Discussion on Pavement Management System

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Abstract

In this paper, based on the module of Pavement Management System, the composition of Pavement Management System in China is introduced thoroughly. Through the review of recent years of literature, some of the new research results and application methods are also introduced.

Keywords

Pavement Management System, Artificial Neural Networks, Geographic Information System.

1. Introduction

In 1960s, the concept of Pavement Management System (PMS) was proposed in Canada. At first, PMS was only used to eliminate defects and optimize design on pavement and alignment. After the large-scale construction of highway in developed countries, in order to deal with the heavy pavement management and maintenance work, new PMS was began to research and develop. Until now, the PMS of California State and the PMS of Alberta are most representative among a number of systems.

In China, PMS was began to research in 1980s. During the seventh five-year development planning, a larger number of systems were developed. Until now, some of the systems were applied and promoted very well. However, with the gradual deepening of the engineering practice, there are still some problems improved in the current mainstream PMS.

2. Definition of Pavement Management System

PMS contains pavement riding quality, pavement distress condition, mechanical reflection of pavement structure and fatigue, deformation, cracking, aging characteristics of pavement materials. Based on the practical experience, PMS is a fast tool for technical and economic analysis on pavement and used to achieve the optimal allocation of resources and more reasonable technology[2]. According to the different management level, PMS is divided into network management system and project management system.

PMS is expected to use the existing funds most effectively to make the pavement of road network keep the best service level and produce the greatest economic benefits[3]. Through the comprehensive utilization of the pavement professional knowledge and system engineering technology, PMS can deal with the problem of pavement maintenance activities with the help of the computer. Therefore, PMS is divided into two categories and each category is composed of five modules. By comprehensive consideration of various factors, PMS can coordinate the activities of the pavement management and make the process systematic. Through such tools and methods, the managers of relevant departments can compare with possible countermeasures and get a best cost-effectiveness program finally,

3. Composition of Pavement Management System

3.1 Pavement Condition Data Acquisition

The actual condition of the existing road surface can be reflected objectively by pavement condition data. So pavement condition data is the basis of not only the road maintenance and reconstruction plan but the whole system as well. At present in China, the pavement condition detection is divided into five projects, respectively, pavement damage status detection, pavement roughness detection,

pavement rutting detection, pavement skid resistance performance test and pavement structural strength test.

Pavement damage status detection is divided according to different pavement types. The damage of asphalt pavement is divided into 11 categories of 21 projects and the damage of cement concrete pavement is divided into 11 categories of 20 projects. At present, pavement damage status is detected in the field survey by manpower through the comparison of the standard.

Pavement roughness detection is the disparity of height which makes the moving vehicles vibrate. Pavement roughness detection can be combined with pavement damage detection and pavement rutting detection. Pavement roughness detection can be tested alone by high precision section detection equipment. The longitudinal section of road can be plotted by the determination of flatness, and then through mathematical analysis, the smoothness is characterized by a comprehensive statistics.

Pavement rutting detection should be based on the rapid detection equipment. Pavement rut depth (RD) can be calculated by the sectional data and saved as 10m for the unit.

Pavement skid resistance condition is the force generated by the surface slip along the road when the tire is braking. Pavement skid resistance performance should be tested by the equipments based on lateral force coefficient or other automatic detection equipments with reliable data calibration relationship.

Structural strength test is divided into non-destructive testing and destructive testing. In practical engineering, non-destructive testing is generally adopted. However, the deflection value of road surface under load is used to characterize structure carrying capacity of pavement. Static determination such as Backman beam deflection tester and automatic deflection tester can measure the maximum deflection of pavement. Dynamic determination such as steady state dynamic deflection and pulse deflection tester can measure the maximum deflection and deflection basin.

Besides these five aspects of data, the traffic data such as daily traffic volume, pulse deflection tester and annual average growth rate need to be collected. These traffic data are important for the establishment of the prediction model and the estimation of the economic benefit.

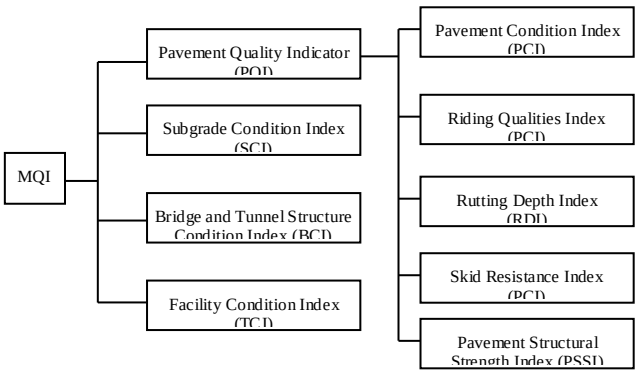
In summary, the pavement management system should have the function of data processing in order to input, storage, retrieval, transfer and analysis these data.

3.2 Pavement performance evaluation

Based on the data collected by the ways described in previous, pavement performance can be evaluated whether meets the needs. In this paper, the method of pavement performance evaluation is introduced according to the standard of China.

$$MQI=\omega_{PQI}PQI+\omega_{SCI}SCI+\omega_{BCI}BCI+\omega_{TCI}TCI$$

In China, the length of highway evaluation unit is defined as 1000 meters and the Maintenance Quality Indicator (MQI) is used to characterize the pavement condition.



Figue 1 Highway technical condition evaluation index

There are different technical content in pavement quality indicator according to different pavement types. For asphalt pavement, the evaluation includes pavement damage, smoothness, rutting, anti sliding performance and structural strength. For cement concrete pavement, the evaluation includes pavement damage, smoothness and anti sliding performance. The pavement performance can be calculated by the following formula.

$$PQI = \omega_{PCI}PCI + \omega_{RQI}RQI + \omega_{RDI}RDI + \omega_{SRI}SRI$$

The weight of the formula is given in the standard.

By the above parameters, the MQI of the route is gotten by the arithmetic average value of the MQI of all roads. According to the MQI and each pavement sub technical indicator, the pavement performance can be graded and evaluated finally.

3.3 Pavement performance prediction

In the process of using, pavement performance would be gradually reduced with the increase of time or axial load. There are two aspects in pavement performance prediction. On the one aspect, it is pavement condition prediction. In the effects of various factors, pavement service life is characterized by the changing way of the pavement us performances with the increase of time or axial load. On the other hand, it is reconstruction measure prediction. The level of pavement performance would be achieved after a certain maintenance and reconstruction measures. Generally, pavement performance prediction can predict not only when pavement needs to be maintained but also the level of service that can be achieved after the use of certain measures. This is the most basic components which affected pavement maintenance management.

The relation called performance prediction model is established in order to predict. Depending on the difference of application scope, the performance model is defined by the specific pavement performance technical index in the project level system, but in the regional network level system, the comprehensive index is used because of more attention to the general situation of the road network. At present, there are two using pavement performance prediction model called deterministic model and probabilistic model respectively.

The deterministic prediction model is used to estimate the pavement life or a specific performance index, and the results are expressed in a numerical value. At present, the kinds of the deterministic prediction used frequently are basic reaction model, structural performance model, functional performance model, service life model and so on. Different models are used to estimate different kinds of pavement in the action of combined load and climatic. Most of the determined models are built by mechanics experience method and experience method.

The probability model is different from the deterministic model. The model is only used to estimate the state distribution of a performance index and the decision is made by comparing the probability of different states. The probability model can be divided into the remaining curve, Markov and semi Markov model, etc. At present, the Markov model is frequently used because it is more perfect. The core content of the Markov model is a state transition matrix which means that a set of the pavement with the same attribute in the road network transfers from one state to another in a predetermined time period. In view of the establishment of such model, the key is to find out the corresponding transition probability matrix through the methods called empirical analysis, statistical analysis and regression analysis.

At present, besides the methods mentioned above, Grey Clustering Method is also used. The method proposes grey clustering index called HSPJ and establishes the membership function between grey clustering index and damage[6]. In addition to the use of the classic model for prediction, the finite element software called ABAQUS is also used to analyze by numerical simulation in order to get a reasonable prediction about the pavement performance[7].

In addition, in order to make up for the deficiency of the traditional prediction model, artificial neural network theory is used to build the prediction model[7]. The influence of environmental factors is rarely considered by the prediction model because it is difficult for environmental factors to be

quantified. It is also difficult to find the exact mathematical relationship expression because of its complicated function. However, because of good non-linear quality and the ability of approximating non-linear mappings in arbitrary precision, artificial neural network can achieve non-linear mapping and deal with the problem of unclear background knowledge. MATLAB software is used to write artificial neural network generally, the pavement performance index is conducted non dimensional treatment by using BP network for comparison. Because the decay of pavement performance is the result of long term effects, in order to weaken the randomness of the original random sequence, original sample data is conducted by cumulative generation method. The disposed sample data are input to the network for training, In order to meet the requirements of error and convergence, after selecting the appropriate number of hidden layer nodes, the future pavement condition can be predicted by the model.

3.4 Economic analysis and comparison

In order to compare with effects of different maintenance and reconstruction measures on the same route or benefits of different routes in the same road network through maintenance and reconstruction, the life cycle cost analysis is used to transform the management cost and user cost of each period into present value representation through a particular economic analysis method. In this way, the different schemes can be compared. The final purpose of economic analysis and comparison is to make the decision of greater efficiency. For the network management system, through the analysis and comparison of all possible items, the economic feasibility of each project can be determined in order to make management decisions about project selection and planning. For the project management system, the projects with the economic feasibility are analyzed and compared whether meet the general requirements in order to get the best economic result[1].

In the whole economy analysis and comparison, the most basic is the service life and performance prediction which are mentioned in the last section. By predicting pavement performance and comparison the pavement performance index with one of specification, pavement performance index can be analyzed in full life cycle when the index will not meet the service requirements and when the maintenance and reconstruction need to be carried out. After that, combined with the construction experience of the local department, department management costs and user costs of various construction measures will be gotten.

After getting the department management costs and user costs, the cost and benefit of the analysis period occurred at different times during the analysis period is converted into the present cost and benefit by economic analysis methods such as present value method, annual fee usage and annual fee usage. After being converted into present value by the same economic analysis method, the different schemes can be compared and selected.

3.5 Scheduling and optimization methods

Because of limited capital, the different schemes through economic analysis are sorted in order to achieve the best conservation and reconstruction strategy and the purpose of the optimal allocation of funds. Specifically, for the project management system, considering the effectiveness of different maintenance levels and reconstruction strategies in the analysis period, the key is when to carry out reconstruction and what countermeasures should be used to rebuild. For the network management system, in the whole road network environment, when the reconstruction method will be carried out, which one of several routes should be rebuilt and what kind of reconstruction method will be used can bring greater economic benefits to the entire road network. In contrast, the network level management system needs to be sorted and optimized.

Sorting should be selected sort model. At first, the time of reconstruction is arranged preliminarily and the countermeasure of reconstruction is selected, and then the budget constraints and priority requirements are considered, and at last the planning for one year or many years is projected[1]. Sort model follows a set of standards to sort. The standard is roughly divided into two categories, respectively, pavement performance parameter and economic analysis parameter. Sorting according to the pavement performance parameter is graded by prediction of pavement performance in the life

expectancy and considering the road level and the related policy. It is easy to use but the result may not be optimal. Sorting according to the economic analysis focuses on the effectiveness of countermeasures. The result of this method is close to the optimal.

For network management system, the optimization method is introduced because sorting method does not take into account the compromise between the projects. In the analysis period, the solution for each project and the time to take measures are considered at the same time in order to provide the best solution for the whole road network to get the maximum benefit in the planning period[1]. Optimization system is divided into static optimization and dynamic optimization. The linear programming method which is one of static methods assumes that not only pavement performance after use of a certain alteration measures follows a certain change in the law, but also each renovation strategy has been pre specified in the analysis of the maintenance and renovation measures sequence. However in practical application, the variation of pavement performance is uncertain, which gives the necessity of dynamic optimization. Dynamic planning method according to the principle of each optimal policy can only set up by the optimal policy. The big problem is divided into a series of small problem that are easy to solve according to the stage. The best strategy is chosen for each small problem and its basic components include the stage, the state, the decision variables, the transfer function and the recurrence relation.

4. Establishment and application of pavement management system

4.1 Establishment of pavement management system

Steps to establish a pavement management system is similar to general engineering steps. After feasibility study, the work plan is worked out following the goals and objectives of the road management system strictly. According to the characteristics of the system engineering, the establishment process and the structure of pavement management system have similar characteristics.

The foundation of the pavement management system is the pavement performance database, so the establishment of a complete database of road database is the first step of the establishment of a system. There are six types of data files in databases generally such as section division and identification, collection of data, pavement structure, traffic, performance data and pavement history. The pavement performance index which should be collected must be determined before the establishment of the system. When the database is initially established, it can play the role of pavement network management. However, because of the uncertainty of pavement performance, the data in the database needs to be updated according to a certain period in order to get the latest data.

After establishment of the database, the system can not only make a pre-set assessment thought the data in the database or input of the latest pavement performance data, but also evaluate results according to the set prediction model of maintenance and reconstruction measures.

4.2 Application of pavement management system

According to relevant literature search of pavement management system, it is easy to find that the application of the road management system is combined with the use of GIS system. Geographic Information System (GIS) is an important spatial information system. It is the technology system by which the relevant geographic distribution data is collected, stored, managed, computed, analyzed, showed and described with the help of the computer hardware and system software[8]. Because of the geographical characteristics of the road data and advantages of GIS in dealing with geographical and spatial analysis, the combination of pavement management system and GIS is the trend of the future development.

The combined application of pavement management system and GIS establishes spatial data model of geographic pattern and defines the relationship between the spatial data[9]. Through the visual GIS system, the pavement performance index data in the database is used as the bottom data and bound with stake in order to make them have a good interaction. In this way, through the characteristics of GIS, pavement performance indicators can be vividly presented in the electronic map of the road network. Data and space can be analyzed together. In addition, pavement performance indicators can

be managed and called better in the GIS page. That makes decision makers easy to read. Finally, based on spatial analysis and statistical computing of GIS system, double analysis on road and traffic will be achieved in the subsequent development.

4.3 Existing problems

Because the entire pavement management system is very large, in the district without the establishment of road management system, it will take lots of human, time and financial resources to establish a system from the beginning.

For the pavement management system which has been used, there are also many problems. First, it is difficult to update the new pavement performance index in time. Then, there are many problems in the pavement performance prediction models which have been used already. All factors that affect the pavement can not be considered, so that the prediction can not accurately reflect the actual situation, thereby affection the decision-making. Therefore, the pavement management system needs to be further research.

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