1. INTRODUCTION

A good urban mobility system (UMS) may be defined as a system in which the travel requirements of users (inhabitants) are satisfied on an adequate level in line with the specific requirements of the general society, namely, the relief of congestion and public budgets, safety and security, and environmental preservation. There is no doubt that “accurate” mobility and a modal split may enhance the quality of city life and boost its economy. Unfortunately, due to the relatively high density of inhabitants it is not possible to further support and maintain individual car transport on the level which is common in most cities in the USA; on the other hand, people in Europe are not so “system-submissive” like, e.g., in Japan. These examples show that it is actually possible to sustain and encourage an economy by both approaches, i.e., supporting “individualistic” private car and “collective” public transport modes (see [4], pp 13-19). The issue is to create such mobility conditions that people who really need to drive a private car can exploit this advantage, while others are not disadvantaged by (their choice) taking a bus or tram…

In almost all larger European cities, overloading of the transport infrastructure is a daily routine, no matter what its quality and extension. If we wish to investigate the best solutions for urban mobility systems, it is inevitably necessary to understand the reasoning of passengers in the decision-making process from many aspects – and modal choice behaviour is surely one of the most important. The basic assumption of this paper is that accessibility plays a predominant role in this process. Finding appropriate mobility solutions for a specific condition in urban agglomerations is a fairly complex issue. One of the promising ways is adopting solutions which are usually related to good experience from the cities which have succeeded in (at least partially) coping with their traffic problems. However, many such ‘best practice’ examples are probably not even identified, because
it is problematic to compare transport situations in different cities. To have reliable mobility and accessibility indicators describing the situation is the logical prerequisite of being able to do that. To what extent commonly used indicators are suitable for this purpose is the objective of discussion in this paper. The definition of "mobility" is more or less clear, whilst there are usually a lot of specific meanings expressed with the single word "accessibility". If we define accessibility as “the ease with which a person can reach and take part in, or use, an (transportation) activity”, and understand it as a feature which affects the willingness of people to use a specific transport mode, we must consider various aspects. In this broader sense of meaning, "accessibility of transport” particularly covers:

- **Availability**, i.e. the existence of a transportation sub-system (mode) and/or a vehicle necessary to perform a journey, which is also further described through:
  - (Local) **spatial accessibility** – distance to overcome to get to the stop or station, parking slot, bike-shelter and etc., measured in longitudinal or time units
  - **Reachability** – time required and ease of ability to get to the destination, in real time or, even better, time as perceived by user (e.g.; the double-weight of waiting, transfer penalties)
  - **Approachability** – quality of infrastructure (roads, stops, walkways, cycle-paths, etc.), accessibility for handicapped and/or elderly people included
  - **Other aspects** – reliability, comfort, readiness to use, strenousity, etc.
- **Affordability**, i.e., financial costs of transport from the user’s perspective, including, e.g., (PT) fare, the cost of the fuel consumed, parking fees, etc.
- **Informability, i.e.**, awareness and easiness to get information necessary for the journey

**2. COMPARISON OF MOBILITY INDICATORS IN VARIOUS EUROPEAN CITIES**

When we (try to) compare the mobility indicators in various cities all over Europe, we can find interesting findings and figures, as well as several methodical problems. The mobility of people can be evaluated through the following mobility indicators:

- **Mobility**, i.e., the number of trips and/or mileage per inhabitant per time period
- **Modal split**, i.e., the proportion of use of various modes on a total trip number / kilometrage
- **Ownership of vehicles** (private cars, bicycles and motorcycles)
- Other indicators, such as lengths of trips, time, purpose, etc.

From observations of past developments it is clear that the total mobility of people is rising over time. The average number of trips taken by citizens in Slovakia has already reached the value which is common in Western Europe, where this indicator has been rather stagnant in recent years after a rapid evolution in the 1970’s and 1980’s [2]. This might lead to the (false-?) conclusion that around 3.5 trips per capita per week-day or 1000 trips per capita per year (English) are "necessary" to satisfy the needs of present-day people and that if we improve the transport infrastructure to accommodate this volume, we can get rid of congestion as well.

However, the average length of trips and (only slightly) the total time spent on travelling is rising over time all over the world, and Europe is definitely not an exception. There is a strong incentive that is the result of higher incomes, enabling people to afford to travel farther and purchase greater freedom on travelling by a car(s). Variation of the kilometrage is relatively high (30%) by the same GDP~income ([5], p. 87); therefore, there must be other factors acting, such as extension of urbanized areas (urban sprawl), cultural and demographic factors, etc.

Figures related to modal split are more interesting from the point of view of traffic problems in urban areas. For a comparison of modal split in various European cities, data collected in the Urban Audit project in 2003 [1] were used. With respect to the available indicators from the Audit, the comparison is focused especially on trips to work. From a geographical distribution of cities according to the proportion of trips to work by car, we can see that there is still quite a distinct difference between Western and Eastern European cities. In the West, the proportion is mostly over 50%; in the East (the Czech Republic, Hungary, Slovakia, etc.) only around one third of trips to work are made by car. The worst situation is probably in England (70-93% in all the cities monitored!). Reversely and logically, in the East there are higher proportions of trips to work made by public transport. Relatively, high shares are achieved in larger cities in Germany, the Iberian and the Scandinavian regions. Surprisingly, in defiance of expectations – that the concentration of potential passengers would stimulate better figures, the situation is not as good in the most densely populated agglomerations in the Ruhrland, the Netherlands and England.

Some higher proportions (over 10%) of trips made by bike are indicated only in the Netherlands, and Scandinavian countries and few cities in Germany.

Maps of geographical distribution of the cities according the proportions of usage of private car and public transport, respectively, for the trips to work are to found in Annex in the end of this paper. Serious limitations to the significance of the mobility indicators are based in the statistical processing of the data and survey methodology. Commonly, there are different methods applied to inquire the number
of trips in various countries, and there is a slight difference in 7-day and working days-only surveys. Much of the available mobility data from England is expressed in trips per year, which indicates a different (and perhaps less exact) method of data collection (estimation by respondents) compared to the daily or weekly reports used in other countries. Moreover, people are extremely inaccurate, especially in providing data on the length of their trips. Another often unconsidered issue is the distinct difference in the value of the modal split related to the number and kilometrage of trips, respectively – since the length of private car trips is on average usually higher than that of other modes (does this explain the very bad figures for England?) The last but not least, important (and often different) is even in the definition of a trip; how many trips should be calculated when, e.g., children are escorted to school along the trip to work or when one stops to refuel on the way home?

3. COMPARISON OF ACCESSIBILITY INDICATORS IN VARIOUS EUROPEAN CITIES

In order to evaluate the accessibility of different transport modes (as a predominant factor for modal choice behaviour), the accessibility indicators should be specified and defined. The general assumption is that a private car is the most accessible mode; usually it is possible to use it most areas of cities. The only limitation considered are car ownership, but today there is more and more congestion and a lack of parking facilities, especially in city centres. In the case of public transport the limitation is in the quality of the supply provided by the operators. In most European cities bicycle transport is still limited due to the lack of (safe) infrastructure, the ownership of bicycles, the geomorphological conditions and perhaps the climate as well. The length and density of a road network are most probably not interesting indicators for a comparison of the accessibility of car transport between cities, because all over Europe it is possible to comfortably get to any urbanised place by car (with the exception of pedestrian zones). The scattered graph in Figure 1 shows that there is also no obvious relation between the automobilisation and the proportion of trips by car; the fairly wide range in the proportion is achieved by the same level of car ownership in various cities, respectively. This indicates that the car usage is more affected by other parameters than ownership. Some of the superior figures (a lower car share compared to the average), which should signify potential solutions, could be mainly observed in cities where there are better conditions for alternative modes.

With other private car transport accessibility indicators, methodological problems occur. The total number of parking places is practically “inaccessible” data for any city. Moreover, an in-depth analysis of the distribution of parking lots over a city’s area would be required. The data on the average speed of inner-city car traffic is strongly dependent on the selection of measurement places, and the method is not clear enough. Therefore, an analysis of the influence of these indicators on car usage provides no reliable figures. Public transport is the mode which should provide the most convenient alternative to cars. It is especially the only mode available for longer distances for people who do not own a car. The assumption could be made that in general, the higher the penetration of private car ownership, the lower the potential public transport usage. Nonetheless, just like in the case of private car proportions, according to the data available through Urban Audit [1], no dependence on public transport proportions could be observed either (Fig 2).

Table 1 Common accessibility indicators for basic transport modes

<table>
<thead>
<tr>
<th>Private car</th>
<th>Public transport</th>
<th>Bicycle transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobilisation ratio</td>
<td>Length of network (total, per area/capita)</td>
<td>Bicycle-ownership</td>
</tr>
<tr>
<td>Number of parking places</td>
<td>Stop density, Area/population coverage within d/t bands %</td>
<td>Length of network (total, per area/capita)…?</td>
</tr>
<tr>
<td>Avg. on-street vehicle speed/travel times</td>
<td>Supply indicators: km.veh. and places.km, Advanced (e.g. PTAL) …?</td>
<td>Pedestrian transport</td>
</tr>
<tr>
<td>Avg. delay due to congestion</td>
<td>Clustering of destinations, Density of population, …?</td>
<td></td>
</tr>
<tr>
<td>Length and density (per area/capita) of network, …?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 1 Dependence of car usage on automobilisation in various cities in Europe

Table 1

26 MOBILITY INDICATORS AND ACCESSIBILITY OF TRANSPORT
An essential prerequisite for the use of public transport is the accessibility of its stops and stations throughout the whole area of the city. In most European cities, the network is designed in a way that there should be at least one stop within a band of 5 minutes of walking (cca 400m). However, through the density of PT stops, there are no other important PT accessibility features expressed, such as frequency, “reachability” (total/average travel time to the destination), and etc.

The same problem is with the next set of “network” indicators, which are associated with the length of the network. There is no surprise then that there is no relation to be observed between these indicators and PT usage in various cities, even when reduced by the area or number of inhabitants (Fig 3). Of course, the figures are probably strongly affected by the geographical conditions of each city (as discussed further), but this only proves the exclusion of these indicators from further analysis.

Another group is public transport “supply” indicators, measured in places.kilometres or total kilometre(s).vehicles driven by PT vehicles (e.g. Urban Audit [1]). These indicators are relatively easy to calculate, but are not a satisfying expression of the public transport supply. More dispersed cities with distant suburbs and thus longer journeys and links would be evaluated better by any indicator comprising distance, though the number of trips actually served may be lower than in more compact cities. The importance of the frequency is neglected in both “supply” indicators; a connection twice an hour by tram with capacity of 300 places is evaluated as better than a bus with only 100 places, but running every 12 minutes. Actually, the number of places (seats and standing) should be normally adjusted to the actual number of passengers using the public transport; hence, it is self-expressive.

The average waiting time for a PT connection is an indicator which is directly dependent on the frequency of connections. But again, all the other features are ignored. No wonder then that no relation could be observed between the proportion of trips by public transport in this case either. Another possibility as to how to cope with the “frequency” and to eliminate the “kilometre” problems is to divide the supply by the length of the network. Forsoth, a better correlation is achieved (Fig 2). In the cities with a “density of connection” above 200 [km driven (by public transport) per km length of the network], there are also higher PT usage percentages. Nevertheless, the group consists of all the larger (over 100 thousand inhabitants) East European cities, Vienna and Porto. At lower densities, lower and more spread values are registered. Therefore, it is not possible to honestly determine what is cause and effect; thus this indicator is also not possible to accept for the purposes intended.

All the figures (including the Annexes) so far are based on the data from Urban Audit [1]. As usual, the statistical data on transportation is also quite confusing in this project. Many countries (11 out of 25!), including some very interesting ones, such as Italy, Belgium...
and Poland, have not submitted any transportation data; from some other countries only some cities did. Some other data was obviously biased by the geographical definition of the city extent (especially public transport indicators for Madrid, Barcelona, Lisbon and Porto), where probably only cores of agglomerations were indicated. Probably due to the indeterminate methodology huge differences occurred, and surely the wrong data was submitted by some cities. Just compare the public transport supply in places. kilometres in Lisbon (4.3x10^6), Porto (3x10^6), Bratislava (4x10^5) and The Hague (2.3x10^6) – all cities with similar number of inhabitants. This precludes a comprehensive analysis for now. Since another round of the collection of data was done in 2006, we can only hope that this time, the data will be better.

Obviously, more complex indicators are required to enable the comparison and study of mobility/accessibility relation among European cities. An example of such methodology is Public transport accessibility level (PTAL). PTAL is calculated for every single point of interest (e.g. a school) by summing a series of indices for bus, tram, underground and rail services to obtain an index number. Walking distances, the number of services and their frequency, and the reliability of service are all used in the calculations. Theoretically, it would be possible to express the overall quality of an urban public transport system based on, for example, the calculation of the “total” PTAL for all the points of interest in a city.

Naturally, due to complexity of the calculations, the use of computers and supporting GIS tools is required, and thus no further data is available except that from London and a few surrounding towns. Nonetheless, there is one essential limitation of PTAL, besides those already identified in other papers [see 4]. It was created as a tool to determine a location’s expediency, i.e., the number of potential ‘customers’. But the real requirements of travellers, which are at the roots of their mobility, are slightly different from those of planners and authorities. Therefore, the potential relevance of the data, even when available, is doubtful.

Even ignoring the fact that not so much attention is devoted to bicycle transport, it is also very difficult to determine any relevant indicators for bicycle transport. For instance, the ownership of bicycles is perhaps not as high as in the Netherlands, but still is enough for superior use as is common in other countries. There is

---

**Fig. 5** Dependence of usage of cycling on climatic conditions

![Graph showing temperature vs. cycling usage](image-url)
no doubt that an extended and safe network have positive influence on proportion of cycling but it is also very disputable to compare the network length between the cities; since not just special cycle paths are used to bike, no one is able to precisely determine which street is part of the bicycle infrastructure and which is not. No exact relation concerning the proportion of bicycle use could be observed due to climatic conditions (Fig 5), although it may be assumed that people do not ride so often in the countries with more extreme weather (too hot in the summer and too cold and lots of snow in the winter), because they simply cannot use it whole year long comfortably. What the cities do have in common is that they are located on flatlands. However, most other cities are built on flatlands, valleys and basins with not so sharp geomorphological profiles, too. The cultural environment and general acceptance of bicycle transport seem to be essential characteristics, which are unfortunately impossible to represent by any indicators.

4. TRANSPORT COSTS AND INFORMATION

The price to be paid for a trip when using a particular transport mode is no doubt one of the most important variables for the modal choice, however, it is practically unconsidered in all the indicators. A comparison of transportation costs between cities in UK (Sheffield), the Netherlands (The Hague) and Slovakia (Bratislava) is presented in Fig 5. The cities were chosen for comparison due to the similar number of inhabitants and public transport systems (no metro, but trams are available) and as typical representatives of different mobility figures in East and West Europe, with low (less than 1/3), medium (1/3-2/3) and high (over 2/3) usage of car and public transport, respectively and low or high share of cycling (Tab. 2).

Only direct distance-related costs for a single trip by one passenger were calculated in the price of a trip, the fare in the case of public transport and the cost of fuel for a private car. It is assumed that other costs (car tax, insurance, and maintenance, but also contributions to operators from public budget) play no role in the decision process of a passenger for a single trip; hence, they are not considered. Indeed, parking fees are direct trip costs as well; however are not distance-dependent, therefore could not be displayed in the graphs. Normal consumption of 13 km per litre (= 7.71 per 100 km) of petrol or a minimal 20 km per litre of diesel (economy class vehicles) is considered for a private car’s fuel costs. The price of fuel was based on the average as in February 2007. The most commonly used ways of ticketing were considered to calculate the fare costs of public transport:

- In England, the price of a one-week pre-paid ticket of a local (South Yorkshire) PT operator valid for all kinds of vehicles: buses, trams and regional (suburban) trains;
- In the Netherlands, half the price of a train return ticket, with and without 40% discount (off-peak trip only and discount pass required) and the average price of a stripe when “stripkenkaart” (pre-paid ticket) for 15 or 45 stripes are used for urban public transport;
- In Slovakia, distance-based regional inter-city bus fare and travel-time-based – 10 min, 30 min, and 1 hour – tickets for UPT in Bratislava (and the corresponding average ranges of the possible distances travelled within the urban conditions) were considered.

As indicated, normally a trip by public transport is about 40% more expensive than by car in the Netherlands; in Slovakia the situation is the reverse – in favour of public transport. This may be one of the reasons for the higher usage of public transport in East European countries; the fact that public transport is still relatively cheaper than a private car. If time-loss costs (the value of time) due to usually longer travel times would be added and more than one passenger per car considered, surely a car trip is cheaper in both countries. But what if the parking costs are added? An example of a comparison of the direct costs for an imaginary trip (e.g., a visit to the cinema) for the cases of Bratislava and The Hague is shown in Tab. 2. For simplification, both trips are considered to take the same time and thus no value of time is included. Very interesting values are provided, especially when the costs are expressed relatively as a percentage of disposable income. The costs of public transport are (surprisingly?) fairly similar in all the cities studied when expressed as a percentage of disposable income. As the relative direct costs for driving a private car are in fact comparable with a public transport ride in the Netherlands and the UK, is there any wonder then the driving is more often the final choice, since higher comfort and mostly shorter travel times are possible?? When parking fees are included, the cheapest car trip is the trip in the UK that may be the explanation of such high

Tab 2 Modal splits in the cities of Bratislava, The Hague and Sheffield

<table>
<thead>
<tr>
<th>city</th>
<th>Number of inhabitants</th>
<th>Modal split % (trips to work within the city area)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>car</td>
<td>public transport</td>
<td>walk + bike + (other)</td>
</tr>
<tr>
<td>Bratislava</td>
<td>428 672</td>
<td>24.3</td>
<td>72</td>
</tr>
<tr>
<td>The Hague</td>
<td>442 356</td>
<td>43</td>
<td>29</td>
</tr>
<tr>
<td>Sheffield</td>
<td>513 231</td>
<td>82.1</td>
<td>15</td>
</tr>
</tbody>
</table>

Source: Urban Audit 2003
Another hypothesis to be introduced in this paper is that another aspect of accessibility, namely informability impose on the mobility figures as well. The availability of reliable information for the customers is understood under the term promoted, along with the general awareness of people about transportation issues, such as knowledge of the actual travel times to certain destinations by different modes (private car and public transport par excellence), knowledge of timetables and connection possibilities, fare charges and parking fees, etc. Specialized unified surveys should be carried out to inquire into the level of informability in various cities at first, although a determination of its impacts on mobility would most probably be another complex issue with uncertain results (a comparable indicator of informability).

5. CONCLUSIONS

Public transport is a natural alternative to a car in any larger city, especially when commuting to work, usually for longer distances. An explanation of the differences in the modal split outlined above could lie in several aspects. Indeed the aspect of historical development plays an important role. Automobilisation in the East is still on average lower, although over 200,000 private cars (though including service vehicles) for 428,000 inhabitants in Bratislava is in direct contrast with that assertion. A more probable explanation is a kind of

Tab 3 Comparison of direct costs: return trip for 10km (one-way), no value of time

<table>
<thead>
<tr>
<th>city</th>
<th>PT fare € min/max</th>
<th>% of dispos. income +</th>
<th>car costs € no parking</th>
<th>% of dispos. income +</th>
<th>car + 2hr parking *</th>
<th>% of dispos. income +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bratislava</td>
<td>0.78/1.20</td>
<td>1.7/2.6 x10^-4</td>
<td>1.50</td>
<td>3.2 x10^-4</td>
<td>2.10/4.30</td>
<td>4.5/9.3 x10^-4</td>
</tr>
<tr>
<td>The Hague</td>
<td>2.20/3.60</td>
<td>1.5/2.5 x10^-4</td>
<td>1.90</td>
<td>1.3 x10^-4</td>
<td>5.60</td>
<td>3.9 x10^-4</td>
</tr>
<tr>
<td>Sheffield</td>
<td>2.70/5.50*</td>
<td>1.8/3.7 x10^-4</td>
<td>2.05</td>
<td>1.4 x10^-4</td>
<td>3.00</td>
<td>2.5 x10^-4</td>
</tr>
</tbody>
</table>

* standard parking fees: Bratislava 30/90¢; The Hague 180¢; Sheffield 95¢ per hour (on-street/pplace)
+ Bratislava €4617.8; Zuid-Holland €14458.3; Yorkshire €1494.6 per capita per year (Eurostat, 2003)
* dependent on number of trips accomplished within the one-week ticket (20/10 trips a week)

Fig 6 Comparison of distance-based direct travel costs in the UK, the Netherlands and Slovakia
historical ‘memory’ – people in Eastern Europe were more dependent on public transport in the past, and they are yet accustomed to use it. Or is the quality of public transport so much better?

The question cannot be properly answered. The one thing which is clear from this is that in East European countries, the costs ratio is not as much in favour of private car. Lower relative costs, and thus more affordable transport in the West, should also be considered relevant for explanation of higher mobility figures in terms of average trip distance. There are two possibilities: either there is no correlation between accessibility and mobility – and the latter is dependent just on other both local conditions, geographical and historical – or the indicators used are just not suitable. Hopefully, the second one is more likely.

All the common indicators analysed in this paper give no good correlation with the modal split. Actually, any indicator in which distances or spatial density is incorporated cannot be used for a reasonable comparison of the transport systems, and cannot provide an satisfactory in-view on its real expediency for a customer - passenger, since dependency on local geographical and demographical circumstances. Applying them, it is only feasible to contemplate about the development (in majority of European cities deterioration) of transport supply quality in time in the particular city only.

Moreover, accessibility should not be viewed only in the classical way of availability of an advantageous connection provided through accessible network. As it is shown here, affordability – and maybe informability as well – are probably in many cases even more predominant factors that actual “network” accessibility/availability. However, it is still impossible to determine the actual weights of these three aspects, unless no suitable indicators for each of these accessibility forms are found.

For all these reasons, it is important to find out a new approach which would enable an evaluation and comparison of public transport accessibility (in all the complexity of its aspects) and quality in various cities in a coherent way. A proposal of such a methodology is under development and will be presented after verification in the close future.

Acknowledgement
This paper is a part of the TransportNET research project on "Urban mobility policy and systems". All the support is gratefully acknowledged.
REFERENCES