How Local is Travel?

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ABSTRACT

This paper analyzes the distribution of travel time across different classes of roads for 47 subjects in the Minneapolis-St. Paul metropolitan area. We use global positioning system (GPS) and geographic information system (GIS) data to analyze subject road use, with the objective of getting a sense for how much time individuals spend on different types of roads during their commute trip (in a sense, how “localized” their travel is). The results reveal an association between the amounts of time spent on various functional classes of roads and home and work locations. Subjects that live and work in the city of Minneapolis are found to spend a higher percentage of their travel time on lower-level (city and county) roads. The results may be used to further inform local road finance decisions in light of the free-rider problem and other problems associated with current financing mechanisms.

INTRODUCTION

Travelers make choices based on self-interest to determine their most efficient journey. The hierarchy of roads, which includes local, feeder, collector, arterial, and interstate links, provides a network to serve those choices. Along the network, users can cross jurisdictional and service boundaries without gaps in service. This fluidity is the result of inter-jurisdictional coordination between local, state and federal agencies to provide a road network that is funded, maintained, and managed. Users benefit because of the spectrum of service levels provided, that is, it increases their ability to change their behavior depending on their travel needs. Each type of trip may be associated with a different class of road or combination of classes, depending on their destination. Trips to work may be associated with more highway usage due to their typically longer distance, while shopping trips may be associated with more local roads.

Financing arrangements adopted by local jurisdictions in the United States (primarily cities, but also counties) that rely heavily on property taxes or other local, broad-based taxes implicitly assume that most travel on the roads in these jurisdictions is local in nature. If this assumption holds, then most of the benefits from local roads accrue to local residents and it is reasonable to impose charges on these residents to finance the roads. If not, there may be a substantial amount of free-riding by travelers on local networks outside their home jurisdiction.

Surprisingly, there has been little attention paid to the question of correspondence between the locality of travel and road ownership. This may have been due partly to the absence of a perceived problem with existing structures of local road finance. In most jurisdictions revenue from local taxes is generally adequate to finance core infrastructure needs and is perceived as more or less fair. Another reason why this question may not have been posed previously is the lack of adequate data. Until recently, travel behavior data sets have been predominantly trip-based and not sufficiently dynamic to capture complex patterns of urban travel. The advent of the use of global positioning system (GPS) data for travel behavior analysis offers one potentially viable alternative (*1*)

This paper will analyze GPS data in the Minneapolis/St. Paul metropolitan area, which tracked volunteers' travel behavior to determine what types of roads users chose to accommodate their travel needs. The hypothesis of this paper is that users will spend more travel time on local roads, especially if their home and work locations are within the same jurisdiction. Local travel is defined by travel on city and county roads that are not part of the principal arterial network, but that may cross jurisdictional boundaries. The implications are that resident A lives in one city and pays property taxes to City and County A to maintain the roads. However, this resident also uses the roads in City B, but does not pay their property tax for that service. If more of resident A’s travel takes place on local roads in other jurisdictions, this may increase the incidence of free-riding and decrease the efficiency of a financing scheme based on local taxation. The results will be indicated by the amount of travel time spent on roads managed by different jurisdictions. The results of some preliminary analysis of the GPS commute trip data reveal an association between the locality of travel (as measured by the use of local roads) and the maintenance of one’s home and workplace in the same city.

DATA COLLECTION AND PREPARATION

GPS Data Collection

The data was provided from a study that documented travel behavior using GPS-based vehicle location data before and after the reconstruction of the I-35W Bridge over the Mississippi River in Minneapolis. The study consisted of 47 subjects in an eight-week long GPS travel study between the months of September and December 2008. The identity of the drivers is known and the gender distribution consisted of 29 females and 22 males. The origin of their trips is based on a specific address, which was identified with an origin city and county. Home and work locations were identified by geocoding them to a street address in a GIS network file. The home origin for the subjects varies throughout the metropolitan area, but the work destination for all but two subjects is Minneapolis or the University of Minnesota-Twin Cities campus. The GPS data did not contain route characteristics, meaning that they needed to be mapped in order to identify routes between origin-destination pairs.

Previous research regarding GPS data and travel time analysis exists. Studies have used GPS to identify the types of trips taken place on various weekdays and weekends to analyze travel behavior. Zhou (*2*) concluded that people's activities are routine due to work or study but variability exists over the weekends or free time. This could indicate the change in the amount of travel time on various types of roads. Weekends may result in trips to destinations further from home and therefore may increase the amount of time spent on interstates or arterials.

Linking GPS Data to the Road Network

The road network data file is a Geographical Information Systems (GIS) layer created by The Lawrence Group (TLG) and contains 153,178 centerlines. Each line is a segment of road with various attributes such as names, type of road, highway numbers, and functional class. Centerlines are helpful in eliminating small features in the road network such as small curves and dropping out feature (*3*). The functional class of road feature separates the TLG road files. The functional classes consist of A10 – Interstate Freeways, A15 – Interstate HOV lanes (I-394 HOV), A20 – US Highways, A25 – State Highways, A30 – County Road, A40 – City Street, A63 – Ramps and Loops, and A64 – Service Drives. Figure 1 shows a small sample of the road network in Minneapolis and illustrates some of the different functional classes of roads. The GPS points did not contain attributes for functional class of road and therefore needed to be joined to the TLG road file using ArcGIS software.

The GPS data point files are extensive and range from a low of 80,345 to maximum of 973,317 observations, with a median of 284,106. These are from mobile GPS units that track the motion and general position of the vehicle on the network. The points were collected at a rate of 1 point per second. Both the GIS network and GPS point layers were projected using NAD 1983 UTM Zone 15N coordinates and were geographically coordinated for the GCS North American 1983 level. The geographic fit of these layers allows the GPS and GIS files to be spatially joined.

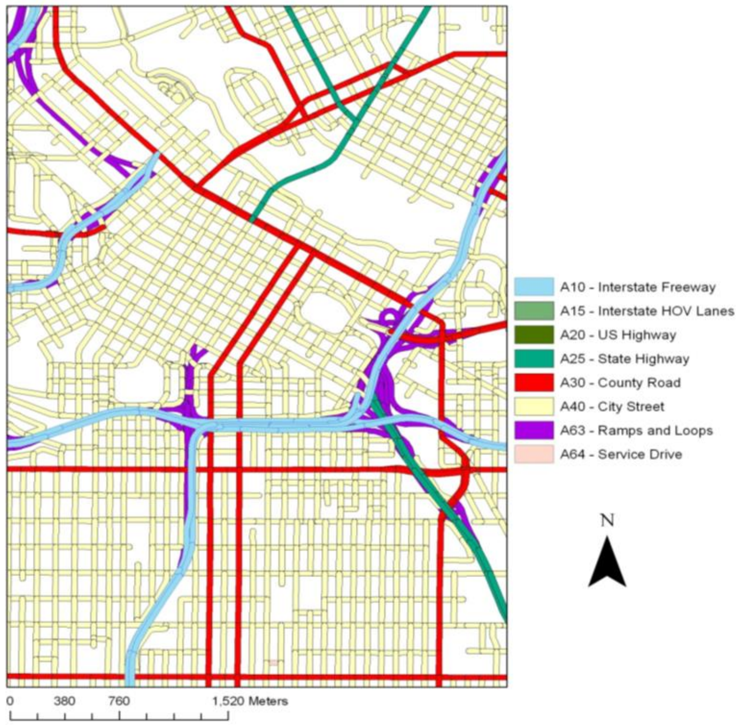

FIGURE 1 Functional classes of roads in Minneapolis.

The combination of the GIS centerline file and GPS points required an organized process of smoothing out the data, establishing linking techniques, and recognizing the errors. Errors are due to a number of factors throughout the data collection, processing, and smoothing process. Human error may also be present due to the size of the data set.

The errors that existed during the collection phase could be due to mistakes in calibration, or could represent systematic and/or random error. These errors can be the result of satellite error, atmospheric error, operator error, and/or geographic limitations of the GPS. Obstacles can interfere with the mobile signal to the satellite and alter the readings (*3*,*4*,*5*).

A data cleaning technique was used to integrate the GPS points and the GIS map lines for data review and smoothing. This stage is known as a quality control stage to build assumptions and error rates in the data. The large size of the data set required some data points to be either corrected or eliminated.

The TLG road file consists of GIS line shape files, which had limitations in connecting points to lines. The GPS points did not contain the road attributes and were linked in order to acquire the type of functional class of road the point was located on. First, the centerlines can cause errors for connecting GPS points by incorrectly linking multiple intersecting lanes. This can cause the GPS points to link to the wrong road segment. This mainly occurs at an intersection or junction of two lines. The initial methodology was to link the points directly to the lines using a spatial join function and remove points that were joined to too many roads. This methodology produces accurate results because only points that are within 10 meters of one centerline were counted.

This methodology, however, was difficult to compute. Joining the line files was unpredictable and created blank joins regardless of data size.

An alternative data joining method was created using a 20-meter buffer around each of the lines and was applied to join the GPS points more consistently. The points could be joined if they were within the specified buffer. The GPS points then contained the attributes for the functional class of road, county, and city location. A comparison between the points-to-line and the points-to-buffer methods revealed similar results. The 20-meter buffer joining method was used to join the GPS points to the road attributes.

The 20-meter buffer assumed that a majority of GPS points would be within 10 m of a centerline. Practically, segments of subject travel on roads would be captured even if they changed lanes. This is evident on interstate roads with multiple lanes and produces a dispersed appearance compared to local roads with one or two lanes, which result in more concentrated paths.

The buffers captured and joined all points within 20 meters. Errors may exist when a path of points travels over one jurisdiction of road and onto another. This happened most consistently at the intersections of A10-Interstate Freeways and A63-On-Ramps and Loops, as shown in Figure 2. The red arrow in Figure 2 shows a dispersion of points that may not be accurately joined to the correct road. This may skew the travel time slightly on these two functional classes of roads. The green arrow in Figure 2 indicates a segment error caused by GPS disruption of data points. These points can still be captured when the local street buffer is applied.

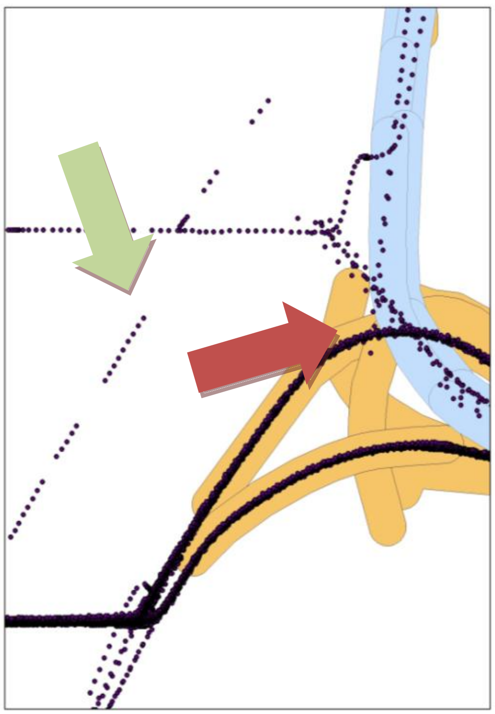

FIGURE 2 Dispersion of data points due to overlapping links.

Errors also exist when data points follow one jurisdictional road that intersects or crosses over another jurisdiction. The green and red arrows in Figure 3 indicate this error. A state highway section of road crosses over an interstate and is capture by the interstate buffer. This also happens for on-ramps and loops as indicated by the red arrow. The points are not double-counted when they are joined with an incorrect road. Data capture procedures such as capturing the points in order of the hierarchy of roads were tested. For example, only interstates were first used to capture points, then state highways. This method, however, revealed similar results to capturing the points with all road layers present.

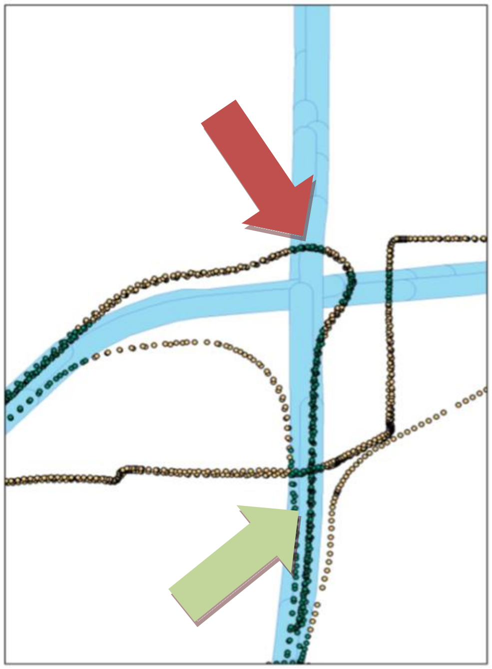

FIGURE 3 Error due to intersecting jurisdictional links.

STUDY AREA

The study area from which the data were collected is the Minneapolis-St. Paul metropolitan area. We focus our attention on the core seven counties of the region: Anoka, Dakota, Hennepin, Ramsey, Scott, Washington, and Carver. There are 187 cities within this seven-county area. Jurisdictional fragmentation has lead to numerous different agencies building, operating, and maintaining different functional classes of roads. Functional classes A30 (County Road) and A40 (City Street) will be specifically examined for the purpose of this study.

RESULTS

The data from the 47 subjects involved in the GPS data collection effort permitted an analysis of travel times of commuters by type of road link between their home and workplace. Subjects predominantly work in the city of Minneapolis but live in various counties and cities. The analysis divides the travel time by functional class of road for each subject and summarizes the results, then disaggregates the analysis of travel time by home jurisdiction (Minneapolis vs. other cities), and finally summarizes travel time by day of week.

Figure 4, which charts the distribution of travel time by road class for all subjects, indicates that a large share of all travel is in fact local. Nearly two-thirds of all travel time is spent on city or county roads, with city streets accounting for just under half of all travel. About one-quarter of all travel time is spent on interstate and state-level highways. The relatively high share of travel time (eight percent) spent on loops and ramps probably reflects the fact that many of the trips are peak-period commute trips, and so may be subject to delay at ramp meters.

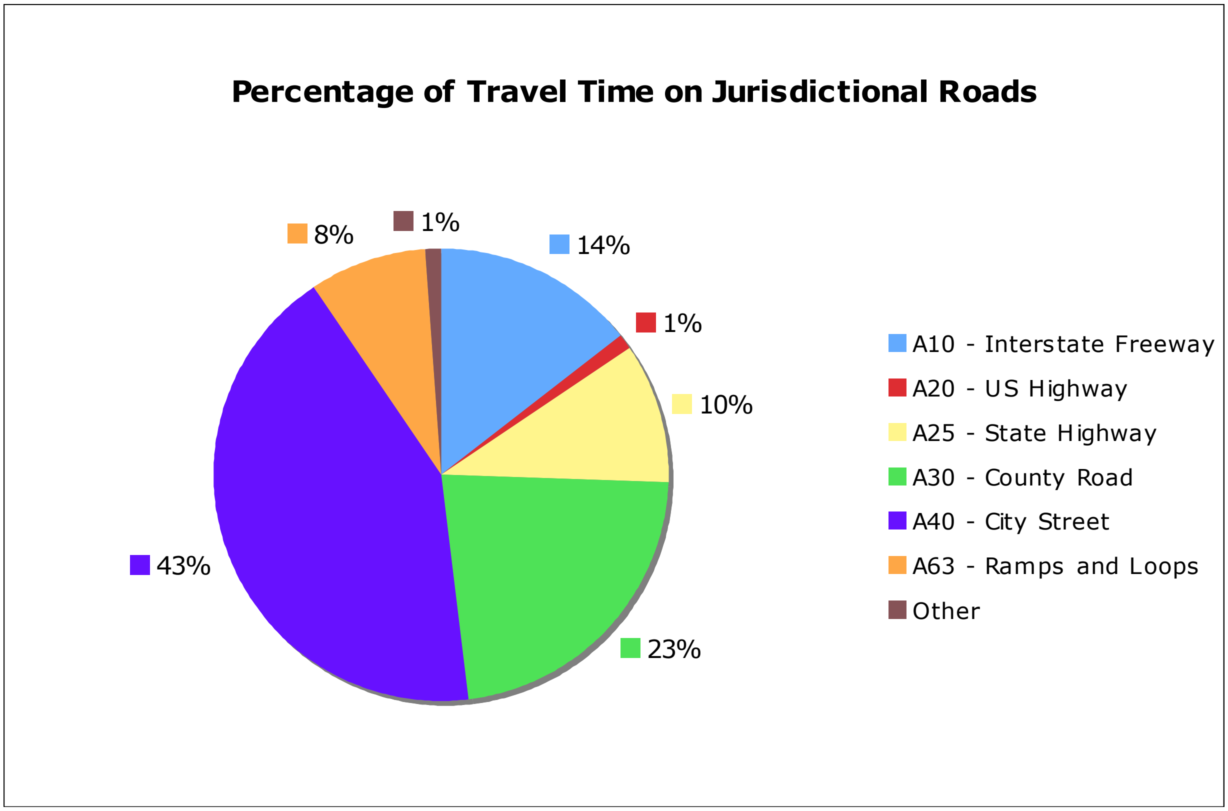

FIGURE 4 Percentage of travel time on various classes of road (all subjects).

The data indicates that a majority of travel time is spent on city streets. County roads were the second highest category for total time spent, while interstate freeways were third. This could be due to a number of different variables such as differences in speeds and congestion levels, differences in network structure by location, and possibly user preferences for route types.

The amount of travel time spent on various classes of roads appears to depend in part on a subject's home location. Subjects that lived and worked in the same jurisdiction tended to use local roads for a higher percentage of their overall travel, as is indicated by the comparison of Figures 5 and 6.

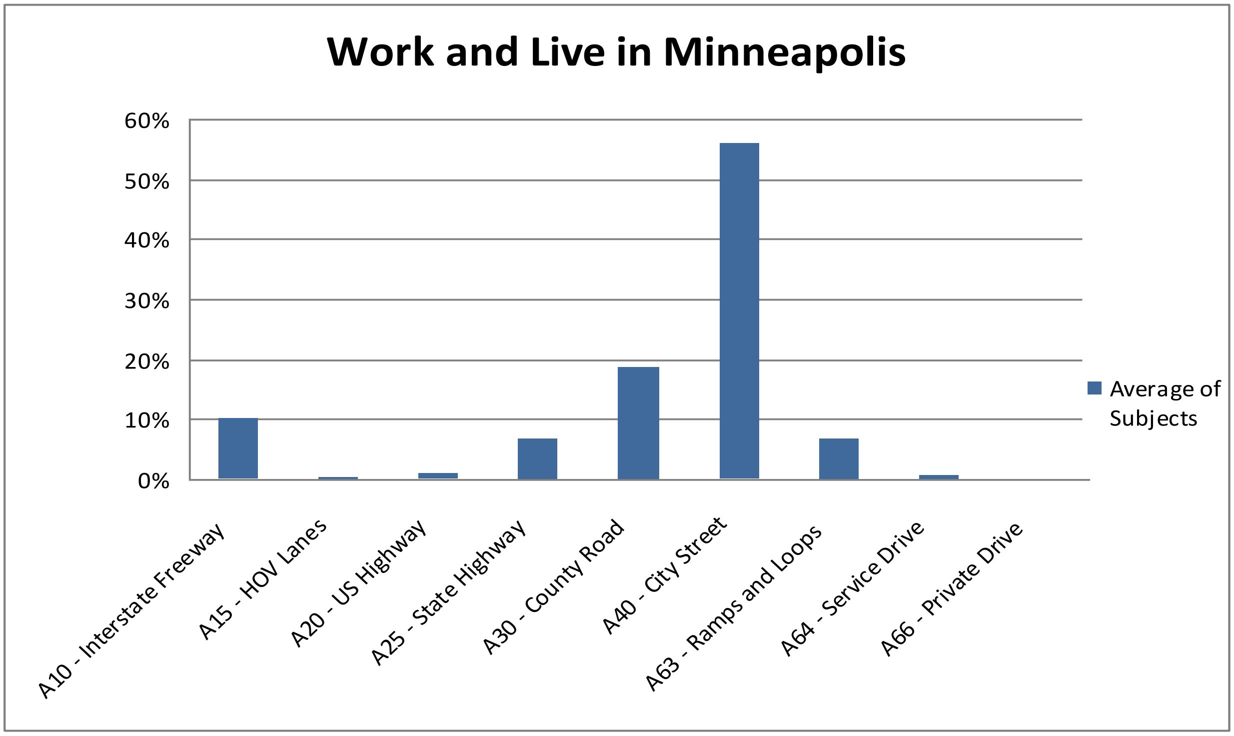

FIGURE 5 Percentage of travel time on various classes of road (Minneapolis residents).

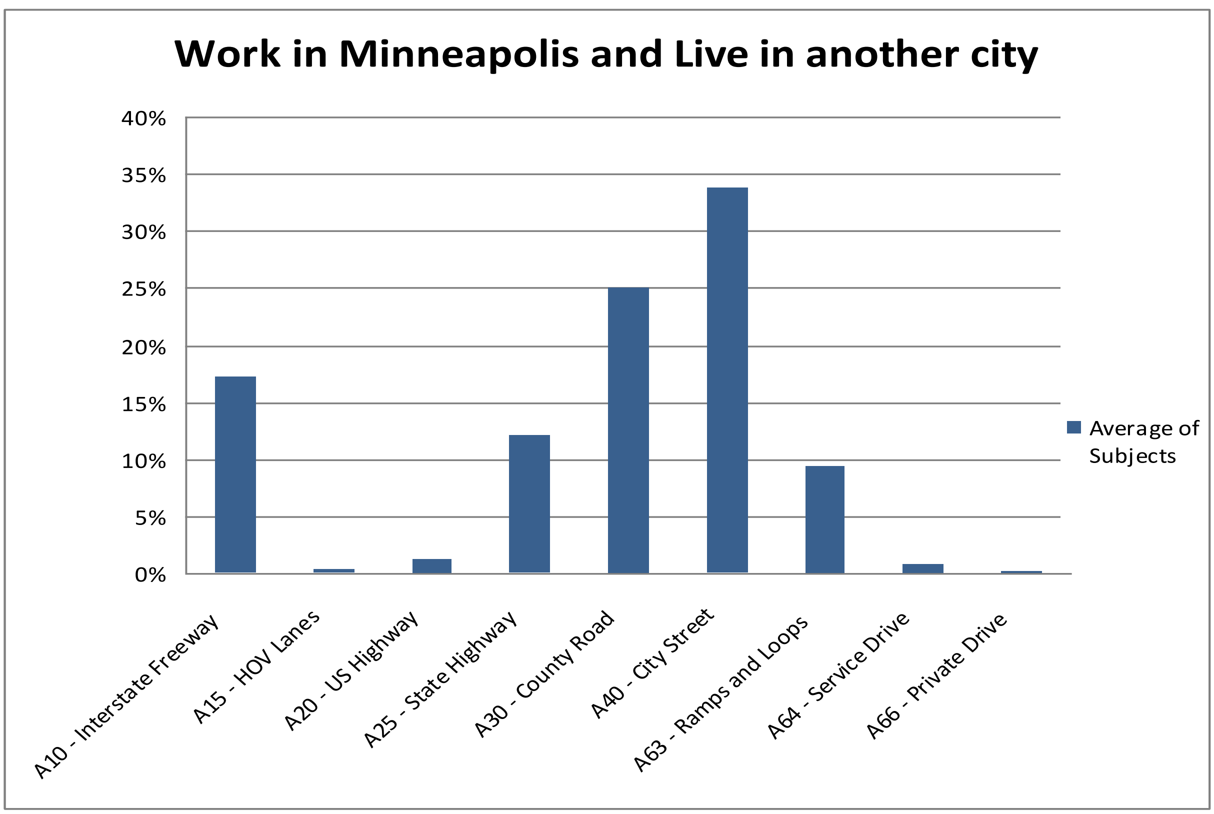

FIGURE 6 Percentage of travel time on various classes of road (suburban residents).

The breakdown of home location and travel time spent on city streets and county roads varies by subject, but in general reveals an association between higher percentages of local road use and having one's home and workplace in the same jurisdiction. Subjects in the sample living and working in Minneapolis spent over half of their travel time on city streets and just under 20 percent on county roads. Interstate highway travel accounts for about 10 percent of travel time. For subjects who work in Minneapolis but reside in another jurisdiction, considerably less travel is on city streets (about one-third), while slightly more time is spent on county roads relative to people who both live and work in Minneapolis (about 25 percent vs. 20 percent). Also, a higher percentage of travel takes place on interstate highways for non-Minneapolis residents relative to those who live and work in Minneapolis. The picture that emerges is one of travel being more localized for people who are both employed in and live in the city of Minneapolis relative to others.

Table 1 further summarizes the distribution of travel time by level of government responsible for road ownership. Thus, several of the categories used previously are collapsed into more inclusive categories, such as interstates and U.S. highways being collapsed into a single, "federal" category. Also, city streets and county roads are collapsed into the "local" category.

TABLE 1 Percent of travel by level of government responsible for road ownership.

	Work and Live in Same Jurisdiction	Work and Live in Separate Jurisdictions
Federal	11%	18%
State	7%	12%
Local	81%	68%

One percent of travel time is spent on a combination of service drives, private roads, and HOV lanes

The results in Table 1 indicate that subjects spend a majority of time on local streets in their own jurisdiction if they also work in that jurisdiction. All subjects' results were averaged by home location and revealed disparities in travel time on different classes of roads depending on whether a subject worked and lived in the same jurisdiction. A subject is more likely to rely heavily on local roads if they live and work in the same jurisdiction. Subjects that live outside of their working jurisdiction spend a higher percentage of their travel time on higher-level (state and federal) roads.

The local nature of most travel links the user directly to the service they pay for in local taxes. If a user spends more time on local streets in a city other than their own, a free-rider problem arises. These users are not directly paying for the local streets that others fund through property taxes and assessments. This issue may become more contentious as the amount of funding required for maintenance of county roads and city streets increases due to inflation in construction costs (*6*). Increasing pressure on local governments to construct, operate and maintain roads at a high level of service will most likely increase the amount a local government is required to spend.

Some of this pressure could conceivably be relieved through the provision of intergovernmental transfers. For example, in Minnesota state general-purpose aids are designed to equalize the disparities between local governments in public service provision. Property taxes pay only for a portion of the construction and maintenance of local roads. Under state user tax distribution formulas, both counties and cities of a certain size (5,000 or more residents) receive a share of the proceeds from state-level taxes on motor fuels, vehicle registrations and vehicle sales. In 2002 dollars, the average Twin Cities homeowner received $206 in local road services while paying only $145 in property taxes; they pay about 70% of the road value in property taxes (*7*). State aid provides relief for cities and counties that would otherwise wholly fund local roads with local taxes.

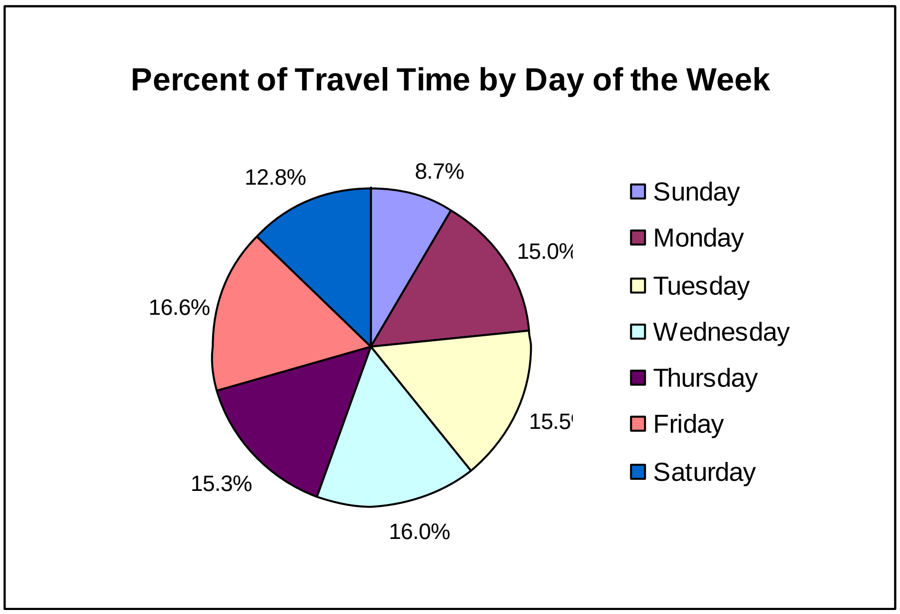

FIGURE 7 Percentage of travel time by day of week.

The amount of travel time by day of week could indicate a difference in use of roads between weekdays and weekends. Figure 7 summarizes the distribution of weekly travel time by day of week. The percentage of travel time for subjects by weekday suggests that travel time is relatively consistent during the weekdays. This number holds steady throughout the week but indicates that less travel is engaged in on Saturday and particularly Sunday. Many subjects in the sample, however, showed a peak in travel on either Friday or Saturday. The increased level of travel on these days may reflect an increase in the flexibility of work arrangements, or simply greater weekend travel due to longer, recreational trips to farther destinations.

CONCLUSION

This paper sought to provide evidence on the extent to which travel is localized, using GPS-based data on a group of subjects' travel times on various types of functional classes of roads. The analysis revealed that subjects that live and work in the same jurisdiction tend to spend a higher percentage of their travel time on lower-level roads in the network, namely city and county roads. Subjects that lived and worked in separate jurisdictions tended to spend more of their travel time on roads owned by higher-level jurisdictions as a part of their commute.

The present work could be extended further to summarize the respondents' travel by jurisdiction. That is, given a "home" jurisdiction (a city, county or even state), one could calculate the amount of travel that takes place within each level of jurisdictional boundary. As the size of the home jurisdiction increased, one would expect more travel to be considered local. This finding would be more valuable, since it would provide the ability to more closely link travel to a particular jurisdiction, rather than relying on road class as useful but imperfect proxy. This type of analysis seems feasible, given that political jurisdictions can be represented in geographic information systems as simple polygons. Indeed, this is the type of representation that is being used in some prototype GPS-based road user charging systems (*8*). If this type of system were demonstrated to be feasible, it could potentially solve many of the current problems associated with local road finance (*9*).

Yet, the current structure of local road finance still has many useful features. Local forms of taxation, like property taxes and special assessments, are relatively easy and costless to administer. As the current study has indicated, a large share of travel seems to be quite localized, with the implication that the users are broadly representative of those who bear the tax burden. While some non-users may also be using local roads for which they are not charged, the effect is usually reciprocal, with travelers typically being able to free ride on use of local roads in neighboring jurisdictions. Also, with some modifications to financing arrangements, issues with temporal and spatial free-riding can be minimized (*10,11*).

There are also shortcomings to this approach. To the extent that local roads are congestible (and many collectors and minor arterials surely are), fixed charges will not be of much use in managing congestion. Likewise, the efficiency argument for property tax financing is weak in the case of heavy vehicles, which may impose disproportionately higher damage costs. Again, the ability to charge users from outside the jurisdiction is effectively prohibited, though as mentioned previously that is a rather minor issue. Lastly, the price signal to users regarding the cost of road provision is rather weak, especially in regards to the variable costs of local road provision.

Local roads do have some of the characteristics of public goods, indicating that perhaps there is some justification for continuing to finance them at least in part through fixed charges. Yet, there does seem to be some scope for efficiency gains in tailoring charges to more closely reflect the costs that users impose on local road networks. Whether this takes the form of a GPS-based road pricing system, a local version of the motor fuel tax, or some other form of local taxation, knowledge of the characteristics of local travel behavior seems like a good foundation on which to design such a system of charges.

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