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Environmental sustainability of urban traffic: the European backdrop and the Portuguese case

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Abstract

The impacts of urban traffic are considerable in number and diversity and they are typically categorized according to the 3Es of sustainability: social Equity, Economic efficiency, and Environmental responsibility. For a truly sustainable urban traffic system all of these interrelated dimensions should be taken into account but as a result of the enormous attention that has been devoted to the environmental aspect ("at the agenda" of the modern world), this work focus the synergies between the urban traffic system and the related environmental system (in particular, the air quality case). The European backdrop is described, in terms of milestones and most relevant directives and guidelines and then, the Portuguese case is explored in more detail.

In order to achieve a sustainable traffic & environment system is then proposed a set of Intelligent measures (based on Intelligent Transportation Systems' applications and technologies) for urban green transportation.

This paper intends to present a review work on the traffic & environment subject and to catalog some intelligent measures to help the local authorities to improve the traffic & environment system of their urban jurisdictions. Supporting locally developed tailor made solutions based on accurate data/models and enforcing public consultation processes and citizens' active participation are critical aspects to make the city a better place to live, work and play. These actions require a comprehensive modelling & simulation platform (based on a GIS) able to model the traffic and environment interactions and able to evaluate their impacts on the society.

Keywords: air quality, Intelligent Transportation Systems, sustainability, urban traffic.

1 Urban Traffic & Environment

The urban traffic system is typically evaluated by its performance, its impacts, and the costs incurred in its construction, utilization and maintenance. This work is dedicated to the adverse impacts of the urban traffic system on the surrounding environment. The case of the air pollution is emphasized since it is probably the most prominent and the most experienced by the urban citizens.

The contemporary challenge of the urban traffic system is more related with the "green management" and a qualitative improvement (through real time personalized travel services) of the available network and constituent entities than with the expansion of the network (prohibitive due to territorial, financial and environmental constraints) (Ramos, 2011). These concerns are reflected in the objectives of the modern Intelligent Transportation Systems (ITS) initiatives and are supported by an integrated operation of wireless communications, control and electronics technologies which are implanted in the infrastructure, vehicles, and users. As Tuominen and Ahlqvist (2010) state, by 2025-2050, the transportation system will be "a global system or a grid that functions and constantly communicates at every level: man-to-man, man-to-machine, and machine-to-machine".

The ITS encompass the three major elements of the transportation system namely, the infrastructure, the vehicles, and the users. The computing, information and communication technologies are coupled to these elements. Typically, the ITS are characterized along two dimensions: the functional categories and the user services. The general ITS subsystems or functional categories, based on the primary functional intent or application, include the ATMS (Advanced Traffic Management Systems), the ATIS (Advanced

Traveler Information Systems), the AVCSS (Advanced Vehicle Control and Safety Systems), the APTS (Advanced Public Transportation Systems), the CVO (Commercial Vehicle Operations), the EMS (Emergency Management Systems), and the EPS & ETC (Electronic Payment Systems & Electronic Toll Collection).

Each of these functional categories includes a series of user services, such as: i) *ATMS* (Traffic Management Centers (TMC), ramp metering, adaptive traffic signal control, Variable Message Signs (VMS), HOT lanes), ii) *ATIS* (trip planning, location, route selection and guidance, en-route driver information, parking availability and reservation), iii) *AVCSS* (Intelligent Speed Adaptation (ISA), collision warning/avoidance systems, vision enhancement), iv) *APTS* (Automatic Vehicle Location (AVL), smart cards, Demand Responsive Transport (DRT), bus dedicated lanes, pre trip and en-route multi modal travel information), v) *CVO* (vehicle scheduling and dispatching, weight-in-motion, real time shipment status, monitoring hazardous materials cargo), vi) *EMS* (incident detection, emergency vehicle management, emergency notification and personal security), and vii) *EPS & ETC* (electronic toll collection, electronic road pricing, Automatic Vehicle Identification (AVI), variable parking fees, Vehicle Miles Travelled (VMT) fee system).

The technologies associated with these functional categories and user services are diverse, at constant evolution, and can be considered as the basis that provides intelligence (the "I") to the transportation system. In general, they can be accommodated into three major categories: i) Sensing/Surveillance (for example, GPS, probe vehicles, inductive loop detectors, radar and laser detectors, closed circuit TV cameras), ii) Communications (for example, dedicated short range communications, wireless networks, mobile telephony technology, digital broadcasting), and iii) Information/Control (for example, Internet, Geographical Information Systems, automatic passenger counter, ramp meters, computer controlled traffic signal systems, license plate recognition systems). The integrated utilization of these functions, services and technologies (or ITS), in a real time basis, will contribute to more efficient, safety and environmental friendly urban transport networks.

The impacts of the urban traffic system are considerable in number and diversity. Normally, they are categorized according to the definition of sustainable transportation provided by the Council of Transport Ministers of the European Union and the Centre for Sustainable Transportation in Toronto (EU/CST definition) that considers the social/cultural, the economical, and the environmental dimensions. They are obviously interrelated and must be all taken into account for a truly holistic development of a sustainable transportation system but, due to the enormous attention that has been dedicated to the environmental dimension of sustainability, it was decided to accentuate this aspect. The traffic related environmental dimension, which is probably the most perceptible one, is "at the agenda" of the modern world being a priority in the political scene.

People like cars because they provide transportation flexibility, they are often (not always) the fastest mode to reach a destination, they are private, they reflect a given position in society, and because people simply enjoy the sensation of driving (Sussman, 2006). Frequently, the most important Level of Service (LoS) variables for urban travelers, such as travel time, reliability, cost, waiting time, availability, comfort, and safety are "fulfilled" by the car. This significant utilization of private vehicles, allied to the growing mobility needs of modern societies, is causing notable congestion problems concentrated in and around cities where, according to Banister (2010), approximately 80% of the world's population will live by 2030. As a result, the transportation sector is becoming increasingly linked to the environmental aspect (Rodrigue and Comtois, 2009).

The environmental damages of this urban traffic congestion are quite dramatic (Eriksson et al., 2008) and are reflected on the air pollution, on the climate change, on the energy consumption, on the noise levels and vibration, on the land take and urban sprawl, and on the road accidents. The impacts on the environment are not just due to the vehicles' travel activity. In fact, the construction and maintenance of the road infrastructure, the vehicles' manufacturing, the vehicles' maintenance, and the vehicles' disposal are transportation related activities that may cause severe environmental damages. The air pollution is probably one of the most prominent cases and the most experienced by the urban citizens thus, it will be highlighted along this work.

2 European Backdrop and Portuguese Case

In the following paragraphs it will be provided a description of the current European context and the Portuguese case, in particular, in terms of the major milestones, directives and practices concerning the deployment of ITS and the evaluation of the environmental impacts (air quality) of the urban traffic.

2.1 Intelligent Transportation Systems

The first works on ITS are assigned to U.S.A., Europe and Japan. Today, the ITS are spread through a considerable number of nations and countries.

Japan, South Korea and Singapore are becoming the world leaders in what concerns ITS national relevance, deployment, and applications' maturity (Ezell, 2010). In these countries, where the major goal is to provide real time traffic information on major urban expressways and arterials, the market penetration in ATMS, ATIS, APTS, and ETC applications has been prominent (Wu and Lee, 2007). The commitment and investment of the government and national authorities, and the synergies between public and private actors have been critical factors to achieve the leadership in the field. In the United States, the leader of ITS technologies in the 1990's (with the GPS and the first generation of telematic systems), the adoption and deployment of ITS was not as successful as in the Asiatic countries. The ITS in U.S.A tend to be sporadic, isolated and not connected into a national integrated system.

The European case is not so vibrant as the Asiatic but, the European Union (EU) has been making, since 2006, considerable efforts to create a dynamic knowledge-based economy and an integrated vision for the information space. These efforts are also reflected in the transportation field, being the ITS one of the major applications of information and communication technologies. This vision and leadership is crucial for the development of the field but, by this time, there is still a lack of effective implementation. The majority of ITS applications that have been developed, since the 1980s, in areas such as traffic congestion, clean transport, and road safety, are stand alone systems that are neither integrated nor interoperable (like a "patchwork" of applications and services). Furthermore, the urban dimension asymmetries within European countries call for appropriate ITS solutions integrated in an overall framework but compatible with the city size.

The European Commission (EC) has been underlying the relevance of ITS since 2001 when, with the White Paper on *European transport policy for 2010: time to decide*, the potential of ITS to provide solutions for the 21st century urban transportation system was manifestly emphasized. In its mid-term review *Keep Europe Moving: Sustainable mobility for our continent*, the agenda was renewed and, although following the main line of the White Paper, the concept of co-modality was underlined, given more importance to the efficient combination of the different modes instead of alternatives to the car.

In 2008 the EC turned clear that the acceptance and market penetration of these intelligent novel applications and services was still low and, consequently, launched an *Action Plan on Intelligent Transport Systems for Road Transport*. This action plan aimed to accelerate and coordinate the deployment of ITS in road transport, in order to develop a more green, efficient, and safety transportation. This action plan was developed with the support of a wide consultation of stakeholders that enabled the identification of needs and priority issues. The majority of the stakeholders reveal that, for example, the deployment of ITS was slower than expected due to the lack of full coverage, consistent deployment and low penetration rates derived from too high costs for the public authorities.

With this information, the *Action Plan* suggested six priority areas where mature and interoperable ITS applications can be deployed in the short to medium-term (until 2012-2014). They are (European Communities, 2008): a) optimal use of road, traffic and travel data (e.g., provision of real time traffic and travel information), b) continuity of traffic and freight management ITS services on European transport corridors and in conurbations, c) road safety and security (e.g., deployment of advanced driver assistance systems), d) integration of the vehicle into the transport infrastructure (e.g., adoption of an open in-vehicle platform architecture for the provision of ITS services and applications), e) data security and

protection, and liability issues, and f) European ITS cooperation and coordination (e.g., proposal for an ITS European legal framework, development of a decision support toolkit for ITS investment decisions).

The actual initiatives taken by the EC comprise, for example, the Trans-European Transport Network Programme TEN-T, the GALILEO deployment, the eSafety project, the i2010 initiative on Intelligent Cars, the eCall project, and the 7th Framework Programme for Research and Technological Development (more details on each of these initiatives and related projects can be found at the website of the EC). The ERTICO European association for ITS has been actively working with the EC support in the R&D of intelligent initiatives for Cooperative mobility, Safety mobility, Info mobility, and Eco mobility.

Regarding the intelligent urban mobility thematic, the EC launched a broad public consultation in 2007, involving the main stakeholders on urban mobility, gathering a consensus on the lack of efficient management of urban mobility, with ITS solutions underexploited or developed without due attention to interoperability, and on the need to establish a framework for ITS deployment in EU cities.

As a result, the development of a sustainable urban mobility policy is a priority for world leaders, national governors and local authorities and the EC has been strengthen this preoccupation through the adoption of the *Thematic Strategy on the Urban Environment* in the 6th Environment Action Programme 2002-2012, the publication of the Green Paper *Towards a new culture for urban mobility* and the promotion of several initiatives like the European Mobility Week, the SMILE (The Gateway to Sustainable Mobility), the INSPIRE (Infrastructure for Spatial Information in Europe), and the CIVITAS (Cleaner and better transport in cities: CIty VITAlity Sustainability). All these plans and programmes recognize the car monopoly problem and the related environmental degradation, and identify the urban areas as the places that can significantly contribute to accomplish the EU policy objectives in the area of sustainable transportation. It is also highlighted the imperative responsibility of local authorities in the evaluation and enhancement of the environmental performance of their cities.

The measures of this strategy, invoked as *Sustainable Urban Transport Plans* (SUTPs), intend to promote urban transportation systems more fluid, green, smart, accessible, and safe and are diverse: encouraging co-modality, and walking and cycling, promoting flexible, affordable and high quality public transport, encouraging car sharing and car pooling, endorsing urban charge schemes, promoting the development of clean, energy efficient transport technologies and alternative fuels, etc.

Besides the EU networking support to improve and share knowledge between Member States, and the efforts to develop significant urban mobility initiatives and integrated databases, there are also common financial resources to assist national and local governors. They include, for example, the European Regional Development Fund and the Cohesion Fund that will contribute to almost 8 billion Euros for urban transportation during the period 2007-2013, the European Investment Bank that provides something like 2.5 billion Euros per year for urban transportation projects, the Intelligent Energy Europe programme, the CIVITAS initiative, and the 7th Framework Programme (FP7) for research and technological development.

In 2009, to encourage this development, the EC launched the *Action Plan for Urban Mobility* that proposes twenty measures to encourage and help local, regional and national authorities in achieving their goals for sustainable urban mobility. This action plan, for the next four years, constitutes the first comprehensive support package in the field of sustainable urban mobility. The Action 20 refers to ITS for Urban Mobility and aims to complement the previously mentioned *ITS Action Plan*. The target goal is to develop an Urban ITS Platform, multi modal and broad in nature that can act as a guide to deploy ITS solutions on urban environments.

The main barriers for ITS deployment are more organizational and institutional relying on the complexity of the urban transportation system with shared responsibilities across different stakeholders, the lack of "political will" and culture of ITS use, the variability in city size claiming for adjusted solutions, the lack of ITS expertise at the city level, the modal tension (mainly, car versus public transport), and the lack of interoperability and standards.

In Portugal, the ITS initiatives follow the same patchwork pattern that has been observed in the rest of Europe, with an obvious lack of institutional interest in the field.

The National Strategic Reference Framework (QREN, 2007-2013), supported by the Structural Funds and the Cohesion Fund, provides three Thematic Operational Programmes and several Regional Operational Programmes which aim to qualify people and the national territory. The transportation field is obviously a strategic area involved in these programmes, including a particular regulation for Mobility. This regulation involves, as eligible actions, the development of transportation coordination centers, the promotion of sustainable mobility actions and alternative modes of transportation, the development of innovative solutions for public transportation, and the deployment of intelligent systems for passengers and drivers' information, among others.

The central administration body responsible for the coordination of inland transport with jurisdiction over the national territory IMTT (*Instituto da Mobilidade e dos Transportes Terrestres*), under the responsibility of the MOPTC (*Ministério das Obras Públicas, Transportes e Comunicações*) is, since 2009, a member of the European Platform for Mobility Management (EPOMM) (dedicated to the promotion and development of the European Mobility Management). Within this platform, the IMTT aims to develop a network for managing the mobility (CIDADES MÓVEIS, launched in April 2010) supported by the exchange of key information and knowledge between the involved European cities.

The IMTT had established, in January 2010, the priorities of Portugal in the Urban Transportation field taking as reference the *European Action Plan for Urban Mobility*. The priorities include fostering the adoption of SUTPs, inciting eco driving habits, and analyzing financing sources. The development of IC Technologies for ITS is also a strategic concern but, unfortunately, without proper emphasis. In April 2010, the IMTT recognized the nonexistence of a coherent conceptual and operational framework devoted to this set of priorities and announced the *Mobility Package* which is a national strategy for mobility. This package includes a set of national directives (e.g., to ensure accessibility for all citizens, to reduce the negative environmental impacts of urban mobility, to promote the rational utilization of motorized vehicles, to improve the information about transportation and urban mobility, to involve the public on the decision processes), a guide for the elaboration of Mobility and Transportation Plans directed to the municipalities, a set of thematic fliers on sustainable mobility solutions (e.g., demand responsive transportation, car sharing), a collection of technical brochures on methodologies and technical tools for mobility solutions (e.g., Origin/Destination surveys, traffic counts), and a guide for the elaboration of enterprise and services plans.

At the municipal level, the CIVITAS PLUS Projects (co-funded by the EU, from 2008 to 2012) are by now in intense activity. The group includes different target projects where are included some Portuguese cities (e.g., the CIVITAS ELAN project with the partner city of Oporto, the CIVITAS MODERN project with the partner city of Coimbra). A brief overview of the Portuguese medium size municipalities' websites reveals that only some of them display a section dedicated to Mobility describing the different sustainable mobility projects that the municipality is promoting (e.g., the LifeCycle project in Aveiro, the Bus Blue Line in Bragança and Viseu). They also display insipient Geographical Information Systems (GIS) services that enable the interactive search of geo referenced information mostly related with road infrastructures and parking areas. These websites are considerably different and puzzled with a lack of clear and relevant information concerning the mobility issues.

This fragmented pattern reflects, at some degree, the multifaceted problem of the Portuguese jurisdiction/organization associated to a lack of guidance strategies and coordinated policies. The municipalities are under the jurisdiction of Metropolitan Areas (AMTL and AMTP, for Lisboa and Porto, respectively) and/or Regional Authorities (CCDRs, *Comissões de Coordenação e Desenvolvimento Regional*, based on the statistical territorial units NUTS II) that are under the jurisdiction of the Central Government (MOPTC, MAOTDR, IMTT and INIR (*Instituto de Infra-Estruturas Rodoviárias*)) that manages the EU structural funds and must follow the EU directives. According to Viegas (2009), the European and national integrative guidance, strategic framework, and support are vital to the development of sustainable urban

mobility solutions but, it is the municipality that has to develop its own mobility strategies and plans and then engage the regional and national authorities in that tailored plans.

In terms of R&D and education, the country has been significantly active with several research projects approved by the Foundation for Science and Technology (FCT) in the "Engineering Systems – Transport" track, with the post graduate courses in ITS offered by the MIT Portugal Program, and with the research projects being developed under this conjoint Program.

The ITS deployments like advanced traffic monitoring systems, highway management systems, electronic toll collection systems, and intermodal traveler information systems are, for the Portuguese case, relatively scarce and, usually, limited to major urban centers. The medium size municipalities, which are spread over a considerable part of the territory, are implementing some piecewise intelligent solutions, yet with a clear lack of integrated guidance and support.

Probably, the most famous ITS in Portugal is the system *Via Verde* that is a national system for electronic toll collection, using RFID technology. Since 2002, the system has been enlarged to allow the electronic payment at fuelling stations and parking areas, and the access to restricted historic zones in Lisbon. The website from *Estradas de Portugal* displays, to the public, a traffic monitoring system supported by cameras and sensors installed along the major arterials of metropolitan areas and along national highways, a system of road incidents' alert, and a route planner tool. The Advanced Traffic Management Centre at *Vasco da Gama* bridge is another example of ITS.

The national mass transit companies like Carris and STCP provide the general public with several Intelligent APTS that are strongly supported by AVL systems that enable GPS-based fleet location. The electronic panels at bus stops that display the "next bus" arrival time, the sms services to inform the public about the waiting times at given bus stops, the contact and contactless Smart Cards for "virtual" payment and multimodal travel, and the route planning services with public transportation are well known examples of these intelligent services. The ITS car sharing initiatives are also intelligent solutions supported by national public transportation companies and private business companies (e.g., Mob Carsharing from Carris, Citizenn.com from Transdev). The private companies Advantis, Critical, Dynasys, Efacec, Link, Makewise, NEC, OPT, SolTráfego, and TIS are examples of ITS stakeholders that contribute with their technical products and consulting services for Portuguese intelligent urban road solutions.

The cooperation between all the stakeholders of the urban transportation system like national, regional and local authorities, citizens and users, public transportation organizations, employers and employees associations, urban transportation industries, universities, and research agencies is decisive to achieve the goals of sustainability. Furthermore, the public involvement and participation in the decision processes is critical to guarantee their commitment with the mobility system and to encourage effective change in their behaviors. It is probably the best option to attain well succeed plans of action. The public participation is becoming a more relevant issue in modern societies being one of the directives of the national *Mobility Package*.

2.2 Environmental Impacts – Air Quality

The *Air Quality Framework Directive*, adopted in 1996 (with following revisions known as "air quality daughter directives"), the *Clean Air for Europe* (CAFE) Programme, launched in 2001, the following *Thematic Strategy on Air Pollution*, adopted in 2005 under the 6th Environment Action Programme, and the *EU Air Quality Directive*, released in 2008, represent the most emblematic EC milestones regarding the air quality subject. These rules provide target values for the major air pollutants and force the Member States and their local authorities to monitor air quality, to provide information to the public, to introduce improvement plans and programmes in order to meet the specified criteria, and to develop better systems for gathering information, modelling and forecasting. The main underlying objective is to deliver cleaner air raising the overall quality of life for every European, with particular concern for vulnerable groups such as children, elderly people, and pregnant women. The air quality directives are aligned with the guidelines provided by the World Health Organization (WHO).

The EU air quality concerns cannot be dissociated from the other European policy intervention areas like the vehicle emissions, the alternative fuels and the fuel quality, and the inspection and maintenance programmes for vehicles. Regarding the first aspect, the stricter longer term EURO 6 standard is scheduled to enter into force in January 2014 and will mainly reduce the emissions of NO_x from diesel cars. The Renewable Energy Directive aims to increase the share of renewables in energy use to 20%, by 2020, and the share of biofuels to 10%. The Fuel Quality Directive, from 2009, sets the technical specifications for the content of gasoline and diesel fuels in order to reduce the emission of key air pollutants and to achieve the GHG reduction target of 20% (by 2020).

The directives and guidelines for air quality have also significant synergies with the strategies and rules for the Urban Environment. As stated in the *Thematic Strategy on the Urban Environment*, from 2006, "Four out of five European citizens live in urban areas, and their quality of life is directly influenced by the state of the urban environment". In line with the 6th EAP, the Strategy encourages the Member States and the local authorities to adopt more integrated approaches to manage the urban space, improving the quality of the urban environment, making cities more attractive and healthier places to live, and reducing the adverse environmental impacts of urban metabolism. The *European Action Plan for Mobility*, from 2009, proposes twenty measures for the effective achievement of sustainable urban mobility, mentioning the critical role of ITS for that purpose.

Despite the efforts of the EU and Member States to develop greener urban spaces, and the improvements that have been achieved in the last decades (mainly through fuel quality improvements, more efficient engine technologies, and development of cleaner fuels), the growth of transport, the increasing number of diesel cars on the market (when compared to gasoline engines, they emit less CO_2 but they may lead to an increase in the PM emissions), the large number of short trips, and the current traffic congestion may offset the benefits derived from those improvements. Based on several epidemiological and toxicological studies, the latest version of the *Air Quality Guidelines*, from the WHO, recommends target values for the main air pollutants. These values aim to support the action of policy makers and public authorities in order to establish long term sustainable actions to protect the population health.

The *EU Air Quality Directive*, from 2008, also defines that Member States should divide their territories into a number of air quality management zones and agglomerations reflecting the population density. For each of the defined areas it is requested to assess air quality using measurements, modelling, or other empirical techniques. Whenever possible, modelling techniques should be used to enable point data to be analyzed in terms of geographical distribution of concentration. When the air quality is good it should be maintained or improved. When pollutant levels are elevated, they must prepare plans and programmes to comply with air quality legislation. They are also forced to inform the public and warning particularly sensitive population groups regarding poor air quality episodes (EEA, 2010).

For the Portuguese case, the national entity in charge of these matters is the Portuguese Environment Agency (*Agência Portuguesa do Ambiente* - APA), under the jurisdiction of the *Ministério do Ambiente e do Ordenamento do Território*. The agglomerations are characterized by a population in excess of 250 000 inhabitants or by a density greater than 500 inhabitants/km^2 but with a population not inferior to 50 000 inhabitants. The monitoring stations (which were, for the year of 2010, 72) are installed according to population and exceedences numbers, and are classified according to the type of area where they are located (urban, suburban, and rural) and the type of emissions source that determines the pollutant levels at the station (traffic, industrial, and background). The majority of traffic stations is located in the more populated agglomerations of Lisboa Norte and Porto Litoral.

A recent study performed by APA revealed that the most preoccupant levels of pollutants were observed for PM_{10} and O_3, followed by NO_2 in the agglomerations of AML Norte and Porto Litoral. The exceedences for the daily and annual limit values of PM_{10} occurred in several agglomerations (e.g., Vale do Ave, Porto Litoral, Aveiro/Ílhavo, AML Norte, Setúbal) while the exceedences for the target value and long term objectives of O_3 were generalized through the territory.

In order to establish a national information system for air quality, the APA has developed a national online database (QualAr) that makes public the data from each monitoring station. It is also provided a daily Air Quality Index (IQAr) for each zone and agglomeration. The Air Quality Index is an important informative tool that aggregates information on different pollutants and provides a simple and clear message for the general public. The computed values are compared with a set of concentration intervals associated with a 5 grade colored scale, and the pollutant(s) with higher concentrations dictate(s) the final color of the Index (from green - Very Good to red - Bad). For example, the red Index suggests that every adult should avoid open air exercise and the sensitive groups (children, elderly, and individuals with respiratory problems) should stay at home with closed windows. The Agency also offers, since 2006, an air quality forecasting system (PrevQualAr) that provides a daily forecast for the pollutants that are exceeded more frequently and that are considered to be more damaging to human health (PM and O_3).

This air quality information is only available for the zones/agglomerations that have monitoring stations. For the particular case of traffic monitoring stations, the air quality data is restricted to an area on the proximity of that station. The mass emission rates are averaged to form hourly or daily mean values. For example, the medium size city of Aveiro, belonging to the agglomeration Aveiro/Ílhavo, has just one urban traffic monitoring station and it is quite evident that the city has other traffic hot spots. The installation and maintenance costs of these facilities is expensive and is not a feasible option for the majority of Portuguese municipalities. There exist other roadside instruments to measure the emissions from a specific vehicle as it passes or on board air quality monitoring vehicles that measure data directly from real world conditions (e.g., SNIF AirLab mobile laboratory from *Universidade Nova de Lisboa*) but, once again, these monitoring techniques are expensive and impractical for widespread utilization.

Furthermore, without a modelling basis it is not possible to test ITS strategies and evaluate their environmental impacts, before to implement the adequate traffic solutions. Whenever possible, the combination of monitoring & modelling techniques offers the best approach to tackle the urban environmental assessment problem, enabling the development of simulation models and forecasting analysis.

3 Intelligent Measures for Urban Green Transportation

The traffic related environmental impacts are increasingly relevant in the contemporary discussion of sustainable transportation and urban livability. The estimation of the urban traffic contributions for air quality are particularly important to evaluate pollution reduction measures (e.g., dynamic speed limits, VMS, ramp metering) and to implement them appropriately (Smit et al., 2010). Furthermore, to keep the citizens informed and vigilant is vital to their well being and to achieve some behavioral changes.

The primary studies in the field of transportation have emphasized the congestion mitigation but, the present day challenges claim for an emphasis on environmental impacts reduction (mainly, air quality, noise and fuel consumption). The measures to reduce congestion and the measures to reduce traffic emissions are usually different and can be, sometimes, conflicting. For example, the settlement of dedicated bus lanes can improve the traffic operation but may increase the CO emissions by cars (Chen and Yu, 2007). Consequently, the urban traffic strategies should consider both aspects: mitigating traffic congestion and improving traffic operations while reducing traffic emissions. To evaluate these strategies the modelling approach is fundamental since it enables the assessment of the impacts on emissions of traffic control measures or ITS deployments.

The Figure 1 presents a collection of measures (and a set of instruments), mainly related with ITS solutions (that the authors named as Intelligent Measures), that the urban municipalities can appraise and implement in order to achieve a more "greener" traffic system. The ITS can contribute to reduce the environmental side effects of traffic and thus deliver better quality of life and long term sustainability of towns and cities (Bell, 2006). As already mentioned, measures to mitigate congestion are not always measures that reduce emissions and consequently, they all must be evaluated, by means of

modelling & simulation, to assess, simultaneously, the potential impacts on the traffic operations and on the environment (Traffic & Environment).

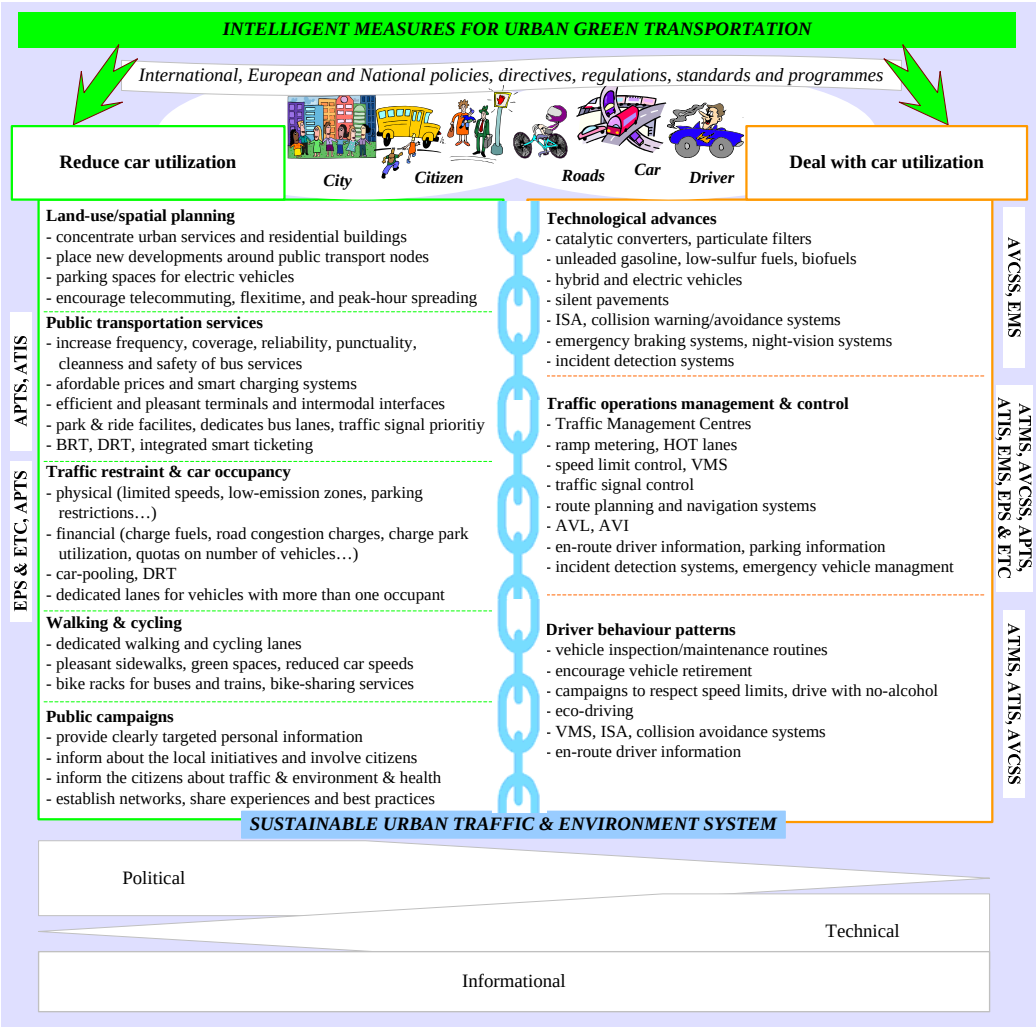

Figure 1: Classification of Intelligent Measures for Urban Green Transportation.

The proposed classification of Intelligent Measures embraces two major categories: *Measures to reduce car utilization* and *Measures to deal with car utilization*. The first category, probably the most sustainable and "green", aims to encourage the utilization of alternative modes such as public transportation, walking, and/or cycling. The second category, probably the most pragmatic one, in the short term horizon, aims to improve traffic operations in order to both reduce congestion and mitigate the resulting adverse environmental impacts, and is effectively more related with the ITS philosophy (it does not aim to increase capacity by building more roads). The first category can be considered as "political" while the second one can be entitled as "technical" since the main instruments within each one are more related with strategic/political decisions and operational/technical decisions, respectively. The "informational" dimension, as the means to attain and disseminate information, is transversal and critical for both categories and relies on modern sensing, surveillance, communication, and computing technologies.

The focus units of the former category are the city and the citizen. The focus units of the latter category are the car, the roads, and the driver. The measures within the categories should be supported by a legal framework that is, by international, European, and national directives (e.g., Air Quality Directive), regulations, standards (e.g., EURO standards), and programmes (e.g., CIVITAS). Obviously, the categories and associated measures and techniques are not exclusive and present a high synergetic degree. So, whenever possible, they should be combined in order to attain a truly holistic sustainable urban traffic & environment system.

4 Conclusion and Further Work

The described measures can both contribute to smooth urban traffic and to mitigate the negative environmental effects but, as also mentioned, this is not always true (e.g., the road humps can benefit local speed reduction but, the associated deceleration/acceleration typical profile can increase emissions) and consequently, it is vital to test each of these instruments before to deploy them. This fully integrated traffic & environment operations management system is essential to support the urban transport decisions of every medium size (and large) city.

The local authorities have a fundamental role in improving the traffic & environment system of their urban jurisdictions. Locally developed tailor made solutions, based on public consultation and active participation, are essential to make the city more attractive, cleaner and healthier thus, a better place to live, work, and play. A higher level supporting institutional framework is as well critical to hold up strategic guidance, coordination and cooperation and to steer the actions towards a sustainable urban traffic system. According to the European Environment Agency, the EU policies and programmes have been mostly sectoral in nature and project driven, and the urban management requires more integrated and comprehensive approaches to address the modern challenges, as well as a solid basis of information and intelligence to support decision making.

With these concerns in mind, the authors intend to carry on this traffic & environment work by developing (using a holistic systems engineering approach) an integrated system that can act like a comprehensive database, modelling & simulation platform for the municipalities. This platform can be supported by a GIS, several microsimulation models (e.g., traffic microsimulation models) and 3D visualization tools able to appropriately describe the urban traffic & environment dynamics and to support cooperative decision environments involving technical and non-technical stakeholders.

The Thematic Strategy on the Urban Environment and the Green Paper highlight the imperative responsibility of local authorities in the adoption of more integrated approaches to urban management, and in the evaluation and enhancement of the environmental performance of their cities which should become more fluid, green, smart, accessible, and safe. The EU Air Quality Directive reinforces the need to assess urban air quality and the obligation to inform the public. Like in the traffic system, monitoring the environment is expensive, geographically limited, and not adequate to test alternative strategies and scenarios so, modelling is a decisive way to deal with the subject. The proposed platform considers the traffic & environmental modelling as a key aspect and highlights the need of micro approaches to offer personalized urban traffic & environment services. It is the authors' conviction that more greener mobility habits can proliferate with the availability and dissemination of information on the traffic & environment relationships and on the adverse effects of urban traffic on health.

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