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01090 - DECISION-SUPPORT SYSTEMS FOR URBAN MOBILITY

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Abstract. This research seeks to develop a set of instruments specially designed to monitor the evolution of the sustainable urban development in order to keep and renew cities. These instruments are grouped on three main domains: environment, economic, and social. A methodology is presented to compute this set of indicators, based on feasible and comparable data that leads to objective and clear results. This methodology is applied, as a case study, to the Porto city (Portugal) that has recently attained high levels of sustainable development. Public planning policies and private initiatives are analysed, and related to the proposed set of indicators, in order to consolidate an overall methodology for the assessment of sustainable urban development, generally applicable to other urban realities.

Keywords: Mobility; Sustainability; Urban mobility; Urban renewal

1. INTRODUCTION

The research reported in this article intends to relate the urban conservation and renewal of cities to its sustainable mobility. In a world more and more impacted by anthropogenic activities (namely climate change and pollution), it is outstanding that public organizations are endowed with funds and vested with the appropriate means to assess their consequences on citizens' life quality, so that they can trigger improvements in environmental conditions in sustainable ways.

The current research characterizes the concept of "sustainable urban mobility", as found on the relations among sustainability, urban life quality and public transports.

A deep revision is carried out not only in terms of bibliographical background but also through a survey on Portuguese and European Union's documents that emphasize the main goals and strategic orientations to achieve urban sustainability in what particularly involve mobility issues.

This research seeks to develop a set of instruments specially designed to monitor the evolution of the sustainable urban development in order to keep and renew cities. These instruments are grouped on three main domains: environmental, economic, and social. A methodology is presented to compute this set of indicators, based on feasible and comparable data that leads to objective and clear results. This methodology is applied, as a case study, to the Porto city (Portugal) that has recently attained high levels of sustainable development. Public planning policies and private initiatives are analysed, and related to the proposed set of indicators, in order to consolidate an overall methodology for the assessment of sustainable urban development, generally applicable to other urban realities.

A discussion is pursued on the topicality and urgency of these kinds of methodologies and instruments in urban policy definition and implementation, as its application will enable the assessment of urban mobility, as well as the definition of concrete policies aimed at urban sustainability and urban preservation, thus promoting citizens' quality of life.

2. THEORETICAL CONTEXT

The sustainable urban mobility may be defined as the set of transport and circulation policies, means and patterns that fulfil efficient, equitable and inclusive economic, social and environmental needs, in relevant spatial and temporal scales, prioritizing non-motorized and collective modes, and minimizing respective impacts (Brasil, 2004; Extra, 2001).

This concept accrues from the joint consideration of the concepts of mobility and urban sustainability, involving, at the same time, an efficient urban management and the rational use of resources. Within the scope of a sustainable urban development, it strengthens the principles of protection of natural resources within certain pre-settled bounds (observing the natural habitat and minimizing the effects of human activities), and the need to keep the productive capital for future generations, simultaneously assuring a just and equitable access to high levels of quality of life (Costa, 2003; Magagnin and Silva, 2008; Morais, 2012), and good accessibility and mobility conditions (Extra, 2001; WBCSD, 2004).

So a transportation system is sustainable if it fulfils some environmental, social and economic requirements in people and activities' territorial assignment, and effective resource conservation, promoting a sustainable competitiveness (SUMMA, 2004). This system should afford good environmental quality through, namely, noise reduction, use of renewable energies and recycled materials, and through the minimization of land use in activities that potentially endanger health and the environment. It should further be able to promote access to goods, services and resources in order to reduce trips' requirements, through a safe transport of people and goods, thus fostering equity among people, communities and generations. Besides, it should be affordable and efficient, promote economic competitiveness, reduce the demand for road systems, promote more sustainable modes, and hold users accountable for the social and environmental costs accruing from their own transport mode choices (Extra, 2001).

Sustainable urban mobility has been increasing relevant both in literature and in urban management, and underlies the settlement of efficient and dynamic policies aimed at the minimization of negative impacts (Azevedo Filho, 2012; Costa,

2003). It aims, additionally, at managing the transportation system (UNCED, 1992), in order to integrate transport and land use planning; favour the use of public transport and inter-modality; foster the use of non-motorized transport means; manage traffic efficiently and assure the proper maintenance of infrastructure and transport; stimulate the interchange of experiences and good practices among countries, regions, metropolitan areas and places; reduce the consumption of energy and non-renewable resources, observing future needs (UNCED, 1992); improve public health and safety; and ensure sustainable social, economic and environmental policies (Shiller, Brunn and Kenworthy, 2010).

3. EUROPEAN AND PORTUGUESE LEGAL FRAMEWORK

The most relevant European documents that convey the strategic priorities on sustainable urban development are: the Green Book – for a new culture of urban mobility (CCE, 2007); the Action Plan for Urban Mobility (CCE, 2009); The Strategy Europe 2020 for a smart, sustainable and inclusive development; and the White Book: guidebook of the European transportation unique space – Towards a competitive and resource economical transport system (CE, 2011).

The main Portuguese documents that frame sustainable urban mobility are: the Nacional Strategy for Sustainable Development (Mota et al., 2005); the National Program for Land Use Policy; the Transportation Strategic Plan – Sustainable Mobility for horizon 2011-2015; the National Action Plan for Energetic Efficiency; the National Plan for Renewable Energies; and the National Program for Climatic Changes for the period 2013-2020.

A careful survey of these different European and Portuguese documents that frame sustainable urban mobility enable the identification - in most of them - of social goals (urban quality of life, accessibility, safety, health, and smart urban transport systems); environmental goals (environmental concerns; and reduction in fossil fuel use, in emission of toxic gases into the atmosphere, in noise pollution, and in the number of vehicles on roads; incentive to share private cars, to use public transport, more energy-efficient transport means, and park & ride); and economic goals (economic development, decongestion of traffic, parking policy, user/payer principle, and interchange of good practices).

4. INDICATORS OF SUSTAINABLE URBAN MOBILITY

Indicators summarise a great amount of data in parameters, goals and deadlines; disclose the features of a system, organization or policy; show tendencies; and identify weaknesses that require some form of intervention (Costa, 2003; Gudmundsson, 2004). Indicators of sustainable urban mobility may be either qualitative (mainly descriptive and organisational) or quantitative (based on mathematical models, measurable variables, and clear and objective methodologies that support analysis throughout space and time (Martins, 2005). Systems of indicators of sustainable urban mobility support goal settlement, policy definition, and management processes (through the monitoring of actions in order to attain goals, the assessment of their efficiency and economic, social and environmental consequences (Brasil, 2010; Litman, 2009), and the provision of information on planning decisions by different involved stakeholders), and keeps people informed, fostering their civic participation (Cartwright, 2000; Martinez and Leiva, 2003).

Thus indicators should be (Costa, 2008): quantifiable; intelligible; relevant in measuring a certain phenomenon; reliable; and able to provide timely information, anticipating decision and action. They may be used either ex-ante (in problem identification and description, situation diagnosis, and policy proposal), or on going (in order to monitor and assess the performance and the achievement of goals and deadlines).

The number of indicators that enable sustainable mobility goals' fulfilment have increased throughout the last years (Campos and Ramos, 2005; Costa, 2008; Litman, 2009); covering a wide range of definitions, according to the existence and availability of data, and based on different collection methods. This is mainly due to the adoption by developed countries of new technologies that support the measurement of the impacts of motorized mobility on sustainability and on quality of life.

To render operational a system of indicators on sustainable urban mobility, it is first of all necessary the identification of the main economic, social and environmental issues (Gudmundsson, 2004). For each identified category of issues, the indicators that focus on more specific goals should then be defined, in a quantified way. This renders concepts measurable and, as a result, relevant for decision processes (Costa, 2008; Gudmundsson, 2004; TRB, 2008). The subsequent monitoring of performance should further support the inclusion of updated information throughout time, or even the redefinition of goals or deadlines.

Many different international organizations and projects have been proposing systems of indicators of sustainable urban mobility. Such is the case of project SUMMA – Sustainable Mobility, Policy Measures and Assessment (SUMMA, 2004); of Mobility 2030 – the final report of the project on Sustainable Mobility of the World Business Council for Sustainable Development; of the Scientific Forum on transport Forecasts (TRANSFORUM, 2007); and of the project Propolis Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability (Campos and Ramos, 2005; Guarese, 2012; PLUME, 2003).

In Portugal a system of indicators specifically directed towards the study of the sustainable urban mobility haven't turned up so far, despite the existence of many systems to assess urban sustainability that provide statistical data to international bodies, such as the European Agency of the Environment, the Statistics Office of the European Communities (Eurostat), the Organization for Cooperation and Economic Development, and the Organization of the United Nations. The System of

Indicators of Sustainable Development (SIDS) – besides responding to these requirements -, assesses the progress towards sustainability, establishing a close link between the most important levels of national, regional and sectorial strategic decision. The indicators of SIDS pointing at goals of sustainable urban mobility that fit into the goals of the National Strategy for Sustainable Development refer to climate and air, agriculture, nature and biodiversity, land use, noise, health, economy, energy, industry and transport (APA, 2007).

The indicators of sustainable development support the monitoring of goals and deadlines' attainment settled in the National Strategy for Sustainable Development. They were first designed within the scope of the collaboration with the National Statistics Institute and Eurostat, considering the indicators of SIDS Portugal (2007). The indicators with potential interest to monitor the sustainable mobility refer to the settled strategic goals – sustainable growth, global competitiveness and energy efficiency, environmental quality and heritage enhancement, equity, equal opportunities and social cohesion, country's international connectivity, and balanced territorial appreciation – and with the priorities defined within these goals (INE, 2011a; Silva, 2015).

The project ECO XXI, worked out by the Association Blue Flag of Europe acknowledges municipal good practices that strengthen sustainable development, founded on education for sustainability and environmental quality. As far as sustainable mobility is concerned, a marking is assigned to the topics covered by indicators – public transport, accessibility and pedestrian mobility, bicycle mobility, mobility plans and projects, traffic mitigation, and awareness sessions – subdivided into specific punctuations for the indicators connected to each topic.

To sum up, the most recurrent indicators of sustainable urban mobility in European and Portuguese systems mainly group according to its social (accessibility, accidents, equity, quality of service), environmental (air pollution, noise, global warming, use of energy, use of land and transport), and economic perspectives (economic costs, productivity/efficiency, rates, traffic hold-up, displacing time, reliability, and operational costs) (Silva, 2015).

5. URBAN MOBILITY IN PORTO HISTORICAL CENTRE

The city of Porto locates in the Portuguese northern region, by the seaside and near River Douro mouth. It covers a surface of 41,42 Km², holds a resident population of 237 584 inhabitants (INE, 2011b), and is administratively subdivided into seven parishes: Cedofeita, Santo Ildefonso, Sé, Miragaia, S. Nicolau and Vitória; Lordelo do Ouro and Massarelos; Aldoar, Foz do Douro and Nevogilde; Ramalde; Paranhos; Bonfim; and Campanhã.

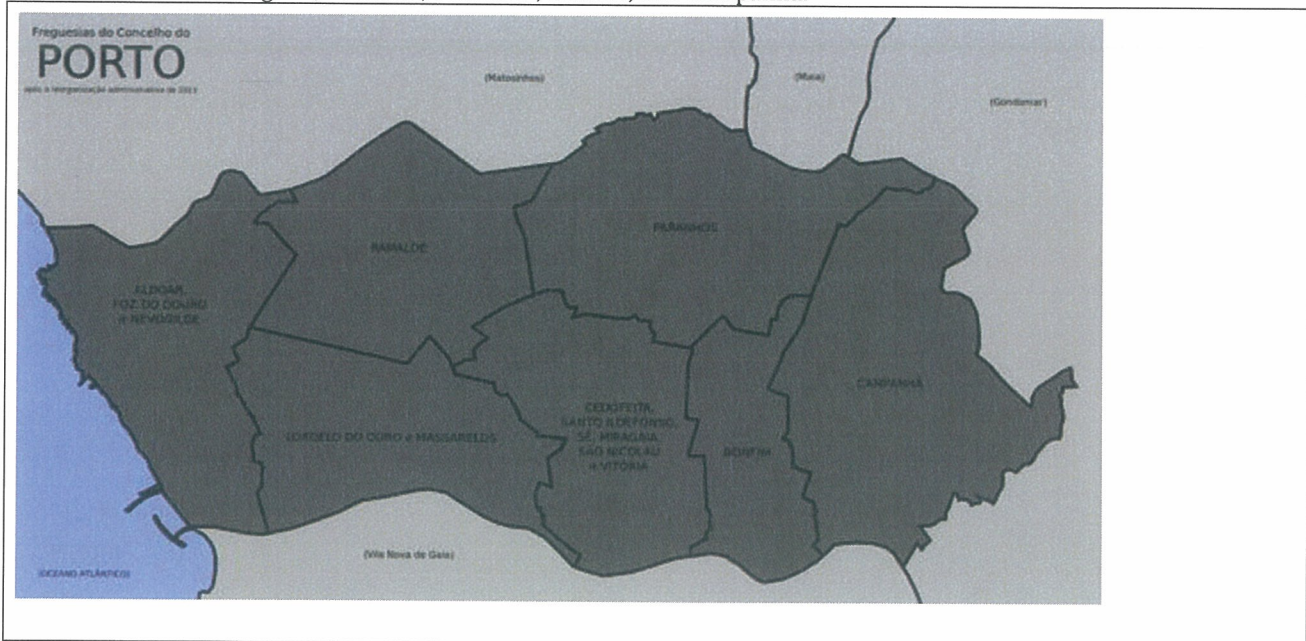


Figure 1. Parishes of Porto city

Source: www.google.com

Porto and the remaining Portuguese cities are linked together through many different infrastructures, such as motorways and railways, Leixões commercial port, and Francisco Sá Carneiro airport. It holds an important logistic area that spans many different public and business services, linked together with the infrastructure. The Porto light underground is also an outstanding public transport means at Porto metropolitan scale.

The report of the Territorial Development Program concerning the Porto metropolitan area (2008) points out that the absence of a national policy of urban integrated development implied many serious consequences for urban mobility. So it may be realised, at the national level, the reduction in cities' competitiveness (with consequent increased investment costs, productivity shrinking and efficiency loss), the aggravation of air pollution (due to congestion in metropolitan areas conveyed by the excess of time wasted in transport, fuel consumed, and hydrocarbon and carbon monoxide produced),

social exclusion (inability of some population groups to access public transport and subsequent access to work, health, education, leisure and social participation), accident rate (expressed through the number of dead and wounded each year), and traffic hold-up. Throughout last years some problems have turned up concerning the traffic conditions in Porto, resulting from the increased displacements of people from the centre to the outskirts within the metropolitan area, and from the increasing motorization rates. Thus new mobility patterns have emerged, featured by longer trips required by urban sprawl and by the attraction exerted by the city over its surrounding urban, metropolitan and regional environment.

The Sociedade de Transportes Coletivos do Porto, S.A. (STCP) – that devotes itself to explore road collective public transport in Porto metropolitan area – harmoniously linked together with the remaining road, rail, and light underground operators (Metro do Porto) – decisively contributes to people’s increased mobility, providing a competitive alternative to private transport, within the scope of economic rationality, engendering environmental and social benefits. The improved mobility conditions in this metropolitan area are definitely strengthened by the light underground that, since its introduction in 2002, has until present carried about 442 million people.

The evolution in the use of different transport modes in Porto city throughout last years express a prevailing and increasing use of private transport in daily displacements (it passed from 42,24% of displacements in 2001 to 54,42% in 2011), with the correspondent reduction in public transport use (in 2001 28,0% of displacements were in bus and 0,01% in tramway, whereas in 2011 17,12% of displacements occurred by bus and 7,53% by tramway or light underground, adding up to 24,65%).

The average length of pendular displacements by employed or student resident population in collective transport amounts to about 31 minutes, whereas the corresponding displacements in private transport last about 19 minutes. Besides, public transport rates are not competitive enough in relation to individual transport (INE, 2011a).

The total number of passengers that use collective transport – bus and light underground – have decreased throughout the last five years. Although the use of light underground has remained stable, the use of bus had a sharp fall.

Table 1. Number of passengers transported in public transports in Porto metropolitan area

Means of transport	2010	2011	2012	2013
Metro do Porto	53,5	55,7	54,5	55,9
STCP	109,2	108,4	93,8	78,7
Total number of passengers (millions)	162,7	164,1	148,3	134,6

Source: Relatório e Contas, 2013; Relatório e Contas, 2013b.

The city of Porto holds the characteristics of a metropolitan centrality, as it embraces significant flows founded on its specialization – in high tertiary activities - in relation to its environment, and due to the fact that its active population mainly lives outside the municipality (about 70%), whereas about 22% of the population that live in Porto city works or studies in a different municipality (INE, 2011b).

The Porto town council and its main collective transport operators – Metro do Porto and STCP – have been taking along last years different initiatives aimed at the consolidation of sustainable urban mobility. All these entities are strongly committed with the economic, social and environmental principles of sustainable development. This is attested through certifications; quality, environment, safety and work health audits; improvements in accessibility conditions for all users; adoption of an including design; and issue of sustainability reports by these stakeholders.

STCP has adopted and implemented a series of initiatives aimed at reducing vehicle pollution emissions, and to improve its users’ transport and mobility conditions. So it has modernized and diversified its fleet (from the whole of about 400 buses of the fleet, 54,5% are moved by natural gas), extending bus corridors, and providing wifi cover inboard buses (using an innovative technology entirely developed in Portugal).

The complementarity among the different transport modes has been assured through the initiative MOVE PORTO, the Park & Ride service, and car sharing. The first one consists in the continuous operation of the underground on Friday, Saturday and holidays’ eve, and in the provision by STCP of eleven lines of night service all week days, thus promoting mobility, especially in most nightly crowded places. The second one enables the joint use of private and collective transport in users’ routes, parking at low cost at the outskirts and travelling there in collective transport. In Porto city 32 car parks (representing over 3400 parking spaces) jointed this initiative. The third one is a system of urban mobility that enables the shared use of a certain vehicle by multiple users, being the service paid according to the length of the displacement, the distance covered, and the kind of selected vehicle. This concept – that contributes to the rebalancing of transport modes, and ensures that part of urban displacements don’t exert negative environmental impacts – renders the private transport a complement – and no more a rival – of public transport.

Concerns to keep users informed in real time have been ensured through the integration among three initiatives: the smart panels, the MOVE-ME service and the project “Future Cities”. So, LCD screens provide real time information on public transport timetables near respective stops. The service MOVE-ME is an application for smartphone that keep users informed in real time on the timetables, delays, alternatives of different public operators, as well as distances to walk, thus helping users to plan and optimize their displacements. The project “Future Cities”, by its turn, consists in using Porto as a living laboratory at urban scale, where researchers, firms and start-ups may test technologies, services and

products aimed at smart cities (especially concerning smart transport and sustainable mobility systems). London, Stockholm and Paris also joined this project (Relatório e Contas, 2013a).

The awareness of sustainable urban mobility issues has also been reinforced through different initiatives, such as the European Mobility Week, and the project CIVITAS ELAN. The former (adopted by over 80 cities and regions in 30 countries) stand up for public transport as a driving force for sustainable development, thus definitely contributing to economic development, job creation, social inclusion, pollution control, life quality improvement, safety, worth creation, and reduction of energy costs (Relatório e Contas, 2013a). This specific week triggers a reflection on how urban quality of life can be enhanced through public space requalification (shaping traffic in road networks), favouring smooth transport modes (on foot or by bicycle) and collective transport, at the expense of the use of private transport. Some permanent measures already implemented in this scope consist in the creation or increase in pedestrian roads, improvement and extension of public transport networks (new stops, lines and/or timetables), use of new technologies to improve public transport, and new traffic and parking rules. The project CIVITAS ELAN aims at promoting the required changes in order to warrant all citizens high-quality mobility, shrinking respective environmental impact, namely through the minimization of road traffic effects, and through changes in peoples' travelling habits (directing them to more sustainable modes).

Porto town council has significantly contributed to sustainable mobility, namely through the conversion of certain roads to pedestrian use, and through parking management. Thus, some roads located in the historical centre have become pedestrian – Rua das Flores, Rua de Afonso Martins Alho, Rua do Ferraz, Rua da Ponte Nova, Rua de Sousa Viterbo, Rua de Trás, Rua dos Caldeireiros, Rua Estreita dos Lóios, and Largos dos Lóios and de S. Domingos. This fosters trade as well as the use of public transport.



Figure 2. Rua das Flores and Largo dos Loios

Source: www.google.com.

In the historical centre the high traffic has been mitigated through the application of parking rates, what increases its rotation and availability - shaping attitudes in order to reduce the use of private car -, and through the development of the predisposition to use public transport means. The government is also enhancing the use of electric vehicles, namely exempting users from taxes.

6. SYSTEM OF INDICATORS OF SUSTAINABLE URBAN MOBILITY IN PORTO HISTORICAL CENTRE

In the current research is proposed the development of a system of indicators specifically designed to measure and monitor sustainable mobility, focused on the quantification and monitoring of economic, social and environmental impacts (which are the three main sustainability dimensions), applied to Porto city.

Thus, for the environmental dimension the topics of global warming (indicator: emission of greenhouse effect gas), atmospheric pollution (indicator: number of days with good or very good air quality index), and resource consumption (indicators: evolution in energy consumption by the transport sector, and number of buses that use alternative energies) are proposed. In the economic dimension are proposed the topics of accessibility (indicators: length of displacement out of rush hour, and average speed of public transport), traffic hold-up (indicator: length of displacement by mode in rush hour), and personal mobility (indicators: percentage of smart transport means in relation to the total number of transports used in daily population displacements, and percentage of population that uses public transport). The selected topics in the social dimension refer to health (indicators: number of road accidents with dead and serious wounded, population exposed to atmospheric pollution, and population overexposed to high noise levels), accessibility (indicators: percentage of use of cycle lanes, and relation between the number of priced parking spaces and the number of Park & Ride free parking spaces), and community issues (indicator: specific measures to promote public transport, especially smart modes) (Silva, 2015).

Considering the previous nonexistence in Portugal of a system of indicators resembling this one, it is necessary first of all, to carry out a survey on the current situation (expressed in numbers, percentages, quotients or ratios), whose values will stand as reference for monitoring procedures. A periodical assessment of these indicators will support timely interventions, decision realignment, or even goal redefinition, if necessary.

7. CONCLUSIONS

Despite the goals of sustainable urban mobility are clearly settled in European and Portuguese documents, and the existence of many concrete governmental, municipal, or private initiatives, a clear and straight system to quantify and monitor the evolution of their performance towards goal fulfilment hasn't yet been developed and implemented in Portugal.

The development of a system of indicators of sustainable urban mobility – based on the diagnosis of the current situation, and on the goals of promoting sustainability, urban quality of life, and sustainable urban mobility – is more and more essential to support policy sketch and implementation of efficient planning and effective mobility management decisions. It further enables the monitoring of the evolving performance of these measures, as well as the assessment of the adequacy of the proposed measures to pre-settled goals.

Besides, the diffusion of the results of the application of these indicators throughout the whole population strengthens the awareness of the importance of decisions and behaviours pointed to sustainability, as it enables the close monitoring of the implemented actions, and involves citizens in sustainability and urban quality of life.

The joint efficiency of these indicators may be even improved through a better adjustment to needs, namely through the introduction of new or updated information that supports on-going development and monitoring of action plans.

This system of indicators to monitor sustainable urban mobility may be extended to other cities, in different contexts and urban realities, and may be further used as a platform to interchange good ideas and practices among cities.

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