Developing Flexible Mobility On-Demand in the Era of Mobility as a Service: An Overview of the Italian Context Before and After Pandemic

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Abstract. The COVID-19 pandemic required the implementation of restrictions in the transport sector, changing the movement habits of users and, at the same time, highlighting the importance of creating a flexible transport system aimed at guaranteeing an uninterrupted supply of goods and people in any event. In the last decade, the pace at which sustainable and resilient mobility strategies were developed grew significantly due to the spread of technologies (such as ITS systems) and digital platforms related to Mobility-as-a-Service (MaaS). These strategies might improve the overall efficiency of the transport system and reduce dependence on private cars in urban area. Moreover, the development of the demand responsive transport (DRT) is one of the solutions for planning end-to-end travel according to the transport needs. Actually DRT, such as the other shared modes, appears more convenient and capable to turn private car superfluous, reducing traffic congestion and noise and atmospheric pollution levels. After a review of the state of the art in literature, this paper shows the results of a descriptive and a preliminary analysis of DRT services in Italy. In particular, in the studied areas, the authors detected the type of service given and its national displacement, the category of users, the kind of stops, the fleet of vehicles and the presence of shared mobility services. Finally, the authors assessed the possibility to include these services within the Maas platforms suggesting some possible strategies for optimizing the implementation of intelligent mobility systems at Italian national level.

Keywords: Sustainable local public transport · Flexible mobility on demand · Mobility-as-a-Service (MaaS) · Shared mobility · Demand responsive transport (DRT)

1 Introduction

The current pandemic has inevitably led to rethinking new ways of life (such as smart working [1]), and new forms of travel, questioning the previous demand for mobility

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and the offer of services and infrastructures. Several studies applied on the European contexts addressed the impacts of COVID-19 on public transport, walking and other mobility choices [2–4]. With regard to local public transport (LPT), the rules on quotas within public transport and on the necessary social distancing have made all shared modes perceived as "less attractive" [5]. This was evidenced for the pandemic period (i) by the significant decline in daily use of LPT [6]; (ii) by an increase in the use of private vehicles [7], and (iii) by an overall increase in mobility on foot or by bicycle for short trips [8]. Therefore, the need to pursue new modes of transport is evident in order to be able to encourage sustainable travel, also considering that the pandemic has generated new areas with weak demand. In other words, areas with a reduced presence of transport supply that do not include only the peripheral areas but also those that, due to the economic restrictions of the transport companies, have been characterized by a reduced or absent presence of connections.

Furthermore, the pandemic has led many companies and administrations to plan mixed forms of work (in person and in smart working mode) as a stable model for future work [9]. In relation to transport sector, a correlation exists between the implementation of smart working with the reshaping of the staggered schedules of daily journeys and also with probably a possible on-site road toll system (feasible only if initially intervening on improving the infrastructure is possible). A general reduction in the demand for transport for home-work reasons could better support the current pressure on the transport network, also in light of current habits, such as the restart of the use of private vehicles to the detriment of public means. Therefore, a future for public transport assumes even more a necessary duty, to guarantee the right to mobility for all, also in view of the concept of "expanded accessibility" [10].

Considering these premises, the strategies for improving cycling and pedestrian infrastructures [11], the provision of vouchers for the purchase of micro-mobility and/or electric mobility [12–14] can reduce the use of private vehicles, especially for first and last mile travel, by leading to a reduction in congestion, to a lower environmental impact and to a constant respect for social distancing.

With the pandemic, the reduction in the number of passengers has led to the purchase of fewer season tickets and, consequently, has caused large losses for the service operators. For this reason, the busiest lines before the pandemic could be weakened to have frequencies similar to those in rural areas before the COVID-19 emergency. A solution to this problem could be the support of public transport with on demand responsive transport (DRT) services, as often happens in areas with low demand. In the hypothetical case that a public transport service is converted into a DRT service, all passengers will have to book in advance. On the one hand, the security of always finding a place on board and being able to travel with greater safety conditions exists. In addition, the possibility of DRT services also makes possible to reduce the risk and the perception of the same risk by users [15]. On the other hand, the difficulties of having all travel information from each passenger, protected by current legislation and not obliged to release all data. A more useful solution could be to monitor, through the Bluetooth and

wi-fi technologies incorporated in all smartphones, the quality of the travel experience [16, 17], the number of passengers on board each vehicle and at each stop in real time, reshaping the concept of mobility in smart mobility [18, 19], within the smart cities' paradigm [20–22]. Based on these considerations, this work investigates firstly mobility as a service, (recognized in the literature as MaaS) and secondly the DRT concept. Subsequently, the literature relating to European and Italian DRT services is analysed, focusing on a first step of exploratory investigation of DRT services in Italy and activated in the last decade. Finally, the authors define a characterization of the services in order to understand their potential and possible integration within the MaaS digital platforms.

1.1 The Evolution of MaaS in the Pandemic Era

Mobility as a service (MaaS) has as its core in most Countries the shared modes of public transport and rideshare (Uber, Ola, Didi and/or taxi) and the shared mobility of cars, bicycles and micro-mobility. In the pandemic era, the word "service" connected to MaaS can have a much broader and more meaningful multisectoral definition, which can be the basis of a business case that can turn into a new commercial proposition [23]. Social distancing, until a vaccine is widely available and administered, appears to be the primary means of suppressing the spread of Covid-19. MaaS can be a way to stop a decline in the use of public transport by users for example by offering a series of incentives (discounts) for the first and last mile when using public transport. The issue of hygiene in Uber and in taxis still remains a concern for many users today. Sharing space within a vehicle (although risk levels increase) can become minimal when traveling with a group of family members and this could incentivize the use of shared mobility and the use of on-demand mobility. Mobility-as-a-Service (MaaS) combines the digitalization of services as the main enabling factor with the integration of multiple collective and individual modes of traditional and shared transport, offering increasingly flexible, personalized travel solutions to the user. This makes possible to implement mobility strategies aimed at improving the transport offer and, at the same time, a reduction in CO_2 emissions and pollution, thus supporting the advancement of the European Green Deal agenda. With this in mind, the DRT could become a turning point for public transport, because it is an important link within the intermodal transport chains that build the core of Mobility as a Service and provide more alternatives to the private car. Indeed, the DRT inclusion in the itinerary planning and booking systems offers users the possibility to choose between different travel options, taking into account travel time, fares and transport means. The possibility of planning a multimodal itinerary using a single search and a single booking system is a great advantage for the user. The flexibility and adaptability of the itinerary encourages a more rational use of one's own vehicle.The technological platforms for DRTs permit: (i) travel optimization; (ii) cashless payment systems; (iii) integration of booking and payment systems including other services (MaaS); (iv) better synchronization of the modal interchange; (v) the achievement of a wider audience of users. The DRT can also contribute to reduce journeys with individual vehicles by

intercepting occasional needs and/or weak or disadvantaged users [24]. The service can use low-zero emission vehicles and the inclusion in sustainable urban mobility plans (SUMPs) can incentivize the reduction of road congestion [25, 26]. To optimize the service, some companies aim to increase the filling coefficient of vehicles and in a multimodal context can help make the LPT system more efficient [27]. The next paragraph illustrates the diffusion of the DRT service in Europe and Italy, highlighting its characteristics and the connection to other forms of mobility such as shared ones (cars and bicycles).

1.2 The Growth of the DRT Service in Europe

The on-demand transport is also known as Flexible Transport Services (FTS) [28], Dial-a-Ride [29] or Paratransit [30] and it is a service between taxi and conventional bus. Public transport can be classified as on-demand transport or DRT if the service is available to the public without any limitation to particular groups of users based on age or disability criteria or the place of work. A DRT service is generally limited to a defined operational zone, within which journeys must begin and end. Trips can be completely free or adapted to routes and timetables, varied as needed. In general, the service is provided by low-capacity road vehicles such as small buses, vans or taxis; the service responds to changes in demand by modifying its route and/or its timetable and the fare is applied based on the passenger and not the vehicle. Table 1 describes the characteristics of on-demand transport, compared with the bus transport service and also of shared taxis (another form of DRT). The latter operate along a fixed route at specific times, but can change their original route for picking up or dropping off passengers who have requested the deviation. The vehicles used for DRT services are usually small minibuses, reflecting the low number of passengers, but also allow the service to provide door-to-door service as close as possible, being able to use residential roads, such as, for example, the "door to door" and on-call bus service, called Amico Bus, of CTM, the public transport company of Cagliari [31, 32]. In some cases, taxis are hired by the DRT provider to serve their routes on demand. DRT programs can be fully or partially funded by the local transit authority.

The main features of the DRT are: (i) user-oriented (flexibility/adaptability of the route, timetables and frequency based on demand); (ii) accessibility of the service online, through specific platforms available for smartphones, apps, PCs; (iii) versatility of use, by considering the areas and users to be served (more calibrated vehicles and mileage). Exogenous factors influencing the performance of public transport are related to the characteristics of the operating environment and include car ownership rates, economic conditions, etc. [33–36]. Recently, different types of power supplies and systems are used in different parts of the world. An automated demand-responsive transport system (ADRTS) as an urban public transport service for the city of Arnhem in the Netherlands indicates operated by highly automated vehicles (AV) [37], in which driver costs and programming constraints are eliminated as well as through the comparison of systems

Table 1. Comparison of the different types of public mobility

Features	DRT	Bus	Taxi	Details
Type of vehicle	Min 9 seats	Min 18 seats	Min 1 seats	Diversification of the user and the areas to be served (such as those with low demand)
Type of service	Flexible	Fixed	Single ride	Service dynamically adaptable to the basic route, stops and passage frequencies based on requests entered by users through a digital platform
Frequency of service	Discontinuous manner	Continuous manner	Frequency depending on demand	BUS service scheduled while the DRT is booked

shared automated vehicles in a parallel transit service (PTS) and a tailored time-varying transit service (TVTS) [38]. In the past, the spread of the DRT service was common in economically less developed countries, where institutional and/or land use factors prevent conventional buses from meeting the demand [39]. In the UK and Western Europe in general, such flexible transport options are largely focused on meeting the needs of passengers with mobility problems. Since the 1970s, on-demand transport has been seen on several occasions as the solution to transport problems. Particularly when the more traditional services are not economically sustainable, despite several barriers (technological, social, market, economic and institutional ones) have so far prevented their widespread adoption [40]. However, this lack of adoption may be about to change. Indeed recently, new developments in operational and vehicle technology, coupled with significant cuts in public transport subsidy budgets, are promoting the integration of transport provision across a range of different sectors. Some studies focus on their strategic, tactical and operational results at the different levels. Over the past decade, Demand Responsive Transport (DRT) services have grown in popularity for several reasons, including: (i) the lack of traditional regular buses and taxis services; (ii) the lack of special transport services; (iii) new developments in Community transport system; (iv) the development of the Maas; (v) the new concept of a post-pandemic weak demand area. Traditional on-demand services are often criticised due to their relatively high cost of provision, their lack of flexibility in route planning and their inability to handle high demand. The potential to overcome these limitations can be realized through the introduction of telematics-based on-call services, particularly analysed by Mageean et al. [41]. They highlighted the results of the assessment of on-demand technologies and operations in urban and rural contexts across Europe. Figure 1 shows several projects launched and completed since 2012.

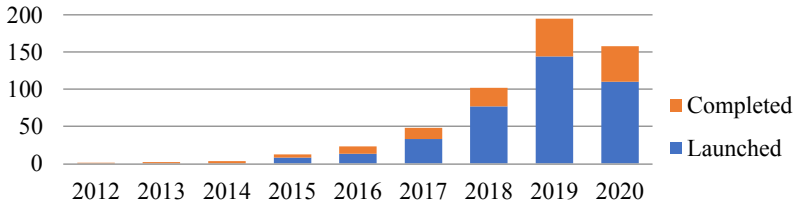


Fig. 1. On-demand ride pooling service per Year. Source: https://lukas-foljanty.medium.com/mapping-the-global-on-demand-ridepooling-market-f8318de1c030

The combination of an on-demand service and a scheduled service offers better mobility and greater service coverage. Studies conducted in the Netherlands show a performance scoreboard for on-call service and related changes in accessibility. From this study the calculation of generalized travel times of on-demand journeys and DRT's alternatives can help to identify whether the on-demand transport is used as a complement or a substitute for LPT [42]. This study is a pioneer in measuring the increase in accessibility that the implementation of on-call transport has ensured to passengers of on-demand transport, compared to the LPT alternative. The results of an empirical analysis showed a reduction of more than half of users for half of the trips made using the on-demand service, compared to LPT alternatives. This reduction was most noticeable in areas with a low supply of LPT connections.

Other research provided an alternative categorization of major implementation issues, in order to support transit authorities in their effort to understand methodological steps for assessing potential transport investments of such services [43]. Other studies conducted between 2005 and 2011 in the UK showed that the DRT service was linked to "social need" in terms of people accessing the services. Particularly in 2011, the service was particularly related to the geography of the place or areas served (areas with low demand such as rural areas or suburbs). Furthermore, the importance of the environment as a target of on-demand schemes has apparently decreased in recent years, from being a "secondary" target in 2005 to being almost ignored in 2011 [44–47].

The results obtained from a survey released in the UK in 2014 highlighted an increasing role for stakeholders from the voluntary sector and the private sector on on-demand services. Furthermore, the survey found that the number of interested passengers is influenced by the size of the operation (in terms of seats offered) and by the use of smaller "car" vehicles, particularly in rural areas [48].

Several comparative studies with local public transport relating to the application of specific analysis models are found in the literature in which different methods have been used to compare on-demand transport with buses and other "traditional" transport services, from simulation based on simulation agents to agents and algorithmic approaches [30, 49] to economic and qualitative approaches [29]. Everyone focuses on different aspects of the problem. In addition to simulation methods, which often focus only on travel optimization, in favour of the operator, extensive research is also devoted to the use of analytical methods. Analytical models for various network layouts are developed to compare the performance of on-demand transport with alternative modes [50, 51]. This allows both operator and user side modelling, developing cost functions that are minimized to find the optimal values of the network design variables, balancing the cost and the cost of the user. Although many network layouts and contexts are studied, no generic analytical model is developed for the case of connecting low-demand long-distance areas with a nearby city center, in a typically call-to-call context.

With the exception of [52] that however develops generic analytical formulations to evaluate on-call services in cases of low long-distance demand by presenting the numerical results of a case study in the long-distance area of Thessaloniki, Greece.

2 Methodology

This paper focused on a descriptive and a preliminary exploitation analysis of DRT services in Italy, and was structured as follows: (i) First general assessment of the geospatial identification of the service and the presence of shared mobility in the areas examined; (ii) Second evaluation on the type of user of the service; (iii) Third evaluation on active services and available fleet. As regards the first assessment, the on-call transport services were identified and divided into the various regions and provinces, by analysing, at the same time, the presence of car and bike sharing services. These services are examined in depth in various researches, for the characterisation of users [53, 54] and also for the definition of the service [55, 56]. At the same time, the type of stop was assessed by classifying the presence of fixed stop or demand services as defined in Fig. 2.

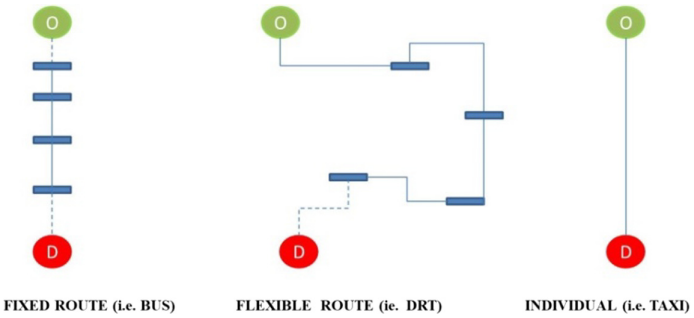


Fig. 2. Type of stop assessed by classifying the presence of fixed stop or demand services

The DRT service is characterised by a specific collection point and a time window for collection. Some DRT systems can be defined through one or both ends of a route (e.g. an urban centre, an airport or an interchange).

DRT systems allow passengers to request travel by booking with a central dispatcher that determines available travel options based on users' location and destination. This is possible through fleet telematics technology in the form of vehicle tracking systems, planning and dispatch software, and a laptop in the vehicle. Various degrees of fixity can be applied in route planning and stopping points, so that specific destinations are served. Most of the on-call services are on a small scale, or aimed at specific categories of people characterizing the community. In the second evaluation phase, the different types of users were investigated, by classifying 7 different types for purposes mostly of the home-work or home leisure type. Finally, the type of fleet, the type of service, ie whether temporary (test pilot) or continuous, and the presence of the service on the MaaS digital platforms were researched. The data collected were then classified initially by associating a single character to each individual user or to sample (DRT service) and subsequently through a "complex" distribution with at least two characters (for example the name and surname of the user).

3 Results

DRT schemes currently are in urban and peri-urban areas, as well as in rural communities. The service is generally operated by both public transport companies and private service providers. DRT systems are offered as intermediate collective transport services for general users or as schemes for specific user groups. In Italy it is possible to identify about 25 DRT services. They are mostly located in the North of Italy (64%), then in the central regions (32%) and finally only 4% in the regions of Southern Italy, as shown in Fig. 3.

Some of these services are active starting from 2021. The coverage of the service in relation to the size of the city shows that small cities and metropolises are served by 28% of the services surveyed, while a higher percentage, 36%, covers areas with a population between 100,001–200,000 inhabitants. Finally, only 8% covers urban centers with populations between 50,000 and 100,000 inhabitants. An initial assessment is made by considering the presence of DRT services, classifying their type (fixed or on demand) and analysing the presence of shared mobility as a possible other mode of transport in the cities analysed, such as Empoli (see Table 2).

Table 3 shows the second evaluation based on the type of user, classifying 7 different types. Table 4 shows the services and their users in the Central-southern Italy area. Of the 23 services active in Italy, 87% of them allow the transport of workers and students and all except one allow the transhipment of people with disabilities. Only the Rimini service allows company transhipment. Considering the presence of these services within the Maas platforms, it was highlighted that only about 10 services are present within the digital platforms. Of these services it was considered appropriate to evaluate the type of service and fleet as well as the use as shown in Table 5.



Fig. 3. Distribution of DRT in Italy

Table 2. DRT services in Italy from 2016

Area	Region	City	Typology*	Car sharing	Bike sharing
North Italy	Lombardy	*Milan	On demand	Yes	Yes
		Vimercate (MB)	Fixed	No	Yes
		Mantua and its Province	Fixed	Yes	Yes
		Crema, Cremona and neighbouring areas	Fixed	Yes	Yes
		Pavia and neighbouring areas	Fixed	Yes	Yes
	Piedmont	Alexandria	Fixed	Yes	Yes
		Turin and its Province	Fixed	Yes	Yes
	Liguria	Genoa	Fixed	Yes	Yes
		Sarzana (SP)	Fixed	Yes	Yes

(*continued*)

Table 2. (*continued*)

Area	Region	City	Typology*	Car sharing	Bike sharing
	Aosta Valley	Aosta and neighbouring areas	Fixed	No	Yes
	Veneto	Padua	Fixed	Yes	Yes
Central Italy	Emilia Romagna	Parma	N.d	Yes	Yes
		Modena and its province	Fixed	Yes	Yes
		Bologna and its province	Fixed	Yes	Yes
		Ferrara	Fixed	Yes	Yes
		Reggio Emilia and neighbouring areas	Fixed	Yes	Yes
		Rimini and neighbouring areas	On demand	Yes	Yes
	Lazio	Rome	On demand	Yes	Yes
	Tuscany	Siena	N.d	Yes	Yes
		Empoli	N.d	Yes	Yes
		Florence	Fixed	Yes	Yes
		Livorno	Fixed	Yes	Yes
		Prato	Fixed	Yes	Yes
	Umbria	Perugia	Fixed	Yes	Yes
		Terni	N.d	Yes	Yes
		Narni (TR)	Fixed	No	Yes
		Castiglione del Lago (PG)	Fixed	No	Yes
Islands	Sardinia	Cagliari and neighbouring areas	On demand	Yes	Yes

*Fixed = variable route with fixed stops
On Demand = Variable route and on-demand stops
N.d. = not definited

Table 3. Type of users (North Italy)

	City	Aosta and neighbouring areas	Genoa	Vimercate (MB)	Crema, (CR) and neighbouring areas	Pavia and neighbouring areas	Cremona and Province	Alessandria	Turin and Province	Padoa	Cagliari and neighbouring areas
	Services Name	Allo Bus e Allo Nuit	Drinbus	Autoservizi Zani	Miobus	Miobus	Stradibus	Eccobus	Provibus	/	Amico Bus
Users											
Workers		■	■	■	■	■	■	■	■	■	
Students		■	■	■	■	■	■	■	■	■	
Disabled people		■	■	■	■	■	■	■	■	■	■
Senior citizens		■	■	■	■	■	■	■	■	■	■
Tourists		■	■	■	■	■	■	■	■	■	
Leisure		■	■	■	■	■	■	■	■	■	
Companies											

Table 4. Type of users (Central-southern Italy)

	City	Modena and Province	Bologna and Province	Ferrara	Reggio Emilia and neighbouring areas	Rimini and neighbouring areas	Roma	Florence and neighbouring areas	Livorno	Prato	Perugia	Terni	Narni (TR)	Castiglione del Lago (PG)
	Services Name	Tper	Tper	Aladino	Concabus	/	Tper	Ataf Nottetempo	CTT Nord Servizio Taxi	Pronto Bus	Pronto Bus	Telebus	Chiama bus	/
Users														
Workers		■	■	■	■	■		■	■	■	■	■	■	■
Students		■	■	■	■	■		■	■	■	■	■	■	■
Disabled people		■	■	■	■	■		■	■	■	■	■	■	■
Senior citizens		■	■	■	■	■	■	■	■	■	■	■	■	■
Tourists		■	■	■	■	■	■	■	■	■	■	■	■	■
Leisure		■	■	■	■	■		■	■	■	■	■	■	■
Companies						■								

Table 5. Status of business to Government (B2G) service considering the period 05–09 2020.

North-West Italy				
	Vimercate	Pavia	Stadella	Varzi
Company		Shotl (ES)		
Service Name		Miobus		
Operator	Zani viaggi	Autoguidovie		
Main Use	1	2	1	1
Fleet Size	2	1	2	1
Lauch Date	02/2019	09/2019		
End Date	01/2020			
North-Est Italy				
	Padua	Venice	Belluno	
Company	Padam (IT)	MVMANT (IT)	Shotl (ES)	
Service Name	Night Bus	Venice Mestre On-Demand Pilot	Prontobus	
Operator	Busitalia Veneto	Radiotaxi Cooperative of Venice Mestre	Dolomitibus	
Main Use	2	3	4	
Fleet Size	1	1	4	
Lauch Date	01/2019	01/2017	08/2020	
End Date		02/2017		
Central and South Italy				
	Ravenna	Ragusa		
company	Shotl (ES)	*MVMANT (IT)*		
service name	Ravenna On-Demand Pilot	On-Demand Pilot in Ragusa		
operator	TCL	/		
main use	4	3		
fleet size	2	1		
lauch date	09/2020	04/2016		
end date		04/2016		
service 1=PT city wide 2= PT Night time 3= Budget city-wide 4= PT rural				

4 Discussions and Conclusions

On-demand transport services usually operate with vehicles of lower capacity than traditional public transport, ensuring greater flexibility and effectiveness in the organization of routes and transit times. This can exemplify some national recommendations on COVID-19 infections. On-demand transport services are often used to power public transport in areas with low passenger demand, where a regular bus service is not considered economically profitable. Examples of low demand areas are typically rural and peri-urban areas, where poor transport system affects the social-economic development and the determinants of the productive activities, as happens in inner areas of Sardinia [57]. Furthermore, it can be used to provide services for particular categories of users

(e.g. people with disabilities). In this perspective, the spread of the DRT in areas that have remained without mobility services due to the pandemic could be a mitigation and resolutive action. In order to spread the possible multimodal choice and the selection of the most convenient transport service, different modes of transport must be implemented in the different urban and extra-urban contexts of Italy. At the same time, these services should relate to digital platforms for exemplifying reservations.

Unfortunately, demand mobility services are still small and some of them are just test pilots. The Government will have to encourage, in synergy with public transport companies, this mode of transport in order to achieve greater results in terms of sustainable and resilient mobility. This work therefore lays the foundations for further assessments and in particular the exploration of the characteristics of the services currently active through the dissemination of survey campaigns for the knowledge of customer satisfaction and the improvement of future services.

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