Journal of Asian Research
ISSN 2575-1565 (Print) ISSN 2575-1581 (Online)
Vol. 7, No. 1, 2023
www.scholink.org/ojs/index.php/jar

Short Paper

Research on Intelligent Decision-Making of Asphalt Pavement Maintenance in Offshore Soft Soil Area

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Received: December 1, 2022 Accepted: December 20, 2022 Online Published: December 23, 2022

doi:10.22158/jar.v7n1p1 URL: http://dx.doi.org/10.22158/jar.v7n1p1

Abstract

The performance of roads in offshore soft soil areas is different from ordinary pavement. In view of this feature, and based on the summary of the existing intelligent decision-making research on the maintenance of asphalt pavement, this study has selected Ningbo as the survey area. The changes in the performance characterization index of asphalt pavement in offshore soft soil areas were compared and analyzed. The influencing factors of decision-making in the maintenance were analyzed, and the pavement maintenance standards and intelligent decision-making process in offshore soft soil areas were determined, including the timing of preventive maintenance, road section under maintenance, maintenance plan, etc. The conclusions in this study can promote the scientific decision-making on asphalt pavement maintenance in offshore soft soil areas and promote the healthy and sustainable development of highway maintenance.

Keywords

pavement maintenance, intelligent decision-making, offshore soft soil areas

1. Introduction

Due to the uneven settlement of soft soil foundation, roads in offshore soft soil areas generally have many hidden diseases, which seriously impact the performance of roads and the road safety. Therefore, the characteristics of soft soil and the impact of uneven settlement of soft soil should be taken into consideration in road maintenance decisions. The purpose of the pavement maintenance decision-making system is to make scientific decisions on pavement maintenance and reasonably allocate funds for the maintenance. Therefore, various influencing factors in the system should be

comprehensively considered so as to provide the best maintenance options for pavement within the future analysis period, and support decision-making. With the popularization and application of the pavement management system, more and more decision-making methods have been applied to the system to improve the function of the extended pavement management system.

The priority methods are the earliest decision-making methods applied to highway maintenance and management, which was represented by the decision tree method. This method has been used for road management systems in some states and Ontario in the United States. Li Aijun used the decision tree method to establish an asphalt pavement evaluation model suitable for expressways in Hebei Province.

The mathematical programming method is to obtain the extreme value of the target under a given constraint. The essence is to use mathematical methods to solve some problems in decision-making. Linear programming and dynamic programming belong to this category. Using the principle of dynamic planning, Zhao Chen et al. established a maintenance planning model for roads in forest areas, and discussed the determination of the maintenance section and the maintenance time. Li Weichao analyzed the needs and countermeasures of pavement maintenance, and gave a combination of maintenance countermeasures. In addition, the countermeasures were applied to the highway maintenance ranking in Heilongjiang Province, and the dynamic decision-making model was applied to the optimization of network-level pavement maintenance funds in the province.

Since multiple influencing factors need to be comprehensively considered in highway maintenance decisions, there is a certain correlation and randomness between each influencing factors, and it is difficult to achieve the expected results by using traditional decision-making methods. In this case, the mathematical theory of multi-objective analysis and solution is applied to highway decision-making, such as fuzzy theory, gray correlation, matter element method, neural network, genetic algorithm, etc. Based on the idea of fuzzy optimization, Li Jinlong established a fuzzy programming model under conditional constraints. Wang Jia applied the gray correlation theory to establish a prioritization model for pavement maintenance projects. With high-grade asphalt pavement rut prediction as the research focus, Hou Chaoping established a chaotic neural network model for rut long-term prediction to serve preventive maintenance decisions. Yu Anjun used hybrid genetic algorithms and NSGA-II to optimize single-objective and multi-objectives in maintenance decisions, and verified their feasibility through simulation experiments.

The existing decision-making theories are mostly aimed at project-level highways, but there are fewer decisions on network-level pavement maintenance. Network-level pavement decision-making is more complex and needs more considerations than the project level. In addition, intelligent pavement maintenance decision-making methods tailored to the characteristics of offshore soft soil areas are scarce.

2. Analysis of the Performance Characteristics of Asphalt Pavement in Offshore Soft Soil Areas

Based on the actual research data of asphalt pavement in Ningbo City, Zhejiang Province, the typical regional characteristics of the performance of asphalt pavement in offshore soft soil areas were analyzed.

2.1 Investigation on the Performance Status of Asphalt Pavement

In this study, a total of 1167.926 kilometers of county and township roads were tested, of which the county road mileage was 936.728 kilometers, accounting for 80.2%. The mileage of asphalt pavement in township roads was 231.198 kilometers, accounting for 19.8%. Figures 1 and 2 are the current statistics of RQI and PCI indicators of asphalt pavements in counties and township roads in Ningbo, respectively.

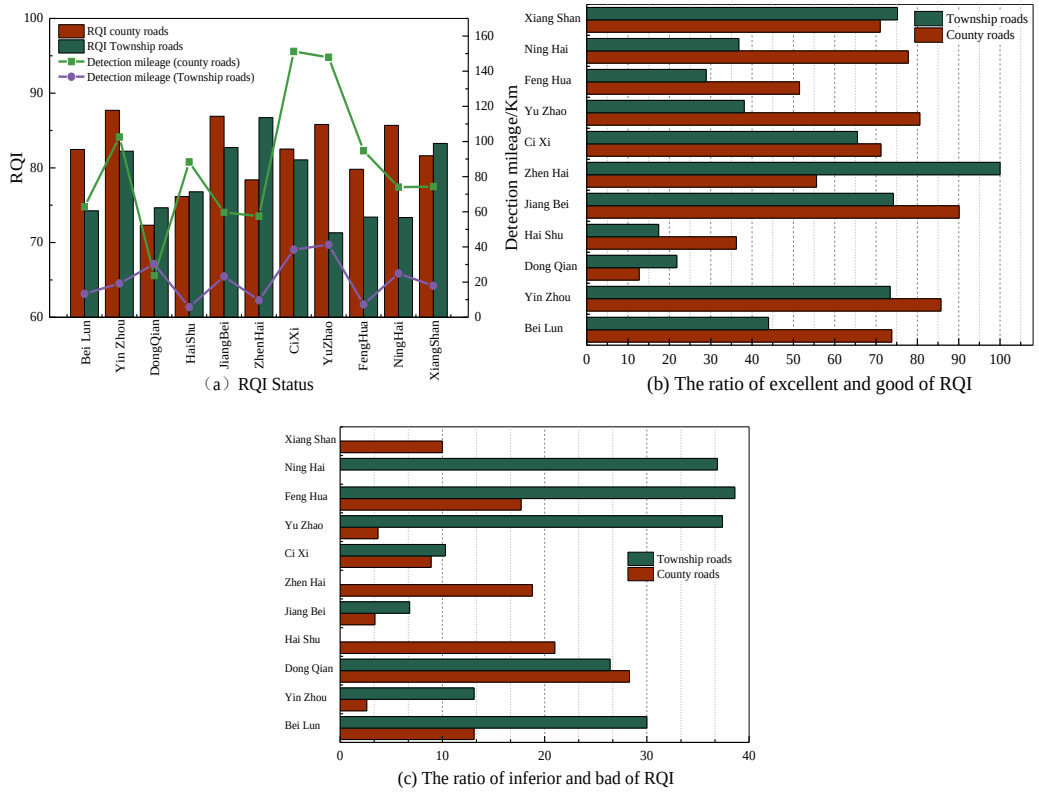

Figure 1. Analysis of RQI Indicators of County and Township Roads in Ningbo

As can be seen from Figure 1, the road quality index of county and township roads in Ningbo is generally less than 80, and the maximum value does not exceed 90, indicating the poor road leveling in Ningbo. At the same time, it can be seen that the proportion of roads in less-poor conditions in various urban areas of Ningbo is relatively large, which exceeds 20% in soft soil areas such as Dongqian Lake and Haishu District.

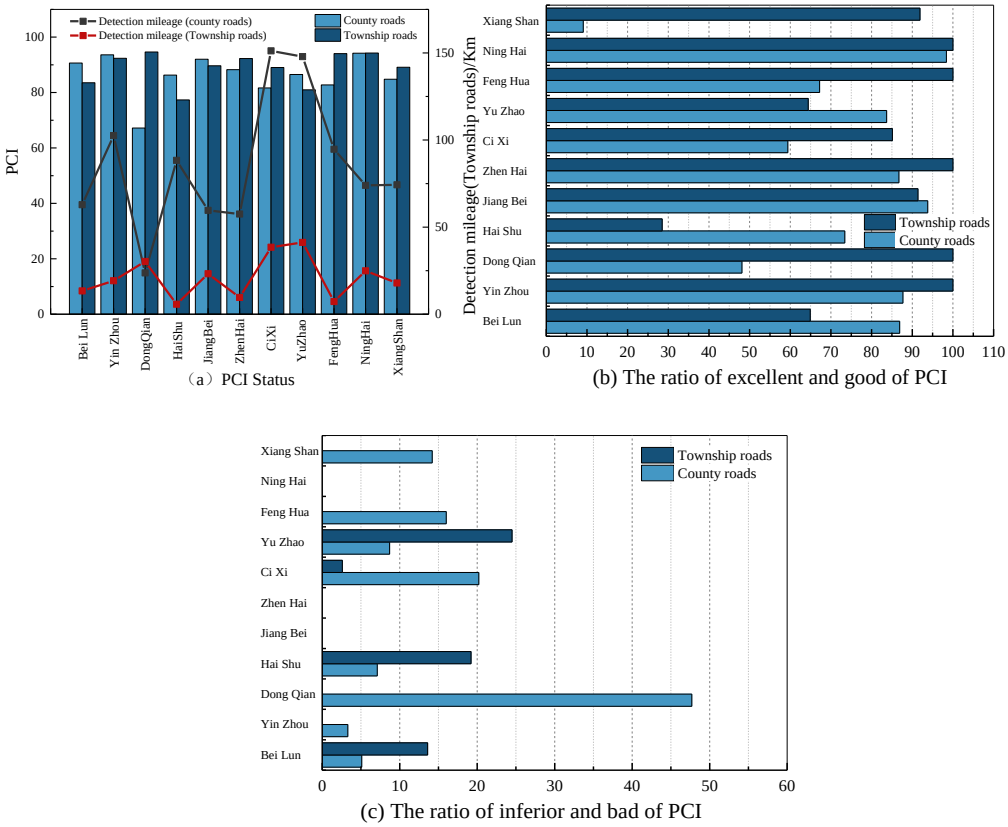

Figure 2. Analysis of PCI Indicators of County and Township Roads in Ningbo

As can be seen from Figure 2, the PCI of county and township roads in various regions generally exceeds 80 and is close to 90. Compared with the RQI indicator, the value of this indicator is large. This shows that compared with flatness, the road damage in Ningbo is better. However, from the perspective of the whole city, the road damage in Haishu District and Dongqianhu District is more serious.

2.2 Statistical Analysis of Asphalt Pavement Damage

Through statistics, it is found that the main types of damage on the asphalt pavement in Ningbo include 10 diseases such as transverse cracks, longitudinal cracks, cracks, repair, etc. The proportion of the diseases is shown in Figure 3. As can be seen from the figure, the 4 typical diseases with a large proportion of damage area are transverse cracks, cracks, longitudinal cracks and subsidence diseases. This shows that the typical diseases of offshore soft soil mainly include 3 types of cracks and subsidence. The damaged area of transverse cracks accounts for the largest proportion of asphalt pavements, which is 32.61%. The subsidence disease is the main reason for poor flatness, which is consistent with the above-mentioned analysis results of RQI indicators.

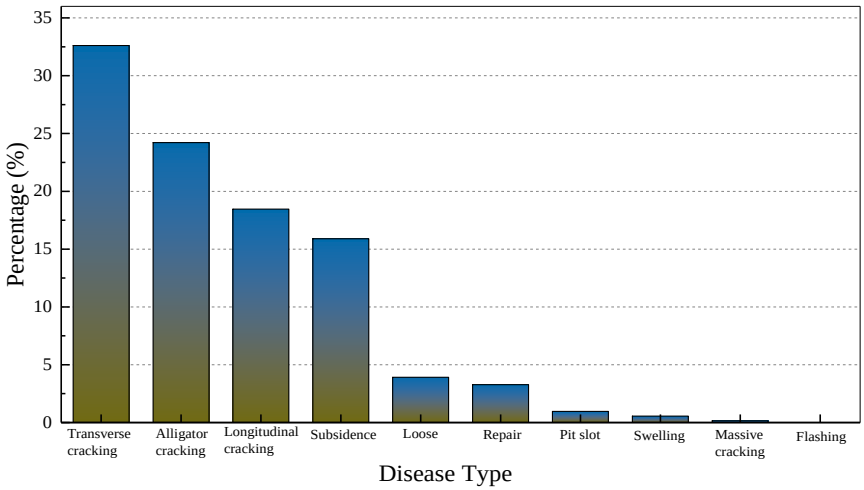

Figure 3. Statistics on the Damage Types of National Highways, Provinces and Counties Highways in Ningbo

3. Determination of Influencing Factors and Criteria for Asphalt Pavement Maintenance Decision-Making

3.1 Analysis of Factors Influencing the Decision-Making of Asphalt Pavement Maintenance

Pavement maintenance decision-making is a multi-objective, multi-level and multi-factor decision-making problem. Usually, when designing pavement maintenance plans and formulating maintenance countermeasures, the main factors to be considered are as follows:

Pavement condition: If one of the indicators of pavement performance reaches the threshold of preventive maintenance, preventive maintenance measures need to be taken to restore pavement performance. Early preventive maintenance of the disease will put the road performance back in good condition, which can prevent the continuous intensification of the disease and keep the highway safe and unblocked.

Traffic volume and axle load: The larger the traffic volume, the greater the impact on the road surface, and the easier it is to shorten the service life of the road. When making preventive maintenance decisions, full consideration should be given to the size of traffic. The proportion of trucks in the traffic composition of highways is also increasing, the phenomenon of overload transportation is becoming more and more obvious, and the degree of overload is becoming more and more serious. The axle load of the truck acts directly on the road surface, which is very easy to cause road damage, especially overloaded trucks. Therefore, if the preventive maintenance decision of asphalt pavement is to be studied, the impact of axle load must be fully considered.

Administrative factors: Administrative intervention and administrative factors will influence the principle of road maintenance countermeasures. If it is a tourist road, the aesthetic requirements of the road will be relatively high; If funds for maintenance are limited and some sections need to be

thoroughly repaired, the requirements for preventive maintenance in other sections will be reduced; The professionalism and tendency of administrators will also influence the preventive maintenance decisions to a certain extent.

Expert experience: Decision-making itself is the process of digitizing expert experience, it thus plays a certain reference role in maintenance decision-making.

Natural conditions: Impacted by natural conditions, highways in different regions have different road disease characteristics, which objectively influences the selection and determination of highway maintenance policies, especially the influences of meteorological conditions such as precipitation and temperature.

3.2 Principles for Determining the Standard Value of Asphalt Pavement Maintenance

After using pavement technical condition data to evaluate and analyze the evaluation unit in the Code for the Maintenance and Design of Highway Asphalt Pavement (JTG5421-2018), each evaluation unit can be divided into maintenance types such as preventive maintenance and repair and maintenance. The division method should comply with the provisions of Table 1.

Table 1. Evaluation of the Classification Method of Unit Maintenance Types

Range of values				Maintenance type
PCI	RQI	RDI	SRI	
≥A1	≥B1	≥C	< D	Preventive maintenance
		< C	—	Restorative maintenance
	B2~B1	—		Preventive maintenance
	< B2	—		Restorative maintenance
A2~A1	≥B2	—		Preventive maintenance
	< B2	—		Restorative maintenance
< A2	—			Restorative maintenance

The range of values in Table 1 should be comprehensively determined according to the construction history, traffic conditions, maintenance level, road conditions and maintenance goals of each evaluation unit. In the absence of relevant data and experience, the range of values in Table 2 can be referred to.

Table 2. Reference Range of Maintenance Standard Values

Highway grade	Range of values					
	PCI		RQI		RDI	SRI
	A1	A2	B1	B2	C	D
Freeway, first-class highway	90	85	90	85	80	75
Secondary and tertiary highways	85	80	85	80	80	—
Class 4 highway	80	75	—	—	—	—

4. Intelligent Decision-Making on Asphalt Pavement Maintenance in Offshore Soft Soil Areas

4.1 Pavement Maintenance Standards

According to the above analysis, and combined with the network inspection and evaluation data of Haishu District, Ningbo City in recent years, this study has obtained the preliminary judgment threshold of pavement maintenance types and pavement indicators in Haishu District, Ningbo City. Maintenance personnel can preliminarily judge the type of pavement maintenance according to the size of an indicator, and the maintenance threshold values are shown in Table 3.

Table 3. Pavement Maintenance Standards

	Maintenance type	PCI	RQI	RDI
High standard	Preventive	> 90	> 90	> 85
	Functionality	80-90	80-90	75-85
	Structural	< 80	< 80	< 75
Medium standard	Preventive	> 80	> 80	> 75
	Functionality	70-80	70-80	65-75
	Structural	< 70	< 70	< 65
Low standard	Preventive	> 70	> 70	> 65
	Functionality	60-70	60-70	55-65
	Structural	< 60	< 60	< 55

When the road level is higher, or when the traffic load is large, the high value can be appropriately taken. When the road level is low or the traffic load is less, the lower value can be appropriately taken. Maintenance personnel can determine the threshold according to the road level, traffic volume and the actual economic development of the local economy and the degree of damage of other indicators, and preliminarily predict the type of road maintenance.

4.2 Intelligent Decision-Making Process of Pavement Maintenance

Intelligent decision-making methods need to be used to determine the timing of preventive maintenance, including decision-making tree method, benefit cost method, life cycle benefit evaluation method, etc. The maintenance section should be divided according to cluster analysis methods (systematic clustering, dynamic clustering, orderly clustering, etc.), and finally the intelligent decision-making method can be used to determine the maintenance plan and further determine the maintenance measures.

5. Conclusions

Based on the actual research data of asphalt pavement in the offshore soft soil areas of eastern Zhejiang Province, this study has summarized the typical characteristics of the performance of asphalt pavement in offshore soft soil areas, and analyzed the influencing factors and standards of asphalt pavement maintenance decision-making. According to the characteristics of offshore soft soil areas, the maintenance standards and intelligent decision-making process of asphalt pavement in offshore soft soil areas have been determined. The conclusions can provide guidance for solving relevant problems related to the scientific development of maintenance and management in the future.

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