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PAVEMENT MAINTENANCE MANAGEMENT APPLICATION FOR ROAD NETWORK IN ROMANIA

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Rezumat

Realizarea condițiilor pentru exploatarea optimă a rețelelor rutiere, constituie una dintre activitățile primordiale ale administratorilor acestora.

Elementele de bază pentru stabilirea actului decizional se obțin prin evaluarea corectă, din punct de vedere tehnic și financiar, a ceea ce este necesar pentru derularea normală, fără întreruperi și în deplină siguranță, a traficului auto.

În procesul de evaluare, organismele de administrare trebuie să aibă la îndemână informații suficiente, referitoare la starea tehnică a rețelei rutiere din administrare, când și unde este oportun să se intervină și ce operații de întreținere și reparații trebuie executate.

Numai în acest mod, un organism de administrare va putea să adopte strategia adecvată astfel încat investiția să atingă rata cea mai mare de rentabilitate și bineințeles să se încadreze în limita fondurilor alocate.

Lucrarea de față prezintă aplicația D.A.S.T. (Determinarea Automată a Stării Tehnice), aplicație realizată cu programul Microsoft Access. Aplicația permite determinarea stării tehnice a drumurilor, stocarea, preluarea, actualizarea și verificarea informațiilor referitoare la starea tehnică a drumurilor. Informațiile sunt păstrate într-un tabel de referință a drumurilor, ca și model de stocare în bănci de date, care pot fi utilizate de administratorii drumurilor publice în activitatea lor, referitoare la programarea lucrărilor și justificarea necesității finanțării lucrărilor de intervenție la drum.

Cuvinte cheie: rețele rutiere, PMS, stare tehnică, Microsoft Access, metoda Electre

Abstract

Maintaining the conditions for optimum exploitation of road networks is one of the primary activities of their administrators.

The basic elements for establishing the decision-making act, are obtained by the correct evaluation, from the technical and financial point of view, of what is necessary for the normal unfolding, without interruptions, and in complete safety, of the car traffic.

In the evaluation process, the managers must have at their disposal sufficient information, regarding the technical status of the road network from the administration, when and where it is appropriate to intervene and what maintenance and repairs operations should be performed.

Only in this way, road managers will be able to adopt the appropriate strategy so that the investment reaches the highest rate of return and of course falls within the limits of the allocated funds.

This paper presents A.D.T.S. (Automatic Determination of the Technical Status) application, designed using the Microsoft Access program. The application allows the determination of the technical status of the roads, storage, retrieval, updating and verification of information regarding the technical status of the roads. The information is kept in a road reference table, as a storage model in data banks, which can be used by public road administrators in their work, regarding the scheduling of works and justifying the need to finance road intervention works.

Keywords: road network, PMS, road technical status, Microsoft Access, Electre method

1. INTRODUCTION

In the last decades, at the European level, a new discipline with scientific character regarding the maintenance of road structures has been introduced. It is based on non-destructive, direct and high-speed measurements for evaluating the functional (roughness index, skid resistance, degradation index) and structural (bearing capacity) characteristics of road systems.

The data obtained are used to analyze the behavior of the road structures in time, as well as the diminution of their performances, as a result of the aggressive action of the traffic and exceeding the operating time. This activity is carried within a program for monitoring and coordinating the maintenance of road structures, called the Maintenance Management Program or Pavement Management System, PMS.

The program provides the decision-makers, in a unitary concept, the essential elements of technical and economic efficiency, which allow establishing with objectivity all the technical and financial needs for the optimal planning, operation and exploitation of a road network.

Through the implementation of the program, the aim was to establish the technical status of the road network, the changes that occurred over time, the determination of the bearing capacity of the road structures, the determination of the residual life and the identification of the sectors that need interventions.

In the late 1990s, Austria was one of the first countries in Europe that implemented a pavement management system for the maintenance of road structures, in cooperation with Ministries of Transport and Economy, the Federal Statuses and the Academic Environment [1].

The implemented PMS system provides road administrators a decision-making support tool that helps them to carry out maintenance programs to optimize the general condition of the road network. The limitations of this system are represented by the small budget allocated to road maintenance activities. For a certain set of conditions (budget, the technical condition of the road network), the system uses a cost-benefit analysis and heuristic optimization techniques to identify an optimal maintenance strategy.

In 1999, a pavement management system was implemented in Germany [1]. The PMS system was successful in monitoring the status of the network and is now being used in almost all federal statuses to support the planning process for the maintenance of road structures. The system is able to evaluate the status of the road structures for the individual sections of the network, based on the measured input data and the empirically observed long-term conditions.

In Romania, the pavement management system – PMS has been implemented since 1997, but the information provided by the system has been used by the road administrators only for information purposes.

Currently, the Administrator of the national roads and highways in Romania also uses the Optimized Road Management System of the roads in order to draw up annual maintenance and repair programs for 3-year periods and to develop and apply these preventive road maintenance programs.

The technical status of the modern roads in Romania is evaluated with the help of the functional and structural characteristics of the road systems according to *Indicative CD 155 - 2000: Technical instructions regarding the determination of the technical status of the modern roads* [2].

Often, road network administrators make repairs to the road structures without taking into account the priority of maintenance and without using a systematic procedure. These types of arbitrary decisions do not usually guarantee the efficiency of budget allocation.

2. LITERATURE REVIEW

Maintaining the viability of existing road networks is essential for the economic growth of any country, in addition to the development of the network of highways and national roads. Inadequate maintenance policies adopted by several countries result in significant financial losses, resulting in increased costs and discomfort for users.

In a developing country such as Romania, where the funds allocated to maintenance and repairs of the existing road network are limited, it is important that the funds allocated to these works be used as efficiently as possible, so that the investment reaches the highest return. A "healthy" approach to the management of road structures both at the network level and at the project level will surely lead to an optimal solution for road maintenance.

Thus, the multicriteria approach is the ideal option for planning maintenance and repair work, an approach tried and tested by many researchers in the field of operational research for the classification of alternatives in different situations.

Babashamsi P., et al., presents in the research article *"Integrated fuzzy analytic hierarchy process and VIKOR method in the prioritization of pavement maintenance activities"*, [3], the use of the fuzzy analytical process and the Vikor method for prioritizing maintenance works, taking into account the following indices of analysis of the technical status of the road network: the PCI index, the traffic congestion, the width of the road, the maintenance costs and the time required to complete the works.

The fuzzy AHP was used to assign the weights for the specified indices, and the priorities of the alternatives were ranked according to the weights given to the indices using the Vikor method.

The choice of these independent methods was motivated by the fact that the fuzzy AHP integration with the Vikor model can help the decision-makers to solve the problems of the multi-criteria decision analysis methods.

The case study was carried out on a road network in Tehran, with 3 roads chosen, which needed urgent maintenance work. After completing the decision matrix and applying the mathematical methods, it turned out that Delavaran Boulevard has a higher priority in terms of maintenance and rehabilitation activities on the pavement network. After its rehabilitation, work continued on Farjam Boulevard and Hengam Street.

In the Ph.D. paper *"GIS-based pavement maintenance management model for local roads in the UK"*, [4], Emad A., presents the use of a multi-criteria decision-making approach to ensure the balance between the conflicting factors. This approach is processed in the Analytical Hierarchy Process (AHP) using Excel software, and the database developed in Excel is then imported into GIS to allow easy querying, analysis and visualization of results. The GIS-based decision support model was developed for the Runnymede County Road Network from the administration of the Surrey County Council in the United Kingdom.

The most important factors that influence the decision making, in pavement management of the maintenance, were established following a survey conducted at a national level among pavement maintenance experts. 14 factors were identified such as the remaining lifetime, the indicator of the technical status of the roads, the type of degradation, the observed degradation rate, the class of roads, the annual average daily traffic, possible overlaps with other road works, traffic distortion, risks, safety. traffic, accident rate, costs, available budget and the cost of the whole life cycle.

The AHP method was applied in two stages: to establish the relative weights – resulting the weight of factors vector, and to prioritize the alternatives (roads) - resulting the priority matrix.

Each factor is assigned a grade from 1 to 3, where 1 represents a good technical condition of the pavement, 2 represents a mediocre technical condition of the pavement, 3 represents a bad technical condition of the pavement. After that, the author calculated the Pavement Maintenance Priority Score, which indicates the ranking of alternatives. This is done by multiplication of the priority matrix and the vector of factors weights. The output of this calculation is the vector that indicates the ranking of alternatives.

The outcome of the calculated PMPS was integrated into GIS to form the final model. In the study were selected 25 roads of different classes, for which the Surrey County Council provided information. The base map was made using ArcGIS 10 software.

Moazami D., et al., presents in the research article *"The use of analytical hierarchy process in priority rating of pavement maintenance"*, [5], the use of an AHP model based on fuzzy logic and a deduction program that helps them, road managers, to set priorities for the rehabilitation and maintenance of the road network in urban areas.

The presented model was applied on 131 road sectors in Tehran and in the calculation, the following criteria were introduced:

- PCI index: because is the most precise index in many pavement evaluation studies and incorporates data from 19 different kinds of pavement distresses as well as their severity and quantity. In all 131 road sectors, specifications of the street's cross-section, distress type, quantity, and severity were inspected. Pavement distresses details were then entered into the MicroPAVER system for automatic PCI calculation.
- traffic volume: over each section also affects the pavement maintenance priority (the greater the traffic volume through a section

is, the higher the priority will be). Traffic data in this study were collected by the detectors, buried in the asphalt layer, in the SCATS system and by means of recorded videos from CCTV.

- road type: three functional classes for roads, include expressway, arterial and access (expressways have the highest mobility and the lowest level of access which result in high speeds of vehicles).

Comparisons between criteria and subcriteria performed in AHP are pairwise comparisons. The comparisons were done by considering the ideas of 200 PMS experts.

In order to obtain a more realistic and reliable comparison matrix, all personal judgments were converted to group judgments.

To calculate the relative weights in each pairwise comparison matrix the author used Expert Choice software. The software provides lesser computation time without any loss of accuracy. The proposed model in this study can be easily used to specify the maintenance priority index for each section according to its specifications. The final rating model was used for the prioritization of 131 sections in the case study.

Based on the condition survey performed, it was found that approximately 80% of the sections surveyed were in „very good" and „good" conditions. Approximately 11% of the sections surveyed were in „fair" condition, and those sections should receive maintenance as soon as possible to avoid costly maintenance actions in the future. Also, the road network studied was considered „very good" with a Pavement Condition Index of 76.

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 [6,7].

Fancello G., et al., describes in the research article *"A decision support system for road safety analysis"*, [8], the application of a procedure that supports the road network administrators. The procedure allows planning the activities that lead to the increase of the degree of road safety by using a multicriteria method called *"Analysis of the matches that derive from the Electre I method"*. Within the method are used outclass relations based on the analysis of matches and discrepancies. The paper presents a methodology for classifying alternatives by comparing them based on different variables.

The method was applied on a 100 km long motorway sector in Sardinia, which was divided into 11 homogeneous sections of different lengths, which had similar characteristics in terms of traffic volumes and topography.

In order to conduct the multicriteria analysis, 3 different domains (mobility, geometry and road safety) were identified to evaluate each section, each domain being assigned different characteristic criteria and thus the decision matrix was prepared.

The weights assigned to the objective functions were chosen by indicating the weight for the target area alone and then dividing this into equal parts for each criterion.

After performing the mathematical calculation and the diversification of the weights, different results were obtained which indicated the road sector on which the intervention is necessary in order to increase the degree of road safety.

As future directions of research, the authors of the paper proposed the introduction of new criteria that deepen the level of detail of the analysis, criteria such as the indicators related to road maintenance and the comparison of results using the Electre III method.

Taking into account that worldwide, the road administrators are trying to use new methods for analyzing the viability of road networks, within this paper, a modern and fast procedure for informing about the technical status of the roads will be presented. Prioritization of the road sections that present a deficient technical status will be determined using a multicriteria decision analysis method, respectively the Electre method, as a tool for optimizing decisions under conditions of certainty.

By describing the use procedure designed by Bertrand Roy, the authors analyze and propose the application thereof for the Romanian road network, in order to create a managerial work tool in the intervention strategy for the viability of the road networks in operation. The model will be developed for National Road 1 (km 350+000 – km 630+000), the sector administrated by Cluj Regional Roads and Bridges Directorate (abrv. D.R.D.P. CLUJ) in Romania.

The operating principle of the Model of the assessment of the technical status of a road, in order to establish the intervention strategy, implies the application of the following working steps:

- Selecting the representative criteria for the technical status of the roads;
- Assessment of the coefficients of importance/weights different to each criterion of technical status;
- Identification of the homogeneous sectors of the road (alternatives V_1, V_2, V_3, V_4) under analysis, by assessing the technical status during the period of operation, sectors that involve the representation on a section of road with the same composition of the road structure, on which various forms of degradation have appeared;

- establishing a possible intervention scenario for the viability of the road sectors analyzed by means of a calculation parameter called importance vector k=(C_1, C_2, C_3, C_4), which is determined according to the weighting/weighting coefficients, previously evaluated, by which a higher weight to the bearing capacity and the degradation index.

3. A CASE STUDY REGARDING THE DETERMINATION OF THE TECHNICAL STATUS OF THE ROAD NETWORK USING THE ELECTRE METHOD

Within the present work, the Electre method was applied in the field of Road Transport Infrastructure, for Cluj Regional Roads and Bridges Directorate road network in Romania. The road sector studied covers approximately 280 km of the national road that presents various types of road surface degradation.

In order to carry out the multicriteria analysis, the following steps have been taken:

- four criteria were considered for the technical status of the roads (C_1 = roughness index, C_2 = skid resistance, C_3 = bearing capacity, C_4 = degradation index). In the road management domain, these criteria represent the basic elements of the technical status assessment on a road subject to analysis, in order to establish the intervention solutions envisaged for its viability for a normalized duration of operation envisaged in the intervention strategy of the road administrator. Their choice is based on the assumption that the indicators must be easy to measure and must be clear to the decision-makers. Those criteria are determined according to the following regulations [9-12].
- since the criteria used to determine the technical status of the roads do not equally influence the technical status, in order to take into account their individual effect, coefficients of importance/weights were assigned differently to each criterion of technical status C_1, C_2, C_3, C_4. This practice is common in the relevant published literature [13-18], where the road network administrators assign different weights to the criteria that characterize the technical status of the roads, based on the opinions offered by the experts in the field, field engineers as well as university professors.
- thus, a possible intervention scenario was established for the viability of the analyzed road sectors and the importance vector was obtained, within the Case Study, $k=(C_1=0{,}15; C_2=0{,}1; C_3=0{,}45; C_4=0{,}3)$ whereby an

increased weight was assigned to the C_3=bearing capacity parameter and C_4= degradation index, compared to the other two analyzed, that is, the C_1= roughness index and the C_2= skid resistance.

- to exemplify the calculation, 4 consecutive and homogeneous sectors (alternatives V_1, V_2, V_3, V_4) from National Road 1 in Romania were chosen, sectors that presented different types of road surface degradation. The length of each road sector considered was 10 km, thereby V_1=sector 1 (km 350 + 000 - km 360 + 000), V_2=sector 2 (km 360 + 000 - km 370 + 000), V_3=sector 3 (km 370 + 000 - km 380 + 000), V_4=sector 4 (km 380 + 000 - km 390 + 000).
- According to regulations currently in use, the values of the criteria used to determine the technical status of the roads are collected from 100 to 100 meters. To simplify the calculation, for the criteria used in the assessment of the technical status of the road (C_1... C_4), the arithmetic mean of the values of the criteria collected on each sector was calculated, for 10 km.

A major advantage of the multi-criteria methods and implicitly of the Electre method is that these methods do not eliminate the decision-making process of the decision-maker. The purpose of multicriteria methods is to provide decision-makers with methods that increase their ability to examine and decide, eliminating personal intuition or reasoning from the decision process.

The disadvantage of the Electre Method is that the entire process is laborious and the interpretation of the results is difficult to explain in layman terms. Therefore, in the perspective, a procedure will be proposed, using specialized software, in which to introduce the input data of the technical status parameters evaluated in the field. Following the processing with the specialized software, the administrator will directly receive results, which will be used in the intervention strategy, which he will approach in the future.

Thus, in order to optimize the decision process, the selection method of the Electre method was implemented in an original application proposed in this article, designed using Microsoft Access program, an application that will help future road network administrators to determine the technical status of the roads, after approval of this proposal in technical regulations in the field of road transport infrastructure in Romania.

In order to create the application, the following steps have been taken:

1. generating the structure of the database: within this stage, the fields will be established that will make a record. Each field will be assigned a name, data type, and representation range.

2. in the next step, the tables in which the records will be distributed as well as the links between these tables are established.
3. filling in the database with information, an operation that is carried out in parallel with the exploitation of the database.
4. the exploitation of the database involves the elaboration of reports and statistics based on the data held.

The actual exploitation of the application proposed in this article realized implies the completion of the forms (Forms). Forms are tools used to present and update information from tables, record by record. Thus, we have created 3 forms: one for the European national roads, one for the main national roads and one for the secondary national roads (Figure 1).

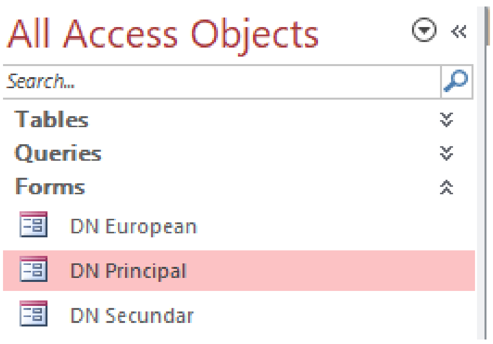

Figure 1. Forms **-** National road

Accessing the form is done with the mouse (double click on the Main DN in the Forms area). To calculate the technical status of a main national road, we proceeded as follows (Figure 2):

- in the *Road Name section* (Nume Drum), the national road was selected (in this Case Study applied on DN 1 classified as the main national road);
- in the *MZA section*, the values of the average daily traffic per road sector, determined in the last traffic census, were completed;
- *MZA section standard axles* are automatically updated as the product between the MZA (annual average daily traffic intensity) and Fek (the coefficients of equivalence of the physical vehicles in the standard axes);
- the evolution coefficients of the pki traffic are default values introduced from the keyboard, for each category of the national road, in the stage in which the form is made and does not require modifications; they can be updated at the new traffic census with the values determined in that year by accessing the Design View menu;

- for the studied road sector, the *start km section* (in this case km 350+000), *end km section* (in this case km 390+000), respectively fields for the characteristics used in the evaluation of the technical status of the roads were completed from the keyboard;
- the vector field of the coefficients of importance has implicit values that do not require modifications; these can be updated or modified by the user as needed;
- to memorize the road sector studied in the database, press the Add button; if you want to calculate the technical status for another road sector, the user will press the Reset button and repeat the steps described above.

Figure 2. D.A.S.T. working interface

The exploitation of the database involves the elaboration of reports and statistics based on the data held. The report is the tool that allows the user to export lists and statistics based on the data entered in the tables.

In Figure 3, the Road Technical Status report was presented. The report provides information on the technical status class of the studied road sectors (in this Study, the entire DN 1 road sector in D.R.D.P. Cluj administration, about 280 km, DN 1-1 represents the sector from km 350+000 to km 390+000, DN 1-2 represents the sector from km 390+000 to km 430+000 and so on), the day and time at which the report was prepared. Similarly, we will proceed for the entire Cluj Regional Roads and Bridges Directorate road network to determine the roads technical status.

TECHNICAL STATUS

Saturday, January 11, 2020
6:45:06 PM

DESCRIPTION	TECHNICAL STATE	ROAD SECTOR
DN1-1	POOR	Sector 1
DN1-1	POOR	Sector 2
DN1-1	POOR	Sector 3
DN1-1	POOR	Sector 4
DN1-2	POOR	Sector 1
DN1-2	POOR	Sector 2
DN1-2	POOR	Sector 3
DN1-2	POOR	Sector 4
DN1-3	POOR	Sector 1
DN1-3	POOR	Sector 2
DN1-3	POOR	Sector 3
DN1-3	POOR	Sector 4

Figure 3. Report no.1 - DN 1 technical status

At the same time, the user can customize the way the reports are displayed according to their preferences:

- sectors that have the best technical status of the studied sectors can be exported (figure 4).

TECHNICAL STATUS - B — Saturday, January 11, 2020 6:55:03 PM

ROAD_ID	ROAD SECTOR INDICATIVE	ROAD SECTOR	TECHNICAL STATUS INDEX	TECHNICAL STATUS
88	DN1-1	Sector 4	0.8375	POOR
87	DN1-2	Sector 4	0.9975	POOR
86	DN1-3	Sector 2	0.9175	POOR
85	DN1-4	Sector 2	1.0175	FAIR
84	DN1-5	Sector 1	1.0175	FAIR
83	DN1-6	Sector 1	1.1075	POOR
82	DN1-7	Sector 3	1.0175	POOR
81	DN1-8	Sector 2	1.22	FAIR

Figure 4. Report no.2 **-** DN 1 technical status, sectors that present the best technical status

- Only sectors with a poor technical status can be exported from those studied (figure 5).

TECHNICAL STATUS - W — Saturday, January 11, 2020 6:58:22 PM

ROAD_ID	ROAD SECTOR INDICATIVE	ROAD SECTOR	TECHNICAL STATUS INDEX	TECHNICAL STATUS
88	DN1-1	Sector 2	0.8175	POOR
87	DN1-2	Sector 1	0.8375	POOR
86	DN1-3	Sector 4	0.8175	POOR
85	DN1-4	Sector 1	0.7725	FAIR
84	DN1-5	Sector 1	1.0175	FAIR
83	DN1-6	Sector 4	0.9275	POOR
82	DN1-7	Sector 2	0.8375	POOR
81	DN1-8	Sector 1	1.1975	FAIR

Figure 5. Report no.3 **-** DN 1 technical status, sectors that present a FAIR or POOR technical status

4. CONCLUSIONS

Within this paper, a multicriteria analysis method - the Electre method - was used and described as a support tool for solving complex decision problems related to determining the technical status of the roads and choosing the right maintenance and repair works.

Following the interpretation of the obtained results, it was observed that only 4% of the studied road sectors present a good technical status, while the rest is characterized by a fair and poor technical status, repair work such as in situ recycling or asphalt carpet realization.

The results obtained by using these procedures for assessing the technical condition of a road, allow the measurement of the amplitude and gravity of the problem of assessing the technical condition of a road, but for this, there is a need for a consistent history, which should exist in the Database of the road administrator. All these statistical methods and techniques can represent essential working tools in the field of road network management and allow the setting of clear objectives for strategic actions of intervention in the road transport infrastructure.

A major advantage of the multi-criteria and implicitly of the Electre method is that they do not eliminate the decision-making process of the decision-maker. The purpose of multicriteria methods is to provide decision-makers with methods that increase their ability to examine and decide, eliminating personal intuition or reasoning from the decision process.

The disadvantage of the Electre Method is that the entire process is laborious and the interpretation of the results is difficult to explain in layman terms.

In order to provide a working method accessible to the specialists in the departments dealing with the operation of the road infrastructure, we have made an application using the Microsoft Access program, to determine the technical status for each type of road. The application is based on the multi-criteria decision analysis method, respectively the Electre method. Thus, by applying the method and in the system of administration of the road network in Romania, a managerial work tool was developed in the intervention strategy for the viability of the road networks in operation.

In future research, the authors will try to integrate the application created with Geographic Information Systems, as GIS is becoming increasingly used in the field of transport, due to special features such as spatial analysis and visualization, which can improve the management system of existing networks.

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