Person-Based Accessibility in MATSim: Demand-Responsive Transport's Potential for the Elderly Population in Rural Japan

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Short summary

Older adults in rural areas are vulnerable to transport exclusion, particularly when they lose access to a car. We assess whether Demand-Responsive Transport (DRT) can mitigate these inequities in the largely rural Gunma Prefecture, Japan. We introduce two methodological extensions to the econometric accessibility module in the agent-based transport model "MATSim." First, accessibility is reformulated from a location-based to a person-based framework, allowing outcomes to depend on individuals' home locations and sociodemographic characteristics. Second, the DRT accessibility calculation is refined to capture spatial variation in service levels, especially waiting times. We analyze supermarket accessibility for residents aged 85+, and observe substantial disadvantages among older adults, particularly rural women. Introducing a pooled DRT system (1000 vehicles) can substantially reduce disparities in accessibility across sociodemographic groups (age, gender, home location); this holds even when driver's licenses are revoked at age 85 to improve road safety.

Keywords: Agent-Based Modeling, Demand-Responsive Transport, Elderly, Equity, Person-Based Accessibility, Rural Mobility

1 Introduction

Japan is facing a demographic shift towards "super-aging": over a third of the population is aged 65 or older (Buhnik, 2023). The elderly population living in car-dominated rural areas is especially prone to transport exclusion, as driving may become unsafe at older ages due to physical or cognitive limitations (Ahern & Hine, 2012); in Japan, there has been an increase in accidents on Japanese roadways involving elderly people (Buhnik, 2023). This paper examines the tension between safety and accessibility for the elderly population in Gunma Prefecture, a predominantly rural area of Japan; in particular, the use of Demand-Responsive Transport (DRT) to improve transport equity will be explored using a person-based econometric accessibility metric (Geurs & van Wee, 2004), in the agent-based model (ABM) MATSim (Horni et al., 2016).

DRT is a more flexible mode of (public) transport, not bound to fixed routes or timetables; many examples of DRT use dynamic ride sharing to bundle passengers with similar routes into the same vehicles (Hensher et al., 2020). DRT has a strong potential to improve accessibility and equity in rural regions (Lu et al., 2023), especially among disadvantaged population groups, such as the elderly (Knierim & Schlüter, 2021). Gunma Prefecture is exploring the use of DRT to address mobility poverty among aging populations (Gunma Prefectural Office, 2024).

We address the following research questions:

RQ 1) How can person-based accessibility be implemented within a transport ABM to capture demographic heterogeneity?

RQ 2) How does incorporating spatially heterogeneous service levels influence accessibility estimates for DRT?

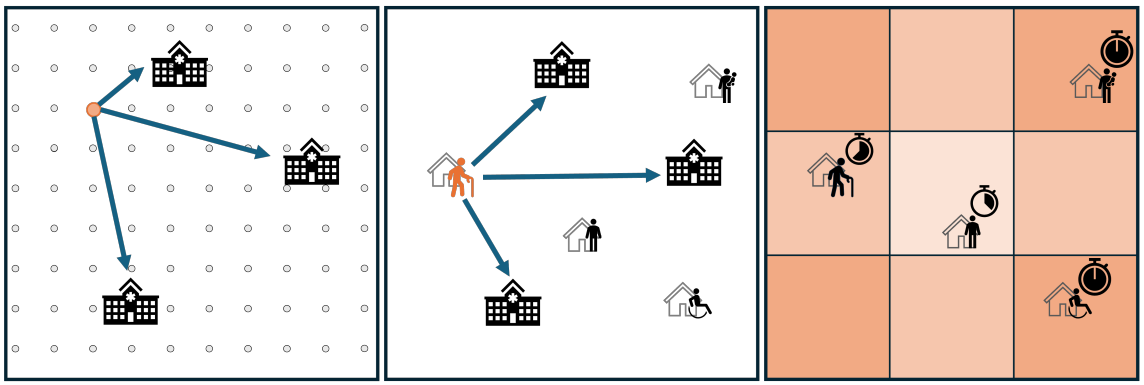
RQ 3) To what degree would the accessibility gains of a DRT system offset the accessibility losses of a driver's license ban over the age of 85?

This paper introduces two methodological contributions that enable MATSim to capture sociodemographic and spatial heterogeneity in accessibility, improving its suitability for equity analysis (see Section 2). These methods are applied to Gunma Prefecture to examine the transport disadvantage of elderly residents in the status quo and several policy cases (see Sections 3-4).

2 Methodological Framework

MATSim ("Multi-Agent Transport Simulation") is an open-source ABM for simulating and evaluating transport policies (Horni et al., 2016). Agents are heterogeneous in their sociodemographic attributes and their daily plans (trips and activities). Within a simulated day, agents use different modes of transport to travel between activity locations; this single day is repeated hundreds of times, allowing agents to improve their daily plans ("co-evolutionary algorithm").

MATSim's accessibility extension measures the ease of reaching a set of opportunities from predefined measuring points at a given time of day (congestion-dependent) and by a specific mode of transport (Ziemke, 2016). Accessibility is computed using an econometric framework in which the utility of travel between each measuring point and the opportunity depends on travel time, distance, monetary costs, and an alternative-specific constant (ASC). Utilities across all reachable opportunities are aggregated using a log-sum measure that reflects both proximity to the nearest option and the availability of multiple alternatives (see fig. 1a)



(a) Location-Based **(b)** Person-Based **(c)** Spatially Varied DRT

Figure 1: Accessibility Calculation within MATSim. (a) Location-based accessibility, wherein accessibility is measured from each measuring point (grid of gray points) to each opportunity (hospital icons). (b) Person-based accessibility is measured for each person based on their home location; the person's sociodemographic characteristics influence their accessibility. (c) Spatially differentiated DRT accessibility varies wait times per zone.

Person-Based Accessibility

Person-based accessibility is the potential of each person to overcome spatial separation to take part in activities, *dependent on their individual characteristics* (Geurs & van Wee, 2004). There are studies in which person-based accessibility is calculated to examine equity; however, most rely on real-world data rather than models, so the effects of transport policies cannot be explored (e.g., Dixit & Sivakumar, 2020). Nahmias-Biran et al. (2021) develop a person-based accessibility metric for DRT services within an ABM; the main difference from our approach is that they focus on the realized trajectory of an agent rather than the general potential to participate in an activity.

This paper's first methodological contribution is a person-based accessibility framework within MATSim, wherein agents' home locations are the measuring points. Using MATSim's modular routing and scoring modules, an agent's sociodemographic characteristics influencess the travel (dis)utility associated with reaching opportunities (fig. 1b). In this paper, an agent's age, household car availability, and driver's license status are used to determine the binary availability of transport modes for each agent (see Section 3). However, the framework is structured such that more complex relationships between sociodemographic characteristics and accessibility can be represented; e.g., walking speeds and distance-based disutility can be parameterized to depend on age.

Spatially Varied DRT Accessibility

Our previous work developed a methodology to calculate econometric accessibility for DRT in MATSim (Rehmann & Nagel, 2026, preprint). First, a car trip is routed over the network between the measuring point and the opportunity, accounting for congestion. The resulting travel time is passed to the DRT Estimator (Lu et al., 2025, preprint), which produces estimated DRT travel and waiting times. Prior to an accessibility analysis, the DRT Estimator must be configured to represent the intended level of service. When representing an existing system, this configuration is based on operational data. When evaluating a prospective service, as in this paper, a MATSim simulation of the DRT system is first run to parameterize the DRT Estimator.

Building on the existing DRT accessibility calculation, the second methodological contribution of this paper is to incorporate spatially heterogeneous wait times into the accessibility estimates (see fig. 1c). The DRT Estimator was updated to produce DRT wait time estimates based on the pickup location. For this purpose, the DRT Estimator is provided with a shape-file containing a zonal system; each zone has a waiting time associated with it. This update is especially important for representing heterogeneous study areas.

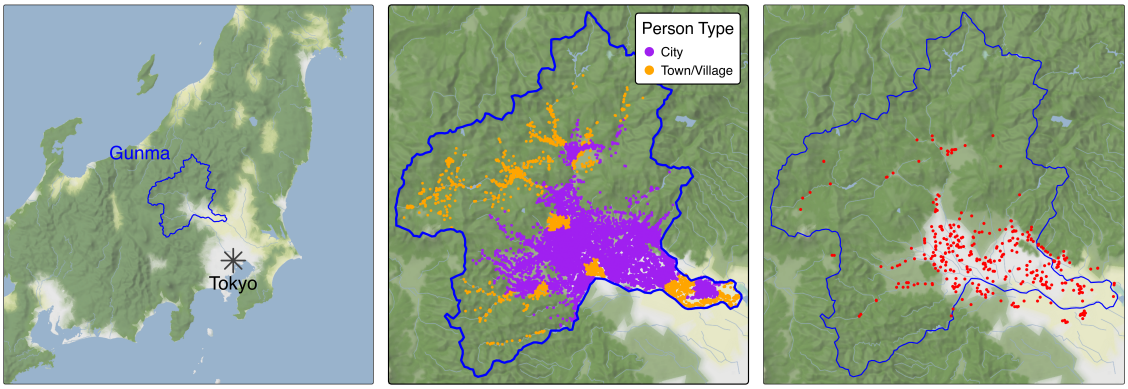
3 Case Study

This paper examines Gunma Prefecture, a landlocked area in Japan's Kantō region with about 2 million residents (see fig. 2a). The study area is car-dominated: 74% of trips are made by car, while only about 2% use public transit (Gunma Prefectural Government, 2025).

A previous paper introduces the MATSim model for Gunma Prefecture (Rehmann et al., 2026, preprint). Home locations and daily plans in the Gunma model are extracted from the 2015 Gunma travel survey, which is sensitive towards age and gender.

This model is used as the basis for four case studies regarding the population aged 85+:

1. *Base Case*: Status quo.
2. *Policy Safety*: car is no longer available.
3. *Policy Mobility*: a DRT service is provided.
4. *Policy Combined*: car is no longer available and DRT service is provided.



(a) Overview Map **(b)** Population Distribution **(c)** Supermarkets

Figure 2: (a) Location of Gunma Prefecture with respect to Tokyo. (b) Home locations of the 1% population (color indicates official municipal land-use designation). (c) Distribution of supermarkets in Gunma with a 5 km buffer

Accessibility Calculation

For all four case studies, we calculate person-based accessibility for the 1% sample of Gunma's population: 18,800 agents (see fig. 2b). We calculate person-based accessibility to supermarkets

(n=370), as shown in fig. 2c. A person's accessibility to an opportunity type is defined as the maximum accessibility of all modes available to them, as determined by their sociodemographic attributes. While all agents can walk, car is only available to agents with both a driver's license and a car in their household; DRT, in the relevant scenarios, can only be used by agents aged 85+. We do not consider public transit or bikes because of their low modal shares. We further exclude the ride mode (car passenger), as the model does not represent household or social support structures that may be required to provide transport to older adults' activities. This is a limitation.

We assume an ASC of -1.653 utils for DRT; this disutility is double that of car, to account for the inconvenience of sharing a ride. We assume a monetary fare of 36 ¥/km, and a marginal utility of traveling of -2.04 util/hr (in addition to the opportunity cost of time); these values are based on a stated preference survey for Gunma Prefecture regarding a pooled door-to-door autonomous vehicle service (Kamijo et al., 2021).

To calculate the actual accessibility for DRT, we need information about its level of service to feed to the DRT Estimator. The following subsection explains how we simulated a DRT service in MATSim using different fleet configurations to obtain detour factors and spatially heterogeneous wait time estimates.

Preparatory DRT Simulation

Since pooled DRT services are sensitive towards down-sampling, we set our demand as 100% of the car trips of the 85+ population; this results in 24,000 trips among 91,500 agents. These trips are simulated using MATSim's DVRP and DRT extensions (Maciejewski, 2016).

The simulated DRT service is configured conservatively, to estimate an upper bound for the fleet size: door-to-door, no fleet rebalancing, no prebooking, and no booking request rejections. At the beginning of the day, the vehicles are positioned on a randomly chosen link in the service area. Vehicles offer ride-pooling, allowing up to 4 different passengers to be served simultaneously. We run the DRT service with three different fleet sizes: 500, 1000, and 1500. We analyze the simulation outputs to determine average wait time per geographic zone, as well as detour factors for the entire study area.

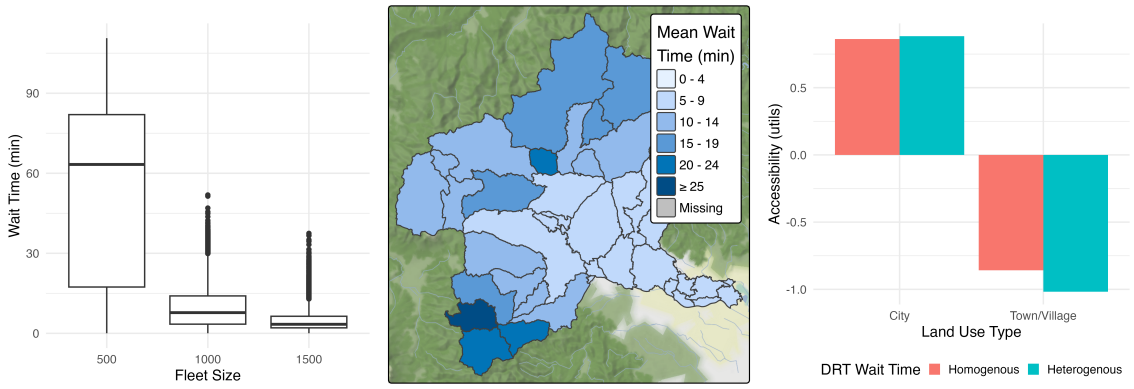
4 Results

The mean and interquartile range of the wait time decrease as the fleet sizes increase (see fig. 3a). Since the 500 vehicle fleet provides an unsatisfactory level of service, we focus on the 1000 vehicle fleet. There is a strong geographic variation in level of service; mean wait times are up to 20 minutes longer in rural, mountainous zones than in the urban core (see fig. 3b). If we include spatially differentiated wait times in our DRT accessibility calculation, we see that accessibility decreases in rural areas and increases in urban areas, compared with assuming a homogeneous level of service across the study area (see fig. 3c).

Fig. 4 shows person-based accessibility to supermarkets. We see a clear differentiation by age and gender: starting with the 65–74 age group, driver's license rates decline for women, reducing accessibility relative to the remaining adult population. Men's accessibility also declines with age, albeit at a slower rate. The accessibility of agents living in urban areas (fig. 4a) is higher than that of those living in rural areas (fig. 4b); the difference is the starkest for children and elderly women, the sociodemographic groups with the lowest car access.

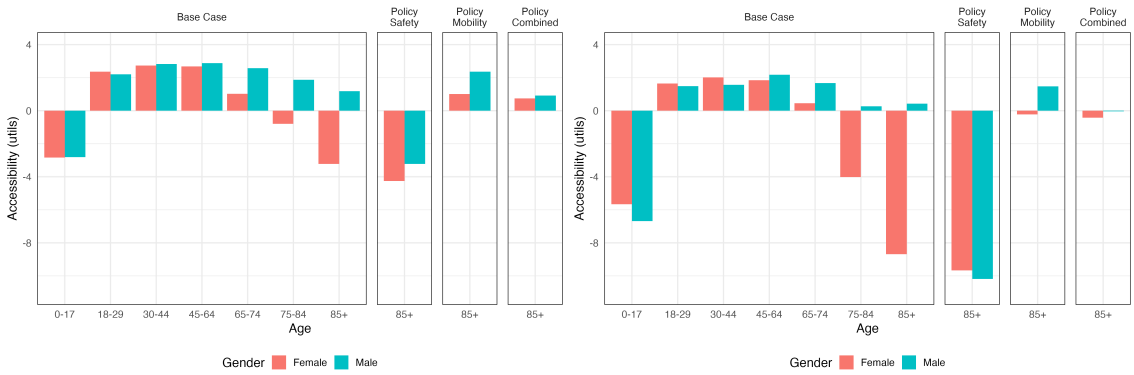
Policy Safety removes car availability for individuals over the age of 85. We see that accessibility decreases significantly, especially in rural regions, because all elderly agents would have to walk. This change affects men more than women, as men had greater car availability in the base case. The alternative *Policy Mobility* adds a DRT service specifically for the 85+ age group, increasing accessibility for all relevant subpopulations; the lowest increase is among urban men, and the highest among rural women.

Finally, the accessibilities produced by *Policy Combined* are bounded by the accessibilities of *Policy Safety* and *Policy Mobility*, with a clear skew towards the latter. With respect to the *Base Case*, we see that men fare slightly worse while women fare significantly better. The winners are rural women, with an 8 util increase, where 1 util approximately corresponds to the utility gained by receiving ¥180 (about €1).



(a) Wait Time Comparison **(b)** Spatial Distribution **(c)** DRT Accessibility

Figure 3: (a) Simulated mean wait time (min) for DRT pickup for fleet sizes of 500, 1000, and 1500 vehicles. (b) Spatial distribution of wait times with a fleet size of 1000 vehicles. (c) Mean accessibility for city vs. town/village zones. Homogeneous case (red) shows the result of the accessibility calculation when constant DRT wait time is assumed across study area, while heterogeneous case (blue) shows when the zonal wait times from (b) are applied to the accessibility calculation.



(a) City **(b)** Town/Village

Figure 4: Person-Based Accessibility to supermarkets, by age, gender, and land-use of home location: (a) city (b) and town/village. For the DRT case studies, we assume a fleet size of 1000 vehicles. Note: Absolute magnitudes (including sign) are difficult to interpret directly; the meaningful comparison lies in the relative differences between sociodemographic groups and policy cases.

5 Discussion and Conclusion

The case study shows that elderly residents of Gunma Prefecture experience lower accessibility than the general adult population, with the largest disadvantages among rural residents who lack access to a car, particularly children, teenagers, and elderly women. The results indicate that providing a DRT service (*Policy Mobility*) to people aged 85+ reduces accessibility inequalities across age groups, genders, and urban–rural areas.

The results suggest that a DRT service with 1000 vehicles can compensate for the accessibility losses associated with rescinding drivers' licenses for the population aged 85+. More broadly, this study demonstrates how person-based accessibility can be used to evaluate whether mobility gains from one policy can offset losses from another. Future work should examine more efficient DRT configurations, such as pre-booking, and incorporate cost–benefit analysis. This type of policy framing may also be relevant in other mobility debates, such as reducing car use in urban areas while maintaining adequate access to daily activities.

This paper develops a framework for calculating person-based accessibility within MATSim, extending the model's ability to analyze transport disadvantage in existing systems and to evaluate policy interventions. In addition, the DRT accessibility calculation is updated to incorporate spatially heterogeneous service levels. These features are implemented in a configurable manner within the existing MATSim framework, enabling reuse and further development by the open-source research community. The approach presented here provides a practical tool for evaluating mobility policies in aging and car-dependent regions.

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