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Safety and Energy Saving Evaluation Model Based on Driving Behavior of Transportation Vehicles

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ABSTRACT. *With the rapid development of road transportation industry, on the one hand, compliance with the safety norms of driving behavior has become a vital guarantee for road safety environment; on the other hand, in the new era of advocating green energy conservation, energy-saving driving can fundamentally improve the phenomenon of energy waste and environmental pollution. In order to improve the level of transportation safety management and transportation efficiency, this paper analyses the GPS data of 450 transport vehicles and driver's driving operation, calculates the weight of driving behavior by analytic hierarchy process, and establishes a comprehensive model of driving safety and energy-saving bad behavior by weighted average, and establishes a comprehensive efficiency evaluation model of safety, energy-saving and meteorological road conditions based on driving behavior.*

KEYWORDS: *Safety; Energy-saving; Analytic-hierarchy-process; Scoring-model; Score-on-meteorological*

1. Introduction

Drivers' bad driving behavior has always been the leading cause of traffic accidents, but also one of the leading reasons for the waste of resources such as high fuel consumption and severe wear and tear of vehicles. The evaluation of drivers' behaviors can help the relevant departments to strengthen supervision, urge drivers to improve their awareness of safe driving, and effectively improve road transportation safety. Therefore, this passage defines seven bad driving behaviors, including fatigue driving, rapid acceleration and deceleration, idle preheating, super-long idling, flameout taxiing, Overspeed and sudden lane changes, and takes safety bad driving index and energy-saving bad driving index as the first index, 14 specific bad behaviors as the second index, and divides them into three levels, and uses analytic hierarchy process to analyze each bad driving behavior. In order to evaluate the severity and get the weights of each item, the comprehensive scoring

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model (the higher the score, the higher the ranking, the more serious the bad driving behavior) is obtained by weighting the indicators.

At the same time, weather conditions will also have a serious impact on road safety and driver behavior. According to the real-time meteorological conditions of the corresponding vehicles, the geographical location of each area has been transformed and matched with the driving path of each vehicle to get the meteorological conditions of the day when the vehicle is running. In this passage, meteorological indicators are taken as first-level indicators, wind level, temperature, and weather as second-level indicators. The analytic hierarchy process is used to evaluate the weather severity, and the weight of each index is obtained. Finally, the meteorological model of vehicle driving is obtained, and the meteorological conditions of each vehicle are comprehensively scored (the higher the score, the worse the weather).

Finally, combined with safety and energy-saving poor driving indicators and bad weather indicators, the comprehensive driving behavior of driving vehicles is modeled. The comprehensive scores of each item are weighted again, and the final scores are obtained. The vehicle is scored and ranked (the higher the score is, the higher the ranking is, the lower the comprehensive driving safety and efficiency index is).

2. Presume and Variable Description of the Model

With the rapid development of economy and society, the number of automobiles continues to grow. Compliance with road traffic rules is even more important for every driver. Any minor mistake may evolve into a family tragedy. Therefore, in order to provide the rigor and applicability of the model of effective regulation and integrated services, the following assumptions are made:

(1) The factors affecting safe driving of transport vehicles are classified as driving time, driving environment and traffic regulations.

(2) The data collected from the trajectory are all based on facts and no one has changed it.

(3) The vehicle safety evaluation model, such as safety configuration, technical performance, maintenance status and other factors, is at a normal level.

(4) Night driving and daytime driving are treated equally.

Table 1 Variable Specification

Variable name	Illustration
T	Time difference
T_a	Time threshold
A_k	The acceleration at time k
V_k	The velocity at time k
V_a	Velocity threshold

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3. Evaluation Model of Bad Driving Behavior

3.1 Criteria of Behavior Judgment

(1) Fatigue driving: When the driver drives continuously for more than 4 hours (240 minutes) and the rest time is less than 3 minutes, fatigue driving behavior is judged.

(2) Rapid acceleration or deceleration: The act of slamming on the accelerator (brake) in the course of driving may lead to vehicle accidents and high fuel consumption. According to the acceleration, an increase (decrease) speed threshold $10m/s^2$ is introduced. When the acceleration or deceleration of the vehicle $A \geq 10m/s^2$, it is judged that the vehicle has a sharp increase or decrease behavior.

(3) Idle preheating: Idle preheating occurs when the vehicle engine starts to start up and the vehicle starts. When the speed of the transport vehicle is $V = 0$ and the ACC state is on, and the time for the continuous maintenance of the state is $3s < T \leq 60s$. That is to say, idle preheating behavior is judged.

(4) Super-long idle: idle refers to the condition of engine in idle state. Super-long idle is used to determine whether the idle time of parking is too long. Setting a time threshold $T_a = 60s$, then when the speed $V = 0$, ACC state on, idle time $T > T_a$, it is determined as super-long idle behavior. According to the results of idle preheating, when the time of its first occurrence exceeds 60 s, the number is counted once.

(5) Flameout taxiing: When the ACC state of the vehicle is off and the driving speed is $0 \leq V \leq 50km/h$, and the continuous time t of the state is more than 3s, the behavior of flameout taxiing can be judged.

(6) Overspeed: overspeed refers to the behavior of exceeding the speed stipulated by the law in the course of driving. That is to say, setting the threshold as V_a, when the speed is $V > V_a$, the overspeed is judged. According to the law, the maximum speed is set at $V_a = 100km/h$ (if the continuous overspeed time exceeds 3 seconds, it is judged to be overspeed, where 3 seconds is to prevent misjudgement caused by incoherent satellite data).

(7) Sudden lane changes: When the turning angle of the vehicle exceeds 60 degrees within three consecutive seconds, a sudden lane changes behavior is judged.

3.2 Comprehensive Evaluation of Bad Driving Behavior

(1) Analysis and Method of Problems

In order to numbering the bad behavior of each vehicle, and the evaluation of each kind of bad behavior index has different importance to the evaluation results of driver's safety and energy-saving bad driving behavior. Therefore, according to different indicators, this paper gives weight to the importance of driver's safety and

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energy-saving bad driving behavior, and then obtains the comprehensive score of each driver (the higher the score, The more serious the behavior is).

In this passage, we use AHP (Analytic Hierarchy Process) analytic hierarchy process to combine the qualitative and quantitative analysis of seven indicators, and calculate the weight of each index to the total score to get the final score.

(2) Safety and Energy Conservation Evaluation Method

According to the above seven bad behaviors, this paper divides them into safety behavior evaluation index(W1) and energy-saving behavior evaluation index(W2), as a first-level evaluation standard. The second-level indicators of safety behavior are rapid acceleration (deceleration), overspeed, fatigue driving, flameout taxiing and sudden lane changes, and the second-level indicators of energy-saving behavior are super-long idle, rapid acceleration (deceleration), idle and sudden lane changes.

Table 2 Comprehensive Criteria of Safety and Energy Saving Bad Behavior Model

Comprehensive score (The higher the score, the worse the bad driving behavior)	$\frac{(W1+W2)}{2}$

Table 3 Ahp Evaluation Index Scoring Criteria

the first level index	The Second level index	The third level index	score criterion
The Judgement of Driver's Safety Behavior W1	Rapid acceleration and deceleration	Proportion of accumulated duration of rapid acceleration and deceleration y1	$10y_1$
	Overspeed	Proportion of accumulated time of overspeed y1	$0.5\times(10000y_1+2000y_1)$
		Proportion of accumulated duration of overspeed y2	
	Fatigue driving	Proportion of accumulated duration of fatigue driving y1	$1000y_1$
	Flameout taxiing	Proportion of accumulated duration of flameout taxiing y1	$0.5\times(1000y_1+10y_1)$
		Proportion of accumulated time of flameout taxiing y2	
	Sudden lane changes	Proportion of accumulated time of sudden lane changes y1	$100y_1$
The Judgement of Driver's Energy Saving	Super-long idle	Proportion of accumulated duration of super-long idley1	$0.5\times(1000y_1+10y_1)$
		Proportion of accumulated time of super-long idle y2	
	Rapid	Proportion of accumulated duration of rapid	$10y_1$

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Behavior W2	acceleration and deceleration	acceleration and deceleration y1	
	Overspeed	Proportion of accumulated duration of overspeed y1	$0.5\times(10000y_1+2000y_1)$
		Proportion of accumulated time of overspeed y2	
	Idle preheating	Proportion of accumulated duration of idle preheating y1	$0.5\times(100y_1+10y_1)$
		Proportion of accumulated time of Idle preheating y2	
	Sudden lane changes	Proportion of accumulated time of sudden lane changes y1	$100y_1$

(3) Judgment Matrix and Final Weight

By using the 1-9 scale method and comparing the seven indicators, the discriminant matrix is obtained as follows:

$$B_1=\begin{pmatrix}1&1&2&2&1\\1&1&3&2&1\\\frac{1}{2}&\frac{1}{3}&1&\frac{1}{2}&\frac{1}{2}\\\frac{1}{2}&\frac{1}{2}&2&1&\frac{1}{2}\\1&1&2&2&1\end{pmatrix}\qquad B_2=\begin{pmatrix}1&3&\frac{1}{2}&2&3\\\frac{1}{3}&1&\frac{1}{2}&2&1\\2&2&1&3&2\\\frac{1}{2}&\frac{1}{2}&\frac{1}{3}&1&2\\\frac{1}{3}&1&\frac{1}{2}&\frac{1}{2}&1\end{pmatrix}$$

Using matlab to calculate, the weight is as follows:

$$w_1=\begin{pmatrix}0.2455&0.2655&0.1007&0.1428&0.2455\end{pmatrix}'$$

$$w_2=\begin{pmatrix}0.2770&0.1472&0.3350&0.1288&0.1119\end{pmatrix}'$$

(4) Consistency test

Finally, the consistency test is used to determine whether the weights given are reasonable. Calculate the consistency ratio C.R, and then determine the value:

$$CR=\frac{CI}{RI} \qquad (3.1)$$

$$CI=\frac{\lambda-n}{n-1} \qquad (3.2)$$

Find the corresponding RI value and get the following results: $CI_1=0.0139$、$CR_1=0.0124$、$CI_2=0.0717$、$CR_2=0.0640$ That is, the proportion of consistency is less than 0.1, and the weight is reasonable.

(5) Result analysis

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Car number	Score of overspeed	Score of Idle preheating	Score of Sudden lane changes	Score of Fatigue driving	Score of Super-long idle
AA00001	0	0.037718667	0.065190281	0.0489315	0.067813653
AA00002	0.498239305	0.193564097	0.405334532	0.0165445	0.319360156
AA00004	0	0.09672845	0.166426134	0.0573669	0.099666968
AA00036	0	0.387399965	0.184240038	0.0082716	2.744127587
AA00045	0	0.266911335	0.193927767	0.0428339	0.226631357

Score of Flameout taxiing	Score of Rapid acceleration and deceleration	Score of Safety Index	Score of Energy saving index	Comprehensive Score	Rank
0	0.069115686	0.037901696	0.041119879	0.039510787	415
0	0.084211571	0.2541397	0.338070276	0.296104988	16
0	0.117793288	0.075556188	0.076046993	0.075801591	188
0	0.044170196	0.056909521	0.837217394	0.447063458	7
0	0.094662897	0.075165528	0.132817387	0.103991458	153

Figure.1 Safety and Energy Conservation Bad Behavior Comprehensive Score (Part of Results)

The table gives the scores of each index. After giving weights, the comprehensive scores of safety bad behavior and energy-saving bad behavior are obtained respectively. Then the comprehensive scores of safety bad behavior and energy-saving bad behavior are obtained by weighting the two scores and sorted. The rules are as follows: The higher the score, the higher the ranking, the more serious the bad behavior. Among these cars, AA00036 ranks 7, and its driving is the most non-standard, its safety and energy-saving bad behavior is the most serious, while AA00001 ranks 415, its driving is the most standardized, and its safety and energy-saving bad behavior is the least.

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4. Comprehensive Model of Vehicle Driving Safety and Efficiency

4.1 Meteorological Evaluation Index

(1) Evaluation criterion

The first level index	The Second level index	Score criterion			Total score	Weight
Meteorological index W3	Wind scale y1	Level 1-5		1	0.05*sum	0.320238095
		Level 5-6		4		
		Level 7-8		6		
		Level 11-12		10		
	Weather y2	Cloudy/Overcast/Sunny		1	0.05*sum	0.557142857
		Medium/Light rain		3		
		Heavy rain/Shower		6		
		Rainstorm		8		
		Thunderstorm/Snow		10		
	Temperature y3	Maximum temperature	15-30℃	1	0.05*0.5*sum	0.122619048
			<15℃	5		
			30-35℃	8		
			35-40℃	10		
		Minimum temperature	else	1		
			>30℃	7		
			<0℃	10		

Figure.2 Ahp Evaluation Index Scoring Criteria

(2) Result analysis

Similarly, analytic hierarchy process (AHP) is used to analyze the meteorological conditions in the corresponding areas of vehicles. According to the importance of each index, a definition matrix is given, and the weight of each index is obtained. Finally, the worse the natural weather of each vehicle is obtained (the higher the score, the worse the weather). Finally, combined with the bad driving behavior evaluation model of the previous question, a comprehensive safety and efficiency model for each vehicle is given (the higher the ranking, the lower the driving safety and efficiency index).

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Table 4 Meteorological Score (Part of Results)

Car number	Score of Weather	Rank
AA00002	0.187619048	1
AB00006	0.115907133	4
AD00003	0.116795233	3
AD00013	0.140463435	2
AD00053	0.107429316	5

According to the above results, among these vehicles, AA00002 scored the highest and ranked the highest, while AF00373 scored the lowest and ranked the lowest, indicating that AA00002 experienced the worst weather conditions during driving, while AF00373 experienced the best weather conditions during driving.

4.2 The Result Analysis of Comprehensive Model

The two-question model is combined to get the final comprehensive model of safety and efficiency.

(1) The Method of Comprehensive Judgment

Table 5 Comprehensive Criteria for Safety and Efficiency Models

Comprehensive score (The higher the score, the lower the safety and efficiency index)	$CI_1 = 0.0139$、$CR_1 = 0.0124$、 $CI_2 = 0.0717$、$CR_2 = 0.0640$

(2) Result analysis

Table 6 Comprehensive Model of Safety and Efficiency (Part of Results)

Car number	Score of Safety Index	Score of Energy saving index	Score of Meteorological index	Comprehensive Score	Rank
AA00002	0.2541	0.3381	0.1876	0.2599	1
AB00006	0.0514	0.0300	0.1159	0.0658	7
AD00003	0.0254	0.0147	0.1168	0.0523	9
AD00013	0.0543	0.0531	0.1405	0.0826	6
AD00053	0.2068	0.2443	0.1074	0.1862	2
AD00083	0.1302	0.1671	0.0554	0.1176	5
AD00419	0.0507	0.0488	0.0525	0.0506	10
AF00098	0.1761	0.1695	0.0593	0.1350	3
AF00131	0.1922	0.1555	0.0554	0.1344	4
AF00373	0.0737	0.0533	0.0500	0.0590	8

The table combines the results of previous safety and energy saving bad behavior scores and natural weather scores. After giving weight, the comprehensive scores of safety and efficiency of transport vehicles are obtained and sorted. The rules are as

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follows: the higher the score is, the higher the ranking is, the lower the safety and efficiency index is. Among these vehicles, AA00002 ranks 1, and its driving safety and efficiency index is the lowest, that is, its comprehensive safety and energy-saving bad behavior and driving weather road condition safety index is the lowest, while AD00419 ranks 10, its driving safety and efficiency index is the highest, that is, its comprehensive safety and energy-saving bad behavior and driving weather road condition safety index is the highest.

5. Conclusion

In the era of rapid development of transportation, massive data are generated based on satellite positioning system. Extracting and analyzing these data to obtain valuable information is the key to improve the severe security form, energy crisis and environmental pollution brought by transportation. Based on the bad driving behaviors such as fatigue driving, acceleration, acceleration, deceleration, idle preheating, super-long idling, flameout taxiing, overspeed, abrupt change of lane and meteorological data, safety index, energy-saving index and meteorological index are defined to establish the analytic hierarchy process model. Finally, a complete set of scoring methods is given, which is of great significance for driving safety, energy saving and emission reduction.

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