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DETERMINING THE FAVORABLE AREA FOR THE CREATION OF A "PARK AND RIDE" ARRANGEMENT, IN THE EASTERN PART OF CLUJ-NAPOCA MUNICIPALITY USING GIS TECHNOLOGY

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ABSTRACT. – Determining the Favorable Area for the Creation of a "Park and Ride" Arrangement, in the Eastern Part of Cluj-Napoca Municipality Using GIS Technology. At present, population mobility is not a choice, it is a necessity, and with the economic development of the city, the population growth of metropolitan and non-metropolitan areas working in the urban environment and the inefficiency of the public transport system, people have become dependent on cars.

Traffic congestion remains one of the problems of Cluj-Napoca municipality and continues to be a major concern for researchers. Extra-urban mobility has a significant role in the structure of city traffic. The study aims to highlight two increasingly important features of population mobility research, intermodality and multimodality. Therefore, on the basis of the geomorphological evaluation, the sites in the eastern part of the city where it is possible to create an intermodal passenger center, which will benefit from all the functional transport means in the city, will be analyzed. Thus, this area would become a metropolitan and non-metropolitan area reception center, and at the same time an alternative for individual motorized transport, promoting a sustainable form of mobility of the extra-urban population. An integrated component of many public transport systems in developed countries, "Park and Ride" support the planners' effort to eliminate as many vehicles as possible from the daily traffic.

The geomorphological studies made in the study area, namely the southern slope of St. Gheorghe Hill, are numerous in the last 50 years (Morariu et al., 1967; ISPIF project for soil erosion in the northern area of Cluj-Napoca, 1986; Surdeanu et al., 2006; Poszet, 2011, etc.). The results of the previous geomorphological research reveal the fact that this territory presents a dynamic of the moderate slopes, due to the efficiency of the land improvement works. However, certain sections of the slope are found to accelerate landsides and torrential erosion in surface, especially in terraced areas. This is not, however, an impediment to

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finding solutions to problems such as the one mentioned above. Taking into account the intense expansion of Cluj-Napoca, especially in the West-East direction, the most suitable place for arranging such a car park is in the eastern part of a city. An argument in favor of this option is that in this urban area the degree of occupancy of buildings or infrastructure is lower compared to other sectors. The sustainability of the territory for such an arrangement will be determined on the basis of morphological indicators specific to a risk study.

The paper develops a GIS-based approach to assess the area as favorable as possible for the creation of a "Park and Ride" arrangement both geomorphologically and in terms of population mobility.

***Keywords**: "Park and Ride", mobility, commuting, landslides, susceptibility.*

1. INTRODUCTION

One of the current problems faced by both Cluj-Napoca residents and those who come to this city for different activities is that of having a parking place. Convenience, easy access to the institution in which they operate and time-saving are some of the reasons that make people enter the city using their personal cars. However, non-resident persons encounter difficulties in parking close to the target, high price of parking or even parking in forbidden parking spaces, making traffic even harder. Some of the drivers entering Cluj-Napoca from the eastern part, park their cars at the entrance to the city, in unsuitable and unsafe places (the IRA area), after which they continue to travel by means of public transport. Finding a suitable space for the construction of a "Park and Ride" parking and arranging such parking is imperative in these circumstances.

2. STUDY AREA

St. Gheorghe Hill with an area of 8.46 km^2 is located in the north-eastern part of Cluj-Napoca (figure 1). Its altitude drops from 513 m, in Fânațele Satului Hill, to the west, 478 m, in La Pipă Hill, in the eastern area. The general aspect of the slope is southern, with a large span towards the Someşul Mic valley. At the base of the slope and in the meadow of the river, the land is occupied by buildings with different destinations. Some public institutions (eg the Technical University), housing blocks and homes built during the communist period have preserved their destination. Numerous spaces support new buildings of public interest (eg the Auchan supermarket), individual dwellings or economic units, but geomorphologically, the location of some of these buildings is risky. We refer to housing construction on the streets traced on the slope after 2000, for example the Voroneţ Street.

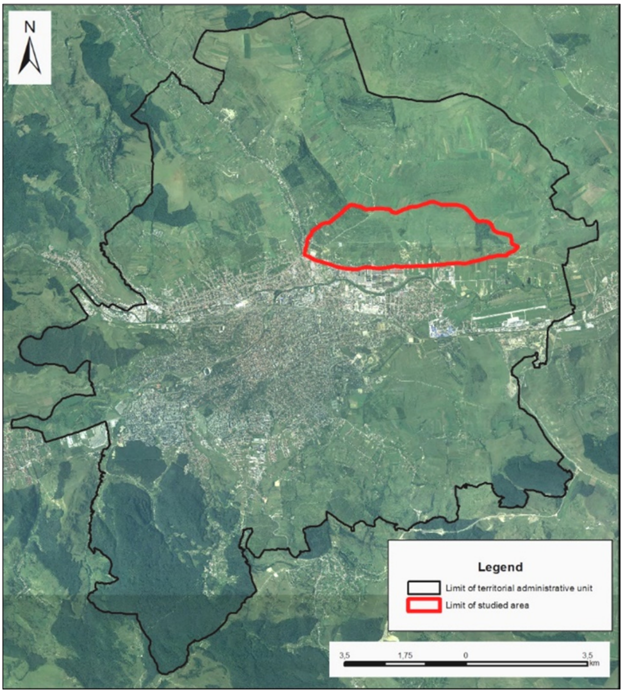

Fig. 1. The studied area

3. DATA AND METHODOLOGY

In order to determine the susceptibility to landslides and to identify the optimal space for a “Park and Ride” arrangement, a specific GIS database was used. This includes: 1: 5000 topographic plans, ISPIF Project no. 6855/1986 regarding the erosion of the soil in the northern part of Cluj-Napoca, which presents the proposed and realized land improvements, the geological map (1: 200000), the land use categories according to the Agency for Payments and Intervention in Agriculture, traffic census (2015), Population and Housing Census (2011), observations and measurements made on landslides (2015, 2017), and the construction of buildings in the planned areas from the General Urban Plan (2012) on road traffic (2016).

Land susceptibility to landslides was determined taking into account the following control factors: hypsometry, slope, aspect, plan curvature, profile curvature, wetness index, stream power index, geology and land use. The method of statistical analysis of the frequency of landslides on different categories of factors is widely used today (Goțiu, 2007; Bathrellos et al., 2009; Bilașco et al., 2011, etc.).

The first seven control factors taken into account to determine the susceptibility of the land to control slides were the result of GIS operations. The results were reclassified according to the susceptibility ranges shown in the table below.

Table 1. Susceptibility ranges for control factors

	Hypsometry	Slope	Aspect	Wetness index	Stream power index	Plan curvature	Profile curvature
Low	314 – 400 m	0 – 2 º	flat	0 – 14	< -0.01	< -0.1	< 0
Medium	401 – 500 m	2.1 – 6 º	N, NE	14 – 16	-0.01 – 0	-0.09 – 0	0 – 0.1
Medium-High	501 – 700 m	6.1 – 17 º	E, NV	16 – 18	0 – 0.01	0 – 0.1	0.1 – 0.2
High	> 900 m	17.1 – 32 º	SE, S	18 – 20	0.01 – 0.02	0.1 – 0.2	0.2 – 0.3
Very high	701 – 900 m	> 32 º	SV, V	> 20	> 0.02	> 0.2	> 0.3

For this model of spatial analysis, we used the technique proposed by Bilaşco et al. (2011) based on the binary variability equation proposed by Yin & Yan (1988) and Jade & Sarkar (1993).

$$Ii=log\frac{Si/Ni}{S/N}, \text{ where:}$$

I_i - the statistical value of the factor “i”

S_i - the area identified with landslides on the susceptibility category of the factor taken into account

N_i - the area of susceptibility category of the analyzed factor on the study surface

S - total area with landslides in the studied area

N - the area of the study area

Following the use of the equation and the assignment of each susceptibility interval of the “i” factor, the nine rasters were summed up. The result obtained, susceptibility to landslides, was reclassified into five classes.

4. RESULTS AND DISCUSSIONS

The digital elevation model of the land

Analysis of the DEM indicates that 52.7% of the sloping surfaces are in the altitude below 400 m, 46.6% are between 400 – 500 m altitude and only 0.7% are at heights higher than 500 m (figure 2a).

Slope

Landscape decay is one of the control factors that have a high share in the triggering and evolution of landslides. The southerly aspect of St. Gheorghe's Hill is a complex one and landslides appear in all sectors, in a different proportion. Thus, the slope was reclassified into five classes: 0 – 2^0; 2 – 6^0; 6 – 17^0; 17 – 32°; over 32^0. The first class holds 2.37% of the landslides. This includes quasi-horizontal fields. The second class holds 11.35% of the landslides. The third class holds 72.29%, the values of 5 – 6^0 and 15 – 17^0 being the thresholds between creep, compaction, suffusion and slip on the one hand, and respectively, subsidence, topple, fall and slip, on the other. The fourth class has 13.92% of the landslides, and on slopes above 32^0 there are only 0.06% of the landslides (figure 2b).

Aspect

Alongside the slope, the aspect has a decisive role. Thus, 70% of the landslides appear on the sunny slopes exposed to South and South-East, while 23.09% of the landslides occur on the slopes exposed to the West and South-West. These slopes benefit from maximum sunstroke, while weathering cycles (wet-drying, freeze-thaw and alteration) are carried out more quickly, providing faster unstable, slip-resistant materials. The semi-shaded (eastern and north-western) slopes have 4.25% and the shaded (northern and northeastern) slopes, 2.64% of the landslides (figure 2c).

Plan curvature

The plan curvature represents a curvature of a normal surface of the terrain surface and is perpendicular to the section of vertical curvature in a point A of the terrestrial surface (Irimuș et al., 2005). The horizontal curvature is a measure of concentration or dissipation of leakage and helps to map accumulation, transit or dissipation areas. If its values are less than 0, then convergence is recorded, if the values are higher than 0, the currents are divergent. The plan curvature is a factor that influences soil moisture, its pH, soil horizon thickness, organic matter, and vegetal carpet distribution (Figure 2d).

Profile curvature

The profile curvature represents the profile of a normal section of the terrestrial surface on a plane Q containing a vector of the gravitational acceleration at a given point of the terrestrial surface (Florinsky, 1998, quoted by Irimuş et al., 2005). The vertical curvature gives the measure of the increase ($K_v > 0$) or the relative decrease ($K_v < 0$) of the leakage rate. Its influence is similar to the one corresponding to the plan curvature.

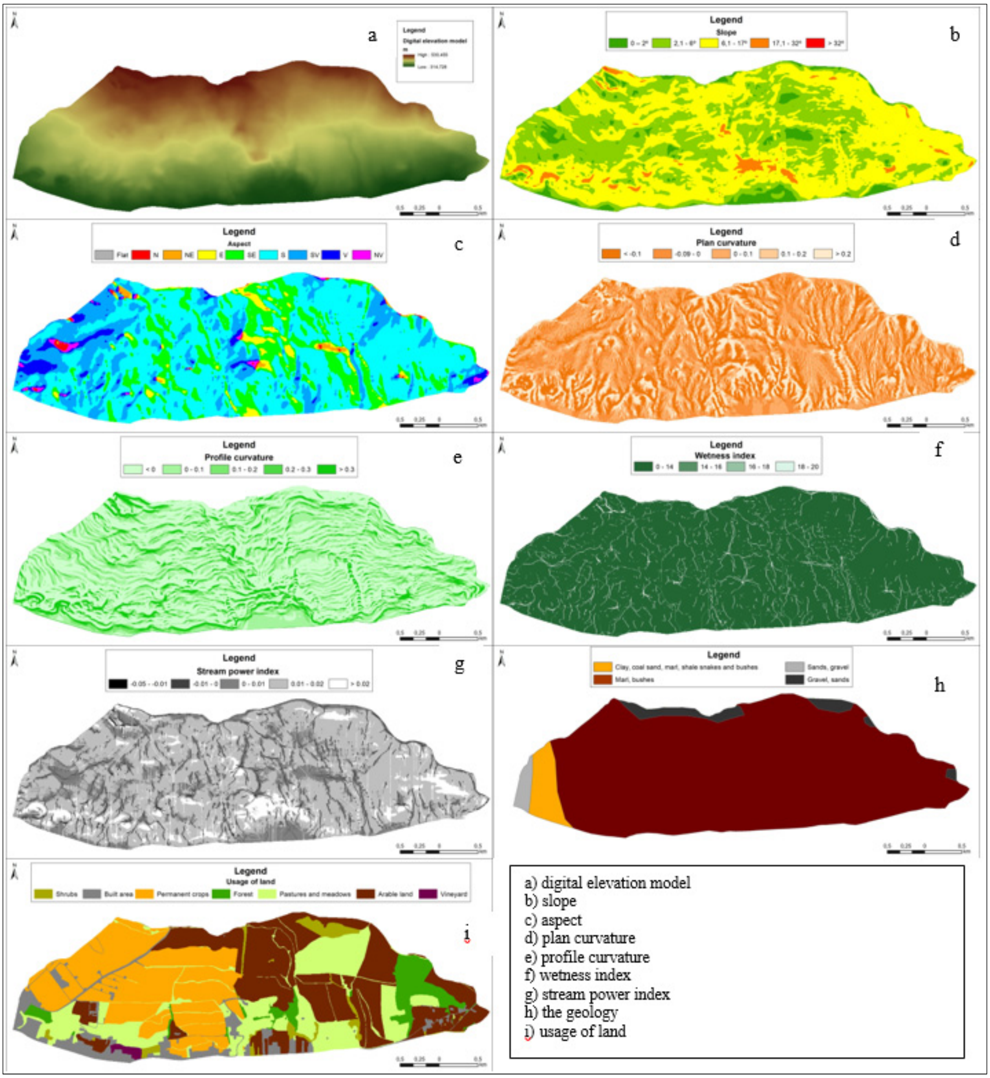

Fig. 2. Control factors

To determine susceptibility to soil erosion, leakage on the side is calculated. The type and characteristics of leakage are influenced by precipitation, side physiognomy, soil type and vegetation. Two indices for leak assessment are used:

1. The Wetness index represents the relationship between the water layer thickness at any point in the basin and the average thickness of the pool water. The higher the index value, the higher the pixel's humidity (Figure 2f).

2. The Stream power index measures the predisposition of soil particles to be transported by a stream (Moore, Burch, 1986, Moore et al., 1982, Mitasova et al., 1995). It expresses the degree of soil erosion (tonnes / hectare / year) (Figure 2g).

The geology

As shown in figure 2h, two types of lithological formations are observed in the studied area. On the one hand, there are Miocene formations, found on most of the slope. The largest part, 77.25% of the area affected by landslides, is located on deposits of marls and tuffs, while 17.03% of the sloping surface has subsoil deposits of clay, coal sand, marl, marl shale and tuffs. These rocks have a high susceptibility to landslides as well as deep erosion (torrents, holes, ravens) and areolar erosion.

On the other hand, quaternary formations are formed, consisting of sands and gravel. There are 1.97% of landslides on the lands that have sands in their composition, and on those with gravel there are 3.75% of the sloping surfaces. These are mainly located in the alluviums of the two streams that delineate the slope (Chinteni Valley, Calda Valley), as well as the watershed between Someșul River basin and the Valea Caldă sub-basin.

Landslides

Out of the 846 hectares of St. Gheorghe Hill, 200 hectares were affected by landslides in 1986. As a result of the landscaping, the sloping areas have been reduced, and are now more than 61 ha. Following eight field observations, eight areas with landslides were identified. Those located in the upper third of the slope, located near the watershed, are either stabilized landslides or superficial landslides. One of the stabilized landslides is in the vicinity of the Fâneţele Satului peak. Stability can be seen from the disappearance of the lakes behind the slopes and the good preservation of fruit trees and forests. On the water sector between the two peaks, two superficial landslides were formed. The lenticular landslides have been reported in three areas along the entire length of the slope. The common element of the landslides is the degradation of the agro-terraces following the cutting of the trees, as well as their lesser extent.

There are four areas with deep landslides that occupy larger areas. Their sectors have been reactivated. One of them is just behind the Auchan shopping center and is a reactivated slip, although acacias and sea buckthorn were planted on the mass supply area and on the body of the slide, moving the material to the base of the continuous slope. Evidence in this regard is the lake formed behind the supporting wall that surrounds the supermarket, as well as cracks in the wall in some places. The second massive sliding, a sliding step, is in the vicinity of the previous one, in its north-eastern part, being also the most active in this area. Another active slip is in the northeast of the former Heavy Equipment Factory (CUG) at the right of Voroneț Street. It was found that new lenticular slides developed over the main body of the slide (Figure 3). The fourth sloping area is in the vicinity of La Pipa Peak, just below the hydrographic basin.

Fig. 3. Map of the landslides on St. Gheorghe Hill
Source: own draft, based on own observations (2015, 2017)

Susceptibility to landslides

From the analysis of the susceptibility to landslides map (Figure 4), 8.49% of the surfaces have very low susceptibility and 28.19% low susceptibility. These lands generally overlap the "free-face" sector of the slope (Dalrymple et al., 1968), with slopes up to 10^0, but also the watershed. Another sector with low susceptibility lies in the glacis area that connects the base of the slope and Someșul Mic meadow. Average susceptibility is 39.98% of the surface area, and is found in all sectors of the slope. The critical areas of the slope are U2, distribution, U5, mid-slope and U6, the deluvius and colluvium accumulation sector (Dalrymple et al., 1968). Out of these lands, 16.38% have high susceptibility and 6.94% are very susceptible to landslides. Most are lands with landslides at different stages of development, unfit for construction.

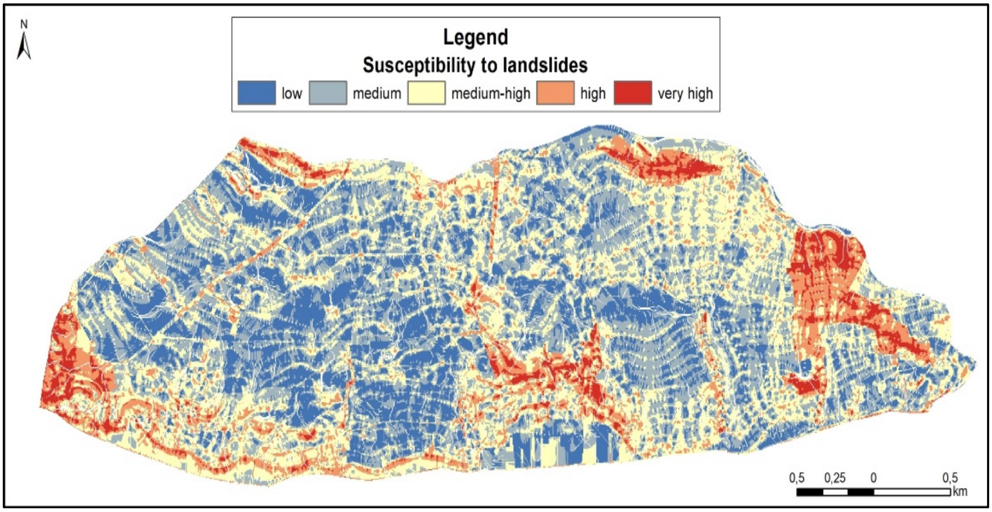

Fig.4. Map of susceptibility to landslides

Choosing the place for "Park and Ride"

According to the traffic census conducted between February 18 and February 24, 2015, approximately 5750 cars enter daily (working days) the city of Cluj-Napoca from the eastern part. As can be seen in both tables (Table 2 and Table 3), most cars were recorded between 07:00 and 09:00. The large number of cars in this period is mostly due to people who work in the city but who have their residence in another settlement in the county.

Table 2. Average number of vehicles/h and the incoming travel speed in Cluj-Napoca on the Bridging Belt Cluj-Napoca (DN1F)

Schedule	Direction			
	East		West	
	Average number of cars/h	Average speed	Average number of cars/h	Average speed
05:00 – 07:00	80	80.48	104	77.65
07:00 – 09:00	310	75.88	349	77.42
09:00 – 12:00	317	72.70	270	73.97
12:00 – 15:00	272	76.16	284	76.50
15:00 – 18:00	305	75.31	372	77.61
18:00 – 20:00	192	75.58	235	78.18
20:00 – 22:00	74	81.13	97	80.00
22:00 – 05:00	24	80.66	27	68.43

Data sources: Traffic Census 2015

Table 3. Average number of vehicles/h and incoming traffic in Cluj-Napoca on Traian Vuia Street (DN1N)

Schedule	Direction			
	East		West	
	Average number of vehicles/h	Average speed	The average number of vehicles/h	Average speed
05:00 – 07:00	227	59.57	283	51.53
07:00 – 09:00	639	56.27	837	52.35
09:00 – 12:00	680	55.82	672	52.07
12:00 – 15:00	722	54.20	658	53.30
15:00 – 18:00	762	54.12	744	52.78
18:00 – 20:00	569	56.93	470	53.53
20:00 – 22:00	314	59.82	254	53.10
22:00 – 05:00	95	59.30	83	49.76

Data sources: Traffic Census, 2015

According to Benedek et al. (2016), a significant number of people from the north-eastern part of the metropolitan area of Cluj and from the non-metropolitan area, especially the Someșul Mic corridor, are working in Cluj-Napoca (Figure 5). This growth pole, located in the northwestern part of Romania, draws thousands of people a day as a magnet. The attraction is due to the economic development, which implied the improvement of accessibility to it, using the road transport. We are at a time when the value of real estate exploded in the county seat, the relatively good price of fuel, the growing number of cars imported with lower fuel consumption or the lack of jobs at the level of education of the population has only encouraged the county population to find a job in Cluj-Napoca.

Urban mobility has undergone numerous transformations in the past due to the increasing use of cars, highlighting the reduced dimensions of road infrastructure in relation to current demand (Rusca et al., 2014). Following the analysis of a representative sample of data on the speed of car journeys in the city, it was found that for most of the working days in the central area, the average speed did not exceed 13 km/h. As shown in Figure 6, the average speed of movement in the four neighborhoods included in the analysis decreases very much during the day. This decrease is based on a large number of vehicles and numerous interruptions due to pedestrian crossings that do not allow a continuous flow. From the analysis carried out it was found that the traffic is difficult due to the internal and penetration traffic, and not because of the transit traffic.

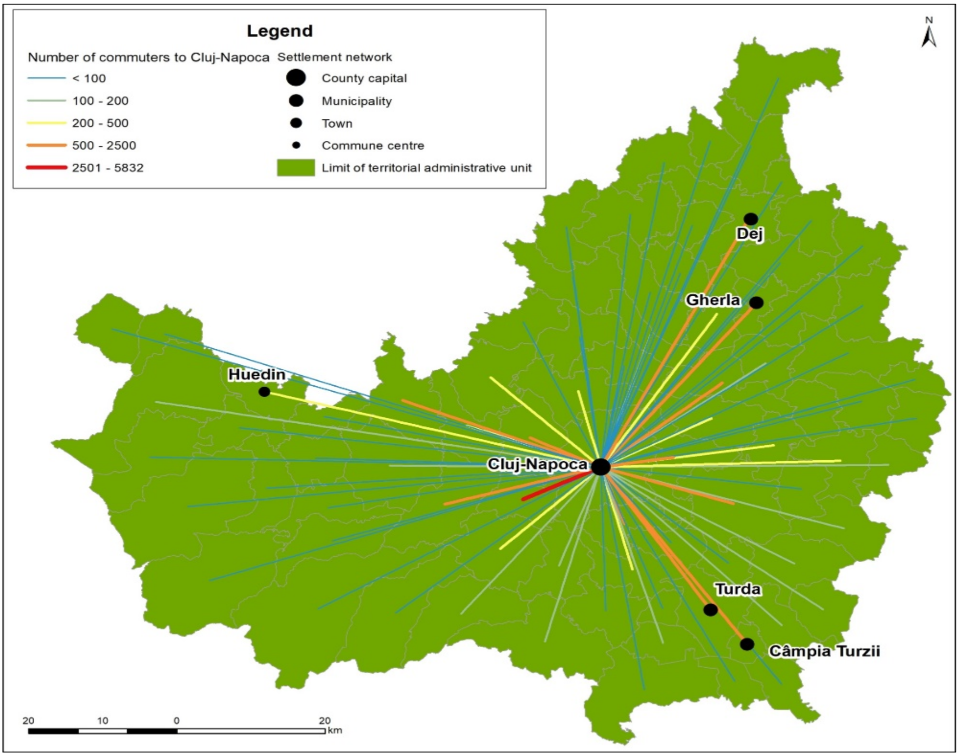

Fig. 5. Number of people in Cluj County who work in Cluj-Napoca, but have their residence in another locality
Data Source: Population and Housing Census, 2011

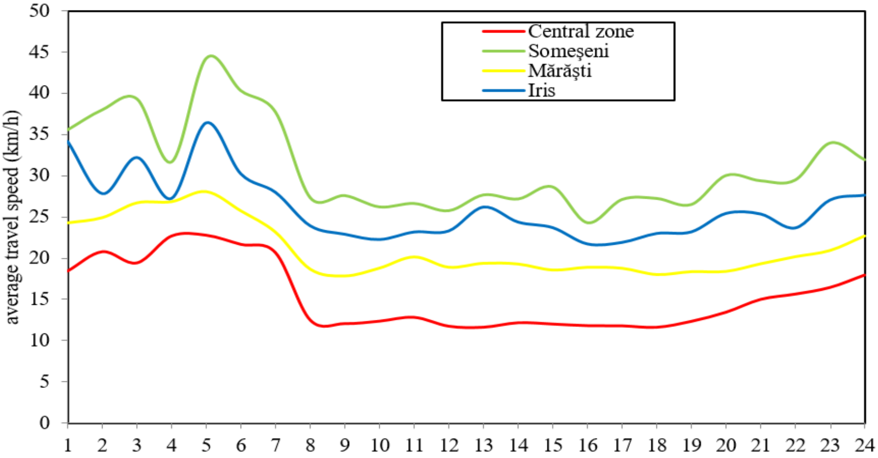

Fig. 6. Average travel speed in four neighborhoods in Cluj-Napoca
Source: own draft, based on own measurements (2015-2016)

It is clear from the above that Cluj-Napoca has problems regarding the movement of the population within the city due, first of all, to the large number of cars. In order to solve such a problem, a strategy to alleviate traffic congestion and reduce emissions is needed to encourage people to use public transport at the expense of motorized individual transport. One of the solutions that could solve the problem to some extent would be to create a "Park and Ride" facility in the eastern part of the city. Such an arrangement is often associated with the promotion of sustainable mobility, involving the creation of reliable and frequent transport links between P&R and the city center (Dijk et al., 2013). In order to determine the optimal location for such an arrangement, we considered that a preliminary geomorphological analysis on susceptibility to landslides was necessary given that the studied area is known for this phenomenon.

Based on the results of the susceptibility to landslides, as shown in Figure 4, and considering the restrictions in the General Urban Plan (2012), we considered that the best place for a "Park and Ride" arrangement is near the tram depot in the Bulevardul Muncii area (figure 7). This area has several advantages which place it in the first place, of which we mention: values of the slope not exceeding 5°, the proximity to one of the main traffic roads in the city, the presence of the public transportation means.

Fig. 7. Area proposed for "Park and Ride"

The area proposed for building this facility has an area of 24745 m^2 and could provide about 960 parking spaces at the upper level. In the lower part of the building, potential customers would have the means of public transport or the vending machines for purchasing travel passes.

Encouraging the use of such an arrangement would have a major impact on the road traffic on the eastern part of the city, which would increase the speed of travel and, implicitly, a shorter travel time to destination, using the means of public transport at the expense of individual motorized transport. The expansion of the main communication routes to support current traffic is impossible, but the speed of public transport could increase as they would be given a special lane for travel.

5. CONCLUSIONS

Finding a suitable space for the construction of a “Park and Ride” parking is imperative, given the increasing number of people moving in the city and the increasing number of vehicles. However, in order to determine the most favourable place for the creation of such a facility, a number of factors must be considered in such a way that the construction should not create problems in the future. Therefore, we have considered that the most important factors that should be taken into consideration are the geomorphological ones, highlighting the morphological characteristics and the susceptibility to certain geographical phenomena of risk.

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