Manage energy/environmental footprints of travel: A proposed solution/methodology

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December 2017

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Abstract

Congestion is a growing challenge in major urban areas worldwide; a challenge that imposes enormous social and private costs to society. Despite these substantial costs, our knowledge is limited about how transportation users value choices that can reduce fuel consumption, greenhouse gas (GHG), and criteria pollutant emissions (PM2.5, NOx, CO, etc.). In this regard, I proposed the *advanced traveler general information system (ATGIS), a scheme that can estimate/provide travelers with travel cost data that they currently do not have.* In this paper, I explain the steps required to test, examine, and develop such a scheme for a metropolitan area.

Keywords – Advanced traveler information systems, emissions costs, fuel costs, travel behavior, and social/private costs of travel.

Background

Transportation systems are formed by complex interconnected components. On one hand, the search for a policy/strategy that can serve as a silver bullet is hard to accomplish/justify/use [Rouhani et al., 2015a]. On the other hand, saving a small improvement in the transportation network of a major metropolitan area [Poorzahedy and Rouhani, 2007] can offer substantial energy savings, can reduce travel time losses, and can decrease exposure to unhealthy travel-related emissions. The question is then how policy makers can promote such a change.

To answer this question, I propose the advanced traveler general information system (ATGIS), a system that estimates/provides travelers with their variable travel cost data. ATGIS is a more advanced version of the advanced traveler information system (ATIS), which provides real-time travel time information, only, to users [Mid-Ohio Regional Planning Commission, 2009].

In practice, fuel consumption and emissions costs have a minor effect, if any, on travelers' behavior. The fundamental reasons are that they do not perceive fuel costs as out-of-pocket costs [Hughes et al., 2008; Anas et al., 2012], and they usually do not have intelligible information about their emissions costs [Rouhani and Gao, 2014]. An information communication system could provide such information to users [McCord et al., 1997] by calculating and providing effects to different user groups [Yang, 1998; Rouhani and Zarei, 2014].

I originally proposed this innovative scheme in a previous study and showed (with a simplified modeling framework) that with an ATGIS for Fresno, CA, the system-wide travel costs could be reduced significantly by mitigating travel demand and by promoting the minimum general cost routes/modes (adding fuel and emissions costs to time costs) [Rouhani and Gao, 2014].

The ATGIS has two major functions: (i) estimate variable (rather than considering a constant/fixed emission rate) travel time, fuel consumption, and greenhouse gas (GHG) and criteria pollutant emissions on all parts of a transportation system, and (ii) provide these variable costs to users for alternative routes/modes of transport. Figure 1 illustrates the potential outputs that such a system can offer to drivers for an origin/destination (O/D) and how a least-general-cost route (Route 1) might be overlooked when using a system (Google-map for example) that focuses on travel time only.

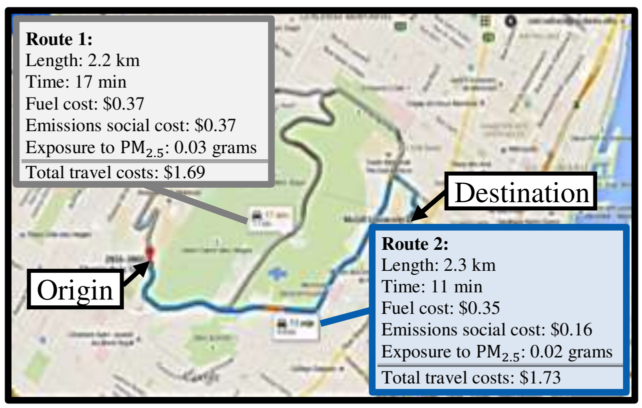

Figure 1 Illustration of information provided to users

In fact, the shortest travel time paths/modes and the least general cost paths/modes could be different, which leads to inefficient travel behavior without the relevant information. In addition to this inefficiency, two other important advantages of implementing an ATGIS over other transport management policies (such as increase in fuel taxes) are (*i*) no potential public opposition since it only provides information, and (*ii*) costs less, generally.

The key objective of this research is to determine the steps required for examining the feasibility of an ATGIS for a metropolitan area. The proposed research will also play an important role in efforts to estimate transport-related GHG emissions from major cities worldwide and to calculate annual national GHG inventory to meet international UNFCCC obligations [Madani et al., 2011; Rouhani, 2013]. The ultimate product of the research in the future will be an ATGIS mobile application offered to transport users.

Approach

In the short-run, my proposed research will provide insights into how users perceive fuel and emissions costs, and how the information could change travel behavior. In the long run, I plan to develop an ATGIS for a large metropolitan (urban) area to inform and conduct outreach to the public and thereby induce a progressive change in travel behavior. A change that could increase social welfare for the whole society and could mitigate GHG emissions from the transport sector [Rouhani et al., 2016; Rouhani, 2016a].

To achieve the above research goals, I propose a three-task procedure. First, I will estimate fuel consumption and emissions costs for each trip and each travel alternative based on recurrent congestion conditions, and then I will develop the modeling formulations required for the impact analysis. Next, I will examine the effects of implementing an ATGIS on the transportation system of interest and will provide a guideline regarding implementation, practical issues, and operational requirements of such a scheme. Finally, my ultimate goal is to provide a prototype mobile application that uses personalized vehicle/driver characteristics to offer the detailed information to the ATGIS users. Figure 2 illustrates my proposed flow of tasks.

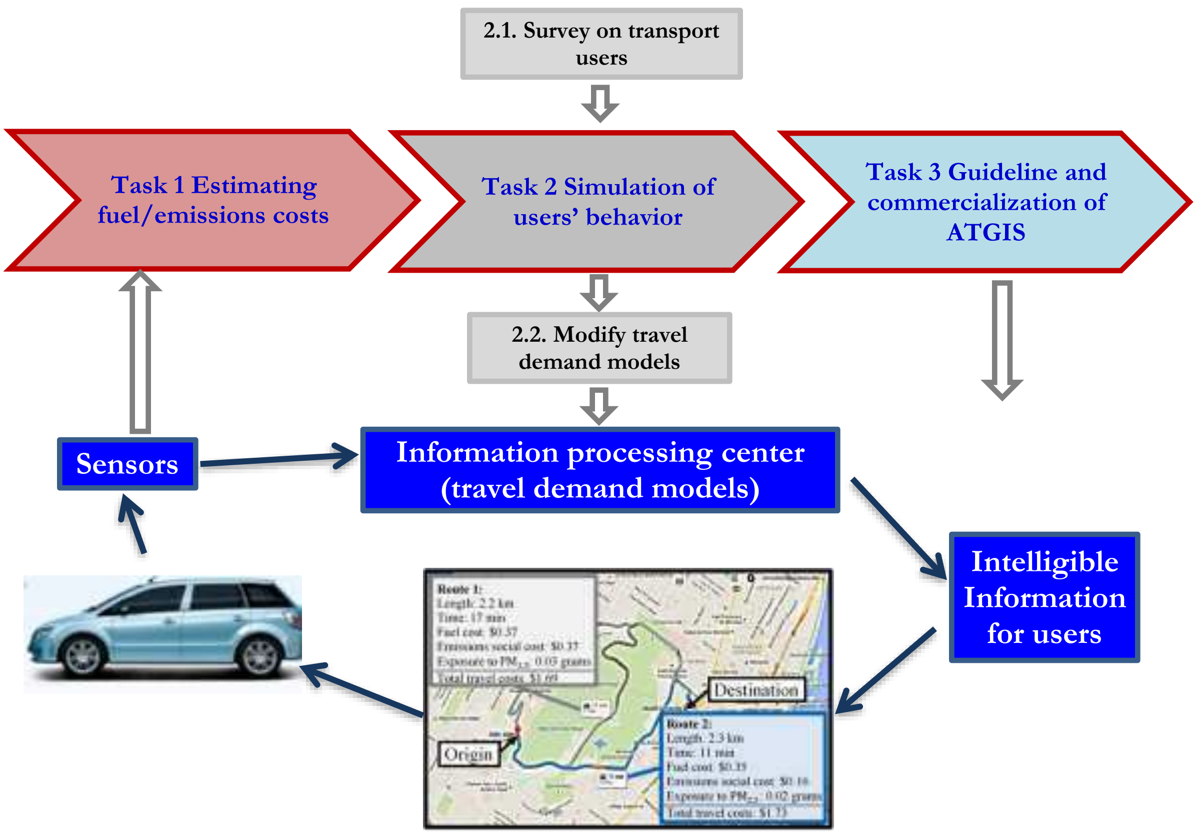

Figure 2 Illustrative design of an ATGIS with the proposed tasks

Task 1. Estimation of variable costs

The first step is to estimate fuel consumption and emissions costs under various conditions (e.g., vehicle types, traffic intensities, pollution levels, fuel price levels, etc.). Transportation researchers generally agree that drivers should be charged for the social costs they impose on the society [Rouhani, Knittel, and Niemeier, 2014; Rouhani et al., 2015b] in order to promote a more efficient and environmental-friendly transportation system [Levinson and Gillen, 1998; Anas and Lindsey, 2011]. Despite the crucial impacts of such social costs, we lack research projects that estimate varying fuel and emissions costs of driving, particularly on disaggregate levels (for each driver considering her/his personal characteristics).

The common assumption in many studies is that fuel consumption and emissions are functions of speed or, basically, functions of traffic volumes per capacity. Even knowing this, it would be extremely difficult for a user to guestimate her/his associated energy and environmental costs. In practice, many factors, other than speed, could impact these costs, including weather, road conditions, vehicle make and model, air pressure in the vehicle's tires, and AC or heater usage. I have already studied and calculated these costs for California in a previous study [Rouhani and Beheshtian, 2013].

Figure 3 shows how CMEM model determines fuel consumed by a typical compact vehicle. By employing the most advanced modeling techniques, we could estimate more realistic energy and emissions inventories, considering various traffic and weather conditions and vehicle types. Combining emission-inventory models to estimate energy consumption (for example, EPA's MOVES) with modified travel demand models (see the next step), we can estimate time, fuel, and emissions related to alternative travel routes/modes. The estimation requires inputting vehicle fleets and specific conditions of the urban area under study into MOVES. Then, we need to validate the fuel consumption and emissions estimates, using vehicle telemetry recorders, which provide information about vehicle performance (RPM, acceleration/deceleration, and speed), under various driving cycles. Installed on a few representative vehicles, these recorders can provide information about local driving behavior (conditions).

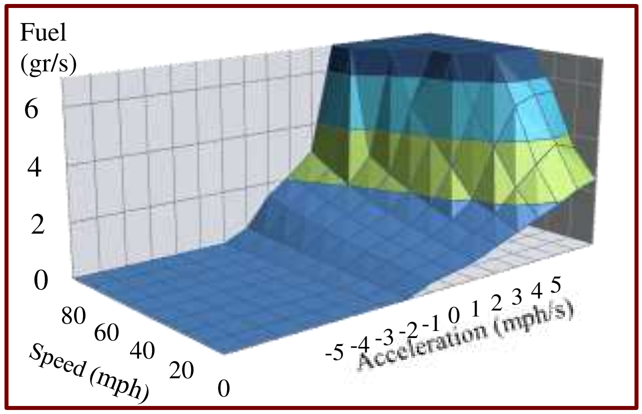

Figure 3 Velocity/acceleration-indexed fuel consumption [12]

This task will provide detailed and accurate estimates of the private and social costs of fuel and emissions under various travel choice decisions. For instance, we could provide behavior-based estimates of the private/social emission abatement cost, in units such as $/gr or $/km (for GHG emissions and Criteria pollutants such as PM2.5, CO, and NOx). These measures are invaluable inputs, not only to inform users about them, but also to guide transport, energy, and environmental policies [Lin et al., 2009; Mirchi et al., 2012; Madani et al., 2014; Rouhani and Beheshtian, 2016]. The estimation of the health-related costs of criteria pollutants will be based on how much they could decrease the lifetime of transport users, and the private/social costs of GHGs will be based on their marginal costs of abatement.

Task 2. Simulation of users' behavior

Task 2.1. Analysis of drivers' response to energy and environmental information

The next goal is to study the behavior of users and the modeling required for simulating users' travel choices when perceiving fuel and emissions costs. To this end, we need to collect data on attitudes toward the gains/risks associated with less energy-intensive choices, exposure to emissions, and willingness to pay to offset energy/environmental footprints.

In environmental economics, the consumers' willingness to pay either for renewables [Rouhani et al., 2016b] or for energy-efficiency gains is becoming a more relevant research topic [Brouwer et al., 2008; Scarpa and Willis, 2010]. In this proposed project, I propose conducting a stated-preference survey, based on a discrete choice experiment (DCE) [Rose, and Bliemer, 2009; Avineri and Waygood, 2012], including different treatments on how to provide information about emissions to users, and on the possibility of offsetting those emissions. With the stated preference data (choice among various hypothetical travel scenarios/alternatives), we could specify utility functions to explain the mechanism that travelers process the information and make decisions. We should complement the travel behavior analysis (survey) with installing mobile applications on a few vehicles (to track their travel choices) and two laser-based sensors on few representative stations. The mobile applications can provide data about the actual behavior of drivers when they are informed by an ATGIS. Traffic simulation software programs can further simulate the driving behavior of ATGIS's users and analyze their travel behavior when informed.

Task 2.2. Modification of existing travel demand models

This task will develop a clear modeling procedure to simulate users' behavior both before and after the research team implements an ATGIS. We need to understand how users estimate a more general cost that incorporates fuel/emissions costs in addition to travel time. Travel demand models typically assume that travel time is the only factor used for choosing among different paths (i.e., that all users choose the least-time path(s)) [Rouhani and Zarei, 2014]. To estimate the behavior, we could use and modify the existing travel demand (transportation planning) models [Rouhani, 2015]. The modification includes general travel cost considerations for examining users' behavior on aggregate and for analyzing the impacts of environmental management policies/schemes like the ATGIS.

To this end, we should incorporate the perceived fuel consumption and emissions costs (estimated from the previous task) into travel demand modeling. This modification requires the use of a general cost equilibrium (GCE) model [Rouhani, 2012; Rouhani and Gao, 2016]. I have conducted numerous studies on how to incorporate a more general 'cost of driving' concept into travel demand modeling [Rouhani et al., 2013; Rouhani and Niemeier, 2014a,b]. My proposed approach is to modify the existing travel demand models by including the multi-user general equilibrium (MUGE) concept, in which one user group has precise information on the fuel and emissions costs of possible routes (i.e., users of the ATGIS), and the other group (non-ATGIS users) randomly perceives these costs, if any, and therefore chooses routes mainly based on their travel time [Rouhani and Zarei, 2014]. Incorporating a stochastic feature in link (road segment) cost estimation rather than in route choice, we could employ a new stochastic modeling approach (through Monte Carlo Simulations) that uses existing travel demand models without major changes in modeling [Rouhani and Gao, 2014].

The inclusion of fuel consumption is significant for travel demand calculations and also for understanding travelers' behavior when choosing a route/mode. As mentioned before, the shortest time modes/paths are not the same as the least general cost modes/paths. Even though the fuel cost might not be completely perceived precisely by users, e.g., when fuel prices are really low, transport modelers should reconsider the current travel demand models' assumption by including perceived fuel and emissions costs into modeling. The major challenge is how to incorporate these costs.

Task 3. Estimate system-wide impacts of ATGIS

The key public policy question is: what would be the overall impact of an ATGIS on a transport system's performance? The performance should cover various measures such as the public transportation share, total travel time and fuel consumption, system-wide congestion, total emissions [Rouhani and Niemeier, 2014a], route/mode choice [Ahn et al., 2008], and social equity (considering various user/resident groups) [Gao et al., 2011].

We need to consider many factors in our modeling, including the initial perception of users regarding their fuel and emissions costs (prior to implementation of the ATGIS), the travel demand level (peak vs. off-peak demand), the market penetration of the ATGIS (percentage of ATGIS users), the accuracy of the information provided, etc. Using the modified travel demand model's traffic flow outputs under various ATGIS assumptions/design, we can determine the overall system-wide impacts on travel time, fuel consumption, GHG emissions, and Criteria Pollutants. The analysis will lead to policy insights into how to design an ATGIS (e.g., the instrument, the type of information, the metrics, the price of providing the information to be used if any, etc.), along with the conditions that could lead to a successful ATGIS.

These insights are extremely valuable because from other aspects, the ATGIS implementation would be less costly, would encounter less political and public opposition, and would provide long-term improvements in travel behavior that no other policy could offer.

Next steps: Develop and initiate ATGIS commercialization

I plan to examine the potential of commercializing an ATGIS mobile application for a major metropolitan area. The outputs from the previous tasks will offer insights into the design of the mobile user interface. To my knowledge, no mobile application in the world can provide detailed travel cost information I proposed in this paper, specifically in real time (could be done using cloud-computing in real time).

Conclusions- Social benefits

The direct benefit of the research is related to the tools and results generated by this research, which will help municipal governments, local environmental and information agencies, and also private companies to understand travelers' behavior with respect to their energy and environmental footprints. In the long run, this research could lead to a progressive change in travel behavior. Another important avenue to use the research outputs will be to share the findings with the public and possible private stakeholders through meetings, seminars, and workshops (educate the mass educators).

The question of commercializing the ATGIS will depend on how the research outputs will be. This step requires extensive discussions with various potential customers (Uber, Google, Truck companies, etc.) However, ATGIS has the potential to reduce social costs of travelers in urban areas, where travel cost (time, fuel, emissions, pavement, health, safety, etc.) reductions could save millions of dollars for major metropolitan areas in the world.

Copyright Note

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