Construction and Optimization of Traffic Safety Evaluation Index System for Long Downhill Tunnels of Mountain Highways

Tingjing Wang(✉)

School of Digital Construction, Shanghai Urban Construction Vocational College, Shanghai 201999, China
jianchidada@sina.com

Abstract. The traffic accident rate and severity of mountain highways in China are high. Long downhill tunnels, as important sections, greatly affect the safety of the whole highways. Therefore, it is of great theoretical and practical significance to establish the traffic safety evaluation index system for long downhill tunnels of mountain highways to ensure the traffic flow and traffic safety. This paper expounds the design principles and functions of the evaluation index system, and constructs the traffic safety evaluation index system of long downhill tunnel of mountain highway initially. Then an importance clustering analysis of each index is carried out by SPSS software. Combined with expert opinions, the evaluation index system is improved and optimized, which makes the traffic safety evaluation index system more reasonable, practical and feasible. Combined with expert opinions, the evaluation index system is improved and optimized, which makes the traffic safety evaluation index system more reasonable, practical and feasible. So this system can guide and evaluate the safety of long downhill tunnel of mountain highway more actively and effectively.

Keywords: mountain highway · Long downhill · Tunnels · Traffic safety evaluation · Index System

1 Introduction

Mountain highways have a higher bridge and tunnel ratio and more long tunnels than plain highways. In order to meet the requirements of the technical specifications of the motorway, the number of long downhill tunnels inevitably increases [1, 2]. For long downhill tunnels, due to the coexistence and interaction of long downhill and tunnel safety influencing factors, traffic accidents such as skidding, overturning and tailgating are prone to occur, which in turn cause traffic accidents such as casualties, tunnel fires and dangerous goods leakage in the tunnel, causing great danger to people's lives and property safety.[3].

The construction of a traffic safety evaluation system for long downhill tunnels can objectively and accurately reflect the current basic situation of traffic safety in long downhill tunnels of mountain highways, objectively evaluate their actual condition and

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detect potential safety problems and hidden dangers. By predicting the trend of development according to the corresponding indicators in the safety evaluation system, the accidents risk in special sections of long downhill tunnels can be effectively reduced, providing a reference for safety measures in long downhill tunnels [4, 5].

The four basic elements of road traffic - people, vehicles, roads and the environment - interact and depend on each other, and changes to any one of these factors will have an impact on road safety [6]. As a special section of the road, the traffic safety of the long downhill tunnel section is systematic, complex and dynamic, so it is also necessary to consider the impact of traffic flow and management conditions, such as traffic volume, traffic composition, transport management, etc. [7, 8].

2 Initial Construction of a Traffic Safety Evaluation Index System

2.1 Selection of the Evaluation Indicators

There are two basic methods for the selection of evaluation indicators, which are Principal Component Analysis and expert consultation method [9, 10].

Principal Component Analysis is a method of regrouping a large number of factors into a smaller number of unrelated and independent factors. The advantage of this method is that it eliminates the interaction between factors and reduces the number of indicators, thus reducing the workload. However, the disadvantage is that the new combination of factors is very demanding and must accurately reflect the actual problem.[11].

The Expert Consultation Method, also known as the Expert Survey Method, has the advantage of being simple and easy to implement, and the content of the selected indicators is more comprehensive and can give full play to the expertise of the experts. However, the disadvantage of this method is the lack of communication between experts, there is a certain degree of subjectivity and one-sidedness.

There are many factors affecting the traffic safety of long downhill tunnels on mountain highway. In order to conduct a more comprehensive analysis of relevant factors, as much as possible should be retained in the primary stage of security indicators, and then screened later. Therefore, this paper adopts the expert consultation method to preliminarily determine the evaluation indicators.

This paper presents a detailed analysis of the factors influencing traffic safety in long downhill tunnels on mountain highways, as well as consulting experts and scholars in tunnel traffic research, long downhill tunnel managers and drivers with extensive experience driving in long downhill tunnels, to initially determine evaluation indicators. The indicators thus selected are more comprehensive and reflect the actual needs of tunnel managers and users, and are of greater relevance.

In accordance with the concept of relevant traffic safety, taking into account the design principles of the evaluation index and system and the functions they should have, traffic safety in long downhill tunnels on mountain highways is divided into six subsystems, which are then classified into each specific index. The evaluation indexes with strong characterization, reliable data sources and easy access to long downhill tunnels on mountain highways are selected, and the initial proposed index system is shown in Table 1.

Table 1. Primary index system

Target Level A		Guideline Level B		Indicator Level C	
Coding	Target	Coding	Indicator	Coding	Indicator
1	A primary index system for traffic safety in long downhill tunnels on mountain motorways	1	Driver characteristics B1	1	Visual characteristics
				2	Psychological characteristics
				3	Fatigue characteristics
				4	Driver experience
				5	Driver personality
		2	Vehicle condition B2	6	Braking
				7	Vehicle Condition
				8	Handling stability
				9	Comfort
		3	Road conditions B3	10	Radius of flat curve
				11	Longitudinal slope length
				12	Longitudinal slope gradient
				13	Road surface levelness
				14	Road surface skid resistance
				15	Tunnel Length
				16	Traffic Facilities and Signal Completeness
		4	Environmental characteristics B4	17	Tunnel Lighting Brightness
				18	Tunnel noise intensity
				19	Road-scape
				20	Tunnel ventilation
				21	Weather conditions

(*continued*)

Table 1. (*continued*)

Target Level A		Guideline Level B		Indicator Level C	
Coding	Target	Coding	Indicator	Coding	Indicator
		5	Traffic flow characteristics B5	22	Traffic Volume
				23	Traffic composition
				24	Speed
				25	Headway
		6	Management characteristics B6	26	Traffic Safety Management Plan
				27	Level of traffic safety organization
				28	Emergency rescue team first aid capability

2.2 Optimization of the Evaluation Indicator System

The preliminary evaluation index system for traffic safety in long downhill tunnels on mountain highways is only a prototype of the evaluation index system. Whether the evaluation index system is scientific and reasonable, the initial selection of indicators still needs to be screened and amended again. It is necessary to consult with experts in the form of questionnaires, use SPSS software to process the data, determine the relevant importance of the initial selection of indicators, and then combine expert opinions to remove some unsuitable indicators as well as check the important indicators missed.

The basic functions of SPSS include managing relevant data, analyzing statistical results, and analyzing graphs and charts. Using SPSS software for statistical analysis, the main processes include comparison of means, general linear models, correlation analysis, regression analysis, cluster analysis, simplification of data, survival analysis and time series analysis. Depending on the objective of the analysis, the user can choose different analysis methods and parameters. The paper used SPSS software for the importance clustering analysis and, according to the relevant literature, the "shortest distance systematic distance method". The purpose of cluster analysis is to determine the importance of each factor in the indicator system to the upper level, so that the importance of each factor in each level of the evaluation indicator system can be fuzzy ranked. It can provide guidance for two-by-two importance comparison of indicators and indicator optimization in the AHP (Analytic Hierarchy Process) method.

Several factors in guideline layers B1 to B6 in Table 1 include: driver factors, vehicle condition, road factors, environmental factors, traffic flow factors and management factors. The following cluster analysis method in SPSS is used to cluster the importance of the indicators of the six factors relative to the target and criterion layers using the nearest neighbour analysis method respectively, and to determine the fuzzy ranking of the indicator factors in order of relative importance from largest to smallest.

Table 2. Fuzzy languages

Rating	Fuzzy languages
1	Some impact
2	Fairly significant impact
3	Slightly high impact
4	High impact
5	Very high impact

In the calculation of the procedure, an expert scoring matrix is used to score the importance of each factor indicator by consulting five experts (experts familiar with relevant scientific fields such as long motorway descents, tunnels and traffic safety). Referring to the relevant literature, experts scored the five fuzzy languages on a scale of 1 to 5, corresponding to the criteria in Table 2.

3 Result

The program assigned a value of 3 to n, i.e. the indicator factors were divided into three categories according to their relative importance, including important, relatively important and marginally important.

The expert scoring table for each influencing factor in the guideline tier is shown in Table 3. The cluster analysis of the factors in the criterion layer is carried out according to the expert scoring table, and the spectrum diagram obtained through the program is shown in Fig. 1. Through the spectrum diagram analysis, it is initially judged that indicators 1, 3 and 5 are important, indicators 4, 6 and 2 are relatively important, and the ranking of importance relative to the criterion layer is (1, 3 and 5) and (2, 4 and 6).

According to the expert scoring table, the clustering analysis of each indicator factor under B1 is carried out, and the spectrum diagram obtained through the program is shown in Fig. 2. Through the analysis of the spectrum diagram, taking the scale value

Table 3. Importance scoring of criterion layer.

Influencing factor	Expert scoring				
	one	two	three	four	five
Driver characteristics	5	5	5	5	5
Vehicle condition	3	4	4	4	4
Road conditions	5	5	5	5	4
Environmental characteristics	4	3	4	3	3
Traffic flow characteristics	4	5	5	5	4
Management characteristics	3	3	3	4	3

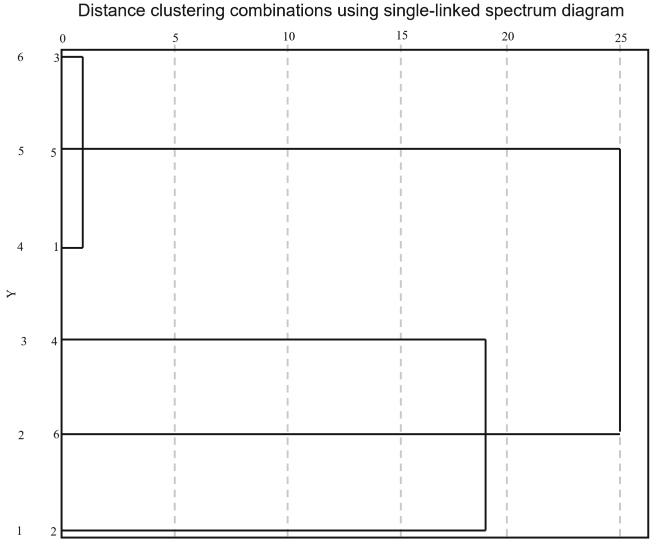

Fig. 1. The spectrum diagram of criterion layer

of 4, it is initially judged that indicators 1 and 3 are important, indicator 2 is relatively important, indicators 4 and 5 are slightly important, and the indicators are ranked as (1, 3), (2) and (4, 5) in importance relative to B1.

According to the expert scoring table, the clustering analysis of each indicator factor under B2 is carried out, and the spectrum diagram obtained through the program is shown in Fig. 3. Through the analysis of the spectrum diagram, taking the scale value of 4, it is initially judged that indicators 1 and 3 are important, indicator 2 is relatively important, indicator 4 is slightly important, and the indicators are ranked as (1, 3), (2) and (4) in importance relative to B2.

According to the expert scoring table, the clustering analysis of each indicator factor under B3 is carried out, and the spectrum diagram obtained by the program is shown in Fig. 4. Through the analysis of the spectrum diagram, it is initially judged that indicators 3, 7, 5 and 1 are important, indicators 2 and 6 are relatively important and indicator 4 is slightly important, and the indicators are ranked as (3, 7, 5, 1), (2, 6) and (4) in importance relative to B3.

According to the expert scoring table, the clustering analysis of each indicator factor under B4 is carried out, and the spectrum diagram obtained by the program is shown in Fig. 5. Through the analysis of the spectrum diagram, it is initially judged that indicators 1 and 5 are important, indicator 3 are relatively important and indicators 2 and 4 is slightly important, and the indicators are ranked as (1, 5), (3) and (2, 4) in importance relative to B4.

According to the expert scoring table, the clustering analysis of each indicator factor under B5 is carried out, and the spectrum diagram obtained by the program is shown in Fig. 6. Through the analysis of the spectrum diagram, it is initially judged that indicators 1, 3 and 2 are important, indicator 4 relatively important, and the indicators are ranked as (1, 3, 2) and (4) in importance relative to B5.

According to the expert scoring table, the clustering analysis of each indicator factor under B6 is carried out, and the spectrum diagram obtained by the program is shown in Fig. 7. Through the analysis of the spectrum diagram, it is initially judged that indicators 1 and 2 are important, indicator 3 relatively important, and the indicators are ranked as (1, 2) and (3) in importance relative to B6.

After the SPSS-based cluster analysis, the relative importance of each indicator for the long downhill tunnel can be obtained, where the indicators such as driver's personality, driver's experience, vehicle comfort, road leveling, tunnel noise, tunnel ventilation and headway time distance are of little relative importance for the long downhill tunnel system and are deleted. Finally, feedback is given to the experts to determine the indicator system after cluster analysis as shown in Table 4.

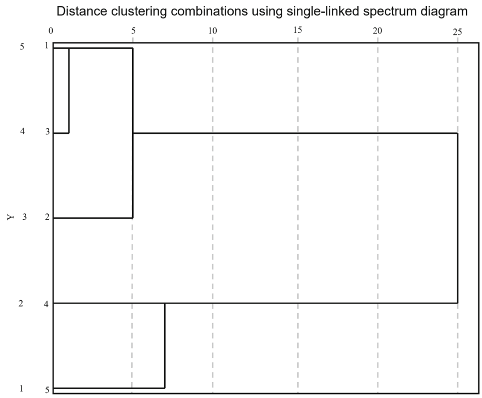

Fig. 2. The spectrum diagram of B1

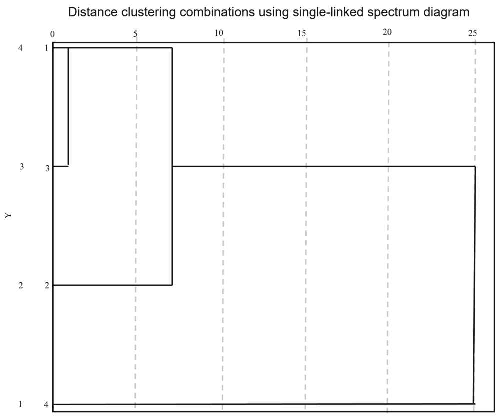

Fig. 3. The spectrum diagram of B2

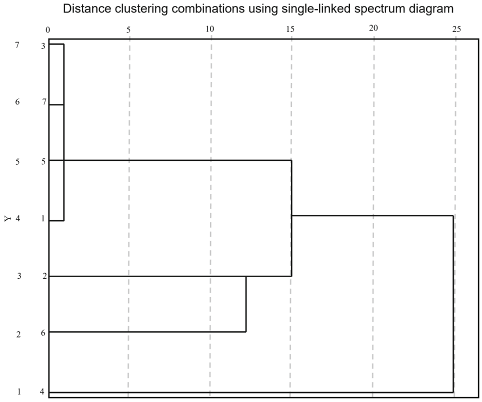

Fig. 4. The spectrum diagram of B3

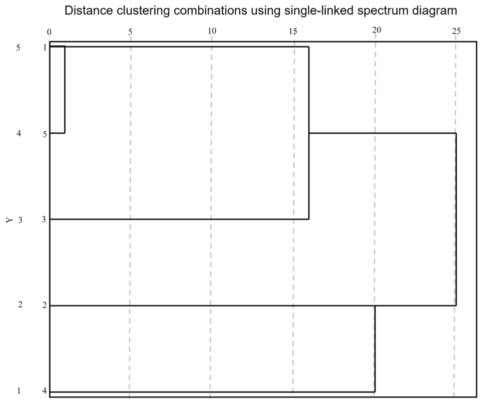

Fig. 5. The spectrum diagram of B4

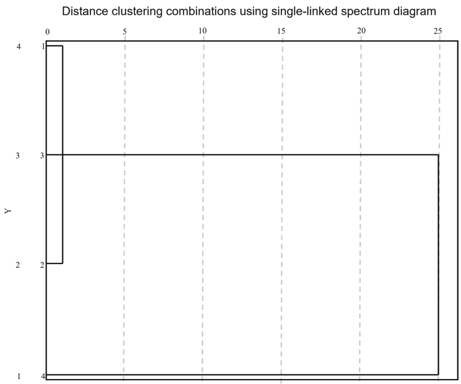

Fig. 6. The spectrum diagram of B5

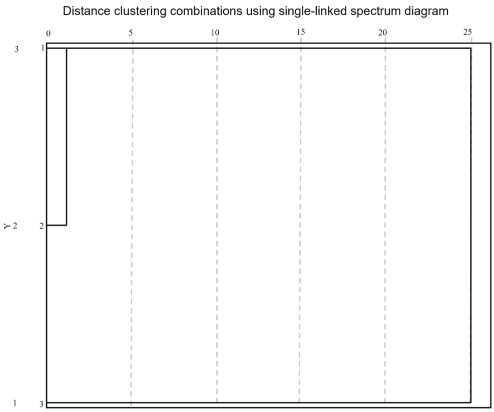

Fig. 7. The spectrum diagram of B6

Table 4. The index system established based on SPSS importance cluster analysis

Target Level A		Guideline Level B		Indicator Level C	
Coding	Target	Coding	Indicator	Coding	Indicator
1	An indicator system for long downhill tunnels on mountain highways based on SPSS importance clustering analysis	1	Driver characteristics B1	1	Visual characteristics C1
				2	Fatigue characteristic C2
				3	Psychological properties C3
		2	Road conditions B3	4	Road surface skid resistance C4
				5	longitudinal grade C5
				6	Traffic facilities and signal completeness C6
				7	Radius of flat curve C7
				8	Longitudinal slope length C8
				9	Tunnel Length C9

(*continued*)

Table 4. (*continued*)

Target Level A		Guideline Level B		Indicator Level C	
Coding	Target	Coding	Indicator	Coding	Indicator
		3	Traffic flow characteristics B5	10	Traffic Volume C10
				11	Speed C11
				12	Traffic composition C12
		4	Vehicle condition B2	13	Braking C13
				14	Handling Stability C14
				15	Vehicle Condition C15
		5	Environmental characteristics B4	16	Tunnel Lighting Brightness C16
				17	Weather conditions C17
				18	Road-scape C18
		6	Management characteristics B6	19	Traffic Safety Management Plan C19
				20	Level of traffic safety organisation C20
				21	Emergency rescue team first aid capability C21

4 Conclusions

Aiming at the problems such as limited applicability of traffic safety evaluation method and imperfect index system of mountain highway long downhill tunnel, this paper analyzes the traffic characteristics of long downhill tunnel section based on road traffic characteristics, and analyzes the influence factors of traffic safety of mountain highway long downhill tunnel on the basis of the relationship between accidents and different factors. In this paper, based on the principle of systematic, scientific and easy operation, the traffic safety evaluation index system for long downhill tunnel of mountain highway is established from six aspects: people, vehicles, highway, environment, traffic flow characteristics and management factors. Then, with SPSS software, an importance cluster analysis of indicators is carried out, combined with expert opinion screening indicators, the evaluation index system is optimized, and a scientific, reasonable, practical and feasible traffic safety evaluation index system is established.

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