Research and application of pavement maintenance decision-making ecosystem based on GIS

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Abstract

In recent years, the demand for road maintenance has entered a period of concentrated release. With the continuous expansion of maintenance mileage and the scale of road network clusters, the maintenance funds management of road network is difficult. Scientific and intelligent information means to assist maintenance managers in scientifically planning maintenance funds and preparing annual maintenance plans are urgent needed. To this end, this paper builds a maintenance scientific decision-making ecosystem, builds a maintenance full-factor database, a self-increasing scheme library, and a multi-level decision-making model library, and conducts in-depth integration and fusion analysis of multi-source heterogeneous data to achieve the purpose of historical maintenance investment benefit analysis, and maintenance requirements analysis, and optimal allocation of road network-level maintenance funds, and preparation of annual maintenance plans based on generated decision-making schemes. Moreover, combined with the GIS maps, the paper visualized the basic decision-making data, decision-making process, decision-making results, and decision-making applications to forming a multi-source heterogeneous data-driven highway maintenance of scientific decision-making technology system. The system has been deployed and applied in Chongqing, Fujian, Zhejiang, Hubei, Guangxi, Yunnan, Anhui and other provinces and cities. The application results have proved that the system is scientific and usable, and has achieved good results.

Keywords

Multi-source heterogeneous data, Decision Ecosystem, GIS map, Self Growth, maintenance plan.

1. Introduction

All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish. With the continuous expansion of the highway network cluster, scientific decision-making of maintenance plans, rational allocation of maintenance funds, and maximum satisfaction of the maintenance needs of all sections of the road network are urgent pain points that the highway management department needs to solve. All along, the maintenance management company
ignored the in-depth excavation and analysis and application of massive historical maintenance data before making maintenance decisions, and only made decisions based on the current road technical conditions, diseases, maintenance engineers and the historical experience of maintenance management companies, etc., which not only violated the requirements of scientific maintenance decisions put forward by the Ministry of Communications, but also had problems such as low decision-making efficiency and unreasonable allocation of road network funds.

In recent years, due to the development of the road maintenance industry and the improvement of the level of intelligence and automation, the construction of "Internet + maintenance" based on GIS, big data, cloud computing and so on has gradually matured and improved [13], providing a good foundation for data-driven conservation decision-making ecology. In order to improve the efficiency of scientifically assisted decision-making and the effectiveness and scientific nature of decision-making, in recent years, many researchers have explored and studied various links in the decision-making process (data collection and cleaning, technical status assessment, decision-making, optimization) and key technologies [48]. However, most of the decision-making research and decision-making system construction fail to really break through the data barriers, and lack the accurate acquisition and efficient management and application of various multi-source heterogeneous data such as road network organization, traffic volume, maintenance history projects, road condition detection, etc. The achievement of the maintenance decision-making are limited to the maintenance project, and there is no practical guidance for the preparation of the maintenance plan, and meanwhile there is a lack of rich and practical application scenarios to test the decision-making effect. Therefore, the maintenance science auxiliary decision-making system developed in this paper set up a maintenance scientific decision-making ecosystem, builds a maintenance all-factor database, self-growth scheme library, and multi-level decision-making model library, performs in-depth integration and fusion analysis of multi-source heterogeneous data, and applies big data, cloud computing, GIS and other information technologies to achieve historical maintenance investment benefit analysis, maintenance demand analysis, optimal allocation of road network maintenance funds, and preparation of annual maintenance plans based on decision-making plans. The decision-making results and decision-making applications are visualized to provide sufficient decision-making basis and improve management efficiency for maintenance managers at all levels involved in highways.

2. System functions and application examples

2.1. Project overview of System application example

This system is used to make maintenance decisions at the project level and road network level for two or more expressways in the next year, and the decision results are used to prepare an annual maintenance plan.

2.2. Management of system basic data

2.2.1. Management of system static data

The static data of the system mainly includes the management of basic information, drawings and photos of road assets such as roads, Bridges, tunnels, culverts, facilities along the road, service areas and toll stations. The static data of road assets can be managed efficiently and dynamically based on GIS map, and the stored basic information, such as pavement structure information, road age and road location information, can provide basic data support for maintenance decisions.
2.2.2. Management of system dynamic data

The dynamic maintenance data in the system mainly include technical status assessment data, disease, maintenance project data, scheme data, order inspection report, etc. Based on GIS map, the system takes 1km as the basic evaluation unit, takes 15 sections of expressways from 9 project companies of Highway Operation Group Corporation as the analysis object, introduces dynamic data, and realizes the visual management of maintenance history based on GIS map. At the same time, the stored dynamic information, such as disease, pavement technical condition index and project, will be directly used to make maintenance plan decisions. See Figure 2.2 for the display content based on GIS map.

(1) Based on GIS map, the technical status indicators, variation trends and distribution of different sections and units in different sections over the years were analyzed statistically.

(2) Based on GIS map, the historical maintenance investment amount, historical maintenance items and historical maintenance records (maintenance programs) of different sections and different sections were statistically analyzed.

(3) The disease distribution of each section unit is visually displayed on the GIS map.

2.2.3. Ecological construction of conservation decision-making and multi-source

To reduce the effects of maintenance decision-making process data islands, more widely for maintenance decision-making foundation supporting data, improve the decision-making efficiency and accuracy, this system directly obtained from each function module, the update maintenance decision required for static, dynamic data and establish detection, maintenance history data mining analysis, decision-making (plan), construction, maintenance decision-making and ecological construction after evaluation, As shown in figure 1. Based on maintenance decision-making and the establishment of ecological highway infrastructure master data, master data maintenance business, the main infrastructure drawings, photographs, and other static information and road patrol, daily maintenance, DaZhongXiu calendar year construction, road damage repair and maintenance business integrating dynamic information, and master data docking platform, realize data sharing, data fusion, It is convenient for unified, real-time and dynamic management and use unified master data to make maintenance decisions.

![Diagram](attachment:image.png)

Fig1: Ecological map of maintenance decision

2.3. System maintenance decision model database and maintenance measures database

Maintenance decision model base and measure base are the basis of maintenance demand analysis and maintenance plan decision. Users can customize maintenance decision models and measures according to the characteristics of sections in different regions, maintenance specifications, historical experience of the company, and actual maintenance needs. The system
selects an appropriate maintenance scheme for each decision unit based on the decision model selected by users and the company’s maintenance measure database. The system decision model base mainly considers the technical condition index, and the decision algorithm adopts multi-level decision mode. Firstly, the maintenance type of each section unit is determined according to the evaluation indexes of the section unit and the maintenance threshold defined by decision tree 1. Secondly, according to decision tree 2 and maintenance big data, specific maintenance schemes of each section unit are decided. If multiple maintenance measures cannot be matched or matched, the corresponding maintenance history scheme under the technical condition of historical road surface of all project companies under the operation group company will be selected (the maintenance type and maintenance measure with the smallest difference in PQI value and the highest frequency of use of the current road section will be matched). The system maintenance measure database has the functions of self-definition and self-growth. The system can enrich and update the maintenance measure database according to the dynamic data of maintenance production, as shown in Figure 2. The standard decision model and general measure library set by referring to the code for maintenance and design of highway asphalt pavement (JTG 5421-2018) and the technical code for maintenance of highway asphalt pavement (JTG 5142-2019) [17,18] are shown in Figure 3. Sharing and data fusion facilitate unified, real-time and dynamic management and use unified master data to make maintenance decisions.

![Decision-tree image]

Fig2: Multi-level maintenance decision trees

2.4. Maintenance demand analysis and cost forecast

2.4.1. Maintenance decision of system project

Based on the decision model and the maintenance measure database, the system carries out hierarchical maintenance demand analysis and maintenance plan decision for a certain section, and determines the maintenance amount required for the implementation of the maintenance plan for this section. As a result of road maintenance plan are investment, regional economic development, and maintenance technology development and so on various aspects of factors, the influence of system according to the road of decision optimization model for all analysis unit according to the technical condition of intelligent sorting with poor roads first for the principle makes maintenance amount control in limited scope. The decision-making scheme is
displayed visually, vividly and in detail. The summary mileage and amount of each maintenance type are displayed visually in the form of cards, the distribution location of each maintenance type is displayed in color image with GIS map as the carrier, and the maintenance measures and amount of each decision-making unit are displayed in detail in the form of lists. The details are shown in Figure 4. Sharing and data fusion facilitate unified, real-time and dynamic management and use unified master data to make maintenance decisions.

![Fig3: Diagram of the Conservation Decision Measures Library page](image1)

![Fig4: Presentation chart of conservation decision-making scheme based on GIS map](image2)

### 2.4.2. Maintenance decision of system road network

The level of highway operation group mainly makes decisions at the road network level and reasonably allocates limited maintenance funds. On the basis of the project-level decision, all section units of all section companies are intelligently ranked according to the technical condition of road surface, and maintenance funds are allocated according to the principle of repairing poor roads first, as shown in Figure 5. The decision scheme of the road section
company is compared with the decision scheme of the group level, and the matching rate is calculated, so as to optimize the allocation of maintenance funds for the group level of the road operation based on the basis and effectively. To display the maintenance measures and amount of each decision unit in detail in a list. The details are shown in Figure 2.6. Sharing and data fusion facilitate unified, real-time and dynamic management and use unified master data to make maintenance decisions.

![Image](image1.png)

**Fig5**: Illustration of the results of the allocation of funds for road network-level decision-making

![Image](image2.png)

**Fig6**: Projection chart of daily maintenance costs

### 2.4.3. Cost forecast of daily maintenance

The system adopts local standard forecast and historical daily maintenance cost fitting forecast to forecast daily maintenance cost. The former method considers the road section traffic volume, road age, precipitation and other factors corresponding to the road, bridge, tunnel and other professional types of single kilometer charging standard, according to the length of the road section maintenance cost calculation; The latter method can predict the maintenance cost.
by fitting the changing trend of the daily maintenance cost over the years, as shown in Figure 6. According to the case analysis, the local standard forecast cost is slightly higher than the recursive forecast cost of historical daily maintenance cost.

### 2.5. Preparation and approval of annual plan

The most important purpose of the research and development of the maintenance scientific decision system is to assist the highway maintenance managers to formulate maintenance plans and programs scientifically. In the preparation of annual maintenance plan, maintenance decision results can be referenced and adjusted according to the actual situation, and pavement decision plans can be taken for comparative approval at any time in the process of plan level by level. See Figure 7 for the system's auxiliary function flow and module interface of maintenance planning.

![Fig7: Submitted submissions and approval of annual plan of the road network cluster](image)

### 3. The conclusion

In this paper, a maintenance scientific decision-making system based on GIS map is established to achieve static and dynamic data management of road production. On the basis of multi-source data fusion, the analysis and output of project level and road network level maintenance schemes under capital constraints are realized according to the multi-level decision-making model combined with historical maintenance schemes. The design of the compilation module of conservation plan provides the basis of practice test for the application of the decision-making system, and the actual implementation plan of conservation plan will feed back the conservation measure pool and form a benign ecological circle of conservation decision. The practical application results show that the maintenance decision system can provide effective and reliable reference for the maintenance management personnel to formulate the maintenance plan scientifically.

Follow-up, To achieve the goal of long-term performance maintenance of pavement and minimizing cost in the analysis period, and applied to road maintenance planning, I will continue to be deep in the study of pavement maintenance decision, optimize the multi-factor and multi-level decision model, predict and analyze the long-term performance trend of pavement, and deepen the decision optimization model of the impact of cost and benefit based on the concept of whole life cycle cost the most provinces.
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References