THE ROLE OF INTELLIGENT TRANSPORT SYSTEMS FOR
DEMAND RESPONSIVE TRANSPORT

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Summary:
Demand Responsive Transport (DRT) is a public transport, which provides the user with both the advantage of collective transport and taxi. It was often considered as a marginal mode of transport reserved to low density territories. Since the end of the 90s, the number of DRTs has increased regularly. DRTs invest new territories such as urban, suburban or rural spaces. DRTs present a large variety of operating services more or less flexible. The flexibility and efficiency of a DRT is influenced by several factors. Eight components are selected to define the flexibility, among them technologies have a main position (without them, flexible DRT can’t be operated). This paper describes the different technological opportunities which can contribute to the management and development of flexible DRT. Most of them are in the field of the Information and Communication Technologies (ICT). They will be illustrated by two examples.

Key Words: Demand Responsive Transport (DRT), Information and Communication Technologies (ICT), Transportation, Flexibility of transport.
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I. INTRODUCTION

Born in the middle 70's, Demand Responsive Transport services (DRT) aimed initially at serving low density areas and offering an alternative of transport to disabled people.

Now DRT also concerns suburban or urban areas, by offering a large variety of services: from the ones for all types of public in substitution of regular lines with low volumes of passengers, to those for specific areas (public equipments, airports, etc). The development of suburbanisation and the dispersion of origins/destinations of the trips have made this form of public transport emerged.

The general idea of DRT is to provide people with a public transport service when conventional transport services would be too expensive and no pertinent, responding particularly to dispersed mobility needs: hours of low demand, areas of low population, for target users dispersed among the general population (disabled and elderly, students, tourists).

DRT is a flexible transport service which adapt to the demand of passengers who have to book their trips. So DRT introduce an innovative approach to Collective Transport both in terms of service production and target population: the transport service is not provided on a fixed line but is offered on a defined area. The bus trips are not bound to a specific route or fixed time-table as the conventional service. The flexibility is provided by the capability to adapt the service to the demand level and characteristics. Each trip is planned based on the user request in terms of start/arrival timing and origin/destination. In DRT services, the bus will reach the stops only when it is needed and at a pre-fixed timing avoiding large and useless waiting at stops by the users. It exists different types of services: door-to-door\(^1\), fixed routes, fixed routes with deviations, free routes among a set of points\(^2\) (Burkhardt et al. 1995; Ambrosino et al. 2004; Castex, 2007). These services are more or less flexible depending on the public, the area and the goals of the service.

In different european cities and regions, DRT services have shown relevant advantages and benefits, in complementarity to conventional and scheduled public transport. One of the main motivation to this success is due to the availability of different Information and Communication Technologies (ICT) which have radically improved the possibilities to provide personalised transport services, both in terms of interface with the potential customers, optimisation and assignment to meet the travel requests and of service production and management. The support

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\(^1\) “A service that picks up passengers at the door of their place of origin and delivers them to the door of their destination” (Burkhardt et al. 1995).

\(^2\) e.g. stop-to-stop services.
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of adequate ICT tools is neccessary in many cases for the management of DRT, particularly for DRT with relevant dimensions in terms of user booking volumes, number of trips, etc.

After having described DRTs existing in France, we'll show how technological opportunities can contribute to the management and development of DRT. Some examples will be described in the last part.

II. STATE OF THE ART OF DEMAND RESPONSIVE TRANSPORT IN FRANCE

The french Demand Responsive Transport (DRT) is managed by “transport authorities”, which correspond to administrative divisions (such as the communes\(^3\), county council). Sometimes an association or a private firm can also manage a DRT. In certain cases, a transport authority can manage several services of DRT, each “service” corresponding to one specific offer of transport located on a particular space.

A database of 650 DRTs services in metropolitan France was established between 2003 and 2005, Castex (2007). It includes a national census on the DRT (DATAR, DTT, ADEME, 2004; UTP, 2005) completed with other sources gained in websites or directly to the transport authorities. The characteristic of the database is to make an inventory of the DRT at the scale of the “service” and not at the scale of the “transport authority” like other census. This information is more accurate to observe the DRT evolutions and to map them.

1. A number of DRTs services increasing since the end of the 90's

In 2005, 615 services are organized by 384 transport authorities. They cover more than 7000 communes.

The figure 1 presents the number of new DRTs services created each year and registered in the database. Their number has increased in France more especially since the end of the 1990. This growth was encouraged by several laws for a best management of transportation system in accordance to the urbanization and on the environment protection. They promote DRT in cities or in territories without transportation.

\(^3\) the commune is the smallest administrative subdivision in France. There are 36 000 in metropolitan France.
DRTs are offering a large variety of services. For instance it is possible to distinguish different kinds of DRT according to their users targets. The majority of DRTs carry out all the people like the other modes of transport (general DRT), some services are dedicated to specific users like disabled people (Paratransit), customers of private firm (private DRT), members of association (Social DRT) or railway users (TAXITER).

2. DRTs services on the french territory

The map (figure 2) shows that the DRT are scattered on the territory and all kinds of territory are concerned. The DRTs for all users (General DRT) are more numerous than the others. A lot of them are located in rural areas. Social DRT are wider, but concern few people (only members association), they are numerous to be located in rural space. TAXITER is also used in rural space to substitute to low attendance railway station.

A lot of cities use General DRT in order to complete their transportation system. Generally they are used to serve the outskirts of the bus network or to take the place of bus during the off-peaks hours or the night. They are also numerous in suburbs, where the transportation network is less efficient. Most of cities set up Paratransit. Private DRT are only in the biggest cities.

DRT are located in almost all the french metropolitan areas more especially the services dedicated to specific users. General DRT are more scattered. The territory concerned by general DRT represent only 15 % of the french territory but 50 % of the population. All the kinds of DRT cover 24,4 % of the territory which correspond to an area where live 90 % of french population.
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The variety of services concerns also the transport supply. *Door-to-door* is the kind of DRT which imposes the least of constraints, the service offered is alike one of a car or a taxi. On the opposite side, *fixed routes* can be compared to a bus line: the trip is predefined with the departure and the arrival hours. The first one is considered more flexible than the second. The other kinds of DRT are the intermediate forms. *Stop-to-stop* services are flexible because they permit a free routes among the set of points, but their flexibility depends on the stops number’s and their location. Convergent DRT users have their arrival stop prefixed but their departure is free. These two kinds of services get near to *door-to-door*. *Fixed routes with deviations* DRT are close to *Fixed routes*.

The figure 3 shows that *door-to-door* systems are the most important especially to the services dedicated to specific users (figure 3). A lot of *general DRT* are *convergent* but *Fixed routes* are also numerous. *Stop-to-stop* services and *fixed routes with deviations* are rarely used in our country, although they are often chosen for the recent DRT.

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**Source:** Avignon University

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DRT which the destination stop is predefined by the Transport authority.
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3. Small services

The DRT in France is actually a set of small services by their sizes or the number of passengers carried. Indeed, the majority of services are located on small territories. Some DRT organized by County-council has a big size but they are located on rural space with low density. On the other hand, DRT in cities are usually located on the outskirts of the city (with low density too). Moreover, their spatial configurations rarely correspond to the movements of the people which are generally based on a large scale. In public transport, this situation lead people to use several modes of transport for travelling with waiting times between the connections, so many people prefers to use their personal cars to travel.

In the future, the DRT services must be considered to a large scale to improve their efficiency. A large scale not mean necessarily a big size, it can mean an important DRT-going too. It leads one to suppose that create DRT in places with high density or during the rush hour in the city. The purpose of large-scale DRT is to offer a better quality of service, a competitive supply and to realize economies of scale. This subject is also studied for its impact of the environment (Tuomisto and Tainio, 2005).

Several DRT in Europe are based on a large scale as Flexlinjen in Göteborg (Sweden), Treintaxi and Reggiotaxi in Netherlands (Enoch et al., 2004), Drintaxi in Genoa (CIVITAS project). These services want to be flexible and they have been allowed by technologies improvement. All DRT launched in european projects such as SAMPO, SAMPLUS, FAMS (Enoch et al.) or CIVITAS are based on a great level of technologies. In the second part, we shall describe the role of these technologies, but before we shall present what is the flexibility for DRT.

Source: Avignon University
III. NEW TECHNOLOGIES PROVIDING FLEXIBILITY TO DRT

The flexibility is an important characteristic for transportation modes. The car presents a strong flexibility in comparison to the other modes (no booking, door to door trips, strong accessibility at any time) but in European cities its performance is now limited by traffic jams and parking capacities. So, public transports are more efficient in the city centers. On the other side, users criticize the lack of flexibility of public transportation (numerous connections due to fixed itineraries). In suburbs and little towns, the car often appears as the most efficient mode of transport. The DRT, which is an intermediate form between car and bus, presents a variable level of flexibility according to the transport authority choices.

1. What is flexibility for Demand Responsive Transport?

Several factors influence the flexibility of a DRT. For example, it can be influenced by the booking time but also by the form of the DRT trips. We've seen the role of the transport supply, now we will speak about the other factors which influence the flexibility of a DRT.

In order to compare and evaluate DRT services, we develop a graphic with the main components of the flexibility (figure 4). An arrow or an axis represents each of them. On the arrow it is indicate the different possibilities of DRT functioning. The services of DRT can be placed on each axis. A position on the graphic centre symbolizes a low level of flexibility. At the opposite, the end part of the arrow indicate a good level. Some components refer to the time (they are represented on the bottom part of the figure) and others to the spatial organization (on the top part in grey).

For instance, the first arrow “flows direction” indicates the trips opportunities with a service. A DRT can have “multidirectional” flows (all trips are possible inner a territory) or “convergent” (only the trips in direction to a “convergent point” are possible). The first one is considered more flexible than the second one. An “multi-convergent” flows is an intermediate possibility (several “convergent points” available). The second arrow shows the “spatial functioning” of a DRT : a service can have a zonal functioning (e.g. door-to-door), an organization based on stops (e.g. stop-to-stop services) or on lines (e.g. fixed routes, fixed routes with deviations). The eighth axis on the left shows the “spatial cover” of a service. It can cover all the territory of the transport authority or just a more or less important part and with a more or less central place. Together, this tree arrows condition the “spatial accessibility” of a service.

The “temporal accessibility” is determined by :

- the flexibility of the “departure and stop hours” (fourth axis) : they can be free, prefixed or limited to slots;
- the “period of booking” which varies from few minutes to one day;
- the “functioning schedule” : the DRT can run during a large period on the day (e.g. 8 am/7 pm), a short period (e.g. 10 am/5 pm) or only during the off-peaks hours.

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5 A convergent point can be a railway station, a town or a shopping centre.
Between these two groups of axis (spatial, temporal accessibility) are located the components, which depend both time and space. Indeed the “tariffing” can be based on the time (such as a “variable” tariffing) or the space (i.e. covered distance : “zonal price”, “travel distance”). ICT or Software include time and space too. Their employ is very important because they permit a better management of trips and to rationalize the cost of the service. Moreover, without them it is impossible to manage a flexible service inner a large territory or an important number of users. On the graphic three levels of flexibility are represented : the case of no use (many french services have a “by-hand” control), a small use (some technologies) and a strong use (several technologies used in complementarity). The different technologies can be employed in DRT, they are detailed in the second part.

![figure 4. The eight components of the DRT flexibility](image)

Source : Avignon University
2. Description of technologies used for DRTs

The success of DRT services is due, in part, to the availability of different Information and Communication Technologies (ICT) which have radically improved the possibilities to provide personalised transport services both in terms of interface with the potential customers, optimisation and assignment to meet the travel requests, and of service production and management. The current breakthrough in IT platforms (advanced architecture, web platform, palmtop, PDAs, In-vehicle terminal, etc) and in mobile communication networks and devices (GSM – Global System for Mobile Communication /GPRS – General Packet Radio Service /UMTS – Universal Mobile Telecommunication System, PRN/TETRA/P25, WiFi/DSCR, WAN-Wide Area Network/LAN-Local Area Network, GPS – Global Position System, etc)\(^6\) has been suitable to face and support:

- the work of the DRT operators on the service model dimensions (route taken, timing of services, vehicle assignment) in order to alter the service offer in response to the current demand;
- the different four steps of DRT operational cycle among users and transport services operators (trip booking, user trip parameters, negotiation phase, communication of trip to drivers, service follow-up/location, reporting the completed service).

Usually, ICT-based architectures supporting DRT operations are organised around the concept of a TDC (Travel Dispatch Centre), as the main technological and organisational component supporting the management of DRT production workflow. The DRT architecture includes the following main components:

- The Travel Dispatch Centre, including several integrated software procedures supporting the management of DRT service production operations (user's request handling, trip booking and time-window managing, service planning, vehicle dispatching, vehicle communications and location notification, system data management, regular Public Transport notification);
- A communication system usually based on public or private long-range wireless telecommunication networks, supporting communication and information exchange (both data and voice) between the TDC and the DRT vehicles;
- Several types of DRT user interfaces, enabling communication between the user and the TDC through different channels (ie phone, internet, GSM/SMS-Short Message Service, and an automated answering devices – IVR (Interactive Voice Response) with CTI (Computer telephone integration);
- On-board systems (IVT – In Vehicle Terminal) installed on DRT vehicles to provide driver support functionalities during vehicle operations (ie dynamic journey information, route variations, passenger information, driver/dispatcher messages).

This general architecture has been implemented in different ways, and all existing DRT installations are realised through variations on this basic scheme. The implementation of such installations is made possible by a number of key enabling technologies which are:

\(^6\) CONNECT Project, Workshop « Flexible Mobility Services : business models, organizational and contractual issues »
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- Booking and reservation systems to manage the customer requests;
- Regular Public Transport (PT) Information (dynamic or static) to be able for supporting PT operation, or to avoid conflicts with regular PT;
- Web, IVRS – Interactive Voice Response System – CTI – Computer Telephone Integration; and hand-held devices to assist customer booking;
- Dispatching software for allocating trips and optimising resources;
- Communication network to link the TDC with drivers; and customers;
- In-vehicle units to support the driver;
- GPS-based vehicle location systems;
- Smart-card based fare collection systems;
- Management information systems and other data analysis systems;
- Administrative systems for own and client’s needs.

The role of the TDC is important for the operational management to maintain the system performance and the service provision (see figure 5). The optimisation of the user requests management allow to redirect many requests on existing trips making the service more efficient from the economical point of view, avoiding the bus operation specifically for a limited number of trip requests.

Source: University of Newcastle Upon Tyne

*figure 5. DRT architecture*
III. EXAMPLES OF DRT USING A SPECIFIC TECHNOLOGY

This part presents two examples of French DRT which use technologies to improve their efficiency.

1. TADOU : an innovative DRT in a rural area

The « Pays du Doubs central » is a grouping of 99 communes. It is located in the northeast of France. This transport authority (Pays du Doubs central) wanted a mode of transport to serve their sparsely populated area (25 000 inhabitants). Five little towns organize this wide territory.

They develop a DRT named “TADOU » with the Tadvance network. It is a stop-to-stop system (organization based on stops). A set of stops cover all the territory and users can travel in any directions from a stop toward an other (multidirectional flows). The customers have to phone the previous day to book their trip. The taxis carry out them the following day. The main innovation consists in a software named “GaleopSys” developed by Tadvance members. The software calculates the trips and searches to rationalize them.

GaleopSys realizes the trips optimization with a Geographical Information System (GIS) which contains all the stops and users address (figure 6). It works out to find the shortest routes while maximizing the number of carried people by as few vehicles as possible. At the same time it makes sure that users times constraints are respected. The algorithm developed is based on Dial A Ride Problem with Time-Windows (DARPTW) (Garaix et al., 2007). The Prorentsoft firm distributes the software.
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figure 6. Trips optimization on GaleopSys software (TADOU)

Source: Avignon University

The price depends on an original method based on the travelled distance. The fare is counterbalanced for the longest travel, so the fare is proportionally less important for a longer travel than for a shorter one. In 2006, the number of trips was 1863 for 2454 passengers which corresponds to 1.3 passengers per vehicle. At the beginning of the year 2007, the service had 230 trips a month.

2. A complementary DRT in the city of Toulouse

A DRT called TAD 106 has been created in Toulouse in 2004, by Public Transport Authority Tisseo – in partnership with companies of services\(^7\) - to provide people in the eastern suburban

\(^7\) « Réseaux, Conseils et Solutions Informatiques », « Grand Sud Navettes ».
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area of Toulouse with a high level of flexible public transport service, complementary to existing regular lines.

![Figure 7. Principles of DRT « TAD 106 » in Toulouse](image)

**Source:** RCSI Toulouse

This DRT shows a certain number of innovations:
- A large geographical scale: the trips are possible on every origin/destination among 100 stop points dispatched on six municipalities;
- Direct connexion to a fast and pertinent transport mode (subway) (see figure 8);
- High and clear level of offer: departures every 30 mn from 5 am to 0h30 pm every day of the year;
- Flexible management: no pre-established itinerary, only stops are fixed;
- Rapidity and conviviality: capacity of vehicles between 8 and 15 maximum;
- Adaptability: variation of then umber of vehicles function to the demand;
- Low constraint: optional reservation at the hub of subway end stop for non planned come-backs from the centre-town, otherwise booking 1h40 in advance with cancellation possible until the departure;
- Information and Booking Centre with high availability: special telephone number available between 6h30 am and 22h30 pm everyday of the year;
- Complementarity to the urban public transport network: no competition with regular lines and a common system of information with them, integrated tariffing, etc.

The realisation of this DRT has shown that users in this part of Toulouse were eager of this kind of flexible and frequent public transport:
- In average 650 clients/day in 2007 with more than 1000 clients/day for certain days (particular events like the Music Festival);
In 2007, 180 000 trips have been made (161 000 trips in 2006, an increase of 12%) ;
A rate of satisfaction of 97%.

Information and Communication Technologies have been used:
- Information and reservation centre by telephone with multimodal data base regularly updated a software (SYNTHESE) for reservation and dispatching of trips ;
- Permanent radio link between vehicles and the centre ;
- Computer terminal at the hub of terminal metro station (Balma Gramont) for the printing of allocated trips.

In the future, the strong evolution of the service since its creation, the waiting for a more flexible system of reservation, and the will of the actors involved (local authority, operator, etc) for an optimized development of the DRT on other sites, bring the necessity to implement innovative technologies like :
- Automatisation of responses to the most current demands for information and reservation by phone, allowing to open the centre 24h/24 ;
- Real time assignment of users on vehicles, the automatic recalculation of itinerary taking also into account the conditions of traffic, the on board guidance, allowing to increase the flexibility of exploitation and then reduce the time in advance for reservation ;
- Continuous or discontinuous communications, but with high rate, between fixed and on board systems, to allow permanent structured information exchange (cancellations, road congestion, etc) ;
- Hybridization of satellite localisation means with localisation systems of telecommunication network.

As illustrated below (figure 10), these technological innovations will allow to improve the quality of service and reduce the management costs.

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8 Developed by « Réseaux, Conseils & Solutions Informatiques » RCSI firm.
IV CONCLUSION

One of the main reasons of the development of DRT in recent years has been the development of technology. Advances in software, computers, digital maps, expert systems, remote communications, in-vehicle computers and GPS technologies have suddenly made DRT viable. If we consider the level of technology required, the first issue concerns the scale and complexity of the operation envisaged. For DRTs involving many-to-many journeys and important number of clients, complex routing software will be required. Even if many DRT, which represent quite simple networks, are often « manually » managed, it's necessary in these cases to have specialist staff with sufficient scheduling and local knowledge to work effectively. In fact, technology offers almost close to « real-time » demand responsiveness, particularly in complex networks, to a level far in advance of manual systems.

However, the costs of establishing high-tech schemes are still significant, which implies that some local authorities are sometimes reluctant to make investments in such softwares. Moreover, suppliers are often providing specialist hardware rather than adapting standard platforms, which is a limit to the growth of this technology.

For the future, the internet technology has a key role to play because it offers the possibility of an automated booking, and is thus far cheaper. The mode of booking is very important and has be flexible for the clients.

Source: RCSI Toulouse
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The potential of development of DRT is still important if we consider the need of more economically sustainable public transport systems and alternatives to the private car. Like other flexible transport services like car-sharing, car-pooling, collective taxis, DRT services bring their contribution to the improvement of the global transport offer. All these services have to be integrated in a same mobility centre which can manage their spatiotemporal interconnexions, attracting important number of users and also bringing more attractiveness to public transport.

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