Quantifying the Benefits of Taxi Trips in New York through Shareability Networks

by Paolo Santi, Giovanni Resta and Carlo Ratti

Shareability networks demonstrate that more than 95% of taxi trips taken in New York can be shared with minimal passenger discomfort.

The increasing pervasiveness of digitalized information has unleashed unprecedented opportunities for understanding aspects of human behaviours and social lives, including individual mobility. An enormous amount of digital traces are now obtainable from a range of sources (e.g., cell phone records, taxi GPS traces, etc.) which allows human mobility to be analyzed to an extent that would have been inconceivable several years ago [1]. Although this raises privacy concerns, this “big data” era offers unique opportunities to improve understanding around human mobility needs and, hence, improve transportation system efficiencies.

The goal of this project, performed in cooperation with a team from the MIT Senseable City Lab (Michael Szell, Stan Sobolevsky and coordinated by Carlo Ratti), is to quantify the benefits of taxi sharing in New York City (NYC). Our analysis was based on a dataset which captured all the taxi trips taken in NYC in 2011 (over 150 million trips). For each trip, the dataset captures the pick-up time and location and drop-off time and location.

In this project, we posed the fundamental question, “How many taxi trips can be shared in NYC?”. To answer this question, the intrinsic trade-off between shareability opportunities and passenger discomfort must be considered: the longer a passenger is willing to wait for a shared trip, the higher the sharing opportunities. This tradeoff is made explicit by the novel notion of a shareability network in which we have defined the model sharing opportunities: each network node represent a separate trip and links between two nodes represents a sharing opportunity between those trips. The criterion used to determine whether two trips can be shared is based on spatial and temporal constraints. For two trips, \( T_1 \) and \( T_2 \) a sharing opportunity only exists if a route connects the respective pick-up and drop-off points such that both passenger groups can be picked up and delivered to their destinations with a

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delay of no more than \( \Delta \), where \( \Delta \) explicitly models the tradeoff between passenger discomfort and shareability. A higher value of \( \Delta \) results in a denser shareability network and corresponds to more opportunities for trip sharing.

Using a shareability network allows an optimal solution to be found to an otherwise computationally intractable problem. Shareability networks impose a structure to an otherwise unstructured, immense search space by constraining the number of trips that can be shared (up to \( k \), where \( k \) is a user-defined parameter, set to 2 or 3 in this study) and considering only static trip sharing. This term means that once two or more trips are combined into a shared trip, the combined trip is served by a single taxi that cannot be rerouted for further sharing. Once the search space has been reduced and structured, an optimal trip sharing figure can be computed in approximately 0.1 seconds by running a computationally efficient maximum matching algorithm on the shareability network (10,000 nodes and 100,000 links) [2] using a standard Linux workstation. Thus, our proposed methodology is suitable for real-time implementation.

A notable result of our analysis is that constraining the search space to reduce computational complexity does not impair trip sharing opportunities. The percentage of shareable trips is shown to increase with the delay parameter and we found it was as high as 95% if a delay in the order of five minutes was permitted. Thus, the vast majority of taxi trips taken in NYC can be shared with minimal passenger discomfort.

We also investigated the effects of the sharing penetration rate which accounts for the true fraction of passengers that want to use a shared taxi service. We are extending this analysis to other cities (Singapore, Vienna, San Francisco, etc.) to investigate whether similar sharing opportunities arise in other urban contexts.

References:

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Integrated Electric Vehicles Sharing and Pooling Mobility Solutions for Smart Cities

by Marie-Laure Waterin, Gérard Arnould, Hedi Ayed and Djamel Khadraoui

Integrating public transport systems with individual car-and-ride sharing concepts is considered as an attractive, convenient and emissions reducing mobility concept in the frame of Smart Cities. The pooling of mobility services is considered to be an important enabler of the Smart Cities’ concept, especially with regards to achieving flexibility and integration with existing transport modes (mostly public transport). Even if the levels of user acceptance towards new smart sustainability concepts are still challenging their uptake, it is important to address ICT-related challenges to ensure adaptive solutions are found to reduce complexities. This is especially relevant in the case of electro-mobility related systems.

Tudor, via its mobility projects, has developed a concept for sharing electric vehicles (EVs) and cross-company optimization solutions. This concept aims to increase sustainable resource productivity by sharing EVs across various companies or organizations. This approach is likely to increase the overall usage of each vehicle but reduce costs per kilometre and users. During the work-day the vehicles are used for professional activities, but for the rest of the time, they become a collective resource that can be placed in carpooling mode.

Such a combined usage presents significant algorithmic complexity and solving this so that an e-fleet can be used for public and professional purposes is challenging. The actual concept was evaluated via simulations of different scenarios using MATSIM, A multi-agent approach was considered, where each agent represented a traveler. A previous national project, Moebius [1,2], provided the simulation data. The main objectives were to validate the concept of combined car-sharing and carpooling from the perspective of resource optimization and find strategic charging locations [3].

The EV sharing service concept presents users with a hop-on, hop-off system that has demand responsive fleet management (which includes predictions of what locations are going to have the highest user needs). The system’s resources (e.g., EVs, e-bikes and associated infrastructures) are mutualized along with an information system, the service and, in future, public transport services.

The goal of the mutualisation concept is to maximize the use of vehicles across the day (both work and recreational times) but decrease the residual cost of the EVs. This can be achieved with an optimization algorithm [1] that can minimize the required number of vehicles at all times, based on planned usage (determined using statistics and simulation tools), real-time demand, and third party companies that can manage the fleets (by zones) with new business models. EV sharing can also be associated with other transport means such as car-pooling and public transport.