Dynamic Ride Sharing Implementation and Analysis in MATSim

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ABSTRACT

Introduction

In many urban areas, low occupancy rate of private cars leads to the aggravation of traffic externalities, such as severe traffic congestion and pollutant emissions. To solve these problems, approaches such as traditional ridesharing (also referred as carpooling) were proposed as an alternative form of travel, which would move more people while using the existing infrastructure and would use vehicles more efficiently.[1] In the United States, HOV(high-occupancy vehicle) lanes have already been constructed to encourage ride sharing since 1991, culminating with the passage of the Intermodal Surface Transportation Efficiency Act, which favored high-occupancy vehicle (HOV) lane construction [2]. However, carpooling requires long- term commitments among people and implies them having fixed schedules and origin and destination points, which is not suitable for the fast pace of life in today's cities. Thus, carpooling usage rate for work trips decreased significantly in the US during the period of the 1970s – 2000s,[3] peaking in 1970 with a commute mode share of 20.4%, by 2011 it was down to 9.7%.[4]

Now mobile internet technology ubiquity has renewed the interest around ride sharing as a possible way to mitigate traffic externalities. In the last few years dynamic ridesharing, also known as real-time ridesharing, gained traction. Compared with traditional carpooling, a dynamic ridesharing system can provide matches between drivers and passengers on very short notice, which means a ride-share can be established only a few minutes before departure time. Additionally, in a dynamic ride sharing system, each trip is considered individually, and can accommodate by design trips from/to any point at any time[3], while a driver can get a match at any point along his ride.

The development of algorithms for optimal matching in real-time and for fast detour computation have been tackled recently by several researchers.[5-8] However, as for the further study of its effect on network traffic performance and on the individual travel behavior, it is still nearly blank. In the few attempts documented in the literature, given the difficulties in dealing with such problems analytically, simulations have been used to tackle them.

This paper reports on a research effort were the agent-based simulation MATSim is used and it aimed at

a) Improving the already existing capability of MATSim of dealing with the Dynamic Vehicle routing problem;

b) Assessing the impact of a ride-sharing service on the transportation system as well as to provide a theoretical basis for relevant policies and measurements.

Methodology

The Multi-Agent Transport Simulation (MATSim) is a platform[9], can perform network loadings with millions of persons or vehicles (represented through the agent paradigm) and trace each agent throughout the whole day.

In MATSim's a Dynamic Vehicle Routing Problem (DVRP) extension was already developed and used to simulate and analyze regular and shared taxi services. [10-14]That contribution creates a dynamic vehicle routing system, using the concept of dynamic agent for the taxi vehicles. Unlike regular agents, this kind of agents, are notified of any new relevant event during the simulation, and re-routed taking into account the current situation [15]. However, the DVRP is especially designed for the taxi mode, which shares similarities but also have some fundamental differences with ride-sharing. From a simulation standpoint, taxis also have dynamic activity chains, pick up and drop off activities and need to be routed dynamically. However, taxi agents do not belong to the population of agents and therefore their plans do not need to get a score or to be replanned. This is clearly different for ridesharing drivers and passengers. Therefore, the current DVRP framework had to be updated, and a specific Ride Share Agent was created to represent ride sharing systems. Once an agent chooses ride share driver as its trip mode, it will act as Ride Share Agent, which has the attributes of both dynamic agent and normal agent. Ride Share Agent will switch to Dynamic Agent when it is on the leg of ride share driver mode and will switch back to population agent when it decides to execute the next activity. The concrete implementation is as follows:

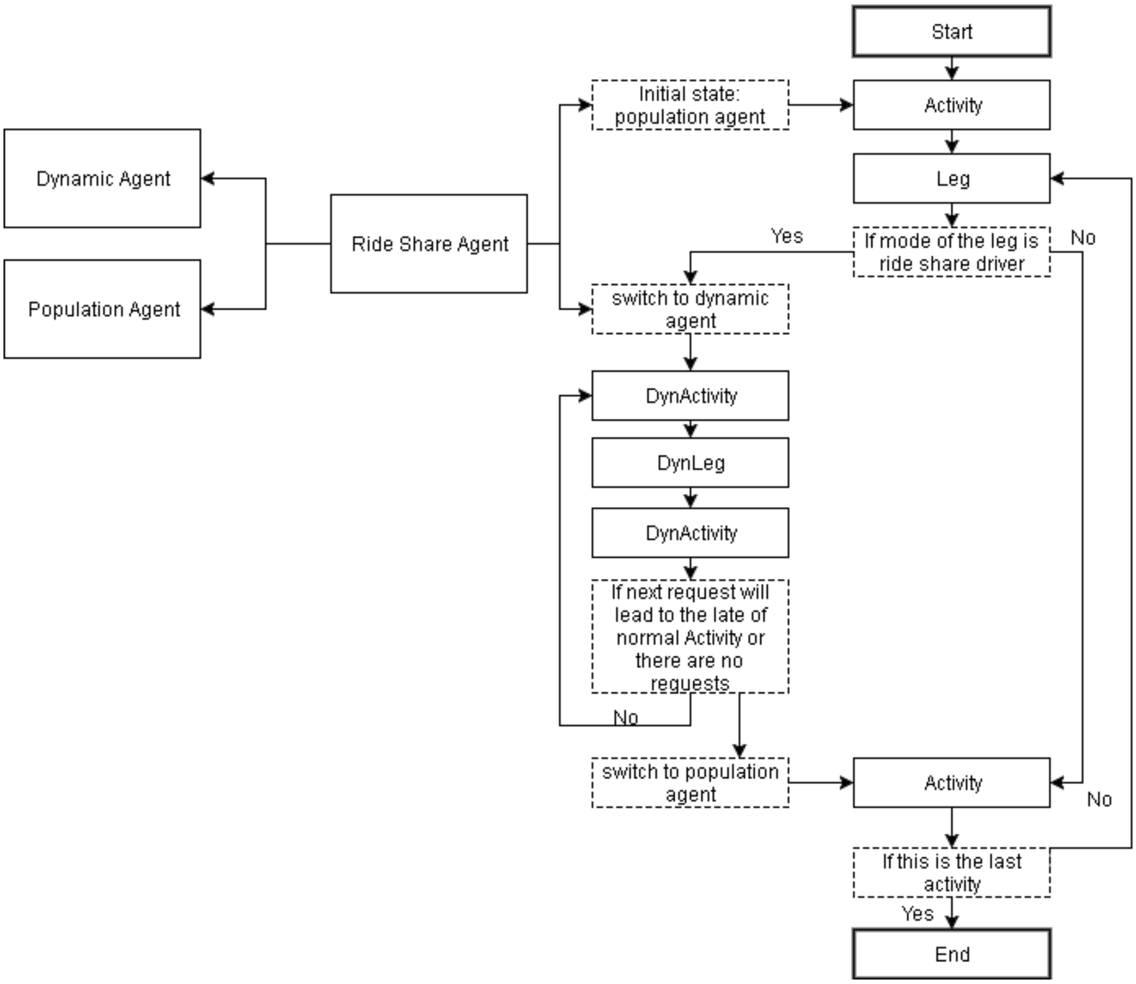

Figure 1 Implementation of Ride Share Agent

Request allocation is another core problem of the ride-share dynamic system, which should be handled in both temporal and spatial aspect. This problem has already attracted attentions from some scholars. Geisberger developed an algorithm to solve the fast detour problem in ride sharing.[7] And Shuo Ma's algorithm dealt with the ride-share taxi searching and scheduling.[8] Based on these results, the request allocation system was developed as follows:

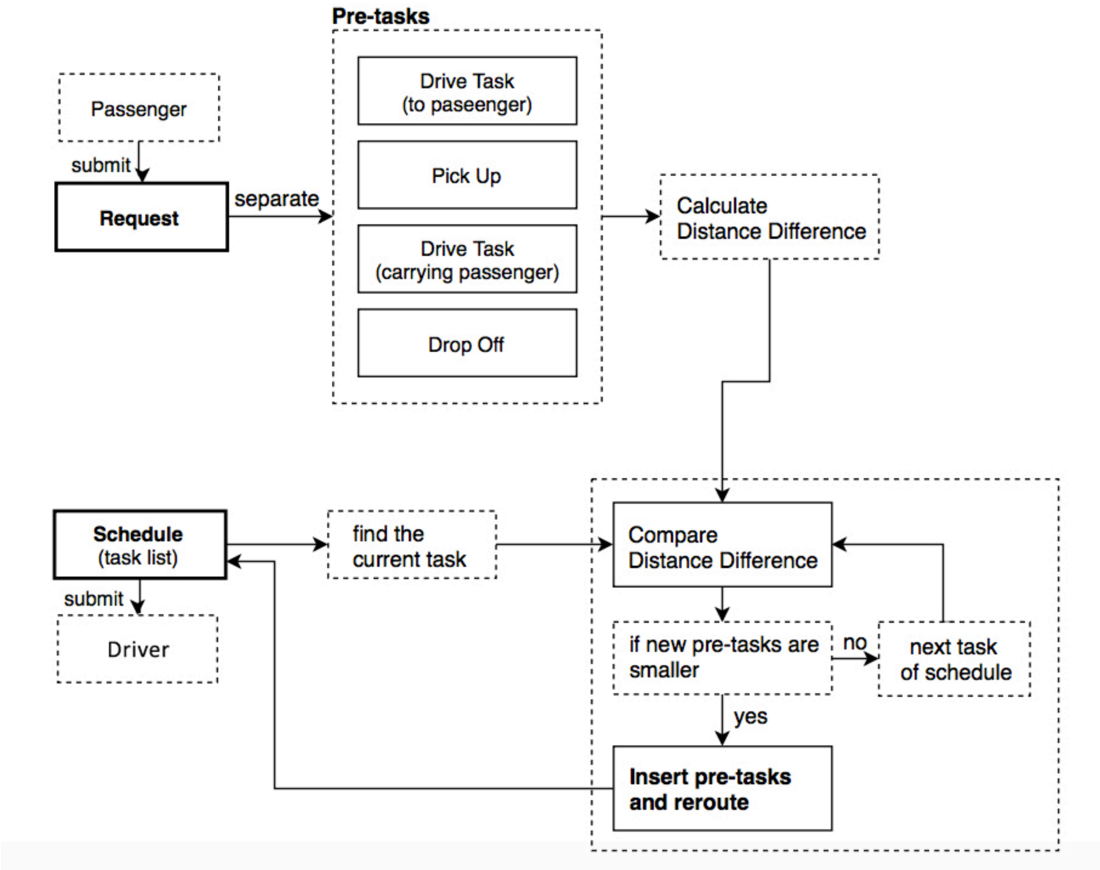

Figure 2 Request Allocation System

Likewise, a reasonable scoring configuration is also a decisive issue in the new model, which determines the relationship between supply, the share of ride share driver, and demand, the share of ride share passenger.

Case study and preliminary results

Some preliminary tests, executed on scenario of Sioux Falls (SD, USA)[16], allowed testing the functionalities introduced. Sioux Falls is a small city and the model has 24 zones, 76 links and 24 nodes[17]. It was chosen to test the new ride-sharing implementation because, while being a complete and to a large extent realistic scenario, it is nevertheless simple and small enough that the computation time is not too high. To further simplify the problem, the maximum capacity of each vehicle is 2 which means each driver can only have one passenger in the car. Other configurations of vehicle are exactly same as vehicles of car mode.

In this simulation case study, driver agents plans are evaluated with a special scoring system. They get positive utility when they are on a link with passengers, but get negative utility as the normal car mode when driving alone. (See more details in Table 1) The parameters of rideshare driver and rideshare passenger are basically determined by the price. For example, passenger need to pay driver 30 dollars per hour. By converting monetary cost to utility, passenger will lose 30 * 0.062 = 1.86

utility per hour, which is set as travellingRideSharePassenger in the configuration. At the same time, after excluding the normal car consumption, ride share driver will get 1.86 – 0.992 = 0.868 utility per hour, which is set as travellingRideShareDriver in the configuration. The simulation will run for 100 iterations, in the first 80 rounds agent will have the possibility to change mode, using a random imitator, and in the last 20 rounds agent will choose the mode with highest score.

Table 1: Configuration

Parameter	value	unit
writeExperiencedPlans	TURE	
BrainExpBeta	1	
constantPt	-0.124	utils
constantCar	-0.562	utils
onstantWalk	0	utils
constantRideSharePassenger	0	utils
constantRideShareDiver	-0.562	utils
earlyDeparture	-1.5	utils/hr
lateArrival	-2	utils/hr
learningRate	0.4	
marginalUtilityOfMoney	0.062	utils/unit_of_money
marginalUtlOfDistanceWalk	0	utils/m
monetaryDistanceRateCar	0	unit_of_money/m
monetaryDistanceRatePt	0	unit_of_money/m
monetaryDistanceRateRideSharePassenger	0	unit_of_money/m
monetaryDistanceRateRideShareDriver	0	unit_of_money/m
performing	0.96	utils/hr
traveling	-0.992	utils/hr
travelingPt	-0.18	utils/hr
travelingWalk	-1.14	utils/hr
travelingRideShareDriver	0.868	utils/hr
travelingRideSharePassenger	-1.86	utils/hr
utilityOfLineSwitch	0	utils
waitingPt	-0.18	utils/hr

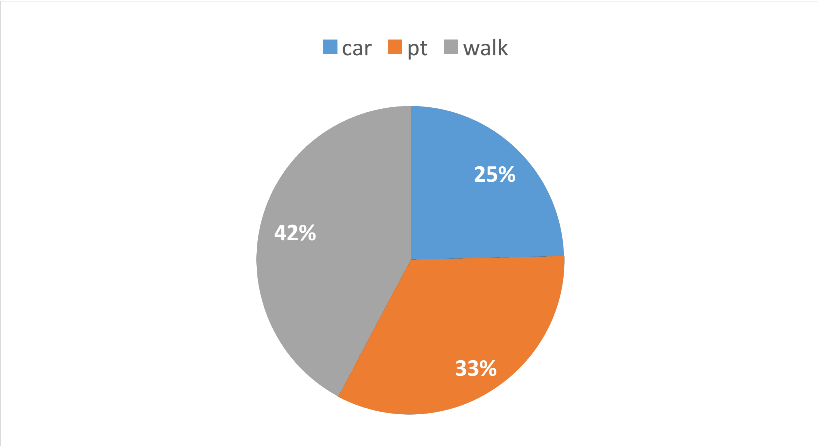

Figure 3 Mode Share of Basic Scenario

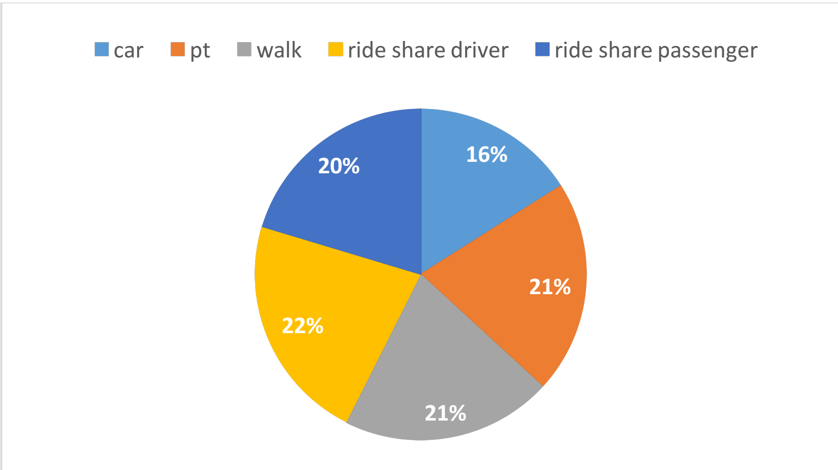

Figure 4 Mode Share after Ride Share Implementation

As the present results shows, the new trip mode of ride sharing indeed affects trip patterns of agents compared to the base scenario. Currently the fare rate for ride share mode is zero and changing mode randomly is encouraged for each iteration, which could explain the relatively evenly distributed mode share. A proper estimation of the parameters, based on revealed or stated preferences, as well as setting a realistic price would obviously influence not only the behavior of ride share passengers and drivers, but also the balance of the demand-supply relationship. This would be needed in order to have results which could be used for policy making.

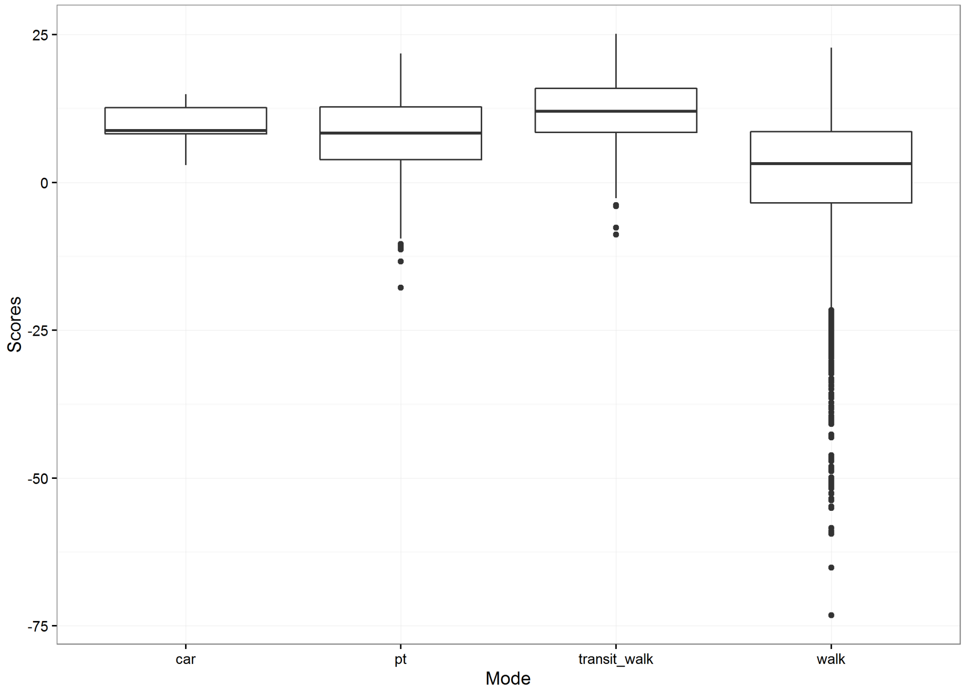

Figure 5 Executed Score of different trip modes in basic scenario

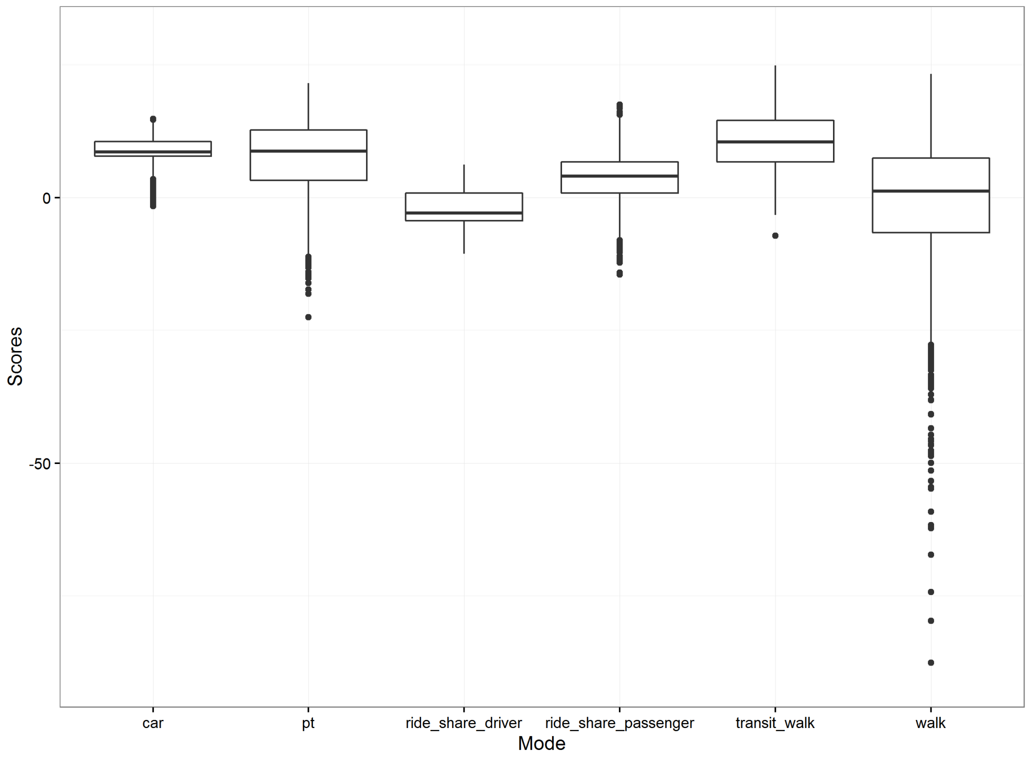

Figure 6 Executed Score of different trip modes with ride sharing

The further expected result will be traffic performance of the new ride share mode compared with other traffic modes, as well as the relationship between new mode share and various pricing strategies. The work will be therefore extended to find optimal pricing strategies in order to reach different targets (VKM minimization, welfare maximization, etc.).

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