

Prospective Research in the Technological and Mobile Society: New Demand Responsive Transports for New Territories to Serve

Elodie Castex, PhD; Sophie Houzet, Master; Didier Josselin, Researcher
UMR ESPACE 6012, CNRS, Université d'Avignon et des Pays de Vaucluse
Avignon, France
Phone: 33 490 16 26 93
Fax: 33 490 16 26 99
didier.josselin@univ-avignon.fr, www.modulobus.org

SUMMARY

This paper follows and completes the one we presented in the AGILE Conference in 2001. Keeping in mind the operational Demand Responsive Transport we designed and installed in Besançon, France, we aim in this paper to handle the following questions. What are the characteristics and the trends of the urbanized territories, and the resulting mobilities, that would justify the spread of flexible transportation, such as DRT? Under cover of the enlargement of the service Evolis to the whole communes of the "Communauté d'Agglomération du Grand Besançon" (enlarged community of communes around Besançon), how will become the DRT efficiency regarding new heterogeneous served territories, and how can we try to predict its evolution? What new systems can we imagine to solve the difficult equation combining the versatile mobility demand that a survey reveals, and the variety of territories where we begin to develop new research about DRT?

KEYWORDS: *Demand Responsive Transport, mobility, prospective transport, geomarketing*

INTRODUCTION

This paper follows and completes the one we presented in the AGILE Conference in 2001 (Bolot *et al.*, 2001). After having designed the concept of a demand responsive service during a research pluridisciplinary project, and developed a commercial dedicated software which manages, since 2000, the DRT called Evolis in Besançon (France), it is the opportunity to get a feed-back from this fruitful experience and to plan for future flexible transports.

TRANSPORT EFFICIENCY AND FLEXIBLY TO RESPOND TO VARIOUS AND VERSATILE MOBILITIES

Ubiquitous mobilities in space and time in the technological society

In some parts of France and in many other European countries, the increasing of the geographical space occupied by human activities induces several effects on urban and suburban organization. The mobility is globally encouraged by a spread road network whose ubiquity and density make very accessible most of places. Timing and daily schedule for any activity, including leisure, force people to save time and to use the more convenient and efficient transport services. Travelled distances increase and peaks of traffic in the cities are more dispersed other the day (Sesame, 1999).

Another focus shows that, while established towns claim and enhance their competitive attractivity, a quite substantial number of new centers emerge, closely linked (each/) to others. In France, this evolution

is correlated to a process which inevitably empties the rural areas in favor of more urbanized areas. Therefore, the gap between rural and urban areas becomes more marked and the population distribution differentiates in many patches populated with various densities. One again, this argues in favor of a high level of transport adaptability.

On a third hand, people use to consume *just in time*, by reducing the delay between the reservation of a product or a service and its delivery. This behavior becomes standard because of the technology evolution: one can access easily and quickly to any information, and this unleashes the mobility capacities (Thurston *et al.*, 2003). People want to go from/to any place, at any time and appreciate when one propose immediately to them a wide range of service alternatives (Dupuy, 1991). Their supposed rationality leads them to arbitrate between several priorities: time, price, convenience... and to choose among those alternatives the one which better fits to their own needs.

How efficient is the public transport?

In this context, it becomes more and more difficult for traditional public transport to compete with more flexible vehicles, because of its rigidity and sometimes its relative weak reliability (strikes, bus lateness, security...). Using it becomes a default choice for people dependent to the collective transportation whereas others in their car think they “control the situation” can adapt to the traffic conditions. Thus, numerous persons complain about time constraints when waiting for the bus and during the journey. Consequently and unfortunately, the choice among all possible transport modes often sets on the car (Dupuy, 1999, Wiel, 2002), most of times the individual and personal one, because of the high price of taxis, notably. This generates a lot of nuisance in urban towns, such as air polluting, parking problems, traffic jams and unpleasant (sometimes unbearable) noise. This is noticeable in France, despite a rather (but not enough) efficient public transportation, which is considered by many people as inappropriate.

Nevertheless, public transport can succeed in the management of heavy flows by connecting efficiently several transportation modes (for instance in the Netherlands) including DRT (for instance in Switzerland). In France, this change must occur otherwise the public transport attractiveness will decrease, inducing a loss for urban community (Thévenin, 2002). We start to feel this evolution, linked with recent laws edicted in order to control urban pollution and network congestion, to help communes dividing up the geographical space, and to group them in the same territory having a strong identity.

At the same time, the political position upholds a certain idea of eco-citizenship, supporting less polluting, more comfortable and more reactive transportation and sometimes recommending public transport and reducing/regulating car use. In this context, this paper aims to present some prospective research about a type of flexible transports: the Demand Responsive Transports.

What Demand Responsive Transport can supply?

DRT is a kind of public transport which combines the advantages of collective transport and individual vehicles (GART-PREDIT, 1999, Banos & Josselin, 1999, Lebreton *et al.*, 2000, Faure *et al.*, 2001). It is often considered as a “versatile” transport because it offers more flexibility for the users, and provides some saving for the carrier and for the decision maker. This system is attractive because it reduces the wasted times and fits to demand. DRT states as a sharing transport which aims to group the passengers from different individual demands within a same or similar trip. For the carrier, the decision-maker or the decision maker, the cost is maintained at a reasonable level, because it runs only when it’s used (the system is activated by a demand from at least a single user) and because the system succeeds in grouping clients.

Many modern systems are launched or experimented all over the world and in Europe (SAMPO/SAMPLUS European project, SATELBUS in Luxembourg, PUBLICAR in Switzerland, etc.). We can notice two main periods where the research investigated this domain: in the Eighties/Nineties (for instance, Daaganzo, 1978, Ewing, 1979, Friesz & Fernandez, 1979, Haines & Wolff, 1982, Tuan, 1984, Ramamohan & Sriraman, 1985, Rhee, 1987,) and at the begin of this Century (for instance, Sadeh & Kott, 1999, Feurstein & Stougie, 2001, Cortes & Jayakrishnan, 2002, Horn, 2002). The first wave corresponds

to new mobility needs from population, supported by a voluntary policy. These systems often failed because the technology (GPS, cell phones) was not efficient enough to provide such new demand responsive services (for instance, a “real time” DRT). Now, there is a renewal of interest because of information technologies full potential, providing a powerful communication network.

Different kinds of DRT exist, according to the complexity of their operating system (including or not technology), the “carrier” (*l.s.*) which manages the service (associations, private firms having most of time a contract with a local administration), the constraints they impose (places and timetable, reservation delay), the type of the vehicles (little buses, taxis), the territory to be served (urban, suburban, rural), the target clients. From a sample of 220 services experimented in France and Europe, we can bring out three main types of DRT, depending on how and on which territory they operate.

A first kind of DRT comes to complement the existing regular urban and periurban transportation services. The process corresponds to a commercial adaptation of the global transport service. These DRT are used most of time, for instance in some outskirts where population density decreases, often to replace a deficient bus line. In most of these cases, the DRT line is activated when a command occurs, on a predefined route.

In rural areas, the needs differ perceptibly. Due to a political impetus, towns and villages often join their means to create a low cost service for captive and elderly people. The objective is then to serve the town centers, the local markets, the hospitals, and to give the opportunity to the population to move from door to door, or from door to places. These services aim to break the remoteness and isolation, to favour the accessibility, even if they operate sometimes during short periods in the week, according to a fixed timetable, a limited number of stops and consequently weak flows.

A third type of DRT involves shopping centres, airports, train stations or any large “flow generators” *i.e.* attractive/emissive poles. Generally these transports become quickly profitable, due to their capacity to group clients, improving their efficiency and their durability. They result from an economic process.

Modelling territories to serve by Demand Responsive Transports

Our aim in this section is not to develop or (re)visit all the theories around the central places and the modelling of flows and mobilities. There exist very complete reviews of such research (*i.e.* Camagny, 1996). It is rather to present different kinds of territories and flows that a DRT can have to deal with, their level of complexity and their peculiarities.

In the figure 1, we designed the pictures according to several DRT we are actually working on in France. Three main features can help to distinguish the models: (i) the number of attractive and/or emissive poles, that may be aggregates of poles at any spatial granularity (ii) the flow directions (iii) and the hierarchical structure of the poles in space. Thus, an arrow represents a flow, or a demand of transport in a direction. Points symbolize all places or buildings which could generate trips. According to the scale or the kind of service, one point can refer to a town, but also to a train station, a market, even a stop on the network. To each model can correspond one or many demand responsive service(s).

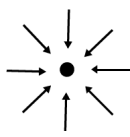
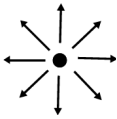
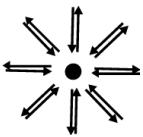
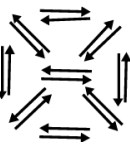
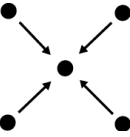
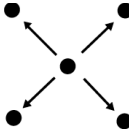
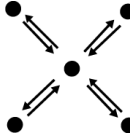
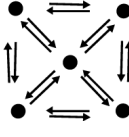
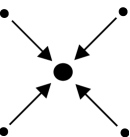
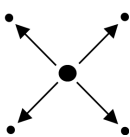
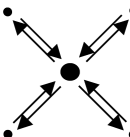
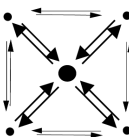
| <i>Flow direction</i> | | <i>Centripetal A</i> | <i>Centrifugal B</i> | <i>Centripetal & Centrifugal, C</i> | <i>Multi-directional, D</i> | |
|-----------------------------------|--|---|---|---|--|--|
| <i>Structure of the territory</i> | <i>Polarity: $p \leq 3$</i> |  |  |  |  | |
| | <i>Polarity: number of poles $p > 1$</i> | <i>Homogeneous, 2</i> |  |  |  |  |
| | <i>Hierarchical, 1</i> |  |  |  |  | |

Figure 1: Different kinds of territories and flows met by DRT.

For instance, a town and its neighborhood may be considered as an (i) “unipolar space”: during the morning peak, flows get a centripetal direction (figure 1, picture A3), centrifugal during the evening (picture B3), or mixed during the rest of the day (C3). Demand comes from anywhere to a central point, possibly the town center, or any point representing the whole town. This scale is the pertinent one for the railway companies. DRT can be solicited in such case for replacing deficient regular bus lines or create new services.

But if we zoom on the town map, we can notice that it is organized in several complementary poles, such as bus and train stations, areas of manufactures and firms, commercial centers, etc. If we get a simple network with a few poles, it can be possible that those are equivalent and compose a system as described in the line 2 of the figure 1 ($p > 1$ with an homogeneous structure), i.e. pictures 2A,2B,2C,2D, depending on the flows. In practice, we often encounter the same network of poles, but marked by a gravity equilibrium due to the relative importance of the poles and the subsequent flows (line 3: case of “hierarchy”). This scale is the pertinent one for the urban carriers. In this configuration, it becomes more delicate for the DRT to serve such territories: it can make the link between existing regular public transports or provide itself the complete service.

If we zoom a little more on the town map, then appear the variety of the territory. Each person is now a moving point, each door a potential of demand, each (even little) pole can generate a group of (future?) passengers... Flows are not any more concentrated, but diffuse and the structure of the model (poles, flows and hierarchies) are redesigned all day long. Responding to any transport need becomes a real

challenge and requires to manage complex systems (picture D3 of figure 1), sometimes using new technologies. This may also occur in the rural areas, where the resources are spread in the territory and the inhabitants live in low density municipalities. This is a mixed “door-to-place” and “door-to-door” model, all points of the city of the rural space being served by the DRT.

Now we present an experiment of DRT led on a french urban territory. We show how our research team have solved the problem of an unipolar space with centripetal flows (morning) and centrifugal flows (evening). We shall see what kind of DRT has been chosen and what constraints are imposed by territory and planners in a context of spatial extension of the service.

TERRITORIAL SCOPE AND EXPANSION OF A FUNCTIONAL DEMAND RESPONSIVE TRANSPORT SERVING A CENTRAL STATION

Brief reminder of the DRT Evolis functioning in Besançon, France

For now two years, the French town of Besançon is served by a DRT called Evolis (Banos & Josselin, 2004). That is the result of an applied research project, including several complementary partners, belonging to different domains: researchers in geography and computer science, carriers and a political organ which promoted and supported the research program. The decisional (political) organ is called the “transport organizing authority” and is composed of lots of urban or rural communes. In the case of Besançon, its name is the “Communauté d’Agglomération du Grand Besançon”. The practical need that led us to develop this service is the following. It has to serve the whole population of Besançon by providing a time limited (30 min. max) access to the early high speed trains (TGV) leaving from the central railway station. Clients generally follow such a spatiotemporal sequence: walking to the Evolis station (max: 5 minutes), travelling as passengers in the vehicle (max: 15 minutes) and waiting for their train (max: 10 minutes). For the way back, the opposite sequence is proposed, with a shortest waiting in the railway station. The service aims to find the shortest routes linking a few of the 650 Evolis stations spread in Besançon to the train station, while maximizing the number of carried people by as few vehicles as possible. The customers have to phone the previous day to book their trip. Each evening, the routes are recomputed for the following day, according to the demand, using a dedicated GIS we developed (©ReSAD2). The taxis carry out the trips, according to the computed routes.

In its actual functioning, Evolis is somewhat a combination of the Shuttles, technological and reactive DRT operating in USA around the big towns and airports, and the “bush taxis” developed in Africa notably, whose aim is to group passengers, even if this may imply some timetable or paths modifications. In our case, DRT states as a public transport, managed by a private firm (a carrier) which is appointed by the territorial and political organ as a delegate to apply the transport system.

Results of Evolis, after two years of operating

Launched in 2001, this service is henceforth operating as a solution for a commercial « nest »: serving occasionally the principal railway station in marginal times, *i.e.* at early and late times (7 TGV to serve). Indeed, after two years of functioning, it almost raises the economic efficiency of a common regular public transport, even if it involves only specific and so quite rare flows. The service also encourages people to leave their personal car and to accept to share a vehicle for a short trip, so taking their own part to air quality improvement and urban noise reduction. Activated only in case of transport demand, the system fits to the flows and provides a rather good grouping.

After more than two years operating, a few interesting elements appear clearly. In 2002 and 2003, the service involved about 1500 clients in Besançon, corresponding to nearly 3000 routes per year. The economical rate remains stable at a high level: about 40% of the price is afforded by the clients, when the community which levies the taxes pays the rest. This rather good result is due to the capacity of our system to group people, with an average of almost 2 passengers per vehicle. Globally, the use of Evolis increases (40 % of more trips between 2001 and 2002), even if it concerns only about 1 % of the

population in Besançon, and about 10 % of the people who could use it for such trips (let us remember that the market is tight, because of the targeted nest). A recent survey on a sample of regular Evolis users (more than 150 individuals) reveals that 66 % of them are “satisfied”, 32 % “very satisfied”. We also asked to the clients what were their usual modes before Evolis was created. The results are very interesting: they show that the goal to prevent the use of personal car is partially reached. Before Evolis service was created, 47 % percent of these clients used to go to station by car (21 % as drivers). This survey also enabled to identify the dominant profile of Evolis user: a middle-rank executive woman, very mobile, unsatisfied by the car and the bus, facing the (future) flexible or soft transport modes, motivated by the competitive price of the service.

Evolis in Besançon is also enlightening on some unexpected social relationship. There exist now a group of users, which have changed the way they move in town, left aside their individual attachment to their own car, and claim their membership to the « Evolis Demand Responsive Transport Club ». These clients use to meet each others, to discuss in the vehicles and cannot come back to their old practice, because they consider the service as efficient, comfortable and cheap (because subsidized). We also noticed that the DRT users are more open than others to new flexible systems.

ADAPTABILITY OF A DRT SUCH EVOLIS TO NEW TERRITORIES

We present now several researches on larger territories where the issues differ appreciably.

Methodologies

Modelling and simulating the transport demand and the location, knows a great interest in geography and GIS technologies (Stiwell & Clarke, 2004). The geographer know-how about the territory problems and the progress in simulation enables to develop new tools for decision making especially on a transportation networks and services. This approach allows social sciences to test assumptions on complex systems in laboratory conditions. Several types of simulating models are described in scientist literature (multi-agent systems, micro-simulation, geomarketing, trends projection...). They can be discerned by their aim, their technical composition and by the way they include time and space. Generally used for reproducing the reality complexity, simulations improve the comprehension of complex systems and spatial organization, and consequently, may be used, with much discernment, for spatial prediction, planning and decision making.

The method we developed requires the software Resad2 as a flow and DRT simulator and a estimation of the potential geocoded market. From the actual situation of Evolis in Besançon, this software can simulate an extension of a station-to-station service, not to say a door-to-door system with a hierarchical organization of centers and “flows generators”. Three stages are necessary to succeed in such a task: the numerical geographical data base must include the topological network, all possible points that represent the population spots, and the identification of the places and centers. On top of that, knowing the specific potential demand attached to any couple {space-time} is of great interest, even necessary. In other words, we have to estimate the probability that a transport demand occurs at any time and at any location. Processing these data, it becomes possible to assess what could be the potential demand, and how our system could group passengers and fulfil the solicited service.

Geographical extension of the DRT Evolis for the whole territory of the *Communauté d'Agglomération du Grand Besançon (CAGB)*: assessing the market

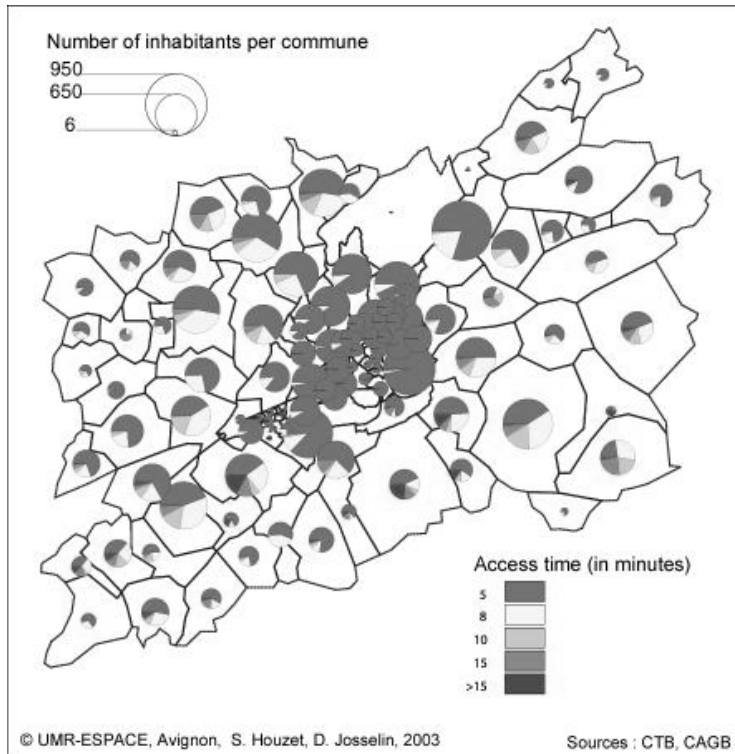


Figure 2: Access time to Evolis stations from housing for each commune in the Communauté d'Agglomération du Grand Besançon (CAGB), France

Extending a DRT to a large territory requires to evaluate and to adapt the service in order to maintain its economical productivity, its social appropriateness in respect with the contract (de)signed for the client. The CAGB asked our team to evaluate the social, economical and ecological impact due to the change of the served territory and to (re)design the concepts of the service to fit to the new enlarged demand. This new territory (about 30 km long) covers 59 communes (170000 inhabitants), including Besançon (120000 inhabitants). New territorial characteristics induce several constraints: lengthening of covered distances to access to the service in the added communes, decreasing of the potential market (population low density), deterioration in the service attractivity and in the Evolis stations accessibility within the periurban communes. This is illustrated by the figure 2, where we computed the time access to the service according to the new Evolis station locations. This is an important point: accessibility appears worse for some of the periurban communes. Population is much more spatially dispersed, so requiring supplementary Evolis stations. Indeed, it is clearly difficult to force users to walk more than 5 minutes, especially in peripheral areas. This would greatly impair the service attractivity and can depreciate its economical efficiency.

The survey we presented previously allows us to estimate the potential market of transport customers. If we project a ratio of 1% of future passengers on the whole territory, we obtain a new annual market of about 500 new clients using the extended service Evolis. Another way to proceed from the user profiles deduced in the survey provides a lower market. Indeed, the population structure (data: General National Census 1999 of INSEE) of the additional communes (age, socio-professionnal categories and gender) doesn't seem really favorable if we assume the person behavior to remain stable and coherent with the one identified in Besançon. Thus, we can consider that globally the market calculated from the ratio overestimates the real market (Besançon keeps the leadership), while the one processed with the profile

underestimates it (we can hope a more important need in the other communes, where only a few transportation exists). For each commune, we then find the minimum and the maximum of these two market values. The figure 3 gives an idea of the (weak) potential market and shows the difference between the under/overestimated market. The range of the values is very large and can be used to give very large estimations of potential market, subsequent economical efficiency and induced costs, as our operational partners expect.

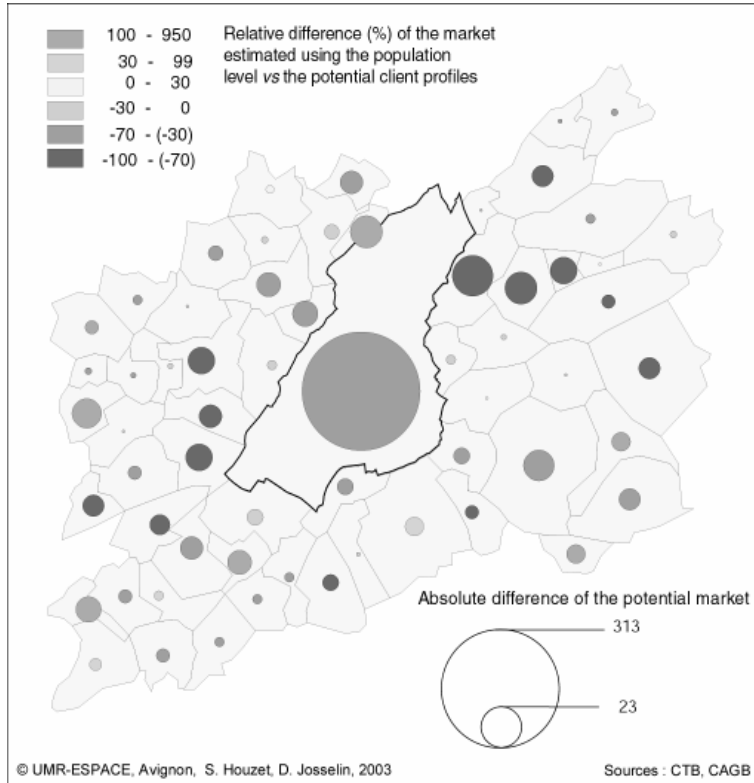


Figure 3: Evaluation of the potential market and difference between the market estimated from the population ratio and from the clients theoretical profiles in Besançon (center of the map), Communauté d'Agglomération du Grand Besançon (CAGB), France.

The DRT Evolis extension implies the average distances to be longer, the mean prices to become more expensive. Our simulator generates large sets of virtual routes using Monte-Carlo process, according to the probability of occurring demand at each Evolis station, demand estimated from the potential markets presented above. This method also aims to anticipate what could be the necessary modifications of the design of the service, including the spatiotemporal features mandatory for the client, in particular for the remote communes.

Our simulations show that the economical ratio may go down to 20 % (80% of the cost will have to be paid by the CAGB, and so, the community), due to a very weak grouping and a significant increasing of travelled distances. But we observe also that, in case of a significant increase of the demand (for instance, if the service is proposed at any time, for all the trains), up to a mean of 20 people per train, the economic leverage provides a very good rate (about 70% supported by the client) with a very good grouping (3 to 4 passengers per vehicle). It also prevents pollution, due to about 70% of personal cars set aside, and

approximately 25% of less travelled distances (not so much as the cars, because of the generated detours). This is a proof of the potential efficiency of generalized DRT, if its status goes from the management of marginal flows to a strong supply in territories to be served by such flexible transports.

CONCLUSION

DRT are promising fruitful perspectives in public transport, especially when they (will) largely use information and communication technologies, and combine GIS and operational research. This kind of transport is now waited by numerous persons and won't stay at the stage of "experiment" if private firms and local organizations propose them, in France and Europe. A survey made in 2003 on 1053 people allows us to imagine these concepts thanks to a study about the perception of spatiotemporal constraints by the potential users. When we asked people about some close future Demand Responsive Transport systems, able to group and move them when and where they want without any preliminary reservation, they say they would use it for 70 % of them, even if these kind of systems would require new constraints for them and a higher level of complexity (varying price scale fixing, time uncertainty, notably). The only strong constraint seems to be the price: higher will be the price, lower will be the use of the DRT. We pretend this difficult equation can be solved by using spatio-temporal optimisation, to reach sufficient levels of grouping, as our simulations show. These encouraging results lead us to feel that we may be at a turn of transport consuming and conception in France. As we have previously drawn the social context, the perception of DRT and the behavior for mobilities seem to change quickly and opens to new concepts, renewed services responding to the specific needs of various territories.

Three complementary projects are now being examined for improving and introducing DRT on new territories: the conurbations of Avignon (a medium-sized city with 89 000 inhabitants and 150000 people living in its agglomeration, South of France) and Montbéliard (North-East of France, about 100000 inhabitants). Avignon is an example of "scattered" and dense population, and Montbéliard shows a multipolar structure, with a hierarchy of territorial functions. For these two territories, DRT can be an efficient solution for many problems of transportation, especially because the political demand is strong. We can foresee several possible solutions by associating the DRT to the regular public transport network to attempt the system to evolve. We shall test different levels of DRT integration (serving of a flow generator, "intermodal" system, or ubiquitous DRT) and study their advantages and limits. In this spirit, we shall simulate four hypothesis of combination from classic to flexible transport: a first one foresees the minimal use of a DRT, in periphery for low density and demand; a second scenario imagines a little more integrated, flexible transport for replacing deficient bus lines; the third assumption plans to test a judicious combination between bus and DRT; and the last scenario will implement a complete and ubiquitous versatile DRT.

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