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Demand responsive transport options in rural area

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ABSTRACT

There has been a constant lack in transport resources in rural area, hence rural residents have relatively less access to basic opportunities; in highly motorized contemporary societies, residents of rural and other low-density areas are often more car-dependent as a result. In order to facilitate the post-car transition and to propose context sensitive policies, the basic prerequisite is a clear and comprehensive understanding of all alternatives to car. Due to technological developments as well as social changes, DRT (Demand Responsive Transport) has returned to the hot spot of practical exploration in recent years. As a mode of transport adapted to low-density areas, it may be the main option for alternatives.

DRT is an elastic alternative to traditional public transport, characterized by lower capacity road vehicles and routes or schedules that can be varied in response to demand. So far, DRT research has shifted from studies on service supply to the direction of market niche and service satisfaction, though relevant studies are still insufficient. Although empirical studies are limited, empirical explorations over the years have resulted in some generic conclusions and recommendations. DRT is often treated as a single option, but there are different DRT service schemes which suitability to low density areas depends on several factors.

Given the local sensitivity of DRT service schemes, this thesis provides a comprehensive examination of different types of transport provision and a tentative assessment of their suitability to different contexts. In doing so, the thesis aims to contribute to bridging a gap in research.

Within the theoretical framework of the RECAP project, a set of DRT alternatives to the car in low-density areas is explored. After a literature review on the challenges of rural accessibility and demand-responsive transport, the demand-responsive transport options are classified into three categories (fleet sharing, for-hire ride services, not-for-hire ride services). Based on the review of literature and research projects, the features of these options are analysed and assessed against a set of territorial features. The result of the study is a matrix comparing the characteristics of different types of transport provision, as well as a discussion about their local adaptability.

Key words

Demand Responsive Transport, Shared mobility, Rural Accessibility, Low-density area

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CHAPTER 1

Introduction: addressing the challenge of rural accessibility

The challenge of rural accessibility have a multifaceted background, including the evolution of urban and rural development processes, globalisation and urban-rural relations, and the impact of the automotive industry on urban-rural life. In the face of the problems that these changes have brought to rural areas, the development of ICT and the accumulation of practical experience have increased the possibility of solving accessibility problems.

This chapter discusses the background of rural accessibility issues from the above aspects to provide a broader perspective on this interdisciplinary topic.

1.1 Rural accessibility

1.1.1 Urban and rural area

Villages were an early form of human settlement. As people's economic and trade needs increased, bazaars emerged and people settled around them, which were the precursors of cities. In essence, therefore, cities are synonymous with density. Dense demand, population, the resulting economic and social opportunities and possibilities constitute a city.

Nowadays when we talk about rural areas, we tend to imagine "vast areas outside the city", accompanied by farms, ranches and oil fields. The countryside often seems to exist as a counterpart to the figurative and glittering cities that have been the key stage in the course of human civilization. As cities grew in size, a series of urban problems began to emerge. After the Industrial Revolution, when capital was further developed and the use-value of land was exploited as a result of utilizing unevenly distributed resources, the term 'development' began to be used frequently, while urban problems escalated further, with traffic congestion and pollution, and until recent modern times urban planners and policy makers are still trying to deal with them. With the emergence of the theory of competitive rent, the use value of land and the importance of transportation became more and more apparent. As urban problems became more pronounced and the automobile industry and railroads grew rapidly, the trend toward suburbanization occurred in many places; cities spread, low-density areas increased in

extent and became more diverse. Land use patterns became increasingly decentralized.

With increased globalization, the problems of urban areas have become more complex, and the urban centrism of the past can no longer explain current phenomena. Rather than seeing cities as linear, population-centered types of agglomeration, perhaps it would be more meaningful to switch the object of observation to the ongoing process of socio-spatial transformation, the development of organizational elemental relationships, and the creative reorganization of socio-spatial configurations behind the urban entity; rather than looking at geographic phenomena in an urban-rural dichotomous way, the fact is that the operational landscapes (dialectically) support the agglomerations (not only demographic, but resource/relationships as well) and grows on logistical space, which is closer to the essence of human constructs. (Jonas, McCann, and Thomas 2015) However, as a process that prioritises the economy over society, globalisation has brought with it a neoliberal discourse that has had a significant negative impact on rural areas. Global markets have drawn power from the local to the international level, and the boundaries of inequality have shifted.

The countryside quietly feeds the city, providing cultural heritage, agricultural support and ecological value, but people are looking more to the cities. With the development of urbanisation, the attractiveness of the city and the countryside is becoming increasingly unequal. This has been exacerbated by the government's neo-liberal shift and the associated privatisation of services. Sensing a lack of opportunities to survive, many rural residents have no choice but to move to the big cities. The countryside is gradually being hollowed out and, in response, service facilities are not sufficiently supported by the population and service outlets are gradually closing. At the same time, the social capital in rural areas has been eroded, and they have gradually lost the power to defend themselves. And this process is still going on.

Returning power to the local level and enriching it is a major challenge in the context of globalisation. This, of course, includes the right to mobility.

1.1.2 Rural mobility deprivation

Transportation conditions, as one of the necessary conditions for cities to come into being in the first place, are perhaps one of the key qualities that distinguish agglomerations from operational landscapes. The technological development of transportation in the nineteenth century, with railroads, steam trains, and telegraphs, brought about important advances in globalization. The importance of the city in this process also lay in its geographical location /transportation advantages, which made it

easier to organize the flow of global elements. Thus, it can be argued that rural areas by their very nature suffer from low accessibility.

Rural deprivation is therefore becoming a common phenomenon, directly linked to the difficulties of transport provision in rural areas. The population and resources of the countryside are dispersed, but the transportation needs of rural residents do not converge because of this low density. In the face of insufficient demand, it is more difficult for public transportation to maintain its operation in economic terms, and at the same time, it is difficult to cover services, both spatially and temporally, to meet the different needs of the population. Due to the low quality of public transportation services, people have to choose private transportation, i.e. cars, to meet their transportation needs. Cars alleviate the demand for transportation, but once they are purchased and used, people have little incentive to use public transportation, and this exclusivity in turn further hinders the development of public transportation. In this stalemate (reminiscent of a vicious circle), people in rural areas tend to be highly dependent on cars, and those who do not have access to cars are forced to face severe mobility deprivation.

Transportation services accessible to all are considered important for social equity (Hine & Mitchell, 2001). The United Nations Special Rapporteur on Extreme Poverty and Human Rights has argued that the failure to provide such services is "incompatible with human rights" (Alston, 2019, cited in Alston et al.) The EU has highlighted how sparsely populated and underpopulated areas are plagued by a number of structural problems, such as lack of transport links, low employment opportunities and inadequate social services. In a recent publication by the European Parliament, lack of public transport was identified as one of the main problems faced by low-density and sparsely populated areas, with the result that residents without access to private car suffer from social exclusion. According to a 2003 statistical study by the Social Exclusion Unit in the UK[1], two-fifths of jobseekers said that lack of transport was a barrier to finding work; more than 1.4 million people said that they had missed, refused or decided not to seek medical help in the past year because of transport problems; 16% of people without a car found it difficult to go shopping at the supermarket and 18% had difficulty visiting friends and family because of transport problems, which was much higher than the group with a car. (SEU, 2003)

However, as Lucas says, transport and social exclusion can never exist as a

[1] http://www.socialexclusion.gov.uk/downloaddoc.asp?id=229

transport-focused agenda alone (Lucas 2012). To truly improve the aforementioned social exclusion, it is necessary to integrate transport, planning, education, health and other sectors. To achieve this, we need an interdisciplinary concept that will help us to formulate better policies, namely the concept of accessibility.

1.1.3 Accessibility as a tool

The early concept of accessibility was proposed by Hansen (1959) and was mainly used to describe and quantify the existing situation in land use and transport modelling. Moseley's book (1979) introduced and fully developed this concept in a rural context, which is the current mainstream concept of accessibility. Twenty years later it began to be introduced in an urban context, making it a more general concept.

Accessibility is a concept that has much deeper implications than mobility or transport itself, and is more akin to constrained access to a certain level of social activities and opportunities. Mobility is only one way of achieving accessibility. For example, there is no need to improve mobility if the required services are not accessible due to spatial planning or the location of other policy sectors. Compared to the concept of mobility, accessibility not only adds a spatial dimension (considering geographical proximity) but also a deeper relationship with people and facilities. According to (Farrington 2007), *a place is not just 'more' or 'less' accessible, but accessible relative to people in all their different circumstances: people experience more, or less, access to places.* Constrained access to life opportunities and possibilities can cause wider and deeper deprivation than a lack of mobility.

The value of the accessibility concept in bringing location into the structuring of social problems such as poverty lies in the fact that it opens up a dimension of understanding that is relevant for policymaking. Clarifying and legitimising this concept can inform and provide a basis for the redistribution of resources in policy making. The construction and application of the accessibility concept is closely linked to cross-sectoral integration and requires a clear (quantitative and qualitative) identification of trade-offs between the social, economic and environmental elements of local, national or global systems, which can help to implement sustainable approaches in policy.

To better understand how to improve accessibility in low density areas, another important issue that cannot be ignored is car dependency.

1.2 Car dependency in low-density area

1.2.1 The development of car dependency

For a hundred years before the advent of the car, the beating heart of major cities was a public transport system of trains and trams. In the early 20th century, Henry Ford's mass production of the Model T led to a rapid increase in car ownership. This was accompanied by the dismantling of basic transport infrastructure such as tram lines and the construction of large motorways and car parks. Public transport was gradually undermined or even replaced, while car use became the focus of urban development and planning. Although the extent and timing may vary, similar urban development processes have taken place all over the world.

In the 1970s and 1980s, the environmental problems caused by cars became apparent, and people began to realize the need to reduce car use (the lagging relationship between car production and car use: in fact, increased car ownership has shrunk the car industry, e.g., Detroit.) However, due to urban infrastructure development, psychological inertia, and the social attributes attached to small cars, the problem of car dependency is already widespread and has led to a range of problems including social isolation, car-based discrimination and financial pressures. In the United States, a strong correlation has been found between car ownership and the chances of finding a job. In some cases, the relationship between car ownership and employment opportunities even outweighs the influence of spatial constraints. (Cervero et al., 2002).

Over the past 30 years, urban planning concepts have undergone a dramatic change, from car-centric planning to advocating the revitalisation of city centres and the renaissance of public transport. The concept of transit-oriented development has led many cities around the world to create a large number of urban sub-centres around the rail transit systems; some cities have reused abandoned motorway infrastructure with new concepts. It can be said that the end of car dependency has become a reality in some urban areas, and because the urban knowledge economy fits well with regional characteristics such as high-density services and low car dependency, the end of car dependency is unlikely to be reversed.

However, low-density areas, which are the opposite of these urban areas, are still facing the severe test of car dependency, sitting at the end of the global urban network.

1.2.2 Car dependency in low-density area

Compared to cars, buses are cost-effective especially for long-distance travel. They reduce the total distance travelled, reduce carbon emissions and reduce congestion on urban roads. The challenges for public transport are limited flexibility and reliability, and the need for sufficient occupancy to ensure basic operation and service coverage. These problems are magnified in rural areas. Lower densities means greater travel distances for most trips, fewer origins and destinations within walking distance of any single route, and more kilometers traveled to reach activities.

As mentioned earlier, public transport does not work well in rural areas, and the vicious circle brings service inefficiencies, reduced ridership, and smaller budgets for public transport, whereas cars are more in line with the need for complete flexibility and exclusivity, without the economic and ethical constraints related to pollution that are present in cities, and with a high degree of exclusivity due to their higher initial investment costs. This situation makes traditional public transportation uncompetitive and almost unsustainable.

In developing regions where rural poverty persists, car ownership in rural areas is still lower than in urban areas due to the high cost of cars, although this gap is rapidly narrowing. In relatively developed countries and regions, car dependency is much higher in rural areas than in cities. In the most urbanised region of the Netherlands, 36% of residents say they are becoming more car-dependent, while in rural areas the figure is almost double: 64%. (Toon, Stefan and Jan-jelle 2022) Regional differences in this issue can also be seen in the level of academic interest. Rural accessibility issues are often studied in more developed regions with higher rural densities, where car ownership is high, but public transport services are also expected for non-car owners, the poor, the elderly, the young and the disabled, for example in Europe and Japan. In regions such as the United States and Australia, where there is less research interest and where it started relatively late (compared to the overall research situation in these areas), the affluent and widely dispersed population makes people think more about owning several cars.(Nutley 2003).

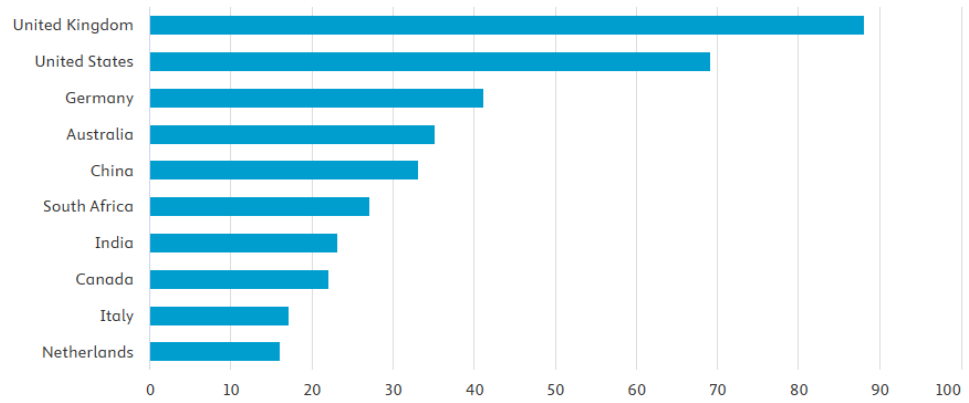

Figure 1.1 Search results of 'rural accessibility' & 'public transport' by country, source: Scopus

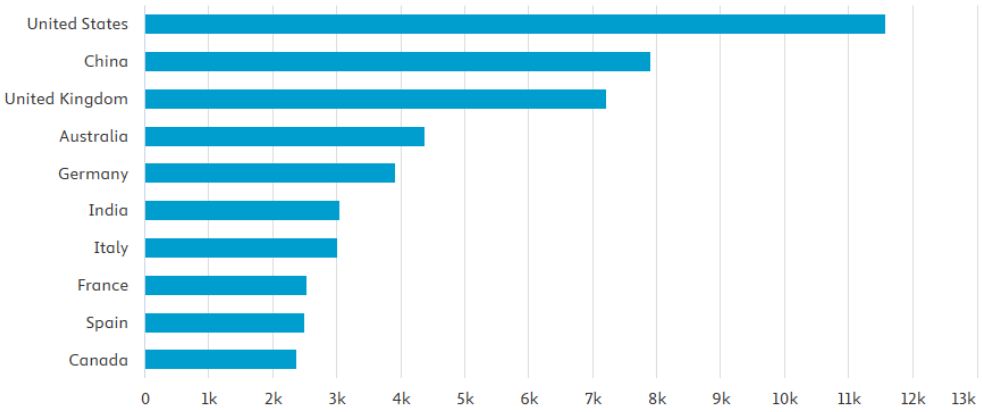

Figure 1.2 Search results of 'public transport' by country, source: Scopus

1.3 Finding alternatives to single occupancy vehicle

1.3.1 The post-car transition: looking for alternatives

Cities are undergoing a post-car transformation, with public transport and slow-moving environments becoming better and better; whereas, to meet people's needs in low-density rural areas, alternatives to the car need to be more resilient than regular public transport, and able to move longer distances than active transport.

Today, transportation systems are undergoing a shift toward smart mobility, thanks to advanced technologies (Docherty et al., 2018), new attitudes toward mobility-on-demand services and demographic changes (Shaheen and Cohen, 2020)

Many rural areas in Europe are experimenting with some innovative modes of transportation, which are called demand responsive transport, or micro transit. In this thesis, DRT (demand responsive transport), a phrase commonly used in the field of transportation, is used to refer to this type of elastic alternative to PT in a general way, which is characterized by low-capacity road vehicles and demand-responsive routes or schedules. In comparison to taxicabs, this type of service can more efficiently bundle demand for similar trips, and it can potentially provide a higher level of service at the same level of funding than traditional buses, with flexible operations.

Because of its suitability for the above issues, DRT is seen as a possible alternative to the automobile as a common strategy in low-density areas.

1.3.2 The development of DRT: how does DRT go back to the stage

DRT is not a new term. The earliest formally documented DRT appeared in the United States in 1916 as a rapid transit service open to the public, operating on fixed routes and picking up and dropping off passengers on request. In 1960s, the rise of low-density areas in the United States and the emergence of DRT as a low-cost transportation response began to see some research interest, and influence in the European region after several years. In 80/90s DRT technology changed qualitatively with the advancement of science and technology, but economically viable solutions did not exist, so its implementation was very dependent on sponsorship. In the UK region there have been several waves of DRT boom, often due to either new sponsorship or deregulation.

Traditional DRT services have often been criticised because of their relatively high cost of provision, their lack of flexibility in route planning and their inability to manage high demand (Goodwill & Carapella, 2008). The emergence of the TNC Transportation Network Company, which made carpooling systems known to the general public; The large number of demand-driven DRT transport innovations over the years has also stored practical experience and knowledge for the further development of the system. A comprehensive study of DRT in the UK was conducted in 2009, which produced a series of findings that marked a resurgence of interest in DRT research.(Davison et al. 2014).

Although DRT is now regarded as a panacea, in reality many problems make it difficult to succeed. Considering its important role in addressing rural accessibility and reducing automobile dependence in low-density areas, a literature review and case studies, both theoretical and practical, are necessary for us to find a suitable application

approach to DRT. We will dedicate Chapter 3 to the research on DRT.

1.4 Beyond bus on demand

In the above context, there has been an interest for rural-area-oriented accessibility studies, such as the SAMPO (1996-1997) and SAMPLUS (1998-1999)[2] projects, FAMS (2002-2004)[3], the FLIPPER (2008-2011)[4] project, the SMARTA [5]project etc., conducted in the European Union since 20th century. In recent years, the ESPON URRUC research project has developed a research tool based on a multi-level approach and has carried out a series of case studies. The results of the studies show that most regional transport authorities prefer DRT as an alternative to single occupancy vehicles to solve the problem of rural accessibility. In reality, however, as we have just discussed, DRT, or actually Bus on Demand has many limitations and its implementation alone will not suit all situations. In order to improve the path dependency of rural managers due to a lack of knowledge, there is a need to extend the scope of public understanding of the DRT concept, and improve systematic knowledge of the circumstances and possibilities of other alternatives to single occupancy vehicles and to provide a decision-making tool for rural transport policy makers.

In order to achieve the above-mentioned research objectives, this thesis takes the matrix[6] proposed in (Vitale Brovarone and Cotella 2020) and the related definitions as a starting point for analysing and further exploring the classification of different transport provision methods, supplemented with theoretical information and application cases. It should be noted that due to the complexity of transport modes and concepts and their overlapping, DRT, as a relatively popular, valuable and widely used research topic (although rarely used to refer to atypical demand-responsive transport services), was selected as the initial search keyword. It will be examined and discussed in detail in Chapter 3 of this thesis, providing initial theoretical material for the selection

[2] https://ruralsharedmobility.eu/wp-content/uploads/2019/08/SAMPLUS-Final-Report.doc

[3] https://ruralsharedmobility.eu/wp-content/uploads/2019/08/20090112_191123_11203_FAMS_Final-Report.pdf

[4] www.interreg4cflipper.eu

[5] https://ruralsharedmobility.eu/

[6] The basis of the research in this thesis is the 'DRT options matrix', the prototype of which was compiled by Vitale Brovarone and Cotella (2020) on the basis of a series of literature reviews, in order to analyze the different possibilities of the DRT service at the operational layer. The columns of the matrix represent the different DRT service models and the rows represent their operational characteristics.

of keywords for subsequent transport modes. Demand responsive transport options beyond bus on demand are further discussed in Chapter 4 and are categorically discussed along with related issues on a case-by-case basis. This analysis is developed further in Chapter 5, where the DRT options matrix is used to combine, compare and analyse each of the service options in an attempt to understand their applicability and relationship to each other. The theoretical framework of the multilayer approach provides an opportunity to revisit the matrix and the whole research experience in this chapter. At the end of the chapter, an attempt is made to provide experiences and perspectives on the knowledge choices of policy makers on this cross-cutting issue.

CHAPTER 2

Research aim and methods

2.1 Research aim

In the context of globalisation, the relationship between urban and rural areas has changed. Rural areas, by their very nature lacking in mobility, have gradually lost power, leaving residents with the choice of suffering from low accessibility, compounded by social exclusion, or moving to the city and joining the vicious circle of rural transport deprivation. Although part of this vicious circle, the industrial age has brought a welcome, if only, option for rural dwellers - the car. The convenience it brings is also limited - no one can have the exclusive use of a car at all times for the rest of their lives. To improve accessibility in sparsely populated areas, DRT services have gradually become an important option for solving the problem with the advancement of ICT. However, it is still emerging, complex, uncertain and, most importantly, not fully understood, which may lead local governments and local stakeholders to blindly invest in a particular model and lead to failure.

There are many projects and organisations collecting best practice, but there are fewer comprehensive comparisons of specific service models. The aim of this research is to raise awareness of the possibilities of rural transport options and to enrich the decision-making tools for rural accessibility policies.

Research objectives

- Clarify the content of DRT services
- Extend the systematic understanding of DRT options beyond Bus on Demand
- Explore ideas for rural transport model selection within the multi-layer approach

Research questions

In order to improve the understanding of the operational layer, this thesis collects and categorises existing research results and tries to answer the following questions:

1.What exactly is DRT? Under which conditions is it more likely to be successful?

2. What transport options are actually available in rural areas and what are the characteristics of the area to which they are adapted? How can they be combined?

3. How can target knowledge be selected, at different stages of the decision making process for transport options, from various domains to help make the right decisions?

2.2 Methodology for classification and searching

This thesis mainly adopts the research methods of literature review, case study and comparative analysis. The first step is to search and analyse the mainstream literature with DRT as the keyword, to gain an understanding of the content and research direction of the popular ICT Bus on Demand service, and then to expand the search for specific models and related topics based on this. Through the literature review and the regrouping and rearranging of the matrix, each transport service model and service characteristics are compared and evaluated at different levels.

For all subsequent searches, the search results up to June 2024 from Scopus have been used.

2.2.1 DRT main theory searching and analysis

Literature review through snowballing

In order to gain an initial understanding of the topic of rural accessibility and research related to transport service models, a snowballing approach was first used to find literature related to(Vitale Brovarone and Cotella 2020). In this step, the bibliography and results of the analysis of the Connected Papers tool were the main references, and finally 23 publications were selected.

Literature review through search string

|n order to understand how DRT has been researched in different fields, this thesis attempts to retrieve important practical/theoretical research findings that meet the needs of contemporary DRT practice.

According to a study by Currie and Fournier (2020), the contemporary DRT model characterised by ICT began in 2010, corresponding to a recent wave of theoretical research. Therefore, this thesis selects literature from 2009 onwards for research.

Here is the literature screening rules/process:

a. Filtering criteria: selected keywords (demand responsive transport); after 2009;

English as the written language; exclusion of field (Biochemistry, Genetics and Molecular Biology; Chemistry; Medicine; Chemical Engineering; Immunology and Microbiology; Neuroscience; Pharmacology, Toxicology and Pharmaceutics; Physics and Astronomy)

b. Of the 761 search results, those in computer science and engineering were temporarily further excluded. For the 263 results, the 20 most recent and the 50 most cited papers were examined.

This set of search results contains 41 key documents.

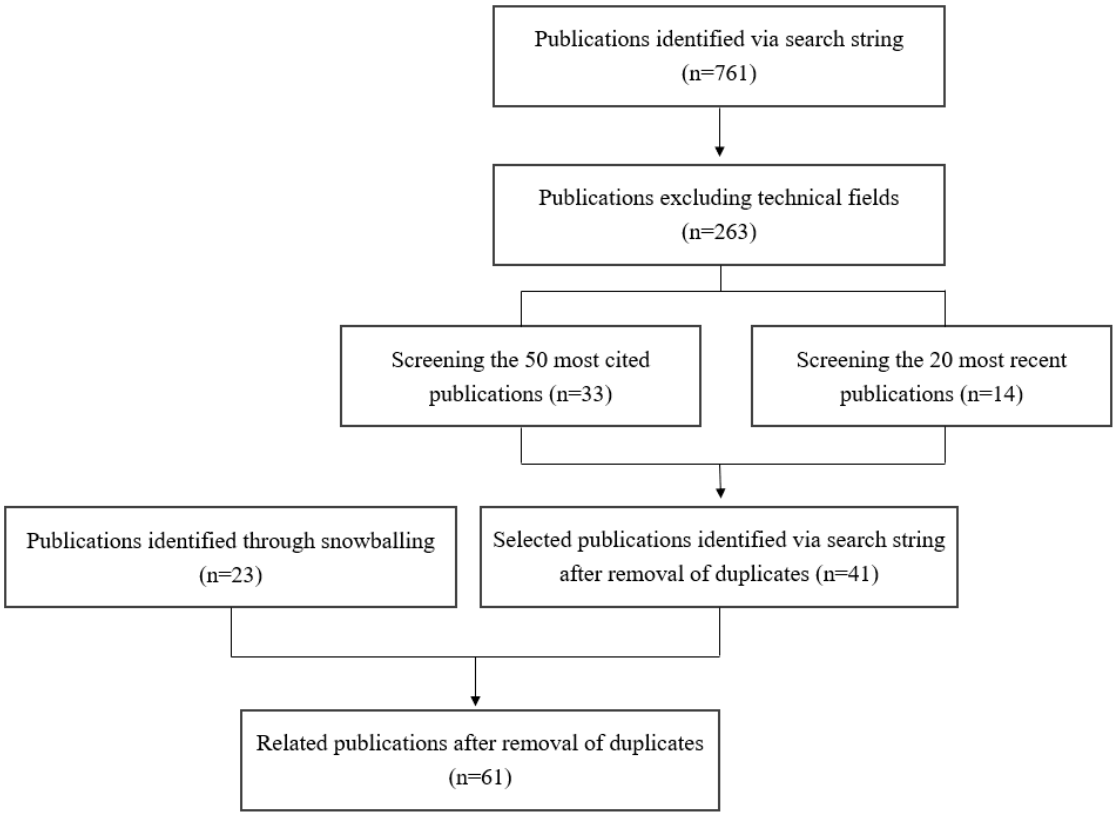

Figure 2.1 Flowchart of a DRT-related literature search

2.2.2 Classification on service models

Based on the matrix mentioned earlier, demand responsive transport is divided into ten service models (as well as service delivery as a non-transport solution), which we use as a basis for another round of search and analysis. We refer to SAE's taxonomy[7]

[7] Taxonomy of On-Demand and Shared Mobility. The document standardized the definitions of shared

published in 2021 to relocate and categorize current service models into 3 groups, and then identify keywords in conjunction with the research literature to segment and complement the research.

Search methodology

After the first round of searches, a set of initial search terms was established; during the search and literature review process, confusion/substitution in the use of terms was identified and is also summarised in this table.

Service model		Key words used for searching	Terms usually used in articles
Fleet sharing	car club; car sharing	car club; car sharing	car sharing
For-hire ride services	taxi; shared taxicabs	shared mobility; shared taxi	Shared taxi
	ride sharing (ride hailing)	shared mobility; TNC; ride hailing; ride pooling; ride sourcing; ride splitting	ride sharing/ride pooling, ride hailing, ride sourcing
	bus on demand; village minibus; feeder (public)	demand responsive transport; feeder; mobility on demand; flexible transport services; micro transit; FMLM; P+R;	demand responsive transport; multimodal transport
	shuttle van (private)	airport shuttle; employment shuttle; MRT;	shuttle
Not for-hire ride services	ride sharing (carpooling)	ride sharing; Hitchhiking; lift share;	ride sharing; carpooling
	social transport; service delivery	school bus; paratransit; community transport; elderly; mobile service	heath care access; telemedicine

Table2.1 Keywords initially selected and keywords actually used in the literature

In order to see the difference in the level of discussion of the core keywords of the different transport services in urban and rural areas, the number of results that is 'without rural keywords' and 'with rural keywords' is shown in the table below (table2.2).

For some transport services, additional keywords (column ‘extra searching’) is particularly important. In this step, a manual overview and information filtering from highly cited documents was used to supplement and filter the additional literature for further analysis.

ground, aviation, and maritime services.

For some atypical service content, such as the keyword ‘health care access’, which touches on the core services of remote villages, and the keyword ‘service delivery’, which is actually not a transportation service, the covered fields are too diverse. Instead of screening the search results comprehensively, the extra searching method is used to find related information.

Service type	Service model/ Screening process	Only model name	Plus ‘rural’	Screened	Extra searching
car club/car sharing	car club	420	11	3	5
	car sharing	4820	69	32	
	carpooling	1093	11	3	1
taxi; shared taxicabs	shared taxi	643	13	7	3
ride sharing	ride sharing	3109	50	33	0
	ride hailing	1758	20	12	
Bus on demand; feeder	feeder	2328	46	16	1
shuttle	shuttle	-	26	14	0
social transport; village minibus	passenger freight transport	2518	54	7	0
	paratransit	765	47	32	
	health care access	-	-	4	
service delivery	service delivery	-	-	3	0

Table 2.2 Classified search results for typical keywords

In the following discussion of each transport service model, the search results in the table above will displayed again in categories to help with discussion.

The categorised literature reviewed totalled 68 articles (Figure 2.3).

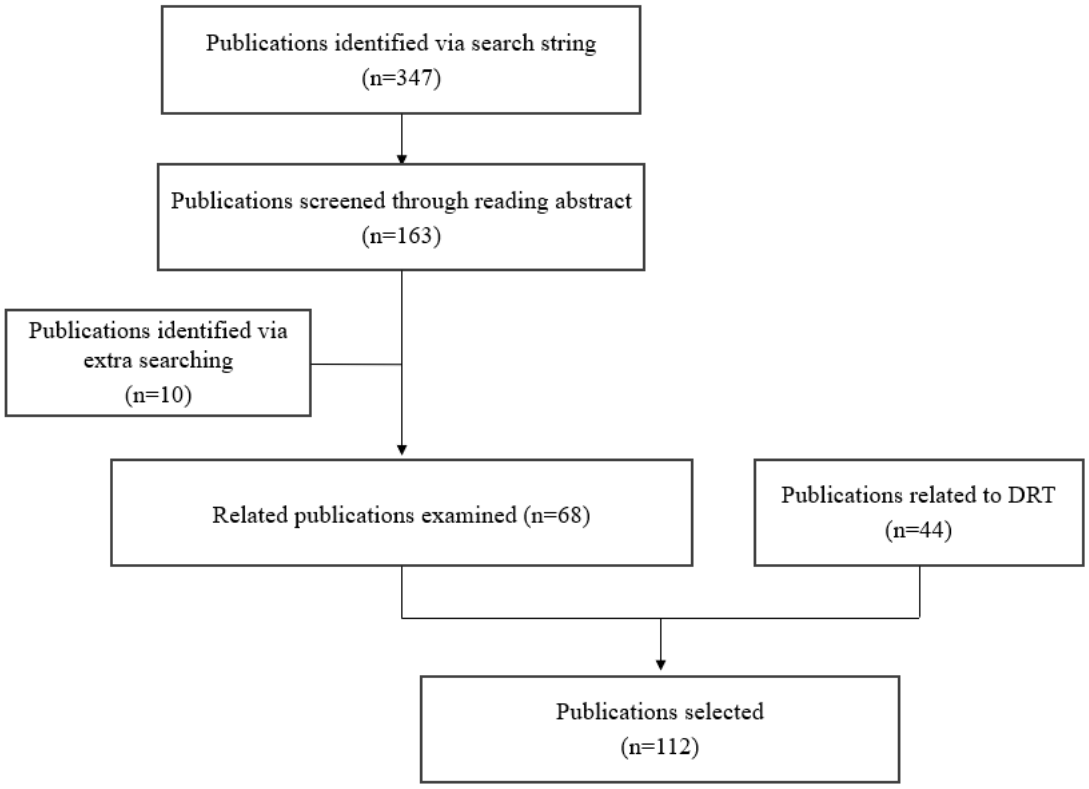

Figure 2.2 Flowchart of a classified literature search

In parallel with the categorical search results, a classified analysis is developed on a case-by-case basis and the matrix framework is dynamically adjusted.

2.2.3 Review and analysis of service models

This part of the theoretical research analysed uses the theoretical framework of a multilayer approach. (Vitale Brovarone and Cotella 2020) draws on marketing theory to summarise the conditions and challenges that DRT as a product faces encounters at the micro (operational), meso (specific) and macro (general) layers. Of these, elements at higher layers can have an impact on lower layers. The discussion of DRT service models in this thesis remains mainly at the operational layer, the general layer is largely left out of consideration.

Classified analysis

The service models were categorised in order to highlight the main differences between them and to facilitate a horizontal comparison of their characteristics. In this part of the study, the use of perspectives from different layers better complements the

results of related fields of research and compensates for the lack of results from single search studies.

For each model, the discussion consists of five parts:

- Definition of the transport service model from the URRUC report[8]
- Based on the search results of different keywords, presenting a broad picture of the service model, including the tendency of the use of words and the region where the study was carried out.
- A literature review
- One or two typical case studies. The case will be chosen from the good practices of the Smarta project[9], which has carried out extensive practical research in the European region.
- Summary of the above and a preliminary assessment of what kind of occasions the transport model is suitable for and what aspects need to be considered. The assessment will take into account the results of the research in Chapter 3, in particular the experience of practical implementation, economic viability and scope. For modes that currently have less experience of rural implementation, the focus is on their potential in rural areas and the possibilities offered by new technologies.

This is followed by a review in conjunction with clusters of related topics covering transport policy objectives, emerging service modes and transport system integration. Each mode may be more relevant to one of these themes, or the in-depth examination of one theme may shed light on the operation and integration of a number of modes.

Comprehensive analysis

Although the discussion of the service model itself focused on the operational layer, it could not avoid addressing the impact that specific layers have on the layer below. In the comprehensive review, the impact of the specific layer on the general layer is shown

[8] URRUC - Urban-rural Connectivity in Non-metropolitan Regions. Final report / Begley, Jason; Jarvis, David; Jones,Andrew; Macneill, Stewart; Cotella, Giancarlo; Scudellari, Jacopo; Staricco, Luca; Vitale Brovarone, Elisabetta;Grunfelder, Julien; Kristensen, Iryna; Löfving, Linnea; Ferrandis, Adrian; Noguera, Joan; Riera, Mar; Scardaccione,Giuseppe. - ELETTRONICO. - (2019), pp. 1-75.

[9] https://ruralsharedmobility.eu/good-practices/

in the matrix. The original matrix has been regrouped and reordered as follows :

- The columns of service models are grouped into three main service types.;
- The rows of operational characteristics are either defined as being related to territorial characteristics or categorised on the basis of links to other layers' elements;
- The sequential order of transport services roughly follows demand from lowest to highest.

The framework of the multilayer approach is also applied to the synthesis review of the full-text literature research process. Territorial characteristics were added to complement the discussion of specific and operational layers. DRT involves interdisciplinary research and generates cross-sectoral interests, so the integration of knowledge can be facilitated by analysing the analytical categories corresponding to the different research sub-themes.

CHAPTER 3

A literature review on demand-responsive transport

The topic of DRT has a long history of academic research and practical experience, and can reflect the common problems that may be encountered in rural transport decisions. In this chapter we will start with the theoretical research and examine these two aspects separately.

3.1 DRT research

3.1.1 DRT definition

DRT Definition

DRT (Demand Responsive Transport) is a concept with considerable perturbations. In the panel discussion in (Davison et al. 2012), it can be seen that common characteristics perceived for DRT include: Public services with some degree of route and timetable flexibility, multiple booking methods and different vehicle options, although they may have very different operating models and specific service objectives.

According to the definition of Brake, Nelson, and Wright (2004), DRT is an intermediate form of PT, somewhere between a regular service route that uses small low floor buses and variably routed, highly personalised transport services offered by taxis. Mageean and Nelson (2003) defined DRT as “an intermediate form of transport, somewhere between a regular bus and a taxi” (p. 255). In Schasche's definition, there are three core characteristics of DRT: customers need to book the service in advance, low-floor vehicles, and operator flexibility in designing the service

The above discussion is closer to a narrow definition of DRT services. Among the ten service models studied in this thesis, ‘demand-responsive bus’ falls into this category. In fact, the conceptual scope of DRT is much broader in different historical stages and research contexts.

Different names of DRT

DRT has gone through several stages of historical development according to the different needs of people and has produced constant changes in the degree of resilience and integration according to the needs of society, so the scope of the discussion of DRT

is large and vague, and it has been known by many different names.

DAR dial-a-ride services is the earliest DRT and arguably the predecessor of the narrow DRT concept. It is also called paratransit or STS special transport services (Mulley and Nelson 2009). It is a tool that has been used in the past to address the mobility issues of people with mobility impairments, mainly in relatively developed regions, and is provided in parallel with traditional public transportation. As the name suggests, passengers have to call to book a service. As a traditional transport service, it is effective but not very efficient.

Based on years of relevant research, (Nelson et al. 2010) attempts to expand the traditional concept of DRT using the term FTS Flexible Transport Services. The definition here is closer to the broader sense of DRT referred to in this thesis and is used to avoid confusion with the traditional concept.

MOD Mobility on demand is sometimes used by academics in the United States to envision a connected and collaborative mobility system. It is based on the principle that transportation is a commodity where options have distinguishable values (Lucken, Trapenberg Frick, and Shaheen 2019)

DRT and different transportation service concepts

Considering the lack of a clear consensus on terminology within the field, there is value in sorting out how DRT in a narrow sense relates to other transportation services at different levels. Compared to traditional modes of transport, DRT (in the narrow sense) and Shared Mobility are two parallel modes of transport that together lie between traditional buses and taxis on the axis of flexibility. The research object of this thesis is flexible public transport from DRT to TAXI and is not limited to DRT services in the narrow sense.

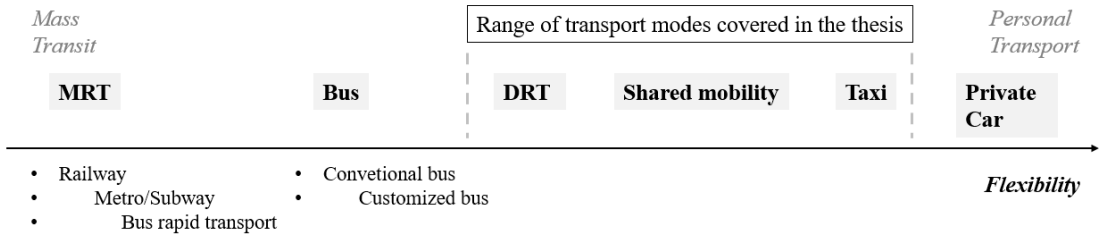

Figure 3.1 DRT within transport system source: adapted from (Filippi et al. 2023)

In the third subsection of Chapter 4, we will build on this chart and further discuss

the relationship between the modes covered in this thesis and other common synthesis themes.

3.1.2 DRT research landscape

Vertical/temporal shift

According to the WOS search results, there has been a gradual increase in DRT-related research interest since 2013. The number of studies has exploded again in recent years (2019-2023).

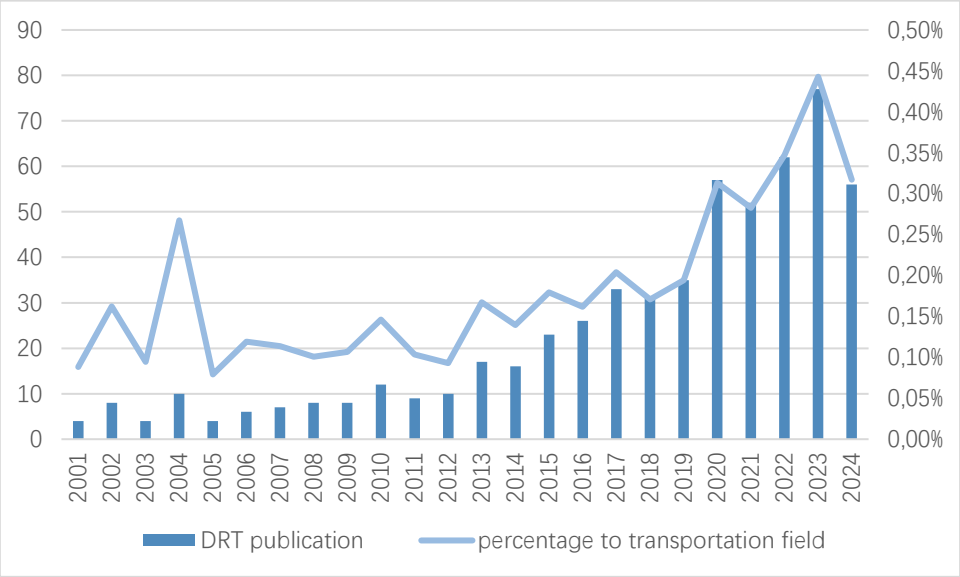

Figure 3.2 publication year of 'demand responsive transport' within the field of transportation, 2001-2024 source: WOS

In terms of the trend of shift in research topics, DRT research has gradually shifted from service supply side research to market niche and service satisfaction direction. (Davison et al., 2012, Haglund et al., 2019).

According to (Vitale Brovarone and Cotella 2020), three layers have been proposed to study the issue of rural accessibility, namely the operational layer, the specific layer and the general layer. If we place the DRT-related research interest in this framework, we can see a gradual shift in the object of study from the operational to the specific layer.

This may be related to the frequent failures encountered in DRT practice: often economic models are difficult to implement, partly due to the fact that the demand for carpooling is not high enough and not enough dimensions are considered. It may be

equally important to carefully understand exactly what kind of demand is being faced than what kind of service can be provided. In a moment we will further discuss the problems that DRT encounters in practice

User acceptance is still under-researched. Not only for the needs of older people as an important user group (Bond et al., 2017), but also for the lack of knowledge of non-user groups, although they can provide a broader understanding of the market demand for DRT services (Wang et al. 2014). However, as the number of DRT-related studies has grown rapidly in recent years, there are more and more empirical studies related to the user side, supplementing the research landscape. Perhaps this indicates an increased need to further improve the quality of DRT services.

Horizontal/topic variations

As a transport service product, different aspects of DRT are categorised as supply-side and demand-side.

Supply side: Service delivery

1. operational schemes (Davison et al. 2014) (Laws, 2019)

- the degree of flexibility of routes and timetables (Brake et al., 2004, Mageean and Nelson, 2003)
- operating times (Nelson and Phonphitakchai, 2012)
- the fleet size and the coverage of operating areas (Haglund et al., 2019)

2. Economic aspects (Laws, 2019)
3. Market potential (Ryley et al. 2014)
4. Operational and institutional barriers to DRT systems (Enoch et al. 2006)

Demand side: User satisfactory

It is important to consider how to increase the competitiveness/attractiveness of DRT services (compared to cars) from the USER side than the OPERATOR side for the current development of DRT services. There are a large number of studies on the quality of service of public transportation, but there is more limited research on the elements that enhance DRT services.

1. individual level factors: age, gender, having car access, values, awareness and attitudes towards the services (Nelson and Phonphitakchai, 2012)

2. experience of the service: Cost, travel time and reliability of services(Teal and Becker, 2011)

3.1.3 Research fields related to DRT options

These academic studies on different concerns have deepened DRT theoretical research over time. In terms of disciplinary context, transport policy, transport engineering and the psychology of transport behaviour have been the most common areas. For DRT services, as well as other transport services that may be used in rural areas, cross-cutting transport policy research is an important disciplinary area, but there is a strong geographical focus. This thesis here briefly describes the consensus reached in the latter two more general areas. By prioritising the discussion of these broad common elements, a clearer understanding of the differences between transport service models could be gained later.

Traffic engineering technology/operations research

In the fields of transport engineering and technology as well as transport operations research, on-demand transport and shared mobility are commonly modelled as Dial-a-Ride Problems (DARP), especially flexible door-to-door on-demand transport services. The Dial-a-Ride Problem (DARP) consists of designing vehicle routes and schedules for n users who specify pickup and delivery requests between origins and destinations. The objective is to plan a set of m least-cost vehicle routes that can accommodate as many users as possible, given a set of constraints. (Cordeau and Laporte 2007) DAR services can improve the accessibility of transport services and is an important strategy for solving FLM problems and mobility issues in low density areas, although it still involves complex behavioural patterns that need to be further understood.

There are different variants of DAR services to meet different needs. DRTs providing door-to-door services are typical examples of DAR services, but the MAST problem model and the DRC model can also be used when feeder DRT services are provided, taking into account costs. In MAST (mobility allowance shuttle transit service) services, vehicles have a fixed set of stops that they must always visit, e.g. fixed routes, and these stops also have fixed schedules. However, vehicles may deviate from the fixed route. Customers served off the fixed route are served at their requested location and must be within a certain radius of the fixed route in a so-called 'zone'. This service combines the high flexibility of a door-to-door service with a fixed primary route. Where cost effectiveness is more important, the Demand Responsive Connector

(DRC) service model does not consider mandatory stops, with buses transporting passengers from the point of origin to an interchange within the intended service area. In the current ride-sharing service, which is easily accessible to the public, people are willing to share rides if they can save money. This situation is known as DARP-M (Dial-a-Ride Problem with Money as an Incentive).

For rural areas, it may be necessary to combine the DARP-IT problem, which refers to: planning, coordinating vehicle operations, and synchronising trips and vehicle service times to provide convenient service and short wait times for users (Johnsen and Meisel 2022) Linked trips are particularly important because customers in low-density areas may also require guaranteed return trips, synchronised arrivals for joint meetings, or other complex service patterns(Soth et al. 2023). Where different types of transport are available, such issues may be more easily addressed.

The trend towards vehicle electrification and automation in this century has provided new research directions for the problem of on-demand transport service technology compared to the classic DAR service problem that has been around since the last century. In 2012, Google demonstrated a fully automated car for the first time; today almost all major car manufacturers have fully automated vehicle (FAV) programmes. It is probably only a matter of time before these vehicles cross the line from pilot road demonstrations to actual consumer use. And the relatively quiet traffic in rural areas can provide a good environment for testing AVs. On the other hand, as people become more environmentally conscious, EVs, with their lower energy costs and lower maintenance requirements, are becoming the green travel choice. Over the last decade, as the price of EV batteries has continued to fall, charging facilities have become more convenient and the market share of renewable energy sources has continued to grow, EVs will become more economically and environmentally competitive with conventionally fuelled vehicles.

In our discussion below, vehicle alternatives have been divided into two main categories, fleet sharing and ride services, based on the underlying service model. SAVs (shared autonomous vehicles) are at the intersection of the two, requiring the operation of a fleet of vehicles, while being able to provide ride services even without a driver.

With shared autonomous electric vehicles, the DAR problem we face can be called e-ADARP, where in addition to the basic fleet operation issues, the location/network design of charging stations for the trams needs to be considered. The operating costs and quality of service are closely related to the development of rechargeable battery technology. Finding routes with the lowest energy consumption, scheduling the vehicle

charging process and optimising battery life have been identified as new challenges in the context of integrating electric vehicles into public transport (Soth et al. 2023).

Travel behaviour psychology

In the previous subsection it was observed that there is a tendency for DRT-related research to move towards the demand side. The question of the rural population's acceptance of other rural transport options is also very important, and there are many pre- or post-project questionnaires using the UTAUT methodology to analyse and predict the population's propensity to travel.

Within the rural population, the elderly population is a group that has received special attention. The elderly population is growing faster in suburban and rural areas than in urban areas, and they represent an important potential market niche in many low-density communities. For emerging rural transport modes, fully exploiting the market niche and increasing demand are important prerequisites for the success of the programme. Increased research into the needs of older people can therefore be effective in improving the overall level of service provision. Despite the decline in physical abilities, mobility barriers for older people in rural areas mean that they are still dependent on driving for their quality of life, which can be dangerous. Therefore, older people need to be encouraged to plan ahead for transport and to make a smooth transition to a car-free life by retiring from driving.

On the other hand, in low-density areas, most car replacement options require some level of integration with digital platforms to achieve a sufficient level of service to compete with cars. This can create a technological barrier for older people, preventing them from considering driving retirement. Marketers need to adapt innovative transport concepts to the needs of people in rural areas, especially the older population.

3.2 DRT operation

3.2.1 DRT implementation situation and dilemmas

DRT Basic Model and Operating Environment

DRT services cover a wide range. In general, DRT is implemented in two directions:

One is to replace traditional public transportation in a particular area. They're called 'substitute DRT' (Enoch et al. 2006) 'rural hopper' (Ryley et al. 2014) The other is to connect to the station as a feeder to reach FLM services. interchange DRT (Enoch et al. 2006) We will refer to these two models as 'Bus on Demand' and 'Feeder' and discuss them in comparison in Chapter 4. In terms of scheduling and operations-related model selection, the classic models include: Many to one, many to few, many to many (transfer), many to many (D'este et al. 1994)

From an operational perspective, there are often two very different trends of social and economic benefits in relatively developed and relatively underdeveloped regions. The first is special transport for the elderly or disabled, often closely linked to specific legislation. The second is informal transport, which sits between private transport and traditional public transport, responding to real-time user demand and flourishing particularly in developing countries with weak infrastructure.

DRT Program Operations Profile

DRT programmes have been in practice for 40 years. However, according to (Currie and Fournier 2020; Enoch et al. 2006) the majority of DRT projects have failed.

Three clear periods of operation can be seen in the figure below, namely the early dial-a-bus services (1970-1984), the paratransit/community transport DRT era (1985-2009), and in recent years the ICT micro-transit DRT (2010-2019).

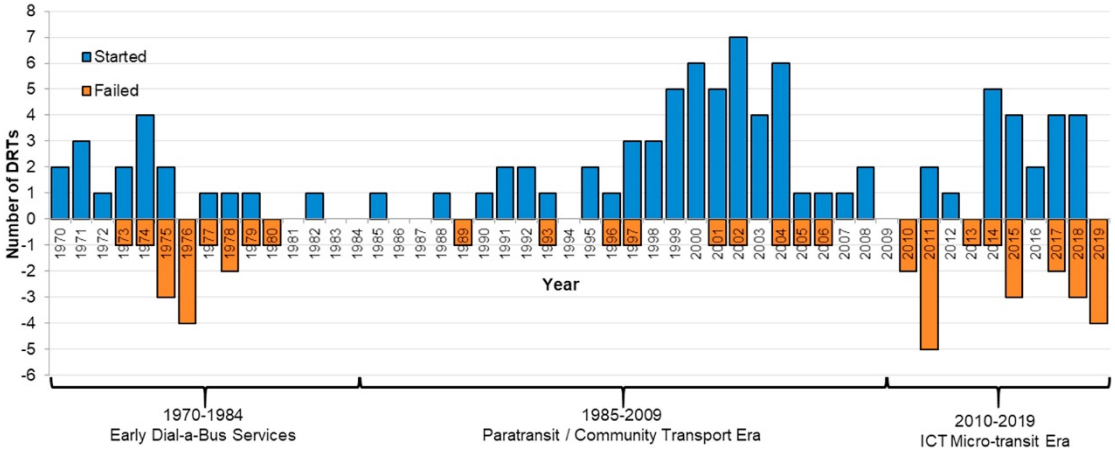

Figure 3.3 Frequency distribution of DRT start-ups and failures
Source: (Currie and Fournier 2020)

In the early days of dial-a-bus, more than 80 per cent of projects did not survive into the next period; 58 per cent of community transport managed to survive to the present day and is still a common mode of transport today. nearly half of the projects in the ICT era have already failed, reflecting a high level of vulnerability. This may be

closely related to the cost-intensive nature of ICT-era DRT services with insufficient ridership.

Problems faced by DRT

Low demand is both the type of adaptation and the challenge for DRT. Providing on-demand services requires technical support, which raises costs in low demand, As a result, suppliers often need to rely on subsidies to cover their costs, making it difficult to reach a sustainable status; while inflexible transit contract structures expose DRT to institutional challenges, with some governments phasing out or banning DRT provision.

Other challenges faced by DRT are:

- Poor understanding of mobility needs, the lack of integration with other modes, the difficulty in framing demand and user behaviour, and the lack of communication between users and agency (Brake, Mulley, Nelson, & Wright, 2007; Te Morsche, Puello, & Geurs, 2019; Velaga et al., 2012);
- The missing integration of those services into existing public transport information and booking systems (Gilibert et al., 2020, König and Grippenkoven, 2020, Luiu et al., 2018, Weckström et al., 2018);
- Discomfort around sharing vehicles with strangers(Nguyen, 2013);
- The time costs of both putting necessary technology in place, and developing relationships with stakeholders, such as employers(Calvert et al., 2019)

3.2.2 DRT general success factors

By studying successful DRT projects from SMARTA, common success factors may include:

- Good community resources and their mobilisation. Identification of volunteers and founders
- Tailoring services to demand and designing effective systems Targeting of specific socially excluded groups
- Good management and collaboration. Integrated management of the booking centre, good cooperation between local government and transport operators, cost control and optimisation, effective monitoring, evaluation and adjustment.
- Investment of external resources. Umbrella organisation, software technology company, links to relevant knowledge projects with extensive know-how and clear

communication mechanisms (e.g. the Transport Working Group in Ireland works to ensure that the needs and priorities of each community are clearly defined, which helps stakeholders and other external organisations to discover the potential of the area [10]).

Well-functioning DRT cases do not require a combination of all the success factors, nor do they require a large volume. However, targeted service design is often the secret to a successful project. This is not only based on research into local needs, but also requires a good understanding of possible DRT service operating models.

[10] http://www.ringalink.ie/

CHAPTER 4

Classified analysis on demand responsive transport options

Typically, innovation in transport occurs in cities due to the higher concentration of resources and market density. Transit-oriented development, walkable and bikeable cities, self-driving cars, the sharing economy and shared mobility are all transport concepts that originated in cities and have been adapted to the needs of urban areas. The two existing transport models that have been highly successful in cities - car-sharing and ride-sharing services - are simply not available in rural areas, and the latter requires a great deal of effort and restriction to use or be effective. However, upstream innovation in cities can have a positive impact on downstream dynamics in rural areas.

As we discussed in the previous chapter, sustainable and successful operation of DRT is rare, and DRT operating in isolation often struggles to meet travel demand in different types of low-density areas. Car dependency in rural areas is rarely changed. Therefore, we now turn to a discussion of innovative alternative transport modes that could potentially be implemented in non-urban areas, both DRT services in the narrow sense (bus on demand), but also derived or other types of transport modes capable of providing on-demand transport services in a broader sense. These services vary in terms of asset model, degree of flexibility, suitable regional characteristics, etc., but are more likely to work in the right circumstances. The fact that they are fully operational in urban areas provides us with the basic understanding to provide local authorities with on-demand transport options in addition to DRT, helping to enable multimodal transport in areas outside of cities.

Based on the SAE definition, we classify these alternative transport options into three categories. Fleet sharing, which is predominantly car sharing; for-hire ride services, which is the dominant mode of transport provision (including Bus on Demand as well as Ride Sharing); and not-for-hire ride services, which is primarily driven by societal benefits.

In the next section, we will discuss each service model in categories, starting with the definitions in the text (Vitale Brovarone and Cotella 2020), a general introduction to its overall research context describing its relevance to rural/low-density areas, as well as tables of search results and related literature information. This is followed by a discussion of its applicability for implementation in rural areas, and the characteristics that need to be taken into account, either at the operational layer or at the specific layer.

In conjunction with the Good practice findings of the SMARTA project, different types of relevant cases can be seen in each subsection.

4.1 Classified analysis on service models

4.1.1 fleet sharing

Fleet sharing, mainly in the form of car clubs, takes fleet operation as its core business. The location and scope of fleet deployment determines the density of service and the target population, which will greatly affect the frequency and quality of service.

FS differs from the other two categories in that trips are served one by one and passengers belonging to different trips do not meet in the vehicle. Generally, the traveller himself is also the driver.

- **Car sharing/ Car club**

Car sharing is intended as short-time car access. Car sharing generally involves accessing a car owned by another person or entity in exchange for an agreed monetary payment. During the time when a person has access to a car, they are responsible for it and its use is for their exclusive benefit. The car is personally driven. Usage is billed in time increments of minutes or hours, and sometimes also based on distance travelled. Usage is round-trip as the customer must (with few exceptions) return the car to the same place that it was accessed, and pay for the entire time between when they gain access to the car and when they return it at the end of their reservation.

Another similar, but more commercial model, car club, is also discussed here.

Car clubs provide access to shared vehicles to members on a pay-as-you-drive basis. Normally a location-based organisation, the company owns a number of cars and vehicles, and you can rent them out when you need them; as more of an on-demand service than a traditional hire car vendor. Car clubs tend to be organised on an area basis with cars located in clusters so that if one car is not available, a member will only have a short walk to access another car. There are three main types of car clubs;

1. Round-trip car clubs

2. Fixed one-way car sharing

3. Floating one-way car sharing

The flexibility, management difficulty and cost, and technical requirements of the several car club business models vary widely. The third type, also known as the one-way point-to-point system (also called free-floating), is the profitable car club business model. In large cities, car clubs, or "car sharing" as it is often called, are offered by large profit-oriented companies that can provide efficient and flexible services with highly differentiated and customized pricing, using the latest technology, and is the most successful model implemented in many cities around the world (Rotaris and Danielis 2018).

The overall discussion of the term car club is limited (420 search results) and confined to urban areas. Perhaps this is because the term car club, in contrast to car sharing, carries strong connotations of brand culture and often goes beyond mobility services and is associated with providing leisure and status services to members. Obviously, building a brand community is only feasible in cities. At the same time, car club emphasizes consumption and the exchange of market value itself, whereas the altruistic and pro-social attributes associated with the term sharing may be more easily understood and accepted by the general public (4820 results).

Car sharing can be seen as a form of access-based consumption: by breaking the link between access and ownership of a car, it offers a way to move away from car ownership and improve equality of mobility for non-car owners. Although the term car sharing is often used to refer to car clubs, access differs from sharing in terms of ownership, as access only includes the right to use the car and does not involve co-ownership or transfer of ownership. Traditional leasing has historically been stigmatized, but today, with increasing social mobility and the collaborative nature that digital technology brings, access-based consumption is no longer seen as flawed, but can represent a convenient and flexible culture and lifestyle. Comparing car clubs with car sharing in this thesis, it may be possible to distinguish between purely commercial car sharing and a model compatible with peer-to-peer car sharing.

In car sharing, the emergence of negative reciprocity disrupts the creation of brand communities. People are embarrassed by the logo of the car-sharing company on the car they drive when they use public goods only for their own benefit, or even when they are disgusted by the shared use of others and completely instrumentalize their sharing behaviour. (Bardhi and Eckhardt 2012). In Schaefer et al.'s investigation of shared mobility use behaviour, we see that in addition to the basic level of utility of the shared

service, trust in the brand/operator has a significant impact on the initial choice, but it is community cohesion that has a greater impact on the second choice (Schaefer et al. 2022).

Service type	Service model/ Screening process	only name	plus rural	screening	extra searching
car club/car sharing	car club	420	11	3	5
	car sharing	4820	69	32	

Table 4.1 search result of car sharing/car club

For the search results of car clubs in rural areas, we used the keyword "car sharing", which was selected from the more popular and mainstream literature. 32 relevant documents were filtered out of the 69 search results. Sometimes car sharing is used to refer to a combination of car clubs and ride sharing. Car sharing is often mentioned together with ride sharing, especially in the SAEV sector where the two overlap. As discussed in the previous section, electric car sharing programs can be useful in rural areas, especially where traditional car sharing may not be economically feasible.

For the implementation of car club/car sharing in rural areas, the technical aspects of the research have focused on exploring the feasibility of different fleet sizes and fleet deployment areas through fleet operations simulation analysis. Car sharing needs to consider the critical mass of the fleet, i.e. the size of units (fleet) needed to keep the system running properly. If the fleet size is too small, supply will exceed demand during peak hours; if the fleet size is too large, parking costs during off-peak hours must be considered. (Though obviously, it is not feasible to deploy a large fleet in rural areas, where investment costs tend to be low.)On the other hand, the location of the fleet is more sensitive compared to other transportation alternatives. Expanding the CS network in for-profit urban CS operating models needs to be carefully considered; cost recovery for car sharing requires high utilization, which is difficult to achieve in rural areas. However, in cities where CS operates well, a small increase in service to rural areas with specific socio-demographic characteristics and replication in several cities may be feasible. Long travel distances between urban and rural areas can compensate for lower utilization within rural areas; at the same time, CS vehicles traveling from rural to urban areas during the day can slightly increase the level of service achievable in urban CS networks.

In terms of market niche and user experience, there is some preliminary research on the acceptance of shared trolleybuses in rural areas and the potential customer base. (Hu, Javaid, and Creutzig 2021) demonstrated through 1583 questionnaires distributed online in China that attitudes toward environmental protection and perceived benefits

(economic and safety) play a key role in accelerating the adoption of shared electric vehicles. In the rural community of Lohmar, Germany, expectations for car sharing are significantly lower compared to the provision of bicycles/scooters through existing sustainable transport projects, which may be due to higher car ownership, but also related to perceptions of CS (Schaefer et al. 2022). Another study by (Rotaris and Danielis 2018) found that in addition to environmental awareness and knowledge of CS, socioeconomic characteristics, household composition, and characteristics of individual travel modes play an important role in determining potential demand for CS, with potential groups including students vs. unemployed, families with children, and those with non-commuting travel needs. Other customers mentioned in other literature include young residents who do not yet own a car, families who are considering purchasing another car, elderly couples who need a car temporarily, and tourists and business people.

In addition, hedonic motivation and convenience are two important factors in people's choice of car sharing. Test-driving a car is fun, while familiarity with the car can change attitudes towards its use and reduce the impact of mileage anxiety, which in turn promotes the development of this new propulsion system. Therefore, offering test drives and promoting the vehicles to residents, as well as improving accessibility to carsharing locations through vehicle automation or integration with DRT, may increase resident acceptance of carsharing. (Silberer et al. 2022).

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Schofield et al., 2023)	literature review	-	ride sharing; private car	driving retirement, road safety
(Silberer et al., 2022)	social research	E car sharing, south Germany	E car sharing	electric car sharing, UTAUT
(Bardhi and Eckhardt, 2012)	social research	zipcar, Boston	car sharing	access-based consumption
(Möhlmann, 2015)	social research	car2go, Europe	car sharing	sharing economy, user satisfaction
(Illgen and Höck, 2020)	Engineering/ Computational	-	car sharing	rural car sharing, transportation simulation
(Wadud and Mattioli, 2021)	literature review	-	car sharing, ridehailing, private car	car ownership, shared automated vehicles, travel time costs
(Bergman et al., 2017)	literature review	UK policy documents	E car club	car clubs, electric vehicles, imagined public, future mobility
(Johnsen and Meisel, 2022)	Engineering/ Computational	-	automated car sharing	Autonomous vehicles, Dial-a-ride, interrelated trips

(Stickler, 2023)	Case study	US	Car sharing, carpooling, taxi, DRT	Car sharing, New energy vehicles, Regional differences
(Hu et al., 2021)	social research	China	E Car sharing	UTAUT, electric car sharing
(Soth et al., 2023)	Engineering/ Computational	-	Car sharing, ride sharing	Rural, Shared autonomous electric vehicles, Interrelated trip
(Zerrer and Sept, 2020)	Case study	DSI projects, Germany	Car sharing,	Digital social innovation, community building, elderly, ICT, rural areas, village development
(Schaefer et al., 2022)	Social research	Germany	Car sharing, shared mobility	UTAUT, acceptance, shared mobility
(Rotaris and Danielis, 2018)	Social research	Italy	Car sharing	Business models, carsharing, less-densely populated areas, potential demand

Table 4.2 Related literature of car sharing/ car club

Case study: Talbont[11]

A locally based energy company provides low-cost services to areas with very low demand, bringing together local villagers with a sustainable community approach and a range of related activities.

Pic. 4.1 Organisation staff with new energy vehicle

- Operating environment: A riverside village in Wales within a national park. Population: 179 people, with a population density of 9.5 people per square kilometre.
- Services: Two shared alternative fuel cars and electric bicycles, with fixed pick-up and drop-off point;

[11] talybontenergy.co.uk

- Funding: A sustainability trust; annual user fees and user charges
- Organisational structure: The organisation consists of an energy company (whose directors are all residents of the local community), a sustainability foundation and a community hall that provides parking.

Pic. 4.2 Energy car presentation

Pic. 4.3 'freecycle' event day

Assessing the applicability of car sharing in rural areas:

Carsharing in suburban areas has strong links to urban areas; for relatively accessible rural and mountain areas, it may be possible to systematically establish links to several cities where carsharing works well. Due to the nature of fleet sharing, carsharing in these areas is often an extension of the city's vehicle network.

Higher parking costs in cities are an important reason for residents in urban areas to use carsharing. In more remote, low-density areas, where car dependency is much higher, the demand for car sharing is even lower, and commercially operated car clubs are essentially impossible. On the other hand, the characteristics of low-density areas are directly responsible for the fact that available vehicles are often almost completely unreachable.

However, in the context of vehicle electrification and automation, car sharing has great potential in low-density rural areas. Automated driving can somewhat overcome vehicle inaccessibility and improve service levels, while electrification can significantly reduce maintenance costs. Car sharing can benefit from the cohesion and trust within rural communities, avoiding the problem of negative reciprocity, and can further integrate carpooling to meet the different types of travel needs of residents.

4.1.2 for-hire ride services

In this section, we discuss some other common business service models. However, passengers are no longer provided with access to vehicles, but access to rides. In

ridesharing services, a vehicle can serve multiple requests from different users at the same time, i.e., passengers can share the vehicle. Alternative public transport services such as DRT, narrowly defined, are also included in this category.

For-hire ride services are the main mode of alternative transportation to the automobile, and are economically viable by using completely different modes of operation for different levels of demand for rides.

- **Taxi/ Shared taxicabs**

Taxis are licensed to operate in public spaces and to take passengers either who hail them on the street or who walk to predetermined taxi stands or ranks. Taxis may also be pre-booked at radio dispatch reservation centre. The activities included are also those of the contracted taxis, i.e. taxis that have a contract with the public authorities in order to carry out specific transport on demand to complement public urban transport.

Shared taxi cabs are a shared ride taxi service that provides a taxi form of transportation in which more than one passenger is in the vehicle at the same time, usually at a reduced rate for each of the passengers. Shared ride taxi is also used as a way of using taxis for paratransit services.

Taxi services are the smallest, most regulated, most flexible and most expensive form of public transport, while shared taxi could be considered taxi with carpooling service.

As a more traditional, flexible transport service, taxis are an important part of urban public transport. However, with the advent of ride sourcing companies (or TNCs) and ridesharing services, people's travel patterns have changed and the taxi market has been hit hard. ride-hailing services are the most direct competitors of taxi services, with their digital network systems enabling more efficient hailing and cheaper dynamic hailing prices, which directly reduces the attractiveness of taxis.

Many countries and regions have prevented TNCs from disrupting the taxi market by banning those that do not meet regulatory requirements from entering the market, but taxi service providers and regulators still need to rethink their operations to cope with the new ridesharing trend. The development of taxi companies' own apps is on the agenda, and e-hailing services are starting to roll out, including taxi ride splitting

services[12]. However, whether taxis will be allowed to carpool and the exact pricing model will still depend on local governments and regulators in each region. In many areas, taxi carpooling is highly regulated or even prohibited; in most areas, taxi prices still do not vary according to market rates. (Shaheen and Cohen 2019)

Poor information in the traditional taxi industry leads drivers to congregate where they think passengers will go - usually hotels, airports and city centres - rather than where potential passengers are actually located. As a result, taxi services are often limited outside of city centres (Brown 2019). And it is almost impossible to operate on a commercial model in low-density areas outside the suburbs of cities.

Service type	Service model/ Screening process	only name	plus rural	screening	extra searching
taxi; shared taxicabs	shared taxi	643	13	7	3

Table 4.3 search result of taxi/ shared taxicabs

When we included the keyword '*rural transport*' in our search, the taxi services observed in the results are quite different from those we are used to in cities. Many of the 104 search results are about informal transport in developing countries, mainly in the African region. In the African region, and particularly in sub-Saharan Africa, where the level of urbanisation is relatively low and rural transport infrastructure is inadequate, there are a large number of studies on the thriving informal transport industry, represented by motorcycle and motor taxi services, to meet the high demand for mobility in large rural areas.

In the search results more relevant to this thesis, taxis are discussed as vehicles for low-capacity versions of DRT services. Sometimes referred to as taxis or collective taxi-based services (Mulley 2010), they have strong public transport service attributes and a number of applications already exist. The replacement of traditional public transport services with state-subsidised on-demand taxis is common in rural Europe, such as Regiotaxi in the Netherlands; children's schooling and healthcare needs in rural areas of the UK are often met by taxis; and the introduction of taxi subsidy schemes to meet the travel needs of the elderly in transport gap areas is a common strategy in Japan.

Community taxi services can provide a sense of security. In a field study in Japan, older people, people with mobility impairments and children could feel safe in

[12] Although traditional taxis may also provide small-scale offline carpooling services for special trips, such as at the airport, ridesplitting is used here to refer to online carpooling services that rely on routing algorithms.

community taxi services (Ozaki, Aoyagi and Steward 2022). And the discomfort associated with sharing a taxi may be similar to that of ride sharing.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Bilgin et al., 2023)	Engineering/ Computational	taxi market data in England and Wales	taxi, ride hailing	Ride sourcing, transport network companies, taxi market
(Stickler, 2023)	Case study	US	Car sharing, carpooling, taxi, DRT	Car sharing, New energy vehicles, Regional differences
(Ozaki et al., 2022)	Case study	community taxi in Japan	micro transit, taxi	Community transport, sustainable mobility, shared mobility
(Elting and Ehmke, 2021)	Engineering/ Computational	-	shared taxi, ride sharing	Degree of dynamism, ride sharing, Dial-a-Ride problem
(Mounce et al., 2018)	Engineering/ Computational	FITS tool applied in Scotland		Constraint relaxation, flexible transport system, rural transport, subsidy
(Nie, 2017)	Case study	taxi market data in China	taxi, ride hailing	Ride sourcing, e-hailing; Street-hailing; Capacity utilization rate
(Rayle et al., 2016)	Social research/ Transport survey	survey in US	taxi, ride sharing	On-demand transport, Taxis, transportation network companies
(Mulley, 2010)	Case study	taxi-based schemes in Europe and UK	taxi/ shared taxi	Rural transport, taxi-based public transport system, social inclusion
(Brake and Nelson, 2007)	Case study	DRT services in Northumberland, UK	DRT, Taxi	Telematics-based demand responsive transport, Intelligent transport systems
(Alberto et al. 2024)	Engineering/ Computational	Automated taxi scenario simulation, Italy	shared taxi	Rural public transport, on-demand shared taxis, autonomous vehicles
(Ayiguli et al., 2022)	Social research/ Transport survey	taxi subsidy scheme in Japan	taxi	Elderly mobility, rural areas, taxi subsidy scheme

Table 4.4 Related literature of taxi/ shared taxicabs

Case study: RegioTaxi[13]

Regiotaxi was formerly the experimental FLM service Treintaxi operated by the Dutch State Railways and is now a transport service provided jointly by several municipalities. It is open to residents who need assistance for medical purposes as defined by national legislation (WMO).

Pic. 4.4 RegioTaxi operational vehicle

Operating environment: The Dutch region of Gelderland (or Versis, covering both urban and rural areas) has a population density of 351 people per square kilometre.

Service: D2D shared taxi service, vehicles can be cars or minibuses. Aimed at solving the mobility problems of people with disabilities, carers are free to accompany the trip.

Funding: User fees, government grants (WMO)

Organizational structure: Organized by the government, the service is subcontracted to local operators in each municipality.

Assessing the applicability of taxis / shared taxicabs in rural areas:

The traditional taxi model is too expensive to be viable in low-density areas. For tourist areas where there is a need for FLM travel, outsourcing to a taxi company that offers e-hailing with ride splitting capabilities may be able to provide a satisfactory service. Another possibility is that in areas where demand is too low, the use of taxis as on-demand social transport vehicles, strictly regulated by transport authorities, can balance economic viability, vehicle utilisation and social benefits.

[13] https://www.versis.nl/home/

- **Ride sharing (ride hailing)**

Ride sharing refers to the common use of a motor vehicle by a driver and one or several passengers, in order to share the costs. The terms not only refer to the common use of a motor vehicle for cost compensation in the context of a ride that the driver performs for its own account, but also to common use of a professional hired vehicle among various passengers which have the same (or different) destination in order to share the costs of the ride (such as for airport transfers). Ride-sharing has also become synonymous as a term for companies such as Uber and Lyft, encompassing a range of companies and services, including traditional taxis and car services. Here the customer hires a driver to take them exactly where they need to go, something accomplished by hailing from the street, calling up a car service on the phone, or virtually hailing a car and driver from an app.

Based on the categorisation of this thesis, we will discuss ride-sharing in two parts, starting with the ride-hailing service operated by TNCs.

TNC (Transport Network Company), represented by Uber, initially had ride sourcing services and e-hailing services as its core business. As TNC became a big success in the market, it gradually developed into an integrated transport service platform, operating various types of businesses.

Ride-hailing provides an alternative to taxis, while also picking up passengers from buses and other transport systems. Transport authorities and transport agencies often have to enter into partnerships with TNCs, partly because the ride-sharing services operated by TNCs create subtle competition with public transport operators, and partly because transport authorities need the help of TNCs to improve their operations. However, even with a degree of partnership, transport authorities still face serious data ownership issues, i.e. TNCs tend to provide only aggregated trip data, while each retains the right to carry out detailed data analysis. An important issue is the lack of motivation and commitment of TNCs in rural areas, where there are barriers related to affordability and adaptation to rural geography.

Service type	Service model/ Screening process	only name	plus rural	screened	extra searching
ride sharing	ride sharing	3109	50	33	0
	ride hailing	1758	20	12	

Table 4.5 Search result of ride sharing (ride hailing)

The term ride sharing is widely used in practice and discussion. As TNCs often refer to their services as ride-sharing, we will here separate peer-to-peer services that is not for hire, i.e. car-pooling, from the broader sense of ride-sharing and discuss them separately, see 4.1.3. We additionally retrieve ride hailing as it more accurately refers to this type of transport service provided by the TNC-provided transport service, whereas ride sharing in the narrower sense can be defined as its pooled version.

A number of studies on the use of online ridesharing in urban and suburban areas show differences between urban and rural areas in terms of who uses it and for what purposes. The literature suggests that the average ride-hailing user tends to be young, employed (often with a flexible schedule), educated, male and urban. A study in California divided the population (millennials) into three categories, where the lowest adoption rates were observed, tended to be the least educated, least affluent, and more likely to live in rural areas (Alemi et al. 2018).Nevertheless, these populations are likely to travel more frequently and share more trips (Brown 2019).Ride-hailing is better able to capture demand for rides in suburban areas and even in small towns around the city, compared to taxi services. While ride-hailing is primarily used by more affluent residents, it can be used as a tool to meet the travel needs of groups seeking equity. (Benaroya, Sweet and Mitra 2023)

In urban and peri-urban areas, income level becomes a relevant factor as public transport is well developed and fares are relatively low. Even if economic incentives are already in place to make it cheaper, many low-income households may still not choose to use ride-hailing services. (Sener, Sibu and Hansen 2023) Whereas in relatively remote rural areas, where the level of service that can be provided by ride-hailing is limited, higher income households are more likely to travel by private car instead.

The effect of the level of education on the use of ride-sharing services shows less importance in rural areas than in urban areas. In contrast, age has the same significant effect regardless of region, i.e. young people are more likely to use ride-hailing, while the over-65s and people with disabilities tend to have the most negative attitudes, even though this group may have a greater need for ride-hailing services due to declining driving ability and general physical fitness. Research by (Shirgaokar et al., 2021) suggests that older people who are dependent on others for rides are more likely to use ride-hailing services for the purpose of independence and for help with carrying heavy loads, regardless of neighbourhood. This is more pronounced for older or female seniors. Older people are often reluctant to use online ride-hailing services due to relatively low digital literacy, which can be a significant barrier. However, we can

expect the digital literacy of the new generation of older people to gradually improve compared to the previous generation.

In terms of customer perceptions, the interactivity that ride-sharing has can, on the one hand, satisfy the hedonic motivation of socialising, but on the other hand, it can also bring uncomfortable feelings. (neoh et al., 2017) show that people may avoid carpooling due to comfort and privacy issues. Safety is also an important factor that should be considered by service operators (Gupta et al., 2019).Drivers sometimes also have safety issues because they feel the need to be responsible for their passengers.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Soth et al., 2023)	Engineering	-	Car sharing, ride sharing	Rural, Shared autonomous electric vehicles, Interrelated trip
(Sener et al., 2023)	Social research/ Transport survey	Ride sharing service usage in Texus, US	Ride sharing, carpooling	On demand transport services, transportation network companies, microtransit, pooling
(Pyrialakou et al., 2023)	Social research/ Transport survey	Small ridehailing program MLTA, US	Ride hailing, demand responsive transport	Small transit agencies, Ride-hailing service models, Multi-criteria decision analysis
(Benaroya et al., 2023)	Social research/ Transport survey	Small ridehailing program Innisfil Transit, Canada	Ride hailing	Ride hailing, public transit, transportation network companies, Small towns
(Tang et al., 2022)	Social research/ Transport survey	Malaysia	Ride hailing, social transport	Mobility, frailty, Mild cognitive impairment
(Yu et al., 2021)	Engineering/ Computational	-	Ride sharing, shuttle, multimodal transport	Multimodal mobility system, ride sharing, rural community
(Wadud and Mattioli, 2021)	Literature review	-	car sharing, ride hailing, private car	car ownership, shared automated vehicles, travel time costs
(Shirgaokar et al., 2021)	Social research/ Transport survey	California, US	ride hailing	gender, home location, older adults, ride-hailing, technology adoption
(Molkenthin et al., 2020)	Engineering/ Computational	-	Ride sharing, carpooling	Collective behavior in networks, Collective dynamics, Scaling laws of complex systems

(Manik and Molkenthin, 2020)	Engineering/ Computational	-	Ride sharing, carpooling	Ride sharing, street network topology
(Wang and Yang, 2019)	Literature review	-	Ride sharing, shared mobility	Ridesourcing systems, demand and pricing, supply and incentives, platform operations
(Brown, 2019)	Social research/ Transport survey	Lyft travel in L.A., US	Ride hailing	Car access, equity, ride-hail, ridesource, transportation network company
(Schröder et al., 2018)	Social research/ Transport survey	Germany	Ride sharing, service delivery	Rural medical care, car access, telemedicine
(Alemi et al., 2018)	Social research/ Transport survey	California, US	Ride hailing	Ridehailing, on-demand ride serivices, Millennials, lifestyle

Table 4.6 Related literature of ride sharing (ride hailing)

Assessing the applicability of ride hailing in rural areas:

In a study by (Manik and Molkenthin 2020), the road topology model is more conducive to ride sharing in rural areas than in urban areas, although this advantage is offset by typically lower usage rates. There may be barriers to the introduction of TNCs operating ride-hailing services in low-density rural areas as a business model, but suburban or rural services to address FLM issues are already common. Transport disadvantaged groups, such as low-income people in urban suburbs, already use ride sharing to meet their travel needs and even complete their commute, benefiting from lower prices compared to taxis; some accessible rural areas are also covered by ride sharing. There is reason to believe that by integrating ridesharing into a multimodal transport system, it is likely to make a positive contribution to public transport in both directions, solving the FLM problem and avoiding competition.

So far, not enough attention has been paid to the impact of ride-hailing on transport disadvantaged groups, including the elderly, disabled and low-income groups. These populations are highly dependent on public transport services and at the same time have barriers to using ride-hailing services. When such internet services are introduced as public transport in low density areas, additional consideration needs to be given to digital thresholds and vehicle accessibility issues.

- **Shuttle van**

Shuttle bus service in which the vehicle runs between two or more fixed points, typically connecting major transport centres, airports, railway stations, bus terminals, private homes, and hotels, or connecting work commuters to employment locations. They are frequently minibuses that can carry between 9 and 12 people.

Shuttles are capable of providing FLM services and are close to feeder services in terms of route design, often requiring connections to public transport hubs, with the difference that shuttles are more privately operated, targeting profitable specific markets, rather than being a public transport service for all. When used as a business model, shuttles place more emphasis on aggregation efficiencies and therefore tend to provide point-to-point transport services. Therefore, when they are not used to connect transport nodes, they still tend to have a fairly defined population and purpose to serve, such as shopping shuttles connecting communities in low density areas to shopping centres, commuter services connecting communities to businesses in the suburbs, and so on.

In (Ryley et al. 2014)'s analysis of DRT markets and products, the services provided by shuttles are often based on strong existing markets. There is already a strong product offering for the shopping needs of the general public in suburban and rural areas. The demographic that typically uses DRTs for shopping is the elderly, as they enjoy shopping together and see it as a social outing. For commuter shuttles in employment areas, product supply remains less certain. The most likely scenario is suburban/outlying business parks with a large number of shift workers who tend to live in roughly the same geographical area. To be successful, the service would need to be door-to-door and cover the majority of shift working hours.

Service type	Service model/ Screening process	only name	plus rural	screened	extra searching
shuttle	shuttle	-	26	14	0

Table 4.7 Search result of shuttle van

The search for rural shuttle services revealed that most research interest is focused on automated shuttles and self-driving electric shuttles. This may be due to the fact that traditional shuttles are simpler and easier to operate due to their relevance to specific markets, while automated vehicle automation and electrification, as an emerging direction of transport research, is still at an experimental stage. Lower traffic levels in

rural areas can provide good experimental conditions for automated driving, reducing the likelihood of serious accidents. There are several important studies between 2018-2020 that explored the user acceptance and benefits of automated shuttles through extensive market research.(Hilgarter and Granig 2020; Nordhoff et al. 2018; Rehrl and Zankl 2018)

Due to the excellent tourism resources in many remote rural areas, shuttles that can connect stations and destinations become an important transport service to improve the travel experience of tourists, and also become the main type of existing shuttle practice in rural areas. In a case in the Ticino Valley in Switzerland, in order to reduce local traffic congestion and improve travel for tourists and ordinary local residents, the transport authority's plan to provide shuttle services in combination with parking fee adjustments was positively accepted by tourists, which is likely to be effective in changing tourists' travel patterns. In a case in the Ticino valley in Switzerland, in order to reduce local traffic congestion and improve travel conditions for tourists and local residents, the transport authority's plan to provide shuttle services in combination with parking fee adjustments was positively accepted by tourists, which is likely to be effective in changing tourists' travel patterns. On the other hand, the provision of non-motorised micro-transit(for instance, e-bikes) may better meet the needs of local residents. (Curtale, Sarman and Evler 2024)

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Curtale et al., 2024)	Social research/ Transport survey	Ticino valley, switzerland	shuttle, slow mobility	Natural destination, traffic congestion, residents' attitude, transport alternatives
(Sharma et al., 2023)	Engineering/ Computational	-	shuttle van, multimodal transport	Sustainable transport, Human mobility, Ride-pooling
(Chinbat et al., 2023)	Social research/ Transport survey	AI shuttle in Shobara, Japan	MaaS, shuttle	Social equity, accessibility, Mobility-as-a-service
(Ikeh and Yuen, 2022)	Social research/ Transport survey	Klang valley, Malaysia	Shuttle, ride hailing, slow mobility	First-mile connectivity, income, travel distance, mode choice, alternative modes
(Calvert et al., 2022)	Social research/ Transport survey	survey on job-seekers in England	Demand responsive transport, shuttle van	Employment, job-seekers, demand responsive transport, share-ride, commute

(Hilgarter and Granig, 2020)	Social research/ Transport survey	Navya Arma DL4 in Klagenfurt, Austria	shuttle van	Autonomous vehicles, driverless car, public perception, urban rural, mobility behavior
(Rehrl and Zankl, 2018)	Engineering/ Computational	Navya tech AV experiment in Koppl, Austria	shuttle van	Autonomated driving, first/last mile, public road trial
(Nordhoff et al., 2018)	Social research/ Transport survey	EUREF campus shuttle Olli in Berlin, Germany	shuttle van	Acceptance, automated shuttles, automatic public transport
(Ryley et al., 2014)	Social research/ Transport survey	UK	Demand responsive transport, social transport, shuttle	Demand responsive transport, public transport, sustainability

Table 4.8 Related literature of shuttle van

Assessing the applicability of shuttle vans in rural areas:

As the transport service model with the clearest and most direct service provision, the shuttle van can easily become a profitable business model once a certain level of demand is reached. When connecting to transport hubs, a smaller fleet size than that of feeder services can be used to provide a clearer and easier to understand service, with a higher frequency, targeted at specific users.

Where there are specific destinations in the region, identifying and trialling shuttle services at an earlier stage may produce beneficial results. For example, linking stations and scenic spots to stimulate and excite potential tourist destinations, and running employer-subsidised on-demand services could improve employment. Depending on the situation, a combination of autopilot services best suited to this model may offer unexpected attractions.

- **Feeder/ Bus on demand**

Feeder

A local transport service that picks up and delivers passengers to a rail station or express bus stop, transfer point, or terminal. For example, feeder bus services carry passengers from one locality and take them to a transfer point where they then make an onward journey, for example rail station, park and ride etc.

Bus on demand

Bus on demand services are a Demand Responsive Transport service where passengers are transported after they reserve a seat. The vehicle operator awaits reservation and this allows potential passengers to request services via internet or mobile phone, with requests for ride being processed by a server computer. The requests are composed of pick-up location, delivery location and desired delivery time (or pick-up time). The demand response operation is characterised by the following:

1. The vehicles do not operate over a fixed route or on a fixed schedule except, perhaps, on a temporary basis to satisfy a special need, or within a predefined catchment area.

2. Typically, the vehicle may be dispatched to pick up several passengers at different pick-up points before taking them to their respective destinations and may even be interrupted en route to these destinations to pick up other passengers.

In the previous sections we discussed the definition and research background of DRT, and Bus on Demand and Feeder are the two most typical DRT service models. In comparison, BOD can have a higher capacity and can cope with a higher level of demand. It corresponds to the narrow concept of DRT, with more of a many-to-many pattern in route design to meet regional transport demand. The feeder, on the other hand, puts more emphasis on connectivity with transport stops, with a focus on one-to-many/many-to-one. It may be a fixed route or a DRF (Demand Responsive Feeder) and often needs to be combined with the MRT timetable to achieve a higher level of service. Another variant of DRT service in rural areas with even lower levels of demand is the village minibus, but the low level of demand makes it heavily dependent on government subsidies, so we will discuss it later as a free ride service.

On-demand transport is an important part of the alternative to the car in low-density areas. We have already discussed BOD in the previous section, and here we add the retrieval of information related to feeder services.

The traditional feeder service emerged in the context of the highly successful rapid transit system. As the number of passengers carried by rapid transit increased, the demand for access to stations far exceeded the capacity for which station car parks were designed. The level of service that can be provided by Park and Ride alone is quite limited, while conventional buses tend to increase transfer times significantly. Therefore, in densely populated areas around stations, a feeder service can alleviate the

FLM problem while providing wide coverage and high ridership. In low density areas, demand responsive feeders need to be introduced to ensure sustainable operation. According to (Calabrò et al. 2022), DRFs are preferred in TOD-type areas with high negative density gradients at MRT stations or in peripheral areas where station spacing is quite large. On the contrary, fixed-route feeders should be preferred in single-function land use areas (e.g. residential or workplace) during peak hours. Switching between feeder services with different levels of flexibility during peak and off-peak hours within the same day may help to improve the viability of the system.

Service type	Service model/ Screening process	only name	plus rural	screened	extra searching
Bus on demand; feeder	feeder	2328	46	16	1

Table 4.9 Search result of feeder/bus on demand

When we use 'feeder + rural transport' and 'demand responsive feeder' as keywords, the search results often work together with concepts such as interchange hubs and multimodal mobility.

Interchange hubs can facilitate multimodal mobility between transport arteries and feeders, improving complementary transport systems. Different DRF services can be grouped together in identifiable waiting areas, which may be located in front of the station building, with much shorter walking distances than car parks, greatly increasing the attractiveness for time and convenience sensitive passengers. Where interchanges have high passenger volumes, parking charges can become very high and there will be more scope for flexibility in DRF charges. As parallel elements to transport provision at the operational level, interchange and multimodal considerations are closely related to multiple modes of transport, so we will continue to discuss this topic in 4.2.3.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Verastegui and Esenarro, 2024)	Social research/ Transport survey	Huánuco, Peru	feeder	Informal transport, transportation stystem, urban transportation, vehicular flow

(Mortazavi et al., 2024)	Case study	Canberra, Australia	Demand responsive feeder	Environmental impact, equity, integrated demand responsive transport
(Galarza Montenegro et al., 2024)	Engineering/ Computational	-	Demand responsive feeder	Demand-responsive feeder
(Yang et al., 2023)	Engineering/ Computational	-	Passenger freight transport, demand responsive feeder, multimodal transport	Demand-driven service, Green logistics, passenger and freight transportation
(Thao et al., 2023)	Case study	Ebuxi DRT in Herzogenbuchsee, Switzerland	Demand responsive feeder	peri-urban area, demand responsive transport, niche market
(Sener et al., 2023)	Social research/ Transport survey	Ride sharing service usage in Texus, US	Ride sharing, carpooling, demand responsive transport	On demand transport services, transportation network companies, microtransit, pooling
(Rongen et al., 2023)			Demand responsive feeder	Mobility hub, rural accessibility, shared mobility, public transport, mult-sided platforms
(Rongen et al., 2022)	Social research/ Transport survey		Demand responsive feeder	Mobility hub, Multimodal transport, Policy analysis
(Vansteenwegen et al., 2022)	Literature review	-	Demand responsive feeder	Classification, Demand-responsive public bus systyems, flexible public tranport
(Calvert et al., 2022)	Social research/ Transport survey	survey on job-seekers in England	Demand responsive transport, shuttle van	Employment, job-seekers, demand responsive transport, share-ride, commute
(Calabrò et al., 2022)	Engineering/ Computational	-	Demand responsive feeder	Demand-responsive transport feeder service, Agent-based model
(Frank et al., 2021)	Engineering/ Computational	Heinsberg, Germany	car sharing, multimodal transport	Accessibility, Decision support system, Intermodal transportation

(Bauchinger et al., 2021)	Case study	the Metropolitan Area of Styria (Austria), Ljubljana Urban Region (Slovenia) and rural Wales (UK)	Demand responsive transport, shared mobility, MaaS	complementary mobility, micro-public transport, multimodal mobility, rural-urban
(Bischoff and Maciejewski, 2020)	Engineering/ Computational	Rural area in switzerland	Demand responsive feeder, ride sharing	Demand responsive tranport, MATsim, Ridesharing, vehicle rebalancing
(Ryley et al., 2014)	Social research/ Transport survey	UK	Demand responsive transport, social transport, shuttle	Demand responsive transport, public transport, sustainability
(Yim and Ceder, 2006)	Social research/ Transport survey	suburban communtiy in San francisco, US	shuttle, feeder	smart mobility, smart shuttle, optimal routing

Table 4.10 Related literature of feeder/bus on demand

Case study: Texelhopper[14]

Against a background of budget cuts in public transport, the Texelhopper, which replaces two traditional bus lines and a number of fragmented private on-demand transport services, integrates transport demand and connects the port, the main town and all other areas of the island. The preparatory phase of the project lasted two years, during which a great deal of work was done to gather user requirements and to communicate and adapt to the government's regulatory framework.

[14] www.texelhopper.nl

Pic. 4.5, 4.6 Texelhopper's test vehicle and operational environment

Operating environment: The island of Texel in the north of the Netherlands is a tourist region with extreme seasonal passenger flows. The population is 14,000, half of which live in the market town. The population density is 85 people per square kilometre.

Services: A conventional bus line connects the port with the market town, and another on-demand service is provided by 8+1 minibuses. The ICT service regularly determines the best route based on past trips, and an average of 5 trips can be combined per vehicle.

Funding: Provincial government provides funding; users pay for trips

Organizational structure: The municipality of Texel is responsible for the organization and management, while the public transport operator and taxi operators are responsible for the two types of services. During the start-up phase, the public transport users' association and the tourism department were also involved.

Assessing the applicability of Bus on demand/Feeder in rural areas:

These two core DRT transport services are the closest alternatives to public transport. They offer the most socially efficient services due to the control that comes from their autonomous operation by transport authorities, but they are demanding in terms of government willingness and the technical resources of transport authorities. It is often more practical to improve service levels through appropriate collaboration with on-demand service technology companies.

This is particularly true for BOD. As noted above, although BOD has become a mainstream option for poorly accessible areas and is a relatively appropriate approach, its high technical and service design requirements and the low level of demand to which it responds mean that it should be prioritised for economic viability and chosen with

caution; where demand is too low, TAXI can be used as a vehicle. Demand-responsive feeder services may choose to switch to a fixed-route mode at peak times, or to provide services in low-density areas with high station spacing.

4.1.3 not for-hire ride services

This last category is characterised by the strongest social benefit objectives and often depends on services provided by deliberate commuters or volunteers with a strong sense of community, or on special subsidies provided by the government, and cannot operate from a market perspective.

Its main forms are P2P and G2C.

- **Ride sharing (carpooling)**

In the SAE definition, carpooling is the formal or informal sharing of a vehicle by a driver with passengers with similar origins and destinations, using a vehicle with 2 to 6 people. The most common terms used in the literature to refer to these services are '(flexible) carpooling' and 'ride-sharing'.

Service type	Service model/ Screening process	only name	plus rural	screening	extra searching
car club/car sharing	carpooling	1093	11	3	1
ride sharing	ride sharing	3109	50	33	

Table 4.11 Search result of ride sharing (carpooling)

Typical everyday examples are often based on apps like Blablacar. As a P2P component of ride sharing, carpooling can be described as a modern form of hitchhiking: it is digital and profitable, while offering the possibility of a safer social environment. It is a regular, advanced, and cost-effective mode of transportation, but it is less adaptable to unexpected schedule changes than DAR services. Due to the limited and random availability of individual drivers, passengers may not always be able to find suitable services if they want to change their trip at short notice, and may even have to pay a fee to cancel their previous booking. A study of the operation of Blablacar in the French region of (Talandier et al. 2024) demonstrates the effectiveness of carpooling in improving urban-rural links, especially between densely populated large or medium-sized cities and well-equipped rural hinterlands (such as rural tourist destinations). However, it must be wary of the uberisation of services, which simply introduces a rent-seeking intermediary that exploits workers and users alike.

Depending on the level of organisation, carpooling can be divided into two categories: organised and semi-organised. One of the earliest organised carpooling initiatives dates back to the 1970s in the United States during the oil crisis, when employers provided vans for employees commuting to the same location, and employees took turns driving to work. (Furuhata et al. 2013) Another relatively flexible form of organised carpooling is the sharing of users' cars with the help of private matching agencies such as Blabla car.

There is also a semi-organised approach, where drivers and passengers are not matched in advance or according to a fixed schedule. Instead, carpools form spontaneously at predetermined locations on a first-come, first-served basis. A good example is the carpool bench introduced in the German-speaking part of Belgium, which offers participants the advantage of a low digital threshold and is easy to understand and use.

In a survey on car-sharing benches organised by (Eichholz 2023), most people were familiar with the concept and expressed a willingness to participate, with a greater willingness to offer a ride (73%) than to use a car-sharing bench (44%); however, there is a gap between the willingness to adopt such solutions and actual usage. This is partly due to the comfort issue common to ride-sharing, with a significant proportion (63-68%) of people saying they feel uncomfortable hitch-hiking or sharing a ride with strangers, and partly due to the lack of participants, which reduces the reliability of the service. On the first point, Wessels' (2009) survey shows the positive role that social media can play in this respect. In the latter, Apps could help and encourage people to use the service by integrating the location of benches and improving the matching process. However, in rural areas, the feasibility of implementing a dedicated matching system may be questionable due to the limited options for shared rides.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Talandier et al., 2024)	Social research/ Transport survey	Blabla car, France	Carpooling	Carpooling, Urban hierarchy, Data-driven research
(Stickler, 2023)	Case study	US	Car sharing, carpooling, taxi, DRT	Car sharing, New energy vehicles, Regional differences
(Eichholz, 2023)	Case study	Ride-sharing bench, Germany	carpooling	Smart region, shared mobility, ride-sharing benches, co-creation
(Madani et al., 2022)	Case study	Ride-sharing	carpooling	Ride sharing, travel choices, rural areas

		bench, Belgium		
(Furuhata et al., 2013)	Literature review	-	ride sharing	Dynamic ride sharing, sustainable transportation, cost-sharing

Table 4.12 Related literature of ride sharing (carpooling)

Case study: Rezopouce[15]

Rezopounce, which operates across France, attracts young and old alike through good user design. Large-scale projects play an important role in helping people build consensus.

Pic. 4.7 Form of ride-sharing request

Operating environment: Covers approximately 10% to 20% of rural France, 22 million inhabitants, 2,000 municipalities

Services: Registered users and operators receive a mobility kit containing: a sticker for the car window, destination cards (to show the destination when hitchhiking), a manual and a list of hitchhiking points. Through an app, passengers can see the location of drivers who have booked the service to estimate waiting times.

Funding: Municipalities, central government, European funds and public transport companies; municipalities pay for the service based on the number of inhabitants.

Operational structure: RezoPounce provides know-how, assists municipalities in the location of stations and is responsible for training municipal staff. The association is a collective interest cooperative (SCIC) and represents other associations,

[15] www.rezopouce.fr

municipalities, companies, employees and users.

Assessing the applicability of Bus on demand/Feeder in rural areas:

Organised carpooling services are already common in some areas for intercity travel, especially for long-distance journeys. While ride-sharing benches are a convenient, low-threshold option for specific locations and situations where alternatives are lacking, or where people need to reach their destination flexibly and without strict time constraints.

Safety and reliability are fairly certain criteria, and digital ride-sharing solutions can only be effective if they are long-term and involve a large proportion of the population in the area. Overcoming these fears and building trust is crucial to successful implementation and must therefore exist as part of a shared mobility service system.

- **Social transport/ Village minibus**

Village minibuses and social transport in low-density areas with serious accessibility problems require government subsidies and more targeted and specialised operating methods.

Village minibus (mixed use) :

All-purpose vehicle operated to supplement existing public transport services in remote towns and villages, or replace defunct public transport journeys. The service provides for the carriage of passengers at specified intervals along specified routes, passengers being picked up and set down at predetermined stopping points, by whomsoever organised, which provide for the carriage of specified categories of passengers for predetermined specific tasks.

Village minibuses are similar to bus-on-demand and feeder services, but are often used to serve areas with lower demand. The term minibus is used for informal transport in many developing areas. In a difficult operating environment, there is still a need to fulfil a social function at a low price, so it often has to rely on subsidies. Under certain conditions, it is also possible to adopt special operating methods, such as mixed-function transport.

Transport that combines passenger and freight transport is referred to as 'cargo hitching' (Van Duin et al., 2019) or 'integrated passenger freight logistics' (Bruzzone et al., 2021). Related research has developed mainly in urban areas and for long-distance

journeys, but there is less research and practice in rural areas, which may be due to the often insurmountable legal barriers to combined transport and the resistance to changing and reintegrating existing systems. Nevertheless, it is a solution worth exploring. Case studies by (Bruzzone, Cavallaro and Nocera 2021) et al. found that this model can be particularly effective in cases of reduced freight volumes, limited pick-up/delivery points for goods and reduced elasticity of travel demand. (Cavallaro and Nocera 2023) proposed a unique solution to combine it with DRT to reduce the number of kilometres travelled for parcel delivery, demonstrating the potential of this model. There are also many relevant quantitative studies in China and Japan, where e-commerce and the logistics and transport industry are developing rapidly (Xue et al. 2024; Yang, Chu and Wang 2023; Feng, Tanimoto and Chosokabe 2023).

Social transport:

Older people, those with long-term health or social care needs and people who live in remote and rural areas may need support to access core services such as health and education. This can include financial support, or making specialised transport available on key days for specific purposes. These services can be operated on a not-for-profit basis with volunteer drivers, or with the support of local or national authorities. Funding for these services is often generated through fares, grants and donations. It requires significant planning and is usually aided by local officials and other governmental networks.

Social transport is the most demographically targeted of all the car alternatives, strictly limiting the number of passengers who can be carried, and aiming to meet the basic needs of this group of people, thereby maximising social benefits. The accessibility of vehicles, such as low-floor vehicles, is emphasised in this category.

Service type	Service model/ Screening process	only name	plus rural	screened	extra searching
social transport; village minibus	passenger freight transport	2518	54	7	0
	paratransit	765	47	32	
	health care access	-	-	4	

Table 4.13 Search result of social transport/village minibus

Paratransit is a term that is often used to describe this type of transport service.

This thesis takes its target group, the elderly and disabled, as the search target and adds a focus on access to healthcare. The search results show that rural older people may face five types of barriers to health care: transportation difficulties, limited health

care services, lack of quality health care, social isolation, and financial constraints. (Goins et al. 2005) The discussion of transport difficulties for medical treatment is consistent with the previous text. (Arcury et al. 2005) The study found that those with a driving licence were 2.29 times more likely to receive health care for chronic conditions and 1.92 times more likely to receive regular check-ups than those without a driving licence. A small number of people who use public transport have 4 more chronic care visits per year than those who do not use public transport.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Xue et al., 2024)	Engineering/ Computational	China	passenger freight transport	Passenger-freight-postal integration, sustainable development, uncertainty theory
(Yang et al., 2023)	Engineering/ Computational	China	passenger freight transport	Demand-driven service, green logistics, passenger and freight transportation
(Feng et al., 2023)	Engineering/ Computational	China	passenger freight transport	Feasibility, freight-passenger integration, rural area
(Cavallaro and Nocera, 2023)	Engineering/ Computational	Municipality Misano Adriatico, Italy	passenger freight transport	Demand responsive transport, Integrated freight passenger transport, rural areas
(Nocera et al., 2021)	Literature review	-	passenger freight transport	FLM problem, transport planning
(Bruzzone et al., 2021)	Engineering/ Computational	Italy	passenger freight transport	FLM, Freight-passenger integration, key performance indicators
(Cirella et al., 2019)	Literature review	-	social transport	Mobility narratives, older people, transport innovation
(Levasseur et al., 2020)	Social research/ Transport survey	Quebec, Canada	social transport	Local environment, monthly social engagements, paratransit, population health
(Ryley et al., 2014)	Social research/ Transport survey	UK	Demand responsive transport, social transport, shuttle	Demand responsive transport, public transport, sustainability
(Goins et al., 2005)	Medical	-	social transport	Health care access, older adults

(Arcury et al., 2005)	Medical	-	social transport	Health care access, rural region

Table 4.14 Related literature of social transport/village minibus

Case study: Sopotniki[16]

In the sparsely populated rural areas of Slovenia, a free transport service run by a non-profit organisation provides vital support to lonely elderly people.

Pic. 4.8, 4.9 Sopotkini operational vehicles, volunteer drivers and passengers

Operating environment: 9 municipalities in south-western Slovenia, average 52 inhabitants. /km2

Service: Free service for elderly people only. The nine municipalities are divided into seven units, each with a car and a coordinator who co-ordinates transport requests from volunteers and users, providing a door-to-door service.

Funding: Municipal grants (80%); user contributions (only for long-distance trips outside the city); funding from car companies.

Organisational structure: Non-profit organisation Sopotniki, 47 volunteer drivers in 2018. Volunteer drivers are recruited and trained by the Slovenian Employment Service and non-profit organisations.

Assessing the applicability of Social transport/Village minibus in rural areas:

In areas where density is too low, there may be a need for passenger and freight transport to meet the travel needs of residents or to provide access to transport for groups that are chronically dependent on health services.

[16] www.sopotniki.org

- **Service delivery**

Service delivery, although not actually part of ride services, is discussed alongside other socially beneficial modes of transport services as a social service that improves accessibility.

Brings services to users by distributing service provision across multiple locations. Can be door-to-door or limited to some predefined collection points. This can also include electronic delivery of services through e-services or telemedicine, for example. As far as public services are concerned, examples are mobile post offices, mobile libraries, mobile medical prescriptions at pharmacies, mobile dental clinics, etc. Private service delivery can also include goods or facilities.

The results of the search for rural service provision show that health services are the most important and typical problem in low density areas. The research interest is particularly evident in countries such as Australia and the United States, which have a large number of very low density rural areas.

Service type	Service model/ Screening process	only name	plus rural	screened	extra searching
Social transport	health care access	-	-	4	0
service delivery	service delivery	-	-	3	0

Table 4.15 Search result of service delivery

The difficulty and need for transport to medical facilities in low density areas was discussed in the chapter on social transport. Accessibility to healthcare can also be achieved by reducing the cost of services and the need for transport. Telemedicine can effectively reduce the need for patients to travel to GP clinics by providing a preliminary assessment of medical conditions through video consultations. Telemedicine has been well accepted in remote areas of Germany (Müller, Alstadhaug, and Bekkelund 2016). However, telemedicine is controversial. It can only be successfully implemented if patients are also regularly examined and treated by a real doctor, and it can weaken the doctor-patient relationship (Schröder et al. 2018).

The URRUC report's evaluation of the implementation of one case suggests that: this should be seen as a complementary measure, as it does not in itself solve the problem of geographical distribution. On the contrary, it may even aggravate the problem by making people stay at home even more and disrupting their social life. One possibility would be to provide services only to those who are currently facing critical situations due to low demand (such as traditional post offices). Another possibility

would be to provide services with relevant socio-cultural value and link them to social activities that aggregate dispersed demand. For example, in the case of libraries in river valleys, mobile libraries could be linked to book club activities.

For areas with a severe lack of basic medical services, small mobile medical units may be an option. There are cases in rural South Africa where mobile clinics based on vans have been set up to provide basic health care to women in poor areas. (Schnippel et al. 2015) For these low- and middle-income areas, however, even the most basic telemedicine services can be problematic. Targeting women and children in rural areas, mHealth services in the Ghana region (Laar et al. 2019) reach a large audience at a relatively low cost, although limited availability of electricity and network infrastructure, as well as education and income levels, limit access to services.

Literature	Research field/ Method	Case study	Service models involved	Keywords
(Laar et al., 2019)	Medical	Upper west region, Ghana	service delivery	Ghana, health providers, maternal and child health, mHealth
(Schröder et al., 2018)	Social research/ Transport survey	Waldshut, Germany	ride sharing, service delivery, passenger freight transport, social transport	Germany, mixed methods, mobility, primary health care, rural health
(Müller et al., 2016)	Medical	Northen Norway	service delivery	Headache, management, consultation, telemedicine
(Schnippel et al., 2015)	Social research/ Transport survey	Two rural areas in South Africa	service delivery	South africa, primary health care, mobile service delivery
(Alston, 2007)	Literature review	-	service delivery	Globalisation, rural restructuring, health service delivery

Table 4.16 Related literature of service delivery

Assessing the applicability of Service delivery in rural areas:

Telemedicine services in rural areas are widely discussed and accepted, although there is little literature exploring the possibilities of other mobile services. Subject to network coverage, it can facilitate patients in need of an initial consultation as well as other specific situations. Its use can disrupt the doctor-patient relationship as well as

other social life, further exacerbating geographical inequalities, and should therefore only be used as a complementary facility.

4.2 Classified analysis on emerging topics

In this sub-section a number of issues are added at different levels. The first group of topics relates to the challenges and objectives of these service models in transport policy, which are added to the matrix. The second and third groups of topics summarise and extend these service models in terms of flexibility and level of integration.

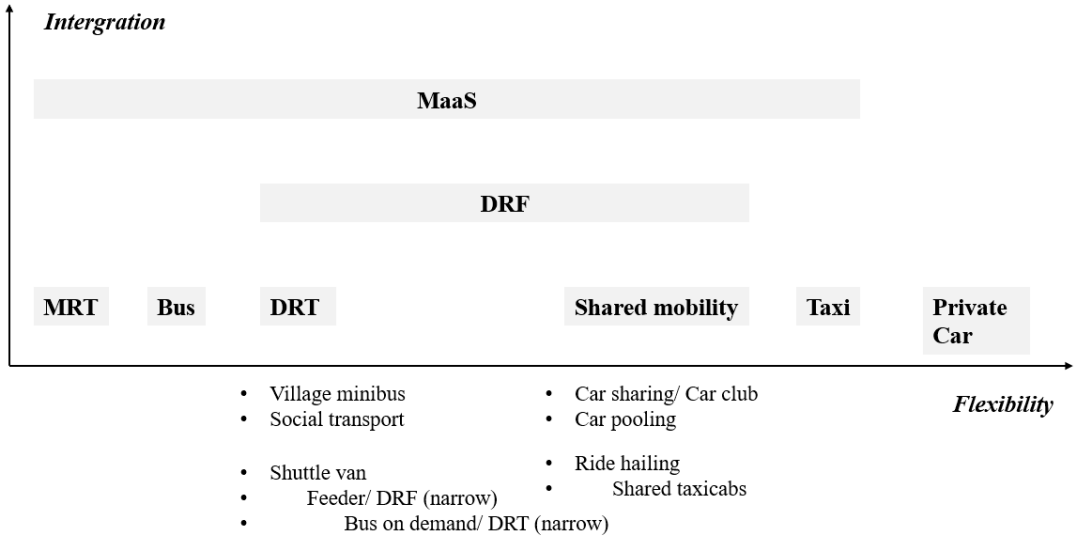

Figure 4.1 DRT options and different concepts source: adapted from (Filippi et al. 2023)

4.2.1 Low density and First last mile problems

Our earlier discussion of on-demand transport services focuses on transport challenges in low-density areas and may intersect with paratransit issues. Such services tend to have an identifiable regional structure where the level of demand cannot support traditional public transport operations.

In addition to low-density transport and paratransit, another common transport challenge addressed in our search results is the FLM (first and last mile) challenge, which refers to long-distance travel and the lack of transport connections between passengers' origins or destinations and public transport stops. P+R services within the TOD (transit-oriented development) concept are one way of responding to this. The

FLM problem is a rather integrated and difficult challenge across the entire transport logistics sector, requiring a combination of public and business-led efforts, tailored strategies, technological solutions (e.g. alternative fuel vehicles, real-time fleet management, etc.), logistical solutions (e.g. supply chain collaboration), and policy solutions to effectively reduce the FLM problem (Nocera, Pungillo, and Bruzzone 2021).

The context of the problem does not only apply to high-density urban areas, but also has many overlaps with rural mobility issues. Improving connectivity between urban and rural areas has important implications for improving the situation of the transport disadvantaged in rural areas. The emerging modes of shared mobility and on-demand transport, as the main possible alternatives to the car, can provide high quality and cost effective transport connections to and from bus stops to address this challenge.

The FLM problem differs from the low density mobility problem in that it places a greater emphasis on urban-rural mobility, and is therefore more suited to transport services such as DRF, shuttles and some ride-sharing services that use a one-to-many model in their route design rather than Bus on Demand. it tends to be a target for private sector operations and has the may compete with existing fixed routes.

4.2.2 Demand responsive transport and shared mobility

Demand-responsive transport and shared mobility are the two main categories of emerging transport modes.

In addition to the core services of DRFs and BODs, shuttle vans, village minibuses and social transport in low-density areas may all need to incorporate algorithmic techniques for on-demand transport operations to improve viability and service levels, although they have very different service scenarios.

The two modes at the heart of shared mobility are car sharing and ride sharing. In car sharing, customers typically use cars one after the other, so requests are processed sequentially. In ride-sharing, multiple customers who need to travel to and from similar locations can share the same car. In this subsection, we will further discuss shared mobility and compare it with DRT.

In terms of transport service provision, both modes provide vehicles that operate

flexibly within a defined area. Where there is a relatively concentrated pattern of demand, the use of public transport services that follow a fixed route with possible deviations, or shared mobility services with vehicles tied to fixed stations, can significantly reduce operating costs.

As part of the growing sharing economy, many shared mobility services are organised through contracts between operators and users. The need to ensure high utilisation means that a high density and balanced distribution of vehicles at key locations within the area of use is essential for fixed-station systems. As a result, common, or we could say commercially oriented, shared mobility services are usually only found in cities above a certain size.

In terms of funding and operating models, two models are more common, both of which are somewhat compatible with on-demand transport and shared mobility.

One is an agency-operated public transport service, where the transport authority provides drivers and vehicles, and may supplement the service by simply purchasing DRT software. The advantages are full control and data access to the transport service, higher vehicle occupancy and lower VMT; the disadvantages are higher demands on the authority's resources and the fact that ridership is often insufficient to support the operation. The other type of agency subsidised privately operated transport service is the opposite of the first in terms of ease of service provision, data access and VMT. It can be applied to both DRT and shared transport.

When it comes to digitisation and user experience, there is again a big difference between shared mobility and DRT. The former is based on digitisation and therefore needs to include real-time online booking services and tends to be expensive, commercially run for economic performance objectives. The latter is the opposite and may require the use of traditional telephone booking. This may require more effort on the part of the user and is seen as a barrier by young people in particular. Call centres also have higher operating costs. For areas where there is a willingness to innovate and a demand for quality of service from users, there is an opportunity to shift the initial business logic and develop innovative shared mobility models.

As discussed earlier, regular shared mobility services are often not available in rural areas for a variety of reasons. The high cost of regular shared services and their digital thresholds may also discourage use by low-income and elderly populations.

On the other hand, vehicle electrification and automation have opened up new

opportunities, and there is greater community cohesion in rural areas and road topology models that are more conducive to ride sharing. With government and community facilitation, it is possible to promote innovative shared mobility models with smart villagers.

We can argue that DRT is seen as a key solution to today's rural transport challenges, while alternative shared mobility modes can be an important complement. Efficient shuttles can be combined with shared rides to provide door-to-door services connecting to airports, or they can be provided in parallel to meet the needs of different populations in rural areas where tourist destinations exist. This is related to another concept, multimodal transport.

4.2.3 Multimodal transport and mobility as a service

Multimodal transport

The rural mobile services we have discussed so far are often difficult to operate in isolation. This can make them expensive and only meet the needs of a small percentage of users. It is therefore essential to discuss combinations of different transport modes, i.e. multimodal transport. Integrating small-scale mobility services with other modes and routes into the regional transport system not only improves the operation of small-scale transport in low-density areas, but also helps to increase the attractiveness of public transport. The FLM problem discussed earlier can be considered a subset of the multimodal transportation problem.

An important component of multimodal transportation is the mobility hub, which can facilitate multimodal service levels at designated locations. Similar early transportation node concepts include P+R, TOD, and concepts focused on reducing transfer barriers between collective and individual modes. Influenced in recent years by the emerging concept of integrated transportation, it has evolved into the mobility hub, a location-centric concept that complements the node concept by managing the spatial distribution of travel demand. In the literature of recent years, mobility hubs have been described as clusters of new, shared or electric mobility services at designated locations with high travel demand that can be integrated with traditional public transport services. In the Netherlands, mobility hubs are seen as a panacea for traffic-related problems.Rongen et al. (2023) conducted a series of studies in 2022. They found a facilitating relationship between stakeholders and riders in peripheral mobility hubs, i.e.

the coordination of mobility service providers between mobility hubs is crucial to provide integrated provision to users.

In contrast to the DRT feeder discussed earlier, the use of ridesharing as a feeder may encounter an uneven distribution of travel demand. At certain times of the day, demand traveling to the station will be higher than demand traveling from the station. Reasonable fleet rebalancing can reduce wait times during certain periods (Bischoff and Maciejewski 2020).

According to (Bauchinger et al. 2021), factors that can contribute to a complementary multimodal system include: well-established governance arrangements; close coordination between stakeholders; ICT; marketing and promotion of services; support and expertise from regional institutions; and effective interfaces with existing public transport. Transport authorities can propose a range of complementary measures, such as the introduction of strict parking regulations in attractive destinations, carpooling schemes, or the integration of shared vehicle and public transport fares. Combining complementary measures with travel hubs, such as road pricing, land use planning, or carpooling programs, can help increase the effectiveness and efficiency of travel hubs in achieving their intended policy goals.

In addition to the geographic scope and long-term viability of project funding and financing models, user-friendliness is a constraint that could have a significant impact. Even if there are a variety of carefully managed alternative modes of travel, there is a high likelihood that people will be unfamiliar with these services or even unaware that they are operating. On the other hand, individual multimodal transportation planning involves searching, comparing, and selecting the right combination, which in itself requires a lot of effort. Therefore, in addition to basic marketing strategies and user education, a transportation information and travel planning tool for the general public, which can be called an IMM (Integrated Multimodal Transportation) platform, is needed. Research on IMMs (Keller, Aguilar, and Hanss 2018) suggests that residents of small towns and rural areas may be later adopters of innovative platforms than residents of large cities with stronger innovative intentions. However, at least in the first phase, the platform could raise awareness among residents. They would learn that micro-public transport can also be a perfect feeder for car-sharing vehicles, or that bus stops complemented by safe bicycle infrastructure can improve the quality of both modes. (Bauchinger et al. 2021)

MaaS

The use of on-demand mobility through integrated multimodal networks is known as MOD Mobility on Demand in the U.S. In Europe, when it comes to combinations of different modes of transportation, the concept of Mobility as a Service (MaaS) is often used, focusing on the aggregation of passenger mobility services and ultimately offering them as a bundled subscription option. (Lucken, Trapenberg Frick, and Shaheen 2019) MaaS can be considered as a subset of IMM platforms.

Despite the growing interest in rural MaaS, few initiatives have moved beyond the pilot stage of research funding infusions. The rural environment seems to both reinforce common institutional barriers to MaaS development and introduce new ones. As a result, questions remain about how to build business models, allocate responsibilities, and interact with citizens to make rural MaaS solutions attractive, viable, and resilient. (Hult, Perjo, and Smith 2021)

CHAPTER 5

Comprehensive analysis with DRT option matrix

Continuing the discussion from the previous chapter, service models and related topics are put into a more systematic perspective, namely the DRT option matrix.

Remembering the previous sections, the literature review on DRT in chapter 3 covered a wide range of different topics from the general to the operational layer, while subsequent studies tended to focus on one or a few analytical categories. In this short comprehensive review chapter, an attempt has been made to include some of the analytical categories from the multilayer approach, which can help us to better understand whether the operational characteristics in the matrix are influenced by different factors in other layers, and to clearly see how the focus of the research has moved between the different layers throughout the text.

5.1 Development of DRT option matrix

In order to better compare the characteristics of these service models, through adjusting and regrouping the entries of the matrix in (Vitale Brovarone and Cotella 2020), a new DRT options matrix is proposed. (Table 5.1)

			fleet sharing		for-hire ride services						not-for-hire ride services			
			car sharing	**car club**	**taxi**	**shared taxicabs**	**ride hailing**	**shuttle van**	**feeder**	**bus on demand**	**car pooling**	**service delivery**	**village minibus**	**social transport**
	Service type		*shared mobility*	*shared mobility*	*DRT*	*shared mobility*	*shared mobility*	*DRT*	*DRT*	*DRT*	*shared mobility*	-	*DRT*	*DRT*
Territorial characteristics	Geographical coverage	Rural accessible												
		Rural remote												
		Hill - Mountain accessible												
		Internal mountain												
		suburb												
	Level of demand	Very low -												
		Low -												
		Medium -												
		High -												
	Modal type	FLM												
		Low-density												
		Paratransit												
General layer: Market niches	Eligible users	Territorial assigned persons												
		Commuter												
		Student												
		Tourist												
	Type of use	Single user / small group												
		Collective users												
General layer: Stakeholders	Price	Free/discounted												
		Paid/standard												
		Paid/premium												
	Financing	Subsidised - unsustainable												
		Partly subsidised - justifiable												
		Commercial												
	Performance objectives	Economic												
		Social												
		Environmental												
Operational layer: Digitalization	Booking - how	Telephone call - SMS												
		Internet (app/website)												
		Other												
	Booking - when	On day - real time												
		In advance (>one day)												
		Repeating												
Operational layer: Service provision	Timetable	On demand												
		Fixed												
		Mixed												
	Route flexibility	Fixed route												
		Fixed route with possible deviations												
		Fully flexible												
	Routing pattern	One to one												
		One to many/Many to one												
		Many to many												
	Vehicle size	car												
		Minibus - van												
		bus												

Table 5.1 Demand Responsive Transport options matrix source: adapted from (Vitale Brovarone and Cotella 2020)

The columns of the matrix are made up of eleven modes of transport services, divided into three groups (including a complementary operation), roughly corresponding to increasing levels of demand from left to right; while the rows represent a series of operational characteristics, with entries more relevant to the territorial characteristics of the place grouped together and the rest grouped according to the analytical categories proposed by (Vitale Brovarone and Cotella 2020). The operational characteristics are distributed on the operational and specific layers, and do not include features related to customer perception as well as to the transport structure (multimodal), although they've been discussed in former parts.

According to the recent literature review, there was no need to add new operational characteristics. However, in order to make the matrix clearer, in the new matrix, compared to the original one, some of the service models are split into two (ridesharing) and two sets of topics focusing on the operational layer are added (low density and FLM problem; demand responsive transport and shared mobility).

Discussions based on operational characteristics

The first way in which local decision-makers can check this is by identifying the nature of local transport needs and the mode and level of service provision that is appropriate to the local resource situation.

The first group is territorial characteristics.

- Geographical coverage: almost all transport services are relatively more likely to cover areas closer to or more accessible from the city, the difference being only in the degree of adaptation; the village minibus is the only one that is relatively more adapted to more remote areas, and this is arguably entirely a product of the characteristics of demand in those areas. ride sharing and social transport are likely to be applicable in any geographical area due to their social and technical characteristics.
- Level of demand: Ride-sharing and car-club/car-sharing are adaptable to different levels of demand, partly due to the lower input costs of TNCs and the dynamic response of Internet technology.
- Modal type: or rather the main objective of local transport policy that we discussed in 4.2.1.

The next four analysed categories are.

- Market niches: fleet sharing and not-for-hire ride services have a greater need to improve service levels by taking into account the needs of territorially assigned persons, and are not relevant to the needs of tourists compared to for-hire ride services.
- Stakeholders & digitalisation: These two points, when combined, show two different modes of operation, corresponding to shared mobility and DRT. We have already discussed in detail in 4.2.2 the differences between the two modes of operation and the digitalisation issues that need to be addressed.
- Service provision: Unlike DRT, where the design of routes, timetables and vehicle sizes need to be taken into account, the different types of services offered by shared mobility are basically provided by cars or vans with complete flexibility.

Discussion based on service models

Having created a new column representing the area situation, a side-by-side comparison of different service models of transport services can help decision-makers to find suitable options. The grouped car alternatives can give a clearer idea of the mix of transport services.

Fleet sharing is a relatively stand-alone option that could well be provided in parallel with other services in the right areas. As the closest option to the car, it offers something very different from other ridesharing services, and is able to meet the complex demands of the sequential, multi-leg journeys that often characterise the daily travel of residents in low-density areas. Fleet sharing as a transport service may be more appropriate to add to the mix of transport options when core transport services are working well. While fleet sizes will vary, for economic reasons it is likely that there will be only 1-2 shared vehicles in an area, so peak demand is likely to be much higher than it can afford. At off-peak times, it can provide a strong and convenient transport supplement. If other electric vehicle services are envisaged, perhaps planning for a network of charging points, then the introduction of car clubs or car sharing can always be beneficial as the major costs of operation in low density areas are greatly reduced.

For-hire ride services are a key alternative transport option for a good economic balance. It can be used for different transport policy objectives, but different levels of demand need to be carefully considered.

A decision needs to be made, based on local resources, whether to use an agency-operated model or to subsidise TNCs to operate it. There are a number of business models available to address FLM for urban-rural linkages; where trip volumes at a

transit hub are not too low, or where there is demand for travel between specific destinations, willing transit authorities can also operate their own shuttle or DRF on-demand feeders.

Different scenarios need to be considered for operation in low density areas. Typically, in low-density areas with high demand, the choice between agency-operated BOD and subsidised TNC services as the primary transport service can avoid competition between the two and meet the travel needs of different groups of people by combining them with other car alternatives. Even in low-density areas, where the business model is more difficult to implement, it is possible for regional governments that do not have sufficient resources and financial outlay to operate BODs directly to adequately subsidise TNCs to provide high quality services. Of course, it is important to note that outsourcing quasi-public goods to private companies is risky in the long run, and it is therefore necessary to incorporate equity-based performance measures into the evaluation of any on-demand transport partnership to ensure that a higher degree of equity is achieved. (Benaroya, Sweet and Mitra 2023)

By making for-hire vehicles accessible and training drivers, taxis and TNC vehicles can provide the same public service of paratransit as BOD. If the population is too dispersed, this approach may provide social services more efficiently.

Not-for-hire transport services, in their various forms, are an effective complement to the transport system. Whether they are formed by matching local drivers and passengers, or by providing targeted mobility support to territorially mobile people, they are small but efficient and depend entirely on local demand.

Organised car-pooling facilitates connections between medium-sized cities and rural destinations. Low-threshold carpools can bring interesting mobility to rural areas if they are integrated into mainstream carpooling systems that are more widely known and used. A scheme that requires offsetting expenditure may not always be feasible for a given area. Policy support for travel for specific populations can have significant cross-cutting benefits, and there is a relatively long history of using such subsidies to provide paratransit. An alternative strategy would be to use vehicles more efficiently, with the flexibility to tailor services to different circumstances, including in combination with freight. Supplementing this with telemedicine where appropriate is also an option, and the dematerialization is always welcomed by people.

5.2 Review of research content

At this point in the discussion, we can agree that looking at and responding to the problem from different layers plays an important role in tackling rural mobility issues. We need to build a set of connected and flexible mobility solutions that are sensitive to the temporal and spatial patterns of mobility demand (Poltimäe et al. 2022), which will make it possible to reduce people's dependence on cars while achieving social inclusion for people living in low-density areas.

Practical experience of emerging transport models in rural areas is relatively limited, and successful solutions cannot simply be replicated. In practice, therefore, local transport authorities need to consider the fit between the two, based on a thorough analysis of their own resources and needs, and an understanding of each mode of transport and its context. Examining Table 5.1 interprets the links and differences between modes at different levels and can help to select a relatively appropriate combination of modes to build the framework.

The previous two chapters discuss common issues in different thematic areas, specific transport modes and combined transport concepts and mode comparisons at three levels. Within the framework of a multilayer approach, we can see the difference in focus (highlighted in table 5.2) between the operational and the specific layers .

Analytical categories / Research sub-theme		3,1,3 Research fields related to DRT options	4,1 Classified analysis on servcie models	4,2 Classified analysis on emerging concepts
Territorial characteristics			Discussions are based on specific areas and types/level of demand	Transport policy objectives/ modal types
General layer	Policy and government		Taxi./ shared taxicabs: possible regulations of carpooling; Village minibus: regulations of freight passenger transport	
	Economic			
	Sociocultural		Car club/ car sharing: Sense of identity in brand communities	
	Technological	Automation and electrification of vehicles	shuttle van: automated vehicle technology	
Specific layer	Market niches		Car club/car sharing: potential user profiling; Ride sharing: Extensive research into ride hailing user types in city as to affordability of the service; Shuttle van: targeted at existing specific market, ie employment, travel destination, airport, shopping centre etc; Feeder: commuter between rural and urban areas; Ride sharing (carpooling): need to be known by various user groups; Social transport: territorial assigned persons	
	Stakeholders		Taxi/Shared taxicabs: a paradigm shift is needed; Ride sharing (ride hailing): Lots of discussion about the impact of TNC and ways to work together with public sector	Shared mobility: usually subsidised TNC operation Demand responsive transport: usually transport agency operation
	Customers' perceptions	The psychological needs of the elderly population; The dilemma of older adults facing digitalization	Car club/car sharing: Users' hedonic motives; Community cohesion Ride sharing: Comfort issues; Digital divide shuttle van: user acceptance of automated shuttles	
Opertational layer	Transport alternatives		case-by-case study of 11 alternatives to single-occupancy vehicle	
	Non-material and cross cutting		Taxi/Shared taxicabs: necessity of digital transformation; Ride sharing (ride hailing): key underlying logic of the service; Service delivery: telemdicine	
	Structural		Feeder: connection with transport node	Multimodal transport and MaaS: Intermodal transport facilities and passenger services

Table 5.2 Summary matrix: shift in research focus between different layers

A summary of discussion in Chapter 3 and 4 (Table 5.1) can provide inspiration, i.e. if there is a need to further understand and address an issue at a particular level, it is important to choose the right issue or area to cut through. For example, improving access to resources in transport operations research and the psychology of transport behaviour may be of great help if local authorities perceive problems with the basic design of the supply side and the demand side; if implementation details need to be explored, especially for niche markets and regions, it may be more relevant to focus on theoretical advances and practical examples of the particular transport service model itself; where emerging concepts and practices bring innovation in the combination of asset models and digitalisation, and where decision-makers are unable to decide on a model of cooperation with stakeholders, thinking in terms of emerging integrated concepts may be a good starting point.

CHAPTER 6

Conclusion

In the context of rural accessibility and car dependency issues, this thesis systematically explores DRT and its different service models with reference to the multilayer approach.

DRT services are a rich and sometimes confusing concept that lies between private cars and traditional public transport in terms of flexibility, encompassing what we often refer to as shared mobility and even taxi services. The literature review on DRT shows that DRT services have gone through different phases in their more than 40 year history, and that the current phase of ICT DRT operations requires more in-depth research, which has led to a shift in the direction of research from the operational to the specific layer, and from a single technical study of the service provision side to the user experience on the demand side. The longevity of the concept has led to a public preference for DRT, but elements of the specific and general layers such as governance, flexibility of rules and procedures, and know-how have made programme implementation very complex, and as a result most DRT projects have failed. Experience from a large number of successful practical projects has shown that a combination of factors is required, such as simple and effective system design, adequate internal and external resource mobilisation, and good cooperation with transport authorities. Among these, the design of the service system to be tailored requires not only a good understanding of local needs, but also a clear understanding of the possible modes of operation of DRT and their combinations.

By grouping and rearranging the DRT options, as well as constructing a matrix of corresponding service characteristics, we conclude that in order to build a locally adapted transport solution, fleet sharing, for-hire and not-for-hire services can be provided as separate services in parallel, as core alternative transport for the general public, and as diversified transport complements to be included in the construction of transport schemes. These specific service models are appropriate for different geographies, demand levels and modal types, and their feasibility is influenced by other dimensions, including market niches, stakeholders and level of digitalisation. The selection and combination of these service models has great potential in rural areas, and realising this potential may require the right combination of DRT services and shared mobility services, facilitating the integration of transport modes with ICT technologies, appropriate service marketing and governance, and coordination between stakeholders.

Throughout the decision-making process, it is necessary to be aware of the different roles that different issues can play at different decision-making perspectives and levels. In this respect, this thesis provides some inspiration for interdisciplinary and cross-sectoral decision making.

Although this thesis does not provide an in-depth case study of a specific DRT service model, it does provide a first exploration of the possibilities of DRT experiments. Further case studies on the combination of different DRT models could be valuable.

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