GIS, a tool for improving the road network management

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Abstract. Transport is a significant branch of the economy due to its contribution to the creation of gross domestic product. In order to ensure a reliable transport network that boosts trade and economic growth, prior to the construction of new national roads and motorways, it is necessary to ensure a proper technical condition of the road. Therefore, road network administrators have to attain a balance between the program of maintenance / repair / rehabilitation activities and the works that can be executed within the limits of the available funds so that the investment achieves the highest profitability and the road network either viable. There are currently a number of factors that influence the decision-making process in prioritizing maintenance work as well as allocating funds so that the investment achieves the highest return. Therefore, a multi-criteria decision-making approach is needed to ensure a balance between the program of maintenance / repair / rehabilitation activities and the works that can be executed within the limits of available funds. In the present paper, the authors propose to develop a decision support model based on the principles of the GIS information systems, to help the road network administrators to take decisions that prioritize the maintenance works.

1. Introduction

Road maintenance has significant role for the management of the road networks, the quality of the road structures greatly influencing the journey and the traffic safety. Over time, the strength and quality of road structures deteriorate as a result of road traffic stress, especially heavy vehicles, due to the weather conditions they are subjected to and the operating time being exceeded. For these reasons, road structures maintenance has become an important aspect for the administration of national roads and highways and the development of transport infrastructure.

Adopting efficient maintenance strategies for road transport infrastructures requires a good prediction of their long-term behavior. In order to plan the interventions, without affecting the traffic capacity of the road network, an overview of the expected problems is required.

National Company For Road Infrastructure Administration (C.N.A.I.R-S.A.), the national road network and highways administrator in Romania, is the only company in the field of national roads and highways management and has a territorially distributed organizational structure, which allows the operational and coherent management of the entire highway infrastructure. and national roads [1].

C.N.A.I.R-S.A. it has in its structure the following units and subunits:
- 7 subunits, without legal personality, called Regional Roads and Bridges Directorates located in: Bucharest, Craiova, Iași, Cluj, Timișoara, Constanța, Brașov - figure 1.
- a Center for Technical, Road and Information Studies (CESTRIN), the technical body of the C.N.A.I.R. SA.;
- 45 National Roads Sections;
- 318 districts.

**Figure 1.** Regional Roads and Bridges Directorates.

The Regional Directorate of Roads and Bridges Cluj - figure 2, exercises its entrusted tasks, namely those of preserving the road heritage, by managing, administering and maintaining the roads in the area of activity. The purpose of its activities is to maintain the road traffic in conditions of safety, fluency, comfort and continuity throughout the year, by applying the legislation in force, the specific technical instructions and regulations.

**Figure 2.** Regional Roads and Bridges Directorate CLUJ.

The length of National and European roads from D.R.D.P. Cluj administration is about 2737 km - Table 1 [4].

**Table 1.** D.R.D.P. Cluj road network.

| Nr. Crt. | Road Category                  | Lenght - km | Road administrator                                      |
|---------|--------------------------------|-------------|--------------------------------------------------------|
| 1       | Highway                        | 62          | Regional Roads and Bridges Directorate Cluj             |
| 2       | National european roads        | 1185,878    |                                                       |
| 3       | National main roads            | 166,657     |                                                       |
| 4       | National secondary roads       | 1322,924    |                                                       |
2. Road network management

Fulfillment the conditions that lead to the optimal operation of a road network is one of the main activities of its administrator. The underlying elements of the decision-making act can be obtained through the correct evaluation, from the technical and financial point of view, of what is necessary for the normal running, without interruptions and in complete safety of road traffic.

In the evaluation process, the management organizations must have sufficient arguments so that they can decide depending on the technical state in which the road structures work where it is appropriate to intervene, when and what kind of maintenance and repair work to perform.

At the beginning of 1990, worldwide as well as in Romania, for roads, streets and airports, a new scientific discipline appeared regarding the technology of maintenance of road structures, based on the theory of programmed coordination. It is based on non-destructive, direct and high-speed measurements for evaluating the functional (flatness, roughness, level of structural degradation) and structural (load-bearing) characteristics of road systems.

The data obtained are used for the analysis of the process of diminishing in time the performances of the road structures, as a result of the aggressive action of the traffic and the exceeding the operating time. This activity is carried out within the framework of a program for monitoring and coordinating the maintenance of road structures, called the Maintenance Management Program. In the specialty literature it is known as Pavement Management System, PMS.

Following the interpretation of the data on the technical state of the roads and their introduction in a special program, the intervention policies and strategies, the optimum period of execution, the prioritization of the works and the level of urgency will be chosen.

Johnson et al. [2] stated that the road structure management system - PMS represents a tool that helps the road network administrators to optimize the strategies for monitoring and coordinating the maintenance of road structures, so that they permanently reach the level of the technical state imposed by the road traffic. Without the integration of management practices, the management and maintenance of road structures can be disorganized and inefficient in solving existing problems.

At the same time as the development of PMS systems, Geographic Information Systems have undergone an unprecedented evolution. The main characteristic of the latter is represented by the treatment of the information taking into account its location in the territory, through coordinates. GIS technologies have emerged from the need to facilitate complex geographical analysis operations for which existing systems (CAD, DBMS) did not offer any possibility or required a great deal of time or very time-consuming procedures.

Geographic Information Systems are database management systems that allow the storage, retrieval, analysis and display of spatial data. A GIS contains two broad categories of information, spatial georeferenced data (objects that have orientation and relationship in space) and attribute data (geometric characteristics of a road, traffic volumes, technical condition of road structures).

Johnson A. et [3], al considered that due to the spatial analysis capabilities, which correspond to the geographical nature of the road networks, the Geographic Information Systems are considered the most suitable tools for improving the activities of tracking and coordinating the maintenance of the road structures, with particularities such as the graphic display of the technical state of the roads.

Currently, GIS technology is increasingly used by public authorities with an increasing tendency towards integrating PMS data into GIS. This transposition of data is becoming more and more realistic due to technological advances in hardware and software.

The integration of the two systems is accompanied by numerous advantages such as: easier editing of the databases, the possibility of viewing the results after querying the databases, statistics and diagrams, analyzing the management of road structures on a road network map, visualizing the state network techniques by dynamically coding road sectors using colors, accessing through the graphical map interface.

3. Pavement management system

Kulkarni et al [4], asserted that since their introduction in the period 1960-1970, PMS systems have been constantly evolving in terms of methodology and scope.
The first PMS systems were simple data processing methods, which were used to evaluate and classify road rehabilitation projects, based on factors such as road traffic and the characteristics of the technical state of the roads. These were project-level systems that attempted to prioritize road network maintenance without taking into account network-level planning issues such as budgetary constraints and performance that are to be achieved for a viable road network.

Currently, there are a number of factors that influence the decision-making process regarding the prioritization of maintenance works and the allocation of funds so that the investment reaches the highest return. Therefore, a multi-criteria decision-making approach is needed to ensure a balance between the program of activities involving maintenance / repair / rehabilitation work and work that can be performed within the limits of available funds.

Over time, various methods for analyzing and predicting the viability of road networks have been developed in the specialized literature. Thus, the multicriteria analysis methods have been applied in the decision-making processes related to the maintenance and reconstruction of the transport infrastructure [5 - 11].

One of the methods used in decision making is also the Electre (Elimination et Choix Traduisant la Réalité) method, developed by Bertrand Roy in 1967, being a tool for optimizing decisions under conditions of certainty.

The Electre method is a ranking and choosing method in the presence of multiple points of view. It allows to sort variables according to complex criteria by successive comparisons, two by two. There are several stages in its application.

This technique was applied by the authors for the calibration of the ELECTRE Method in the field of Road Transport Infrastructure, for the network of national roads and highways from the administration of the Cluj-Napoca Regional Directorate of Roads and Bridges in Romania, a network of roads presenting different types of road surface degradation.

In order to carry out the multicriteria analysis, four representative criteria for the technical state of the roads (roughness, load-bearing capacity, flatness, degradation index) were taken into account in this phase of the research [12]. Their choice is based on the assumption that the indicators must be easy to measure and must be clear to the decision makers. The characteristics of the technical state were noted as follows: C1-flatness, C2-roughness, C3-bearing capacity, C4-degradation index. The results of the multicriteria analysis were centralized in an Excel database to be uploaded to GIS. - figure 3.

4. Prioritizing maintenance work

The results obtained after the automatic processing using the Electre method will be displayed through GIS mapping, for easy visualization, the geographical information systems becoming more and more used in the transport field due to special features such as spatial analysis and visualization, which can improve the management system of road structures.

Thus, a series of web applications have been created, that contain information regarding the technical state of the roads from the administration of the D.R.D.P. Cluj [13], applications for the public / administrators of the road network - figure 3.

![Figure 3. Portal ArcGIS online [16].](image-url)
For example, ST_DRDP_CLUJ app - figure 4, addresses road network administrators in Romania and provides information regarding the category of the national road, the indicative of the road, the county crossed, the road administrator, km beginning road sector - km ending road sector, type of road clothing, technical status of the road by kilometer positions, the values of the characteristics used in the evaluation of the technical state of the roads, the number of km analyzed road [14].

**Figure 4. ST_DRDP_CLUJ Application [14].**

At the same time, through the menu bar, the user has a series of commands - Figure 6, which facilitates access to this application, such as: instructions button, legend button, layer list button, background maps button, directions button, measuring tool button, print button, share button – figure 5.

**Figure 5. Menu bar - application ST_DRDP_CLUJ.**

StareTehnicăDrumuri app – figure 6, addresses road networks in Romania users and provides information regarding the category of the national road, the indicative of the road, the county crossed, the road administrator, km started road sector - km ended road sector, type of road clothes, technical state of the road mileage positions, year of last rehabilitation, type of intervention performed, scheduled works. Through the menu bar, the user has a number of commands that facilitate access to this application, similar to the application ST_DRDP_CLUJ.
5. Conclusions
GIS is a computerized database management system that allows the storage, analysis and display of spatial data. It contains two broad categories of information, namely: attribute data (ex. Attributes associated with a road segment include road width, number of lanes, maintenance history, road technical status, traffic volumes) and georeferenced spatial data (this data type defines objects that have an orientation and a relationship in two-dimensional and threedimensional space).

Due to the spatial analysis capabilities, which correspond to the geographical nature of the road networks, GIS are considered the most suitable tools for improving the activities of tracking and coordinating the maintenance of the road structures, with particularities such as the graphic display of the technical state of the roads.

The technological advances in the hardware and software fields make the transposition of PMS data into GIS more and more realistic. The integration of the two systems is accompanied by a number of advantages such as: easier editing of databases, the possibility of visualizing the results after querying the databases, analyzing the management of road structures on a road network map, visualizing the technical status of network through dynamic coding of road sectors using colors, accessed through the graphical interface of the map.

Following the literature review on the use of Geographic Information Systems in the management systems of road maintenance, we observed that GIS have a major advantage in terms of collecting, archiving and analyzing data related to the technical state of the roads and the road transport system. Another recognized advantage of Geographic Information Systems is their ability to manage spatial data and view them using maps.

The use of Geographic Information Systems in decision-making and resource management is essential, the most important being represented by the accuracy of the data, as well as the degree of their updating.

The main features of the GIS application realized in the present paper are the utility for the spatial components and the visualization of the data on maps. However, a limitation of this instrument, relevant in the research, is the membership of a system combined with a multicriteria approach - the Electre method, for calculating the decision algorithm and not as an autonomous system. In this study, the equation / method of prioritizing the analyzed variants, was calculated in the Excel software and then imported into the ArcGIS software.

GIS based Pavement Management System should be considered a decision-making tool, not a decisionmaker in itself. The system does not intend to replace the expertise and judgment of the engineers, but rather to contribute to cost-effective decision making. The system must be flexible enough to incorporate user input into the decision-making process.
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