

STUDY ON DESIGNING MUNICIPAL TECHNICAL NETWORK MAPS FOR AN AGRICULTURAL COMPANY WITH THE HELP OF A GIS

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Abstract

This paper presents a fast and precise method of designing municipal technical network thematic maps for an agricultural company which besides the agricultural production activities, also specializes in the food industry. Because of this, the improvement of the water management is imperative. In order to reach the objectives needed, a field survey was performed at the same time as the one required for "Study on the development of a GIS for improving the management of a drinking water network for an agricultural company". Based on the collected data, a series of thematic maps for the water and sewer systems were designed. They show the surveyed details with great accuracy and are very important for water management. An important characteristic of the GIS developed is that it has the ability of providing all of the departments with data visualisation capacity through a WMS and service for easy map printing, without the need of specialised knowledge. The users only need to choose the paper size and the system will take care of designing and adding the finishing touches to the map.

Key words: database, GIS, thematic maps, water management.

INTRODUCTION

GIS technology integrates operations that are shared with databases, such as statistical analysis and research while benefiting from the ability to visualise the geographical data and perform analyses. These abilities set the GIS apart from other information systems and make it valuable for a wide range of public and private entities to explain events, predict results and strategize (Barazzetti et al., 2010; Tomlinson, 1984).

GIS offers the possibility of designing maps, integrate information, visualise scenarios, solve complex problems, present ideas and develop efficient solutions like never before. GIS is a tool used by individuals, organisations, schools, governments or businesses that search for new ways to solve problems.

Designing maps and performing geographical analyses is not a new thing, but a GIS performs these tasks better and faster than old methods. On the other hand, before GIS, only a few people had the required knowledge to use the geographical information available to aid in decision making. A GIS stores information about the world as a collection of thematic layers and geographical connections can be made between them. This simple concept

proved to be priceless for solving many global issues starting from tracking delivery vehicles, recording details regarding planned projects, to changing global air travel (Patino and Duque, 2013; Păunescu et al., 2020).

Geographical information contains either an explicit geographical reference such as a coordinate grid - latitudinal and longitudinal - or an implicit reference such as an address, postal code or forest parcel identification number. An automated process called geocoding is used in order to create explicit geographical references (multiple locations) from within the implicit references (descriptions such as addresses). These geographical references allow for the localisation of properties such as an industrial compound, a forest, a hotel and events from all across the globe such as an earthquake, to be processed and analysed (Konecny, 2009; Tsihrintzis, 1996).

Geographical information systems use two fundamentally different types of geographical models - "vectors" and "rasters". For the "vector" type, the information regarding the points, lines and polygons is coded and stored as a collection of X and Y coordinates. The position of a borehole can be defined by a single pair of coordinates. Linear objects such

as a road or a river can be stored as a collection of points. Polygon objects such as industrial surfaces or river collection basins can be stored like a closed loop of coordinates (Calinovici and Călina, 2008; GIS Geography, 2021).

The vector model is very efficient in describing objects but it is less efficient for trying to represent elements that are changing continuously such as soil type or cost accessibility for hospitals (Doneus and Neubauer, 2005).

The raster was developed especially for representing these variable features. A raster image is made of a grid of cells. Both vector and raster models have advantages and disadvantages for storing geographical data. Modern geographical information systems are capable of handling both of these models (Călina et al., 2020; Shamsi, 2004)

Many of the requirements of these projects are satisfied by the best-known sources of cartographic data such as: basic maps, maps and commercial data, maps and data regarding the environment, general and thematic maps.

Thankfully, volumes containing geographic data are already available. With the help of the ArcData application, ESRI established a partnership with the most important data suppliers in order to offer a vast amount of plug-and-play information through ArcView. GIS Store and ESRI's ArcData Online offer an easy way to obtain some of the most used geographic data. At the same time a great variety of geographical data is made available with Arc View GIS for a quick start. These datasets can be used as basemaps for future GIS projects or for supplementing already existing data (Surani and Dihora, 2015; Sala et al., 2020).

MATERIALS AND METHODS

In this paper, the fundamental elements of a GIS will be presented and the topographical and geodetic theoretical aspects required for using a GIS developed for a municipal technical network and how it incorporates a wide variety of data and information, stores it, processes it and produces maps and spatial analyses that assist in the decision-making process and the improvement of the provided services.

Geographical information systems include a wide variety of technologies. There are many hardware manufacturers for network storage, database servers, Web servers, visualisation servers and desktops, all connected in various configurations of local area networks or internet. All these technologies need to be able to function in a coherent way in order to have a balanced processing environment (Călina et al., 2018).

Centralised systems with only one database are the most basic and easiest to implement and maintain. Obviously, the ones with more databases can end up being very difficult to implement and maintain. Because of this, many small and medium organisations, such as the one presented in this paper, choose the first option while also maintaining the failure risk as low as possible (Shamsi, 2004).

In this study was used the same working method as the one in the "Study on the development of a GIS for improving the management of a drinking water network for an agricultural company" paper and the following main strategic initiatives were used:

1. Developing and implementing a strategy - A strategic plan is the guide that needs to be followed in order to be able to establish what the initial vision is, objectives, needs and other parameters of a GIS (Bishop et al., 1991).
2. Initiating a pilot phase - Taking into account the investment required for a GIS and the long period of time associated with complete implementation, a pilot phase is an excellent opportunity for the production of tangible results and for increasing the support for the project.
3. Establishing the hardware architecture and the software environment - The foundation of a GIS is given by the design of the hardware structure and the suite of software that need to be able to produce the required results established in the first phase. This will differ from one company to another because of varying needs and requirements (Longley et al., 2004; Adamov et al., 2020).
4. Developing a basemap - The main layer on which the whole system is built upon is the map of the area in which it needs to perform spatial analyses. The instruments used for field surveys are the GNSS Leica Viva GS08 + CS10. Building up the database can easily be

the most costly aspect of the whole project. It will also use up most of the time. The abilities of the project manager will surely be put to the test in this phase because a careful analysis of the requirements that need to be met is needed. The ones that are vital to the department's well being must be prioritized (ROMPOS, GNSS, 2021).

5. Developing standards and procedures - A GIS is more than just software, hardware and data. It needs to include standards and procedures that allow the data and technological components to function consistently and efficiently.

6. Online visualisation - In order to ensure an efficient integration with other departments that do not benefit from specialized IT equipment, a information distribution method is required for the data generated by the GIS. After the system becomes widespread, an online visualisation tool becomes mandatory.

7. Development/Priority applications integration - The system will need an environment that will allow for future modifications as the various systems that make it up are being replaced or updated. This environment needs to be flexible and economically efficient. If the system will reach maturity, modifications and updates will be necessary (Rosca et al., 2020; ROMPOS, GNSS, 2021).

8. Developing a training programme - As the system gets adopted by more and more departments, the project manager will need to take into account the fact that not all of the users have the necessary know-how to interact with the system. Because of this, a training programme needs to be developed so that the level of knowledge will be sufficient for all of the employees and their various levels of interaction that they have with the system's various components (Pop et al., 2019).

9. Project maturity - In an organisation, a GIS can not be implemented and afterwards left without leadership, coordination, support and ability to develop. A departmental management system will have to be developed in such a way that operational efficiency and longevity are guaranteed (Becker et al., 2011; GIS Geography, 2021).

Implementing an organisational GIS needs to lead to the production of some final results, the most important one being the basemap, which

is most of the times, composed of a series of layers that contain the geometry and attributes of the features such as streets, private property boundaries, constructions, water bodies, forests, electricity and lighting poles, parking lots and others. Because these layers, together, will shape the map on which various spatial analyses will be performed, they need to have the highest degree of precision and attribute data accuracy (Mihai et al., 2015; Burghilă et al., 2016; ROMPOS, GNSS, 2021).

RESULTS AND DISCUSSIONS

This study has been made for a private agricultural company located in Valcea County which besides the agricultural activity, also has multiple meat processing activities and the production of feed. All this makes the water usage level to be high, which results in the need of developing a GIS that will design all the thematic maps required for tracking and managing the water use.

The purpose of this study is to develop the planning phases, develop and implement a GIS that will be used for the storage, processing and visualising all topographical data related to the networks that are being used by the company. Also, the intention was that of identifying and promoting the main advantages of a mature GIS that has become an important component in the company's information flow through its abilities to process and visualise data in an intuitive manner (Herbei and Sala, 2020).

Using this GIS through a WMS service has become an advantage in the use of geo-information that is distributed to the employees, no matter the performance of the computer that they use. The reaction times for the various problems that arise have been reduced mainly because the access to correct information is done through an easy to understand method, which leads to planning for a solution more efficiently.

Like any other information system, it is not perfect. It is in a continuous development and improvement. From one day to another new technologies are born, that either add new analysis and visualisation methods or solve past issues in a more efficient way. One of the most important tasks for the team starts the moment the GIS is fully implemented and integrated.

The continuous need for new analysis tools generated by the issues that the company is faced with, makes this system to be in a continuous development and the only way to stay relevant is by having a team with the necessary knowledge that remains dedicated to the project.

In order to create the thematic map with the specific elements of the technical network, during the field survey, all of the water valves were inventoried. Most of these valves are created to be installed in the ground because of the epoxy coating that protects them from rust and because of the ability to be toggled from the surface with the help of a telescopic valve tool.

Taking into account the fact that even though the main distribution water pipe is not visible, because of how the water valves are designed to work, it is usually right underneath the valve cover. The cases where it is positioned at an angle are very rare, making the cover to not be placed on top of the water pipe. This underground valve room contains two valves that work together to create two possible scenarios:

1. In normal use valve 1 is closed and valve 2 is open. This way, the water is sent to the main network; 2. When the water tank is being cleaned and disinfected, valve 1 is opened and valve 2 is closed in order to not send contaminated water towards the main network.

After the field survey with the GNSS system, the ground elevation is determined, and not the main water pipe's elevation. Gathering that information is impossible if the survey is not performed when the pipe is installed. Because the water network is permanently pressurized, not knowing the precise elevation is not a major problem. In order to collect this information, the GIS department is issued with a series of internal memos for each intervention on network pipes that leads to excavation and having access to the pipe. This way the GIS department will eventually gain access to unknown information regarding pipe elevation that was not known previously. It is important for the GIS department members to be accompanied by an employee that has knowledge regarding the details of the water network in that particular area. This way, all of the relevant technical and geographical information is gathered.

This way, by drawing a polyline through the points determined by the water valves and following the details collected in the field, the water pipe will be added to the GIS. In the places here there are more complex construction is located, sketches and photographs will be made that will assist with the accurate digitizing. Such a situation was noticed in the S-E of the study area, at the intersection of roads where there is a small reservoir (Figure 1).

In order to digitize surveyed details, each one of them need to be added to their respective category. This way, in the case of water valves, after the field survey is downloaded to the computer and loaded into QGIS, the editing mode will be turned on for the layer where valves are located. Auto-snapping will also be turned on. The moment when the user clicks, a pop-up window will open that will request the details for that particular network element. These windows have been custom made by the GIS department and are used to accurately add details to each element (Figure 2).



Figure 1. Water network configuration in the s-e area

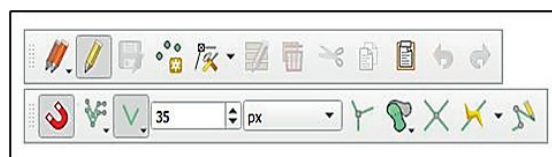


Figure 2. Digitization toolbar (up) and auto-snapping toolbar (down)

As it was mentioned earlier, the GIS has the capacity to hold and arrange a lot of data that belongs to one pair of coordinates. In this case, water valves. For the water valves, a feature attribute window was created. It has the role of guiding the QGIS user through a series of details that need to be filled. These are: type of valve, its role in the network, its diameter, the diameter of the pipe it is installed on, if it is opened or closed during normal operation, the

GNSS precision with which it was surveyed, year of install, and others (Figure 3).

Another network feature that benefits from a feature attribute window are the hydrants (Figure 4). Hydrants are important network elements. Most of the time they go unnoticed with the exception of the ones installed above ground.

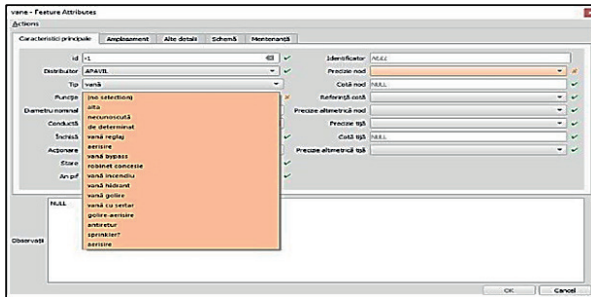


Figure 3. Feature attribute window for water valves
Source: own field observations

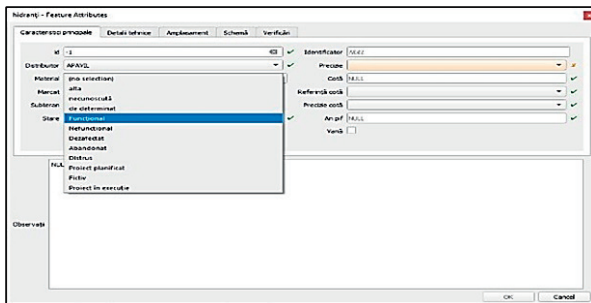


Figure 4. Feature attribute window for hydrants
Source: own field observations

In Romania, most of the fire hydrants are installed beneath the ground level. The only visible thing at ground level is the casing and its detachable cover and most of the times, the markings that are placed on visible permanent markers such as fences, poles, curbs, trees and others. Yearly, they are inventoried, marked and checked in order to be able to generate a list that contains coordinates, status, diameter, water pressure and position details. For each pair of coordinates, the system stores all of the technical specifications and characteristics that are observed in the field. All this, next to a photograph made with the Leica Viva CS10 controller, the GIS can offer all the details required by the firefighters for easy positioning, which can drastically reduce the time required to intervene in the case of a fire.

The information that the GIS department needs to collect are the geographical position determined with the GNSS instrument or total station, the material that they are made of, if

there is any marking available, if they are installed underground or on top of the ground, the elevation of the protection casing, survey precision and other details. At the time of the field survey, a series of photographs are taken that will be correlated with the ID that each hydrant will receive. All this is done in order to have information and landmarks that will allow for it to be discovered if the casing is covered, in case of road resurfacing, and the people at the scene do not have access to topographical instruments.

For many people that do not work in this field or have rarely used a map, identifying such a small element can be difficult just by looking at a sketch. In this case, a photograph can make the difference in identifying and quickly solving such an issue or planning an intervention with the members of the GIS department which can be a few hours later or a couple of days.

Another aspect that must not be overlooked is the positioning of water meters. Its position will be surveyed and digitized just like any other element whose geometry is defined by a point.

In order to obtain a complete GIS model of the network, the specialist needs to process sewer network specific elements where the attention to detail is imperative. The water network is pressurized and as long as the elevation differences between two points are not great, all of the service subscribers will have access to a guaranteed pressure of 2.5 bar.

In the case of the sewer network, everything needs to work with the help of gravity. Since the designing phase, the attention to the elevation needs to be heightened. In the northern part of the study area, the average elevation is 248.1 meters while in the southern part it is 241.3 meters. Taking this into account, the network was built to transport grey water from west to east through secondary pipes that are connected to the main pipe which will flow into the main collector.

For the surveyed elements of the sewer network, the digitization procedure is identical. The appropriate layer is chosen, the editing mode is turned on and auto-snapping is used in order to guarantee the correct positioning of the network elements, on top of the points surveyed in the field with the GNSS instrument. In the study area, the network is build with modular concrete elements. The visitation

rooms are fitted with a concrete cover and the manhole cover and rim are made out of cast iron. The depth at which the pipes are installed is approximately 2 meters. Like in the case of water valves or hydrants that were presented above, for these were also created feature attribute windows that have the role of guiding the user through a series of text fields and drop-down menus that will collect and store as much information as possible. For the detailed representation of the sewer network elements, and for avoiding future visits, in the field, must be collected as much information as possible, such as: visitation room status, type, material, elevation, visitation room depth, access ladder status, manhole status, manhole material, construction year and others. Also, it is important to know details about the pipe that connects two visitation rooms. Information regarding the material that was used, status, depth, shape and others (Figure 5).

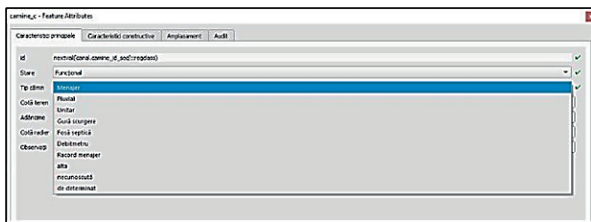


Figure 5. Feature attribute window for sewer visitation rooms. Source: own field observations

After digitizing the pipe's direction, the user is met with a new data entry form, but this time it is adapted for collecting data regarding the pipe's characteristics. When it comes to visually representing the properties of a pipe, there are many details that need to be visible but everything becomes a lot easier as soon as the GIS starts having access to all of the information mentioned above (Figure 6).

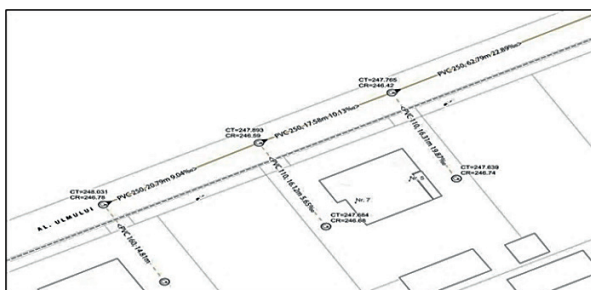


Figure 6. Sewer network details that have been automatically calculated by the GIS. Source: own field observations

The visitation rooms and pipes are automatically categorised, given symbols, have their length calculated, have their slope calculated, and an arrow is drawn to show the direction of flow. Once the details regarding the pipes are introduced into the system, it will know what roughness value it has, which is used for various other calculations and analyses.

Once an area starts to become crowded with all of the digitized elements and details belonging to various elements, as a result of a series of rendering rules, the system will always try to avoid overlapping symbols and labels and where this becomes impossible, it will prioritise certain elements.

For example, if the layers that belong to the sewer network are active and are in conflict with the general topographical data, the sewer system will be drawn on top. In this GIS all of the software elements are modular and taking into account the needs and objectives for managing the details belonging to water and sewer networks are very specific, the database structure and working procedures have been built from scratch. The database has a series of restrictions for certain fields in order to avoid erroneous information from being added. There are a few fields that are dependant on others. This way, one can not be validated without the other.

Such an example is the feature attribute window for hydrants. If one has been identified in the field, it needs to be mentioned if it is placed underground or not and if visible defects were observed. This way, important information is not left behind or forgotten (Figure 7).



Figure 7. Screenshot - sewer system after processing. Source: own field observations

Uploading processed data into the GIS

Most of the steps presented so far are performed locally, on each user's desktop with minimal interactions with the database. In most

situations it is being interrogated for new information only because the extents of the workspace have been modified and new information is required for visualisation.

The system functions in an efficient manner and taking into account the fact that the server does not benefit from raw computational power similar to the one from big corporations such as Google Maps, Apple Maps or Bing Maps), it only supplies the data necessary for visualisation and interaction - in the case of interaction between it and the members of the GIS department. For the adjacent departments the map is supplied through a WMS by using pre-rendered tiles of the map for all of the usual scales and with the possibility of interacting with various features. The information contained by the GIS is not public, therefore the access to the database is granted after authentication with a username and password, through an intranet. After all of the features have been processed, waiting for database upload and meeting all of the requirements imposed by the feature attribute windows, they can be prepared for the „Append” procedure. In this case, this procedure consists of adding a few more columns of information for the database whose structure is very well defined. For an easy processing, the columns are created just like the ones present in the database. Even though during the processing of the data there are data validation requirements for each feature and its feature attribute form, the database into which all the information is appended is the final filter (Figure 8).

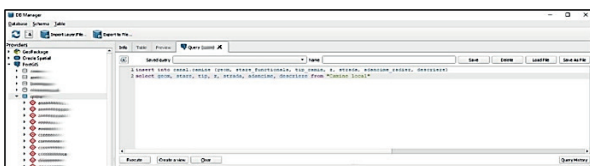


Figure 8. Database management window
Source: own field observations

If the append algorithm returns errors, they need to be corrected. If the append algorithm does not return errors, then that means that the database “understood” all of the new information and like it was mentioned earlier, the system will grant symbols and start performing various calculations for each feature, such as lengths, slopes, areas, elevation differences and more.

In this same step, all of the coordinates and elevation values that have been surveyed will be given a small description of what they represent (ground elevation, ditch elevation, etc.) and will be introduced in a table in the database that contains all previously surveyed values. By doing this, the elevation network will be thickened thus helping system users to understand the terrain without needing to travel to that location.

Designing and printing maps for the study area

In the past, all maps were made by cartographers in workshops, and they benefited from all the tools and materials needed. Today there are still such workshops that have the capability of designing maps that meet the highest quality standards, in great batches and that represent a wide variety of elements such as the ones found in: aeronautical maps, astronomical maps, geological maps and more. Even though these workshops will continue to fill an important gap in the field of cartography, with the birth and development of GIS software, the amount of work is rapidly and permanently changed because of the availability of software elements that can meet even the most difficult requirements. Obviously, just because someone has access to the most advanced GIS software, that does not mean that they have the knowledge and experience of a cartographer. QGIS offers the “Print Composer” tool that allows for the transformation of all the topographical information that was processed to be visualised on a map (Figure 9).

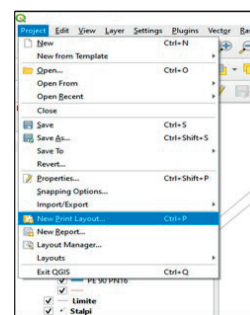


Figure 9. Accessing the “print composer” tool
Source: own field observations

In the pop-up window after clicking on the tool, a name can be given to the future thematic map, for easy access at a later date. The next steps consist of choosing the printing paper size and drawing an extent inside which the map

will be drawn. By default, on the left side of the workspace can be found the toolbar that contains the tools most often used during the map-making process (Figure 10).

After all of the necessary elements have been added, in the following figures you can see the two thematic maps for the water network and sewer network, created by the GIS software easily and with a high degree of accuracy and detail (Figure 11 and 12).

In Figure 13 can be observed the printing menu used for easily printing a map. This way, the adjacent departments do not need to ask the GIS department for a basic map print. The users can choose the location they are interested in and the details that they need for preparing a field visit for various problems that may arise. This level of automation leads to saving up the most important asset - time.

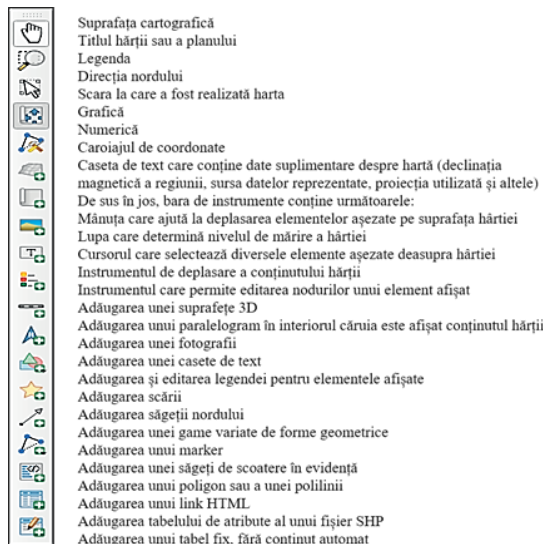


Figure 10. Toolbar for adding various features on the map
Source: own field observations

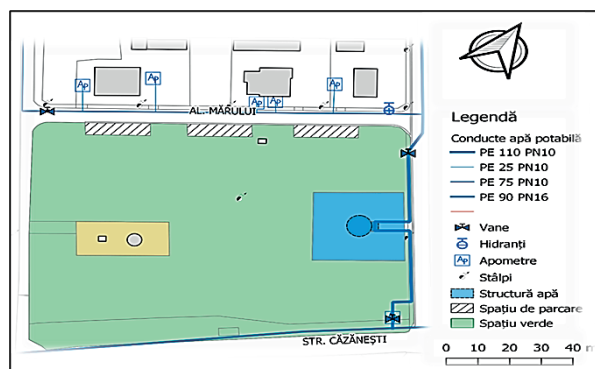


Figure 11. Map of the water network and all of its elements
Source: own field observations

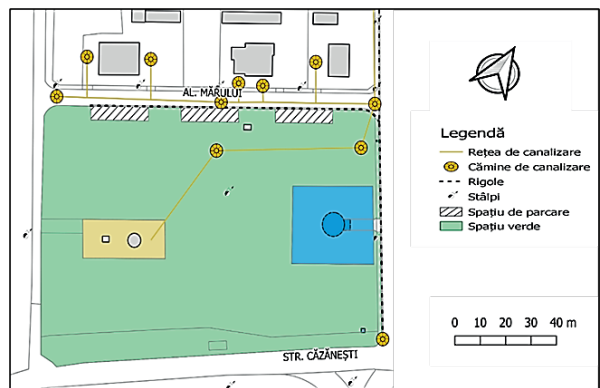


Figure 12. Map of the sewer network and all of its elements
Source: own field observations

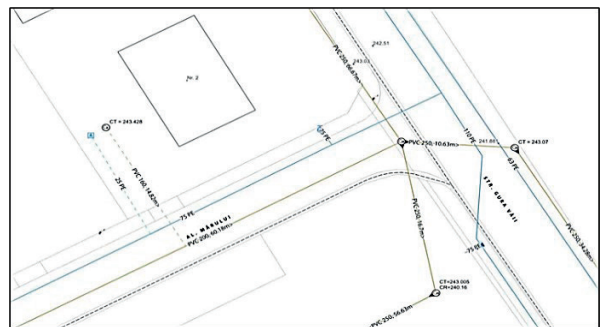


Figure 13. Screenshot - map of the intersection of two roadways
Source: own field observations

In order to not overpopulate the map, the system avoids rendering all of the details that it knows about present features, wherever the labels would not properly fit because of the chosen scale or position on the sheet of paper. The main objective of the GIS is to show technical information in a useful manner. Although there is an esthetical component to the rendering rules that is actively taken into account during development, the focus is always on trying to provide all of the available information for the rendered features in a way that does not impede with the user's actions. Whenever the user will use a larger scale, all of the details will be rendered accordingly.

CONCLUSIONS

From the earlier presented information, we can conclude that by developing a GIS, multiple types of data can be brought together, with the common component being the geographical and positional one of the data. Compared to a paper map, a GIS can hold multiple layers of information. The user will have the capability

of integrating, visualising, managing, solving and presenting the information in a new way. The connections between the datasets will become obvious and because of this, the owned data will be more valuable.

Using all of these tools and deploying GIS technology, we are given the possibility of creating high precision thematic maps, and based on them we can visualize scenarios, solve complex problems, shape ideas and develop solutions in an efficient way that was not available before.

By using the GIS technology and putting into practice the ability to interact with the maps and the data included, numerous advantages are brought forward such as: high level of interactivity, availability, user benefits, cost reduction, lower reaction times, more efficient personnel use, ability to reorganise the management process and a high level of transferability.

An important aspect that was significant during this research was that even today, the technology of geographical information systems is still evolving and updating. In the end, it needs to lead to the development of new results, significant from a quality point of view, with the most important being the end result which is the basemap which is most of the times built from a series of layers that contain the geometry and attributes of the features that are used for creating thematic maps as a result of spatial analyses.

Confirming that the GIS is implemented in the company that is the subject of this study and that it reached maturity becomes obvious when all of the departments have the ability to visualise data through a WMS. The portal grants the ability to easily print maps without needing to have special training. Users only need to know what paper size they want to print on and the system will automatically draw the coordinate grid, point the north arrow, add borders and a legend. All this is done in a dynamic way so that the information corresponds to the elements that are featured on the map.

REFERENCES

- Barazzetti, L., Scaioni, M., Remondino, F. (2010). Orientation and 3D modelling from markerless terrestrial images: Combining accuracy with automation. *The Photogrammetric Record*, 25, 356-381.
- Becker, T., Nagel, C., Kolbe, T.H. (2011). Integrated 3D Modeling of Multi-utility Networks and Their Interdependencies for Critical Infrastructure Analysis. In: Kolbe, T., König, G., Nagel, C. (eds) *Advances in 3D Geo-Information Sciences*. Lecture Notes in Geoinformation and Cartography. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-12670-3_1.
- Bishop, A.B., Hughes, T.C., Fullerton, H.H. (1991). A GIS approach to urban water system planning. Proc. ASCE Nat. Conf. Civil Engig. Appl. of Remote Sensing and GIS, Washington D.C., 14-16 May, 120-129.
- Burghilă, C., Bordun, C., Cîmpeanu, S.M., Burghilă, D., Badea, A. (2016). Why mapping ecosystems services is a must in EU biodiversity strategy for 2020. *AgroLife Scientific Journal*, 5(2), 28-37.
- Calinovici, I., Călina, J. (2008). *Topography*. Mirton, Publishing House, Timișoara, 73-75.
- Călina, J., Călina, A., Bădescu, G., Vangu, G.M., Ionică, C.E. (2018). Research on the use of aerial scanning for completing a GIS database. *AgroLife Scientific Journal*, 7(1), 25-32.
- Călina, J., Călina, A., Miluț, M., Croitoru, A., Stan, I., Buzatu, C. (2020). Use of drones in cadastral works and precision works in silviculture and agriculture. *Romanian Agricultural Research*, 37, 273-284.
- Doneus, M., Neubauer, W. (2005). 3D Laser Scanners on Archaeological Excavations. In Proceedings of CIPA 2005 XX International Symposium, Torino, Italy, 26 September-1 October 2005; Vol. 34(5/C34/1), 226-231.
- Herbei, M.V., Sala, F. (2020). Evaluation of urban areas by remote sensing methods in relation to climatic conditions: Case study City of Timisoara. *Carpathian Journal of Earth and Environmental Sciences*, 15(2), 327-337.
- Konecny, G. (2009). Cadastral Challenges for Earth Observation. In: Li, D., Shan, J., Gong, J. (eds) *Geospatial Technology for Earth Observation (397-409)*, Springer: Boston, MA, USA.
- Mihai, D., Teodorescu, R.I., Burghilă, D., Mudura, R. (2015). A modern approach in data updating for a vineyard agro-system modernization. *15th International Multidisciplinary Scientific GeoConference*, SGEM, 2015. ISBN 978-619-7105-35-3, 651-656.
- Longley, P.A., Goodchild, M.F., Maguire, D.J., Rhind, D.W. (2011). *Geographic Information Systems and Science*, 3rd edn, Wiley, New York, 46-89.
- Patino, J.E., Duque, J.C. (2013). A review of regional science applications of satellite remote sensing in urban settings. *Computers, Environment and Urban Systems*, 37, 1-17.
- Păunescu, R.D., Simon, M., Șmuleac, L., Pașcalău, R., Smuleac, A. (2020). Topo-cadastral works regarding the realization of the gas distribution network in the locality of Constantin Daicoviciu. *Research Journal of Agricultural Science*, 52(3), 145-152.
- Pop, N., Pop, S., Ortelecan, M., Luca, L.C. (2019). Verification of a triangulation network in Cluj-

- Napoca for future topographic surveys. *Agricultura*, 111(3-4), 368-373.
- Rosca, A., Juca, I., Timbota, O., Belin, V., Bertici, R., Herbei, M. (2020). Methods for digitalizing information from analogic support and creating GIS databases. *Research Journal of Agricultural Science*, 52(4), 104-112.
- Sala, F., Popescu, C.A., Herbei, M.V., Rujescu, C. (2020). Model of Color Parameters Variation and Correction in Relation to "Time-View" Image Acquisition Effects in Wheat Crop. *Sustainability*, 12(6), 2470 p.
- Shamsi, U.M. (2004). GIS Applications for Water Distribution Systems. *Journal of Water Management Modeling R220-21*, 459-473, doi: 10.14796/JWMM.
- Surani D.J., Dihora, G.V., (2015). Review on Application of GIS in Water Distribution System Planning. *International Journal for Scientific Research & Development*, 3(1), 186-188.
- Tomlinson, R.F. (1984), Geographic information system: a new frontier. *Operational Geographer*, 5, 31-35.
- Tsihrintzis, V.A., Hamid, R., Fuentes, H.R. (1996). Use of Geographic Information Systems (GIS) in water resources: A review. *Water Resources Management*, 10, 251-277.
- ***GIS Geography (2021). How GPS Receivers Work - Trilateration vs Triangulation. <https://gisgeography.com/trilateration-triangulation-gps/>, accessed 10.06.2021.
- ***ROMPOS, Sisteme GNSS. <https://rompos.ro/index.php/informatii-tehnice/sisteme-gnss>, accessed 06.06.2021.