

AHP Based Driving Behavior Evaluation Model

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Abstract— Driving behavior is one of the most important reasons that affect traffic safety and energy saving. In view of the management problems existing in traffic safety, it is necessary to strengthen the driver's safety and energy conservation awareness. To this end, based on the driving status information collected by the road transportation industry in the vehicle networking system, we propose a data-driven approach to dig deeper into driving behaviors that affect driving safety and energy efficiency. Among them, we used the quantitative description of idle speed preheating, overspeed, fatigue driving and other series of indicators, and combined with the AHP (Analytic Hierarchy Process) to construct a comprehensive driving safety evaluation index system. Assisting the Ministry of Transportation in managing roads more efficiently and creating a harmonious driving environment via our evaluation model.

Keywords—driving behaviors; energy-saving; analytic hierarchy process; evaluation model;

I. INTRODUCTION

With the development of science and technology and the improvement of the economic, vehicle has become a necessary part of modern society and it greatly provides convenient transportation for people. At present, the driver is still the main control body of the vehicle safety. Helping the driver to maintain a safer driving state is one of the most important research field of traffic safety^[1]. According to the data from the Ministry of Transport, the number of passenger buses operated has exceeded 0.9 million and the number of trucks operated has reached 150 million^[2]. However, an increase in the vehicle has also led to an increase in road accidents^[3], resulting in a series of irreparable tragedies. A good driving behavior not only creates a harmonious driving environment but also greatly reduces the probability of road accidents. Therefore, how to evaluate driving behavior has become a key issue.

This paper is written against this background. We conducted related research work, discovering bad driving behavior from the data. And we establish an evaluation standard based on the analytic hierarchy process, aiming to explore the evaluation model of driving behavior.

II. DATA DESCRIPTION

The data we used provided by the Automobile Transportation Center of Ministry of Transport, including 450

trucks, more than 4 million data, which features include direction angle, latitude, longitude, ACC status, speed and collection time.

A. Data Processing

- Add Unix Timestamp: The collection time format is inconsistent, some are “2018/08/01 08:01” and some are “2018/08/02 09:12:26”. Additionally, some separators are “/” and some are “-”. In order to unify time format, we add a new feature—Unix timestamp corresponding to the collection time.
- Divided Data by Day: We purpose to evaluate the driver's behavior in days, so we divided the data by day. The reasons are as follows, for one thing, it can simplify the problem we analyze, and for another, we think this is a more reasonable way to evaluate.
- Divided Data by Motion State: When we research some problems, we need to consider the motion state of the vehicle, that is, whether the vehicle is stationary or driving. So, we can choose the right data for different problems.

B. Feature Engineering

In order to explore the bad driving behaviors, we consulted relevant literature and the definition of the driving behavior used in this paper are summarized in Table I. In addition to the behaviors listed in Table I, we also consider the impact of speed stability.

TABLE I. DEFINITION OF DRIVING BEHAVIORS

Behavior	Definition
Overspeed	$v^d > 100\text{km/h}$ and $t^e > 3\text{s}$
Sharp slowdown	$a^f < -5\text{m/s}^2$ in 3s
Rapidly accelerate	$a^f > 5\text{m/s}^2$ in 3s
Fatigue driving	Driving continuously for more than 4 hours or driving more than 8 hours in 24 hours
Coasting with engine off	ACC status is off and $0 < v < 50\text{km/h}$
Long-time idle speed	ACC status is on, $v=0$ and $t > 60\text{s}$
Idle speed preheating	ACC status is on, $v=0$, $t > 60\text{s}$ and it is the first fire on the day or the previous data ACC is off

d.velocity e.duration f.acceleration

III. DRIVING BEHAVIOR ASSESSMENT

As the data sets and features of the driving behavior are prepared, in this section, we turn to introduce the details of how to build a driving behavior analysis assessment model via AHP. Taking the driving process as the entry point, the evaluation index system is divided into three levels, including the target level, the criterion level, and the scheme layer. To facilitate the understanding, we illustrate the overview of the hierarchical structure of driving behavior, as shown in Figure 1.

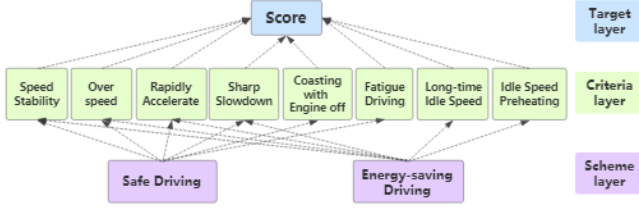


Figure 1. Overview of hierarchy structure.

A. Driving behavior assessment indicator design

In order to construct the driving safety assessment model, in addition to excavating the bad driving behavior of each transportation vehicle, it is necessary to establish a set of safety and energy saving evaluation indicators to overall rating of the vehicles. Meanwhile, we draw on other papers^[7] to build our evaluation of driving behavior to construct our scoring standard and corresponding calculation formula. The specific evaluation indicators are shown in Table II.

B. Driving behavior assessment model

After completing the assessment of driving behavior, we expect to get the driver's comprehensive score from safety and energy efficiency. Different driving behaviors have different

influences on safety and energy saving. Taking safe driving as an example, we believe that fatigued driving is more dangerous than rapid deceleration, so different driving behaviors need to be assigned different weights. Among them, this paper uses the analytic hierarchy process to deal with the problem of weight distribution.

AHP is a method for solving complex multi-objective decision problems, which is presented by an American operations researcher called T.L. Saaty in the 1970s. The following is a description of the four main steps of the method.

1) Safety and energy conservation evaluation indicators

As described in Section A, a set of safety and energy efficiency system evaluation indicators is constructed for different driving behaviors.

2) Constructing the comparison judgment matrix

In this step, we will convert the above evaluation indicators into a comparison judgment matrix. Each driving behavior has a different degree of influence on safe driving, so we compare the importance of the evaluation indicators to determine the weight.

In this paper, we use Saaty's 1-9 scale method^[8] to measure the indicators and construct a corresponding comparison judgment matrix. The content is described in Table III. Among them, the element represents the ratio of the importance of the index i and j . If its value is greater than 1, the importance of the i -th indicator is greater than j . In particular, some energy-saving evaluation indicators are similar to the safety evaluation indicators. The final comparison judgment matrix is as follows, where B1 is the comparison matrix for safe driving evaluation and B2 is the comparison matrix for energy saving evaluation.

$$B1 = \begin{bmatrix} 1 & 1/2 & 1/3 & 1 & 1/2 & 1/3 \\ 2 & 1 & 1 & 2 & 2 & 1/2 \\ 3 & 1 & 1 & 3 & 1 & 1 \\ 1 & 1/2 & 1/3 & 1 & 1/2 & 1/3 \\ 2 & 1 & 1 & 2 & 1 & 1/2 \\ 3 & 2 & 1 & 3 & 1/2 & 1 \end{bmatrix} \quad B2 = \begin{bmatrix} 1 & 1/3 & 1/2 & 1/3 & 1/2 & 1/3 \\ 3 & 1 & 2 & 1 & 2 & 1 \\ 2 & 1/2 & 1 & 1/2 & 1 & 1/2 \\ 3 & 1 & 2 & 1 & 2 & 1 \\ 2 & 1/2 & 1 & 1/2 & 1 & 1/2 \\ 3 & 1 & 2 & 1 & 2 & 1 \end{bmatrix}$$

TABLE II. SAFETY AND ENERGY SAVING CRITERIA

Criteria	Sub-criteria	Sub-Sub-Criteria
Safe driving and energy saving	Speed stability(A)	The standard deviation of speed(A1)
	Rapidly accelerate(B)	Rapidly accelerate time accumulated(B1)
		Rapidly accelerate times(B2)
	Sharp slowdown(C)	Sharp slowdown time accumulated(C1)
		Sharp slowdown times(C2)
	Overspeed(D)	Overspeed time accumulated(D1)
		Overspeed times(D2)
	Fatigue driving(E)	Fatigue driving time accumulated(E1)
		Fatigue driving times(E2)
	Coasting with engine off(F)	Time accumulated of Coasting with engine off(F1)
		Times of coasting with engine off(F2)
	Long-time idle speed(G)	Long-time idle speed time accumulated(G1)
		Long-time idle speed times(G2)
	Idle speed preheating(H)	Idle speed preheating time accumulated(H1)
		Idle speed preheating times(H2)

3) Single criterion weight calculation

In the AHP, there are methods to calculate weights such as square root method, least square method, eigenvector method,

and arithmetic average method^[9]. In this paper, we use the arithmetic average method to calculate.

TABLE III. SCALE OF RELATIVE IMPORTANCE

<i>The intensity of Relative Importance</i>	<i>Definition</i>	<i>Explanation</i>
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is favored very strongly over another; Its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For a compromise between the above values	When compromise is needed
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j , then j has the reciprocal value when compared with i	-
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

TABLE IV. VALUES OF RI AND ITS ORDER

Order	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Normalize the comparison matrix:

$$\bar{\omega}_{ij} = \alpha_{ij} / \sum_{i=1}^n \alpha_{ij} \quad (1)$$

Approximate maximum eigenvalue:

$$\lambda_{max} \approx \sum_{i=1}^n \frac{(AW)_i}{n\omega_i} \quad (2)$$

Where $(AW)_i$ represents the i -th component of the vector.

4) Verify the consistency of the judgment matrix

After obtaining the weight matrix, we need to check whether the weight is reasonable. If the allocation is unreasonable, the indicator with heavy weight will overwhelm the indicator with a less weight, which causes the indicators with a less weight to lose the meaning of existence^[10]. This verification process is called a consistency test and the calculation formula is as follows.

$$CI = \frac{\lambda - n}{n - 1} \quad (3)$$

$$CR = CI / RI \quad (4)$$

Among them, CI is called consistency index, RI is called random consistency indicator, and the specific value of RI varies

according to the order of the matrix, as shown in Table IV. CR is called the consistency ratio and is intended to evaluate whether the constructed comparison judgment matrix is reasonable.

When the consistency ratio $CR < 0.1$, the consistency of the comparison judgment matrix is within an acceptable range. If $CR \geq 0.1$, it proves that the comparison judgment matrix needs to be reconstructed.

The obtained feature vectors are as follows, where w_1 represents the weight of each indicator for safe driving, and w_2 is the weight of the energy-saving indicator.

$$\omega_1 = [0.0872 \ 0.1788 \ 0.2293 \ 0.0872 \ 0.1788 \ 0.2385]^T \quad (5)$$

$$\omega_2 = [0.0935 \ 0.2236 \ 0.1177 \ 0.2236 \ 0.1177 \ 0.2236]^T \quad (6)$$

IV. EXPERIMENTS

In this section, we will evaluate the effectiveness of the model. Specially, we use the real driving behavior data set published by the Highway Science Research Institute of the Ministry of Transport, and conduct a comprehensive evaluation of the behavior of transportation vehicles from the perspective of safety and energy efficiency. Finally, the results of the evaluation model are verified by the method of consistency test.

A. Data Pre-processing

We divide the data set according to the date and the state of motion, so as to facilitate the subsequent mining of poor driving behavior of the vehicle. In addition to the features that the dataset has, we also dig out some features that affect the stability of the vehicle. In Table I. is the definition of driving behavior.

This paper mainly describes the processing methods of these features: rapid acceleration, fatigue driving and long-time idle. For rapid acceleration, we get a copy and move up one line then subtract two tables. If the acceleration is higher than 5 within 3 seconds, it is recorded as sudden acceleration, and the duration is recorded as the time of rapid acceleration. Details are shown in Figure 2.

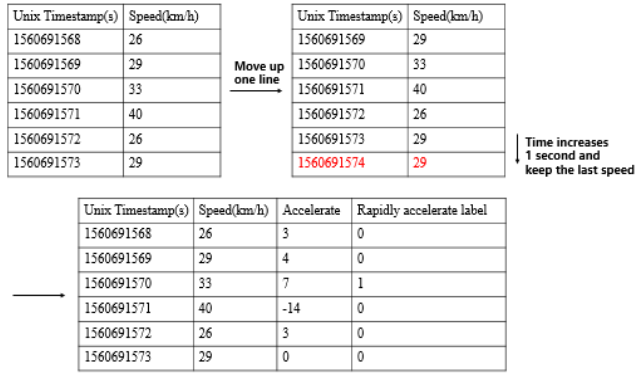


Figure 2. Rapid acceleration calculation diagram.

Fatigue driving is defined as continuous driving for more than 4 hours (less than 20 minutes during breaks) or more than 8 hours for driving within 24 hours. The schematic diagram of the calculation process is illustrated in Figure 3.

The calculation method of long-time idle speed and idle speed preheating is similar. According to the data found, there are the following behaviors: one is that the vehicle speed is 0, the other is that the ACC state is on, and the duration is more than 60 seconds, which can be regarded as long-time idle speed. Figure 3. shows the long-time idle calculation process.

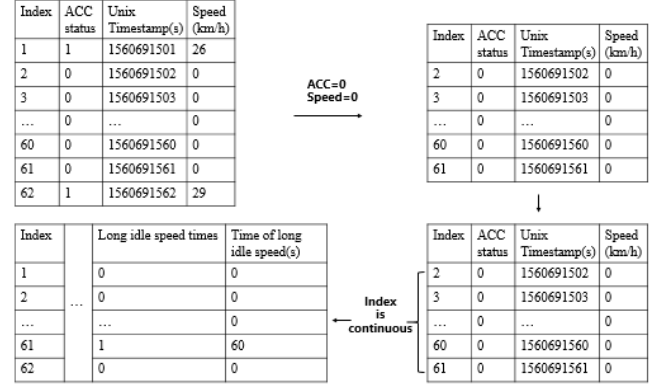


Figure 3. Long-time idle speed diagram.

B. Experimental Results

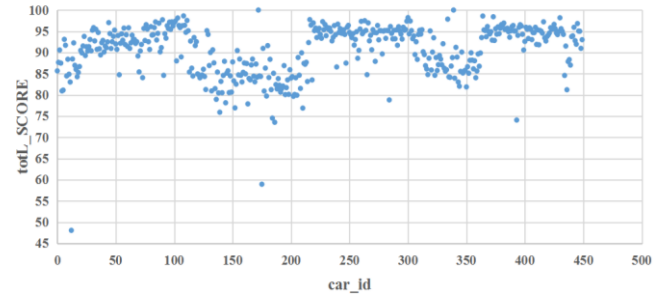


Figure 4. Driver's comprehensive score distribution map.

The experiment covered 450 vehicles with a time span of about 7 days and a total of more than 4 million detailed driving behavior records. The evaluation results of the driving behavior of 450 vehicles are shown in Figure 4. , of which 435 vehicles with 80 points and above accounted for 96.67%. In particular, the final total score is a weighted sum of the safe driving score and the energy saving driving score.

$$\text{total} = 0.5 \times \text{Security}_{\text{score}}^T \cdot w_1 + 0.5 \times \text{Green}_{\text{score}}^T \cdot w_2 \quad (7)$$

TABLE V. JUDGMENT MATRIX OF SAFE DRIVING

Safe Driving	A	B	C	D	E	F	Weight
A	1	1/2	1/3	1	1/2	1/3	0.0872
B	2	1	1	2	2	1/2	0.1788
C	3	1	1	3	1	1	0.2293
D	1	1/2	1/3	1	1/2	1/3	0.0872
E	2	1	1	2	1	1/2	0.1788
F	3	2	1	3	1/2	1	0.2385

TABLE VI. JUDGEMENT MATRIX OF ENERGY SAVING

<i>Energy Saving</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>G</i>	<i>H</i>	<i>Weight</i>
<i>A</i>	1	1/3	1/2	1/3	1/2	1/3	0.0935
<i>B</i>	3	1	2	1	2	1	0.2236
<i>C</i>	2	1/2	1	1/2	1	1/2	0.1177
<i>D</i>	3	1	2	1	2	1	0.2236
<i>G</i>	2	1/2	1	1/2	1	1/2	0.1177
<i>H</i>	3	1	2	1	2	1	0.2236

It has been verified that the CR of the safe driving behavior evaluation model is -0.016, less than 0.1, which meets the requirements of the consistency test. Besides, the CR of the evaluation model for energy-saving driving behavior is 0.002, less than 0.1, and also meets the requirements of the consistency test. Therefore, we believe that the indicator weight setting of the evaluation model is reasonable. Table V and Table VI are the weights of the evaluation indicators for safety and energy saving.

CONCLUSION

Based on the data provided by the Ministry of Transport, this paper draws from the definition and evaluation methods of bad driving behavior in China, digging out the bad driving behaviors. Combing the analytic hierarchy process to establish an evaluation model for the driver, we can transform driver assessment issues that are not easily straightforward into qualitative and quantitative problems. Therefore, it can objectively, scientifically and comprehensively reflect the driver's driving behaviors.

In the future, we will consider more factors affecting driving safety and energy saving. The exists data can't reflect whether the driver is drunk driving or whether he runs a red light. This is the defects of the data affect the model. So, if we could get more comprehensive data, we will try to evaluate the driver behaviors in all aspects.

REFERENCES

- [1] D. Zhong. "Vehicle State Recognition and Driving Behavior Assessment Based on VANET" M. D. dissertation, South China University of Technology, Guangzhou, Guangdong, China, 2015.
- [2] Road freight volume in January, Feb. 20, 2019. [Online]. Available: http://xxgk.mot.gov.cn/jigou/zhghs/201902/t20190220_3167857.html. [Accessed: Apr. 19, 2019].
- [3] J. Y. Yin, "Correlation analysis between driver's driving skills and accident propensity", *Auto Time*, vol. 15, pp. 39-40, Apr. 2019.
- [4] W. Ping, W. Wei, W. Zhenhua and L. Xianqing, "Evaluation of eco-driving behavior of taxi drivers", *Journal of Transportation Engineering*, vol. 18, pp. 41-44, Dec. 2018.
- [5] G. B. Ling, "Analysis of unsafe behavior of car drivers", *Auto Driving & Service*, vol. 2, pp. 80-82, Jun. 2018.
- [6] K. L. Zheng, "Human Factors in Causation of Traffic Accidents", *China Safety Science Journal*, vol. 23, pp. 28-34, Jan. 2013.
- [7] X. Jie. "Driving behavior safety and energy saving evaluation method based on safety production management data of road transportation enterprises" M. D. dissertation, Beijing Jiaotong University, Beijing, China, 2016.
- [8] T. S. Saaty, "Decision making with the analytic hierarchy process", *Int. J. Services Sciences*, vol. 1, pp. 83-98, Jan. 2018.
- [9] D. Xue, L. Jiaming and Z. Haojian, "Analysis and Application of Weight Calculation Method of Analytic Hierarchy Process", *Journal of Mathematics in Practice and Theory*, vol. 42, pp. 93-100, Apr. 2012.
- [10] Z. Jianjun. "Research and Application of Several Problems in Analytic Hierarchy Process" Ph. D. dissertation, Northeastern University, Shenyang, Liaoning, China