1st International Conference on Project Economic Evaluation
ICOPEV'2011, Guimarães, Portugal

ECONOMIC EVALUATION OF A DEMAND RESPONSIVE TRANSPORT IN RURAL AREA

Ana Dias,* José Telhada and Maria do Sameiro Carvalho

Department of Production and Systems, University of Minho, Portugal

* Corresponding author: anacecidias@hotmail.com, University of Minho, Azurém, 4800-058, Portugal

KEYWORDS
Economic evaluation, Sustainability, Transport systems evaluation

ABSTRACT

The provision of traditional public transport services in rural areas have shown to be very inefficient and ineffective. In fact, rural areas are typically characterized by low levels population density leading to complex demand patterns (demand is low and spread over a large area) which leads to low levels of service of conventional transport services (low frequency, old vehicles, etc). Demand Responsive Transport projects have been seen as an interesting alternative solution already adopted in several countries. There are however some issues concerning demand responsive transport (DRT) costs and benefits that still have to be addressed. In this research work a global analysis about internal and external costs is proposed aiming to support decision makers investigating the impacts and measures related to the adoption of a flexible transportation system solution.

INTRODUCTION

Over the years, transport has been playing an increasing role in the world economy, as world trade depends on the movement of people and goods. However, the systematic economic analysis of transports 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 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.

Traditionally public transport systems in rural areas have been based on static services: fixed routes, fixed stops and fixed schedules. The low levels of density observed in some of these areas leads to fragile supply systems with high levels of inefficiency and efficacy as a result of under-investments strategies over the years.

In fact, low rates of occupation of vehicles and high rates of population dissatisfaction are frequently observed (e.g. Quadrifoglio and Li, 2009). Rural area inhabitants are seeing their mobility limited, using frequently, the good-wiling of neighbors or any family member to make their trips. Therefore, functional social exclusion increases in those rural areas.

To overcome some of these problems, flexible transportation systems have been adopted over the last decades, as reported in some studies (e.g. Brake et al., 2004; Mulley and Nelson, 2009). In fact, there are many successful cases all over the world of the flexible transport system called Demand Responsive Transport (DRT). Most of the cases reported refer to rural areas, small towns and to serve special populations (elderly and people with disabilities) in large cities.

DRT is an attractive solution, because offers a user-friendly answer to passengers needs and overcomes some shortcomings of traditional transport services.

Implementations of DRT systems in literature (e.g. Brake and Nelson, 2007; Mulley and Nelson, 2009; Nelson et al., 2010), obeys to several conditions, encompassing high dynamic levels of both planning and coordination processes. The use of modern information and communication technologies, such as 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.

As Brake *et al.* (2004) argued the main architectural component of a telematics-based DRT system is a control centre (usually named as Travel Dispatch Centre (TDC)) using ITS which has the capacity to process demand requests and dynamically assign passengers to vehicles and optimize routes.

The aim of this paper is to develop a framework to carry out an economic evaluation of such a transportation system, setting up the most important evaluation criteria and quantification (all internal and external costs and all benefits).

It aims to develop and prepare a methodology for the evaluation of a DRT system in rural areas.

This paper is structured as follows: in the next section cost structure of transportation systems is reviewed and analyzed and the approach adopted is presented. Then, DRT systems are examined and their specificities discussed. Finally performance indicators are proposed and, in the last section, some conclusions are draw.

COST STRUCTURE IN TRANSPORT PROJECTS

There has been a growing number of research studies (all over the Europe and U.S.), focused on the evaluation of real costs and benefits of transport systems (Jakob et al., 2006).

Most authors involved in transportation studies sustain that transportation choices are expensive and complex and have long-lasting consequences and therefore, it is crucial to analyze a large number of design alternatives to increase the probability of defining a good design for the service (Nickel et al., 2009). A comprehensive evaluation methodology is required.

According with some authors (e.g. Litman, 2009), the term "cost" involves tradeoffs between uses of resources (which can involve money, time, or loss of an opportunity to have a benefit) and can be seen as a reduction in terms of benefits (also, a benefit, can be defined as a reduced cost). This approach allows quantifying impacts, enabling a comparative analysis of alternative scenarios in terms of, for instance, reduction of travel time, reduction of air pollution, noise, accidents, etc.

For the sustainability of transport investment decisions it is important to consider their social costs. These costs can be classified either as internal costs or external costs (from the operator point of view), as described in Figure 1, and detailed in the following subsections.

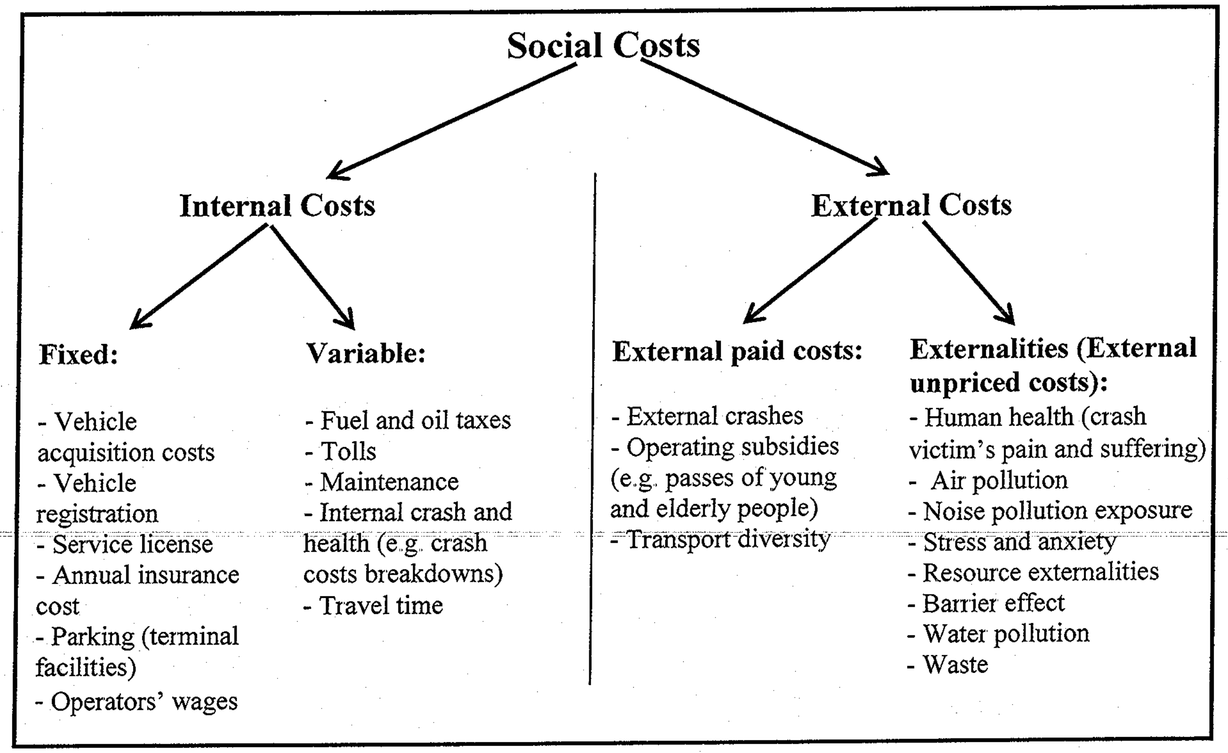

Figure 1. General social costs associated with a transport service (operator's point of view).

Internal Costs

Internal costs are supported by the transport service operator and can be classified into fixed and variable costs.

Fixed costs, are easily measurable and common to all transport investment projects. Among several expenditures, they can include (AA, 2002; Jakob, 2006; Litman, 2009):

- Vehicle acquisition and ownership costs;
- Vehicle registration;
- Service license;
- Annual insurance cost;
- Internal parking (both terminal and maintenance facilities which can involve costs such as: lighting, repairs, security, landscaping, snow removal, access control (e.g., entrance gates), fee

collection (for priced parking), enforcement, insurance, labor and administration)
Additionally, drivers and operators' wages are, in general, internal fixed costs in the transportation sector.

Variable costs, depend on the level of operation and include (AA, 2002; Litman, 2009):

- Fuel and oil taxes (highly dependent on the price of crude and on the level and the type of operation undertaken (kilometers);
- Tolls (vehicles which circulate in highways);
- Maintenance (costs with vehicle repairs and conservation, a function of vehicles usage);
- Internal crash and health (crash costs caused by vehicle breakdowns or accidents and include internal costs associated with repairs and damages to those travelling and costs imposed to other people (e.g. property damages to vehicles, police and legal costs, medical treatment costs, rehabilitation etc (Jakob *et al.*, 2006; Santos *et al.*, 2010));
- Travel time (refers to the costs or benefits from reduced travel time).

Private transport has a similar cost structure as public transport, but it does not include any tax benefits in some attributes such as mandatory annual inspection, road user tax, levies on fuel, motor vehicle registration fees, annual insurance cost and relicensing (Jakob *et al.*, 2006).

External costs

External costs in transport systems are inevitable and are the result of a set of their impacts produced in the society. Santos *et al.* (2010) stated that, the most important negative impacts of road transport are: accidents, road damage, environmental damage, congestion and oil dependence and correspond to a market failure, as incapacity of reaching an efficient equilibrium. For Jakob *et al.* (2006), there are three main external costs evaluated in the literature: external accidents, air pollution and climate change. Litman (2009) considers further external costs: external parking; road facilities; transport diversity; land value; traffic services; noise; resource externalities; barrier effect; land use impacts; water pollution and waste. These authors don't distinguish externalities from external costs.
Recently, there have been some references to externalities benefits, such as, improved mobility and access to resources and goods mitigating social exclusion. However, some authors considered that these benefits are not external because who benefits from transports are those that use them (Jakob *et al.*, 2006; Litman, 2009; Santos *et al.*, 2010). The consumption of resources to allow these benefits has, at the same time, wasted natural resources, such as fossil fuels, devastated forests, ruined soils, deteriorate the quality of air, destroyed biological diversity and produced greenhouse gases.
In this research study, it has been assumed that external costs and externalities are different concepts with frontiers not easy to define:

- External costs defined as measurable costs that affect the financial viability of the project. These costs are caused by external factors and contain external crashes (accidents caused by others), operating subsidies and transport diversity (the quantity and quality of transport services available in a particular situation (Litman, 2007).
- Externalities defined as unpriced costs and benefits caused by an activity (or agent) and have impact on another. For example, in the transportation sector, externalities include environmental and social impacts which are not borne by the producer or consumers of the service.

Externalities are difficult to measure since they are caused by the unwanted effects of the transportation system (e.g. air and noise pollution and congestion) and damage human health and the environment:

- Human health: crash victim's pain and suffering, air and noise pollution exposure, stress and anxiety, delays, etc, (Jakob *et al.*, 2006). (see Table 1).

Pollutant	Quantified Health Effects	Unquantified Health Effects	Other Possible Effects
Ozone	Mortality Minor RADs* Respiratory RADs Hospital admissions Asthma attacks Changes in pulmonary function Chronic sinusitis and hay fever	Increased airway responsiveness to stimuli Centroacinar fibrosis Inflammation in the lung	Immunologic changes Chronic respiratory diseases Extrapulmonary effects (changes in the structure or function of the organs)
Particulate matter TSP Sulfates	Mortality Chronic and acute bronchitis Hospital admissions Lower respiratory illness Upper respiratory illness Chest illness Respiratory symptoms Minor RADs Days of work loss Moderate or worse asthma status	Changes in pulmonary function	Chronic respiratory diseases other than chronic bronchitis Inflammation of the lung
Carbon monoxide	Mortality Hospital admissions - congestive heart failure Decreased time to onset of angina	Behavioral effects Other hospital admissions	Other cardiovascular effects Developmental effects
Nitrogen oxides	Respiratory illness	Increased airway responsiveness	Decreased pulmonary function Inflammation of the lung Immunological changes
Sulfur dioxide	Morbidity in exercising asthmatics: Changes in pulmonary function Respiratory symptoms		Respiratory symptoms in non-asthmatics Hospital admissions
Lead	Mortality Hypertension Nonfatal coronary heart disease Nonfatal strokes Intelligence quotient (IQ) loss	Neurobehavioral function Other cardiovascular diseases Reproductive effects Fetal effects from maternal exposure Delinquent and antisocial behavior in children	

Table 1- Gases emissions sources and scale which pollutes the air and their impacts, that causes people health problems (adapted from Litman, 2009)

- Resource externalities: Economic costs from importing resources; Security risks (maintaining access to resources); Environmental damages (damages from resource extraction, processing and transport, including oil spills e.g. vegetation (Jakob *et al.*, 2006)); Depletion of non-renewable resources (depriving future generations of resources, such as petroleum (Santos *et al.*, 2010)).
- Barrier effect: refers to delays, discomfort and lack of access that vehicle traffic imposes on other transport modes and it is equivalent to traffic congestion costs. In rural areas there are additional barrier effects, such as the need to use private transport to deal with the lack of adaptability between public transport and mobility needs of the residents.
- Water pollution: when water is negatively affected due to the addition of large amounts of materials, such as car oils. These problems are related to vehicle maintenance and usage.
- Waste: includes damage costs associated with the unsuitable dumping of wastes as used tires, batteries, oil and other harmful materials resulting from motor vehicle production and maintenance. These wastes impose economic, human health and environmental costs (Litman, 2009).

Evaluation

Many authors, including the European Union, considered crucial to evaluate a transport project by internalizing externalities of transport (Santos *et al.*, 2010; EUL, 2011). However this is quite difficult to accomplish since, in general, they cannot easily be quantified. (e.g. Jakob *et al.*, 2006; Litman, 2009; EUP, 2011).

There are several techniques in the literature to quantify and monetize external effects of vehicles such as: damage cost method or control and prevention cost method (Litman, 2009). Alternatively, some authors advocate the implementation of eco-taxes, subsidies for using cleaner technologies, thus avoiding socio-environmental costs, or using evaluation methods such as cost benefit analysis or life-cycle analysis (ExternE, 2005).

The more common economic instrument to internalize external costs such as CO_2 emissions is through the implementation of taxes and tolls. While some externalities, such as congestion, have a localized impact (place and time), and justifies a restricted measure (toll), others have global impact (e.g. climate change), so the approach should be more general, like a fuel tax (EUL, 2011).

The European Commission states that external costs should be treated as "social marginal cost charging", which should be the additional short-term cost generated by one extra person using the transportation system. Charging the additional costs imposed to the society will help to ensure fair treatment for users or non-users, basis on "polluter pays" principle. Furthermore, the Commission considered the increase of the use of technology would enable to internalization.

Several authors defend that cost-benefit analysis (CBA) is one of the most widely applied methods for project appraisal for large-scale investments in the terrestrial transport sector (e.g. Stevens, 2004; Jakob *et al.*, 2006; Thomopoulos *et al.*, 2009; Nickel *et al.*, 2009).

On the other hand, an investment project can be evaluated taking into account both social and economic impacts on the local community through social return on investment (SROI) analysis. The SROI approach captures the economic value of social

benefits by translating social objectives into financial measures of benefits and such analysis help communicating the information with stakeholders holding different objectives and preferences (Wright *et al.*, 2009). The SROI analysis methodology was created from the traditional cost–benefit analysis method in the late 1990's (Emerson, 2000).
Other methods, such as the social cost benefit analysis (SCBA) have been broadly applied in many countries, but less commonly in mainstream transport analysis (Haezendonck, 2007).

COST STRUCTURE IN DRT PROJECTS

A DRT system, as a transport service, will have an identical cost structure with internal (fixed and variable) and external costs. However there are some specificities that should be considered when developing an evaluation framework (see figure 2).

DRT costs and benefits

Economic ⟷ **Environmental**

Social

Economic

Costs:

- Vehicle acquisition and registration
- Service license
- Annual insurance
- Parking
- Divers, TDC operators and software operators earnings
- TDC costs
- Maintenance and cleaning vehicles
- Software maintenance
- Updates costs
- Telematics costs
- Fuel and oil taxes
- Tolls
- Vehicle operations
- Crash
- Vehicle usage
- Route flexibility
- Operating subsidies
- Road facilities
- Waste not recovered
- Importing resources
-

Benefits:

- Economic productivity
- Development
- Ability to support services on low demand routes.
- Vehicle occupation

Social

Costs:

- Health problems due to pollution and waste
- Travel time
- Passenger usage
- Transport diversity
- Traffic services
- Congestion
- Crash Impacts
- Loss of cultural cities due to road infrastructure
- Increase public service Costs
- Maintaining access to resources

Benefits:

- Social inclusion
- Improve mobility and Accessibility
- Easier access to medical access
- Bigger groups movement

Environmental

Costs:

- Road damage (bigger vehicles)
- Air pollution and climate changes
- Noise
- Resource extraction, processing and transport
- Barrier effects
- Water pollution
- Waste
- Aesthetic degradation
- Depriving future generation resources

Benefits:

- Less pollutant then conventional transport bus
- Increasing adherence, reduce congestion and accidents risk

rate.

Figure 2: DRT impacts on costs and benefits (adapted from Litman, 2009).

Further to the internal costs of a traditional transport system, a flexible transportation system has different characteristics and extra operational cost, as depicted in Table 2, concerning some of its operational issues. As referred before, the success of a DRT systems involves the use of ITS and, eventually, a TDC, implying additional costs related to its acquisition (e.g. facilities, hardware and software), maintenance and operation (Mageean and Nelson, 2003).

TDC costs are highly dependent on the level of complexity and cleverness of the system, namely degree of flexibility (time window restrictions of pre-booking; dynamic routing and scheduling) and other functionalities, such as Interactive Voice Response System (IVRS) or Internet booking.

Additionally, operating a flexible transportation system might add extra operational costs whenever high route/schedule flexibility is adopted as a result of longer distances travelled.

On the other hand, savings can be achieved by using smaller vehicles (with lower operational costs) and increasing its occupation rate. A relevant aspect about DRT systems is that they typically use smaller vehicles than the conventional transport, so they tend to produce less pollutant emissions. Additionally, they usually use newer vehicles that have more effective emission control systems (note that most conventional transport operators operating in low-density rural areas make use of their older vehicles).

Furthermore, and one of the most important impacts (positive externalities) of flexible transportation systems, are the social benefits - it is expected that demand for public transport will raise eliminating some of the drawbacks of traditional systems, improving people's mobility and accessibility. Social exclusion, isolation and solitude of special populations (elderly, people with disabilities, inhabitants of remote rural areas) can be significantly reduced.

Other economic benefits referred in the literature are economy growth (promoting new jobs), people willingness to pay for a more reliable and flexible transport and environmental benefits (e.g. reducing individual vehicle circulation and reducing accident risk).

Table 2: Characteristics of DRT systems (adapted from Mageean and Nelson, 2004).

Indicator	Positive outcomes	Negative outcomes	Variable outcomes
Operating costs	Cost savings are made: relative not direct	Direct comparison between sites is difficult	High compared to regular services
		Costs are not covered by fare revenue	Vary between sites Lower in areas of high population density DRT is less likely in deregulated open access markets
TDC cost	Simplification of procedures reduces costs		Level of patronage is critical
	IVRS and Internet booking will help reduce costs Economies of scale possible		Wide variations even in similar market environments STS costs are regarded as a social necessity
Vehicle usage	High load factors on virtual flexible routes Increased since DRT introduced		
Route directness	Small increase in distance travelled		
Passenger usage	Increased since DRT introduced		

Mageean and Nelson (2003) concluded that the use of telematics enhances DRT services, improves cost-effectiveness by reducing expenditure or improving fleet operations; also, it improves social conditions by increasing service levels and access to facilities. However, as stressed by the same authors, the viability of DRT services as a self-supporting system has not yet been demonstrated. The complexity of the viability analysis derives from several issues such as fare levels definition, subsidies and total (buses and TDC) operating costs. Nevertheless, they should be regarded as a vital supplier of services where conventional solutions are unsustainable, e.g. low demand areas and special transport services (Wright *et al.*, 2009).

Others specificities of DRT systems must be taken into account: characteristics of the local population, transport network, the patterns of commuters, and the framework within which the system works, determine the demand and operational scale of system and, as such, can affect performance and efficiency.

Telematics based DRT services, by incorporating individual customer preferences, put forward the opportunity of bigger reliability and punctuality than in conventional public transport services.

DRT services using telematics will promote efficiency and effectives and will assist the action plan of the internalization of the externalities costs.

PERFORMANCE EVALUATION

One of the most important aspects in an investment project is the performance evaluation through the use of indicators or measures. With a performance measure it is possible to monitor the progress of the system towards all goals (Sousa *et al.*, 2005). In a transport system, the use of a set of performance measures aims at providing the organization with the ability to assess the outcome of possible changes implemented by measuring and analyzing a set of engineering and operational attributes (NCHRP, 2006).

Social, environmental and economic impacts are increasingly important aspects for decisions in transport investments. According to NCHRP (2006), there are a set of performance measures that are essential to assess and control a transportation system (see Figure 3):

- Economic development: measure direct and indirect impacts of transport on the development of economy and includes preservation of assets, operation and maintenance and service level;
- Environmental impacts: measures effects on environment.
- Social impacts: measures effects on wider society or on population groups, namely: mobility and accessibility, safety and security.

The adoption of good performance measures is required in any investment project before its implementation, to recognize productive strategies and abandon the unproductive ones.

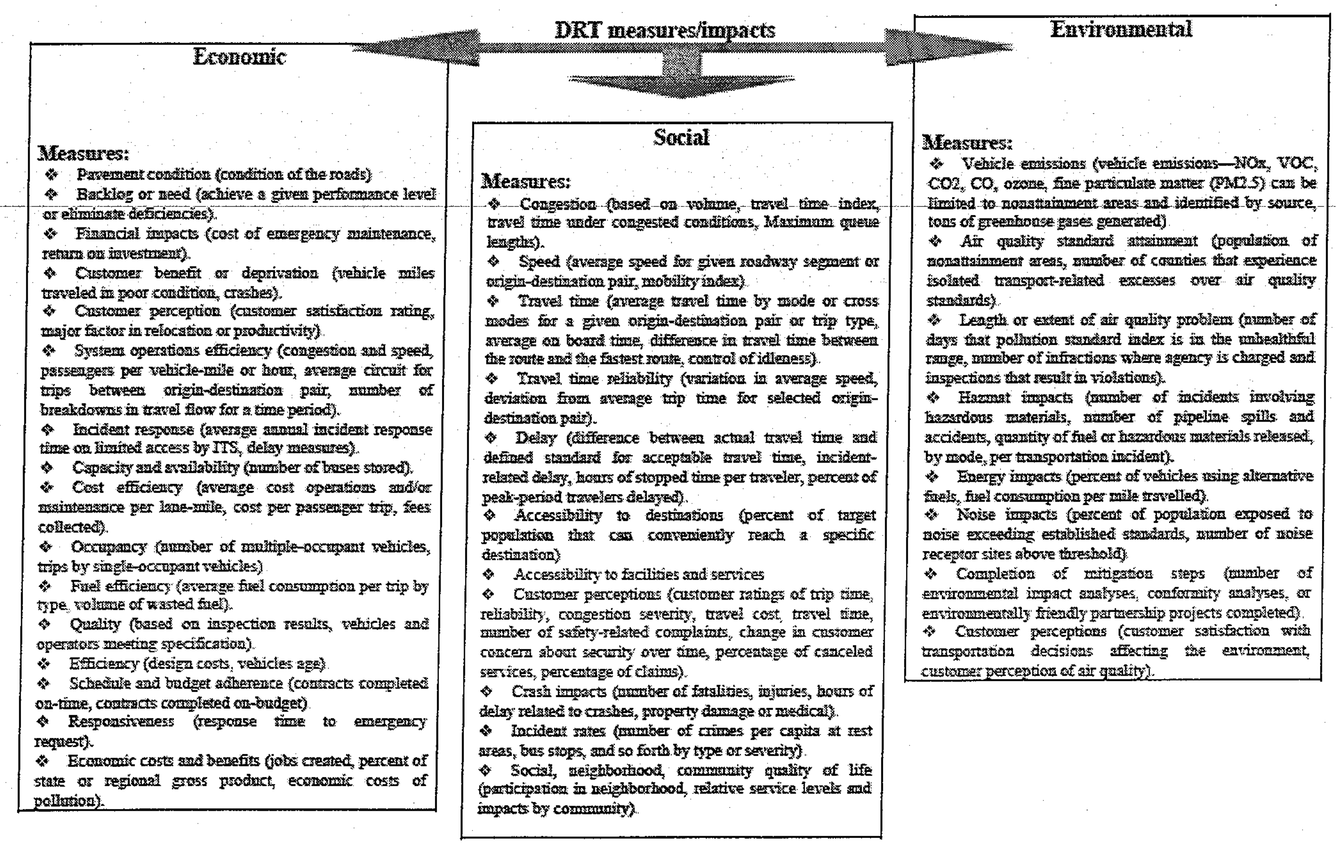

Figure 3: DRT impacts and Measures (adapted from NCHRP, 2006).

CONCLUSIONS AND FUTURE WORK

The objective of this research work was to develop a systematic analysis of the main issues that should addressed when evaluating transport investments, in particular those related to the adoption of flexible transportation systems such as Demand Responsive Transportation (DRT) systems.

Transport systems costs structure were reviewed and discussed and a classification of costs attributes was proposed. The literature reviewed allowed the identification of the complexity of the evaluation process and the lack of comprehensive and satisfactory approaches to the problem.

Specific characteristics of DRT systems were analyzed and the three most relevant impacts that must be considered: economic, social and environmental were considered. A framework of performance indicators was identified as essential to the evaluation process.

Based on the literature review carried out and on the indicators identified, our proposal consists in developing a framework to perform an economic evaluation of such a transportation system at the design phase of the project. 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. The estimating of the impacts of the alternative DRT specifications can be performed by using a computerized simulator that makes the interaction between the demand (customers) and the supply (vehicles and system coordinator) at the individual level thus capturing the proper dynamics of the system.

REFERENCES

AA, Automobile Association, 2002, Petrol-driven vehicles estimated on 14,000 km per year: first 5 years of ownership. In: www.nzaa.co.nz/Online/Issues/May2002/Stories/Motoring/RunningCost.htm. Date: 18 November 2002.

Brake J., Nelson J., Wright S., 2004, "Demand responsive transport: towards the emergence of a new market segment", *Journal of Transport Geography*, 12, pp. 323-337.

Brake J., Nelson J., 2007, "A case study of flexible solutions to transport demand in a deregulated environment", *Journal of Transport Geography*, 15, pp. 262–273.

Emerson J., 2000, "Social return on investment: exploring aspects of value creation in the nonprofit sector", *Social Purpose Enterprises and Venture Philanthropy in the New Millennium*, vol. 2, pp. 131– 173. The Roberts Foundation, San Francisco.

EUL – European Union Legislation, 2011, In: http://europa.eu/legislation_summaries/transport/bodies_objectives/tr0007_en.htm. Date: 15/02/2011.

EUP - European Union Portal, 2011, In: http://europa.eu/pol/trans/index_pt.htm, Date: 15/02/2011

ExternE – Externalities of Energy, 2005, A Research Project of the European Commission, In: http://www.externe.info/. Date: 23/02/2011.

FP - Finance Portal, 2011, In: http://info.portaldasfinancas.gov.pt/pt/informacao_fiscal/codigos_tributarios/bf_rep/bf70.htm. Date:14/02/2011.

Haezendonck E., 2007, "Transport Project Evaluation: Extending the Use of the Social-cost Benefit Approach", Edward Elgar.

Jakob A., Craig J., Fisher G., 2006, "Transport cost analysis: a case study of the total costs of private and public transport in Auckland", *Environmental Science & Policy*, 9, pp. 55-66.

Jakob A., 2003, "Transport Costs Analysis for the Auckland region—Internal and External Cost of Private versus Public Transport", Unpublished MSc thesis, Auckland University, New Zealand.

Litman T., 2007, "You Can Get There from Here: Evaluating Transportation Choice," Transportation Research Record 1756, TRB (www.trb.org), pp. 32-41; at www.vtpi.org/choice.pdf.

Litman T., 2009, "Transportation Cost and Benefit Analysis", Victoria Transport Policy Institute, In: www.vtpi.org/tca/. Date:15/02/2011.

Mageean J., Nelson J., 2003, "The evaluation of demand responsive transport services in Europe", *Journal of Transport Geography*, 11, pp. 255–270.

Mulley C., Nelson J., 2009, "Flexible transport services: A new market opportunity for public transport", *Research in Transportation Economics*, 25, pp. 39-45.

NCHRP, 2006, "Performance Measures and Targets for Transportation Asset Management", USA, Transportation Research Board.

Nelson J., Wright S., Masson B., Ambrosino G., Naniopoulos A., 2010, "Recent developments in Flexible Transport Services", *Research in Transportation Economics*, 29, pp. 243-248.

Nickel J., Ross A., Rhodes D., 2009, "Comparison of Project Evaluation Using Cost-Benefit Analysis and Multi-Attribute Tradespace Exploration in the Transportation Domain", *Second International Symposium on Engineering Systems MIT*, Cambridge, Massachusetts, pp. 15-17.

Quadrifoglio L., Li X., 2009, "A methodology to derive the critical demand density for designing and operating feeder transit services", *Transportation Research Part B: Methodological*, 43, pp. 922-935.

Santos G., Behrendt H., Maconi L., Shirvani T., Teytelboym A., 2010, "Part I: Externalities and economic policies in road transport", Research in Transportation Economics, 28, pp. 2 - 45.

Sousa S., Aspinwall E., Sampaio P., Rodrigues A., 2005, "Performance Measures and Quality Tools in Portuguese Small Medium Enterprises: Survey Results", *Total Quality Management and Business Excellence* 16, pp. 277–307.

Stevens A., 2004, "The application and limitations of cost-benefit assessment (CBA) for intelligent transport systems", *Research in Transportation Economics*, 8, pp. 91-111.

Thomopoulos N., Grant-Muller S., Tight M., 2009, "Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology", *Evaluation and Program Planning*, 32, pp. 351–359.

Venables A., 2007, "Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation", Journal of Transport Economics and Policy, 41(2), pp. 173–188.

Wright S., Nelson J., Cooper J., Murphy S., 2009, "An evaluation of the transport to employment (T2E) scheme in Highland Scotland using social return on investment (SROI)", *Journal of Transport Geography*, 17, pp. 457-467.