Citation for the original published paper:

Dytckov, S., Davidsson, P., Persson, J A. (2023)
Integrate, not compete! On Potential Integration of Demand Responsive Transport Into Public Transport Network
In: Bilbao, Bizkaia, Spain

II. RELATED WORK

This section tries to give a summary of scientific studies of the efficiency of DRT in different scenarios. The two most popular scenarios are: a) very large-scale DRT systems covering a big portion of demand (if not all the demand) in the urban zones and b) replacement of conventional PT in the less densely populated areas.

A vision of a futuristic city where a fleet of autonomous vehicles is always ready to pick you up and drive you to your destination has not yet materialised but is actively studied in the research [6]. These types of scenarios often assume that such an autonomous DRT is the only transport mode available in a city. The results of simulation studies show that DRT indeed can serve all the urban demand. On the positive side, such an intervention reduces the total number of vehicles which in turn reduces the requirement for parking spaces. DRT service can even be cheaper to operate than private cars [7]. However, in the scenarios where PT exists, replacing its demand may lead towards a significantly higher total resulting VKT when conventional PT is also removed [8].

Another, more realistic scenario for DRT is an introduction of a DRT system as a competitor to all the other modes. In these types of studies, travellers choose their transport mode according to a choice model. And while there is limited real-world data on how travellers choose DRT, stated preference-based models allow estimating decision models [9], [10], [11]. The studies allowing competition between DRT and PT show that DRT tends to steal a big portion of PT and active modes: walking and cycling.

A study of a large-scale scenario, when all the private car trips in Amsterdam, Netherlands, were prohibited, observed that, on the positive side, DRT absorbs car demand, but, on the negative side, it also absorbs almost half of PT, walking and cycling modes [12]. A similar conclusion can be made from a study based in Sioux Falls, South Dakota, USA, which shows that increasing DRT fleet size absorbs the share of PT and walking even faster than it absorbs the share of private cars [13]. Different types of DRT services exhibit this behaviour: an accessibility-oriented low flat-fare fleet of minibuses and more luxurious sedans with a large fare plus kilometre-based cost both attract a significant portion of PT and walking modes [14]. Additionally, the study reports a large increase in VKT and emissions from DRT. A similar effect is observed when varying DRT fleet size: the trend of stealing a large portion of its demand from PT and active modes exists at any DRT fleet size [15], [16].

The third large group of works studies the integration between DRT and PT in the scenario when DRT service executes the first leg of a trip in a rural. In a typical scenario, DRT gathers travellers from its area of operation and delivers them to a main hub (a railway station or city centre). In most scenarios, DRT poses lower generalised costs (operational costs plus traveller costs) at lower demand densities, but conventional buses scale better with demand outperforming DRT after a certain even-out point of the demand density [17], [18]. The scenarios are further evaluated by finding the optimal division of a larger area into smaller DRT zones [19] or by dynamically switching vehicles between conventional PT mode of operation at peak times and DRT at off-peak times [20]. However, in the analysis, even if trips are assumed to continue after reaching the hub, are only analysed on their first leg.

More recently the integration between DRT and is being evaluated on a more systematic level. In these studies, travellers have a choice of a multi-mode trip where DRT performs only the first or last leg as well as a direct single-leg DRT trip. To implement this, new algorithms for multi-leg trip generation are being developed [21], [16]. It has been shown that a DRT service operating in suburbs could increase the overall share of PT trips to the city centre [22]. Still, DRT not only absorbs a big percentage of car traffic but also a large portion of active legs to the railway station. The stealing of local bus trips to DRT is observed on a much smaller scale (14% of local bus lines demand). Integration of DRT and PT in urban areas shows larger stealing of active modes and conventional PT by DRT [15], [16].

III. STUDY AREA AND SCENARIO

In this study, we introduce a DRT system without changing the rest of the PT network. DRT service is operating within the borders of Sjöbo municipality (also referred to here as the DRT zone). The trips within the DRT zone are served in a door-to-door manner. For long-distance trips, DRT serves only a first or last leg connecting travellers to bus departures.

We explore the municipality of Sjöbo in southern Sweden. It is mostly a rural area where about half of almost 20,000 inhabitants reside in the largest town of Sjöbo and the rest are distributed in the smaller towns and villages across 500 km^2. Sjöbo town, located in the middle of the municipality, is connected to the neighbouring municipal centres in four main cardinal directions with long-distance buses (including two express bus lines), as shown in Fig. 1, with a headway up to 15 minutes at peak time. Three more bus lines (in yellow) connect the demand of nearby towns and villages to Sjöbo town (line 338 has a final destination the main town of the neighbouring municipality Tomelilla).

IV. METHOD

This section describes the main methods used to generate travel demand, route DRT vehicles and model traveller and service behaviours. In this study, we adopt the micro-simulation approach where each trip is requested by travellers separately and each trip request is processed by the DRT as unrelated trips. We formulate and solve a static vehicle routing problem for DRT service assuming that all the trip requests are submitted in advance before the DRT service routes the vehicles.

A. Demand modelling

Demand for the study is generated with a procedure similar to [7]. The procedure is based on land use data from Statistics

Fig. 1. Bus lines in Sjöbo municipality

Sweden[1] and Open Street Maps[2]; conditional distributions of trip lengths, time of trips and trip purposes from the travel survey in Scania, Sweden [23]; and demographic data from Statistics Sweden. The procedure is heavily based on sampling trip characteristics from conditional probabilities with given age or trip purpose. To model long-distance trips for the study area, the trips for the whole Scania were generated, see Fig. 2

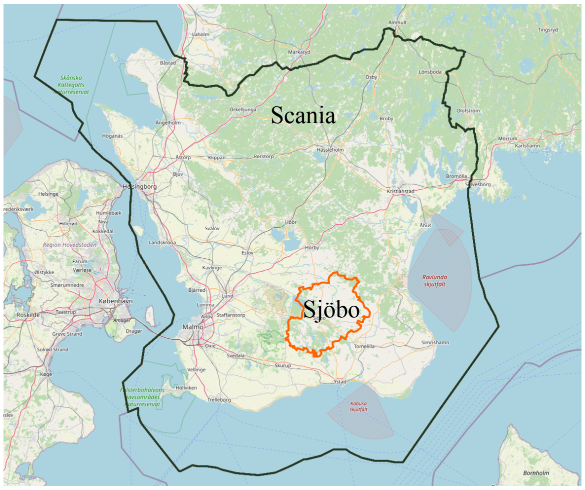

Fig. 2. Scania and Sjöbo municipality

The locations of residential buildings, workplaces, grocery shops, schools hospitals and other types of buildings and points of interest were extracted from Open Street Maps and Statistics Sweden. Eleven types of buildings and points of interest are extracted which are used for assigning the trip destinations of the appropriate types in the latter stage. The travel survey in Scania, is used to extract the distribution of trip chains by trip purpose and traveller's age (including not travelling option), distribution of trip distances by trip purpose, and distribution trip time by trip purpose. The distributions are smoothed with Gaussian kernel density estimation as shown in Fig. 3. And finally, night-time population from Statistics Sweden is used to extract demographic statistics for six age groups (7-15, 16-19, 20-24, 25-44, 45-64, 65+) on a grid of 250x250 meters cells in densely populated areas and 1,000x1,000 meters in sparsely populated areas.

The appropriate number of travellers for each geographical cell in population statistics is generated for each age group. If a traveller has a trip to work, school or a healthcare facility, we define this as the main trip. The distance of the main trip is sampled from the appropriate distribution in the travel survey. The square cells within the sampled distance ± one kilometre are selected as a potential destination. The distances between the cells are computed based on the length of car trips between the centroids of the cells. Home location is sampled from the house buildings in the home cell and the location of the main trip is sampled from the main activity type buildings in the cells within the selected distance from the home cell.

The travellers, who have a trip that we defined as the main, are then allocated an ellipse-shaped zone with an ellipse width twice as large as its height and with home location and main location as focus location. The travellers without a trip type that can be considered main, are allocated a circular area. Within these areas, other types of trips can occur.

The other trip types are allocated by the same principle: a) the distance of a trip is sampled; b) the cells within the selected distance ± one kilometre are selected; c) the location of a trip is sampled from the building of the appropriate type within the selected cells.

When assigning the time of the trip, each trip in the chain is treated separately. The start time of each trip is sampled from the distribution of the appropriate trip type starts.

The described simple procedure cannot represent the accurate demand, but it captures the distribution of trip lengths and trip times, see Fig. 3. For instance, it leads to (what we believe) is rather accurate situation that in the early morning a lot of short-distance trips to drop off the kids at schools are generated. The spatial distribution of the generated demand corresponds to the expectations: about half of the trips related to Sjöbo happen within the municipality, while the largest long-distance demand is split between the neighbouring municipalities. Table I shows the comparison between the number of commuters to or from Sjöbo generated by the described procedure and the number of commuters from Statistics Sweden. While there are significant discrepancies in the numbers, the overall pattern is preserved.

B. *DRT trip model*

DRT operator has the goal trip quality which serves as a hard restriction for the optimisation algorithm at the vehicle routing stage. Each trip is restricted by a time window within which a trip should start. The time window is a constant time interval around the requested departure time. The second

---

[1] scb.se
[2] openstreetmap.org

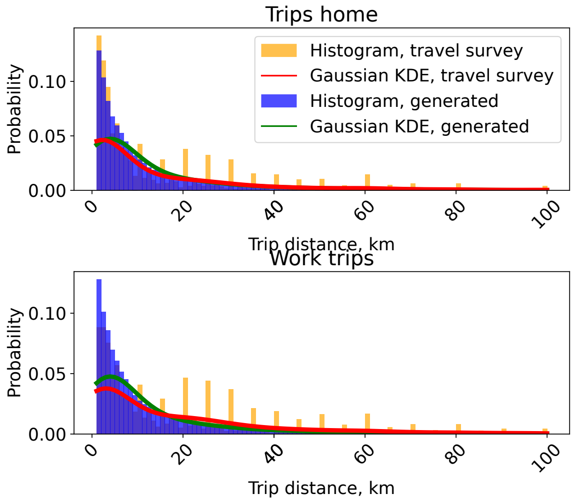

Fig. 3. Difference between the trip length distribution in travel survey and generated demand

TABLE I

THE NUMBER OF GENERATED COMMUTERS TO AND FROM SJÖBO MUNICIPALITY COMPARED TO DATA FROM STATISTICS SWEDEN

	Statistic Sweden	Generated	Difference	Ratio
Skurup	278	452	-174	0.62
Sjöbo	8372	7430	942	1.13
Hörby	320	695	-375	0.46
Tomelilla	666	943	-277	0.71
Malmö	1480	1679	-199	0.88
Lund	1618	1793	-175	0.90
Eslöv	234	307	-73	0.76
Ystad	1151	864	287	1.33
Simrishamn	214	439	-225	0.49

restriction is the maximum detour compared to the direct car trip.

For long-distance trips, Open Trip Planner[3] (OTP) is used to find a PT alternative. Kiss and ride (or ride and kiss) modes are used to find good transfer stops between DRT and PT within the DRT operation zone. The first (or last) legs are extracted and compiled as a vehicle routing problem. The restrictions on the time window and maximum detour for the DRT leg are reduced based on the target PT departure. This way, the whole long-distance trip should satisfy the trip quality goal. Direct trips by DRT within the DRT area are then added to the vehicle routing problem.

C. Supply modelling

The vehicle routing problem are solved with jsprit[4] tool as a static problem with all the trip requests known in advance. Jsprit allows the formulation of complex vehicle routing problems and solves them with a meta-heuristic based on the ruin-and-recreate principle. The type of vehicle routing problem that is solved is the dial-a-ride problem with time windows. The optimisation function is set to optimise operational costs according to table II. The cost model is based on [24]. Additionally, a very high penalty for not-serving a traveller is set. The penalty forces the optimiser to route vehicles for all the travellers as a first priority and optimise the operational costs as a second.

TABLE II

OPERATIONAL COST MODEL

	Vehicle Cost, EUR/day	Temporal Cost, EUR/h	Distance Cost, EUR/km
car	6.3	0	0.17
DRT	9.4	43.3	0.3

The environmental impact is calculated with the simple model based on the open data of HBEFA[5]. DRT vehicles are assumed to be equal to light-duty vehicles with the emission of CO_2 of 258 g/km, and private cars emit 161 g/km. This crude model allows for the comparison of different types of vehicles based on their VKT.

V. SCENARIO

The goal of the scenario is to estimate the impact of the introduction of DRT in the Sjöbo municipality. The DRT service is configured to operate in a door-to-door manner for short-distance trips within the DRT zone. For long-distance trips that cross the borders of the DRT zone, DRT operates in a door-to-stop manner serving the first or last mile of a multi-leg PT trip. The important aspect is that DRT vehicles are connected to specific bus departures in a way that the whole trip is satisfactory for a traveller as explained in section IV. The depot for DRT vehicles is assumed to be located at the main bus stop in Sjöbo town. The vehicle fleet is homogeneous and consists of either eight-seat mini-buses or four-set sedans. The fleet size is unlimited, but the operational costs force the routing algorithm to combine trips into the same vehicle for ride-sharing when possible.

DRT service is restricted to trips larger than one kilometre in order to not replace trips within walking distance. The time window for the trip is set to one hour which corresponds to a worst-case headway between buses. The maximum detour coefficient is set to 1.5.

To evaluate which trips have the potential to use DRT, we estimated a travel time with a kiss and ride (or ride and kiss) mode for the whole demand related to the study area. DRT can potentially serve the trips that satisfy the target trip quality. To estimate the efficiency of DRT, we extract the DRT legs of the trips of the selected users and compile a large vehicle routing problem for the whole day. The problem is then solved with the jsprit solver.

From the trips that DRT can serve, we sample different levels of demand between 580 and 8000 trips, which corresponds to 0.85%-11.7% of the total demand. The highest DRT demand level corresponds to the existing share of PT in the area.

[3] opentripplanner.org

[4] github.com/graphhopper/jsprit

[5] hbefa.net

TABLE III

SIMULATION RESULTS

	Full demand			Long-distance trips only			Local trips only		
	DRT 8-seat	DRT 4-seat	Private Car	DRT 8-seat	DRT 4-seat	Private Car	DRT 8-seat	DRT 4-seat	Private Car
Local trips	2,208			—			2,208		
Long-distance trips	2,359			2,359			—		
Number of vehicles	110	110	2,284	76	76	1,180	49	49	1104
Direct kilometres, km	83,400			75,500			7,800		
Direct kilometres, local leg, km	22,900			15,000			—		
Vehicle kilometres, km	36,100	36,100	83,400	23,300	23,300	75,500	15,800	15,800	7,800
CO_2, T	9.3	5.8	13.4	6	3.8	12.2	4.1	2.6	1.3
Cost per trip, EUR	17.7	16	7.5	22	20.5	10.6	15.9	14.8	4.1
Cost per trip, autonomous vehicles, EUR	4.5	3.3	7.5	5.7	4.2	10.6	4.1	3.1	4.1

VI. RESULTS

A. Full demand scenario

We start by analysing the scenario with 4567 trips which are roughly split by half between local trips and long-distance trips. The main indicators are gathered in Table III.

In the case of full demand, DRT service is able to serve the selected travellers with 110 vehicles. According to the travel survey, the average person is performing 2 trips per day. With this assumption, we can estimate that 110 DRT vehicles could replace 2284 private cars which is a reduction of 95%. VKT produced by DRT vehicles are larger than direct kilometres for DRT (the distance that travellers would produce riding to bus stops by private cars) by 58%. However, if we look at the full trip distance that private cars need to ride (including the trip outside of the DRT service zone, 83,400 km), it is evident that DRT may help to save 67% of that distance.

Eight- and four-seat DRT vehicles show the same efficiency on the discussed indicators because the level of ride-sharing that is shown in Fig. 4 is rather low. Such low ride-sharing does not allow getting benefits from larger vehicles, however, we include the results of the cost and environmental impact of eight-seat mini-buses as this type of vehicle can also be used for transporting people with mobility aid devices.

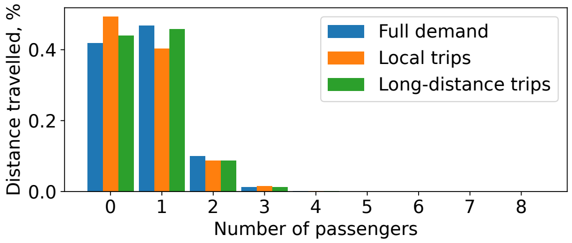

Fig. 4. Occupancy of DRT vehicles

The reduction of VKT leads to a reduction in CO_2 emissions. Here the difference between a fleet of eight-seat and four-seat vehicles is significant. According to the emission model in section IV, larger vehicles produce more emissions per kilometre, thus four-seat vehicles reduce CO_2 by 58% while eight-seat vehicles by 32%. The reduction comes from the assumption that the existing PT lines can absorb the new trips without a large overhead. Extra travellers lead to extra weight for transportation, and potentially more departures due to increased passenger volume. The estimation of the overhead imposed on the existing PT lines is omitted in this study.

The estimation of operational costs shows that DRT the difference between eight- and four-seat DRT vehicles is relatively low. This is a direct sequence of a high relative cost for drivers in small vehicles (see table II). The cost of the modelled DRT service (17.7/16 EUR) is almost on the level of the average costs of special service trips in the area of study: 18 EUR per trip[6]. For comparison, the cost of a PT ticket in the area is 10.6 EUR for a long-distance trip and 2.8 EUR for a short-distance trip while the operational costs of local bus lines in the study area are 8-13 EUR per trip.

The respective cost for private cars is estimated to be 7.5 EUR per trip. This cost excludes the cost for drivers. If we assume similar conditions for DRT by making them driverless (simply by removing the costs for drivers), the operational cost of DRT drops to 4.5/3.3 EUR per trip making DRT financially preferable to private cars.

B. Separating local and long-distance trips

DRT is able to provide VKT reduction due to redirecting its long-distance demand towards the existing PT lines. To better understand the level of impact of such DRT service, we analyse long-distance trips and local trips separately. Table III shows the results of simulations of serving the same local and long-distance trips with separate DRT services.

We can observe that the trip characteristics are different between the two demand groups. Based on the direct kilometres we may see that the average trip length for local trips is 3.5 km while long-distance trips have longer DRT legs of 6.4 km on average. Local trips are shorter and require fewer vehicles, but long-distance trips allow a DRT service to more efficiently utilise the vehicles. Figure 4 shows that DRT vehicles in the local trips scenario produce a larger percentage of empty running. This could be explained by the fact that long-distance DRT trips follow the one-to-many trip pattern where one of the trip locations is always assigned to

---

[6] Here and further on, the costs of existing PT services are received from the local PTA Skånetrafiken.

a bus stop; sort-distance trips are more uniformly distributed. The operational cost of local DRT is 3.9 times larger than the cost of private cars. For long-distance trips, the operational cost of cars is reported for the whole trip distance in table III. If we recalculate the cost of cars assuming park and ride mode (drive by a private car to a PT stop and continue the trip on PT) its cost reduces to 6.9 EUR. Then the relative increase of DRT costs is 3.2 times, which is still lower than in the local trips only scenario.

C. *Demand variations*

When varying the demand for DRT as in figure 5, we can observe the economy of scale for DRT in all the scenarios, although the scaling is rather low. Increasing the demand level eight times from 1000 trips to 8000 reduces the cost per trip by 15% and emissions per trip by 22%.

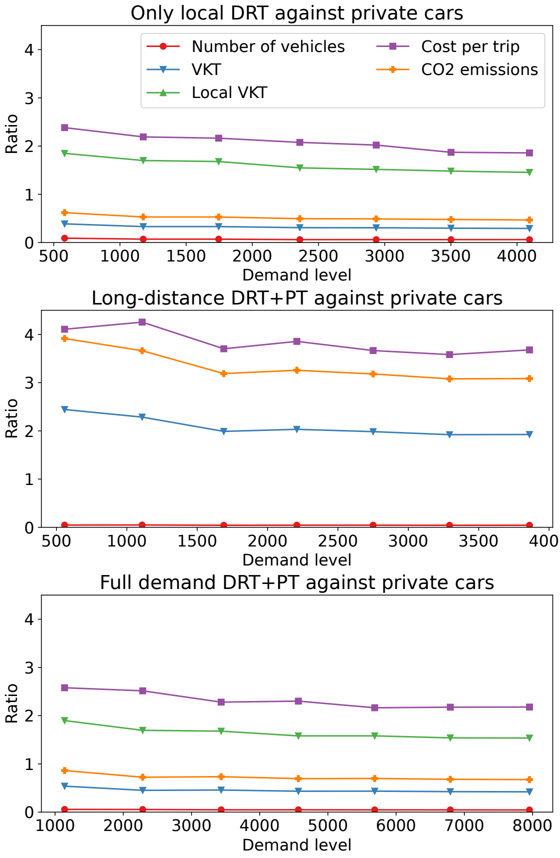

Fig. 5. The scaling of the main KPI of DRT with demand level

Additionally in table III we may observe an improvement in efficiency when combining two separate DRT services into one. For example, the sum of the number of vehicles required for local trips only and long-distance trips only is 115 against 110 vehicles for the full demand scenario. Figure 6 shows that there is a stable improvement by 7-12% in all of the KPI that does not depend on the demand levels.

VII. DISCUSSION

The results indicate that a DRT system by itself would be quite costly to operate and it would negatively affect local traffic and emissions. However, when we account for the absorption of long-distance trips into existing PT lines, the overall traffic flow and emission impacts are reduced, compared to private cars. As a second-order impact, reduced car dependence could lead to a reduction in the required parking spaces and a reduction of resources used on private cars in society.

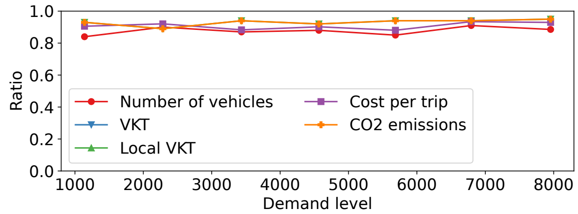

Fig. 6. Reduction in KPI of DRT when combining two services into one

We should also note the potential positive impact of DRT on PT accessibility. DRT is often used as a special transport service and it is considered that DRT can help to improve the possibility of elderly, young or travellers with limited mobility to ride on their own on PT [2], [25], [4], [26]. While we did not evaluate this aspect numerically, it is an important goal of PT and should be taken into account by public transport authorities (PTA) while analysing the potential of DRT in a certain area.

In an urban setting, DRT can increase traffic flow on small streets and free the main streets [8]. Similarly, in our study, DRT increases the traffic volume (as a sequence of increased VKT) inside the DRT zone, but reduces the traffic for the highways as private cars are replaced by buses.

DRT service provides a different tradeoff for transport planners rather than conventional PT. On one side, there is a potential to increase accessibility for travellers, reduce the overall environmental impact, and reduce car dependence. On another side, DRT can lead to larger traffic flows in the local communities and costs a lot to operate. The cost argument is more complex than it may seem. As we are discussing the trips that are currently not covered by PT, it is unfair to compare DRT costs to the cost of PT lines. Covering that demand with conventional PT is likely to be much more costly due to the low density of the demand. Thus, it is desirable to analyse the impacts of DRT services on different objectives and adopt multiple criteria for decision-making [27].

The scenario that we analysed is based on crude models and assumptions about the demand for DRT: demand generation is simplistic, and demand volume and target trip quality are arbitrary. It would be not wise to make predictions based on this experiment. However, our study highlights the potential strong side of DRT when it is integrated with conventional PT.

The door-to-door DRT services often aim to improve accessibility for travellers with mobility limitations. The service design that we described provides trips only to travellers without a good PT option. Such an eligibility criterion is dynamic in its nature and it rises a concern about the fairness of such a system [28], [29]. From the traveller's perspective, the DRT service may seem unreliable if the trip is proposed in one day but not on the other, or if a trip towards a destination can be done on DRT but not a trip back. Such a service could repel travellers with mobility limitations from travelling at all. For example, Danish Plustur[7], which operates in a similar way as in our study, raises a certain degree of confusion among the travellers [30].

VIII. CONCLUSION

This article presented an evaluation of the efficiency of a DRT service in a rural area integrated into the public transport network. The results show that some benefits of such a DRT service can be seen after evaluating it in a context of a larger PT network. DRT services have the potential to increase accessibility, but the service is quite costly and produces more VKT than private cars would. From the whole PT network perspective, DRT can help to replace long private car trips by PT significantly reducing the environmental impact. A potential further reduction of the environmental impact could come from the optimisation of vehicle sizes as the occupation of vehicles remains low in our experiment. The potential automation of driving could help to reduce the costs of DRT service dramatically due to a high proportion of drivers' salaries in the operational costs.

There is a potential to improve PT by integrating DRT services into it. DRT is not the solution that resolves all the issues, but it may help to improve the situation in certain scenarios. We advise further research on DRT to better understand how such a service can affect the performance of the whole PT network.

REFERENCES

[1] F. Pettersson, "An international review of experiences from on-demand public transport services," *The Swedish Knowledge Centre for Public Transport*, 2019.

[2] L. Davison, M. Enoch, T. Ryley, M. Quddus, and C. Wang, "Identifying potential market niches for demand responsive transport," *Research in Transportation Business & Management*, vol. 3, pp. 50–61, 2012.

[3] J. D. Nelson, S. Wright, B. Masson, G. Ambrosino, and A. Naniopoulos, "Recent developments in flexible transport services," *Research in Transportation Economics*, vol. 29, no. 1, pp. 243–248, 2010.

[4] G. Currie and N. Fournier, "Why most drt/micro-transits fail–what the survivors tell us about progress," *Research in Transportation Economics*, vol. 83, p. 100895, 2020.

[5] M. Enoch, S. Potter, G. Parkhurst, and M. Smith, "Why do demand responsive transport systems fail?" in *Transportation Research Board 85th Annual Meeting*, Washington DC, 22-26 January 2006.

[6] F. Golbabaei, T. Yigitcanlar, and J. Bunker, "The role of shared autonomous vehicle systems in delivering smart urban mobility: A systematic review of the literature," *International Journal of Sustainable Transportation*, vol. 15, no. 10, pp. 731–748, 2021.

[7] J. Schlüter, A. Bossert, P. Rössy, and M. Kersting, "Impact assessment of autonomous demand responsive transport as a link between urban and rural areas," *Research in Transportation Business & Management*, vol. 39, p. 100613, 2021.

[8] F. Lorig, J. A. Persson, and A. Michielsen, "Simulating the impact of shared mobility on demand: a study of future transportation systems in gothenburg, sweden," *International Journal of Intelligent Transportation Systems Research*, vol. 21, no. 1, pp. 129–144, 2023.

[9] Y. Xie, M. Danaf, C. Lima Azevedo, A. P. Akkinepally, B. Atasoy, K. Jeong, R. Seshadri, and M. Ben-Akiva, "Behavioral modeling of on-demand mobility services: General framework and application to sustainable travel incentives," *Transportation*, vol. 46, pp. 2017–2039, 2019.

[10] S. Hörl, F. Becker, and K. W. Axhausen, "Simulation of price, customer behaviour and system impact for a cost-covering automated taxi system in zurich," *Transportation Research Part C: Emerging Technologies*, vol. 123, p. 102974, 2021.

[11] N. Geržinič, N. van Oort, S. Hoogendoorn-Lanser, O. Cats, and S. Hoogendoorn, "Potential of on-demand services for urban travel," *Transportation*, pp. 1–33, 2022.

[12] J. Narayan, O. Cats, N. Van Oort, and S. Hoogendoorn, "Does ride-sourcing absorb the demand for car and public transport in amsterdam?" in *2019 6th international conference on models and technologies for intelligent transportation systems (mt-its)*. IEEE, 2019, pp. 1–7.

[13] S. Hörl, "Agent-based simulation of autonomous taxi services with dynamic demand responses," *Procedia Computer Science*, vol. 109, pp. 899–904, 2017.

[14] P. Segui-Gasco, H. Ballis, V. Parisi, D. G. Kelsall, R. J. North, and D. Busquets, "Simulating a rich ride-share mobility service using agent-based models," *Transportation*, vol. 46, no. 6, pp. 2041–2062, 2019.

[15] R. Basu, A. Araldo, A. P. Akkinepally, B. H. Nahmias Biran, K. Basak, R. Seshadri, N. Deshmukh, N. Kumar, C. L. Azevedo, and M. Ben-Akiva, "Automated mobility-on-demand vs. mass transit: a multi-modal activity-driven agent-based simulation approach," *Transportation Research Record*, vol. 2672, no. 8, pp. 608–618, 2018.

[16] J. Narayan, O. Cats, N. van Oort, and S. Hoogendoorn, "Integrated route choice and assignment model for fixed and flexible public transport systems," *Transportation Research Part C: Emerging Technologies*, vol. 115, p. 102631, 2020.

[17] A. Papanikolaou and S. Basbas, "Analytical models for comparing demand responsive transport with bus services in low demand interurban areas," *Transportation Letters*, vol. 13, no. 4, pp. 255–262, 2021.

[18] X. Li and L. Quadrifoglio, "Feeder transit services: Choosing between fixed and demand responsive policy," *Transportation Research Part C: Emerging Technologies*, vol. 18, no. 5, pp. 770–780, 2010.

[19] ——, "2-vehicle zone optimal design for feeder transit services," *Public Transport*, vol. 3, no. 1, p. 89, 2011.

[20] H. R. Sayarshad and H. O. Gao, "Optimizing dynamic switching between fixed and flexible transit services with an idle-vehicle relocation strategy and reductions in emissions," *Transportation Research Part A: Policy and Practice*, vol. 135, pp. 198–214, 2020.

[21] J. Zhao, S. Sun, and O. Cats, "Joint optimisation of regular and demand-responsive transit services," *Transportmetrica A: Transport Science*, vol. 19, no. 2, p. 1987580, 2023.

[22] J. Wen, Y. X. Chen, N. Nassir, and J. Zhao, "Transit-oriented autonomous vehicle operation with integrated demand-supply interaction," *Transportation Research Part C: Emerging Technologies*, vol. 97, pp. 216–234, 2018.

[23] R. Skåne, "Travel survey in scania 2013," 2014, (in Swedish).

[24] M. Estrada, J. M. Salanova, M. Medina-Tapia, and F. Robusté, "Operational cost and user performance analysis of on-demand bus and taxi systems," *Transportation Letters*, vol. 13, no. 3, pp. 229–242, 2021.

[25] Y. Westerlund, "Development and status for large-scale demand responsive transport," in *Paratransit: Shaping the flexible transport future*. Emerald Group Publishing Limited, 2016, vol. 8, pp. 53–74.

[26] R. Kisla, K. Tuba, and H. S. Yildiz, "Demand responsive transport as being paratransit mode: Istanbul modelling," *Transportation Research Procedia*, vol. 14, pp. 3247–3256, 2016.

[27] P. Miller, A. G. de Barros, L. Kattan, and S. Wirasinghe, "Public transportation and sustainability: A review," *KSCE Journal of Civil Engineering*, vol. 20, no. 3, p. 1076, 2016.

[28] F. Behrendt and M. Sheller, "Mobility data justice," submitted for publication.

[29] M. Sourbati and F. Behrendt, "Smart mobility, age and data justice," *new media & society*, vol. 23, no. 6, pp. 1398–1414, 2021.

[30] M. Kjærup, M. B. Skov, and N. Agerholm, "Digital-enabled last mile: A study of passenger trips in rural, low-density populated areas," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 2020, pp. 1–12.

---

[7] dinoffentligetransport.dk/trafikinfo/her-og-nu/plustur/