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The impact of high-occupancy lanes on the uptake of on-demand ridesplitting services

Elham Hajhashemi[1], Patricia Sauri Lavieri[1], Neema Nassir[1]
[1]Department of Infrastructure, University of Melbourne, Melbourne, Victoria, Australia
Email for correspondence: patricia.lavieri@unimelb.edu.au

Abstract

New mobility alternatives such as on-demand ridesplitting services can bring large benefits to cities by increasing automobile occupancy and reducing congestion, pollution, and space allocated to parking. However, the current adoption of on-demand ridesplitting services is still limited and transport demand management (TDM) strategies may be necessary to increase such uptake. This work uses the agent-based simulation tool MATSim to simulate 10% of the population in the Greater Melbourne Area and investigate the effectiveness of dedicated ridesplitting lanes (DRL) on the uptake of on-demand ridesplitting services and overall transport network efficiency. Results suggest that the tested DRL configurations are effective in increasing the uptake of such services. We observe a significant increase in vehicle occupancy and a reduction in vehicle kilometres travelled, which indicate that this is a promising policy. However, in regard to average travel time, DRL scenarios benefit people with trips within the on-demand ridesplitting service's area while deteriorating average travel time for people whose trips' origins and/or destinations are outside the service's area. Future simulations should incorporate multi-modal travel and include transport hubs that facilitate inter-modal transfers to test whether the observed benefits can be expanded to the areas outside the ridesplitting service area.

1. Introduction

Australian cities are highly car-dependent, with road vehicles accounting for about 86.2% of total travel across the 8 Australian capitals in 2014 (BITRE, 2015). Most vehicles on the roads are single-occupant vehicles. Melbourne's average vehicle occupancy during the morning peak was approximately 1.15 in 2014, down from 1.2 in 1999 (Austroads, 2016). The prevalence of drive-alone trips and a car-dependent environment can exacerbate urban transportation problems which make finding new solutions for the congestion problem vital.

While increasing the share of public transport (PT) and active travel is, in general, the most sustainable solution to the congestion problem, traditional PT services have limitations such as the need for a critical mass, fixed routes and schedules. Similarly, active travel modes usually fit medium to short trips and may not suit people with special mobility needs. In this sense, on-demand ridesplitting[1] services (also known as pooled ride-hailing) can be a good complement to traditional PT systems as they enable flexible travel that is similar to that of personal cars but with increased vehicle occupancy rates. Ridesplitting services can also provide reliable and convenient mobility options for mobility-disadvantaged people, reduce parking needs, and reduce traveller reliance on vehicle ownership (Henao and Marshall, 2017).

[1] Ridesourcing/ride-hailing services (such as Uber) are similar to taxi services with fewer regulations and more flexibility in scheduling and pricing. Passengers can request a ride through a mobile app. Ridesplitting services (such as UberPOOL) are a variation of ridesourcing which passengers accept to share their ride with others in exchange for a reduced fare.

Furthermore, simulation studies have shown that on-demand ridesplitting services are necessary to avoid an increase in vehicle kilometre travelled (VKT) and congestion resulting from the use of single-occupant on-demand ride services or ride-hailing (Rodier et al., 2016, Fagnant and Kockelman, 2018).

Despite the advantages of ridesplitting services, their adoption compared to non-pooled ride-hailing is still limited. Uber ridesourcing platform launched its ridesplitting service (known as UberPOOL) in August 2014; by 2017, UberPOOL was only available in 36 cities globally, with only 20% of rides being ridesplitting in those cities (Shaheen and Cohen, 2018). While privacy concerns may, to an extent, be hindering the adoption of ridesplitting, the longer travel times associated with detours and passenger pick-up/drop-off seem to be the greatest adoption barrier (Lavieri and Bhat, 2019). Previous literature has focused on investigating how monetary incentives, such as occupancy-based congestion pricing strategies and reduced fares, could increase the share of ridesplitting trips (Horl, 2017, Gurumurthy et al., 2019, Kaddoura et al., 2020). However, transport demand strategies that focus on directly reducing the travel time of those who split rides, such as high-occupancy vehicle (HOV) lanes, have not been tested. The current study aims to examine the effects of dedicated ridesplitting lanes (DRL) on ridesplitting uptake and overall transport network efficiency. The investigation is performed using the MATSim simulation tool applied to the Greater Melbourne area context.

2. Methodology

In this section, after providing a brief overview of the agent-based simulation framework MATSim, we present a description of the base model components and ridesplitting service characteristics. Then we explain three different scenarios tested for measuring the effectiveness of DRLs on increasing ridesplitting uptake.

2.1 Agent-based simulation framework

MATSim is an open-source activity-based framework that allows for microscopic simulation, that is, it represents travel behaviour at a disaggregated level by modelling individual agents. There is an input population file including each agent's initial set of daily plans with information about their location, duration, travel time, and transport mode. At the end of each iteration of the agent’s entire day (a 24h simulation), the score of the performed plan is calculated based on activity engagement and traveling. Engagement in activity is given positive utility, while traveling is given a disutility. Then agents are allowed to adapt their plan for the next iteration by specific probability. They can change their plan by changing mode, and route to improve their utility (score). The co-evolutionary algorithm in MATSim seeks to maximize the utility of agents based on user equilibrium. Network assignment is done using a queue-based approach (Horni et al., 2016).

Simulation of ridesplitting is performed by adding dynamic vehicle routing problem (DVRP) and demand responsive transport (DRT) extensions to MATSim (Maciejewski, 2016, Maciejewski et al., 2017, Bischoff et al., 2017). Agents that would like to use ridesplitting services request a ride, and the request is assigned to a DRT vehicle. The overall dispatch algorithm tries to minimize the total vehicle operation times spent on serving ride requests. Service quality standards, like maximum wait time and travel time, can be set and if the algorithm is unable to find a ride that meets these standards, the request is rejected. In our simulation set up, if no DRT vehicle can serve the request within the acceptable service quality, the request is not rejected. Instead, the trip is assigned to the vehicle that is closest to meeting the service criteria. However, since agents end up having late arrivals, the ridesplitting mode is penalised with negative utility.

2.2 Base case simulation

The Greater Melbourne area was analysed based on a network adapted (all minor roads were omitted) from Jafari et al. (2022). The final network only included major roads including motorway, trunk, primary, secondary, and tertiary links. In this simulation, all modes besides cars were modelled as teleport, meaning that trips made by these modes are not loaded on the actual transport network, but instead, people are put to the location of the next activity based on a pre-defined travel time.

The synthesized population developed by Both et al. (2021), representing 10% of the population of the Greater Melbourne area, was used as the input population. Flow capacity and storage capacity factors of links were updated accordingly to match the population-sample ratio and model congestion and traffic flow. That is, for a 10% sample, network correction factors of 0.1 were applied. For MATSim scoring function which is the calculation of the positive utility gained by performing an activity and disutility gained by traveling the coefficients of the mode choice model estimated by KPMG for Melbourne Activity and Agent-based model (MABM) were used (KPMG, 2017).

The base case scenario was run for 500 iterations. During the first 400 iterations (innovation), agents were allowed to change their mode and route. In each iteration, 10% of agents were allowed to change their mode, and 10% were allowed to change their route. Each agent stored five travel plans with the best scores, and, in the last 100 iterations, they did not generate new plans anymore and alternated between the stored plans. Alternative specific constants of the mode choice model were used to calibrate the final base modal split to approximately match the data from the Victorian Integrated Survey on Travel and Activity (VISTA) 2016-2018. The calibration target was the mode shares being within the ±1% error threshold of the observed values in VISTA.

2.3 Ridesplitting service characteristics

The area of Inner Melbourne was selected as the ridesplitting service area (trips can start and end only within this area) to address the high trip density requirements of matching systems used in ridesplitting services (in low density areas, matching algorithms tend to fail to find compatible travellers and users end up travelling alone). The proposed ridesplitting service allowed for the pooling of up to 4 passengers, which is equivalent to a traditional passenger vehicle. Different fleet sizes were tested and for the final simulation, the fleet size was fixed at 3,500 vehicles which were found to be enough for serving ridesplitting requests in all of the scenarios with reasonable service quality. Vehicles were considered to be shared automated vehicles (SA). The ridesplitting distance-based fare was set to 0.2 A$/km and the minimum fee was set to two dollars which are within the range estimated for SAV services in other studies (Bösch et al., 2018). The fleet size and ridesplitting fare were equal in all scenarios as they can also be effective on ridesplitting uptake and in this study we were not interested in the effect of fare and fleet size on the ridesplitting uptake.

2.4 Policy design

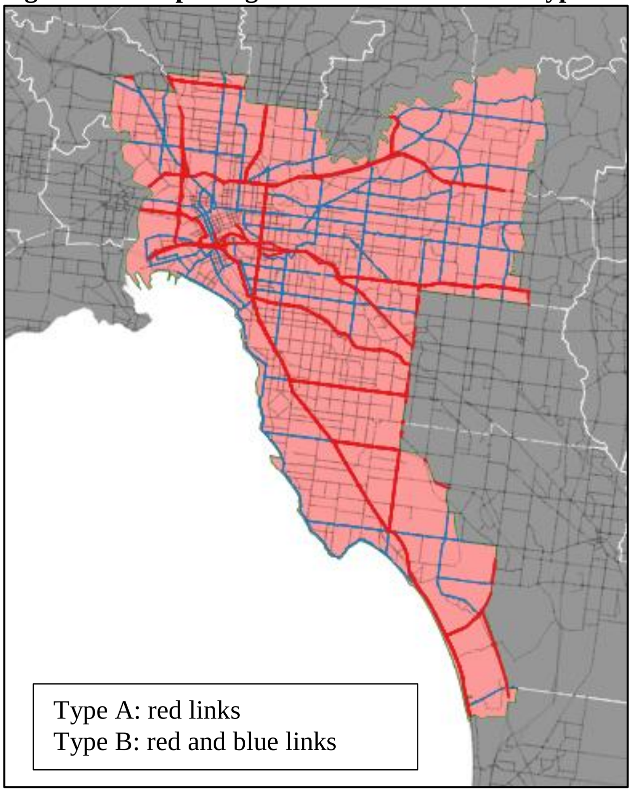
Ridesplitting vehicles were able to use DRL regardless of their number of passengers. The purpose was to make travel with ridesplitting faster and encourage more people to use this service. The increase in the uptake of ridesplitting service will lead to a higher chance of ride match and higher average vehicle occupancy (AVO) and decrease congestion level in turn. Two different configurations of DRL were tested in this study (a) DRL on trunk and motorway roads with 2 or more lanes within the service area, and (b) DRL on trunk, motorway, and primary roads with 2 or more lanes within service area. Three different scenarios were run for the purpose of this study. The characteristics of each scenario are explained as follows:

- Scenario 1 - Ridesplitting base case: in this scenario, the output plan file from the calibrated base case was used and all the car trips within the service area were replaced with ridesplitting. The regular network file was used in this scenario. The simulation was run for 200 iterations to reach equilibrium. In this scenario, only car and ridesplitting users were allowed to change their mode and route while PT, bike, and walk mode shares were kept constant. The reason behind this decision was to isolate the effect of DRL only on moving people from car to ridesplitting.

- Scenario 2 DRL Type A: the setting in this scenario was similar to Scenario 1. The only difference was that within the service area, one lane of trunk and motorway roads with more than 2 lanes was dedicated to ridesplitting vehicles.
- Scenario 3 DRL Type B: the setting in this scenario was similar to Scenario 1. The only difference was that within the service area, one lane of trunk, motorway, and primary roads with more than 2 lanes was dedicated to ridesplitting vehicles.

The ridesplitting service area and location of DRLs in DRL Type A and Type B are presented in Figure1.

Figure 1: Ridesplitting service area with DRL Type A and Type B



3. Results

This section compares outputs of three scenarios in regard to ridesplitting uptake, ridesplitting level of service, and network performance. The calibrated base model was used for running the three different scenarios as explained in section 2.4. Table 1 summarises selected system statistics of the base case and three scenarios. The mode share of ridesplitting in Scenario 1 is 7.4%. Both of the DRL types were effective in increasing the uptake of ridesplitting by attracting car users and increasing the mode share of ridesplitting by 1.5 and 4.5% compared to Scenario 1.

The total system average travel time was the highest in Scenario 3 while VKT was the lowest. Allocating one lane of a road to ridesplitting users decreases the capacity for car users in the network. Consequently, travel time increases for car users, making cars less pleasant for travellers and making them switch to ridesplitting to benefit from shorter in-vehicle travel time. As in this model the ridesplitting service was only available in inner Melbourne, multi-modal trips involving ridesplitting were not allowed, and only car and ridesplitting users were able to switch modes. Therefore, car users that had part of their trips outside of the service area were penalised, as they did not have the ability to switch to ridesplitting or use DRLs. For this reason, DRL scenarios may be better evaluated by analysing trips within the ridesplitting service area.

Table 1: Selected traffic statistics for the whole study area

Scenarios	Selected statistics				
	Car mode share	Ridesplitting mode share	Average tt (min)	VKT (km)	Average speed (km/hr)
Base case	72.7	0	33.5	12,225,997	36.2
Scenario 1	65.3	7.4	31	12,178,712	37.8
Scenario 2	63.8	8.9	33.8	12,139,112	36.8
Scenario 3	60.9	11.9	38.7	12,089,492	35.9

Table 2 presents selected statistics only for trips starting and ending within the service area, where car users have the option to switch to ridesplitting. In this case, Scenario 3 was the best option regarding average travel time, VKT, and AVO. Compared to the base case, in Scenario 3, average travel time and VKT were reduced by 22 and 26%, respectively. While compared to Scenario 1 in Scenario 3, average travel time and VKT were reduced by 6.6 and 16%, respectively. Moreover, AVO increased 25% in Scenario 3 compared to Scenario 1.

Table 2: Selected traffic statistics for trips starting and ending within the DRT service area

Scenarios	Selected statistics					
	Car mode share	Ridesplitting mode Share	Average tt (min)	VKT (km)	Average speed (km/hr)	Morning peak AVO
Base case	63.1	0	27.3	1,564,243	27.8	1
Scenario 1	37	25.8	22.8	1,374,529	32	1.32
Scenario 2	32.3	30.8	22.3	1,297,305	32.4	1.37
Scenario 3	23.7	39.6	21.3	1,160,156	33.5	1.65

4. Conclusion and future research

This study examined the effectiveness of dedicated lanes on the uptake of on-demand ridesplitting services. Two different DRL configurations were tested, and they were both found to be effective in increasing the mode share of ridesplitting and reducing VKT. When considering the trips in the whole study area, implementing DRLs would cause an increase in average travel time. However, when considering the trips within the service area, implementing DRLs would decrease the average travel time. This highlights the importance of implementing DRLs together with other policies that facilitate multi-modal trips and travel behaviour. For example, infrastructure planners should aim to facilitate inter-modal exchange by providing facilities for park and ride close to ridesplitting service areas and DRLs' main access points. This combination would help people whose trips' origins and/or destinations are outside the ridesplitting service area to leave their car behind and travel to denser areas by PT or ridesplitting services. In this sense, future research should focus on finding the optimum ridesplitting service area and DRLs design while accommodating for multi-modal trips.

The simulations performed in this study present some limitations. First, we only allowed users to switch between private car and ridesplitting, so future research should test how DRLs may also push car users to switch to PT and active modes. Second, MATSim considers all car trips to be single occupant, and thus, it was not possible to examine the effect of having HOVs together with DRLs. Future simulations could test the effect of enabling private cars to use HOVs if carrying 2 or more passengers. Finally, it was considered that all DRT vehicles regardless of their number of passengers could use DRLs. With this limitation, even passengers of single occupant DRT vehicles would benefit from DRLs. This limitation is however somewhat realistic, as in current ride-hailing services offered by Uber, for example, when passengers agree to use the ridesplitting option, they will pay the reduced cost regardless of match success. Therefore, allowing ridesplitting users to access DRLs regardless of the number of passengers can be a way of encouraging people to use this service, which in turn will increase ridesplitting match success.

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