SIMULATION APPROACH FOR AN INTEGRATED DECISION SUPPORT SYSTEM FOR DEMAND RESPONSIVE TRANSPORT PLANNING AND OPERATION

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ABSTRACT

Rural areas are becoming more desert from day to day, leading to complex dispersed and scarce demand patterns for public transport. As a consequence, conventional transport services are becoming less frequent, reducing levels of service (e.g., low occupancy rates, usage of old vehicles). With rigid predefined routes and schedules, they are inappropriate to operate in such environments.
Demand Responsive Transport (DRT) systems have been seen as an interesting alternative solution, providing flexible transport services to meet trip requests. This solution has already been adopted in several countries as a way to increase user's mobility and mitigate social exclusion. There are however some issues concerning DRT scheme design and evaluation requiring further developments. Namely, there is still a lack of adequate tools to support some of the strategic and tactic level decisions that must be made at the design phase.
In this research, we propose an Integrated Decision Support System (IDSS) and general action methodology that will allow achieving better planning decisions and allowing the evaluation of alternative scheme designs prior to its implementation. The IDSS and methodology are based on an event-driven simulation framework which emulates real-world customers' behavior and vehicles movements. The paper will concentrate its analysis on this framework. An illustrative numerical experiment is presented and briefly discussed.

1. INTRODUCTION

Rural areas are characterized by low levels of population density, which is unsuitable for a conventional public transport service (with fixed routes, fixed stops and fixed schedules). In fact, traditional public transport systems had revealed low success and large economic inefficiencies in areas with widely dispersed trip patterns, due to low vehicle occupation rates. As a consequence, transport operators tend to cease all or part of their operating concessions, leading to mobility and functional exclusion problems for residents.

In the last decades some efforts have been developed to overcome some of these problems. Some countries have been approving legislation to allow the implementation of flexible public transport systems, such as Demand Responsive Transport (DRT) systems, which services (including their schedules, routes, stops and vehicle size allocation) are triggered and defined dynamically by demand calls. Additionally, a substantial number of on-site DRT experiences have been promoted by central governments funding schemes. For example, in USA, central government policies (ADA 1990 - Americans with Disabilities Act (Brake *et al.* 2007)) require that transport operators running fixed-route services also provide complementary paratransit services for persons with disabilities within their service areas. In England, the Rural Bus Challenge funding that was launched in 1998 promotes the adoption of innovative transport schemes that includes flexible transport services (Enoch *et al.* 2006). In some other EU countries the DRT supply was also supported by EC funds, integrated in projects with the aim of assessing the most effective ways of providing rural transport services and producing a set of recommendations to serve as a guide for the planning and implementation of rural transport systems (Brake *et al.* 2007).

During the last decade, an increasing number of scientific articles have been published, supporting the greater concern of academics on new transportation solutions (including DRT) to address people´s mobility problems. All of these contributions and field experiences allow us to identify the most critical factors (financial, social, environmental, operational, etc.) that should be carefully analyzed when setting up a new DRT scheme.

However, a systematic sustainability analysis of transport system is still a complex issue since it faces a number of specific characteristics associated not only to the nature of its demand and supply, as well as to all its externalities. Transport problems are inherently complex and difficult to handle, and intelligent decisions must be oriented towards maximizing the advantages of the new transport provision while minimizing their costs and undesirable side-effects. Since resources are always scarce, a major effort in adopting efficient investment decisions is required. In this way, further research is still required to assess to which extent they contribute to the success of a DRT scheme or what combination of options should be adopted.

In this research, an integrated decision support system (IDSS) is proposed aiming to support decision makers in designing and implementing by firstly investigating the impacts of alternative potential specifications of the DRT system on its viability and sustainability for a given territorial area. The decision support system combines supply and demand data with analytical and simulation tools in order to provide information that will support top management strategic and tactical decisions.

The objective of this paper is to describe, more particularly, the simulation module and its role in the IDSS, and illustrate results of some preliminary tests in order to register, in advance, the quality of solutions or management strategies.

The remainder part of the paper is organized as follows: Section 2 presents a literature review on DRT systems in order to highlight the main conceptual and design aspects, technologies and methodologies applicable. Section 3 describes a new IDSS framework for setting up and run a DRT. Section 4 presents a more detailed description of the simulation component, including some aspects that concern the creation of demand and supply sub-models from real data and information. Section 5 briefly introduces the general procedure to conduct a DRT design process by using the IDSS framework and its simulation component, in particular. Section 6 illustrates the applicability of this procedure by a simple real-like case. Finally, Section 7 reports the main conclusions and final considerations regarding future developments.

2. LITERATURE REVIEW

Flexible transportation systems, in particular, DRT systems have been adopted over the last decades, as reported in some studies (Brake *et al.* 2004; Mulley and Nelson 2009). These systems provide transport on demand from users, using flexible schedules and routes to satisfy their travel needs. A DRT system receives trip requests either for an immediate service or as an advanced reservation and organizes routes and schedules to accommodate trip requests aiming to respond in real time to user's mobility needs. Its implementation typically involves the use of information and communication technologies comprised in an Operational Decision Support System (ODSS) in a Travel Dispatched Center (TDC), as shown in Figure 1.
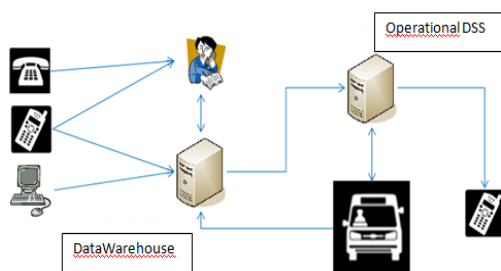

Figure 1: Elements of a TDC in a DRT System

Trip requests are typically made using telephone. In most advanced systems, requests (and related monitoring) can also be made by interacting to a WEB portal. Requests are then stored in a data warehouse which also holds all the relevant data concerning the transportation network. A fleet of vehicles of mixed types (buses, mini buses, taxis, etc.) is generally provided by one or more public and private operators (taxi owners, bus operators, community transport, etc.). Services can be operated on their own or integrated with traditional transportation systems, acting as feeder services for buses or rail services. The heterogeneous fleet of vehicles is coordinated by the TDC that, in some cases, is operated with advanced information and communication technologies such as on-board integrated Global Positioning System (GPS) and/or continuous General Packet Radio Service (GPRS) connection. Vehicles are assigned to trip requests frequently by the ODSS that incorporates some intelligence or rationality to the system, allowing obtaining adequate transport solutions according to the area characteristics and demand patterns. The ODSS should integrate three different types of functions: requests management, scheduling and routing dynamic planning, and effective communication system between the TDC and customers and TDC and vehiches (*e.g.* SAMPLUS 2000; McDonagh 2006). Furthermore, it should export detailed reported service data, allowing carrying out performance analyses to define corrective measures for future implementation. Over the last two decades or so, a few ITS have been developed such as Mobisoft and Trapeze (Enoch *et al.* 2006), and more recently, Astra (Dias *et al.* a) 2011).

The use of modern Information and Communication Technologies (ICT), including Intelligent Transport Systems (ITS), allied to adequate strategy planning services has been pointed out as the solution to improve the costs-effective performance of DRT services by promoting more complex organizational structures, i.e. collaboration of multiple service providers, and improving flexibility and popularity by providing intelligence solutions to process trip requests using dynamic routes definition and an accurate fulfillment of the requirements, in order to respond in real time to users mobility needs (Nelson and Phonphitakchai 2012; Mageean and Nelson 2003; Ambrosino *et al.* 2004; Brake *et al.* 2004; Brake *et al.* 2007; INTERMODE 2004; Mulley and Nelson 2009).

Most of the work developed so far identifies as key success factors a set of strategic level decisions concerned with system conceptualization issues: specific policy goals, target market, area factors (population density, income level, demographic details, land use pattern, etc.), stakeholders involved, financial model and the regulatory framework. From these issues the financial aspect is assumed as one of the most critical aspects: what sources of funding are available to support innovative transport services? What is the time limit of those funds? (Very often, those funds, including UE funds, only apply during the setup phase, putting at risk its permanent sustainability. The lack of funds and

subsidies for innovative transport services can be a crucial aspect or, at least, an important obstacle to the success of the systems, in many cases.) Which institutions are going to give a contribution to provide financial means? What is going to be the passenger contribution (fares)?

In fact, a major concern pointed out in several analysis concerning DRT implementations is related with its financial sustainability. Indeed, DRT are labor-intensive and the cost per passenger is relatively high, comparable to taxis: fares revenues are unlikely to cover costs in any market (Mageean and Nelson 2003). Therefore, these projects tend to close after the first pilot stage (Battelino 2009) or when funding schemes end. In fact, according to Enoch et al. (2006), the imbalance between income and costs is only manageable when it is supported by (central, regional or local) government funding, and financial viability tends to end when funding finishes.

At the tactical level, decisions aim to devise ways to implement the transport system according to the strategy previously defined. This planning stage is crucial for the design of the transport scheme and several authors had identified the most critical decisions (e.g. Giannopoulos 2004; Mulley and Nelson 2009; Parragh et al. 2008; Quadrifoglio and Li 2009), such as:

- What level of flexibility should be adopted, in terms of routes, timetables, frequencies, time-windows (ex, arrivals at stops)?
- What pre-booking mechanisms and rules should be adopted?
- What resources are going to be used (fleet, drivers, informatics, TDC center and staff)?
- What fare structure should be implemented?
- Which level of integration with public transport network (schedule buses/train network, etc.)?
- How is the system going to be evaluated?

It is well-known that all these factors have an impact on the success of DRT systems. However, further research is still required to investigate what combination of options should be adopted and to assess in which extent they contribute to that success. Additionally, it is fundamental to estimate the impact that some of these decisions have in terms of overall system's performance (cost, quality, etc.).

Modeling is a fundamental tool to support large investments decisions which involve social, economic, financial and institutional complex issues such as new and innovative transport solutions. In spite of this, only a few attempts have been made to develop approaches capable of giving insight on the relationship between design options and their impacts on system's performance. In general, several measures or indicators can be used to evaluate a DRT service. Examples of those are (ex, Mageean and Nelson 2003; Brake and Nelson 2007; Fernández et al. 2008; Palmer at al 2008; Quadrifoglio and Li, 2009, 2010): the service reliability (customers' satisfaction, willingness to pay, non-accomplished valid requests, general mobility improvement), core background information, service passenger restrictions (ex, only disabled and elderly

people, or other mobility-constrained persons), trip purpose, coverage of service (which days it works, where it works), easiness of reservations, pre-booking antecedence and time windows for reservations, passenger convenience (the time spent in transit becomes less satisfactory as the service area increases), need for intermodal transfers, satisfaction with the TDC, driver satisfaction, walking time to stops, waiting time for delayed vehicles. However, according to Battelino (2009), there is a lack of research work into evaluation methods and definition of real time evaluation and monitoring systems.

Wilson et al. (1970) pioneered the use of simulation to compare different heuristics to assess the influence of the service area, demand density, and service quality on the fleet size requirements. Some studies (ex, Feuerstein and Stougie 2001) have investigated changes on performance when the dial-a-ride system runs with alternative number of vehicles.

Dias et al. (2011a) proposed a framework that uses a simulation approach to evaluate alternative DRT solutions and select the most adequate for a given territorial rural area and for each of different scenarios. Their approach will permit to achieve better planning decisions and will allow evaluating operating strategies prior to the implementation of such a complex system, as it is the case of a DRT system. The conception and the performance evaluation of a DRT system includes establishing user requirements and expectations, by considering all perspectives from the beginning, running computational models and creating simulated prototypes, analyzing all the main issues (economic, social, and environmental) at its conceptual stage in a holistic way. The simulated DRT system solution should integrate all sectors and alternative scenarios in order to produce better services for users and more efficient and sustainable operations for operators.

In the next section, an extension to the proposal of Dias et al. a) (2011) will be presented and discussed. This proposal consists on a broader framework that integrates different advanced technologies and analytical methodologies, and allows a comprehensive decision support to analysts and managers at the different levels of decision: strategic, tactical and operational.

3. INTEGRATED DECISION SUPPORT SYSTEM

Figure 2 illustrates the proposed integrated decision support system (IDSS) for a DRT system, pointing out its main components and sub-components, their relationships and the different levels of decision: strategic, tactical and operational (ODSS). For example, at the design phase of the DRT system, no real information exists yet on its functioning, so it is considered as a strategic and tactical decision process. In this case, the simulator component must be used in order to emulate what could happen at a real-world scenario, in order to allow the evaluation of different options (essentially, system objectives and rules) by the analyst
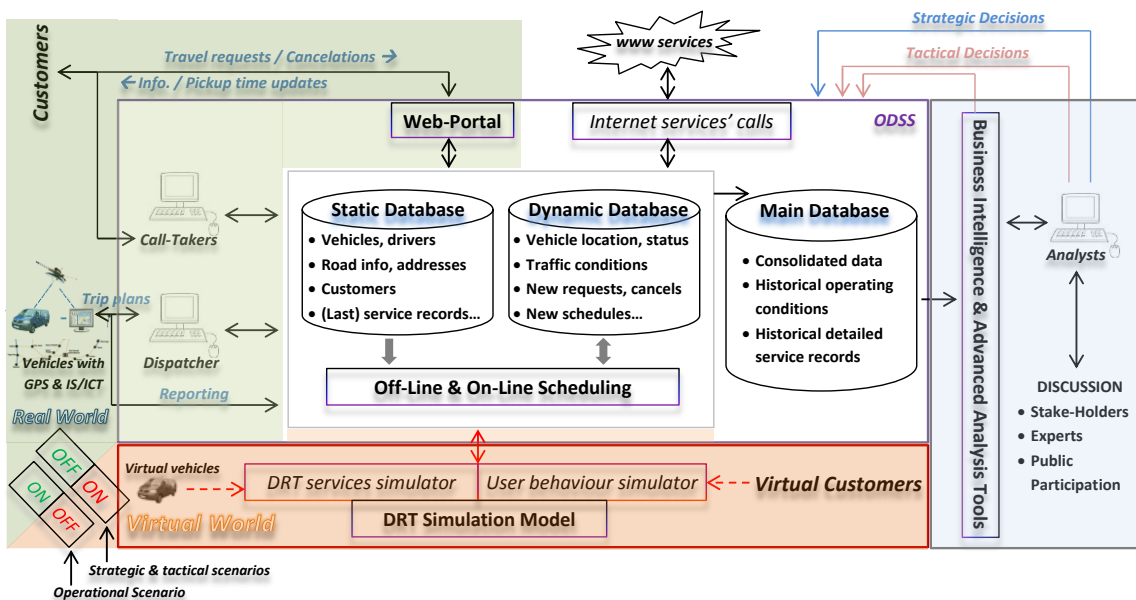
Figure 2: IDSS for Different Levels of Decision in DRT Systems (adapted and extended from Fu, 2002)

component. Details of the simulation component are described in the next section thereafter.

The ODSS component represents the heart of the TDC center of the DRT system, receiving trip calls, processing them in terms of rational/optimized service (route) plans and scheduled services, giving advanced information to customers, monitoring performance and recording detailed historic data. Routes and schedules are solved by applying alternative algorithms, automatically selected according to the patterns of trips. For example, in the case where groups of persons are at the same stop (work-to-home, market-to-home and school-to-home trips), a Vehicle Routing Problem savings-like heuristic can be applied, whereas in the general case where vehicles have to pick up and drop off different customers at/to different stops across the territory, a dial-a-ride problem (DARP) should apply. Currently, the ODSS component incorporates two alternative solution methods for DARP: (1) a fast heuristic adapted from Xiang *et al.* (2006), and (2) an exact method adapted from Lu and Dessouky (2004). Note that the exact solution method aims to solve small instances of the DARP (number of customers per trip less than 8 to 10) and there is enough time to find the solution. So, such a method is adequate to be applied in a real operating context only; so, it is not applied at the design phase of the DRT, where fast processing simulation runs are needed.

The analyst component is used to properly analyze and evaluate DRT options. It is powered by a Business Intelligence (BI) type framework that starts to extract relevant data from the historic main database, transform such data and load it into a proper database system for multi-specialized analyses. It comprises different methodologies: simple and advanced statistical reporting and inference techniques, data mining and operational research inference and prospective models.

Social, environmental and economic impacts are increasingly important aspects for decisions in transport investments. To take care of this, the analyst component has been incorporating a large number of key performance indicators (KPI) hierarchized by their measuring aim (e.g., evaluate client satisfaction, financial performance, organizational performance, etc.) and categorized by the three basic assessment dimensions of sustainability: economic, environmental and social. Details and examples of such KPIs, currently implemented in the proposed framework, can be consulted in Dias *et al.* b) (2011).

The IDSS integrates several types of advanced modern technologies (Figure 3). According to Liu *et al.* (2010), an IDSS which combines the use of models, analytical techniques, data access and retrieval functions, by using advanced differentiated technologies, as it is the case in here, will have the advantage (in relation to traditional "static" DSS) in providing consistent, coordinated, active and global support for the various managers/analysts on their different levels of decision-making processes.

Furthermore, beside the simulator and business intelligence modules, the ODSS proposed includes other characteristics, such as, support to advanced communication systems, Geographic Information Systems (GIS) for analyses and map display purposes, access to Google Maps API services tools integration.
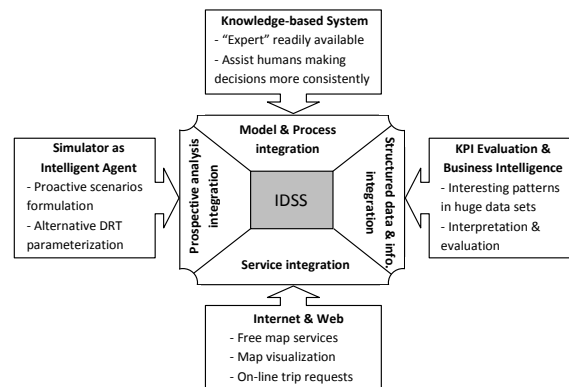

Figure 3: Types of Technologies to Enhance Integration for IDSS in DRT Systems (adapted from Liu *et al.*, 2010)

The IDSS helps DRT managers (TDC coordinators, system designers and analysts) at their different levels of decision:

- Strategic level (objectives, aim, strategies and general policies) – the analyst component decides how the DRT should be operating in the long-term in order to be viable and sustainable in the three basic terms: economic, social and environmental (what the main objectives of its existence? which type of services must offer? at what level(s) of flexibility? at what price levels (whether taking account or not potential subsidization)?

- Tactical level (detailed rules according to objectives and general strategies and policies) – the analyst component monitors and analyses current performance of the system, tries to identify hidden patterns of operational data, and continually tries to devise better solutions to tackling operational problems; some solutions are automatically devised and incorporated into the ODSS component (e.g., a recurrent set of day to day fixed travel patterns are identified and a shortcut route planning procedure automatically generates a fixed service plan); however, the most part of solutions requires the investigation and validation of human analysts before their practical implementation (which new operating rule should be applied? is there any actual rule of policy that must be re-parameterized? what are the new parameters?).

- Operational level (every-day decisions, according to rules) – the ODSS component drives the TDC center, receiving travel requests and determining the most appropriate service plans (which vehicle? what route? what schedule?).

4. SIMULATION COMPONENT APPROACH

The simulation component comprises two main models: (1) a demand-side model implemented as a travel request generator and users' behaviour simulator, and (2) a supply-side simulator that simulates the functioning DRT services, including the decisions made by the ODSS and the vehicles operations.

Both of these models are based on a micro-simulation event-driven approach. The main demand-side events are: trip reservation, trip cancelation, user arrival to stops (origin and destination), user no-show and non-reserved shows at stops. The main supply-side events are: trip planning events (such as hourly and daily time-scheduled planning of advanced reservations, real-time acceptances or rejections and re-planning), vehicle departure and arrival from/to stations, stops and strategic waiting and interface points.

Demand-side model

This model simulates the behaviour of users, from travel requests at each stop of the network by specifying the desired destination and the time of departure or arrival, to the user behaviour of each user with respect to their arrival time at the origin stop, waiting "patience" for delayed vehicles, boarding times, and so on.

Travel requests are generated based on socio-economic characteristics of the resident population (from Census), from domiciliary questionnaires and local authorities interviews, as well as acquired knowledge about the main attracting poles for visiting (workplaces, schools, hospitals, markets, general services, transfer stops to inter-urban transport services, etc.). Such data and acquired information is used to compose macro-descriptive variables small zones of the territory (highest level of disaggregation in accordance to Census). The resulting model starts by simulating the individual patterns of each user by using those macro-descriptive variables. Some degree of freedom (in choosing any random destination) is also modelled by a given probability (as a model parameter) and performed by using a gravity model.

User time arrivals to origin stops is modelled by recurring to alternative distribution probabilities such as triangular, truncated normal and truncated negative exponential distributions.

Supply-side model

This model reproduces a virtual functioning of the supply elements of the DRT system, namely certain modules of the ODSS (DARP planning, vehicle allocation and dispatching, historical data storage in database), and all vehicles' movements.

Travel times between two adjacent schedule stops are generated by parameterized normal distributions. Mean times are taken from OD trip times previously stored in the system database and obtained by invoking Google Maps internet services (shortest route between two points). Some non-recurring real events, such as vehicle breakdowns, road obstacles and bad weather conditions, are also considered according to parameterized Poisson processes.

Recurrent congestion inside (small) urban areas are also modelled by using: (1) mean travel time forecasting models based on chronologic time series of experienced trips and their representation in terms of exponential moving average and ARIMA mechanisms; and (2) lognormal distributions.

5. DRT DESIGN APPROACH

As it was discussed before, in Section 2, the design phase of a new DRT system involves the investigation of a large set of issues and the answer to a large set of strategic and tactical questions.

In terms of the IDSS usage, the simulator component must be "turned on", "tuning off" automatically the sub-components of the ODSS that communicates to real customers and vehicles (i.e., the call-taker, the dispatcher

and the Web portal sub-components) – see Figure 2 above. The simulator will take implicitly account all of their necessary functions, communicating directly with the remaining operational sub-components.

A framework was identified as essential to the process evaluation (Dias *et al.*, b) 2011) based on the literature review (Figure 4). The referred framework is used to determine the system performance to evaluate the alternative specifications for a certain area. It allows choosing the better specifications and the better working rules.
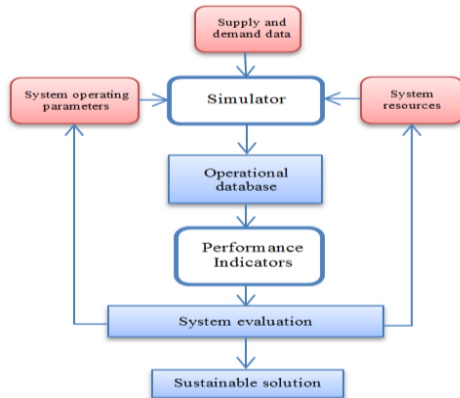

Figure 4: Conceptual Framework of the DSS

An iterative approach is used between the simulator and the analyst components. At each iteration, a solution option is simulated and evaluated. And, for each iteration (option) a large set of simulation runs (days) are realized and their operational details are stored into the main database of the ODSS. The number of days is set in order to infer statistics (e.g., mean values) within a given high level of accuracy. After that, such set of data is analyzed in terms of KPIs that are automatically computed by the analyst component's routines.

In the next Section, some illustrative results of a given iteration of the above process is reported and discussed. It shows the software viability in theoretically speaking (demand is defined randomly).

6. ILLUSTRATIVE EXAMPLE

A small case study has been implemented in a rural area in Minho region, north of Portugal (Amares, Terras de Bouro and Vila Verde counties, with a population density of 155.3 inhabitants/Km2, in average). However, the illustrative results presented hereafter refer to the area of Terras de Bouro, a county with the lowest population density of the region (mean of 26.14 inhabitants/Km2). The area is very large and the population is low and highly dispersed. As a result it is expected that the resulting vehicle occupation rates from simulation runs are low.

The ODSS uses GIS technology by integrating the *Google Maps* service. *Google maps* allows the representation of geo-referenced information on a map in a very user-friendly (and it is a free service). So, the graphical visualization of a particular day run, for a

particular vehicle, is displayed in Figure 5. Green points represent pick up points and red points represent drop off points (or both, if there is anyone to pick up there).

Figure 5: Routes of a Vehicle during a Particular Day

The GIS technology, by integrating the Google Maps service, would be also interesting for customers, as they can see their planned trips online (Web-Portal), for example for a given week. Every line with a different color corresponds to a different route of the vehicle (Figure 6).

Figure 6: User Interface of the System

A large set of KPIs are automatically produced by the analyst component of the IDSS in order to allow analysts and decision-makers to assess the performance of the DRT specification being simulated (or in use, if the system was implemented). Table 1 shows some KPIs obtained from a series of simulation runs (working-day unchanged pattern) for a particular DRT specification, i.e. set of fixed rules and parameters.

Table 1: Some KPIs for a Series of Simulation Runs (Working-Days) – values are rounded to integer numbers (means per day)

Requests number	51
Passengers number	103
Working hours: from 5:30 am to 8:30 pm	15
Mean requests per hour	3 - 4
Mean passenger number per hour	7
Mean travel distance (passenger)	30 km
Mean travel time (passenger)	42 min
Mean delays (passenger)	16 min
Mean waiting time (delays vehicle)	4 min
Mean distance between stops	11 km
Mean time between stops	16 min
Vehicle number	4
Mean occupation rate (total)	24%
Mean occupation rate (partial)	44%
Mean vehicle time (without passengers)	2h 49min
Mean vehicle time (with passengers)	5h 32min

The "Requests number" and "Passengers number" (mean carried per day in one direction) are produced by the demand model, generated randomly. It was considered a working day of 15 hours from 5 am to 8:30 pm. As a result, the "mean request per hour" varies from 3 to 4, and the "mean passenger per hour" is about seven. The "mean travel distance per passenger" is approximately 30kms in about 42 minutes. The "mean passenger delay" is nearly 16 minutes, but the "vehicles waiting time" in the stop is only about 4 minutes. The "mean distance between stops" is approximately 11kms, taking, on average, 16 minutes "mean time between stops".

The "vehicle number" used to serve all the requests is four (one with four seats, another with six seats and two vehicles with 8 seats available). The values in the "Mean occupation rate (total)" and "Mean occupation rate (partial)" refers to the four used vehicles. The partial occupation rate only considers the time and distance with passengers on-board (during the 5 hours and 30 minutes).

As expected the total occupation rate (including all the vehicle times and distances, with or without passengers on-board) is low. But it is also expected to achieve high standards by experimenting improved operating rules of the system (for instance, using smaller vehicles, adjusting supply to demand, would improve utilization rate of vehicles and therefore, the overall performance of the system). Also, it is expected that high occupancy rates will be higher when taking in account all DRT service (and not only this part where the population density is considerably lower than the overall density).

Both, vehicle movement and arrival frequency of the clients to a stop can be critical to define how the system must react in a real situation. In this illustrative example, from the total of 103 passengers, 82 (about 80%) arrived to the destination before the desired time (approximately 33 minutes per passenger) and 21 (about 20%) arrived after (approximately 35 minutes per passenger).

The "No-show" clients are also considered in the simulation. It is a parameter represented by a percentage of the potential customers' population and therefore can be properly estimated along the real operating of the system (if it were implemented). For now, we can only perform some parameterization studies in order to analyze the impacts of different values on the overall performance solution. In addition, there are other parameters to take in account for future simulations, namely, the length of the time window, tolerance delays (clients and vehicles in the stop waiting), and the fleet size, among others.

There are issues concerning the costs of DRT system that require further analyses and still need to be addressed, in order to evaluate the transport system viability and sustainability. Some preliminary studies and correspondent results were reported by Oliveira *et al.* (2011a).

7. CONCLUSIONS AND FUTURE WORK

In order to achieve a successful DRT service it is important to develop a framework that provides different levels of decision-support to enable decision makers to perform systematic analysis leading to intelligent strategic solutions.

The IDSS proposed in this paper, along with the proposed general evaluator procedure, will ultimately assure the adoption of a sustainable DRT system, by properly adequate supply (e.g. fleet of vehicles and typology of services provided) to estimated demand levels and patterns, taking into account financial, economic and social decision criteria.

Since the outcome of the evaluation is highly dependent on the DRT specification (in terms of operational parameters, such as the level of spatial and temporal flexibility of their services), this framework must comprise an iterative approach that consists on defining an initial DRT specification, estimating their impacts in terms of performance indicators, redefining the specification and re-estimating the new impacts, and so on until a suitable solution is found, in terms of technical and economic viability and sustainability.

These results demonstrated that the system, based in an event-driven simulation approach allows calculating the necessary performance measures or PKIs to the assessment.

It was highlighted the importance of combining different technological and methodological means (web-portal, internet services, GIS, intelligent agents, advanced statistical, operational research and artificial intelligent tools), to enhance efficiency in transport operations, as well as, to enhance efficiency in the analyses and assessments. For example, graphical displaying devised solutions can allow further statistical analyses of spatio-temporal indicators; data mining techniques allow finding hidden patterns in demand that can lead to improved routing planning, etc..

The use of the simulator will ultimately allow identifying which are (probably) the best policies and strategies for the system to follow in the implementation phase, depending on the needs and characteristics of the area. Also through a currency demand it is possible to define the structure to analyze the system viability.

From the brief analysis and discussion based on the illustrative example of Section 6, it is suggested that simulation approach works. Currently, a large set of validation tests are taken place by using theoretical extreme cases data and real data (from the case study area).

Further validation tests are currently being done and some more will be performed, along with parameterization tests, for example estimating the effects (on the overall and nature-specific DRT performances) of parameters such as: spots of population concentration within the different counties of the study area; DRT system integration with regular transport service; flexibility of services as a function of economic efficiency, costs effectiveness and resources availability.

Additional studies will follow: IDSS overall validation, and proposal of a DRT specification to the study area (based on the basic principles of viability and sustainability).

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