uncertain [22, 25].

Objective: We assume that people care about minimizing only travel time. It might be
that people are rational but they care about things besides or in addition to travel time.
We have evidence from other transportation choices that people aren’t minimizing travel
time. When you choose a place to live, you are not choosing to minimize your commute
time to work. In fact there have been studies that have considered a hypothetical reloca-
tion of everybody’s place of residence in order to be in a house that was equivalent to the
structure in which they currently reside, but was as close to their work place as possible
(given everyone else was similarly moved), average commutes fell from about 24 minutes to
8 or 10 minutes. There is a significant amount of “excess travel” from a strict travel-time
minimizing perspective [19]. There are many reasons for excess travel, but the most obvious
is that it is not excess from the point of view from people who are making it. They’re
making home location decisions for a variety of reasons; the journey to work isn’t the only
thing in their mind. (Travel time must be a consideration though, otherwise cities wouldn’t
exist). It might be when choosing where to reside people might underestimate the amount of
time that will be spent traveling, and probably underestimate the pain associated with long
commutes, and are thus unhappier than expected [20]. A major source of time estimation
error arises because most people search for homes on the weekend, but tend to commute on
weekdays. Some candidate factors for route choice are given below:

Search cost: How long does it take to figure out what the travel time is on alternative routes? Are you willing to spend ten minutes exploring the network in order to save 30 seconds of travel time every day for the rest of your career? Rationally it might be worth doing so, the payback is only 20 days. People often will discount the possibility of saving time, worrying that this short-cut will actually be longer, or maybe they’re afraid of getting lost. Fear of the unfamiliar is a major deterrent to exploration [23].

Route quality: Many factors describe the quality or condition of a route and its environment. Is it potholed or newly paved? Does it run through a pleasant or unpleasant neighborhood? We have evidence that some people prefer a longer route if it’s an attractive boulevard or parkway rather than drive through a freeway trench [24].

Reliability: The likelihood of arriving on time, and not just the expected travel time, affects willingness to select a route. There is the old parable of the man who drowned in an average of one inch of water. Similarly, it might not matter to a traveler that the average travel time is 20 minutes if one day a week (but never knowing in advance which day) that traveler can expect a travel time of 60 minutes. Traveler’s don’t want to leave 40 minutes earlier to avoid the occasional bad outcome. They might be willing to take a slower but more reliable route. They might even have a mixed strategy, or portfolio, combining different routes in order to achieve a personally satisfactory trade-off between expected time and reliability [11]. In practice this means some people might take surface streets, which are generally slower, but more reliable, instead of freeways, which are faster, but subject to more catastrophic breakdowns of traffic flow [2].

Pleasurability of travel: Maybe people are rational, but they like traveling a little bit more than being at work or home, and so choose longer routes to prolong the experience. Many people want to commute; Redmond and Mokhtarian [17] find positive value to some amount of commuting, that the preferred commute length is not typically zero. However, it
appears that many commutes are longer than the desired amount. However, for some people, the longer route, which provides some psychological buffer between the stresses of work and the stresses of home, is desired.

In short, route choice models need to be reformulated with more realistic behavioral assumptions.

Figure 1: Example with GIS Network
Figure 2: Travel Time Comparison on Links Between TomTom and TBI GPS data

Figure 3: Travel Time Comparison
Figure 4: Travel Time Difference

Figure 5: Overlap Percentage
Figure 6: Percentage of Overlap: Difference Between Actual Route and Shortest Distance Route

Figure 7: Percentage of Overlap: Difference Between Actual Route and Shortest Travel Time Route
<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
</tr>
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<tbody>
<tr>
<td>worker</td>
<td>worker</td>
</tr>
<tr>
<td>$H \leq 500 m$</td>
<td>$W \leq 500 m$</td>
</tr>
<tr>
<td>$H \leq 500 m$</td>
<td>$H2W$</td>
</tr>
<tr>
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<td>$H2W$</td>
</tr>
<tr>
<td>$H + W &gt; 500 m$</td>
<td>$H2O$</td>
</tr>
<tr>
<td>non-worker</td>
<td>-</td>
</tr>
<tr>
<td>$H \leq 500 m$</td>
<td>-</td>
</tr>
<tr>
<td>$H &gt; 500 m$</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Location tested for proximity to Home, Work and Other in sequence.
Destination location identified after Origin.
Where: $H2W =$ Home to Work, $H2O =$ Home to Other, and so on.

Table 1: Definitions of trips based on relative location of trip origin and known Home and Work locations

<table>
<thead>
<tr>
<th>Mode</th>
<th>H2W</th>
<th>H2O</th>
<th>O2H</th>
<th>W2H</th>
<th>W2O</th>
<th>O2W</th>
<th>H2H</th>
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<td>26</td>
<td>138</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>110</td>
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<td>1595</td>
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<td>4895</td>
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Table 2: Number of trips by mode and purpose
References


