URBAN TRAFFIC MANAGEMENT AND INTELLIGENT TRANSPORT SYSTEMS: A EUROPEAN PERSPECTIVE

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ABSTRACT

The objective of this paper is to establish the state-of-the-art of urban traffic management in Europe, with a particular focus on Intelligent Transport Systems (ITS), using data collected from 34 cities directly with the help of a purpose-developed questionnaire. Several areas of traffic management are covered, such as: general statistics of the transport systems, organisational structures, monitoring and forecasting, provision of traffic information and urban traffic control. Special focus is also given to demand management, traffic control centres, public transport and parking. Broadly summarising the results, it can be said that a wide range of traffic management technologies and policies are used in Europe. It is encouraging to see that strategic plans and traffic control centres are generally present in the participating cities, as well as facilities for public transport, ITS technologies and real-time public transport information. In addition, most cities have cycling infrastructure, pedestrian zones and alternative mobility schemes, as well as good policies for weaker population categories, such as the elderly, the jobless and the disabled. While the study has some limitations with respect to the reliability of the data provided by the cities, mainly originating from different definitions or from the absence of data all together, it can be considered a fairly good overview of the state-of-the art of urban traffic management in Europe.

1 INTRODUCTION

Cities today are faced with a number of problems with respect to traffic management, as their expansion has significantly increased transport demand. Municipalities and transport authorities face the challenge of meeting this demand in the most efficient and sustainable way, however the range of solutions that can be applied is constrained by many limitations, arising from a number of transport problems, which can be categorised in five broad areas: land use; congestion; car dependence; environment; and safety. Most cities have taken or plan to take actions to address these problems in order to achieve their short- and long-term objectives, which include changing the modal split in favour of public transport, reducing emissions, decreasing road accidents, etc (*1*). Nevertheless, city transport authorities are very often additionally confronted by political difficulties, difficulties in communication between organisations, and difficulties in sharing information. Various traffic management policies and technologies have been implemented in many cities, but the effects that these have and the comparison with other techniques implemented elsewhere remains an open question.

Intelligent Transport Systems (ITS) seem to play an important role in urban traffic management, as cities place them fairly high in their priorities. They are generally considered as offering potential solutions to many of the cities' problems, with the vast majority of the cities having implemented ITS technologies in terms of providing information to the public and facilitating traffic management, or planning to do so in the coming years. The impacts of ITS, nevertheless, have to date not been quantified and as such, no concrete evaluation framework exists for them.

The objective of this study is to establish the state-of-the-art of traffic management and to identify the role of ITS in European cities. To achieve this, data is collected from a number of cities directly, with the help of a purpose-developed questionnaire. The data is then analysed and summarised, and conclusions are drawn.

This paper is structured as follows; Section 2 presents the background of the study and the methodology used, while Section 3 reports on the general facts and figures of the participating cities. Sections 4 and 5 present the findings of the exercise in terms of transport infrastructures and traffic management policies respectively. Section 6 discusses the results obtained, while Section 7 concludes the paper.

2 BACKGROUND AND METHODOLOGY

The background of the study is given next, including a review of comparison studies in the transport field, followed by a description of the data collection technique employed.

2.1 Background

Comparison studies have been carried out in several instances in the past in the form of benchmarking exercises, whose main aim has been to collect, compare and evaluate data in order to set a general standard with respect to a specific topic. Within the transport sector there are several communities and organisations that have been developed with the purpose of conducting such activities. Reporting on the activities of two urban rail benchmarking groups, CoMET (Community of Metros) and Nova, it has been suggested that by exchanging experience and by sharing data, the representatives of 19 urban rail network operators have been able to improve their performance (*2,3*). In fact, it has been shown that benchmarking has led to benefits, such as reduced operational costs (in the form of a better utilisation of drivers), increased revenues, as well as better service in some of the members. As examples of benchmarking, a comparison of the urban rail boarding and alighting rates at an international level allowed the identification of key operating factors and their effects to metro efficiency in (*4*); and in (*5*), an attempt was made to improve the delay recovery in metro systems by identifying and comparing the strategies used by six metro operators.

The success of benchmarking in the field of railways and metro systems has been an initiative to form similar groups for bus operators. For example, the worthiness of conducting comparison studies for urban bus operations has been examined in (*6*), reaching the conclusion that comparing performance is both useful and justifiable. In (*7*), the development of a standardised measurement system for the purposes of benchmarking the performance of major urban bus systems has been reviewed, and performance measures have been developed. Benchmarking was also carried out in other areas of the transport sector, such as ports (*8*).

Considering benchmarking of road traffic management, several groups have been created for the evaluation of the benefits of ITS systems through the comparison of projects and policies in various cities, but they vary in terms of commitment for their members and are mostly aimed at the facilitation of informed discussions rather than the exchange of data. Examples of those are the IBEC working group (*9*), ERTICO ITS Europe (*10*) and ITS America (*11*), Polis (*12*), Eurocities (*13*), and IMPACTS (*14*).

The first attempt to start a benchmarking process of traffic management policies and technologies between cities is (*15*), which is considered as the predecessor of the present work and features the first comparison of urban traffic management policies and technologies, using data provided by 28 cities directly with the help of a questionnaire. The study examined thoroughly traffic management and ITS systems in cities both in terms of infrastructure and strategies, emphasising on the different approaches used to solve similar problems. The results highlighted the need for introducing strategic performance indices for traffic management that would assist in the development of common solutions for cities.

2.2 Data collection

Following up from (*15*), a questionnaire aiming at collecting detailed data and feedback from cities on a series of best practices in order to create an extended database on the traffic management policies and technologies implemented around the world has been developed. The questionnaire covered several areas of traffic management, such as: general statistics of the transport systems, organisational structures, monitoring and forecasting, provision of traffic information and urban traffic control. Special focus was given to demand management, traffic control centres, public transport and parking. Cities were also given the opportunity to describe in more detail a specific policy or technology that they wished to demonstrate, as well as to state any other aspect of their traffic management strategy not covered by the questionnaire.

The questionnaire was distributed to local authority organisations involved in traffic management in a number of European cities. The overall response included receiving complete questionnaires from a total of 32 cities. Furthermore, two further cities provided their support and feedback to the study, despite not completing a questionnaire, bringing the total number of participating cities to 34, which are shown on the map of Figure 1. Considering the quality and reliability of the information provided through the questionnaires by the participating cities, this is in general fairly complete and accurate. It should be noted, however, that in some cases corresponding authorities had limited access to specific data, thus being unable to supply it, or that the definitions adopted by different cities have been misunderstood, thus resulting in unreliable responses. Those cities were not included in the analysis of the relevant figures.

FIGURE 1 Participating cities

The next three sections present the main findings of the study in terms of three big areas: general facts and figures; transport infrastructures; and traffic management and policies.

3 GENERAL FACTS AND FIGURES

This section reports on the results of the comparison between the 32 cities with respect to the general facts and figures. This includes general data, such as population, modal split and traffic volume; and facts on the organisational structures implemented, such as number of authorities involved in traffic management and the existence of strategic plans.

3.1 General characteristics

The cities that participated in the survey range from small towns to large metropolises: towards the lower end the sample includes the cities of Funchal and Trondheim, with populations of less than 200,000, while towards the upper end, Istanbul has over 12 million inhabitants. The large variation observed in terms of metropolitan area population highlights the need to treat cities with respect to their individual characteristics.

In terms of modal split, it is found that the proportions for each mode of travel across the 32 cities of the sample vary considerably; this is expected, given the wide range of characteristics of the participating cities. The average private means' contribution is slightly lower than 50%, while the contribution of public means ranges from 10% in Trondheim to more than 50% in Zurich. It can also be noted that the Turkish cities of Istanbul and Kocaeli have a large share of walking, though this is not the case for Ankara. No observable patterns can be identified for cycling, with high shares of cycling occurring in cities of varying sizes.

Considering the traffic volume of the cities and taking into account that this is proportional to the size of a city, it is more appropriate to compare the average contribution to traffic at the level of individuals. Figures are found to vary greatly in terms of individual mobility, as they range from around 1500 km/annum (The Hague) to over 15,000 km/annum (Rome).

Overall, it can be deduced that, as expected, cities have different transport characteristics across the sample. These are, naturally, dependent on their size and geographical location.

3.2 Organisational structures

Besides the cities' general and transport facts, it is also important to examine organisational, structural and financial matters. Most cities of the sample (24 out of 32) claim to have a concrete and concise 10-20 year strategic plan in place, while another 6 state that they "may have or will have one in the next five years". By reviewing the strategic plans, it can be noticed that some of the main future concerns of cities regard safety, sustainability, efficiency, pollution and reliability. Most cities' strategic plans analyse the objectives, though some focus only on the cities' targets. For example, Brussels has set a concrete target of reducing car traffic by 20% in terms of vehicle-km, while The Hague has the broader objective of promoting sustainable transport modes. Additionally, several cities stress in their strategic plans the need for more efficient management through the application of ITS.

Performance indicators, mobility indices and travel patterns understanding are used or will be used by most cities. For example, in London performance indices are used to monitor the delivery of transport objectives, but these are mainly public-transport-focussed. In terms of ITS architecture, most cities state that they either already use or are in the process of implementing some form of ITS. A small difference in the types of ITS cities are interested in is observed, although very few cities have provided additional details on this matter. For example, Athens is predominantly interested in optimising traffic on the heavily-loaded roads through ITS, and Bologna is interested in improving its parking system.

Looking at authorities and responsibilities with respect to transport in cities, which can influence the efficiency of traffic management, three to four authorities are involved in most cities, with the most common being national, local and city authorities, as well as the police. In some cities parent companies, public-private-partnerships and public funding initiatives are also involved. Barcelona, Bursa, Funchal, and Munich claim to have implemented simple traffic management structures, with only one authority involved (usually the local or city authority). In terms of funding mechanisms, it is observed that the most common funding sources are taxes and government funding. Governmental contribution ranges from 10% in Zurich and 25% in Trondheim to 100% of the total budget in several cities, including Athens, Brussels and Haifa.

Overall, no clear patterns can be identified across the sample with respect to the cities' organisational structures and decision-making procedures. While there are similarities and differences between the policies adopted by some cities, these do not seem to be inter-dependent.

4 TRANSPORT INFRASTRUCTURES

This section deals with the transport infrastructures of the cities, which can be divided into private transport, public transport and parking.

4.1 Private transport

The management of private transport and the strategies for signal control are of great importance to cities, as according to the modal split, the majority of the trips generated in cities are performed by private means.

The most important indicator in terms of private transport infrastructure is the length of the network. Cities have provided road network length data, along with the road categorisation criteria they use, which can range from a simple "primary-secondary" disambiguation, to an "A-B-C" grading. Without considering minor roads, it is observed that there are substantial differences in the road network per unit population. Munich and Bologna have more than 0.8 metres of primary road per capita, while most cities' respective value is over 0.3 metres per capita.

Taking the number of signalised intersections in each city and normalising it in terms of the primary road network length, Trondheim and The Hague have the highest signal density (Figure 2a). To illustrate for example the density of traffic signals in The Hague, it can be said that "the average distance a driver will travel on the primary network to encounter a signal-controlled intersection is approximately 600 metres". The differences in signal density might reflect different network shapes and different perceptions of the cities on what constitutes smooth and safe traffic (e.g. some cities use priority rules and roundabouts more).

Looking at signalling types at major intersections it is found that most cities use more than one signal control type, with the only exception being Southampton, which has a dynamic response Urban Traffic Control (UTC) area system in place for the entire network (Figure 2b). It is also found that the most common signalling strategy in Europe is fixed-time, used at around 40% of all intersections, while at another 30% fixed-time programs are complemented by control updates. Roughly 20% of the intersections in Europe are vehicle-response isolated and the remaining 10% are coordinated through dynamic response UTC area systems.

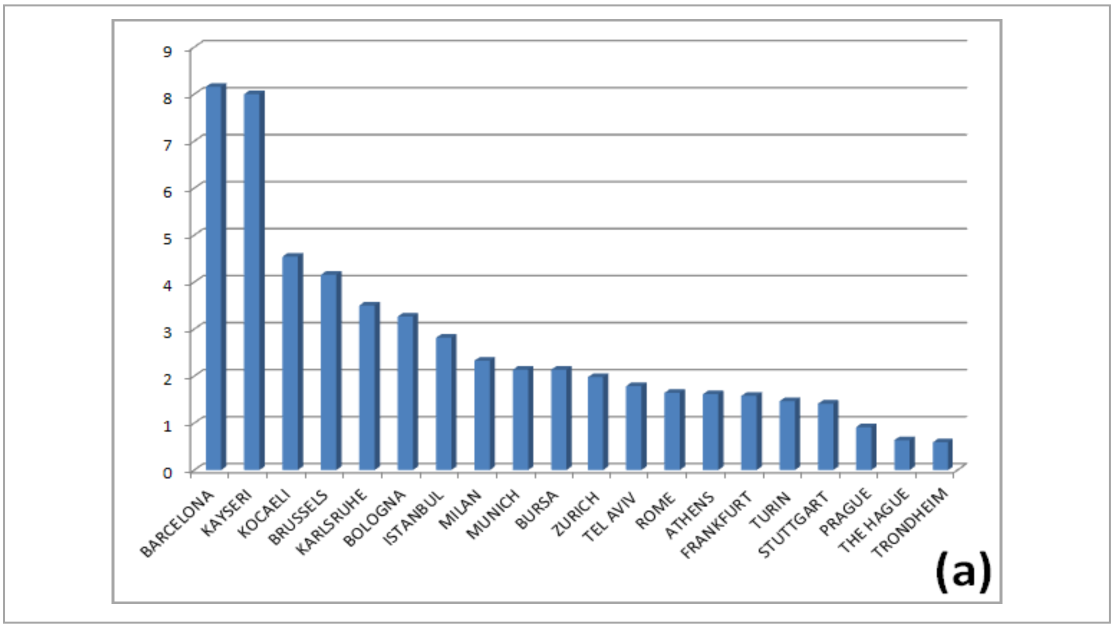

FIGURE 2 Private transport: (a) signal density (km of primary road per signal)

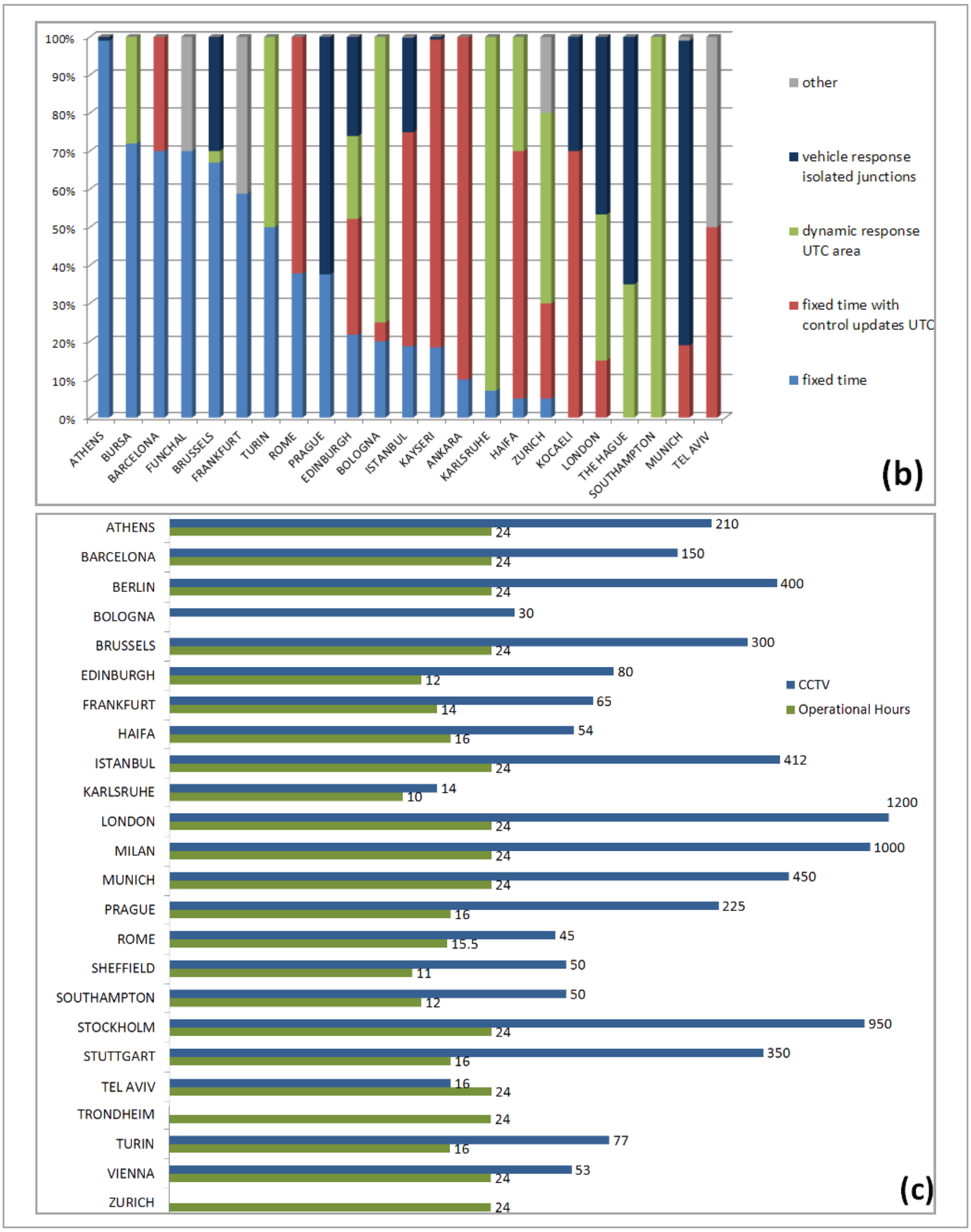

FIGURE 2 (cont.) Private transport: (b) signal types, (c) traffic control centres cameras and operational hours

With respect to traffic control centres, whose purpose is to monitor and manage traffic on the road network, responsibilities and functionalities vary across the cities of the sample (Figure 2c). 24 cities operate traffic control centres, and another 6 plan to do so in the next five years. Most of the cities' centres (20 out of 24) facilitate a command and control system, which is used by the staff for monitoring the traffic conditions in the network. Furthermore, seven cities' centres have a decision support system that sets, for example, Variable Message Signs (VMS) and adjusts traffic lights with only little support from the staff. Also, nine cities' centres use a Geographical Information Systems

(GIS) tool for mapping and analysing objects moving and events happening on the road network. Finally, 10 cities' centres support a real-time database for processing data and handling workloads, whose state is constantly changing. Some of the most technologically advanced traffic control centres can be found in Barcelona, Istanbul, Berlin, Bologna and Haifa.

4.2 Public transport

According to the modal split, discussed earlier, the share of public transport in the cities of the sample ranges from 10% to 50%. Many cities already have or are developing public-transport-oriented systems, in order to realise their long term target that aims at a modal shift from private to public means. Looking at the infrastructure present in the sample, the bus is clearly the most common public transport means in European cities.

The size of the public transport network and the number of service lines are representative indicators for the size of the network. As illustrated in Figure 3, the length of bus networks ranges from 150 km in The Hague and 175 km in Zurich to 9300 km in London. Similarly, the number of services/lines ranges from 18 in Brescia to 683 in London. It is also observed that cities of similar size can have considerably different bus network lengths, depending on the presence of other public transport modes in the city; for example, Bologna, Haifa, The Hague and Zurich all have populations of around 1 million, but the lengths of their bus networks are 464, 2140, 150 and 175 km long respectively, possibly due to the fact that in the former two buses are the sole transport means available, while the latter two also have extensive tram networks.

Looking at light rail/tram systems, these are very common in Europe (present in 21 cities). The tram network length varies significantly across the sample, with Trondheim and Ankara having less than 10 km of light rail track and Barcelona having as much as 530 km. Prague and Zurich seem to have very dense tram networks, as they have over 100 km of track, served by up to 34 lines in the case of Prague. Both cities have tram-oriented public transport systems, as opposed to most other cities in the sample, which are rather bus-oriented; it is worth noting that Prague only has three bus lines.

An important element of road-based public transport infrastructure is the provision of priority measures and systems. The most widely-used public transport priority measure is the use of bus lanes, present in 29 cities (all except Ankara, Bursa and Karlsruhe), whose aim is to improve the reliability of bus schedules. Systems granting priority at traffic signals to buses and trams over private transport are also in place in most cities of the sample (25). Regarding the underlying detection methods of the priority systems, the most common are loop detection and dedicated signals, used in 15 and 10 cities respectively.

Despite not being road-based and thus extending beyond the scope of this study, the metro is a public transport means that directly influences road traffic. Out of the 32 cities, 17 claim to have metro networks, which due to the high construction and operational costs, are naturally much less extensive than bus and tram networks. Almost all cities of the sample with over 1.5 million inhabitants have metro systems, with the exception of Kayseri, Kocaeli and Tel Aviv. Metro network lengths range from 5 km in Haifa to 402 km in London, which also has the network with the most lines (11).

Besides the infrastructure itself, integration schemes with other modes are an additional important component of a public transport system. These can be classified as "traditional", which include schemes such as car-pooling and car-sharing, or as "dynamic", which include integrated public transport and feeder services. In the sample used in this study, 15 out of the 32 cities claim to have integration forms with private transport.

Finally, unitary fare systems for different transport modes and electronic ticketing are very common methods to simplify and encourage the use of public transport. Unitary fare systems exist in 18 cities, with another 3 planning to introduce them in the next five years. Electronic ticketing, on the other hand, is less widespread, with actual implementations having been deployed in 10 cities (e.g. London's "Oyster" card).

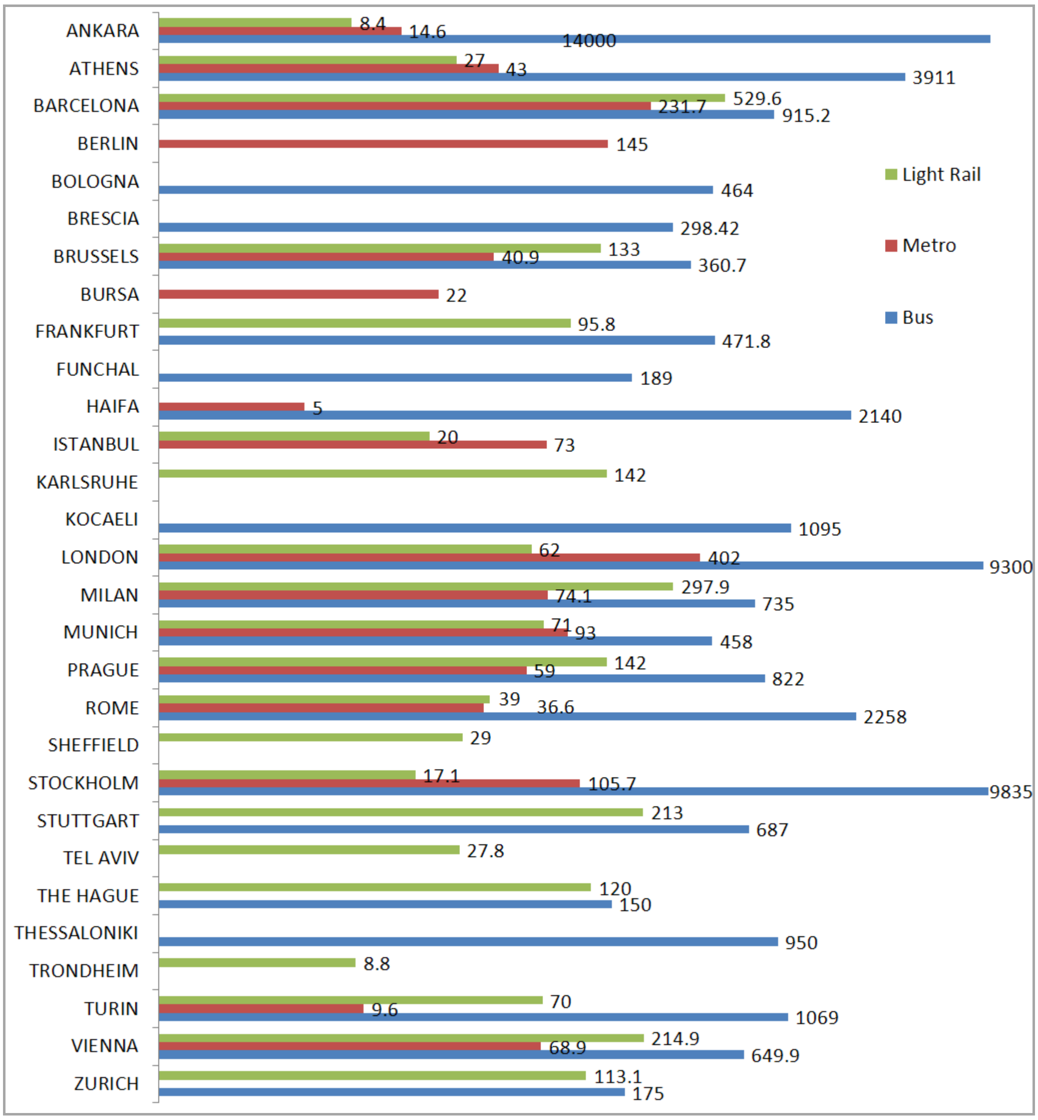

FIGURE 3 Bus, metro and light rail network length (km) (in logarithmic scale)

4.3 Parking

With respect to parking it should be mentioned that the data supplied by the cities is fairly unreliable due to a number of problems. Namely, parking is very often not managed by the same authorities that are responsible for traffic management. An example of this is London, where parking is the responsibility of the 32 individual boroughs and not Transport for London (TfL). In other cities, the authority in charge of parking management may be only responsible for part of the city, thus being only able to provide data for this particular part and not for the rest of the city. The issue of different definitions arises with respect to what different forms of parking are available and how these are defined (on-street, carpark) etc. As confirmed by the data provided by the cities, there are great inconsistencies making a direct comparison rather difficult.

Nevertheless, some of the facts available on parking seem fairly reliable and are presented. Namely, it becomes apparent from the data that schemes such as park-and-ride and bike-and-ride are becoming increasingly popular, with more and more cities introducing them. 22 cities already have such schemes, with more and more cities introducing them. Looking at park-and-ride, existing schemes are variable from one city to another as concerns the extent of the scheme with respect to the city's characteristics; several cities claim to have many small sites spread around the city, while other cities have few park-and-ride facilities accommodating larger numbers of vehicles. For example, Edinburgh has five large park-and-ride sites, accommodating a total of approximately 3000 vehicles; and Sheffield has 2262 dedicated park-and-ride spaces spread over eight sites and another 200 individual informal park-and-ride spaces. Haifa follows the concept of few large facilities rather than many small ones, which is also the dominant park-and-ride approach across the sample.

Compared with park-and-ride, bike-and-ride facilities are more flexible due to their smaller spatial requirements. Such facilities are either located together with park-and-ride facilities, or next to smaller public transport stops and station. For example, in The Hague several bike-and-ride facilities are located next to tram stops, and bike rental is also available at major public transport interchanges; Istanbul operates 32 bike-and-ride sites; and Munich has a “network” of bike-and-ride sites, with a total capacity of 22,000 bicycles. In Bologna, bike-and-ride is even combined with bike-sharing, whereby out of the existing ten facilities, four are bike-and-ride and six are “park-and-bike”, the latter meaning that users park their cars and continue their journey by hired bicycles.

Finally, 14 cities of the sample claim to have a dynamic parking management system, which has, however, different features in each city. For example, Edinburgh uses an Urban Traffic Management and Control (UTMC) compliant system, comprising 11 car parks and 28 VMS for parking with website support. Overall, it is observed that the great variety in the features of dynamic parking management systems offers flexibility, allowing their use in cities of all sizes.

5 TRAFFIC MANAGEMENT AND POLICIES

This section reports on the schemes applied in the cities of the sample with respect to travel demand management, and data collection and information provision.

5.1 Travel demand management

A large variety of travel demand management schemes have been implemented in many cities of the sample. These include access control, pricing, incident management and dedicated lanes’ systems, but also a series of further schemes, such as pedestrian zones, cycling infrastructure, car-pooling, car-sharing and bike-sharing. Also, schemes exist to promote the mobility of groups potentially affected by social exclusion. An overview of travel demand management schemes across the sample is given in Figure 4.

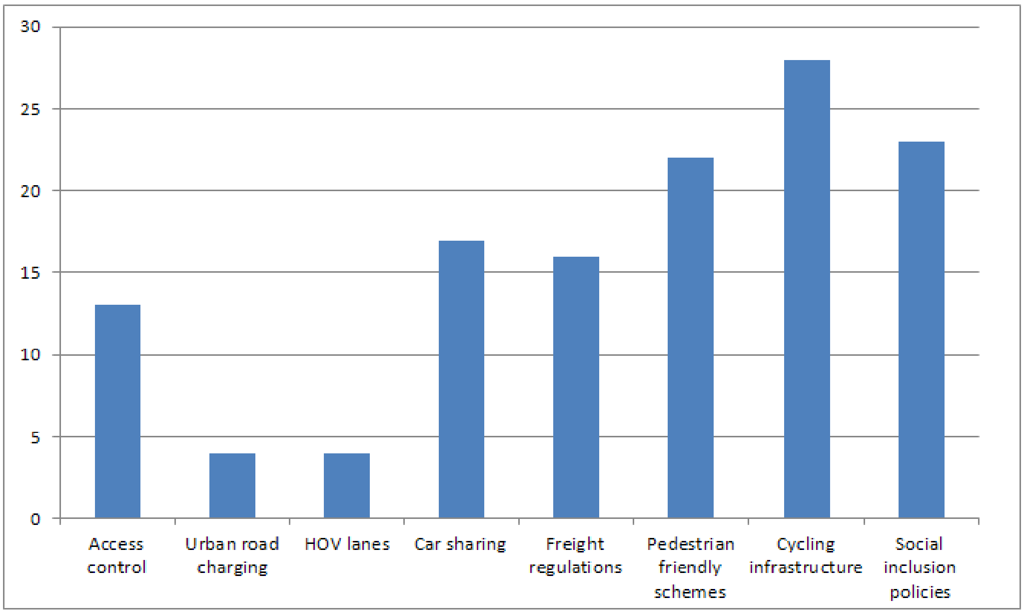

FIGURE 4 Travel demand management schemes

Starting from access control, 13 cities claim that they have implemented access control schemes to restrict access at specific areas and times. One of the most advanced automatic access control schemes is operational in Rome and restricts vehicular access at certain times of the day to a so-called Limited Traffic Zone (LTZ), which covers certain parts of the city's historic centre. Enforcement is carried out by an Automatic Number Plate Recognition (ANPR) system, which only allows the vehicles of residents and those with special permissions to enter the LTZ. Fines are issued to the owner of any other vehicle "caught" in the zone. Access control schemes are also present in many other European cities, a few being Athens, Barcelona, Berlin, Edinburgh, Funchal, Milan, Stockholm and Turin.

Access control is also used to tackle emissions: for example, Frankfurt uses a system in which vehicles are assigned green/yellow/red badges according to their emissions, with the badge's colour determining whether a vehicle can enter a zone of low emissions; and Stuttgart uses an "environmental sticker" system for similar purposes. Access regulations are also imposed on freight movement, dealing with the control of Heavy Good Vehicles' (HGVs) traffic and the routing of hazardous materials. These are also coupled with other measures, such as encouraging night deliveries and applying delivery duration limits (as in Barcelona), imposing limitation on HGVs in terms of length (as in Milan) and weight (as in Southampton and Karlsruhe), and introducing special routes for the transport of hazardous materials (as in The Hague). 16 cities of the sample currently have such schemes in operation.

Considering urban road charging, four cities claim that they have operational systems in place. London being the most notable example, it has two schemes in place: the London Congestion Charging Scheme and the Low Emission Zone. The former, being the largest scheme of this kind, requires the driver of every vehicle entering or circulating in the specified zone (covering most parts of Central London) during certain hours, to pay a flat fee per day. The latter, on the other hand, covers a much larger area and charges drivers of vehicles with high emissions. Enforcement of both schemes is achieved through fairly advanced ANPR systems. Other cities with urban road charging include Stockholm, Bologna and Milan, and their schemes operate in different ways. Stockholm charges drivers according to the duration of the vehicle's stay in a specific zone; Bologna requires drivers to buy "tickets" for their vehicles, enforcing a monthly allowance of tickets to be bought; and Milan charges drivers in proportion to the emissions' level of their vehicle. More cities are considering introducing urban road charging in the next five years; for example, Brussels examines the possible implementation of a pay-as-you-ride scheme that will charge users based on distance, location, time of the day and type of vehicle (emissions level) within a zone.

Looking at measures to increase vehicle occupancy, these include High Occupancy Vehicle (HOV) lanes and car-pooling and car-sharing schemes. HOV lanes exist in four of the sample's cities (Funchal, Haifa, Tel Aviv and Kocaeli) and their principle of operation is that they may only be accessed by vehicles carrying more than a specified number of passengers. Regarding car-pooling and car-sharing schemes, on the other hand, which also encourage high occupancy through the establishment of networks of road users that have common needs; these have been implemented in 18 cities.

With respect to schemes encouraging the sustainable transport modes of walking and cycling, 22 cities claim that they have pedestrian zones, 30 km/h zones or shared space zones, with varying lengths and operating hours. In terms of cycling infrastructure, most cities (28) claim that they have cycling infrastructure in place, or that they plan to implement it in the next five years, thus integrating cyclists into the road transport system; a notable example is The Hague, having over 250 km of cycle tracks and 150 km of cycle lanes. In addition, several cities have implemented public bicycle hire schemes, with Vienna's "City Bikes Wien" scheme being a representative example. The scheme consists of more than 60 bicycle stations throughout the city and is operational 24/7; bicycles can be rented using a "Citybike-card" or a bank debit card at an hourly rate, with the first hour being free of charge.

Policies encouraging the mobility of people potentially facing social exclusion, such as the elderly and disabled, are also fairly popular. 23 cities have such schemes in place, the most common being priority in parking areas, subsidised public transport fares for the elderly and disabled and the equipment of traffic signals with warning systems for the visually impaired.

5.2 Data collection and information provision

Looking at data collection, it appears that a wide range of methods and techniques are employed. Namely, traditional data collection means, such as detectors and sensors, still seem to be the most popular data collection technique (26 out of 32 cities), followed by manual counting (25). Less common are roadside interviews, used by 14 cities, supposedly due to their high labour costs and due to the fact that the data collected by them can now also be collected by novel automated methods, such as online surveys. Interestingly, video cameras are increasingly used for data collection, with 20 cities stating that they use them; this seems to be a natural consequence of the great advances made in the field of ANPR. On the other hand, very few cities seem to make use of satellite tracking.

Looking at the situation of traffic information provision, almost all cities claim that they provide traffic information to the public. The types of information provided, though, as well as the methods of dissemination vary. Most cities (29 out of 32) provide information about planned events, planned roadworks and public transport. Less common, but definitely of importance, seems to be the supply of alternative routes to drivers and public transport users, which is done in 18 cities. 16 cities even go as far as suggesting walking and cycling routes to road users, as an attempt to promote these two sustainable travel modes, while 9 cities also provide weather forecasts.

Finally, considering the methods used to inform the public, most cities have a website with traffic information in place, with 31 out of the sample's 32 claiming so. Many cities use television and radio broadcasts to disseminate traffic information (24 out of the 32), as well as VMS, which are used in 23 cities. 15 cities claim that they have a telephone line for traffic information, and a total of 8 cities use the Traffic Message Channel (TMC). Mobile phones are also used by some cities, either in the form of SMS text messages, or in the form of a software application for Smartphones; 6 cities make use of this method.

6 DISCUSSION

One of the main findings of the study is that data is generally inconsistent between cities, making the comparison of their policies rather difficult. In several instances city authorities adopt different definitions, while in other cases it has been proven difficult for them to collect and supply the data provided, as very often several authorities and contact persons are required to obtain a specific fact or figure. In addition to that, the sample contains cities of very different characteristics, which in some cases means that a meaningful comparison is not possible.

Despite the difficulties reported, the study has come up with some very interesting results, the most important of which are summarised here. Namely, most cities of the sample are found to have private-transport-oriented networks, with very few exceptions of entirely public-transport-oriented cities. Furthermore, in terms of organisation, an average of three or four authorities are involved in traffic management in each city, though some cities have attempted to introduce a more centralised management, assigning all responsibilities to a single authority. Funding is found to be originating mainly from governmental sources, but also from public transport fares or fines.

Transport infrastructure is found to vary greatly across the cities of the sample. Major differences are observed in terms of signal density, as cities have varying degrees of signals used with respect to their road network, as well as in terms of signalling types, as very few cities appear to be using a single signal type. Traffic control centres are operated in 24 cities of the sample, however their features differ depending on the size of the city and the responsibilities they are assigned. The majority of traffic control centres have a command and control system, while decision support, GIS and real-time databases are less common. Several cities use dynamic parking management to assist drivers in locating a parking space quickly and easily, while schemes such as park-and-ride and integrated parking fares are fairly common as they encourage the use of public transport by providing convenient transition points to the users.

Travel demand management schemes promoting more sustainable transport modes are increasingly being implemented. Pedestrian and shared space zones, public bicycle schemes and cycling infrastructure are becoming more and more popular, along with car-pooling and car-sharing. ITS have contributed to the implementation of more advanced traffic management schemes and strategies and have increased the range of techniques available. Examples of these include urban road charging and access control, whose enforcement has become possible through techniques such as ANPR. ITS have also broadened the field of data collection and information provision, with the latter being provided to the public through various means. The information provided mainly concerns public transport, traffic incidents, roadworks and delay times, and users can be updated through websites and telephone information lines prior to their travel, or by VMS and radio broadcasts en route.

Overall, it can be said that, based on the study, a wide range of traffic management technologies and policies are used in Europe. It is encouraging to see that strategic plans and traffic control centres are generally present in cities, as well as facilities for public transport, ITS technologies and real-time public transport information. In addition, most cities have cycling infrastructure, pedestrian zones and alternative mobility schemes, as well as good policies for weaker population categories, such as the elderly, the jobless and the disabled. However, considering that common evaluation measures for these schemes have not yet been developed, city authorities can hardly assess the success of measures and the improvements made. This is because it is often difficult to understand the connection between the different traffic management solutions taken in a city and their implications to the entire network.

Furthermore, the results also emphasise on the need to consider the individuality of cities as a parameter in the evaluation of measures, as it is currently difficult to predict whether a particular solution that has been successfully applied in a city, could be a success in another one. Through the interaction with city authorities it has been made clear that such information would assist transport planners in convincing decision makers and stakeholders. As the majority of cities are mainly interested in improving the efficiency of their transport network and achieving a modal shift from private to public means, infrastructure investments are less attractive. This makes the need for common and accurate performance measures timely.

In addition, this study makes apparent that although there are similarities and common objectives between European cities in terms of future strategies and plans, cities are at different implementation stages and often follow different paths. Although this can be explained to a certain extent by the differences in the cities' characteristics, common research in the form of examining environmentally and financially more efficient systems can potentially assist authorities in making better educated choices.

7 CONCLUDING REMARKS

This paper described the methodology and results of a study aimed at establishing the state-of-the-art in urban traffic management in Europe, using data obtained directly from 32 cities. Data collection was carried out with the help of a purpose-developed questionnaire, which covered several areas of traffic management, such as general statistics of the transport systems, organisational structures, monitoring and forecasting, provision of traffic information and urban traffic control; special focus was given to travel demand management, traffic control centres, public transport and parking.

Having established the state-of-the-art in Europe, an essential next step is to compare the results with non-European cities with a view of establishing the worldwide urban traffic management state-of-the-art. Further work will thus include the extension of this study to North American and Asian cities, many of which are pioneers in the field. Aside from that, future work will concentrate on the next task of the CONDUITS project, which involves the formulation of an evaluation framework for the performance of traffic management strategies and ITS implementations, which will cover the fields of traffic efficiency, traffic safety, pollution reduction and social integration and land use. The measures developed from that task will be applied to a number of cities worldwide in order to draw conclusions, not only with respect to the cities' policies, but also with regard to the measures themselves as to their usefulness and applicability.

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