Urban mobility indicators and road user behavior assessment by means of GPS technology in Cluj-Napoca, Romania

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Abstract: Urban mobility studies require complex analysis of the transport system. In this field, the data is very important and collecting it involves different techniques. This study is based on a GPS data collection system. After being collected, data are analyzed in order to obtain urban mobility indicators and some insights into travel behavior, respectively into the road user behavior in Cluj-Napoca.

Key-Words: urban mobility, road user behavior, GPS technology

1 Introduction

Urban mobility represents the image of the transport system on one hand, and the quantifier of the urban activities, on the other. Therefore, travel investigations provide basic insight not only into the urban mobility but also into the transport users' features. There is a series of general and specific indicators of the urban mobility that need to be investigated in order to build an overall image of the urban mobility (1). Among the general indicators, the network infrastructure supply and the available transport services are very important but the specific indicators such as travel times, travel distances, travel speeds, and users' characteristics, respectively the travel behavior can't be neglected (2).

The lack of a strong theoretical foundation for travel behavior analysis as well as of data has been previously highlighted (3; 4) although a series of models of road user behavior have been recently proposed (5). Travel attitudes of different road users such as driver, pedestrian and cyclists have been analyzed for different subjects such as urban mobility, road safety and traffic flow theory. The data used in this field of research are collected by means of traditional survey and GPS recorded or sometimes by combining the two methods for better results. GPS performances have been seriously improved since 2010 to become reliable for data collection (6). For the purpose of this study the GPS based urban mobility management system (7) was used.

The paper is organized as follows. Section 2 presents the objectives of the study. This is followed by a brief presentation of the study area. The next section describes the methodology and data analysis. Section 5 summarizes the main findings and further, Section 6 presents the main conclusions and highlights some recommendations for improving the data availability of the urban mobility specific indicators and road user behavior.

2 Objectives and scope

This study aims to explore the travel behavior by means of GPS technology in order to provide an insight into the road user behavior in Cluj-Napoca. During the data collection with the GPS technology more aspects regarding urban mobility were documented and analyzed in order to enhance the availability and quality of data for Cluj-Napoca. The present study does not aim to consider the exhaustive analysis of travel behavior characteristics (8) but the aspects that can be revealed with the system at disposal.

3 Study area

The study is focused on the city of Cluj-Napoca that is situated in the North-West Region of Romania and in the heart of the historic region of Transylvania (Fig.1). Cluj-Napoca is located roughly equidistant from Bucharest, Belgrade, and Budapest. The city sprawls on a plateau surrounded by hills, over the valley of two rivers. Cluj-Napoca has a mononuclear and radial-shaped urban form and it covers 179.5 square km. Cluj-Napoca is a

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mid-sized city, with a population of 324,576 inhabitants.

Cluj-Napoca is the largest urban center of the North-West Romanian Region, the capital of Cluj County and the urban center of the Cluj-Napoca metropolitan area. Cluj-Napoca's economic polarization potential placed the city as second in the national economic hierarchy after the capital Bucharest and therefore, as the most important urban center in the region.

The transport system in Cluj-Napoca relies mostly on the road transport for both interurban and intra-urban mobility although the urban road density is just 3.7 km per square km. The interurban transport infrastructure supply includes the railways and airport as well. Public transport service by buss, trolleybus, and tram are also available and they are provided by CTP (9).

So far, some aspects of the urban mobility and travel behavior in the study area have been assessed but they are still scarce and not efficiently organized (3; 10; 2).

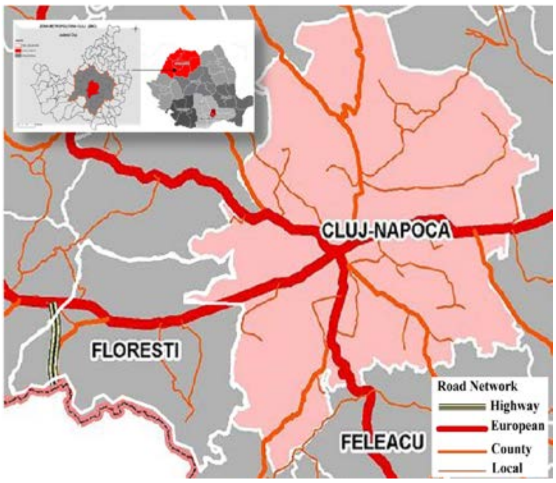

Fig.1. Study area – Cluj-Napoca, Romania

4 Methodology and data

The study aims to provide new insight into the urban mobility and road user behavior in Cluj-Napoca. As a first objective, besides the information regarding transport infrastructure and services supply, modal share, O-D matrices, peak periods (2), more additional specific indicators of the urban mobility need to be assessed. In this respect, the GPS technology based urban mobility management system was used to collect data. As the urban mobility in Cluj-Napoca is mainly based on the road transport, the system is collecting data on five test vehicles: two private cars (PC1, PC2), a taxi (Taxi), an ambulance (Amb) and a garbage truck (GT). The base location of the five vehicles is presented in Fig.2, where there are also pointed out the working places where the two personal cars travel daily. The data was collected over a 76 days period between 01.03.2015 and 15.05.2015. The data sets include daily travel reports presenting times, distances and vehicle speeds of the five test vehicles. Therefore, some specific mobility indicators were able to be assessed: average and maximum travel speeds, travel distances, running and stationary times.

As a second objective, the study aims to connect the vehicle performances to the users' characteristics by analyzing some of the socio-economic aspects of both private car users which have impact on their travel behavior.

This paper proposes a methodology based on GPS data collection. The data are further analyzed in order to achieve more information about the specific indicators of the urban mobility and the road user behavior in order to enhance the knowledge on the urban mobility in the study area by extracting meaningful information about the investigated issues and not by developing a new approach on the subject (4).

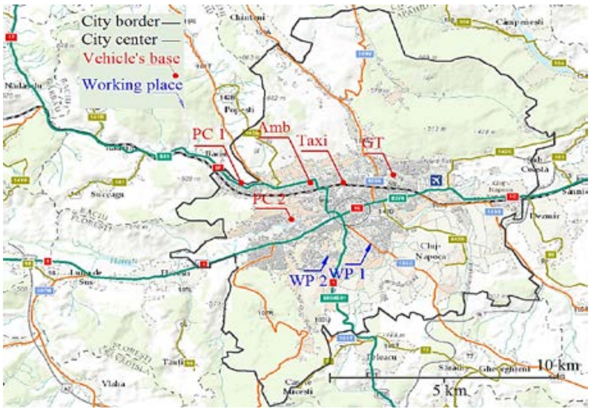

Fig.2. Transportation supply in the study area (11)

5 Results and findings

The analysis is based on descriptive statistics and the results are further discussed.

5.1.1 Specific mobility indicators

One of the most relevant specific indicators of the urban mobility is the travel speed (12). Daily average travel speeds of the five test vehicles are presented in Fig.3. The average travel speed in Cluj-Napoca resulted 21.4 km/h from the collected data and 90% of the average speeds of the test vehicles were up to 30 km/h. The observations at 0km/h represent the values associated with the inactive days. As expected, the garbage truck registered lower average daily travel speeds while the

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ambulance registered, in general, higher ones. The taxi travelled at higher average speeds than the personal cars, with few exceptions.

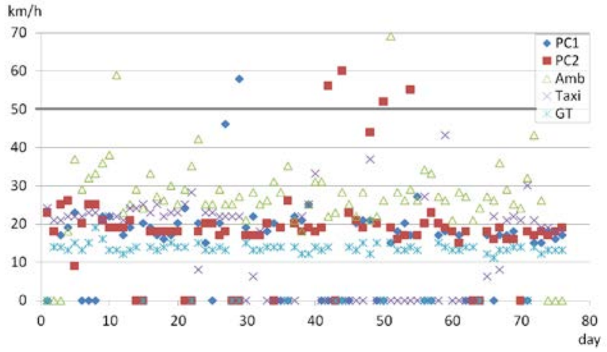

Fig.3. Daily average travel speeds

Table 1. Average travel speed information

Test vehicle	PC1	PC2	Amb	Taxi	GT
Active days	51	65	70	49	63
Daily average travel speed (km/h)					
Mean	20	22	29	22	14
SE	0.99	1.2	0.95	0.91	0.15
Median	18	19	25	22	14
Mode	17	18	27	22	13
SD	7.1	9.8	8	6.4	1.2

The speed limit in Cluj-Napoca is 50 km/h with some exceptions in several particular areas and for some streets. Fig.4 illustrates that in general, the test vehicles registered maximum travel speed exceeding the 50 km/h limit in almost every active day. Most frequently the 70 km/h value was exceeded by the ambulance (96% of total daily maximum speeds) and taxi (69%). The majority of maximum speeds between 50 km/h and 70 km/h were registered by the personal cars (PC1 61%, PC2 85%) and garbage truck (92%). It happened due to the fact that they are usually running in the traffic flow. In this respect, the personal cars and garbage truck are most representative for the usual traffic flow characteristics.

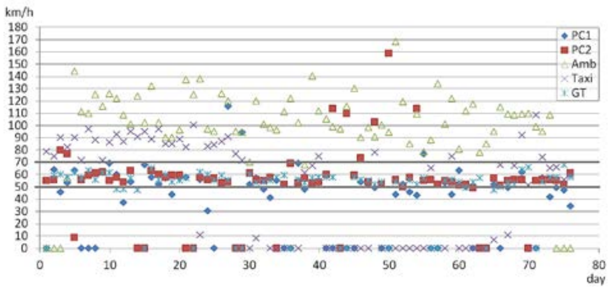

Fig.4. Daily maximum travel speed

Traveled distances are relevant to the urban mobility assessment as they provide an insight on the daily activities of the population and an assessment of the activity volumes of the services vehicles. Therefore, services vehicles such as the ambulance and garbage truck, registered longer daily average travel distances, respectively 304 km and 92 km. The taxi had also an intensive transport activity, traveling on average 151 km daily. Due to the remoteness of the working place, personal car PC2 travelled on average 42 km/h daily which was longer than the distance travelled by PC1 of 33 km/h (Fig.2). With the exception of the taxi, the distance travelled by the vehicles was directly dependent on the number of active days.

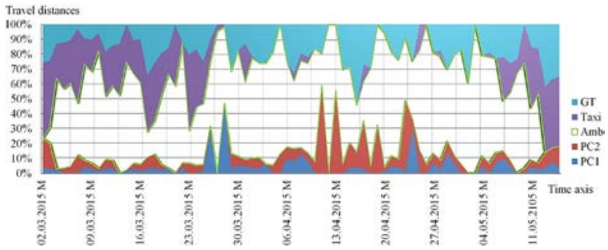

Fig.5. Daily travel distances

The monitoring system also provides general information on the vehicles' activity such as operating times – running times and stationary times with the engine on and off. Travel time is another important urban mobility indicator (13). The two personal cars registered an average stationary time with the engine on around an average value of 11 hours in 10 weeks. Therefore, we can roughly state that the current conditions in Cluj-Napoca cause over one hour delay per week in traffic.

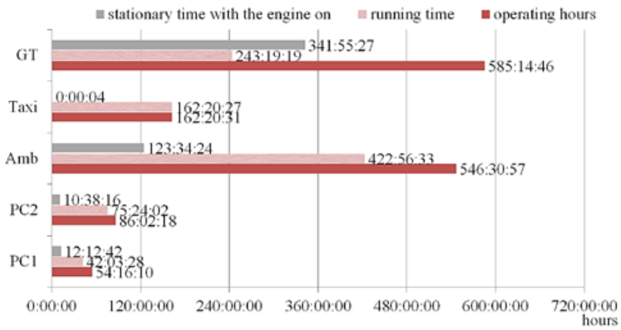

Fig.6. Operating times – running & stationary hours

One of the issues that aren't generally discussed in urban mobility analysis is about the period in that vehicles are being inactive. In this sense, the study presents the situation of the five test vehicles in Fig.7. It is obvious that only the ambulance and the garbage truck present some noticeable transport activity by being inactive only for 98% of the time while the other vehicles exceed 99.4%.

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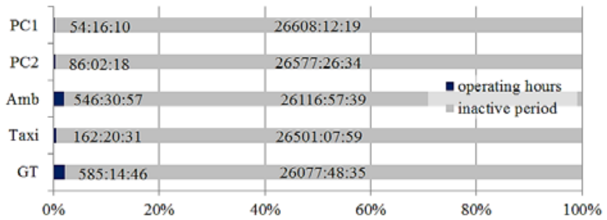

Fig.7. Operating versus inactive hours

Following the analysis of the data collected with the urban mobility management system it resulted that transport activity and urban mobility indicators (e.g. the average daily travel speed) are due the function of the vehicles (Fig.8.)

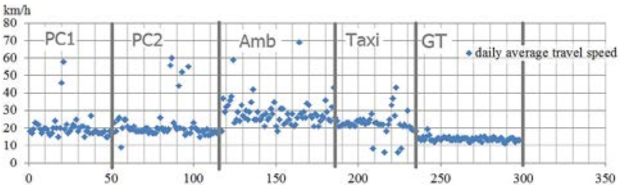

Fig.8. Daily average travel speed

5.1.1 Road user behavior

Taking further the analysis of the collected data, the similarities between the two personal cars' mobility indicators impose a more detailed study.

Therefore, an analysis was conducted with the aim to highlight the difference between the two personal cars activity for a better understanding of the road user behavior. The differences are presented and highlighted in Table 2 and the higher value is bolded.

Personal car 1 is used less than personal car 2, at a share of 78% when considering the entire 76 days period, regardless the day of the week. The daily average travel speeds of the second personal car are higher compared to the values registered by the first personal car. Some of the maximum travel speeds registered by both cars are exceeding the 50 km/h limit but the first personal car registered 55% of the daily maximum travel speeds below 50 km/h and 94% of the values under 70 km/h. That is not the case for the second car which registered 17% of the maximum speeds under the 50 km/h limit and 88% under the 70km/h limit. The inactive time is also higher for the first personal car since the user doesn't use it at all days of the week and especially not in the weekends. Therefore, the operating time of the first car was shorter during the investigation period compared to the second vehicle. The latter one registered almost doubled travel time.

A series of the differences in the mobility indicators of the two personal cars may be explained on the account of the housing and working locations of the two car user. However, some personal characteristics of the users are presented next and thus it is highlighted that not only the transport system features influence the travel and therefore, the urban mobility, but also the socio-economic characteristics of the road users.

Table 2. Detailed travel information of personal cars

Vehicle	PC1	PC2
Travel activity (76 days)		
No of active days	51	**65**
% of active days	67%	**92%**
% inactive week days	**9%**	1%
% inactive weekend days	**24%**	13%
Daily average travel speeds (21.4 km/h)		
Mean (km/h)	20	**22**
Median (km/h)	18	**19**
Mode (km/h)	17	**18**
% above 21.4 km/h	20%	20%
% above 50 km/h	2%	**6%**
Daily maximum travel speeds (168 km/h)		
Travel speed (km/h)	116	**159**
% under 50 km/h	**55%**	17%
% 50-70 km/h	49%	**71%**
% above 70 km/h	6%	**12%**
Active time (h)		
Operating time (h)	54:16	**86:02**
Travel time (h)	42:03	**75:24**
Stationary time with the engine on (h)	**12:12**	10:38
Delays (h)	**12:13**	10:38
Inactive time (h)	**26608:12**	26577:26
Inactive time (%)	**99.8%**	99.7%

Table 3. Detailed personal information of the private cars' users

User of	PC1	PC2
Age group	40-50	26-30
Gender	F	M
Marital status	Married, a child	Single
Occupation	University teacher	Engineer
Education	Phd. Eng.	Phd. Eng.
Income level	< 500€	> 500€
Driving license ownership period	10-20 years	< 10 years

It can be observed that a young male with a medium income is relying more on the private car than a mature woman although her driving experience is longer. Also, the young male adult tends to be more aggressive when driving compared to the mature woman as he registers higher daily average travel speeds and shorter stationary times and delays. Moreover, the single young man is a more irresponsible driver compared to the married woman because 83% of the daily maximum travel

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speeds he registers are above the speed limit of 50 km/h.

Given the considered issues, it was highlighted that not only the technical aspects of transportation are important when analyzing travel behavior but the socio-economic aspects of the users as well. In this respect, a further study is necessary so that all vehicle tests' users to be included in the analysis. In order to be more conclusive, details regarding the origins and destinations as well as the fuel consumption need to be considered.

Following the results of this study, it may be concluded once again that population creates the urban mobility and thus traffic through the trips they are taken in order to take part in some activities. Therefore, travel behavior is one of the key characteristics in urban mobility analysis.

Moreover, the amount of time being inactive, in average 99% for the five test vehicles should be considered for further studies as parking proved to be a very important issue of the urban mobility. The stationary times with the engine on also provide information about the urban mobility aspects such as the waiting time and delays which may be very helpful.

5 Conclusion

This study focused on two major aspects. First, the urban mobility management system utility is to be noted. The collected data are very useful for different analysis. One of the most important directions is about the performances of the test vehicles and the characteristics of the traffic flows. Due to the permanent collection of data with the urban mobility management system in use, a larger number of test vehicles should provide more representative data. A large scale implementation of the urban mobility investigation system on the local government should provide more data for the scope of research as they would run in traffic as multiple investigators and with their help there would be sufficient sample and therefore, findings could be extrapolated to the city level. Gathering statistically representative data on the subject in order to be able to establish the GPS based urban mobility management system as a standardized measurement method is a further aim.

On the other hand, the possibilities to connect urban mobility indicators to travel behavior represent a very important aspect that the study highlighted. The socio-economic characteristics of the road users are useful means to assess road user behavior. This opportunity imposes the expansion of the urban mobility management system by increasing the number of users with a broader area of socio-economic aspects as a means to improve the understanding of urban mobility.

In conclusion, the implications of using such a system overcome the borders of urban mobility analysis. Increased information about urban mobility indicators and road user behavior should become a very useful tool for sound urban development strategies, better urban transport services management and nonetheless, cleaner environment and more qualitative cities. Therefore, the urban mobility studies have to be founded on permanent and reliable data provided by a monitoring system on one hand, and road user behavior aspects on the other.

As a further study, the information gathered for the two personal cars would be analyzed in comparison with other modes, such as public transport and cycling in order to establish possible alternative travel choices in the area.

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