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Using GIS methods to analyze spatial characteristics of urban transportation system in Craiova city

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Abstract

In a world of technology, where the increasing urbanization tries to cope between sprawl and the need to actively manage a sustainable land and resources use, transportation remains among the main challenges for physically active cities like Craiova. The city is the major growth pole located in South-West Oltenia, which connects most of the settlements in the region (both rural or urban) economically and socially. Thus, the transportation system represents the key element in the relation between time and place in this metropolitan area in a continuous development process. While the city expands, the transportation network, inherited from the past, suffers a slower transformation, despite the increasing demand for mobility coming from both passengers and freights. The spatial analysis of new residential areas emerged in the continuous process of urban expansion indicate an additional pressure on the existing road infrastructure and which intensifies especially during peak hours on the access routes to the city and city center. Starting from the analysis of the spatial structure and distribution of the pre-existent rural structure, the present study tries to emphasize the need for an innovative and integrated infrastructure that should connect at its best space, services and people in terms of speed, capacity and cost efficiency. First, using the GIS mapping methods, the authors present the spatial distribution of the transport infrastructure that is correlated with population density and land use, also analyzing the areas with high density of jobs and elements of the urban landscape that may generate attractivity. A special attention is paid to the urban form - street pattern relation, exemplified by case studies in problematic intersections of Craiova city. All these factors are important in order to establish the present capacity of the urban transportation system during peak hours, and what are the main deficiency of the transport system: traffic jams, insufficient parking places, need of new connections in public transportation. The results of the research may be used to improve passenger transport inside the city of Craiova and may also suggest some solutions that mitigate for the introduction of new concepts like car sharing, electric public transportation, hybrid vehicles or new alterna-tives for peoples' movement.

Keywords: *urban transport, connectivity, passengers and freight movement, urban land use*

Rezumat. Utilizarea metodelor GIS pentru analiza caracteristicilor spațiale ale sistemului de transport urban în orașul Craiova

Într-o lume a tehnologiei, în care creșterea urbaă încearcă să facă față extinderii și necesității de a gestiona în mod activ o utilizare durabilă a terenurilor și a resurselor, transportul rămâne printre principalele provocări pentru orașele fizic active precum Craiova. Acesta este cel mai important pol de creștere din sud-vestul Olteniei, care conectează majoritatea așezărilor din regiune (atât rurale, cât și urbane) din punct de vedere economic și social. Astfel, sistemul de transport reprezintă elementul cheie în relația dintre timp și loc în această zonă metropolitană într-un proces de dezvoltare continuă. În timp ce orașul se extinde, rețeaua de transport, moștenită din trecut, suferă o transformare mai lentă, în ciuda creșterii cererii de mobilitate provenind atât din partea pasagerilor, cât și a transportului de mărfuri. Analiza spațială a zonelor rezidențiale noi apărute în procesul continuu de expansiune urbană indică o presiune suplimentară asupra infrastructurii rutiere existente și care se intensifică, în special în timpul orelor de vârf, pe rutele de acces către oraș și în centrul acestuia. Pornind de la analiza structurii spațiale și a distribuției structurii rurale preexistente, studiul de față încearcă să sublinieze necesitatea unei infrastructuri inovatoare și integrate care să se conecteze la cel mai bine spațiul, serviciile și persoanele în ceea ce privește viteza, capacitatea și eficiența costurilor. În primul rând, folosind metodele de cartografiere GIS, autorii prezintă distribuția spațială a infrastructurii de transport corelată cu densitatea populației și utilizarea terenurilor, analizând de asemenea zonele cu densitate mare a locurilor de muncă și elemente ale peisajului urban care pot genera atractivitate. O atenție deosebită este acordată relației dintre structura urbană și a tramei stradale, exemplificată prin studii de caz în intersecții problematice din orașul Craiova. Toți acești factori sunt importanți pentru a stabili capacitatea actuală a sistemului de transport urban în timpul orelor de vârf și care sunt principalele deficiențe ale sistemului de transport: blocaje de trafic, locuri de parcare insuficiente, nevoia de legături noi în transportul public. Rezultatele cercetării pot fi utilizate pentru a îmbunătăți transportul de călători în interiorul orașului Craiova și pot sugera, de asemenea, unele soluții care promovează introducerea conceptelor de partajare a autovehiculelor, transportul public electric, vehiculele hibride sau alternative noi pentru deplasarea oamenilor.

Cuvinte-cheie: *transport urban, conexiune, transportul persoanelor și al mărfurilor, utilizarea urbană a terenurilor*

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Introduction

The rapid urban expansion during the last decade caused by the socio-economic growth of modern society based on technology has major repercussions on urban mobility (Gonzalez M. et al, 2008). Besides the environmental impact, most urban centers face problems concerning the mobility, the transport infrastructure being overcome and causing frequent traffic jams (Jingyuan Wang et al., 2014), which reduce the efficiency of car transport by increasing the time travel for relative short distances, augmenting the fuel consume and producing air pollution (Belik, V. et al., 2011; Pengjun Zhao, 2010).

Nowadays, mobility is essential for the economic development to take place, both locally and regionally, influencing the people wealth fare and that is why policy makers must focus of transport efficiency and sustainability. Although the road density is high, for most cities it became insufficient and road extension is not a viable solution anymore, especially inside the cities, mainly because of urban land use (high price land, historical centers closed for traffic circulation). Also, extending the road infrastructure and encouraging urban mobility based on motorized transportation generates a vicious circle which will cause the exponential increase of the number of cars (Gutiérrez J & García-Palomares J.-C., 2008).

In EU, most cities face problems regarding the urban transport, which generates not only deficiencies in the movement of people and freights, but also a high level of pollution. In this respect, it was decided to find viable solutions by discouraging individual car movement and promoting the collective transportation or by developing non-motorized transportation means. Thus, all big European cities must have a sustainable urban mobility plan, the main objective of which is to improve accessibility of urban areas and providing high-quality and sustainable mobility and transport to, through and within the urban area. It regards the needs of the "functioning city" and its hinterland rather than a municipal administrative region and contributes to a better overall performance of the trans-European transport network and the Europe's transport system as a whole (CE, 2013).

Although Craiova experiences a relatively recent urban sprawl, the city deals with the increase of car number and the intensification of road traffic in both the city center and urban fringe. So, the car use increased, same as the distances covers daily, with the mention that most of the times the time and distance relation is not optimal. (Banister, D., 2008). Because of this ratio, the transportation costs increase for all type of transport (Mir Shabbar Ali et al., 2014). As many other big cities, Craiova develops a spatial structure based on the individual car transportation.

Study area

Craiova is one of the seven urban growth poles in Romania (along Brașov, Cluj-Napoca, Constanta, Iași, Ploiești and Timișoara), being the largest city in South West Ol-tenia Development Region. In the given context, Craiova municipality polarizes most of the economic activity in the region, exceeding the limits of its metropolitan area due to the socio-economic connections established with the rest of the nearby urban and rural set-tlements. There is a strong connection between the transport infrastructure and the urban influencing area of Craiova, creating a functional metropolitan area slightly different from the one officialy established by the Law 215/2001, Law 351/2001, Law 350/2001, Govern-ment Ordinance no 26/2000, Law 246/2005 and based on the Decission of the Local Council of Craiova no 297/27.11.2008 (fig. 1).

The metropolitan area of Craiova holds 54% of the population within Dolj county (75% of the population in the metropolitan area lives in Craiova). The population of 304,089 inhabitants (INS, 2017) is unevenly distributed on the urban area of the city (105.39 sq km out of which 81.41 sq km urban area), with a density of 3,310 inhabitants/sqkm (Table 1). The metropolitan area represents 20% of the total surface of Dolj county (fig. 1). The urbanization rate in the metropolitan area is high, as demographically, 82% of the popula-tion is concentrated in three urban centers and only18% lives in the rural area.

Table 1: Table 1 – Spatial and demographic changes in the urbanized area of Craiova

	1992	**2011**	**Change**
Population	307,077	311,909	1.55%
Urbanized area (sq km)	58,80	81,41	27.77%
Population density (pers/ sq km)	5,222	3,831	-36.31%

Source: calculations made by the author using statistical data

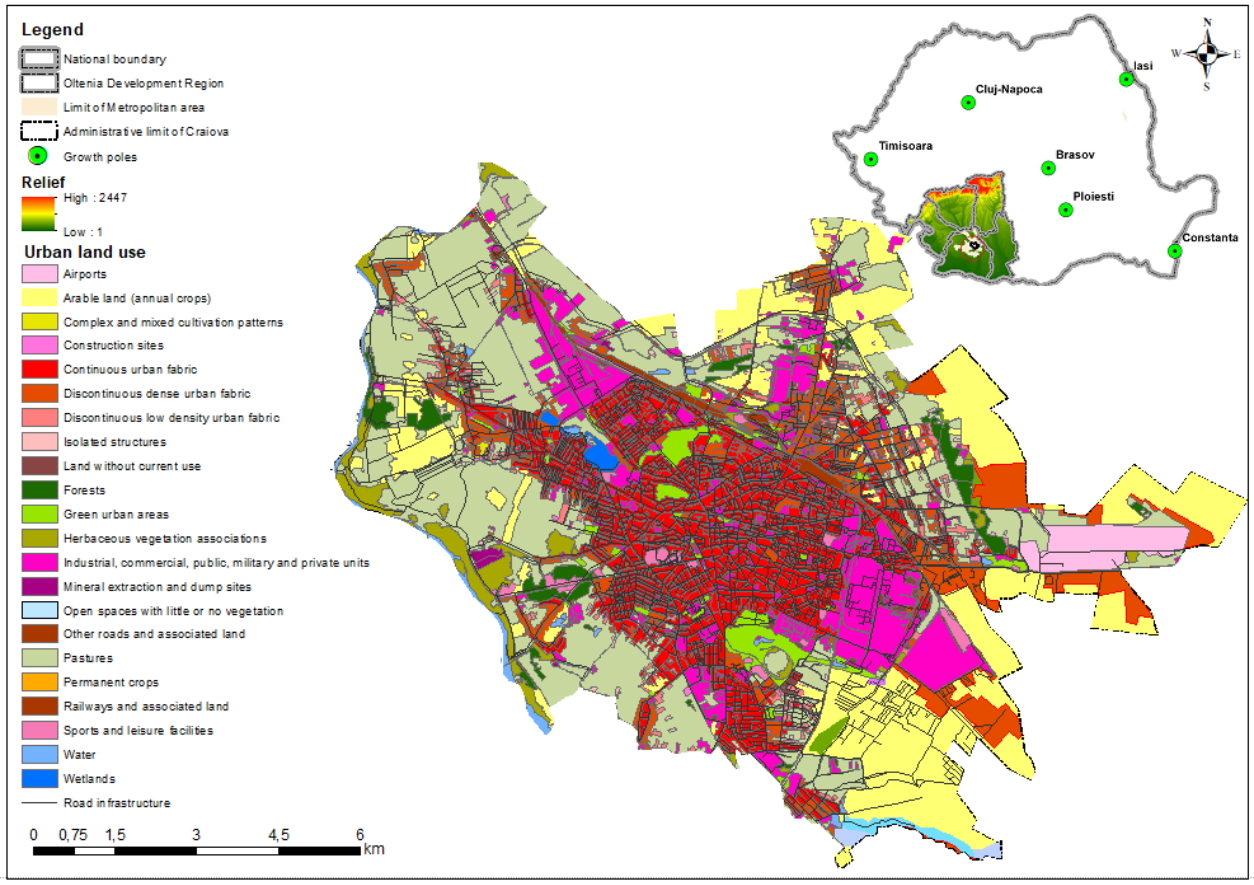

Fig. 1: Location and limits of the study area

Data and Methods

Several specific tools have been used in ArcGIS 10.5 for the processing and geospatial representation of statistical data and raw information. The initial mapping stage began with the collection of available data and the creation of the geospatial database, using both vector and raster data to create a spatial database. For the use of data from different sources in later integrated analyses, they were spatially homogenized using GIS applications that provide specially designed data management tools for defining or transforming projections, as well as georeferencing. As a toolbox, GIS allowed us to perform spatial analysis using geoprocessing functions such as map overlay, connectivity measurement, and buffering. There were also used the Spatial analyst functions and modelling for statistical and land use transport analysis.

The study focuses on analysing the access and coverage of public transport in relation to residential, commercial and job connected areas. The analysis of the coverage to a public transportation line started from the density of transport lines and exiting stations. Two areas of interest have been established for analysis by applying a 200 meters and a 500 meters buffer around the transport lines using the Euclidean (straight line) distance. The land use categories within the buffer area, mapped on SPOT 5 images and 1:5,000 orthophotoplans, were reclassified in three categories: residential (including new residential area), commercial (including commercial areas, industrial and educational) and other (including green areas, services and other). The public transport, serving especially these land use categories, is analysed with an emphasis on the residential areas because of their rapid development during the last period in Craiova. The overlapping and intersection between the sections determined by the two buffers and layers containing information about the land use, functional areas and population density (processed statistical data) were performed in order to determine the residential surfaces covered by the public transport. The sums of the land cover categories have been converted in percentages related to the total area used subsequently to compare the two situations resulted.

In order to identify urban traffic issues on some road sections and in critical points, the second part of the study focuses on collecting and processing the data needed to calculate the speed and travel time on several streets. In this respect, we selected several intersections and four road sections (each being one km long), located on four of the most circulated major road arteries, for which field observations and measurements were made during a week period. Data regarding the road traffic came from field observations

made during a week in three daytime periods: 8:00 – 9:00 a.m, 12:00 – 13:00 p.m. and 17:00 – 19:00 p.m. Also, road traffic data for Craiova and for the same time intervals was analysed; it was offered live by Google Maps (http://www.mapparade.com/map-of-craiova-in_ro-mcza). All information had been processed and data resulted were used to calculate the mean travel speed, in one direction, toward the city center (U.S. Department of Transportation, 2007). The final results were spatially modelled in the GIS environment.

Discussion

In order to understand the traffic problems, the authors pay a special attention to the interaction between transportation and urban land use, which is responsible for the dayly mobility trends in Craiova (worked-based obligatory movements, like commuting or professional ones, and voluntary movements connected to commercial or leisure activities personal or tourists' movements) (Rodrigue J.-P., 2017). There is a strong link between the activities carried out depending on transport and its attractiveness, which influence the urban land use, the latter generating the activities. Staring from the circular relation between the determinants of this equation, there were identified three areas with different features of mobility and transport modalities (fig. 2):

- *The historical city center* in which the pedestrian area prevails, and the car access is re-stricted to locals (access by barriers) and to special services and supply, regulated by a strict hour interval. Nearby there are public transport terminals and connection stations, but there are no bike lanes and no bike rental centers. The activities specific to CBD dominate this area, where a number of public institutions (City Hall, Prefec-ture) and prestigious education establishments (University, 3 high schools), as well as numerous tourist attrac-tions are located (within a radius of 0.5-1 km). This area is characterized by a high density of urban constructions and a high concentration of finance activities.

- *The central area* (which includes the historic center) is the destination for most of the daily movements (mandatory or voluntary). Due to the various activities carried on in this area which concentrates a high number of jobs, but also the direct access to the historic center, the car traffic is intense throughout the day, the waiting time in traffic is high (from 10 to 45 seconds) and the driving speed is low (average 30 km/h). Accessibility to public transport (bus and tram) is very high. In this area, be-sides walking, people can use the bike routes along Calea Bucureşti boulevard to access the central and core area.

- *Periphery / suburban area* characterized by the recent urban sprawl, where car transport (mostly individual) predominates and transport infrastructure occupies important areas (Avram S. et. al, 2010). Other land uses are attributed to new residential areas in continuous development, industrial and commercial spaces, as well as sports facilities.

The three areas identified are relatively concentric, being bounded by important traffic arteries that provide transit (to the east, towards Bucharest or to the west) or access to the central area, or bordered bypasses.

Starting from the relation between urban form and urban spatial structure, accessibility and agglomeration are the key elements that generate the main features of the urban transport in Craiova city. Thus, the first part of the study focuses on the accessibility of residential areas (especially the new residential areas within the suburban area) to collective transportation and identifies the problematic areas. The access of population, living in peripheral areas of the city, to transport system is very important as they depend on it for daily movements (work, school, shopping), using mostly personal cars. By identifying the coverage of the collective transport in these areas, the study highlights the need of improving the accessibility to bus or tram routes and the possibility of shifting the transport preferences from individual to collective. Although the population densities in these areas are low (fig. 2) compared to the ones in the rest of residential areas, they represent the main cause that generates intensive road traffic on collecting streets and increases the travel time and costs.

As the main growth pole of the region, the urbanised area of Craiova is continuously expanding, and the residential land use registered the most rapid growth during the last decade. Although the city is growing, the public transportation system did not registered major improvements, the only growing statistic being for the number of cars. There are 350 cars to 1,000 inhabitants in Craiova and 296 cars to 1,000 inhabitants in the metropolitan area.

Regarding the public transport, the city has a number of 140 buses out of which 17 are modern, purchased in 2014 and 17 have less than ten years of operation, the rest of 106 buses being older. Besides the buses, there are also 29 trams (older than 30 years) and 66 minibuses (33 belonging to a private company which provides services of public transport). The average life time in operation of buses is 15.47 years and 12.54 years for minibuses. The minibuses from the private company have an average operation of 4.15 years (*Urban Mobility Plan of Craiova*, 2017).

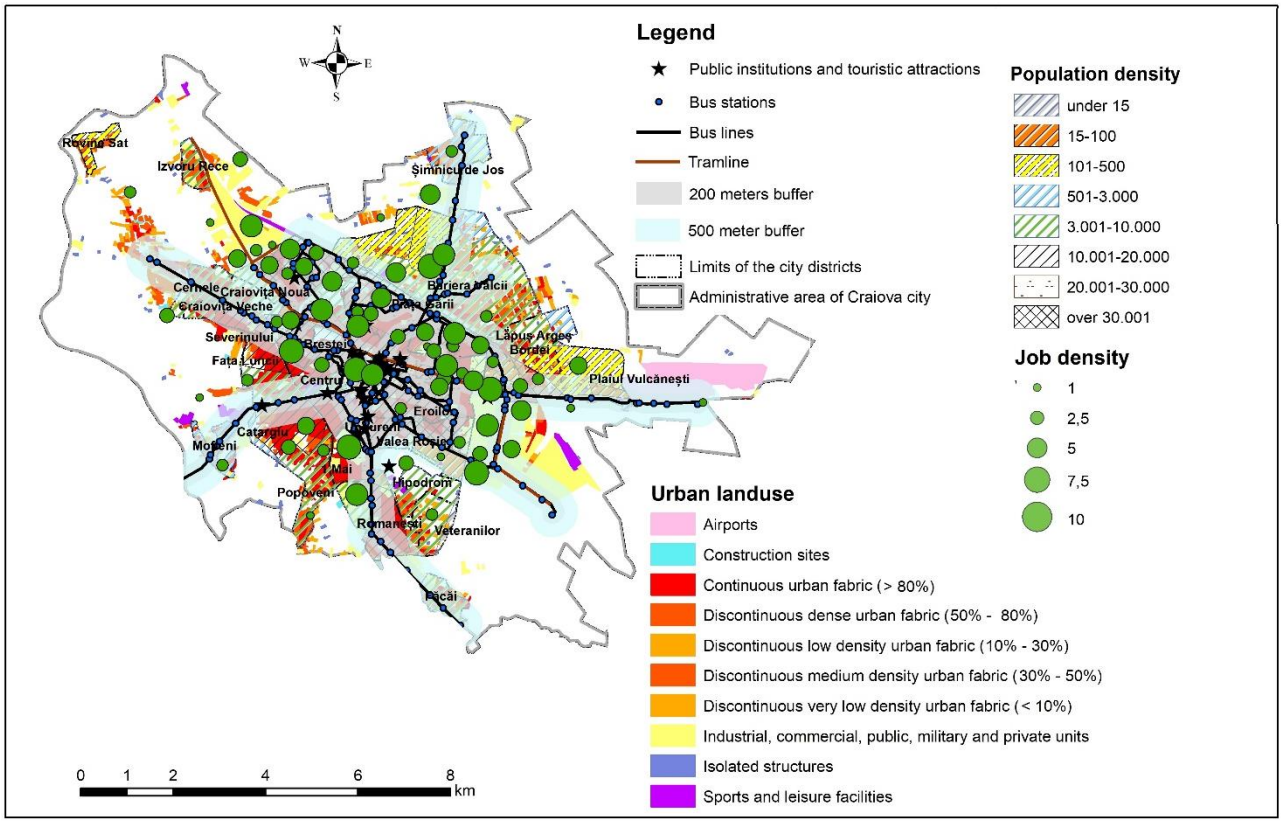

Fig. 2: Spatial distribution of public transport in relation to urban land use, population and job density

Source: population and job density data were processed using the information found in the Urban Mobility Plan of Craiova

From the first observations over the routes of public transport density and spatial distribution, the most reachable areas using this type of transportation, in a limited amount of time and a limited walking distance, are the old city center and the central area surrounding it (fig. 2). These areas can be accessed by bus lines (coming from different parts of the city) and by tram. Also, the density of stations is very high. As we are interested in the access of the population to the public transport, for our study we selected two situations in order to show the minimum distance and walking time to a bus station. For the first scenario, we used a 200 meters buffer around the bus line routes and their stations and in the second scenario a 500 meters buffer was applied. After spatial modelling different amount of geographic data, processing and overlaying the layers containing spatial information about the urban land use, urban density, functional areas, public transport routes and stops along these routes, the GIS data base was queried and several calculations had been made. The final data were converted in percentages for a better comparison. The results showed the following situations (Table 2):

Table 2: Urban land use within the selected buffers

Buffer	Total area		Residential			Other land use		
	(sq km)	% of total urban area	(sq km)	% of buffer area	% of total urban area	(sq km)	% of buffer area	% of total urban area
200 m	21.74	26.70	11.21	51.56	13.76	10.53	48.43	12.93
500 m	40.63	49.90	19.69	80	24.18	15.51	20	19.05

Source: calculations made by the author

The analysis shows that the total area covered by the 200 meter buffer from all the existing bus lines cover about a quater (26.7 sqkm) of the total urban area, while the area included within the 500 meter buffer almost 50% (Table 2). These results show that

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almost half of the activities existing within this area have access to the public transportation (fig. 2 & 3).

The „other" areas, except the residential ones, include the following types of urban land uses within the buffer area: commercial (including commercial, industrial and educa-tional), green areas, services and other. Also, from the total area covered by the 200 meters buffer, the central area has 3.87 sqkm, while the 500 meter buffer includes 5.43 sqkm from the central area. The green areas represent about 10% of the area covered by the 200 meter buffer and 14.34% of the area included within the 500 meters buffer.

In terms of accessibility, the following areas have been identified where public transport offers no service or low service levels (fig. 3):

• the eastern part of the city: the Carpen Street and the northern and eastern parts of Bordei district where the largest new continuous residential area has been devel-oped in the last decade;

• the wastern part: the area located westward of Râului Street and both sides along the Știrbei Vodă boulevard, both areas with new residential areas in development;

• the southern area: Veteranilor și Hipodrom districts, residential area mainly with individual households.

These neighborhoods require improved access to public transport by extending the existing routes or providing new ones. These areas can, however, raise problems of prof-itability either because they have a very low population density (due to the predominance of individual households), especially in the south and northeast, where there are also un-occupied lands or because they have a poor road infrastructure like in the southwest and western areas.

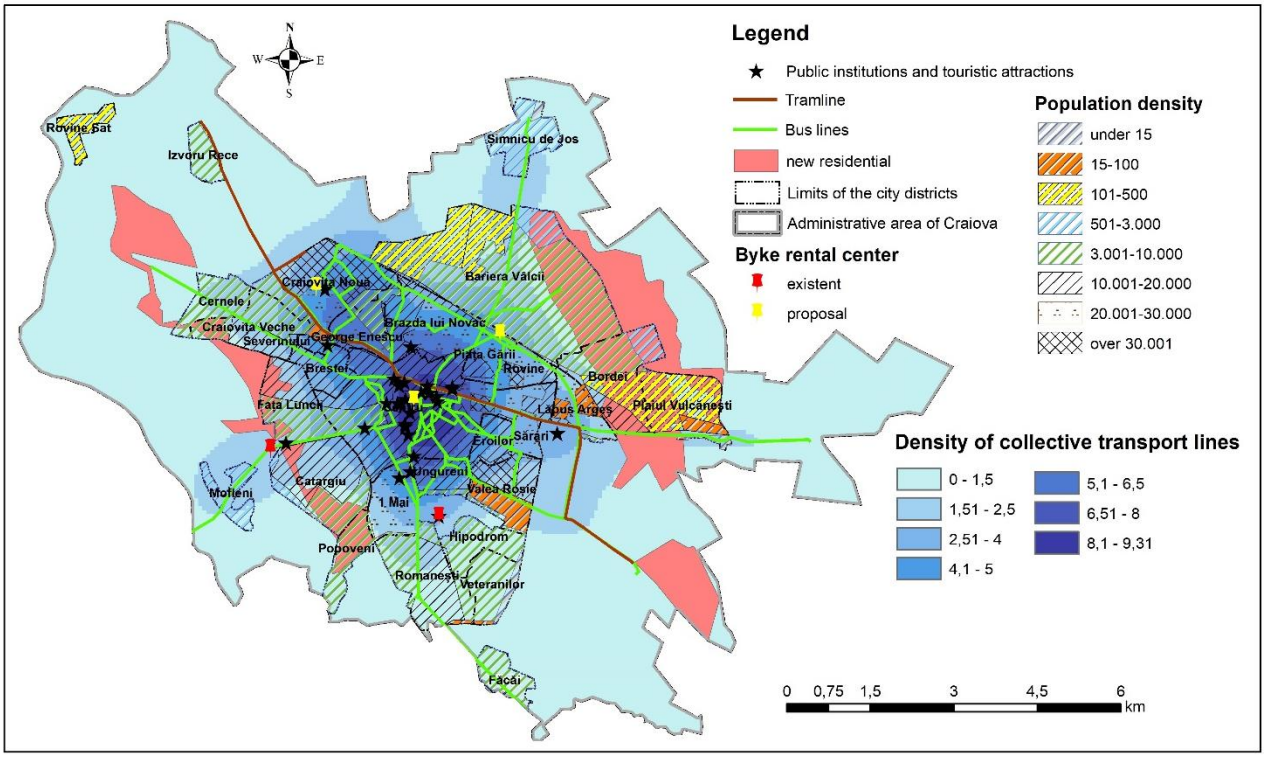

Fig. 3: Map of accessibility to public transport (bus lines and tramline) in relation to population density and main touristic objectives located in the central area

The raw data collected, as well as the field observations, showed two trends in road traffic congestion that contribute to traffic jams and increased waiting times. The analyzes showed that the main road arteries crossing the city from north to south (Amaradia street and Carol boulevard) and from east to west (Calea Bucureşti, AI Cuza, Caracal boule-vards) linking the access and entering points into the city, the residential areas and the city center are the most crowded roads. Also, the number of vehicles transiting these arteries varies between 1,000 up to 2,500 cars/ day. The spatial interpolation of data shows that the most probable cause of the road blockage is on the arteries connecting the northern part of the city (Şimnicul de Sus, Bariera Vâlcii) and its southern part (Mofleni where the ecologi-cal waste platform of the city is located), but passing through the central area. The second route is along the European road E70, which connects Bucharest and Timisoara and cross-es the city from east to west (fig. 4). Craiova is not only a production center, but also a big consumption center, therefore urban activities include also a large amount of freights es-pecially at the main access points in the city and

on the city ring roads. Most of the indus-trial and large warehouses are located along the north ring road of the city. The heavy traf-fic is not allowed in the city, but there are some hot spots at the intersections connecting the main roads.

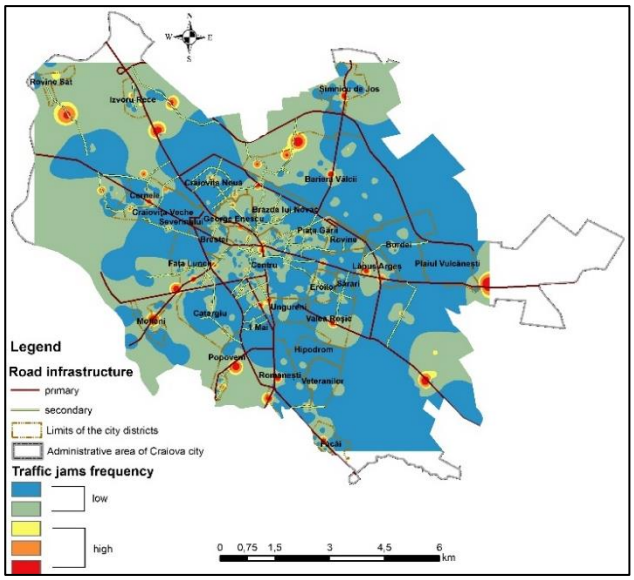

Fig. 4: Road sections with high probability of traffic delays due to traffic intensity on rush hours

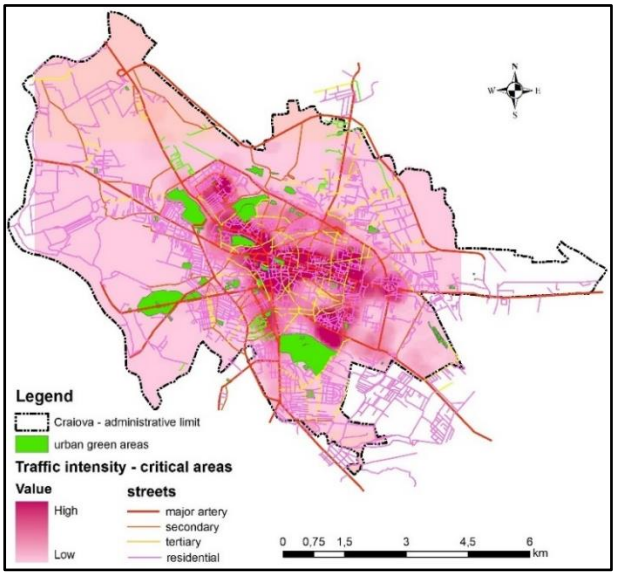

Fig. 5: Traffic intensity on main roads

The traffic intensity map (fig. 5) shows that there is a tendency of agglomeration toward the center, caused also by the numerous activities located within the perimeter enclosed by Dacia and Decebal boulevards, Henry Ford and Caracal streets and Calea București and Tineretului boulevards. Also, this is the area with the highest density of jobs (fig. 2). The activities determined by the urban land use tend to take advantage of the value of a specific location. This value is connected to the accessibility to public transport of special infrastructure, closeness to the city center, production centers or market places. The value of the land determined by its use is also very important. The more valuable a location, the more likely agglomeration will take place. The organization of various activities is hierarchical, determined by the relationships between the agglomeration and accessibility at the local and regional levels (Rodrigue J.P., 2017).

Conclusion

The road network extension to new areas of urban growth is not considered a solu-tion by the authors; a better alternative would be the improvement of the access to public transport by setting up new routes or stations, modernizing buses and increasing their frequency. Although, recently upgraded, the tramline is one-way and only provides a link between the eastern and western parts of the city, with a reduced frequency on extended routes. Increased accessibility to public transport can also have the effect of decentralizing the activities located in the city center that can be relocated to the periphery with a higher level of accessibility. Through an increased accessibility, some locations may become more valuable for a range of activities, but at the same time, cheaper for development than in the central area. In addition to the development of suburban areas and the emergence of new services (educational, banking, commercial, health) that may determine residents from the new residential areas to reduce the number of movements, there is also a nega-tive effect materialized in the increase of land value.

Although the road traffic in the central area has been improved by modernization works like the construction of the supended and the underground passages, it remains among the busiest intersections, having the longest waiting times in traffic. Also, the main boulevard that crosses the city (Calea Bucuresti continued with Calea Severinului) and connecting the arteries (Amaradia, A. I. Cuza, Carol Carol) are very crowded mostly due to the use of personal cars.

As in most large cities, the lack of parking places is another aspect that creates traf-fic problems in Craiova. The time spent to find a parking space in the central area, alt-hough there is an underground parking place for small cars, determines drivers to spend more time in traffic or to park irregularly thus blocking the traffic or the access of buses to stations.

Sustainable transportation should be though measures and metropolitan develop-ment plans issued by local authorities. The management of transpotation should aim the control of local development in the urban fringe of Craiova city. It is also recommended to increase the length of bicycle

tracks, including in the historical part of the city, as well as rent centers. This measure was already foreseen in the Urban Mobility Plan of Craiova. The improvement of urban road traffic can also be achieved by using components of traffic management systems, in particular through optimization softwares or by increasing the number of video surveillance intersections or by increasing the number of traffic boards with informative messages, both for public transport and car traffic.

If we understand the relationship between urban form, land use and transport, one can find the best solutions to regulate the transport and movement of people and freights.

Another solution for solving part of the traffic problems may be the regulation of urban access by using road user charging schemes for certain areas like city center. Also taxation can be applied depending on the technical specification of cars, but defining these features may be rather difficult. Although few European cities use urban road user charging, some take into considetarion to regulate the traffic of diesel cars in the future. Craiova may consider one of these options, as the first step in limiting traffic in central areas was taken by mounting access barriers for residential areas within the old town.

Traffic fluidity is measured by the amount of transportation costs. Additionally, the more time ones spends in traffic the more one increases the air pollution which directly affects human health. Thus, concepts like car sharing, electric public transportation, hy-brid vehicles or new alternatives for peoples' movement may be a viable solution to reduce traffic, transporation costs and additional pollution.

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