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AHP-DEMATEL Based Research on the Influencing Factors of the Daily Maintenance Costs of China's National and Provincial Trunk Highways

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ABSTRACT

Highway maintenance is equally crucial across borders; this paper first conducts statistics and case study research on daily federal and provincial highway maintenance costs in China's principal influencing factors. Finally, it looks at those results with the tools of AHP-DEMAT. Yet, the overall degree of influence of each factor of influence is collected to classify the significant influence factors. The results found that: the main factors influencing the daily maintenance costs of national and provincial trunk highways are: highway grade, traffic flow, service life, structure type, topography, pavement thickness, and pavement width; the influence of climate factors on costs can be adequately considered when formulating standards for daily maintenance costs for provinces/regions with a broad geographic range.

***Keywords*--** National and Provincial Trunk Highway, Daily Maintenance Cost, Influencing Factors, AHP-DEMATEL, Comprehensive Influence Degree

I. INTRODUCTION

In recent years, with the rapid development of expressways and rural roads' construction, the status and role of ordinary national and provincial trunk highways have become increasingly prominent. The expressway is usually called "Artery," rural highways are called "Capillary," while regular federal and provincial trunk highways mainly undertake the task of "internal connection." It is a virtual channel between the expressway and rural highway (rural roads). It has played the role of linking and connecting the back and forth between urban nodes and township communities. It has special functions of connection, trunk line, and distribution, especially in rural areas under the national "Rural Revitalization" strategy; its status and role are more prominent. By the end of 2019, China's National and Provincial highways' mileage has reached 366,100 km and 374,800 km, respectively (Ministry of Transport of the People’s Republic of China, 2019).

With the increase of traffic mileage year by year, highways' daily maintenance workload is becoming more and onerous, and the maintenance funds are also increasing year by year (Tao, Lin and Wang, 2021) . The daily maintenance of highways plays a critical role in the entire highway maintenance project. Good daily maintenance work can prolong the highway's overhaul cycle, reduce subsequent maintenance costs, and increase its service life (Shah, McMann and Borthwick, 2017). Therefore, the highway management and maintenance department's importance to the daily maintenance operation and the amount of investment will directly affect highway construction development and continuation Liu and Wang (Liu, Wang, Li, Feng, Yu and Xue, 2019).

For a long time, due to the management and maintenance system's influence, the daily maintenance cost of provincial trunk highways in China has been divided into blocks, so there are some problems such as unreasonable fund allocation and poor maintenance effects. With the changes in the internal and external environment, such as the scale, structure, and industry development of China's highway network, the current daily maintenance fund allocation method has been inconsistent with the actual situation. It is urgent to develop a scientific and reasonable pricing method to meet the national fiscal and tax system reform's relevant requirements, comply with the development requirements of federal and provincial highways network planning scale adjustments, and improves highway network efficiency. Since the daily maintenance cost of national and provincial trunk highways is affected by many factors Zhao (Zhao, Fu and Zhang, 2016) , such as highway's grade, traffic flow, service life, pavement structure type, and other factors, the key to the research of daily maintenance cost is to determine the main influencing factors, then classify and analyze the cost sensitivity according to the main influencing factors, and finally, comprehensively determine the cost requirements for maintenance of the section of the highway. In response to the above problems, domestic and foreign scholars and relevant experts from highway management and maintenance units have done a lot of research work on the factors affecting the daily maintenance costs and achieved specific research results.

Shi Xiaoli (Xiaoli, Ming, Feng and Ping, 2018)

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aimed at the problem of difficulty in accurately estimating the amount of maintenance in calculating daily maintenance costs of expressways. They used an improved Bootstrap method to conduct an in-depth study on the historical data of daily maintenance costs of expressways and proposed an approach based on cost interval and proportional interval. A practical method for calculating and evaluating the cost of daily maintenance projects of expressways. When studying urban roads' daily maintenance cost, Pengfei Wang (Wang, Liu, Wang, Wang, Guan, Li and Xia, 2021) established a continuous-time stochastic optimal control model to minimize the expected total system cost, including the cost related to traffic flow and road maintenance cost. The research shows that the proposed investment allocation strategy can reduce the daily maintenance cost of roads. Sherzod yarmukhamedov (Yarmukhamedov, Smith and Thiebaud, 2020) believes that highways' daily maintenance cost is related to traffic volume, geographical environment, weather conditions, and maintenance activities. The geographical areas with large traffic volumes and harmful climates need centralized maintenance activities, and the maintenance cost is higher. Zhaoang Lu (Lu and Meng, 2018) believes that the highway's maintenance cost is related to traffic flow, pavement width, pavement performance, and other factors. Yonghong Yang (Yang, Huang, Wang and Xia, 2019) studied the maintenance cost of expressways in Guangdong Province of China and concluded that the main factors affecting the daily maintenance cost of expressways are traffic flow, pavement service life, number of lanes, geographical location, etc. other factors. Kunhee Choi (Choi, Kim, Bae and Lee, 2016) established an FMC highway's maintenance cost prediction model based on life cycle cost analysis (LCCA). They considered that traffic load is the most critical factor affecting pavement performance and highway maintenance cost. Huang (Harry) Teng (Teng; Hagood, Yatheepan, Fu and Li, 2016) conducted a linear regression model of the influencing factors of maintenance cost by using the data from the pavement and maintenance management system of the Department of transportation of Nevada (NDOT). The model research shows that road age, traffic flow, topography, maintenance type, maintenance plan, life cycle stage, and maintenance area are essential factors affecting maintenance costs. Heriberto Pérez-Acebo (Pérez-Acebo, Linares-Unamunzaga, Rojí and Gonzalo-Orden, 2020) and others believe that road age, traffic flow, and pavement structure are the main factors affecting road maintenance costs. Hagood (Hagood, 2014) used the regression method to study the influencing factors of highway minor repair and maintenance cost and established the relationship model between highway section length, area, highway age, climate, etc., and minor repair and maintenance costs. Gibby (Gibby, Kitamura and Zhao, 1990) studied the daily maintenance costs of highways in California, USA, and believed that the maintenance costs are related to the traffic flow of heavy vehicles, the average daily traffic flow of passenger cars, the highway age, temperature, and other factors. Volovski (Volovski, Murillo-Hoyos, Saeed, and Labi, 2017) considered the influencing factors as highway age, annual average daily traffic flow, average yearly rainfall, highway section length, number of lanes, and other factors when analyzing the maintenance cost of pavement overhaul in Indiana. The above research results have laid a specific theoretical foundation for this paper, but there are also shortcomings, mainly reflected in two aspects: 1. The research fields are mostly limited to expressways, and there are a few kinds of research on national and provincial trunk highways. Because the management and maintenance systems of expressways and federal and provincial trunk highways are different in China, the factors affecting daily maintenance costs and the distribution methods are also quite other; 2. The research method is mainly linear regression, which cannot fully reveal the interaction between the various influencing factors comprehensively and systematically, nor can it thoroughly compare each influencing factor's degree of influence. Therefore, based on the research of the above scholars and experts, this paper chooses the national and provincial trunk arterial highways as the research object and strives to break through the traditional mathematical-statistical analysis methods, such as regression analysis, variance analysis, principal component analysis, etc., and using AHP-DEMATEL method to study the influencing factors of daily maintenance costs.

II. RESEARCH METHOD

Analytic hierarchy process (AHP) is a systematic evaluation method that combines qualitative and quantitative analysis proposed by American operations research Satie. According to the nature of the problem and the general goal reached, the problem is decomposed into different components, and in accordance with the interrelated influence and affiliation of the factors, the factors are aggregated and combined at various levels to form a multi-level analysis structure model, so that the problem is reduced to the lowest level (plans, measures, etc. for decision-making) relative to the highest level, the determination of the relative importance of the level (general goal) or the arrangement of the relative order of superiority and inferiority (Wang and Yeap, 2021, Zhu, Zhao, Wang, Huang, Sun and Bi, 2021). Two American scholars first proposed the decision-making trial and Evaluation Laboratory (DEMATEL). Using graph theory and matrix method, it can analyze the structural relationship of elements in complex systems and accurately reveal the interaction relationship between various factors (Cui, Chan, Zhou, Dai and Lim, 2019, Wu, Hu, Lin, Li and Ke, 2018).

This paper first uses AHP to analyze the influencing factors of the daily maintenance costs of national and provincial trunk highways and calculates

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the weight of each influencing factor; then DEMATEL is used to construct the direct influence matrix among the influencing factors, and the "four degrees" of each influencing factor are calculated, namely, the influence degree, the affected degree, the centrality, and the cause degree, and then the degree of influence of each influencing factor is identified; after that, AHP and DEMATEL are combined to get the comprehensive influence degree of each influencing factor, and then identify the main influencing factors of daily maintenance cost of provincial trunk highway. The specific analysis process is shown in Figure 1.

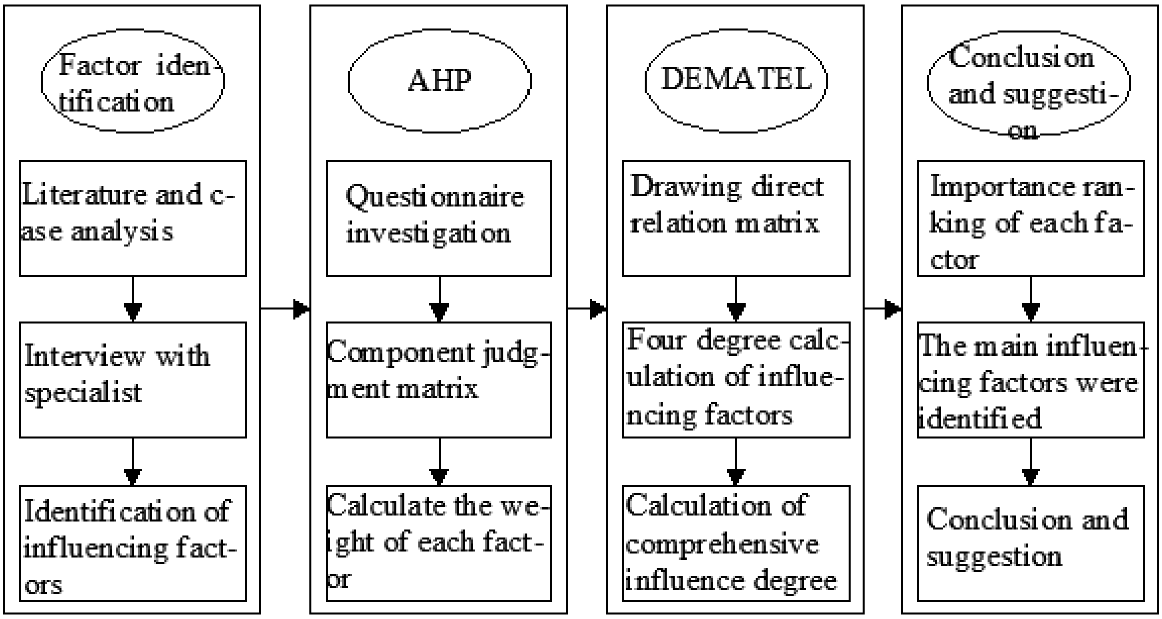

Figure 1: Analysis process of primary factors of highway daily maintenance cost based on AHP-DEMATEL

III. IDENTIFICATION OF INFLUENCING FACTORS

The daily maintenance cost of national and provincial trunk highways is affected by many factors, including climate conditions, topography, highway grade, highway design structure, highway use status, and many other factors (climate conditions: China has a vast territory, complex topography, significant terrain disparity, complex and diverse climate, temperature, humidity, and rainfall will affect highway maintenance in different degrees. Highway design: there are many highways in China with different pavement width, thickness, structure type, and grade. According to the highway maintenance technical standards, the maintenance costs and requirements of different grades are also different. Highway status: highway status mainly refers to the use environment and geographical environment of the highway, which makes the highway maintenance more convenient, the use environment primarily relates to the years of opening to traffic and traffic flow, and the geographical environment mainly refers to the topography and landform, bridge-tunnel ratio and highway length. The daily maintenance costs required for different maintenance conditions are also different. In this study, through experts consultation and literature review, and following the scientific and comprehensive principles, three primary influencing factors have been determined, Respective climate B_1, Highway design B_2. Highway status (Current situation) B_3, It is subdivided into 12 secondary influencing factor indicators, are numbered using, $C_i(i = 1,2,3 \ldots 12)$ and the meaning of each factor index is analyzed, as shown in Table 1.

Table 1: Hierarchical index system of factors affecting daily maintenance costs of highways

Target layer	Criteria level (first level indicators B_i)	Sub criteria level (secondary indicators C_i)	Indicator meaning
Factors Influencing the Daily Maintenance Cost of National and Provincial Trunk Highways A	Climate B_1	C_1Temperature	The influence of temperature is mainly reflected in the difference in daily maintenance content in different seasons, and the maintenance cost is different.
		C_2Humidity	Air humidity has a specific relationship with traffic flow and pavement structure type and indirectly affects the daily maintenance cost.
		C_3Rainfall	Rainfall has a specific relationship with pavement damage rate and service life and indirectly affects the daily maintenance cost.
	Highway design B_2	C_4Highway grade	The higher the highway grade/level, the higher the daily maintenance cost.
		C_5Pavement thickness	Thicker the pavement, lower the damage rate, and reduce the maintenance cycle's daily maintenance cost.
		C_6Structure type	Different pavement structure types have different maintenance standards and maintenance costs.
		C_7Highway width	Wider the road, the greater the cleaning and maintenance work is, and the higher the cost.
	Highway status B_3	C_8Topography	The topography of the maintenance section is different, and the daily maintenance cost often varies greatly. Usually, the maintenance cost in mountain areas is greater than the maintenance cost in the plain area.
		C_9Service life	In an overhaul period, the longer the service life, the higher the daily maintenance cost.
		C_{10}Traffic flow	Greater traffic flow, higher the pavement damage rate and greater is the maintenance cost.
		C_{11}Bridge-tunnel ratio	Higher the bridge-tunnel ratio, the higher the daily maintenance cost.
		C_{12}Highway length	Daily maintenance costs are proportional to the length of the highway.

IV. AHP-DEMATEL ANALYSES

4.1 Comprehensive Analysis

According to the expert consultation and questionnaire survey results, each influencing factor's influence degrees are evaluated. They use the pairwise comparison method to construct the judgment matrix using the nine-level scale method $A = (a_{ij})n * n$. The establishment of a judgment matrix follows the order from top to bottom, from high to low. Judgment matrix is an inverse matrix, and the meaning of elements in the matrix refers to $a_i(i = 1,2,3 \dots, n)$ to $a_j(j = 1,2,3 \dots, n)$ the degree of importance. The element a_{ij} has the following properties : $a_{ij} > 0, a_{ij} = 1/a_{ji}$, $a_{ij} = 1(i = j)$.

The criterion-level judgment matrix A (Table 2) and sub-criterion level judgment matrix B_1 , B_2 and B_3(table 3 - table 5) are established in turn, and the maximum eigenvalue and corresponding eigenvector are calculated by square root method for consistency test. Consistency test index $CI = (\lambda_{max} - n)/(n - 1)$, where λ_{max} is the maximum eigenvalue, and n is the number of elements. When $CR = (CI)/(RI) < 0.1000$ (where RI is the average random consistency index), the consistency test is passed. The above indicators' weight is calculated using MATLAB software, and the calculation results are shown in Table 6. The matrix's results A, B_1,B_2 and B_3 consistency test index CR are -1.9231, -1.9231, -1.1236, and -0.8264, respectively, which are less than 0.1, so they pass the consistency test.

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Table 2: Criteria level judgment matrix A

Standard	Highway design	Highway condition	Climate
Highway design	1	1	7
Highway condition	1	1	7
Climate	1/7	1/7	1

Table 3: Sub-criteria level judgment matrix B_1

Climate	Temperature	Humidity	Rainfall
Temperature	1	1	3
Humidity	1	1	3
Rainfall	1/3	1/3	1

Table 4: Sub-criteria level judgment matrix B_2

Highway design	Grade	Thickness	Structure	Width
Grade	1	5	3	5
Thickness	1/5	1	1/3	1
Structure	1/3	3	1	3
Width	1/5	1	1/3	1

Table 5: Sub-criteria level judgment matrix B_3

Highway status	Topography	Service life	Traffic flow	Bridge-tunnel Ratio	Highway length
Topography	1	1/3	1/5	1	3
Service life	3	1	1/3	3	5
Traffic flow	3	3	1	3	5
Bridge-tunnel ratio	1	1/3	1/3	1	3
Highway length	1/3	1/3	1/5	1	1

Table 6: Calculation results of total weights of various influencing factors

Standard (A)	First-level index (B_i)	First-level index weight	Secondary index (C_i)	Secondary index weight	Comprehensive weight (ω_i)	Weight ranking
Weights of factors affecting daily maintenance expenses of highways	Climate	0.0667	C_1Temperature	0.2	0.0133	11
			C_2Humidity	0.2	0.0133	11
			C_3Rainfall	0.6	0.0400	9
	Highway design	0.4667	C_4Highway grade	0.5599	0.2613	1
			C_5Pavement thickness	0.0955	0.0446	7
			C_6Structure type	0.2492	0.1163	4
			C_7Highway width	0.0955	0.0446	7
	Highway status	0.4667	C_8Topography	0.1141	0.0533	6
			C_9Service life	0.2689	0.1255	3
			C_{10}Traffic flow	0.4189	0.1955	2
			C_{11}Bridge-tunnel ratio	0.1243	0.0580	5
			C_{12}Highway length	0.0739	0.0345	10

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4.2 Calculation of "Four Degrees" of Influencing Factors

DEMATEL is used to collect relevant data through the expert interview, and the direct relationship matrix X (Table 7) is established. The degree of influence between each element is represented by numbers 0, 1, 2, and 3 (0 means no relationship, 1 means weak relationship, 2 means medium relationship, 3 means strong relationship), where a_{ij} is the degree of influence element i on an element j, n is the number of elements, and the diagonal element a_{ii} is 0. Normalize the direct influence matrix X to obtain a new matrix N, and use the formula to find the comprehensive influence matrix T. Then calculate the "four degrees" of each influencing factor, where the degree of influence, $D_i = \sum_{j=1}^{n} x_{ij}(i = 1,2, \dots n)$, where D_i represents the sum of the direct and indirect influences of the influencing factors a_i in each row of the matrix T on other influencing factors; the affected degree $R_j = \sum_{i=1}^{n} x_{ij}(j = 1,2, \dots n)$, R_j represents the sum of the direct and indirect influences of the influencing factors a_j in each column of the matrix T on other influencing factors; centrality $Y_i = D_i + R_j = \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n} x_{ij}(i,j = 1,2, \dots, n)$, Y_i represents the importance of the influencing factors a_i; and the cause degree $Z_i = D_i - R_j = \sum_{j=1}^{n} x_{ij} + \sum_{i=1}^{n} x_{ij}(i,j = 1,2, \dots, n)$ indicates the net influence degree of the influencing factor a_i. If $Z_i > 0$ demonstrates that the factor has a great influence on other factors; it is called cause factor; otherwise, $Z_i < 0$ is called the result factor. The calculation results of "four degrees" of each influencing factor in sub-criteria level are shown in Table 8.

Table 7: Direct relation matrix

Influencing factors		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
Temperature	C_1	0	2	2	0	1	2	1	1	2	1	0	0
Humidity	C_2	1	0	2	0	0	1	0	1	2	1	0	0
Rainfall	C_3	2	2	0	1	1	2	0	1	2	2	0	0
Highway grade	C_4	1	1	1	0	3	2	3	0	3	2	1	1
Pavement thickness	C_5	0	0	0	1	0	1	1	1	3	2	1	0
Structure type	C_6	0	0	0	1	3	0	1	1	3	2	0	1
highway width	C_7	1	0	0	1	1	2	0	1	2	2	1	0
Topography	C_8	1	2	1	2	2	2	2	0	1	2	3	1
Service life	C_9	0	0	0	1	1	1	1	1	0	1	0	0
Traffic flow	C_{10}	1	0	0	2	3	3	3	1	3	0	1	0
Bridge-tunnel ratio	C_{11}	0	0	0	1	2	1	1	1	1	1	0	1
Highway length	C_{12}	1	0	0	1	0	0	0	1	0	0	1	0

Table 8: Calculation results of "Four Degrees" of influencing factors at the sub-criteria level

Influencing factors		Influence degree D_i	Affected degree R_i	Centrality Y_i	Centrality ranking	Cause degree Z_i
Temperature	C_1	1.4700	0.8494	2.3195	8	0.6206
Humidity	C_2	0.8748	0.5218	1.3966	11	0.3530
Rainfall	C_3	1.3642	0.4189	1.7831	10	0.9453
Highway grade	C_4	1.9809	1.4549	3.4358	5	0.5260
Pavement thickness	C_5	1.2964	2.1758	3.4722	3	-0.8794
Structure type	C_6	1.4893	1.9476	3.4369	4	-0.4583
highway width	C_7	1.3046	1.7094	3.0140	7	-0.4048
Topography	C_8	2.1821	1.1602	3.3423	6	1.0219
Service life	C_9	0.8545	2.6508	3.5053	2	-1.7963
Traffic flow	C_{10}	1.9819	1.9511	3.9330	1	0.0308
Bridge-tunnel ratio	C_{11}	1.1473	1.0145	2.1618	9	0.1328
Highway length	C_{12}	0.4126	0.5041	0.9167	12	-0.0915

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4.3 Draw the Cause-Result Graph of Influencing Factors

Based on the data in Table 8, taking the centrality as abscissa and causation degree as ordinate, the cause-result graph of influencing factors of daily maintenance cost of national and provincial trunk highways is drawn. Since the centrality is positive, the influencing factors are distributed in quadrant I and IV, as shown in Figure 2. Taking 0 as the boundary, the influencing factors with cause degree greater than 0 are the cause factors, which indicates that the active influence is strong; the influencing factors with cause degree less than 0 are the result factors, which indicates that they are easily affected by other factors and have strong passivity.

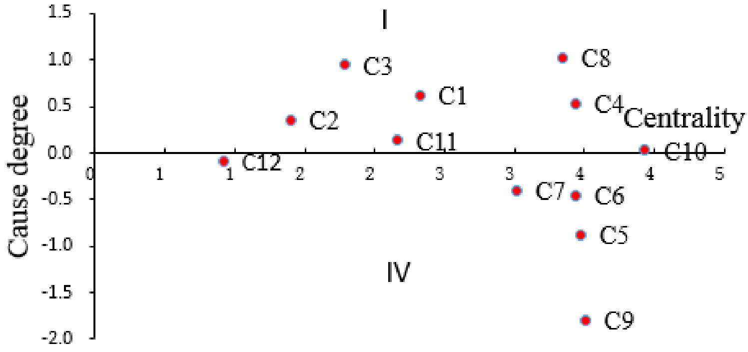

Figure 2: Cause-result graph of influencing factors

4.4 Calculation of Comprehensive Influence Degree of Each Influencing Factor

Since both AHP and DEMATEL are affected by subjective factors, to make up for the shortcomings of the two algorithms, each influencing factor's comprehensive weight and centrality are multiplied and normalized to obtain the comprehensive influence degree of each influencing factor. The calculation results are shown in Table 9.

Table 9: Calculation results of comprehensive influence degree of each influencing factor

Influencing factors		$\omega_i * Y_i$	$(\omega_i * Y_i)/\sum_{i=1}^{n}(\omega_i * Y_i)$	Ranking
Temperature	C_1	0.0308	0.0095	11
Humidity	C_2	0.0186	0.0057	12
Rainfall	C_3	0.0713	0.0219	9
Highway grade	C_4	0.8978	0.2761	1
Pavement thickness	C_5	0.1549	0.0476	6
Structure type	C_6	0.3997	0.1229	4
Highway width	C_7	0.1344	0.0413	7
Topography	C_8	0.1781	0.0548	5
Service life	C_9	0.4399	0.1353	3
Traffic flow	C_{10}	0.7689	0.2365	2
Bridge-tunnel ratio	C_{11}	0.1254	0.0386	8
Highway length	C_{12}	0.0316	0.97	10

V. ANALYSIS OF CALCULATION RESULTS

From the ranking of calculation results of comprehensive influence degree of each influencing factor in Table 9, it can be seen that C_4 highway grade, C_{10} traffic flow, C_9 service life, C_6 structure type, C_8 topography, C_5 pavement thickness, and C_7 pavement width ranked in the top 7, with the highest degree of comprehensive influence. Four of them belong to highway design. Three belong to the highway status quo, indicating that highway design and highway status have a higher impact on national and provincial trunk highways' daily maintenance costs than climate.

From the calculation results of the comprehensive weight of each influencing factor in Table 6, the bridge tunnel-ratio of C_{11} and topography of C_8 are ranked 5th and 6th, respectively. Still, these are

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ranked 8th and 5th respectively in the comprehensive influence degree. Therefore, the calculation of comprehensive influence degree makes up for the shortcomings of AHP and DEMATEL, making the calculation results more objective and scientific, and reasonable.

From the influencing factor cause-result graph in Figure 2, it can be seen that among the 12 influencing factors, there are 7 cause factors and 5 result factors. The top seven influencing factors with high centrality are C_{10} traffic flow, C_9 years of operation, C_5 pavement thickness, C_6 structure type, C_4 highway grade, C_8 topography, and C_7 pavement width. Among the seven influencing factors, there are four result factors (C_9, C_5, C_6 and C_7) and three cause factors (C_{10}, C_4 and C_8), which show that (C_9, C_5, C_6 and C_7) are easily affected by other influencing factors and have strong passivity, while C_{10}, C_4 and C_8 have active solid influence, so they can be used as part of the main factors affecting the daily maintenance costs of national and provincial trunk highways.

Based on the above analysis results, the paper analyzes the highway's daily maintenance characteristics and cost control. As basic understandings, the maintenance costs required for different highway grades are quite different, such as grade I highways and grade III highways. Due to the difference in maintenance standards and maintenance frequency, the daily maintenance costs are different; the traffic flow ranked second among China's comprehensive influencing factors. Obviously, the greater the traffic flow of the maintenance section, the higher the pavement damage rate, the higher the daily maintenance cost; longer the service life of the maintenance section, especially within 1 to 5 years after the opening of the highway, the annual damage rate increases linearly, the maintenance work volume is also increasing, and the maintenance cost rose sharply. The maintenance cost will be increased for 5 to 8 years, due to the medium repair or overhaul in this period, the daily maintenance cost will be slightly eased; the influence of pavement structure type on daily maintenance costs is also remarkable, such as asphalt pavement and sand-gravel pavement, because of the different maintenance standards, the cost control standards are different; The influence of terrain/topography on the daily maintenance costs of the highway is mainly reflected in plain, micro hill, heavy hill, mountain, along lakes and coasts. Due to the different geographical location of the maintenance section, the maintenance cost is determined by the difficulty of maintenance operation such as plain areas, the difficulty of daily maintenance operation in the plain area is significantly lower than that in a hilly area, and the maintenance cost is also lower; the influence of pavement thickness and width on the maintenance cost is obvious, the impact is mainly reflected in the following aspects: thicker the pavement, less prone to damage, and the lowers the daily maintenance costs, while the wider the pavement is, more significant the cleaning area, and the higher the costs will be.

VI. CONCLUSION AND SUGGESTION

This paper uses the AHP-DEMATEL method to carryout theoretical calculation and research on influencing factors of daily maintenance costs of national and provincial trunk highways, and comprehensive influence degree and ranking of relevant factors are obtained, and the main influencing factors are finally determined. The conclusions and suggestions are as follows:

(1) Through calculation and analysis, the main influencing factors of daily maintenance cost of national and provincial trunk highways in China (highway grade, traffic flow, service life, structure type, topography, pavement thickness, and pavement width) are obtained, which provides the basis for the decision- making of the cost for the competent departments of the state authorities, which can further solve the irrational allocation of funds for daily maintenance of national and provincial arterial highways and poor maintenance effect in China for a long time, which has great practical guiding significance.

(2) It is suggested that while formulating the annual cost index of daily maintenance of national and provincial trunk highways, the relevant departments should comprehensively consider the above main factors to determine the overall framework of costs indexes, such as dividing the costs index base according to different highway grades, traffic flow, structural types, pavement width and thickness, and adopting the form of adjustment coefficient for different maintenance highway sections' service life and topography for cost standard calculation.

(3) Due to China's vast territory and complex and diverse climate, even when each province/region separately formulates the daily maintenance cost standards for highways, it is inevitable to consider the impact of climatic conditions. For example, some highway sections in a province/region need winter construction, while other sections do not, so the cost difference is large. Therefore, it is suggested that provinces/districts with a wide geographical scope should appropriately consider the impact of climate factors on the cost when formulating the daily maintenance cost standard, and the cost calculation standard should be reflected in the form of rate.

(4) The paper's research results could be served as a reference for the research on the factors affecting the daily maintenance costs of highways in other countries in the world.

Conflict of Interest

The authors claim no potential conflict of interest.

Authors' Contribution

All authors contributed to this study at different levels. All authors read and approved the final version.

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Muzammal Mehmood contributed to study design; acquisition of data: Muzammal, Baojing Zhang analysis and interpretation of data: Baojing, drafting of manuscript: Baojing; critical revision of the manuscript for important intellectual content: Baojing.

Data Availability Statement

Some or all data, models, or code of MATLAB resource files that support this study's findings are available from the corresponding author upon reasonable request.

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