



Exploring Economic and Ethical Challenges of Implementing Demand-Responsive Transport Systems (DRT) in Italy

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Abstract

In recent years, a change in demand trends has influenced the development of public passenger transport, causing a number of critical issues and consequences for the environment, the management policies of these services and, especially, the users. Various passenger transport services have evolved to reduce the use of private vehicles, including DRT systems that consider technological developments like Mobility as a Service (MaaS). This article focuses on a European literature review on user-oriented research development. The overall objective is to: i) highlight, among all the critical aspects of service development, the factors influencing the economic and ethical aspects; ii) finally identify a discrepancy between the perception of DRT and the empirical research design. The study concludes by providing potential suggestions for improving DRT service deployment and reducing some of the factors influencing users' modal choices. Finally, the paper proposes implications for policy makers and operators.

Keywords: Demand Responsive Transport (DRT); Italian and European case study; Economic and ethics aspects; Sustainable mobility.

1. Introduction

The past two decades have been characterised by different passenger mobility trends. The observed phenomenon may be attributed to both the increasing availability of transport services and the widespread use of technological advancements, such as smartphone applications and digital Mobility as a Service (MaaS) platforms (Abdullah et al., 2021). These technologies and services promote the use of public transport and shared forms of transport. The advancement of the aforementioned technologies led to an increased use of Demand Responsive Transport (DRT) throughout the 1990s across

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several European countries. This adoption aimed to tackle the inefficiencies associated with planned transportation networks in urban and suburban areas. Due to the 2008 global financial crisis, many transport companies faced significant decreases in government subsidies. Concurrently, the widespread adoption of smartphones among the population presented an opportunity for these companies to explore DRT as an achievable option for mitigating operational costs and improving vehicle load factors. The frequency of experiments using DRT services in Italy has shown a notable increase over the last decade (Delponte and Costa, 2023).

It is common knowledge that the promotion of sustainable mobility and the achievement of the 2030 Agenda's objectives are closely linked to the widespread adoption of public transport. However, it is also necessary to realise that around 29% of European Union (EU) residents dwell in rural regions characterised by the inadequacy of public transport systems.

The recent pandemic has drastically reduced the tendency to use public and shared mobility for several months and transport services in peripheral areas of metropolitan cities have decreased in recent years. The evolution of transport systems should coincide with the growth of urban models, oriented towards the definition of a more sustainable and smart city and the model related city of proximity (Garau et al., 2022).

In this perspective, DRT services can be defined as a possible alternative or complementary solution to public transport services. Indeed, they can compensate for the lack of transport services and/or guarantee the service when local public transport is not scheduled. DRT services were developed and implemented at the end of the last century. Their first implementation showed some limitations in terms of usability and ability to attract demand as well as optimise vehicle occupancy (Campisi et al., 2022).

Today, a new generation of services has entered the market as a result of the digital technological options capable of providing valid and immediate support to both the user's travel organising and booking process and the planning of routes through the application of complex dynamic algorithms (Hou et al., 2022). The service is facilitated by a fleet of small public transport vehicles, such as minibuses, which allow for personalised trips based on individual user requests. These requests include specific origins and destinations, and the service is able to accommodate a predetermined number of users per trip. Additionally, the service manages the coordination of routes with a certain degree of flexibility in order to fulfil all user requests. Dial-up systems need adaptation to the operational context based on their intended use. The inherent adaptability of these services enables them to either substitute or supplement conventional services, therefore accommodating a diverse range of needs. The evolution of transport services is dependent on the evolution of operational schemes directly linked to public service contracts and is also connected to a transport demand that is increasingly complex and expresses strong mobility needs that a typical scheduled service often fails to meet, especially in contexts of weak demand (peri-urban, rural areas, etc.). This service has undergone significant development in various European contexts to cater to areas with limited demand, commonly referred to as weak demand areas. These areas include i) urban regions in major cities, where the service facilitates transportation between suburbs or small towns; ii) extra-urban areas characterised by rural or mountainous landscapes, as well as low-density lines of transport.

Furthermore, this service has the potential to cater to specific user groups, including individuals with disabilities, the elderly, and students. Additionally, it can provide

specialised services such as transportation to and from railway stations, theatres, hospitals, shopping centres, airports, or any other public location of significance.

In addition to the definition of different types of services according to demand (type of users' frequency and motivation for travel), it is necessary to consider the factors that have the greatest impact on modal choice and the implementation of services in the examined context. This research analysed the literature in the European context during the previous two decades to determine whether economic, environmental, psycho-social and cultural factors have been properly considered, as well as to determine what gaps remain in the study and understanding of transport demand in Italy.

Throughout the examined period, the Italian context was characterised by a limitation in the implementation of these services due to a regulatory shortcoming caused by the definition of Local Public Transport: art. 14 paragraph 4 of Legislative Decree no. 422/1997. In fact, it allows regions to identify areas where innovative transport solutions can be experimented (such as DRT,) but it is essential:

- they must provide for the experimentation of an on-demand transport model with pre-established stops throughout the entire provincial territory;
- terminals should be located in the main transport hubs or in the most attractive places: The catchment area required to guarantee the economic sustainability of the service can be met by intercepting demand in low-density areas, with a variable-route service;
- it is necessary to involve private stakeholders for the experimentation of this service, both on the user side and on the supplier side of management software and possibly vehicles.

In the last section of this paper, some short-, medium- and long-term strategies are provided to analyse the mobility demand more comprehensively for DRT services and thus highlight what the best strategies and actions for the deployment of these transport systems might be.

2. Background

The development of DRT is closely intertwined with the advancements in communication and information technologies. According to ENEA (2003), the establishment of the first DRT services in Europe can be historically attributed to the 1970s. However, the current structure of DRT was not adopted until the subsequent decade, due to the advancements of information technology, as highlighted by Coutinho et al. (2020). The first documented pilot project of it in Italy dates back to the year 1987, when a supplementary service was introduced in Piacenza to complement scheduled transport in regions with low demand (Pavanini et al., 2023). Numerous research studies highlight the importance of deploying DRT as it not only enhances accessibility for individuals with restricted mobility or those who are socially marginalised, but also produces substantial environmental advantages. These benefits include reducing the volume of private vehicles on roadways and promoting the integration of various modes of transportation within urban areas (Campisi et al., 2023; Delponte and Costa, 2023). In recent years, scholars have been investigating environmental issues associated with emissions reduction. Notably, a study conducted by Dytkov et al., (2022) reveals that, from an environmental standpoint, a DRT service can offer greater cost-effectiveness compared to conventional buses, particularly during periods of low demand. Additionally, the study highlights that DRT services generate significantly lower levels of carbon dioxide (CO₂) emissions.

Similarly, the study conducted by Diana et al., (2007) revealed that DRT services minimise emissions for scenarios including high service quality and low demand density, emphasising the need for smaller vans with lower emission factors and thus greater air pollution benefits.

Although some studies claim that providing DRT services is costly, several scenarios have been analysed in different European contexts in which service solutions have been assumed to vary with the size of the area served, the degree of accessibility of DRT services compared to public transport and a possible doubling of the current transport offer by volunteers.

The study conducted by (Neven et al., 2015) reveals that in the region of Flanders, altering the modal split, which refers to the distribution of various DRT providers, along with the adequate provision of public transport and enhanced flexibility, appear to be crucial factors in reducing the resource demands of a DRT system.

Theoretically, DRT services may be more flexible and cheaper than bus services for public transport companies, by considering low-demand scenarios. Practically, Several DRT initiatives have failed for various reasons.

Davison et al., (2012) assert that technology assumes a key role in addressing niche market need, mostly by facilitating flexible bookings and delivering real-time information. Moreover, technology aids in fostering market expansion, as well as in creating prospects for product development and diversification.

Several studies still underline the discrepancy between service user perception and service design not only in Italy but also in the rest of Europe (Huang et al., 2023).

In addition, the combination of DRT services, smart mobility, and urban planning offers great potential for the emergence of smart cities. By addressing the ethical dimensions of urban mobility, cities may establish transportation systems that are inclusive, sustainable, and efficient, therefore enhancing the quality of life for their citizens. Smart cities optimise resource allocation, provide real-time monitoring, and control, and enhance public participation via the integration of several systems and infrastructures.

The development of smart cities is significantly influenced by urban planning, which considers transport, energy, environment, and social equality. By incorporating DRT services into this system, communities may increase the efficiency of public transportation, minimise traffic congestion, and enhance access for all inhabitants (Annunziata et al., 2022a).

While several works in the literature have analysed economic and environmental aspects and related factors, few studies have analysed the economic aspect and even fewer the ethical and psycho-social aspect related to the modal choices of transport demand and in particular to DRT services: Under the cultural profile characterising transport demand, it is necessary to focus on the social and ethical factors that often reduce the propensity to use shared transport services. Indeed, cities may achieve a comprehensive approach to urban mobility by integrating DRT services and intelligent mobility solutions within ethical urban planning frameworks. This integration guarantees that the design of transportation networks is inclusive, sustainable, and effective. It requires considering the needs of all residents and integrating their feedback into the planning process. In addition, ethical urban planning directs the appropriate use of data and ensures privacy and security concerns are handled. In order to characterise transport demand, researchers must include the social and ethical considerations that often restrict the tendency to use shared transport services.

3. The economic aspect connected to the user, the manager and the environment

In accordance with the objectives of the White Paper and the United Nations' Agenda 2030 the spread of sustainable forms of mobility must be linked to a series of actions that adopt a more balanced approach in which the three dimensions of sustainability (the economic, ecological, social ones) are among its three main priorities:

- smart growth (economic and ecological sustainability);
- sustainable growth (ecological and economic sustainability);
- inclusive growth (social sustainability).

The primary goal of the Transport White Paper (Islam et al., 2016) is to reduce greenhouse gas emissions by at least 60% by 2050 compared to 1990 levels, while maintaining a competitive and resource-efficient transport system. By achieving this goal, the transport sector would contribute to the European target of reducing greenhouse gas emissions of the economy as a whole by 80-95% by 2050 compared to 1990 levels.

The most significant purpose of Agenda 2030 (Ruiz-Mallén and Heras, 2020) is to correlate the environmental impacts aspect (the sustainable aspect) with the economic and social sphere by ensuring a more inclusive and smarter development. The choice of a DRT service is optimal when serving areas with low and unconcentrated demand but may not be the best choice in other areas or when demand is growing rapidly.

Therefore, it is necessary to consider the context of weak demand areas for rural areas (Schasché et al., 2022), suburbs (Delponte and Costa, 2022) but also those areas with a low frequency of local public transport services such as inland areas (Ruocco, 2022).

The rural setting, as well as peripheral areas, present a multitude of challenges pertaining to the provision of transport services. These challenges include restricted accessibility and connection, extended distances, insufficient availability of public transport and/or viable alternatives to private vehicles, and inadequate financing for mobility initiatives.

From an economic point of view, it is necessary to consider three different levels, namely the user as service user, the operator as service provider and the environment as context.

The economic aspect concerns both the impact produced on the three different players but also the potential of implementing the service with respect to the concept of mobility in general. DRT is a form of transport that has gained popularity in recent years in Italy. Correct implementation of the service combined with good user information and increasing integration with traditional fixed-line services means that DRT services can be one of the most sustainable solutions compared to private transport.

In Italy we often see the creation of such services as being unrelated to other modal forms, and this is due to the fact that the service is easier to create and implement, but over time it clashes with a very high cost that is often overlooked. To achieve the goal of optimising public and shared transport and making people free to move around, it is essential that DRT be fully integrated with scheduled services.

Public administration and transport operators who neglect this aspect are in fact faced with the following critical issues:

- user use of several non-integrated apps. This leads to enormous confusion and a poor user experience, which goes against the mission of making life easier for all travellers, as they will lose confidence by entering a vicious circle that will ultimately hinder adoption;
- dual application of hardware and software solutions in the vehicle, with huge additional costs due mainly to installation and maintenance. Drivers will have to juggle multiple systems (increasing the difficulty of action and dissatisfaction in the way they operate);

- increased difficulty in effectively managing day-to-day operations and successfully governing the overall mobility scenario for their organisation. Due to the lack of a centralised tool for the management of both DRT and scheduled transport, their operational flexibility will therefore be greatly reduced.

The full integration of DRT and public transport together with shared mobility and micro-mobility avoids unjustified cost increases, facilitates the operation of administrative staff and improves the user experience by exploiting the inherent ability of on-demand mobility to act as a feeder service of the transport network. Therefore, large-scale MaaS digital platforms need to adapt mobility to the needs of passengers in order to provide freedom of movement, while rationalising the mobility scenario in a holistic way, the true cornerstone of today's mobility and the goal of that of the future (Calabrò et al., 2022). Therefore, these platforms will have to integrate services outlined in Figure 1.

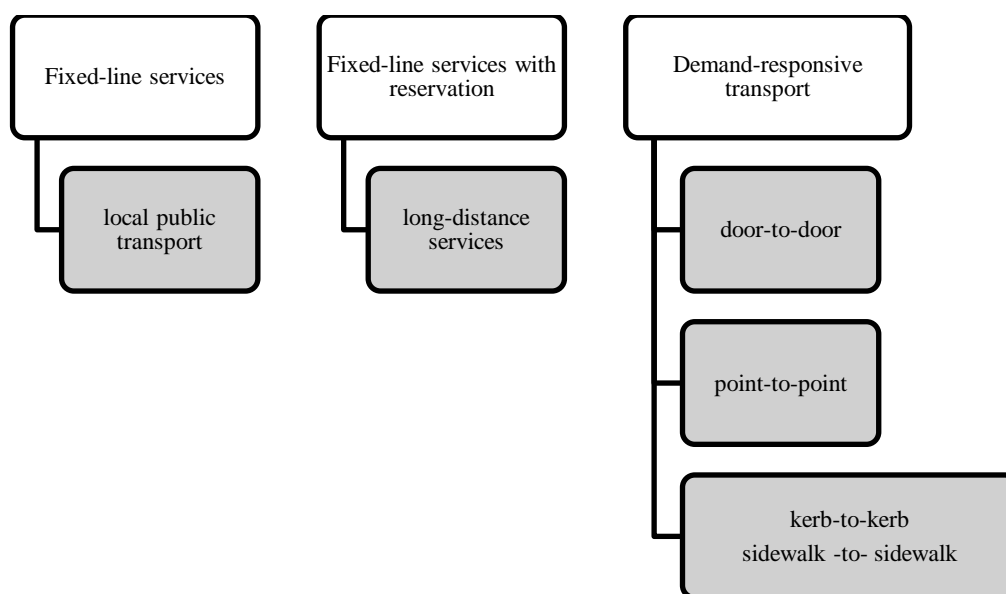


Figure 1: Classification of fixed-line and/or demand services.

It is essential that the development of public mobility solutions be aligned with a grassroots methodology, beginning with an assessment of the requirements and preferences of those who will ultimately use these services.

It is essential to acknowledge that these demands are dynamic and undergo evolution throughout time, exhibiting variations across different users.

Integrating different transport schemes makes it possible to address real scenarios and offer solutions tailored to the needs of individual users, starting from the problem and not the solution.

Therefore, being able to integrate DRT into a broader mobility scenario is the key to implementing a future-ready system in which people are truly free to move and have the opportunity to do so in an economically and environmentally sustainable way.

Having a single software platform makes it possible to switch seamlessly from one paradigm to another, enabling interoperability and saving costs (Labee et al., 2022).

The development of suitable policies and effective operational solutions for urban and rural mobility is a topic of decision-making by legislators, local authorities, and operators in both urban and non-urban environments.

This enables the provision of services to areas with limited demand, thereby facilitating the following:

- Formulating an innovative scenario on rural mobility at the national, regional, and local levels.
- Establishing precise and quantifiable goals tailored to various contexts.
- Allocating distinct responsibilities and obligations to ensure the designated rural mobility objectives.

Urban sprawl, scattered regions, and lack of spatial planning for rural areas contribute to rural populations' high car dependency, which, along with inadequate infrastructure and lack of public transport, limits accessibility and connectivity. Poor accessibility restricts (physical) access to all types of services or amenities, including stores, supermarkets, pharmacies, postal services, health services, and other commercial or healthcare entities. Rural areas are often distinguished from regions and Member States by a variety of distinctions.

In some regions, rural areas may exhibit a notable concentration of prosperous people, but in other areas, a significant proportion of impoverished families may be prevalent. Mountainous regions have distinct characteristics that set them apart from coastal places. The presence of such a wide range of variability poses challenges in identifying a universally applicable model.

The weaknesses in rural mobility have a direct or indirect impact on the well-being of those living in rural regions. However, there are other vulnerable groups that experience even greater levels of impact. These groups include the elderly, those with disabilities, low-income families or those who are jobless, single parents, youths, immigrants, and newcomers to the region.

Hence, it is essential for transport service providers to offer easily accessible travel alternatives in order to effectively attract prospective workers.

The prevalence of extensive automobile mobility among individuals dwelling in rural regions contributes to the erosion of local services, since the availability of vehicle transportation allows people to access services located at considerable distances.

A significant number of EU-27 Member States currently do not possess a comprehensive policy framework addressing the issue of rural mobility. This refers to a framework that explicitly acknowledges the unique challenges and requirements associated with mobility in rural regions, and is tailored to address these special needs.

In contexts characterised by well-established institutional, regulatory, and financial frameworks, a tendency to allocate more attention on metropolitan cities exists, by prioritising urban projects, sometimes at the expense of rural transportation projects.

It is also important to acknowledge that the current global pandemic has emphasised the need of reevaluating the provision of local public transport, particularly in relation to alternative models such as DRT (Cirianni et al., 2022).

In conclusion, the implementation of DRT services is primarily influenced by economic factors, which are contingent upon various contextual factors such as the demand for transport, particularly income levels and private vehicle ownership. Additionally, the regulatory framework and the strategies employed by local administrators and transport service managers also play a significant role in shaping the implementation of DRT services.

The economic dimension, as previously stated, has implications for the environment in terms of emission reduction, expansion of services, and increased mobility of customers, which provide potential economic benefits within the travel sector.

4. The ethical finance and the ethical aspect connected to the DRT user

The heightened focus on sustainability, green mobility, climate change, and social justice, in conjunction with the apprehensions stemming from the 2008 financial crisis and the repercussions of COVID-19 on the global economy, have engendered amplified discourse and interest surrounding a financial sector that conducts itself in a more accountable and principled manner, characterised by enhanced transparency and ethics. The concept of ethical finance is becoming more prevalent in contemporary discourse, indicating its growing significance despite its relatively limited awareness.

Ethical finance diverges from a profit-centric approach by prioritising other dimensions, including climate protection, environmental preservation, and the advancement of social justice. In detail, the term 'ethical finance' is used to describe finance that takes into account environmental, social and governance (ESG-Environmental, Social and Governance) factors. This reflects the growing recognition of the importance and value placed on addressing global challenges, especially those related to economic growth, in a responsible manner. In essence, we can say that ethical finance is a sustainability-oriented approach that includes all those financial and investment practices aimed at reducing environmental, social and economic risk, with the goal of building a more equitable future for all. A topic closely related to ethical finance is green mobility, i.e. all those alternative forms of transport to traditional ones that have a reduced impact on the environment. Investments in green mobility are crucial for the fight against climate change and may concern, for example, the construction of infrastructure for electric mobility, energy efficiency of vehicles, the production of biofuels and the financing of projects to reduce traffic and pollution. Green mobility and ethical finance are therefore strongly linked. Therefore, supporting the growth of sustainable mobility means contributing to building a better future for all and reducing CO₂ emissions through the spread of innovative vehicles, such as hybrid and electric cars, and the creation of an efficient and high-performance infrastructure network. Individual mobility behaviour depends on considerations of economic and social utility, but also on cultural factors, as it appears especially for the car whose dominant role is connected with widespread cultural values and patterns. Mobility poses problems of behavioural ethics, but also of political ethics: its regulation cannot be left to market mechanisms alone but requires political control between conflicting interests and values in view of the common good. The quality of urban areas, and of territories in general, depends on respect for public space. Everyone must be aware that the city must remain accessible to all. New modes of transport act in this sense and open the door to mobility for all. The era in which all travel took place exclusively by car is tending to disappear, to make way for new forms of mobility and the sharing of transport between users. While this solution was already well established in urban areas, it is gradually becoming established in suburban areas, which are often poorly served by public transport. Users are at the centre of the concerns of DRT services, as their objective is to revitalise peri-urban areas by offering a service adapted to the pace of users. Passengers can thus enjoy a quality public transport service, comparable to private transport in the city centre. Users are free to choose the means of transport, timetable and frequency of use, so that they can book a DRT service as easily as booking a taxi service in the city centre.

DRT services offer an alternative transport solution that compensates for the limitations of traditional public transport. These alternative modes of travel make it possible to limit the use of personal vehicles and cars, thus reducing the ecological impact of travelling by car. DRT services can offer an alternative mobility solution that improves the usefulness of existing transport infrastructure without requiring new works or facilities. Over the years, Transport on Demand services have been intelligently and dynamically implemented, limiting empty trips, and creating better calculated routes, thereby optimising existing transport networks. It also shows that the implementation of DRT services encourages travellers to choose an environmentally friendly way of travelling. However, the benefits extend beyond that, as it also provides people with the chance to choose the most rational pathways for minimising energy use and, thus, mitigating pollution. On-demand transport can thus be used in scenarios when the feasibility of zero-emission transport is limited, so serving as a supplementary option to sustainable mobility. Therefore, it is feasible to proactively promote alternative travel behaviours among users via the provision of intelligent, optimised, cost-effective, and environmentally-friendly mobility services.

Therefore, the ethical and social aspect of mobility is closely connected to the concept of inclusiveness and accessibility mentioned in the previous paragraph.

The table below summarises the main benefits and criticalities.

Table 1: Benefits and Criticalities of DRT development.

	<i>Heading level</i>	<i>Smart growth</i>	<i>Sustainable growth</i>	<i>Inclusive growth</i>
Benefits	Companies/users	Exemplification of modal choice (Calabrò et al., 2022)	Exemplification and more modal choice alternatives (Alonso-González et al., 2018)	Diversification of mobility demand (Jittrapirom et al., 2019)
	Infrastructure and services	Increasing devices and technologies, ITS and Big Data (Brake et al., n.d.) Vehicles with innovative power supply (Campisi et al., 2021a) and autonomous driving (Zieger and Niessen, 2021)	Reducing traffic congestion (Pavanini et al., 2023)	Reaching weak demand areas (Campisi et al., 2022) Complementarity of service (Alonso-González et al., 2018)
	Environment	Selection of transport modes with less noise and environmental impact (Coutinho et al., 2020a)	Reducing private vehicle use and encouraging forms of vehicle sharing (Sihvola et al., 2012)	Reaching out to different segments of the population (Campisi et al., 2023)
Criticalities	Companies/users	Regulatory gap (Huang et al., 2023).Risk of digital divide	Reduced user training and information (Abdullah et al., 2021)	High tariffs (Campisi et al., 2023)
	Infrastructures and services	Non-homogeneity of services in the national context (different infrastructure status and spread of mobility	Risk of an increase in vehicles on the road for public transport if DRT is developed in competition with the	High operating costs (Diana et al., 2007)

	services)(Cirianni et al., 2022)	latter (Davison et al., 2012)	
Environment	Widespread home connectivity and Wi-Fi mostly in urban public areas as well as smart infrastructure, smart electricity meters, open data and e-government. (Garau et al., 2022)	Greater environmental impact if not conceived as a complementary service (Davison et al., 2012)	Place of origin/destination (Häme, n.d.) Pre-Post COVID-19 (Campisi et al., 2021c) Gender gap (Campisi et al., 2021d)
		Distances of stops (differences between urban and rural areas) Service levels and quality objectives (Calabrò et al., 2022)	

To develop new, shared and on-demand modal choices, it is therefore necessary to make accessibility, safety, and comfort of transport modes a priority of transport policy.

This means improving:

- the design of transport facilities, considering the specific needs of vulnerable groups;
- increasing the safety of transport with particular reference to women and the elderly.
- the ability of public authorities to find innovative solutions for transport services transport services, activating and coordinating different operators at different levels to provide integrated and flexible transport services capable of reaching different destinations and enabling vulnerable users to organise both short trips and long-distance and cross-border journeys;
- technological devices to support network and coordination activities and improve the efficiency and flexibility of DRT service by reducing transport costs overall.

DRT service schemes have significant potential to achieve value for money, considering the social costs/benefits associated with the service that are not immediately converted into potential revenue for service operators.

5. Conclusion

Although the concept of DRT has existed for a long time, it has grown a lot in recent years, mainly due to technological advances and the increasing digital confidence of users. The increased need for a more flexible service, driven by the disruptions caused by the COVID-19 pandemic, has also contributed to the implementation of mobility schemes other than traditional fixed lines.

Among the new mobility options, DRT has been one of the most adopted. If properly implemented, communicated to passengers, and integrated with standard fixed-line services, DRT brings several advantages and has all the credentials to shape the mobility of the future.

Therefore, the main benefits of implementing these more flexible services than the others concern: (1) optimization of the transport service offer (coverage of more geographical areas and/or times of day when a fixed line would be too expensive to maintain); (2) inclusivity of transport through the provision of a service also to those people who cannot rely on a fixed line service due to barriers preventing access to public transport services.

This is especially true for the elderly and people with special needs a flexible transport service such as DRT helps them to participate more in the social life of their community, become more independent and feel happier, which benefits society as a whole. DRT also becomes a way of socialising, both with the other passengers on board and with the driver; (3) DRT contributes to public transport and the reduction of private vehicle use.

By covering larger areas and offering a flexible service where fixed lines are traditionally weak, DRT, if properly integrated, actually strengthens traditional public transport.

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