Travel-sharing in multimodal systems: a behavioural modelling approach

Francesco Viti, University of Luxembourg (UL)

1. Problem and research questions

The freedom offered by cars is an extremely valued asset for the drivers. However, excessive car usage leads to congestion and related emission problems. Car occupancy rates in Western Europe are nowadays stabilizing around 1.54 persons per vehicle, and these values get down to 1.1 if only commuting travels are considered [1]. Sharing travels (carpools, carsharing, etc.) has been often presented to the travelers as an effective way for solving energy and emission problems already from the energy and fuel crises since World War II. Sharing travels and traveling modes (cars, bikes, etc.) are an effective way to reduce the number of vehicles on the road by increasing occupancy rates, contributing to relieve networks from congestion, and in turn saving fuel and reducing pollution. This is one of the reasons why more and more attention is given to travel sharing services in the last years, both from research and from the public and private service providers. Promoting collaborative and shared mobility is a goal of critical importance for both the society and for the individual traveler. Societal benefits are expected in terms of total cost savings and better utilization of the road capacity through higher vehicle occupancies. With the current world's economic crisis, fuel costs and other car-related taxes have increased dramatically, and owning a car is considered by a great portion of the travelers a luxury. With travel sharing options, car users have the possibility to share car expenses such as fuel costs and tolls, with great reductions of individuals' and total system costs. However, these systems will effectively attract car users only when they will be able to substitute the flexibility and comfort of the car in their weekly activity-travel agenda.

One of the main drivers of this research is therefore to acquire insight into the mobility needs and activity-travel patterns of the users, in order to design solutions offering the flexibility and comfort offered by privately owned cars with equally flexible, but cheaper and more sustainable collective transport systems.

Different forms of sharing concepts have been proposed in the past, both in the form of private and public services, and involving different modalities (cars, vans, bikes). We ma subdivide these services into *travel-sharing* and *mode-sharing* systems. While in travel-sharing (e.g., carpool) the main requirement is the joint use of, e.g., a car (so traveling options such as routes and departure times must be, at least partly, in common), in mode-sharing the mode (car, bike, etc.) has a concurrent use, i.e. the requirement/target is not to increase occupancy rates by partly sharing travel choices, but to intensify the car usage.

Despite the existence and fast market penetration of travel-sharing services and the development of optimization algorithms capable of handling the complexity of matching rides, long run assessments are not yet reported. Exceptions include studies that evaluated travel-sharing matches of individuals using different preferred departure times ([2-3]), or that quantified the reduction in travel expenses when sharing rides [4-6]. The impact of carpooling on traffic is widely accepted and this concept is very often incentivized by travel management solutions such as the US high occupancy vehicles (HOV) lanes, or in the form of dedicated parking spaces. Carpool services can be offered on a large scale, sometimes in collaboration with companies, in the form of, e.g., vanpools, or as demand-responsive solutions such as dial-and-ride, which often complement public transport services in areas where the demand is not sufficient or regular to justify a conventional scheduled transport service.

2. Methodology, research strategy

In this paper, a general modeling framework is proposed using a discrete choice-theoretical approach with the following main features:

1. A given population of users can decide in which of the three groups he/she wants to belong depending on the specific activity characteristics and other players' decisions;
2. A Nested Logit model is adopted to evaluate the costs and decisions of each group in an asymmetric way, to account for the close link between car-suppliers and passengers costs;
3. A policy maker can define whether to introduce incentives or pricing in the system to influence players' decisions, thus achieving a given system performance target.

The algorithm developed to solve the mathematical problem is challenging in many aspects, for instance existence, convergence and uniqueness of equilibrium is far from trivial, given the fact that travelers characteristics change when they switch group. Great attention is also given to the calculation of the externalities, i.e. changing group for instance from car-sharer to solo-driver increases his/her own costs in terms of fuel consumption for the sake of higher flexibility but also may reduce the opportunities for passengers to find a car-sharer and then force them to take their own car, thus increasing car usage and eventually congestion, which then will affect the same solo-driver who will experience extra travel time.

The main goal of this paper is to systematically identify the conditions for which ridesharing can become a competitive mode, and which policies can be proposed to facilitate the penetration of ridesharing in a transportation system. To make this analysis possible in a quantitative way, we need to develop a specific model for this transportation system. This is the main scientific contribution of this paper, together with the sensitivity analysis of some of the most relevant parameters of the model.

3. Major findings

Figure 1 gives an idea of how this model can be used to design and assess a travel sharing service. The example refers to a one-route case, where there are three types of users: *solo-drivers*, who do not want to participate to the travel-sharing option, *suppliers* who offer their car to *passengers*. Ridesharing (both drivers and passengers) participants have extra costs wrt solo drivers, namely loss of flexibility costs (detours, change in departure times,…) and loss of comfort. On the other hand they share travel expenses (fuel, tolls, etc.).

If travel expenses are not equally shared between driver and passenger (or at least is not in the range [50-60]% paid by the passenger, the total cost at equilibrium will dramatically rise, as more ridesharing participants will prefer not to participate to the ridesharing campaign. Similar results in the study have been found for instance using different incentives paid by the government, as well as different elasticity of users towards detours and loss of flexibility.

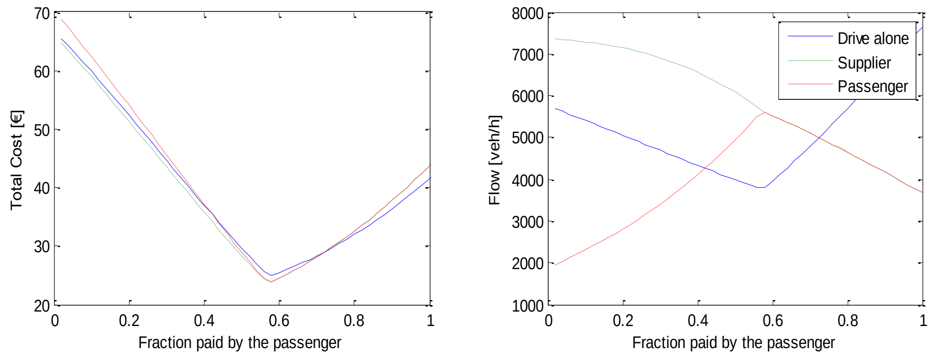

Figure 1:Impact of different fraction of the travel costs paid by the passenger. Left picture shows the total travelers' (generalized) cost by group at equilibrium, while the right picture shows the different fraction of the travel costs paid by the passenger

This is a highly simplified example, which served as proof of concept. The challenge of this new methodology is to model the structure of the decision making in a more realistic way, i.e. the travelers can decide whether to participate or not in the system, which means the users' classes are not predefined but are a result of the equilibrium of the system, and also the matching probability must be considered explicitly.

4. Takeaway

The target of this research is to find the key factors that incentivize modal shifts towards eco-mobility options, and in which form information and services should be provided to the users in order to support them with the most efficient choices. Without sufficient insight into these research aspects there will be the risk to develop services that will not manage to shift part of the demand especially from less sustainable alternatives, primarily the car mode, to collective and more eco-friendly transport options. Acquire insight into travelers' behavior and values for travel sharing modes, learning and feedback mechanisms able to absorb and extract the relevant activity travel patterns is necessary, since the efficiency of these modes of transport strongly depends on how they are organized, and in turn this can be achieved only knowing the activity-travel agenda of the users. By acquiring insight into how travelers value cooperative mobility options in relation to more conventional modes of transport, we expect to have a unique database that will allow to optimize the structure and organization of these new services, e.g. to advice when to incentivize ridesharing systems, or when bike- or car-sharing options would be more appealing and where to strategically locate the stations. Moreover, the research is expected to result in a new behavioral modeling theory which will enable transportation planners to evaluate different scenarios involving travel- and mode-sharing solutions.

5. Keywords

Ridesharing, Behavioural modelling, Policy, Equilibrium, Sustainability

References

1. European Environment Agency, 2010. http://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles/occupancy-rates-of-passenger-vehicles-1
2. Amey A. (2011). Proposed methodology for estimating rideshare viability within an organization: application to the MIT community. TRB Annual Meeting Conference 2011.
3. Baldacci R., Maniezzo V., Mingozzi A. (2004). An exact method for the car pooling problem based on lagrangean column generation. Operations Research, 52(3):422–439.
4. Geisberger R., Luxen D., Neubauer S., Sanders P., Volker L. (2010). Fast detour computation for ride sharing. Proceedings of the 10th Workshop on Algorithmic approaches for transportation modelling, optimization, and systems, vol. 14, OpenAccess Series in Informatics , pp. 88–99.
5. Agatz N.A.H., Erera A., Savelsbergh M.P.W., Wang X (2011). Dynamic ride-sharing: A simulation study in metro Atlanta. Volume 45, Issue 9, November 2011, Pages 1450‑1464.
6. Kleiner A., Nebel B., Ziparo V. (2011). A mechanism for dynamic ride sharing based on parallel auctions. Proceedings of the 22nd International Joint Conference on Artificial Intelligence (IJCAI).