Spatial data acquisition for traffic lights intersections as a basis for GIS development in Timisoara, Romania

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Abstract
The continuous development and the rapid economic growth of Timisoara municipality (western Romania) have contributed to the increase in transport needs. The number of motor vehicles registered by natural persons (125,195), and the number of motor vehicles registered by legal entities (35,303), results in one motor vehicle per two persons. To these figures are added the commuters, students and tourists who come by car to the city. Thus, the main cause of road traffic is the increasing number of vehicles, day by day. In order to maximize road capacity and speed up the pedestrians’ flow, traffic lights are used at approximately every intersection. As such, the proper use of traffic signals can lead to more efficient traffic management. Due to the evolution in time, technology comes to aid precisely to solve such problems and especially to streamline road traffic issues. Thus, the article presents the workflow that includes identifying the elements of a traffic light intersection, measuring, and processing them, in order to realize a layout plan that can be introduced into a GIS system to manage traffic lights in an intelligent manner. Using GIS (Geographical Information System) technology, the problem of road traffic can be solved appropriately and efficiently. Based on the main characteristics of urban traffic and the efficient, appropriate use of traffic lights, approaching, and treating the information according to the area, its spatial and geographical location through coordinates, GIS technology can be used to solve problems given by the zonal agglomeration of heavy traffic centres, or areas with peak hours. The fluidization of the traffic can ensure better circulation and aeration of the crowded areas and the avoidance of the congestion of some central arteries, especially during rush hours.

Keywords: GIS; intersection; spatial data; traffic lights; traffic management
Introduction

Simultaneously with the economic and social development, in many urban centres, there is a massive increase in the number of cars and public transport vehicles. The consequences of these changes at the city level are found in agglomeration and traffic congestion (Metz, 2018; Loo and Huang, 2021). They cause a lot of inconvenience to residents, energy consumption and lost time in traffic. In addition, traffic congestion in cities has adverse consequences on the economy (loss of energy-fuel, time, money) and the environment (accumulation of pollutants, increased pollution, declining quality of life and urban health standards) (Roșca et al., 2012; Jayasooriya and Bandara, 2017). Urban agglomeration has become increasingly expensive in terms of time, money and fuel, especially in the last three decades (Chang et al., 2017).

The limited land areas of large cities and the restrictions on the construction of transport infrastructure due to social and economic pressures, force the urban centres’ administrators to find solutions to counteract the congestion of urban traffic (Wang et al., 2018). Different transport policy instruments could be effective in reducing congestion by reducing the need to travel, reducing the use of passenger cars, improving the functioning of public transport and use of the infrastructure etc. (Koźlak and Wach, 2018). Among the management measures considered are those of traffic control, fluidization and regulation through adequate traffic lights and continuous modernization. The length of the traffic signal cycle designed by F. V. Webster (1958) was to minimize vehicle delays and ensure fluidity and increase flow at intersections. This traditional method of optimization has been used in traffic analysis for years, being a basic method for determining the optimal duration of the traffic cycle and optimization of traffic lights (Calle-Laguna et al., 2019).

Traffic lights can be one of the most important technical means of regulating traffic flow, avoiding congestion and traffic congestion and even reducing exhaust emissions and pollution. Scientific and technical advances and the development of information technology have allowed the efficient use of new functions and technology of computers, but also GIS systems to improve and streamline traffic on urban road networks (Shi, 2008; Tiwari et al., 2012; Kotikov, 2017; Li et al., 2020).

In Romania, data from the National Institute of Statistics (INS, 2021) shows that urban areas are becoming more and more populated (Figures 1, A and B). Thus, as information changes continuously in time and space, the decision makers must find solutions for improved planning in order to maintain community services at a high level and stimulate change and development.

Located in the western part of Romania, Timișoara is the largest city in Timiș County. It is the first city on the European continent with electrically lit streets and the first paved street in Romania. Timișoara is an urban area that knew early industrialization and used intelligently its geographical position and the advantages offered in the vicinity of the borders. Moreover, Timisoara is an important university and financial centre for Romania, an exceptional industrial, commercial, and medical centre (Primaria Timișoara, 2020).

![Figure 1](image)

**Figure 1.** National Statistics Institute of Romania data (INS 2021): (A) Migration of the population to urban areas in 2021; (B) Classification of Romania’s counties based on population’s preference for urban areas
With an area of 130500 km² and 320000 inhabitants, Timişoara Municipality forms the densest inhabited area in Timiș County, Romania. Being a densely populated city (Figure 2), it is also one of the busiest road traffic in the country. Continuous development and rapid economic growth have contributed to increasing the transport need. Hence the city’s biggest problem: road traffic. The number of motor vehicles registered by natural persons: 125195, and the number of motor vehicles registered by legal entities: 35303, results in one motor vehicle per two persons. To these figures are added the commuters, students and tourists who come by car to the city. As such, the main cause of road traffic is represented by the growing number of vehicles. Proper use of traffic signals can lead to more efficient traffic management.

To provide safety and an efficient traffic environment for vehicles and pedestrians, traffic lights are used at approximately each intersection. In order to maximize the road’s capacity and to accelerate the pedestrians flow, the traffic lights work non-stop. Any interruption of these scheduled or unscheduled services would be a nuisance to the public or even a threat to security. Traffic control equipment is essential, so it needs special attention. The aim of the system is to support the operation and monitoring of equipment, to control traffic and pedestrian flow.

Due to the evolution in time, technology comes to aid precisely to solve such problems and especially to streamline road traffic issues. Taking into account the fact that about 80% of daily decisions on national or local level, in different fields of activity, like infrastructure, demography, spatial planning, environment, hazard areas, housing, property evaluation etc. are spatially or geo-referenced (Vîlceanu et al., 2011) using GIS (Geographical Information System) technology, the problem of road traffic can be easily solved.
During the last decade, the visualization and analysis of the GIS data in real time have become growingly significant, especially in those activity domains in which, the operating process involves a direct connexion to the spatial data. Thus, whether it is about different networks such as line system, pipage, railway system, road network, land management or publicity, the people will need rapid access to this data (Grecea and Vilceanu, 2012).

GIS represents the optimal solution for road traffic management on account of its well-known advantages, namely:
- facilitates complex geographical analysis operations;
- the mapping process is faster and cheaper;
- digital maps can be realized according to user requirements and specifications;
- cartographic production is achievable without the need for large staff;
- facilitates the creation and permanent updating of maps;
- allows the interaction between analysis, statistics and mapping;
- easy storage and access to the necessary data;
- allows simulations (experiments) with different graphical representations of the same data;
- selection and generalization procedures are explicitly defined and performed with “consistency”.

The study aims to present the workflow that includes identifying the elements of a traffic light intersection, measuring and processing them, in order to realize a layout plan that can be introduced into a GIS system to manage traffic lights in an intelligent manner (Iovanovici et al., 2020). It has an interdisciplinary character as it includes knowledge from different disciplines such as GIS, topography and road engineering and it highlights the importance of permanently updating the urban GIS for an efficient urban planning with a view to offering high living standards for the city’s inhabitants.

**Materials and Methods**

The study was conducted in Timisoara, a city in western Romania, located at an altitude of 90 m. The work was designed as a case study applied to a pre-established road section in the Timisoara municipality. It includes the analysis of two traffic light intersections, including recognition of the elements that are to be introduced into GIS, determining the coordinates of field details, traffic light times, and traffic simulations.

The representation of the boundary for the built-up area (red outline) and outside the built-up area (green outline) of the Municipality of Timisoara was realized in the ArcGIS software (Figure 3 A). AutoCAD software was used for managing vector data such as roads, the geometry that represents Timișoara Municipality limits, along with attributes such as the street names (Figure 3 B).

**Figure 3.** Digital representation of Timișoara municipality: (A) The urban and extra-urban limit of Timișoara, within which the study area is located; (B) The network of routes located within the city limits of Timișoara.
The direction of the route starts from Continental Hotel located on Revoluției Boulevard, Timișoara, to the “Pius Brînzeu” County Emergency Clinical Hospital Timișoara, located on Liviu Rebreanu Boulevard. Figures 4 and 5 show the digitization of the study section route.

In addition to the two specified points, the intermediate streets or boulevards are also of interest, respectively: Ion C. Brătianu Boulevard; Michelangelo Street, including Michelangelo Bridge; Cluj and Arieș streets. The details regarding the positioning of the studied route inside the Municipality of Timișoara and the length of the analyzed route are presented in Figures 6 and 7.

From the notion of the area where the study route is located, it came to the exact positioning inside the Municipality, and with the help of the online service Google Maps it was possible to find out the length of the entire route, i.e. 2.4 km and the time it can be reached by car, i.e. 5 minutes.
The topographic fieldwork began with the identification of the study area and the details to be surveyed. At the same time, a work plan was established (the area where the measurements will start, the areas where the intermediate stations will be located etc., depending on the visibility in the field). The starting stations (100St and 101Or) were determined using the GNNS Trimble R8s with an accuracy of +/- 8 mm horizontally and +/- 15 mm vertically, and using the national ROMPOS system. From these stations, using the Trimble S5 Autolock total station with an accuracy of 3 cc and 1 mm, the actual survey started. The polar method was used for the fixed and linear details in the field, and the routing method to ensure the number of stations needed to collect data from the field and the necessary accuracy. This accuracy was ensured by closing the routing to the starting points.

From the topographic survey the coordinates specific to each point were obtained, in the Stereographic projection system 1970, then the intersections were drawn.

Liviu Rebreanu Boulevard is a main artery that takes over the traffic flow from six streets: Arieș Street, Calea Martirilor 1989, Sănătății Alley, Sudului Boulevard, Orion Street and Gheorghe Domășneanu Square. Due to the real estate and commercial constructions, it was extended to the Gheorghe Domășneanu Square roundabout, which has a direction to Calea Buziașului, thus becoming an alternative city exit to Buziaș locality.
Case study: Intersection of Liviu Rebreanu Boulevard with Arieș Street

The intersection of Liviu Rebreanu Boulevard with Arieș Street is shown in Figure 8. In terms of traffic, the artery includes: 11 pedestrian crossings, a bicycle lane, approximately 350 parking spaces, of which 150 are sidewalks, a bus station, a tram station, a taxi rank. There are always blockages and queues on the artery, but especially in the morning when most people go to work or school, at noon or in the afternoon when they return home or go shopping.

![Figure 8. Intersection of Liviu Rebreanu Boulevard with Arieș Street](image)

The Figures 9 and 10 present the diagrams specific to light signals times of action for the above-mentioned intersection.

![Figure 9. Plans - signal group synchronization - options (1)](image)
The meaning of the symbols found in the two diagrams is: S and V - traffic light for vehicles, T - traffic light for trams, respectively P - traffic light for pedestrians. Plan 2 for signal group synchronization is presented for 16:00-18:30 hours, in the rest of the hours being applied only plan 1. Each of the two diagrams of 10 sub points each, represents the action time corresponding to each colour and each type of traffic light.

**Case study: Michelangelo intersection**

An overview of the Michelangelo intersection is shown in Figure 11. The difference from the first intersection presented consists in the fact that, in this intersection, there are also video surveillance cameras.
Figure 12 presented the diagrams specific to light signals times of action for the Michelangelo intersection.

![Figure 12](image_url)

In the figure, the following symbols were used: S and V - traffic light for vehicles, T - traffic light for trams, respectively P - traffic light for pedestrians. Each of the 21 sub-points represents the action time corresponding to each colour and each type of traffic light.

By realizing a video of a section of the intersection, viewed from Vasile Pârvan Boulevard to Michelangelo intersection centre, one can observe or even time the action times specific to each colour of the traffic lights. For example, for the suspended traffic light on Vasile Pârvan Boulevard, the light signals act as follows:

- red signal is active for: 1 minute (60 seconds) - time in which vehicles stop and pedestrians cross the intersection;
- yellow signal is active for: 3 seconds;
- green signal is active for: 1 minute (60 seconds) - time when the vehicles are moving and pedestrians are at rest.
Results

After the actual drawing of the traffic lights, markings and road signs, all the layers can be opened in order to be able to see the image as a whole and to proceed to the realization of the layout plan of the studied intersection. Also, it is possible to overlap the intersection with the orthophotoplan of Timiș County, by using the georeferenced drawing (Figures 13, 14, and 15).

![Figure 13. Overlapping of the first studied intersection (Arieș Street with Liviu Rebreanu Boulevard) with the orthophotoplan](image1)

![Figure 14. Layout plan of the Arieș Street with Liviu Rebreanu Boulevard Intersection](image2)
The result of the representation of the Michelangelo intersection is a layout plan that accurately reflects its geometry and positioning (Figure 16).
Discussion

Even though there is still no consensus on how to decongest road traffic efficiently, and traffic agglomeration remains a global problem in big cities, GIS-based approaches are likely to become increasingly useful (Loo and Huang, 2021). Road intersections and their reliable traffic lights are of great interest, consequently, it was analyzed in the current study. The necessary elements of an intersection are represented by the auto vehicles and pedestrian traffic lights and the road signs and markings, being dependent on each other. This conclusion is due to the fact that a traffic light cannot function properly if it is not connected to a road marking, or if the traffic light is defective, the traffic signs, i.e. the signs, must be observed (Jayasinghe, 2019). Or, for example, the sign that indicates a pedestrian crossing in the immediate vicinity of it would not be optimal if the road marking with its meaning does not exist. The identification of the optimal cycle length of traffic at intersections in order to minimize car delays and facilitate traffic flow, and reduce fuel consumption levels and emissions is highly topical (Calle-Laguna et al., 2019).

Based on these considerations, the main requirements of this study were identifying the elements of a traffic light intersection, surveying and processing them, in order to realize a layout plan that can be later introduced into a GIS to intelligent manage traffic lights. We chose the route of this section starting from Continental Hotel to the County Hospital, because both landmarks are of great importance located in central areas of the Timișoara city. After studying the section, it was noticed that most intersections traffic lights operate at full capacity, i.e. non-stop. However, traffic in these intersections would not be optimal without the existence of road signs and markings.

Finally, the geodetic engineer contributes to the intersections representation based on field surveys, using specialized software. In addition, a series of traffic simulations and timing of traffic light times at intersections were performed in order to obtain an eloquent representation of the synchronization diagrams of the signal group. The result of the representation of the two studied intersections is a layout plan that exactly reflects the geometry and positioning of all traffic lights, markings and road signs and other elements that contribute to traffic management. Surveying and processing of all these elements have an important role in managing traffic, reducing jams and queues by intelligent traffic lights. In conclusion, the study emphasizes the fact that the data surveyed in the field and the management of traffic light intersections can be further used at any time to update the urban GIS Timisoara, or create a specific database GIS for traffic management and traffic lights. In the future, from a topographical point of view, the latest generation technologies such as LIDAR will represent the basis for collecting entry data for the Geographical Information System. Until this new technology will become widely used, our approach is also useful. A GIS system for traffic lights is essential for thinking about neural systems for autonomous cars and for traffic predictions.

Conclusions

Certainly, a well-developed data set for the systematization of traffic lights can contribute to traffic decongestion. The resulting processed data set presented in this work provides a meaningful representation of the road features of interest for intersections while excluding irrelevant data. The management and updating of geospatial data will have to be more and more accurate and reliable for the road environment both in the localities and outside them. The need to identify and extract information from GIS for various applications but also for autonomous cars will become significant. The environmental component will also benefit from a well-developed traffic lights system.
Authors’ Contributions

The methodology followed was a common work of all the article’s authors. S. Herban has realized the topographic field surveys, A.-M. Moscovici was in charge of topographic data processing. O.-M. Sîrbu realized the processing for obtaining the plans with signal group synchronization of both intersections and both of them realized the layout plans. C.-B. Vîlceanu was involved in writing the original draft, also review and editing and A. Iovanovici has experience in traffic simulations.

All authors read and approved the final manuscript.

References


