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# Automation of Rural Collective Transport: Conceptualising three Alternative Use Cases based on Underexplored Rural Transport Specificities

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## 1 ABSTRACT

Whereas the introduction of autonomous vehicles (AVs) is widely explored in urban contexts, their usage in rural transport services is still understudied. The few works in this field focus on four main use-case typologies, which are only selectively tested. These typologies are mostly concentred on: (a) the type of route and schedules collective AVs could supply (fixed or demand-responsive); and (b) the type of connection AVs are supposed to provide (chain-with-transfers or door-to-door). However, they often neglect a series of rural specificities that the design of AV use cases should comprise, such as the substantial temporal variability of rural collective transport demand or the tendency towards activity chaining of commuters living in rural areas. Based on these underexplored specificities, this study conceptualises three alternative use cases that combine the four reference typologies to complement them. Additionally, the study defines the main characteristics of each use case by referring to a set of shared assets relevant for any application of AVs, such as the schedule, vehicle type, service period, or pricing scheme. Future works may take these conceptual use cases as a starting point to design concrete solutions in specific study areas, quantify their costs for the transport provider and benefits for rural dwellers, and thus enlarge the knowledge on the interplay between AVs and rural collective transport.

Keywords: use cases, rural areas, collective transport, autonomous vehicles, mobility

## 2 INTRODUCTION

Autonomous Vehicles (AVs) are one of the most discussed innovations of the transport industry (Milakis, 2019). Many studies explore how AVs could be used in transport systems worldwide and what impacts they could have on, e.g. mobility, land use and the environment (Bösch et al., 2016; Meyer et al., 2017). Most of them focus on the urban context, while rural areas are still ancillary (Bernhart et al., 2018; Dianin et al., 2021; Soteropoulos et al., 2019). This condition is linked to various factors. First, rural areas present some technical challenges for the introduction of AVs related to, e.g. the needed internet support and digital 3D mapping of the network (Ort et al., 2018). Second, due to their scattered geographic structure, rural areas are supposed to be less suitable for innovative sharing schemes (e.g. Gelauff et al., 2019). Third, the impacts of AVs on, e.g. mobility, congestion, car occupancy rate or parking space seem to be much more apparent and severe in urban contexts, making rural areas less enjoyable to study (e.g. Thakur et al., 2016).

However, AVs may play an important role also for rural areas and especially for rural collective transport. For example, saved driver costs could lower the dependency on rural public transport (PT) from subsidies (e.g. 40% of operating costs are covered by subsidies in Italian rural areas; Bernhart et al., 2018). Alternatively, such savings could be reinvested to improve the frequency, service period and network extension of rural PT, as well as to introduce more flexible services with the same subsidies as nowadays (Daduna, 2020; Imhof et al., 2020). These improvements would support the goals of the European Network for Rural Development (ENRD) regarding the “Smart and Competitive Rural Areas” (ENRD, 2016). They would contribute to the concept of “smart villages”, which also comprises transport innovations (e.g. SMARTVillages, 2021). Additionally, these collective transport upgrades could mitigate the mobility limitations of some population groups (such as elderly people and pupils; Ranković Plazinić and Jović, 2018) and the risk of social exclusion affecting 23.3% of the European rural dwellers in 2020 (Eurostat, 2022).

Nevertheless, studies developing and evaluating possible usages of AV in rural collective transport are still lacking (Prioleau et al., 2021, 2020), and most rural studies focus either on the technical barriers to AV introduction, or on their acceptance (Hinderer et al., 2018; Prioleau et al., 2020; Walters et al., 2019). With this article, we want to contribute to this research field by conceptualising a set of systemic use cases for introducing AVs in rural collective transport. In particular, we focus on their topologic and functional side, while not addressing their organisational or financial structures. The proposed use cases steam from a critical analysis of the main use-case typologies developed so far in scientific studies and from identifying some underexplored rural transport-specificities that should be integrated into the design of AV usages. Based on that, we propose three so-called "alternative use cases", describe their key characteristics and explain how they respond to the underexplored rural specificities. These alternative use cases may be considered as a starting point for the future design and evaluation of more specific applications of AVs in concrete rural study areas.

The rest of the article is organised as follows. Section 3 focuses on the existing literature about AV applications to collective rural transport, derives four typical use-case typologies and describes their main characteristics. Drawing on this review and the definition of a series of underexplored rural transport specificities, Section 4 conceptualises three alternative AV use cases and defines their main characteristics. Section 5 concludes the study by explaining how they may be used in future quantitative studies.

# 3 AVS IN RURAL COLLECTIVE TRANSPORT

## 3.1 Main use-case typologies derived from literature

The use cases developed in literature may be clustered according to two main criteria: (A) their type of route and schedule, and (B) the type of connection they provide. The former differentiates traditional fixed-route and -schedule services and alternative demand-responsive ones. The latter distinguishes between systems organised either in "trunks and feeders" or in "trunks and branches" (see the definition recalled by Gecchelin and Webb, 2019 and reported in Fig. 1). The first system comprises feeder lines that link settlements to strategic PT hubs where a major trunk line leads to the main centre. The second system includes a series of partially parallel lines (branches), which link different settlements to the same centre through a common route (trunk). By considering criteria (A) and (B) jointly, four main use-case typologies may be recognised in literature: [1] the fixed feeder, [2] the fixed trunk, [3] the demand-responsive feeder, and [4] the demand-responsive trunk with branches. They are schematised in Fig. 1 and described below in detail.

(1) Fixed feeder: AVs operate along minor feeder lines (usually with a fixed route and schedule) to link dispersed rural settlements to major bus or rail nodes. This use case is often introduced to tackle first/last-mile issues (Gühnemann et al., 2019; Rehrl and Zankl, 2018) and is the reference use case of various rural field tests (e.g. Digibus Austria, 2019). Relevant challenges addressed in literature regard, e.g. the development of adequate time schedules (Truden et al., 2021), the forecast of the impacts on transport demand and operator costs (Digibus Austria, 2019; Gühnemann et al., 2019), or the planning of the transfer between the automated feeders and the traditional trunk.

(2) Fixed trunk: AVs are used to improve the performance of major trunk lines linking rural areas to main urban centres (e.g. Daduna, 2020; Mouratidis and Cobeña Serrano, 2021; Rehrl and Zankl, 2018). For instance, AVs allow increasing the frequency of the service (Daduna, 2020), broadening the service period during early morning and late evening, increasing the length of the trunk line or decreasing the fares for passengers (Mouratidis and Cobeña Serrano, 2021). This use case is tested especially along the main rural-urban routes where a significant demand justifies the strengthening of existing PT lines.

(3) Demand-responsive feeder: A fleet of shared AVs replaces existing PT lines and covers a service area shaped by mainly scattered rural settlements. Car- and shuttle-size AVs typically run without predetermined routes or schedules to provide on-demand connections from such settlements to a reference PT hub like a main bus or railway station (Imhof et al., 2020; Johnsen and Meisel, 2022; von Mörner, 2019). Generally, users share rides, but only-vehicle-sharing applications may be tested, especially when the demand is low. This use case is often introduced in areas where the connection from rural settlements to main PT hubs is found to be inefficient by traditional PT.

(4) Demand-responsive trunk with branches: Similarly to the previous case, AVs operate on-demand within a service area. However, they do not have to mandatory take passengers to reference PT hubs. They can also provide direct connections to the final destinations. For instance, they link rural settlements to main urban centres (Schlüter et al., 2021), or offer door-to-door connections to local facilities such as groceries, schools or recreational hubs (Sieber et al., 2020; von Mörner, 2019). This use case is introduced to replace traditional PT when it is found to be unable to properly serve the demand, e.g. because of its spatial dispersion (e.g. Imhof et al., 2020; Sieber et al., 2020).

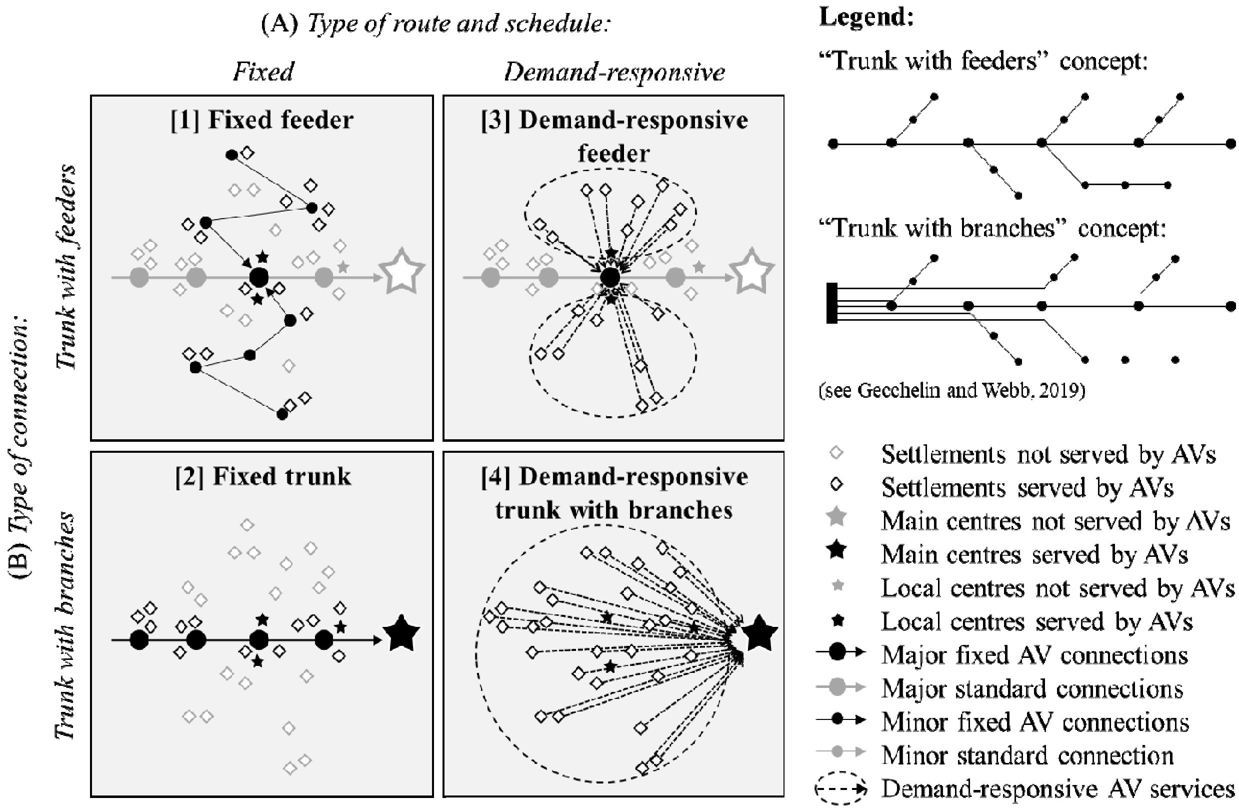


Fig. 1: The four AV use-case typologies for rural collective transport recognised in scientific literature.

## 3.2 Main characteristics of the use-case typologies

For each use-case typology, it is possible to identify a set of core characteristics. They encompass various assets, such as the schedule and routing/stop principle adopted, the covered service period, the type of vehicle deployed to run the service, or the applied pricing scheme. Table 1 summarises the main characteristics usually associated in literature to each use-case typology by referring to eight assets: Time schedule, Route and stops, Sharing system, Booking system, Vehicle type, User friendliness, Service period and Pricing scheme.

Regarding the Time schedule and the Route and stops, the four use-case typologies usually adopt two different approaches. As current PT services, the fixed feeders and trunk typically work with pre-defined routes, stops and schedule. Therefore, there is no real-time variation based on the demand. Conversely, the demand-responsive feeders, trunk and branches are entirely shaped by the demand, meaning that the routes they follow, the stops they make and their schedule is determined based on actual travel requests. The only exception is the demand-responsive feeder, which offers a hybrid stop scheme since its reference PT hub is a fixed destination.

When designing demand-responsive use cases, the type of Sharing and Booking system is also relevant. AVs may offer both ride-shared and only-vehicle-shared services. The first case is prevalent when dealing with connections that have an appropriate demand potential. In contrast, the second case is suitable when the demand is lacking, and implications for congestion are minor. In both cases, the service booking is mostly assumed to be in real-time, with the travel requests collected and processed to optimise the waiting time for users, the detour degree of vehicles, and their occupancy rate (when dealing with ride-shared systems).

Other relevant characteristics regard the Vehicle type, the User-friendliness, the Service period and the Pricing scheme. These assets greatly influence AVs' capacity, performance, acceptance and user costs. The type of vehicle used to offer the service may significantly vary by use case typology (see Table 1). Most studies focus on shuttle-like vehicles since they provide an adequate capacity for shared rides. However, even standard buses are considered when dealing with urban-rural connections with high demand(e.g. Apolitical, 2018). The topic of user-friendliness is mainly related to the options at disposal to book and pay for the services, and digital booking, and payment tools are often assumed. Regarding the service period, AVs are often assumed to run the whole day with the same approach (with no change in use cases between peak and off-peak hours). However, aspects such as the AV fleet for demand-responsive services are often dimensioned based on peak demand data (e.g. Kröger et al., 2017). Finally, the fares of these services are usually planned to be distance-based.

| **Assets** | **Use-case characteristics** | **Description** | **Use-cases typologies** | | | |
|---|---|---|---|---|---|---|
| | | | **[1]** | **[2]** | **[3]** | **[4]** |
| Time schedule | Fixed | The time schedule is predefined by the transport provider and is not subject to changes derived from the demand. | ● | ● | | |
| | Demand-based | The time schedule is not fixed; rather it depends on the travel requests coming from the demand. | | | ● | ● |
| Route and stops | Fixed | The service departs, arrives and stops in fixed points predefined by the transport provider. | ● | ● | ● | |
| | Demand-based | The service departs, arrives and stops in flexible points depending on the travel requests. | | | ● | ● |
| Sharing system* | Ride-sharing | Users might share part or the ride if there are more users with similar travel requests. | | | ● | ● |
| | Only-vehicle-sharing | Users share only the vehicle at separated timing but not the ride, which remains individual. | | | ● | ● |
| Booking system* | Real-time | Travel requests are collected and processed almost in real-time. Vehicles are assigned to requests accordingly. | | | ● | ● |
| Vehicle type | Bus-like | Automation is applied to large vehicles similar to standard busses (e.g. 40-60 seats), especially for high-demand lines. | | ● | | |
| | Shuttle-like | Automation is applied to mini-busses with a lower capacity (e.g. 8-14 seats), especially for medium-demand services. | ● | | ● | ● |
| | Car-like | Automation is applied to standard cars (max 6 seats), especially to offer taxi-like services in low-demand contexts. | | | ● | ● |
| User friendliness | Designed for the digital age | Demand-responsive services are booked only via web and paid via digital methods, while classic tickets/abos work only for PT lines. | ● | ● | ● | ● |
| Service period | Whole day | The service runs the whole day with no interruption or replacement with alternative services. | ● | ● | ● | ● |
| Pricing scheme | Distance-based | The cost of the service for the users is calculated based on the distance travelled or the travel time. | ● | ● | ● | ● |

**Notes:**
**[1]** *Fixed feeder*; **[2]** *Fixed trunk*; **[3]** *Demand-responsive feeder*; **[4]** *Demand-responsive trunk with branches.*
● Characteristics usually associated to each use-case typology in literature.
*****Ride-/only-vehicle sharing and the real-time booking are considered only in demand-responsive use cases.

Table 1: Characteristics typically associated to the four AV use-case typologies.

## 4 CONCEPTUALISING THREE ALTERNATIVE USE CASES

### 4.1 Underexplored rural transport specificities

The presented use-case typologies and their characteristics respond to the typical specificities of rural transport, i.e. the lacking and dispersed transport demand and the distinct rural-urban relations shaping commuters´ and students´ mobility (Banister, 1983; Moseley, 1979). However, rural transport presents other specificities that should be considered when designing AV use cases (Brown and Taylor, 2018; Dianin et al., 2021; Milakis and van Wee, 2020). The following paragraphs and Table 2 summarise them and highlight which use-case characteristics should be designed by considering them. In detail:

Temporal variability of collective transport flows: More than in urban areas, rural zones are shaped by a substantial variation of PT demand between peak and off-peak hours. During the former, several students and commuters travel to workplaces and schools. During the latter, travel demand is low and not concentrated, and mostly generated by people spending a relevant part of their daily life at home (like elderly people, part-time workers or pupils). Existing PT solutions can hardly face this substantial demand variation. They typically serve the peak-hour demand with large-size vehicles and the same vehicles offer an oversized capacity for a few runs during the rest of the day, which are typically low frequented due to their poor time schedule. This condition makes the agency cost efficiency very low and it deteriorates the perception of PT for the uses (Bernhart et al., 2018; Hough and Taleqani, 2018). This suggests the need of differentiating the service design between peak and off-peak hours (especially the time schedule, routing and stops, sharing system and vehicle types), since one single approach hardly fits all the daily phases.

Daily activity chaining: Due to longer distances typically travelled by rural commuters, many daily activities are planned to optimise the daily travel chain (Schwanen, 2008; Talpur et al., 2014). For instance, activities that can be flexibly performed in space and time (e.g. grocery shopping) are performed as stopovers along the routes to and from the locations of daily fixed activities (like work and home place; e.g. Tivers, 1985). This has some impacts on rural transport demand. Rural dwellers tend to rely much more on private cars in order to perform such activity chaining. At the same time, spontaneous unplanned travels are less frequent than in urban areas. To cope with these aspects, the time schedule, route and stops as well as the vehicle design should be planned to ease such activity chaining, as well as the booking system for demand-responsive services could benefit from a more stable planning of individual daily mobility habits.

Spatial distribution of demand: Starting from the general consideration that rural transport demand is spatially dispersed, different conditions apply to e.g. mountain valleys, flat sprawl areas, or polycentric rural settlements. The interplay between these spatial forms and the transport supply should be considered (Dröes and Rietveld, 2015). In particular, the definition of either fixed or on-demand routes and the sharing of either rides or only vehicles might be designed with a stronger consideration of this spatial form. For instance, valleys where all settlements are concentrated along the same route may be more suitable for lines running on pre-defined routes or covering on-demand stops within a band operational area (Nocera and Tsakarestos, 2004). Conversely, sprawl areas may be better served by free-floating taxi services (e.g. Schlüter et al., 2021).

Collective-transport dependency of some user groups: Due to the strong mismatch between private and public transport, rural inhabitants who rely on PT are typically those who cannot access private cars (as people younger than the legal driving age, the elderly, or people unable to afford a private car; Ranković Plazinić and Jović, 2018). This social homogeneity of rural PT users is much higher than in urban centres, where PT is more competitive and even its users are more heterogeneous in their socio-demographic and -economic backgrounds (Rossner and Bullinger, 2020). Starting from this condition, the user friendliness and sharing system of rural AVs should be designed by bearing in mind the characteristics and needs of the typical rural PT users (although the improvements brought by AVs are expected to broaden the range of typical users). For instance, the lower familiarity of older people with new technologies, the higher digital divide experienced by rural dwellers, or the higher perceived vulnerability of young users to safety issues should be integrated.

Affection to private cars of some user groups: More than their urban counterpart, rural inhabitants have the private car as their major if not even only mean to satisfy their mobility needs. This tends to create a strong affection to private cars among rural inhabitants, as well as a lack of habit to share transport means and rides (Mausbach et al., 2019). This is a not-negligible social aspect that should be considered in the design of AV sharing systems. For instance, mixed sharing concepts where users may decide whether to share only the vehicle or even the ride could be a viable solution to cope with this cultural specificity as well as with the lacking demand. This would imply also a deeper discussion on the pricing scheme to introduce (e.g. based on the vehicle occupancy rate in addition to the travel distance).

Perceived lack of safety: Due to the spatial dispersion and lower presence of people on rural streets, travelling (especially by collective modes) gives more safety concerns to rural users than urban ones. For instance, PT vehicles tend to host less passengers in rural areas, which may lead to negative feelings of unsupervised and unsafe environment. The same applies to the lower presence of pedestrians on the street and the average higher speed of vehicles, which may increase a perceived isolation (e.g. Lu et al., 2014). These aspects should be considered in the design of AV use cases. For instance, vehicles could be designed in a user-friendly way that eases the access of external support services. Additionally, only-vehicle-sharing schemes could be introduced during the timeframes where people are less inclined to share the ride (e.g. late evening).

| **Underexplored rural specificities** | **Use-case characteristics** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Time schedule** | **Route and stops** | **Sharing system** | **Booking system** | **Vehicle type** | **User friendliness** | **Service period** | **Pricing scheme** |
| Temporal variability of collective transport flows | ● | ● | ● | | ● | | ● | ● |
| Daily activity chaining | ● | ● | | ● | | ● | | |
| Spatial distribution of demand | | ● | ● | | ● | | | |
| Collective-transport dependency of some user groups | | | ● | | | ● | | ● |
| Affection to private cars of some user groups | | | ● | | | | | ● |
| Perceived lack of safety | | | ● | | | ● | | |

**Notes:**
● Underexplored rural transport specificities to be considered for the design of each use-case characteristic

Table 2: Relation between the underexplored rural specificities and the use-case characteristics.

## 4.2 Three alternative use cases and their characteristics

To incorporate these rural specificities, we propose three alternative use cases, namely: [1] Fixed trunk with hybrid feeders; [2] Hybrid trunk with demand-responsive feeders; and [3] Hybrid trunk with hybrid branches. The word "hybrid" refers to services mixing fixed and demand-responsive approaches over time. These use cases steam from the four typologies described in Subsection 3.1, which are combined and adjusted differently. Fig. 2 displays them, while Table 3 shows their use-case characteristics.

(1) Fixed trunk with hybrid feeders: A trunk line to the primary reference centre is combined with a series of feeders linked to the trunk nodes. The trunk operates for the whole day with a fixed scheme: fixed schedule and route, high and regular frequency, and bus-like vehicles for increased capacity. The feeders instead change their configuration over time. During peak hours, they run like classic PT lines operated by shuttle-like vehicles. During the off-peak hours, there is no predefined line and stop but service areas covered by taxi-like vehicles. This may be helpful, e.g. for elderly people doing grocery shopping, part-time workers, or kids performing leisure activities during off-peaks. Given the low demand during such timespans, AVs may be shared or not (which is helpful for vulnerable users such as elderly people or kids). This use case may be appropriate to serve, e.g. mountain valleys with a relatively high and stable demand concentration along the trunk line and a series of minor settlements around it always located in an almost linear space.

(2) Hybrid trunk with demand-responsive feeders: The trunk line keeps a fixed-route-and-schedule principle with high-capacity vehicles only during peak hours. During off-peaks, it is operated by shuttle-like vehicles that run along the same route and stops, but their schedule depends on the travel requests from users. The feeder services are always performed on-demand with no predefined route or schedule. However, minor service differences exist between peak and off-peak hours. In particular, during the former, the sharing of the ride is compulsory, while during the latter, the ride can be shared or not. Thanks to this combination, the activity chaining is eased. For instance, users travelling between the urban core and the remote rural settlements may stop by at any local hub, access services like groceries, healthcare facilities, of leisure activities, and then complete the travel up to their remote destination via demand-responsive feeders. In this framework, the local hubs play a crucial role. They have to be planned to adequately host both a reasonable fleet of on-demand AVs as well as the stops of the trunk. Compared to the previous use case, this one is more

suitable e.g. for sprawl areas with a high demand fluctuation along the trunk line and a high spatial widespread of settlements making a line-based system of feeders unviable even during peak hours.

(3) Hybrid trunk with hybrid branches: In this case, all transport services change their configuration between peak and off-peak hours. The trunk runs as a standard bus line, with stops only during peak hours. During off-peaks, the stop system is suspended, and demand-responsive shuttle-like services serve settlements within a walkable distance from the trunk line nodes. The secondary on-demand services act as feeders only during peak hours with mandatory connections to trunk nodes. Conversely, they are configured as branch lines during off-peak hours. This means that during these timespans, they can bring passengers to any desired destination (either local or outer ones). Therefore, during the off-peak hours, the trunk and branches partially run parallel. This configuration has an intrinsic limitation to bear in mind: more collective services run along the same route, generating potential competition and exacerbating possible congestion issues. Therefore, this use case is viable only for low-demand rural areas where congestion is a little concern.

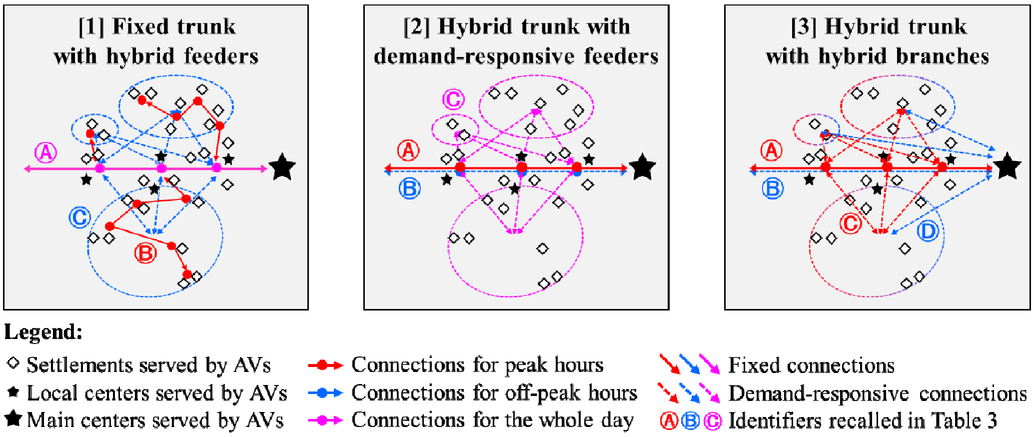


Fig. 2: Alternative use cases for using AVs in rural collective transport.

## 5 FUTURE WORK AND CONCLUSIONS

These alternative use cases may be a conceptual basis for designing collective AV applications in specific study areas and quantifying their impacts on the rural transport system. Regarding such impacts, what seems still ancillary in the rural AV debate is the quantification of the impacts that different use cases might have on the private-collective transport mismatch. Such mismatch is particularly difficult to solve in many rural contexts and it generates great (accessibility) differences between those who have to rely on collective means of transport and the others accessing private cars (e.g. Carroll et al., 2021). If on the one hand it seems self-evident that AVs will reduce such mismatch, on the other hand it is still unclear how much it will be reduced, as well as where and for whom. Moreover, it is neither straightforward to conclude that such mismatch will be substantially reduced at all, since private cars will also gain important benefits from the automation process (e.g. in terms of perceived travel-time disutility, household sharing of vehicles and parking-related costs; e.g. Dianin and Cavallaro, 2019). These benefits for the private car could keep the private-collective gap still high, hampering any substantial change of transport paradigm for rural dwellers.

Future works may focus on concrete rural study areas, quantify the impacts of collective and private AVs on the generalised cost of transport incurred by users (Ricci, 2011), and compare with the status quo. The generalised cost might be quantified, e.g. for different origin-destination relations (space-based) or the same relation. However, different user types (person-based) and the changes in the collective-private mismatch might be pointed out. This kind of evaluation could be carried out only for those collective use cases that have passed a preliminary check of their transport-provider costs, which should comply with the standards declared by transport providers (e.g. Bösch et al., 2018; Imhof et al., 2020). Figure 3 schematises the process that might be followed to perform such an evaluation of the private-collective transport mismatch in rural areas, starting from the conceptual use cases presented in Figure 2.

Regardless of this possible future research direction, the alternative conceptual use cases developed in this study may be an added value compared to the existing ones: they incorporate a set of rural transport specificities that have been underexplored so far in the literature. According to these specificities, they combine both fixed and demand-responsive services, provided as either trunk lines with feeders or with branches. These services are differently combined during peak and off-peak hours to adequately respond to the high travel demand variation typical of rural contexts. Finally, they have some design features considering the specificities of rural uses. Future studies may use these use cases to explore further the relation between AVs and rural areas, which remains an ancillary but needed research niche.

| **Assets** | **Use-case characteristics** | **Description** | **Alternative use cases** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **[1]** | | | **[2]** | | | **[3]** | | | |
| | | | Ⓐ | Ⓑ | Ⓒ | Ⓐ | Ⓑ | Ⓒ | Ⓐ | Ⓑ | Ⓒ | Ⓓ |
| Time schedule | Fixed | The time schedule is predefined by the transport provider and is not subject to changes. | ● | ● | | ● | | | ● | | | |
| | Demand-based | The time schedule is not fixed; rather it depends on the travel requests coming from the demand. | | | ● | | ● | ● | | ● | ● | ● |
| Route and stops | Fixed | The service departs, arrives and stops in fixed points predefined by the transport provider. | ● | ● | | ● | ● | | ● | | | |
| | Demand-based | The service departs, arrives and stops in flexible points depending on the travel requests. | | | ● | | | ● | | ● | ● | ● |
| Sharing system* | Ride-sharing | Users might share part or the whole ride if there are more users with similar travel requests. | | | | | ● | ● | | | ● | |
| | Mixed-sharing | Users may decide whether to share the ride with other users with compatible travel requests or not. | | | ● | | | ● | | ● | | ● |
| Booking system* | Real-time | Travel requests are collected and processed almost in real-time. Vehicles are assigned accordingly. | | | ● | | ● | ● | | ● | | ● |
| | In advance | Travel requests are collected before the provision of the service to shape it accordingly. | | | | | | ● | | | ● | |
| Vehicle type | Bus-like | Automation is applied to large vehicles similar to standard busses, especially for high-demand lines. | ● | | | ● | | | ● | | | |
| | Shuttle-like | Automation is applied to mini-busses with a lower capacity, especially for medium-demand services. | | ● | | | ● | ● | | | ● | |
| | Car-like | Automation is applied to standard cars, especially to offer taxi-like services in low-demand contexts. | | | ● | | | ● | | ● | | ● |
| User friendliness | Designed for all | Services may be booked via telephone, paid in cash, paper tickets are available, etc. | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Service period | Peak hours | The service runs only during the peak hours. Other services are provided during the rest of the day. | | ● | | ● | | | ● | | ● | |
| | Off-peak hours | The service runs only during peak-off hours. Other services are provided during the rest of the day. | | | ● | | ● | | | ● | | ● |
| | Whole day | The service runs the whole day with no interruption or replacement with alternative services. | ● | | | | | ● | | | | |
| Pricing scheme | Distance-based | The cost of the service for the users is calculated based on the distance travelled. | ● | ● | | ● | ● | ● | ● | | ● | |
| | Occupancy-based | The cost of the service for the users takes into account the vehicular occupancy rate beside the distance. | | | ● | | | ● | | ● | | ● |

**Notes:**

**[1]** *Fixed trunk with hybrid feeders;* **[2]** *Hybrid trunk with demand-responsive feeders;* **[3]** *Hybrid trunk with hybrid branches.*

ⒶⒷⒸⒹ See the identifiers included in Fig. 2.

● Characteristics associated to each service of the alternative use cases.

***** Ride/only-vehicle sharing and the real-time/in-advance booking are considered only in demand-responsive use cases.

Table 3: The characteristics of the three alternative use cases.

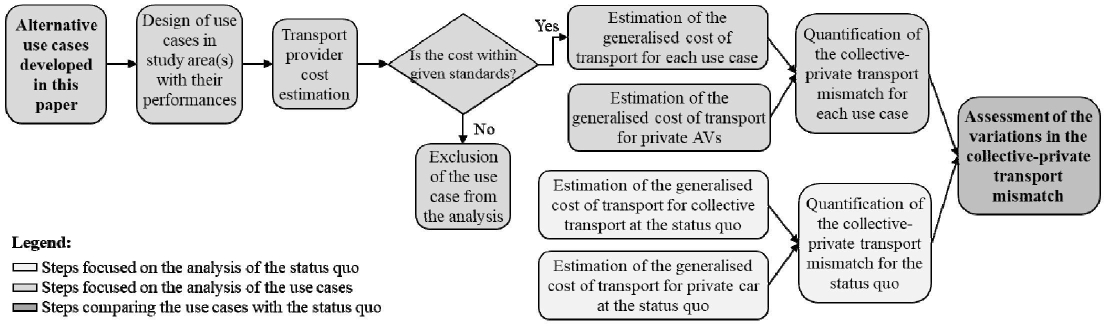


Fig. 3: From the alternative use cases presented in this paper to the analysis of the collective-private transport mismatch.

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