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Investigation on the Optimization Model of Highway Maintenance Construction

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Abstract. In order to enhance the efficiency of maintenance construction and improve the capacity and service quality of expressways, a mathematical model was developed to optimize the timing of road closures. This model takes into account factors such as highway tolls, traffic flow, construction costs, and construction periods. By solving the algorithm, the optimal strategy for determining road closure construction time can be determined. The application method of the maintenance construction time optimization model is demonstrated by using the engineering scenes of Tangxia-Ruian and Ruian-Tangxia direction maintenance construction on the YongTaiwen Expressway as examples. The results show that after optimizing the construction closure scheme, the revenue of the Tangxia-Ruian and Ruian-Tangxia expressways has increased. This optimization has effectively solved the traffic organization problem associated with the maintenance and construction of the expressway toll.

Keywords: Expressway; maintenance construction; road closing time optimization;

1 INTRODUCTION

As the main arteries of national economic development, expressways are an important embodiment of the industrialization and urbanization processes. By the end of 2021, the total length of expressways in China has reached 169,100 km. Meanwhile, the problems related to traffic organization and management in highway maintenance and construction have also become increasingly prominent, thereby affecting the capacity of expressways to a certain extent. In addition, most of the expressways built in the early stages of our country are four-lane dual carriageways, which are seriously inconsistent with the current traffic demand, especially in developed areas. The daytime traffic flow in many core sections is close to saturation, making it impossible to have arbitrary road closure construction. This poses challenges for maintenance and construction organizations, making it urgent to optimize the construction time scheme for road closure [1-4].

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The traffic management of maintenance construction must address two resource allocation issues. Firstly, the allocation of space resources requires studying the construction organization plan and the impact of traffic flow changes during construction to guide traffic management in the affected area. Secondly, the allocation of time resources involves studying and formulating a schedule for maintenance construction [5-8].

Traffic safety is the primary concern in highway maintenance and construction traffic organization. The goal is to enhance the traffic efficiency of work areas while ensuring safety. In recent years, numerous scholars have conducted extensive research on this issue. Li [9] proposed a series of safety measures and strategies for organizing construction traffic. Wang et al. [10] systematically studied the methods for dividing construction areas, including warning areas, transition areas, buffer areas, work areas, and termination areas. These methods improved the efficiency of traffic operations while ensuring safety. In addition, the speed of the upstream flow in the construction area will also affect the safety of the construction site. In order to reduce the traffic accident rate in the area affected by the reconstruction and expansion of the expressway, Xue et al. [11] developed a graded speed limit model that takes into account drivers' visual characteristics and braking characteristics during both daytime and nighttime conditions. They conducted a study on the speed limit for the upstream section of the construction area. Expressways in mountainous areas have unique characteristics that differ from general construction areas, and the problem of traffic organization is particularly complex. In order to address this issue, Chen et al. [12] conducted a study on the traffic organization scheme during the construction of expressways in mountainous areas. They also provided a comprehensive analysis of the traffic design experience for transition sections, long downhill sections, and widened tunnels. In the macro-level analysis of expressway reconstruction and expansion, regional traffic organization is also involved. Based on specifications and Vissim simulation, Zhang [13] studied the dynamic design of a traffic organization scheme for an expressway expansion project to address this practical engineering problem.

At present, there is a considerable amount of research on the allocation of space transportation resources. However, there is still a lack of research on the blocking time for maintenance construction. During maintenance and construction, the impractical schedule of road closures not only decreases the capacity and service level of the highway, exacerbates traffic congestion, but also diverts some vehicles to other roads, resulting in a decrease in toll income for highway owners.

Therefore, while the entire duration of closed construction is advantageous for organizing maintenance construction, it also leads to increased regional traffic congestion and significantly impacts the economic income of expressway owners. In order to study the optimal road closure time scheme for highway maintenance construction, this paper utilizes an optimization mathematical model to establish the optimization model of road closure time. The model parameters are calculated using actual highway traffic data, and the model solving algorithm is written in VBA to determine the optimal road closure time scheme for maintenance construction.

2 Optimization Model of Road Closing Time Scheme

2.1 Decision Variables

In order to streamline the organization and management of maintenance and construction, the start and end times for road closures are standardized each day. The time unit for road closures is set at 1 hour, which means that daily fluctuations in traffic flow are not considered. Instead, the average value of historical data is used as the reference point, taking into account traffic flow and tolls when determining road closures. Therefore, only two variables need to be determined in this optimization model:

1) The time point t_s (o'clock) when the road is closed, $0 \leq t_s \leq 23$, and t_s must be an integer;

2) The time point t_e (o'clock) when the road closure ended, $0 \leq t_e \leq 23$, and t_e must be an integer.

2.2 Duration of Construction

The duration of highway maintenance construction is determined by the road condition and construction technology, and is not dependent on the duration of road closure. The construction time is measured in hours (h), and it is calculated based on the start and end times, t_s and t_e, of the road. The method is as follows:

If $t_s < t_e$, the total construction time is $t_{\text{total}} = t_e - t_s$;

If $t_s = t_e$, the total construction time is $t_{\text{total}} = 24$, that is, all-day road closure;

If $t_s > t_e$, the total construction time is $t_{\text{total}} = 24 - t_s + t_e$.

2.3 Construction Time

Assuming that the total construction time of a certain section is T_{total}, in theory, it can be constructed 24h all day, then the theoretical construction days are $D_{\text{theoretical}} = T_{\text{total}}/24$. In fact, the daily construction time is t_{total}, but the actual number of construction days is $D_{\text{actual}} = T_{\text{total}}/t_{\text{total}}$.

Since the actual construction time t_{total} will not exceed 24h per day, the actual construction days should be greater than or equal to the theoretical construction days, and the time difference is shown in formula (1):

$$D_{\text{time difference}} = D_{\text{actual}} - D_{\text{theoretical}} = \frac{T_{\text{total}}}{t_{\text{total}}} - \frac{T_{\text{total}}}{24} \quad (1)$$

2.4 Opportunity Cost

Since the waiting period of construction machinery and construction personnel has opportunity costs, assuming that the total opportunity cost of a project is C Yuan /d, the additional opportunity cost required according to the actual construction arrangement is shown in formula (2):

$$C_{\text{opportunity}} = C \times D_{\text{time difference}} = C\left(\frac{T_{\text{total}}}{t_{\text{total}}} - \frac{T_{\text{total}}}{24}\right) \tag{2}$$

2.5 Toll Income

There are differences between the theoretical construction days $D_{\text{theoretical}}$ and the actual construction days D_{actual}. In order to facilitate a more comprehensive comparison and analysis of toll fees between the two schemes, this paper will utilize a specific methodology. Specifically, take the D_{actual} as the reference, that is, the actual construction days are taken as the toll time calculation interval, and the difference between the toll income under the theoretical conditions and the actual conditions is calculated respectively.

Suppose that the daily toll income of the construction section is f_d, and the toll income of each hour is f_i, where, $i = 1, 2, 3 \ldots 23$.

The toll income under the theoretical mode is: $F_{\text{theoretical}} = (D_{\text{actual}} - D_{\text{theoretical}}) \times f_d$;

The toll income of the actual construction scheme is: $F_{\text{actual}} = D_{\text{actual}} f_{d'}$, where $f_{d'}$ is the daily toll income of the non-construction section.

2.6 Objective Function

There are two main economic indicators during the construction period, namely toll income and opportunity cost of construction delay. Therefore, the objective function should subtract the opportunity cost of the project from the actual toll fees, and the objective function should be maximized. The calculation method of the objective function is shown in formula (3) and (4).

$$Z = F_{\text{actual}} - F_{\text{theoretical}} - C_{\text{opportunity}} \tag{3}$$

Namely

$$Z = D_{\text{actual}} f_{d'} - (D_{\text{actual}} - D_{\text{theoretical}}) f_d - C\left(\frac{T_{total}}{t_{total}} - \frac{T_{total}}{24}\right) \tag{4}$$

3 Designing Optimization Algorithms

This problem is a discrete optimization problem. In theory, the commonly used algorithms for discrete optimization problems include the enumeration method, the branch and bound method, and the dynamic programming method [14-15]. The challenge of the discrete optimization problem is the problem of dimension explosion. However, in this study, the decision variable only has 2 dimensions, with each dimension having 24 values. Therefore, the number of solutions in the solution space solved by the model in this study is finite, that is, 24 × 24 = 576. Therefore, the enumeration method is initially adopted as the optimization algorithm for the problem. This involves solving the objective function values for all 576 schemes for each construction section. The maximum value is then selected as the optimal solution for this study. The scheme corresponding to the maximum value can be used as the optimal solution. In order to enhance visualization, the VBA programming language is used to implement the solution.

3.1 Case Analysis

3.1.1 Tangxia - Ruian.

Taking the Yongtaiwen Expressway as an example, the average daily traffic flow on a specific section, Tangxia-Ruian, is 31,000 vehicles. Among these vehicles, passenger car 1 accounts for the majority, representing 75.5% of the total number of vehicles. Truck 1 comes next, accounting for 8.61% of the total number of vehicles. The types of vehicles and costs are shown in Tables 1 and 2.

Table 1. Proportion of types of vehicles on the Tangxia - Ruian

Date	Passenger Car 1	Passenger Car 2	Passenger Car 3	Passenger Car 4	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7
20190601	74.4	0.7	1.5	0.5	8.0	1.8	1.5	0.7	9.4	0.4	1.0
20190602	72.6	0.7	1.6	0.5	9.2	1.8	1.8	0.7	9.3	0.5	1.2
20190603	73.7	0.7	1.5	0.4	10.1	2.0	1.7	0.5	8.0	0.3	1.0
20190604	72.6	0.7	1.4	0.4	10.4	2.1	1.7	0.7	8.4	0.3	1.5
20190605	72.6	0.7	1.3	0.4	10.3	1.9	1.5	0.6	8.4	0.4	1.8
20190606	77.9	0.6	1.3	0.3	8.3	1.6	1.4	0.5	6.7	0.2	1.3
20190607	84.5	0.5	1.4	0.3	4.1	1.0	0.8	0.4	6.6	0.2	0.2
Average	75.50	0.66	1.44	0.40	8.61	1.73	1.50	0.57	8.11	0.34	1.14

Table 2. Traffic flow and costs for different vehicle types on the Tangxia-Ruian South

Index	Passenger Car 1	Passenger Car 2	Passenger Car 3	Passenger Car 4	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Total
Average daily flow /Vehicle	23293	203	445	122	2658	534	463	176	2503	105	352	30852.4
Billing Standards /Yuan	3.76	3.76	6.52	9.28	4.1	6.8	10.11	12.31	12.55	13.05	10.66	-
Average daily cost /Yuan	87581	762	2902	1132	10897	3630	4686	2160	31407	1367	3754	150278

According to the charging standard for different vehicle types in the Tangxia-Ruian section, as shown in Table 2, the total daily toll for this road section is approximately 150,000 yuan. Out of this amount, the toll for passenger car 1 is around 88,000 yuan.

3.1.2 Ruian - Tangxia.

The average daily traffic flow in a specific section of Ruian - Tangxia is 27,000 vehicles. Passenger car 1 constitutes the majority of these vehicles, accounting for 79.32% of the total. Truck 1 makes up the second largest category, representing 8.27% of the total number of vehicles. The vehicle types and costs are shown in Tables 3 and 4.

Table 3. Proportion of vehicle types on the Ruian-Tangxia (%)

Date	Passenger Car 1	Passenger Car 2	Passenger Car 3	Passenger Car 4	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7
20190601	79.7	0.8	1.6	0.5	7.7	1.8	1.5	0.6	4.6	0.4	0.8
20190602	79.7	0.7	1.7	0.5	8.4	1.6	1.4	0.5	4.5	0.5	0.5
20190603	79.5	0.8	1.5	0.4	9.1	1.8	1.4	0.5	4.0	0.3	0.6
20190604	77.8	0.7	1.6	0.3	10.0	2.0	1.6	0.6	4.3	0.3	0.8
20190605	77.9	0.7	1.4	0.4	9.8	1.9	1.4	0.5	4.6	0.4	1.0
20190606	77.5	0.6	1.6	0.4	8.6	1.9	1.5	0.7	5.8	0.3	1.2
20190607	83.1	0.5	1.4	0.3	4.3	1.1	1.4	0.7	6.1	0.2	0.9
Average	79.32	0.69	1.53	0.40	8.27	1.72	1.45	0.60	4.85	0.34	0.82

Table 4. Traffic flow and costs for different vehicle types on the Tangxia-Ruian South

Index	Passenger Car 1	Passenger Car 2	Passenger Car 3	Passenger Car 4	Truck 1	Truck 2	Truck 3	Truck 4	Truck 5	Truck 6	Truck 7	Total
Average daily flow /Vehicle	21547	188	416	107	2246	468	395	162	1318	94	223	27163.7
Billing Standards /Yuan	3.76	3.76	6.52	9.28	4.1	6.8	10.11	12.31	12.55	13.05	10.66	-
Average daily cost /Yuan	81017	705	2714	997	9208	3182	3989	1997	16543	1221	2377	123950

According to the charging standard for different vehicle types in the Tangxia-Ruian section, as shown in Table 4, the total daily cost for this road section is approximately 124,000 yuan. Out of this amount, the toll for passenger car 1 is around 81,000 yuan.

3.2 Time-varying Characteristics of Traffic Flow in Sections

3.2.1 Time-varying Characteristics and Tolls of Tangxia Exit Flow.

In the daily 24-hour traffic distribution at the Tangxia entrance and exit, the traffic from 23:00 to 6:00 is very low, accounting for less than 2% of the hourly traffic. The traffic peaks at 08:00 and then gradually declines until 18:00. The toll during peak hours for the Wenzhou South-Tangxia section is 13,000 yuan, while the toll for the Ruian-Tangxia section is 9,000 yuan. Time-varying characteristics of outlet flow and toll are shown in Figure 1.

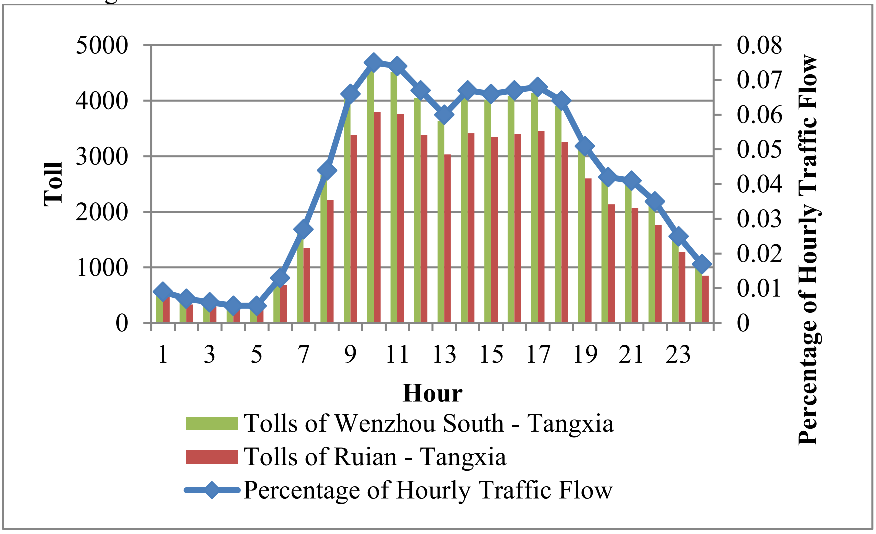

Fig. 1. Time-varying Characteristics and Tolls of Tangxia Exit Flow

3.2.2 Time-varying Characteristics and Tolls of Ruian Exit Flow.

In the daily 24-hour traffic distribution at the Ruian entrance and exit, the traffic from 23:00 to 6:00 is very low, accounting for less than 2% of the hourly traffic. The traffic peaks at 08:00 and then gradually declines until 18:00. The toll during peak hours for the Tangxia-Ruian section is 13,000 yuan, while the toll for the Feiyun-Ruian section is 4,000 yuan. Time-varying characteristics of outlet flow and toll are shown in Figure 2.

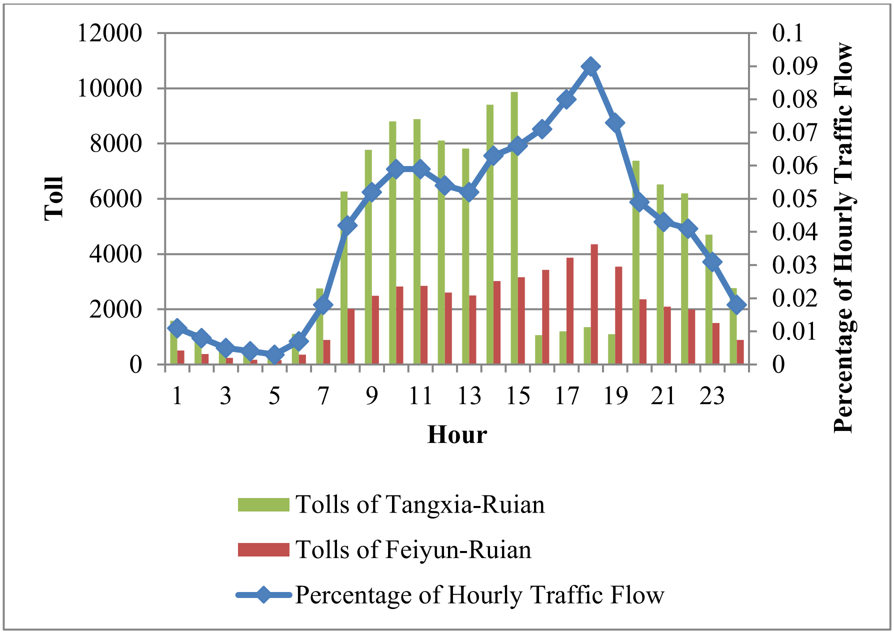

Fig. 2. Time-varying Characteristics and Tolls of Ruian Exit Flow

1) Tangxia - Ruian (Fujian direction).

After obtaining the time-varying characteristics of exit flow and toll data, the objective function formula in the model is used to calculate the construction completion value at each hour from 00:00 to 24:00. The results are obtained by traversing the closure time schemes of the Tangxia-Ruian interval (i.e., schemes with different construction time intervals), and are shown in Table 5. By comparing all the results, it can be observed that the maximum economic benefit is always achieved when construction starts between 19:00-2:00 and the construction time is 12 hours. Furthermore, the economic benefit improves as the construction start time approaches 20:00. The maximum value of the objective function is 180,000 yuan. When the construction start time is between 4:00-12:00, and the construction duration is 21 hours, the maximum economic benefit can be achieved. However, the objective function value is negative when the construction start time is between 13:00-18:00. The maximum economic benefit can be achieved when the construction time is 18 hours, and the maximum objective function value is 130,000 yuan.

To summarize, the optimal plan for this section is as follows: the road closure construction will commence at 20:00, conclude at 8:00 in the morning, and traffic will resume. The construction will be carried out for 12 hours each day. The construction duration of this scheme will be doubled compared to the 24-hour construction scheme, but the total income will increase by 180,000 yuan. If there are restrictions on the construction period, you can also choose to suspend construction between 8:00 PM and 12:00 AM. The construction operates for 16 hours a day, which can generate an additional income of 140,000 yuan.

Table 5. Calculation results of objective function values of different construction time schemes (Fujian direction)

Start time of construction	The toll difference corresponding to the end time of construction/ten thousand yuan											
	00: 00	01: 00	02: 00	03: 00	04: 00	05: 00	06: 00	07: 00	08: 00	09: 00	10: 00	11: 00
00: 00	0	-623	-260	-137	-74	-38	-13	-3	4	4	-2	-6
01: 00	-19	0	-617	-254	-132	-71	-37	-16	-12	-7	-7	-13
02: 00	-18	-19	0	-611	-249	-128	-70	-41	-28	-26	-21	-20
03: 00	-18	-19	-20	0	-608	-247	-130	-78	-57	-45	-43	-36
04: 00	-37	-18	-19	-20	0	-607	-251	-141	-98	-78	-65	-61
05: 00	-36	-38	-19	-19	-20	0	-616	-268	-168	-124	-102	-85
06: 00	-36	-37	-38	-19	-19	-19	0	-640	-305	-200	-152	-125
07: 00	-53	-35	-38	-36	-17	-17	-18	0	-690	-341	-229	-174
08: 00	-47	-48	-31	-31	-32	-13	-14	-16	0	-712	-359	-242
09: 00	-58	-41	-42	-25	-25	-26	-8	-10	-15	0	-727	-367
10: 00	-66	-50	-34	-35	-18	-19	-20	-4	-8	-14	0	-728
11: 00	-72	-58	-43	-27	-28	-12	-12	-15	-2	-8	-14	0
12: 00	-62	-64	-50	-35	-20	-21	-6	-8	-13	-2	-8	-14
13: 00	-82	-55	-56	-42	-28	-14	-15	-2	-7	-13	-3	-9
14: 00	-82	-71	-45	-46	-33	-19	-6	-9	1	-6	-13	-2
15: 00	-80	-70	-59	-34	-35	-22	-10	0	-5	2	-5	-12
16: 00	-85	-65	-55	-45	-22	-22	-12	-2	4	-3	4	-3
17: 00	-94	-67	-48	-38	-29	-8	-9	-1	3	8	0	6
18: 00	-92	-69	-44	-27	-19	-10	7	4	7	9	12	4
19: 00	-105	-70	-48	-26	-10	-3	4	17	9	10	11	14
20: 00	-132	-88	-55	-35	-13	1	6	10	18	9	9	10
21: 00	-185	-115	-72	-41	-22	-3	9	12	10	17	6	6
22: 00	-294	-163	-97	-57	-27	-10	7	15	12	8	14	3
23: 00	-640	-271	-146	-82	-45	-17	-3	10	12	7	3	9
	12: 00	13: 00	14: 00	15: 00	16: 00	17: 00	18: 00	19: 00	20: 00	21: 00	22: 00	23: 00
00: 00	2	-7	-7	-5	-2	-13	-9	-18	-24	-10	-15	-18
01: 00	-15	-5	-16	-16	-14	-12	-24	-17	-23	-28	-14	-17
02: 00	--23	-24	-15	-27	-26	-25	-23	-33	-22	-27	-32	-16
03: 00	-31	-34	-37	-26	-39	-39	-38	-32	-39	-26	-31	-35
04: 00	-49	-43	-47	-50	-38	-53	-53	-49	-38	-44	-31	-35
05: 00	-77	-63	-57	-61	-64	-52	-68	-65	-55	-44	-49	-34
06: 00	-102	-91	-77	-71	-75	-79	-67	-80	-72	-61	-48	-52
07: 00	-140	-114	-105	-90	-84	-89	-94	-77	-86	-76	-64	-50
08: 00	-181	-145	-122	-112	-98	-93	-100	-101	-78	-86	-76	-63
09: 00	-244	-181	-150	-127	-118	-106	-103	-105	-101	-77	-84	-72
10: 00	-362	-239	-183	-153	-131	-125	-115	-106	-103	-97	-74	-79
11: 00	-717	-354	-241	-187	-158	-139	-135	-118	-104	-100	-94	-69
12: 00	0	-712	-364	-250	-196	-169	-152	-141	-117	-101	-97	-89
13: 00	-15	0	-735	-379	-264	-211	-186	-160	-140	-115	-99	-92
14: 00	-8	-13	0	-742	-388	-276	-226	-191	-155	-134	-109	-91
15: 00	-1	-7	-13	0	-754	-404	-294	-230	-184	-147	-127	-100
16: 00	-10	1	-6	-13	0	-774	-425	-296	-218	-172	-136	-114
17: 00	0	-6	3	-4	-12	0	-795	-417	-273	-198	-154	-118
18: 00	11	4	-3	5	-2	-11	0	-759	-372	-239	-172	-129
19: 00	7	13	6	-2	6	-3	-12	0	-706	-340	-216	-149
20: 00	14	7	12	4	-5	2	-7	-15	0	-694	-331	-203
21: 00	8	12	4	9	0	-9	-3	-10	-15	0	-689	-318
22: 00	4	7	10	1	5	-4	-15	-6	-11	-16	0	-667
23: 00	-1	0	2	5	-5	-1	-11	-20	-8	-12	-17	0

2) Ruian-Tangxia (Taizhou direction).

After analyzing the closure time schemes of the Ruian - Tangxia section (specifically, schemes with different construction time intervals), the results obtained are presented in Table 6. Similar to the findings of the Tangxia-Ruian (Fujian direction) traversing, the results were categorized into three groups based on the start time of construction: 19:00 -- 02:00, 04:00 -- 12:00, 13:00 -- 18:00. The maximum objective function was calculated at 12h, 21h, and 18h of the construction.

The optimal plan for this section is as follows: the road closure construction will commence at 20:00, standstill at 8:00 in the morning, and traffic will resume. The construction will be carried out for 12 hours each day. The construction duration of this scheme will be doubled compared to the 24-hour construction scheme, but the total income will increase by 90,000 yuan. If there are restrictions on the construction period, you can also choose to suspend construction between 6:00 PM and 10:00 AM. The construction operates for 16 hours a day, which can generate an additional income of 60,000 yuan.

Table 6. Calculation results of objective function values of different construction time schemes (Taizhou direction)

Start time of	The toll difference corresponding to the end time of construction/ten thousand yuan											
construction	00: 00	01: 00	02: 00	03: 00	04: 00	05: 00	06: 00	07: 00	08: 00	09: 00	10: 00	11: 00
00: 00	0	-636	-273	-151	-89	-54	-30	-19	-11	-10	-16	-21
01: 00	-16	0	-629	-268	-147	-87	-54	-34	-28	-22	-22	-27
02: 00	-16	-17	0	-626	-266	-146	-89	-60	-44	-41	-36	-35
03: 00	-15	-16	-17	0	-625	-267	-150	-97	-73	-60	-58	-51
04: 00	-32	-16	-16	-17	0	-628	-272	-160	-113	-93	-80	-75
05: 00	-31	-32	-16	-16	-17	0	-637	-287	-182	-137	-116	-99
06: 00	-30	-31	-32	-15	-16	-16	0	-656	-314	-211	-163	-137
07: 00	-44	-29	-30	-30	-14	-14	-15	0	-692	-348	-239	-185
08: 00	-39	-41	-25	-26	-26	-11	-12	-14	0	-724	-373	-256
09: 00	-48	-34	-35	-20	-20	-21	-6	-8	-12	0	-741	-381
10: 00	-53	-41	-27	-28	-13	-14	-15	-2	-6	-11	0	-742
11: 00	-57	-45	-33	-20	-20	-7	-8	-11	0	-5	-11	0
12: 00	-48	-50	-38	-26	-13	-14	-2	-4	-9	0	-6	-12
13: 00	-64	-41	-42	-31	-19	-8	-9	1	-3	-9	-1	-7
14: 00	-65	-55	-34	-34	-24	-13	-2	-5	3	-3	-10	-2
15: 00	-63	-54	-45	-25	-25	-16	-6	2	-2	3	-4	-11
16: 00	-68	-52	-43	-34	-15	-16	-8	-1	5	-2	3	-4
17: 00	-78	-55	-39	-31	-23	-6	-7	-1	3	6	-1	3
18: 00	-84	-63	-41	-26	-19	-12	3	-1	2	4	6	-2
19: 00	-101	-69	-50	-29	-15	-9	-3	9	2	2	3	5
20: 00	-129	-88	-57	-38	-19	-7	-2	1	9	0	-1	0
21: 00	-182	-116	-76	-47	-29	-12	-1	1	1	7	-4	-5
22: 00	-296	-169	-104	-66	-38	-22	-7	1	0	-4	1	-9
23: 00	-649	-283	-158	-95	-58	-32	-18	-6	-2	-7	-12	-6
	12: 00	13: 00	14: 00	15: 00	16: 00	17: 00	18: 00	19: 00	20: 00	21: 00	22: 00	23: 00
00: 00	-12	-20	-18	-15	-11	-19	-12	-18	-23	-11	-14	-16
01: 00	-29	-19	-28	-26	-22	-18	-25	-17	-22	-26	-13	-15
02: 00	-38	-38	-26	-36	-34	-30	-24	-31	-21	-25	-28	-14
03: 00	-46	-47	-47	-35	-45	-43	-38	-31	-36	-24	-28	-30
04: 00	-63	-56	-57	-58	-45	-55	-51	-45	-35	-40	-27	-30
05: 00	-90	-74	-66	-68	-68	-54	-65	-59	-50	-39	-43	-29
06: 00	-114	-101	-85	-77	-78	-79	-63	-72	-64	-54	-42	-45
07: 00	-151	-124	-111	-95	-86	-88	-87	-69	-76	-66	-55	-42
08: 00	-193	-156	-129	-117	-100	-92	-92	-90	-69	-76	-65	-53
09: 00	-257	-192	-155	-130	-119	-103	-94	-93	-89	-67	-72	-60
10: 00	-374	-248	-187	-154	-129	-119	-103	-92	-89	-83	-61	-65
11: 00	-727	-362	-242	-185	-153	-130	-119	-100	-87	-83	-76	-54
12: 00	0	-716	-359	-244	-187	-157	-132	-118	-97	-83	-78	-70
13: 00	-13	0	-722	-368	-251	-194	-161	-133	-116	-94	-79	-72
14: 00	-7	-12	0	-734	-375	-259	-198	-162	-130	-112	-88	-72
15: 00	-2	-6	-12	0	-736	-381	-260	-196	-155	-123	-103	-79
16: 00	-10	-1	-6	-12	0	-746	-382	-256	-188	-146	-113	-92
17: 00	-3	-8	1	-5	-11	0	-738	-372	-242	-174	-132	-99
18: 00	4	-2	-7	1	-5	-11	0	-725	-353	-226	-158	-117
19: 00	-2	4	-1	-8	0	-6	-12	0	-702	-336	-209	-142
20: 00	4	-3	3	-3	-10	-2	-8	-13	0	-690	-323	-196
21: 00	-2	2	-5	1	-6	-13	-4	-10	-14	0	-676	-309
22: 00	-8	-5	-1	-8	-2	-10	-16	-7	-11	-14	0	-662
23: 00	-15	-13	-9	-5	-13	-7	-14	-20	-9	-12	-15	0

4 Conclusion

In response to the toll loss caused by highway occupation construction, this research have developed an optimal mathematical model that integrates the factors of highway toll, traffic flow, construction cost, and construction period to determine toll income and construction time delay. Through solving the algorithm, the optimal strategy for minimizing construction time is calculated.

The application method of the maintenance construction time optimization model is demonstrated by using the engineering scenes of Tangxia-Ruian and Ruian-Tangxia direction maintenance construction of Yongtaiwen Expressway as examples. According to the results of the case analysis, the optimal road closure construction scheme is to start construction at 20:00, stop at 08:00, resume traffic, and work for 12 hours every day. This scheme can increase the toll income of Tangxia-Ruian and Ruian-Tangxia by 183,000 yuan and 94,000 yuan respectively, while ensuring the daytime traffic capacity of the expressway.

Simply put, the optimization model proposed in this paper is a scheme for optimizing highway maintenance and construction time. It aims to effectively minimize the economic losses associated with highway maintenance and construction and provides valuable guidance.

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