GIS solutions for smart city development

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Abstract

The geographic information system (GIS) offers advanced capabilities for smart city projects. In this article we aim to show some possibilities of using GIS technology in support of the development of smart cities. In essence, the smart city concept is based on geospatial data to enhance the understanding of complex urban systems. It is important that city managers can quickly obtain relevant information about the urban infrastructure and urban services, as well as stakeholders (citizens) feedback. GIS technology is applied in smart city projects for geospatial and spatiotemporal data analysis, spatial statistics, surface analysis and location analysis.

As a result, given these considerations, we want to highlight some GIS applications - with examples - that could be integrated to work together into the smart city, referring to the possibility of developing the urban model, sharing geospatial information, the possibility of online traffic analysis, the possibility of obtaining feedback of the citizens. All these applications lead to the improvement of the bidirectional information process, ie the decision makers can obtain certain information, but also the citizens can express their opinion regarding certain projects of the municipality. The paper also shows the importance of open data to be used in GIS applications.

Hence the importance of GIS training for all those who interact in the smart city area, as well as awareness of the importance of accurate geospatial information, which will provide confidence in the urban information system to users.

Keywords: *GIS, urban, traffic, drive-time areas, crowdsourcing, ArcGIS Urban, AGOL, CityEngine, open data.*

1. Introduction

At the national level, the National Recovery and Resilience Plan (PNRR) must be implemented, which cannot be achieved if the creation of a Guide on the management and implementation of landscaping and urban planning documentation is considered, including in GIS format. [12] The National Recovery and Resilience Plan (PNRR) is a strategic document setting out the investment priorities and reforms needed for recovery and sustainable growth, linked to the green transition and taken into account by the European Commission. The implementation of PNRR requires the involvement of specialists in various fields of activity, including surveyors with advanced GIS skills.

Approved by the European Commission on September 27, 2021, PNRR contains reforms and investments structured around six pillars and 15 components. De facto, PNRR is a source of financing and a coherent implementation of the development objective adopted towards Romania through these sectoral strategies.

The 2030 Agenda for Sustainable Development adopted by the UN in New York (2015) is a historical document, which was also adopted by Romania with its specific (2018) and proposes a better future through its 17 objectives. Romania needs to change its current development paradigm to meet the challenges of the 21st century. PNRR meets urgent needs, amid the COVID-19 pandemic.

It is therefore necessary that this action be on a large scale and not fragmented into one-off approaches. In line with technological developments, other types of ICT infrastructure need to be developed that can contribute to the implementation of the Smart City / Smart Village concept: the use of drones to inspect risk areas or situations, and real-time monitoring centers through real-time access to the system of cameras, sensors and other data collection devices, GIS databases at metropolitan level, open data - open data platform in which data available at city level (sectoral data) are accessible to the public, urban data center and real-time monitoring of the state of the city (correlated with the GIS database from PUG – General Urban Plan), the application for informing citizens and identifying problems at the local level. Updating PUG documentation in GIS format is very important, to be dynamic and to provide the citizens or the current situation from the documentation.

Another aspect highlighted in the PNRR is elaboration or updating in GIS format of the spatial planning plans (Planning Plan for the County Territory - PATJ, Planning Plan for the Territory of the Metropolitan Area - PATZM) and of the urban plans (General Urban Plan - PUG, Zonal Urban Plan - PUZ), respectively of the urban mobility plans (Sustainable Urban Mobility Plan - PMUD) for the alignment to new principles of the urban policy of Romania.

Urban / metropolitan / ZUF (Functional Urban Area) GIS databases (also connected to PUG) must communicate vertically (city, county, region) and most of the data collected must be open data.

The problem of open data is a real one in Romania, in the sense that there is not yet enough open data to be published at least in the form of services that can be accessed and used in GIS. Technological solutions are needed to manage traffic flow more efficiently - increasing road capacity while minimizing delays and environmental impact.

2. The link between GIS and PNRR

PNRR proposes concerted actions in strategic areas aimed to modernize and increase the potential of the Romanian economy, by reporting to the national strategic objectives in correlation with the contribution to climate change and the digital transition.

The concept of Smart city / Smart village involves the use of new technologies, in line with the field of intervention "Development of highly specialized services and support structures for public administrations and enterprises" [11]:

- Using UAV/UAS to inspect risk areas or situations
- Monitoring of the city center in real-time – by providing real-time access to all cameras, sensors and other data collection devices
- Intelligent management sof the green space systems
- Monitoring and security system of the public space
- Integration of heritage objectives through digitization or digital reconstruction: (VR / AR) virtual reality / augmented reality
- GIS databases at the metropolitan level
- Open Data - a platform where data is available and accessible to the public at the city level – can be connected with https://data.gov.ro
- Online cloud platform for use by the public administration to retrieve data from geospatial services
- Document registration and issuance system - allows online registration and issuance of documents, electronic signatures, etc.
- Urban data center and real-time monitoring of the state of the city (correlated with the GIS database from PUG)
- City application (application for informing citizens and identifying problems at the local level)
- Online payment of taxes and duties
- Online platform and / or mobile application for mapping energy consumption at neighborhood or city level
- Automated management of irrigation systems for green spaces
- Smart sanitation infrastructure - smart bins with sensors and GPS-based technology, which provides data on the degree of filling of bins
- Real-time monitoring of the state of the technical-municipal infrastructure and of the consumption.

The PNRR will promote procedures based on the following principles [11]:

- elaboration and management after approval of the landscaping and urban planning documents in GIS system;
- introduction of the possibilities of electronic signing of documentation;
- increasing road safety and increasing air quality;
- integration of spatial information from spatial planning and urban planning documentation with spatial information from databases at the level of local authorities and other competent authorities;
- permanent maintenance of documentation data;

- integration of the approved lower rank documents in the higher rank ones (integration of PUZs and PUDs in PUGs);
- addressing urban resilience and the risks of natural and man-made disasters;
- integration of components to improve energy performance at the urban level;
- integration of innovation elements - smart city;
- encouraging forms of software mobility;
- integration of transport and land use for sustainable development;
- introduction of cost-benefit analyzes - monetization of direct and indirect social, economic and environmental benefits;
- use of 3D modeling to substantiate the decision;
- quality assurance in constructions (approval of the Territorial Planning, Urbanism and Construction Code, BIM technical regulations, National Register of Buildings).

3. City type approaches

Recently, the process of migration from rural to urban areas has intensified, especially due to: greater opportunities to find a better and better paid job, access to education and better quality health services. At the same time, urbanization is correlated with economic growth. That is why urban and peri-urban areas are constantly expanding, thus creating technical, social and political challenges.

On the other hand, the accentuated evolution of the technology leads to the need for the rapid implementation of Smart City / Digital Twin solutions. These concepts help to achieve Goal 11 of the UN Agenda [13]: "Make cities and human settlements inclusive, safe, resilient and sustainable" In order to understand the common elements and the differences between these approaches, in figure 1 the concepts were highlighted the main concepts regarding the cities.

Fig. 1. City Type Approaches

4. GIS possibilities - case studies examples

At present, the evolution of GIS technology has created adequate conditions for the development of solution-supporting systems at all stages in the planning and design process - although there is still much work to be done to fulfill the promises.

For example, among the ESRI solutions that can be adapted to different situations are Drone2Map, ArcGIS Urban, CityEngine, Dashboard, Survey123. Figure 2 shows some GIS steps that competed in the development of digital management.

In the following we will show some examples of the use of modern software solutions, which can be easily integrated and can be used by the local administration to facilitate the interaction with the citizens. The collected input data can be represented in layers, including socio-economic data, utility infrastructure based on the type of data, and are stored in the database as records, vectorial or raster representations or attribute data of the geospatial features.

Example 1 UAV / UAS Data - The drone images can be georeferenced using the Ground Control Points (GCPs) which are well-defined points both on the ground and on imagery. The image distortions are corrected and stitched together to produce an accurate single image for the entire area. In figure 3 is emphasized an example of products that can be obtained and used to create a 3D model of a built area.

Fig. 2. GIS Capabilities that Contribute to the Development of Digital Management

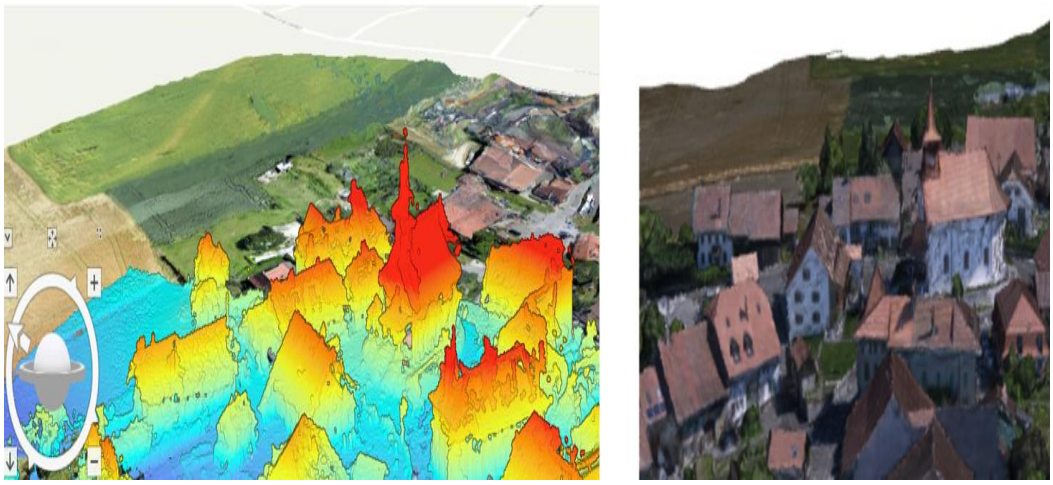

Fig. 3. Point Cloud and 3D Model Generated as a Result of Drone Flight
(processed in Drone2Map, data source: SenseFly)

Example 2 Geospatial Planning using ArcGIS Urban and ESRI CityEngine - A main GIS application for geospatial planning is ArcGIS Urban, used to create 3D renderings of city landscapes, proposed buildings, and compare proposed site projects across key stakeholders, being a web-based system for managing urban development, through a fully interactive 3D environment and offering high quality and flexible planning tools. [8] Defining Zoning and Land Use Plans are useful for visual and analytical representation that allows planners to design while at the same time showing their work to stakeholders (Citizens, Real Estate Agencies, Government, Architects, Developers, etc.) An example of interesting application of the 3D models is that for geospatial planning of the surveillance cameras location in the projected area, using visibility tools in CityEngine. The local administration needs to offer the possibility of the digital submission as best-practice for private developers to submit 3D models and plans over the web for review.

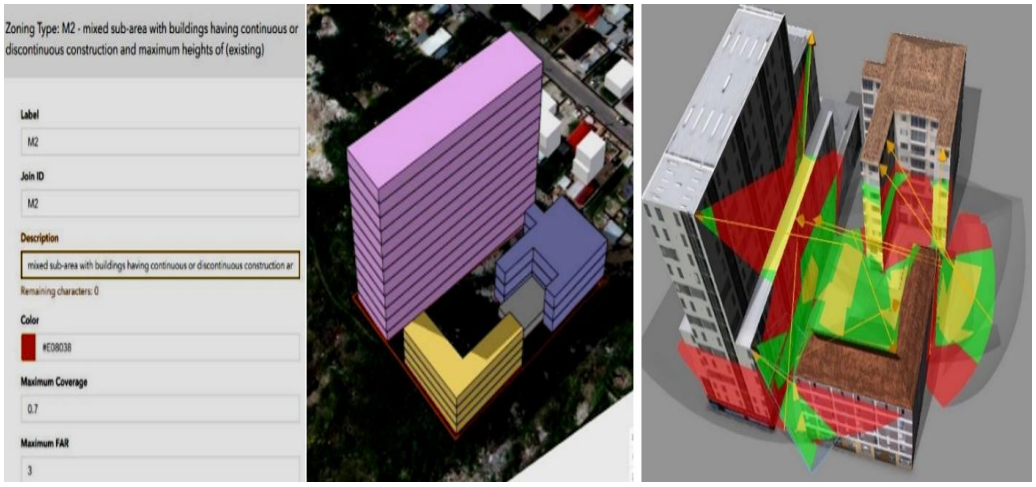

Fig. 4. Spatial Planning in ArcGIS Urban (left side) and Scenario of the Surveillance Cameras Location in the Projected (right side in CityEngine) (adapted from [8])

Example 3 Field Data Collection - In present, the process of using crowdsourcing in land administration is a big challenge. Crowdsourcing represents the act of taking a job or a specific task usually performed by an employee of a company or contractors, and outsourcing it to a large group of people or a community (crowd or mass) via the Internet, through an open call. [5] Some of the specialists consider the concept of crowdsourcing as a niche within the geosciences fields. We can consider that crowdsoucing is synonymous with the concept of Volunteered Geographic Information (VGI), having similarities in the use of 'non-traditional' data providers and being facilitated through web2.0 technology and mobile phones.[6]

The first example is focused on providing data on changes that occur in urban areas, by developping an application useful for data collection that highlights changes of the buildings - authorized or not. (figure 5)

This approach can be implemented for example by city mayors in order to identify: illegal buildings or changes or extensions of them, greenery that was built illegally or the state of the heritage buildings based on images and location provided by interested citizens. One of the main challenges faced by all Local Governments in Romania is the lack of accurate information on the natural and man-made resources under their jurisdiction, representing a major obstacle not only in formulating various development projects but also in implementing them accurately.

	A	B	C
1	type	name	label
2	text	Nume	Operator Name
3	text	Prenume	Operator Surname
4	image	Semnatura	Signature
5	begin group	Date_imobiliar	Data for Urban Information System
6	begin group	Date_fara_proprietar	Data obtained without interacting with the owner
7	dateTime	Data_ora	Date and hour
8	integer	Numar_postal	Postal Number
9	select_one artera	artera	Artery
10	text	Den_artera	Street Name
11	select_one dest_cladire	dest_cladire	Building Destination
12	integer	nr_nivele	Level Number
13	select_one tip_acop	tip_acop	Roof Type
14	geopoint	pozitia	Location
15	image	imagine_constr	Building Image
16	text	obs	Additional Information about Changes
17	end group		
18	select_one info	info	Can You Obtain Additional Information from the Owner?
19	begin group	Informatii	Data obtained based on owner's answers
20	select_one pereti	pereti	Wall Type
21	select_one fundatie	fundatie	Basement
22	select_one str_rez	str_rez	Structural Frame
23	select_one dot_edil	dot_edil	Urban Endowment

	type	name	label
2	select_one str_rez	str_rez	Structural Frame
3	select_one dot_edil	dot_edil	Urban Endowment
4	select_one mod_admin	mod_admin	Administration Type
5	select_one mod_det	mod_det	Ownership Basis
6	select_one tip_prop	tip_prop	Property Type
7	select_one stare_intret	stare_intret	Maintenance Status
8	select_one aut_constr	aut_constr	Building Permit
9	select_one PV_rec	PV_rec	Acceptance Protocol of the Bulding
10	select_one mod_incalz	mod_incalz	Heating Type
11	select_one certif_energ	certif_energ	Energy Certificate
12	end group		
13	text	infos	Additional Info
14	begin group	date_prop	Data about the owner(s)
15	text	nume_prop	Owner's Name
16	text	prenume_prop	Owner's Surname
17	text	init_tata	Father's Initial
18	integer	cnp	CNP
19	text	nationalitate	Nationality
20	date	data_nasterii	Birth Date
21	text	nr_tel	Telephone
22	email	e_mail	E-mail
23	select_one ind	ind	Divided/Undivided
24	decimal	cota_ind	Undivided share
25	integer	num_prop	Number of Owners

Fig. 5. Fields and Domains for a Crowdsourcing App to Collect Changes of the Buildings [6]

The second example is an application is created to collect data about changes in the urban green environment. (figure 6) Using aerial photogrammetry (UAV/UAS imagery), the builtup area can be inspected using the building's footprint and the tax losses can be avoided. The information can also be obtained by a GIS survey, even through a crowdsourcing app, but in this case the collected data needs to be verified by an employee of public administration.

select_one LandParcel	LandParcelData	It is a Land Parcel?			
begin group	LandParcelInfo	Data about a Land Parcel			${LandParcelData}='yes'
select_one GreenSpaceUse	GreenSpaceUse	GreenSpaceUse	multiline	1	
select_one GreenSpaceBuilt	GreenSpaceBuilt	GreenSpaceBuilt	likert	1	
image	PhotoGreenSpace	PhotoGreenSpace			${GreenSpaceBuilt}='yes'
select_one LegalStatus	LegalStatus	LegalStatus	multiline	1	
end group					
select_one Tree	Tree	It is a Tree?			
begin group	TreeInfo	Data about a Tree			${Tree}='yes'
integer	Height	Height			
text	Address	Address			
image	Photo	Photo			
select_one RiskLevel	Risk	Risk	multiline	1	
select_one Viable	ViableState	ViableState	multiline	1	
select_one Type_of_Tree	TreeType	TreeType	multiline	1	
select_one TreeSpecies	Species	Species	minimal	1	
integer	Diameter	Diameter			
select_one MaintenanceStatus	MaintenanceStatus	MaintenanceStatus	multiline	1	
select_one Trim	Trimmed	Trimmed	multiline	1	
end group					
text	Operator	Operator			
dateTime	Data	Data		now()	
note	Notifications	Notifications			
geopoint	Location	Location			

	list_name	name	label	ima
240	TreeSpecies	198	Cedrus_deodora	
241	TreeSpecies	199	Torreya_nucifera	
242	TreeSpecies	200	Ceratonia_siliqua	
243	TreeSpecies	201	Magnolia_acuminata	
244	TreeSpecies	202	Quercus_ilex	
245	TreeSpecies	203	Prunus_fruticosa_Globosa	
246	TreeSpecies	204	Celtis_occidentalis	
247	TreeSpecies	205	Rhamnus_frangula	
248	TreeSpecies	206	Fraxinus_quadrangulata	
249	TreeSpecies	207	Populus_angustifolia	
250	TreeSpecies	208	Robinia_hispida	
251	TreeSpecies	209	Lonicera_japonica	
252	TreeSpecies	210	Ulmus_carpinifolia	
253	TreeSpecies	211	Quercus_imbricaria	
254	TreeSpecies	212	Ulmus_procera	
255	TreeSpecies	213	Ulmus_laevis	
256	TreeSpecies	214	Celtis_glabrata	
257	TreeSpecies	215	Ulmus_pumila	
258	TreeSpecies	216	Gymnocladus_dioica	
259	TreeSpecies	217	Alnus_incana	
260	TreeSpecies	218	Salix_petandra	
261	TreeSpecies	219	Juniperus_squamata	
262	TreeSpecies	220	Prunus_triloba	
263	TreeSpecies	221	Acer_buergerianum	
264	TreeSpecies	222	Magnolia_soulangeana	
265	TreeSpecies	223	Weigela_hybrida	
266	TreeSpecies	224	Vaccinium_corymbosum	
267	TreeSpecies	225	Fraxinus_americana	
268	TreeSpecies	226	Fraxinus_ornus	
269	TreeSpecies	227	Lonicera_pileata	
270	TreeSpecies	228	Camellia_japonica	
271				
272	LandParcel	1	Yes	

Fig. 6. Designing Fields for a Crowdsourcing App to Collect Changes in the Urban Green Environment [7]

It is also possible to integrate all of the applications created for citizens in an ArcGIS Hub site using ArcGIS Online. The ArcGIS Hub site is used by the general public to learn how they can report a nonemergency problem to help improve the community.

Example 4 WebApp for Highlight Urban Changes - GIS offers possibilities to integrate data from multiple sources to be presented in WebApps. In figure 7 it is highlighted a WebApp based on imagery sources, created to analyze urban changes at two moments in time. We used imagery services to analyze changes from the North-East Area of Bucharest. It can be observed the situation from the past (2014) in the magnifying glass by comparison with 2020.

Fig. 7. WebApp for Highlighting Urban Changes – Residential Area – Fabrica de Glucoza Street (2020 – left side, 2014 – in the magnifying glass)

Example 5 Dashboard Application for Technically Expertised Buildings – Bucharest –

Presenting data of interest in the form of a Dashboard is very useful to show the situation at a certain time. For example, in figure 8 is highlighted such an application that can be implemented at the city hall level and in which the status of the works can be introduced, in case the construction has entered the consolidation process.

Example 6 - Traffic Analysis based on Real Time Services - One of the very useful aspects that can be used in GIS is to analyze the traffic situation at a certain time. These detailed situations can be identified on the basis of more advanced technology [1], but quick analyzes that can be done using real-time data services should also be considered.

Spatial planning and strategies created are based on different criteria, taking into account various indicators. One of these indicators should be those related to traffic analysis, in order to prioritize infrastructure works. ArcGIS Online enables the use of near real-time traffic data services through the Esri Living Atlas Traffic Service. [11]

A dynamic traffic mapping service with updated data every five minutes and capabilities to visualize traffic speeds in relation to free-flow speeds as well as traffic incidents can be used. Traffic incidents also have associated attributes that can be viewed and identified.

These data are very useful to provide context for routing, navigation and field operations. The IncidentType field in traffic incident layers can have the following values: Accident, Congestion, Construction, Disabled Vehicle, Lane_Restriction, Mass Transit, Miscellaneous, Other News, Planned Event, Road Hazard, Road_Closure, Weather.

The Severity field in the incident traffic layers can have the following values: critical, major, minor, low impact, where critical indicates a road closure and major indicates the blocking of several lanes. Figure 9 shows the situation on Prahova Valley, using the data from 1.12.2021 (4.15pm and 6pm) and from 4.12.2021 (4.15pm), and the way of highlighting an incident (closed road), on the right side.

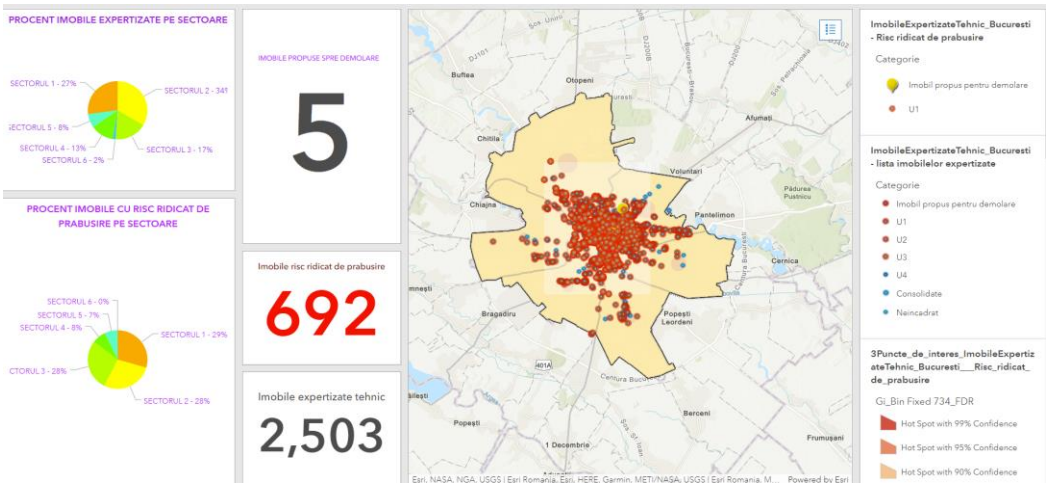

Fig. 8. Dashboard for Technically Expertised Buildings in Bucharest (until 2015) (adapted from [7])
Source: https://amccrs-pmb.ro

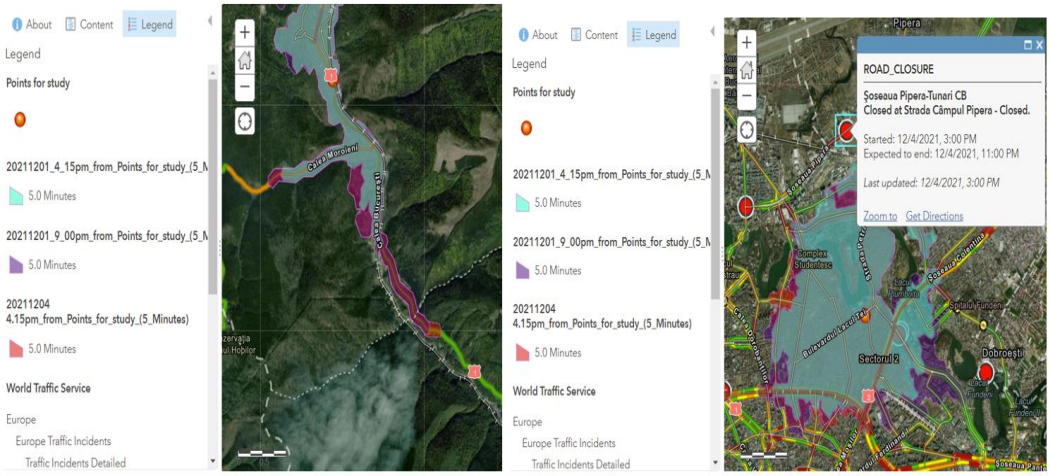

Fig. 9. Examples of drive-time areas that can be covered at any given time in 5 minutes, based on real-time data services

5. Conclusions

The “spatial planning” component is present as a measure in the PNRR, and the involvement of specialists in this field is essential. The proposed reforms can contribute to the operationalization of the concepts of "smart city" and "smart villages", respectively. Architects and urban planners propose urban plans, builders put in place investments in infrastructure, utilities and buildings, and surveyors participate in both topographic surveys, which are the support for PUD, PUZ, PUD, and the tracing of topographic elements, construction stages and tracking over time the evolution of construction.

However, now are specialists trained at the master's level (Spatial Planning and GIS for Sustainable Development – PSGISDD) at the Faculty of Geodesy and they can make a significant contribution through the data they can collect, process and store on an urban digital platform, created as a digital infrastructure containing up-to-date geospatial data and information. The urban landscape is changing day by day, the problems that arise need to be resolved quickly so that the living and living standards correspond to a developed society. Romania has to recover the gap with the European average in many areas. A contribution to these planned measures will therefore have the community of specialists in geodetic engineering, those who practice a profession with an important social and economic impact for society. The contributions of geospatial data specialists (geodesists) with GIS skills to the implementation of PNRR can be present in almost all 15 components of the plan to modernize Romania, in accordance with the Recovery and Resilience Mechanism (MRR) and in the context of post-crisis recovery COVID-19:

- digital geodatabase at the level of local administration;
- property taxation system based on cadastre and land book geospatial data;
- decision-making process based on real data from the cadastre, orthophotoplans used as services;
- modernization and expansion of transport infrastructure - expropriations, removal of land from the agricultural circuit, measurements for construction;
- sustainable urban mobility - mobile mapping, traffic studies;
- inventory of the forestry sector and surveying in the construction sector;
- renovation / consolidation of buildings, historical monuments and buildings located in protected areas – using laser scanning, 3D modeling of the historical monuments and the archaeological sites;
- digital transformation aimed to improve public administration by establishing the necessary framework for achieving the interoperability of ICT systems of various public institutions, ensuring coherence with the eIDAS Regulation and implementing the "one time only" principle, integrated in Regulation (EU) 2018/1724 on the single digital portal - geospatial data are fundamental;
- elaboration / updating of the landscaping and urbanism documents in GIS format;
- acquiring advanced digital skills.

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