

# Research on Multi-level Comprehensive Evaluation Method of Special Vehicle Driving Skill

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**Abstract.** In view of the current issues in selection and assessment system of the special vehicle driver, taking the special vehicle driving skills as the research object, on the basis of analyzing the special vehicle driver training examination outline, in accordance with the principles of index selecting, using The Analytic Hierarchy Process (AHP) to determine the index weight, according to the principle of grey comprehensive evaluation method, this thesis establishes the evaluation model of the special vehicle drivers' driving skill and gives examples to testify its validity and exactness, which has a realistic significance to improve the quality and effectiveness of the selection of drivers.

## 1. Introduction

Special vehicle equipment is a non-general equipment vehicle, taking the car as a carrier, equipped with special and professional equipment, which is equipped with a special purpose vehicle. With the constant development of our military's armaments and equipment, troops are continually equipped with a large number of high, sophisticated and apex armed forces and many special vehicles that are equipped with large-scale weapons and equipment have emerged, so troops' requirements of the number and quality of the special vehicle drivers have increased. According to statistics from relevant departments, the number of annual military accidents accounts for about 58% of the total number of military accidents and the death toll accounts for more than 30% [1]. Vehicle accidents are mainly affected by the four elements of people, car, road and environment, among which the factor of people, especially the driver, is the first. About 80 to 90 percent of traffic accidents are related to human behavior [2], especially for drivers, who are the main perpetrators of traffic accidents due to their poor driving skills. Therefore, in order to prevent traffic accidents in military vehicles and enhance the combat effectiveness of the armed forces, we should first of all strengthen the scientific selection of pilots.

The main task of a special vehicle driver is to realize the displacement of a person or a weapon or equipment by driving a special vehicle within a prescribed time. For those engaged in motor vehicle driving, obtaining the driving license of the corresponding vehicle is the minimum standard for driving skill requirements. While the driving operation of special vehicle has its particularity and driving safety is very important, the driving skill of the driver must undergo more rigorous assessment and evaluation. However, there is a lack of scientific and reasonable selection and evaluation system for special vehicle drivers.

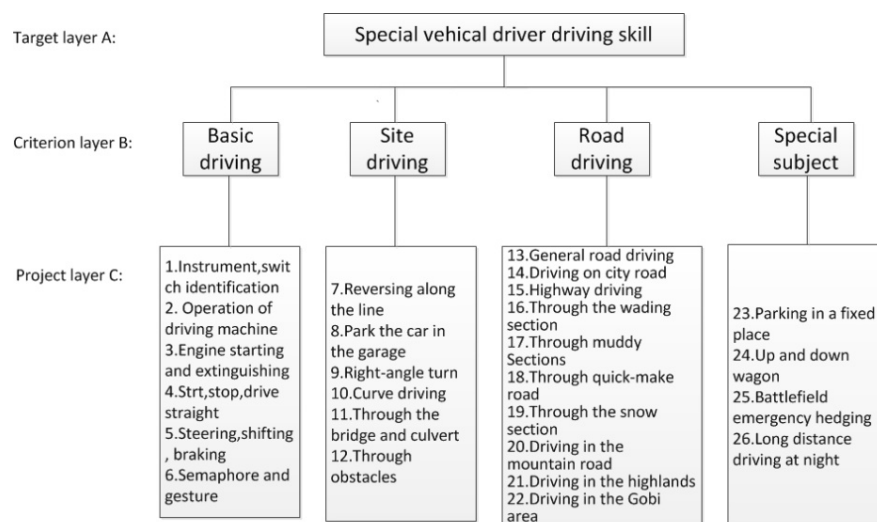
Driving skill assessment is a multi-level and multi-objective comprehensive evaluation problem. At present, the analytic hierarchy process (AHP) only compares the individual index values when



establishing the judgment matrix. However, there is an uncertain relationship between the various factors in the complex system, which is essentially a kind of gray relationship. Gray system theory extracts valuable information to make a correct judgment of the system operating status by the generation and development of some known information with uncertain system as the research object [3]. Analytic Hierarchy Process (AHP) provides an effective solution to determine the weight of each evaluation index, which makes up the deficiency of gray theory. Therefore, gray analytic hierarchy process can not only adapt to the actual decision-making process with less information, more indicators and more objectives, but also make full use of gray information to integrate expert experience into decision-making and transform qualitative analysis into quantitative analysis [4]. Therefore, based on the advantages of gray analytic hierarchy process (AHP) and the full consideration of the related problems in the process of evaluating the driving skills of special vehicles, we put forward using the grey analytic hierarchy process (AHP) to establish a comprehensive evaluation system of driving skills and screen out the driver with excellent driving skill and suitable for battlefield driving, Which is of great significance to improve the combat effectiveness and mobility of the troops.

## 2. Establish a hierarchical model.

The special vehicle has strong maneuverability, difficult operation, bad driving environment and high driving accuracy requirements. In addition to mastering basic driving, field driving and road driving, the driver should also be familiar with the special subject of battlefield environment and practical requirements. According to the special vehicles driving operation requirements and analytic hierarchy process' way of solving problem, the driving skills are decomposed into different driving modules, and hierarchical clustering is formed on the basis of the mutual influence and subordination of the modules, forming a hierarchical and orderly hierarchical structure model. As shown below is the AHP model that we establish [5-6].



**Figure 1.** Special vehicle driver's driving skills assessment model

## 3. Constructive judgment matrix

Using the 9 scale method, the judgment matrix was constructed according to the training schedule and the importance of each factor. The judgment matrix indicates that the relative importance of the factors related to this level in allusion to a certain factor in the previous level. The results of judging matrix and consistency test are as follows.

**Table 1.** A-B Judging Matrix  $A_b$ 

A	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>
B <sub>1</sub>	1	1/2	1/2	1/3
B <sub>2</sub>	2	1	1	1/2
B <sub>3</sub>	2	1	1	1/2
B <sub>4</sub>	3	2	2	1

Where,  $b_{ij}$  is for A, the value of  $B_i$  to  $B_j$ 's relative importance shows that usually  $b_{ij}$  takes 1, 2, 3... 9 and their reciprocal.

By using the square root method, we solve out the single hierarchical ranking weight vector of layer 2 to 1 factors (i.e. the criterion layer to the target layer) and carry out the consistency test. From the judgment matrix  $A_b$ :

$$W_1 = 0.537, \bar{W}_2 = 1, \bar{W}_3 = 1, \bar{W}_4 = 1.861$$

The square root vector is normalized, and the characteristic vector  $W_a$  is obtained by  $W_i = \frac{\bar{W}_i}{\sum_{i=1}^n \bar{W}_i}$ :

$$W_a = [0.122, 0.227, 0.227, 0.423]^T$$

Calculate the maximum characteristic root of  $A_b$ , which can be obtained from  $\lambda_{\max} = \sum_{i=1}^n \frac{(AW)_i}{nW_i}$ :

$$\lambda_{\max} = 4.0115$$

In order to verify the consistency of the matrix, it is necessary to calculate its consistency index CI and define:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

Obviously, when the judgment matrix is completely consistent,  $CI = 0$ . The greater the CI, the worse the consistency of the matrix. In order to test whether the judgment matrix has satisfactory consistency, it is necessary to compare the CI with the average random consistency index RI. For 1~9th order matrix, the RI value is shown in table 2.

**Table 2.** The Average Random Consistency Index for 1~9th Order Matrices

Order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Thus:

$$CI = 0.0038$$

From the table,  $RI = 0.90$ .

So:

$$CR = \frac{CI}{RI} = 0.0042 < 0.1$$

Therefore, the judgment matrix has satisfactory consistency.

In the same way, we can find out the single hierarchical ranking weight vector of layer 3 to 2 factors, and then carry on the judgment. The calculation result is: the third layer on layer 2 factors of judgment matrix is consistency matrix.

#### 4. Index weight ranking

Using the results of single rankings of all levels in the same level, we can calculate the weights for the importance of all the factors in this hierarchy for the last level, which is the total ranking of the layers. The total ranking of the layers needs to be done layer by layer from top to bottom. For the second layer below the top layer, the overall ordering of the layers is the total ordering. We assume that the total ranking of all the factors  $A_1, A_2, \dots, A_n$  in the previous level has been completed, and the weights obtained are  $a_1, a_2, \dots, a_n$ , so the result of the ranking factors  $B_1, B_2, \dots, B_m$  of the level factors corresponding to  $a_i$  is

$$b_{i1}, b_{i2}, \dots, b_{im}$$

Here, if  $B_j$  has nothing to do with  $A_i$ , we can draw  $b_{ij} = 0$ . The total hierarchy is shown in table 3.

**Table 3.** Hierarchical Total Ordering

Layer A	$A_1$	$A_2$	$\dots$	$A_n$	The total order of layer B
	$a_1$	$a_2$	$\dots$	$a_n$	
$B_1$	$b_{11}$	$b_{12}$	$\dots$	$b_{1n}$	$\sum_{i=1}^n a_i b_{1i}$
$B_2$	$b_{21}$	$b_{22}$	$\dots$	$b_{2n}$	$\sum_{i=1}^n a_i b_{2i}$
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
$B_m$	$b_{m1}$	$b_{m2}$	$\dots$	$b_{mn}$	$\sum_{i=1}^n a_i b_{ni}$

At present, we have calculated the relative importance weight  $W_a$  of the criterion layer to the target layer and the relative importance  $W_{b1}, W_{b2}, W_{b3}, W_{b4}$  of the project layer to each criterion layer, and the factors of each project layer are complete and only related to the corresponding criterion layer, which is independent of the other criteria layer. Namely, the weight of other criteria layer is 0. Therefore, according to the total ranking of the layers, we can calculate the relative importance weights or the relative priorities of the project layer relative to the target layer [7].

$$\begin{aligned} W_a &= [a_1, a_2, \dots, a_4] \\ W_{b1} &= [b_1, b_2, \dots, b_6] \\ W_{b2} &= [b_7, b_8, \dots, b_{12}] \\ W_{b3} &= [b_{13}, b_{14}, \dots, b_{22}] \\ W_{b4} &= [b_{22}, b_{23}, \dots, b_{26}] \end{aligned}$$

Thus  $X = [a_1 b_1, a_1 b_2, \dots, a_1 b_6, a_2 b_7, \dots, a_2 b_{12}, \dots, a_4 b_{22}, \dots, a_4 b_{26}]$ .

In the same way, the calculation results of the total hierarchical ranking should be tested for consistency, and the test results are as follows: the whole satisfies the consistency.

#### 5. Grey comprehensive evaluation

Since there are many qualitative and unstandardized indexes in the three-level index  $X_j$ , it is difficult to get accurate results, so the score of the indicator is obtained in the form of expert scoring. According to the training assessment outline, the assessment results mainly take "excellent, good, pass, failed" four-level system. The provisions of 10 ~ 9 is divided into "excellent", 9 ~ 7 is divided into "good", 7 ~ 5 is divided into "pass", 5 is divided into "failed". This standard is used to organize experts to grade the index  $X_j$ . For indicators that can give a definite numerical result, the original data of the evaluation index

can be directly converted into scores based on expert knowledge, so that the values of all three-level indicators  $X_{ij}$  can be obtained.

Let  $F^* = [d_1^*, d_2^*, \dots, d_m^*]$ , where  $d_j^*$  ( $j = 1, 2, \dots, m$ ) is the optimal value of the  $j$ th index. This optimal value can be the optimal value of the scheme (If the large value of a certain index is good, the maximum value of the index in each scheme is taken. If the small value is good, the minimum value of each scheme is taken. ), or the optimal value recognized by the evaluator. When determining the optimal value, it is necessary to consider the advanced nature, but also to consider the feasibility. Considering that other objective factors such as different driving venues will affect the performance of the assessment subjects, we will take the best value of all the assessment results.

After selecting the optimal set of indicators, we can construct matrix  $D$ :

$$D = \begin{bmatrix} d_1^* & d_2^* & \cdots & d_m^* \\ d_{11} & d_{12} & \cdots & d_{1m} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nm} \end{bmatrix} \quad (2)$$

In the formula,  $i$  takes the number from 1 to the number of drivers ( $n$ ),  $j$  from 1 to the number of subjects ( $m$ ) that the driver needs to examine, and  $d_{ij}$  represents the  $i$ -th driver's  $j$ th subject's scores.

Since the evaluation indexes usually have different dimensions and orders of magnitude, they cannot be directly compared. In order to ensure the reliability of the results, the original index values need to be standardized, namely data dimensionless. The commonly used non-dimensional treatment methods are averaged, initialized and normalized. Here we mainly use "data averaging" to deal with. Data averaging is to use the average of each column of the matrix  $D$  to remove all the data in the column, resulting in a dimensionless new sequence whose data is greater than zero. After averaging, the original value matrix  $D = [d_{ij}]$  is dimensionless matrix  $E = [v_{ij}]$ . In the formula,

$$V_{ij} = \frac{d_{ij}}{\bar{d}_j} \quad (3)$$

In the formula,  $\bar{d}_j = \frac{\sum_{i=1}^n d_{ij}}{n+1}$ ,  $j = 1, 2, \dots, m$ .

According to the grey system theory, with the best indicator set  $\{V^*\} = [v_1^*, v_2^*, \dots, v_m^*]$  as the reference sequence, with  $\{V\} = [v_{i1}, v_{i2}, \dots, v_{im}]$  as the comparison sequence, The correlation coefficient  $\xi_i(j)$  between the  $i$ th driver's  $j$ th index and the  $j$ th optimal index was obtained by correlation analysis method. That is

$$\xi_i(j) = \frac{\min_{i,j} \min |v_j^* - v_{ij}| + \rho \max_{i,j} \max |v_j^* - v_{ij}|}{|v_j^* - v_{ij}| + \rho \max_{i,j} \max |v_j^* - v_{ij}|} \quad (4)$$

In the formula,  $i = 1, 2, \dots, n$ ,  $j = 1, 2, \dots, m$ ; (for the resolution coefficient, the value is generally taken  $\rho = 0.5$ ) in  $[0, 1]$ .

$$RI = \sum_{j=1}^m X_j \xi_i(j) \quad (5)$$

In the formula,  $r_i$  represents the grey correlation between the  $i$ th driver and the ideal driver.

If the degree of correlation  $r_i$  is the largest, then  $\{V_i\}$  is closest to the optimal indicator  $\{V^*\}$ . That is to say, the  $i$ th driver's driving skill is superior to other drivers, so according to this, the order of the driver's driving skill can be concluded.

## 6. Model validation

We randomly selected the test scores of the four drivers, as shown in table 4.

**Table 4.** Driver's test scores and the best value

Personnel item	driver 1	driver 2	driver 3	driver 4	The optimal value
1	10	9	8	9	10
2	8	9	9	10	10
3	9	7	9	9	9
4	7	8	6	8	8
5	8	6	7	8	8
6	8	8	9	8	9
7	90	80	90	80	90
8	70	80	80	90	90
9	80	90	70	80	90
10	90	95	80	80	95
11	80	80	90	85	90
12	80	85	95	70	95
13	90	95	80	90	95
14	90	80	75	80	90
15	80	70	95	90	95
16	80	90	70	90	90
17	80	85	90	80	90
18	80	80	90	90	90
19	80	85	70	80	85
20	80	80	70	70	80
21	80	70	90	70	90
22	90	85	80	80	90
23	80	80	90	85	90
24	80	85	90	90	90
25	9	7	7	9	9
26	7	9	8	8	9

If we sum up the achievements of the four drivers, then

$$X1= 1546, X2= 1558, X3= 1558, X4= 1549,$$

Then the ranking of driving skills is

$$X2 = X3 > X4 > X1$$

Using hierarchy grey comprehensive assessment method to deal with assessment results sorting, through expert consultation and by using the analytic hierarchy process (ahp) to determine the weight of each evaluation factor, the weights arranged by the order of the project level evaluation indexes are as follows:

$X = [0.01525, 0.01525, 0.01525, 0.0305, 0.0305, 0.01525, 0.028375, 0.05678, 0.028375, 0.05678, 0.028375, 0.028375, 0.0141875, 0.0141875, 0.028375, 0.0141875, 0.0141875, 0.0425625, 0.0141875, 0.028375, 0.028375, 0.028375, 0.158625, 0.1065, 0.1065, 0.052875]$

We use data averaging to do a non-dimensional treatment of the results of the table. That is, divide the average value of each column by all the values in the table to eliminate errors of different orders of magnitude, and then calculate the gray correlation coefficient.

According to the calculation formula of gray relational degree, for the appraiser 1, the difference between the minimum difference of two levels and the maximum difference of two levels are as follows:

$$\min_i \min_j |V_j^* - V_{ij}| = 0, \max_i \max_j |V_j^* - V_{ij}| = 0.2941$$

Take  $\rho = 0.5$ , then:  $\xi_1(1) = 1, \xi_1(2) = 0.2174, \dots$ , In the same way, the correlation coefficient of the other appraisers is calculated. The results are as shown in table 5.

**Table 5.** The correlation coefficient between the assessment items and the optimal value

Personnel item	driver 1	driver 2	driver 3	driver 4
1	1.000	0.575	0.217	0.575
2	0.217	0.575	0.575	1.000
3	1.000	0.387	1.000	1.000
4	0.521	1.000	0.352	1.000
5	1.000	0.352	0.387	1.000
6	0.553	0.553	1.000	0.553
7	1.000	0.558	1.000	0.558
8	0.376	0.547	0.547	1.000
9	0.558	1.000	0.376	0.558
10	0.721	1.000	0.463	0.463
11	0.556	0.556	1.000	0.714
12	0.455	0.556	1.000	0.333
13	0.726	1.000	0.469	0.726
14	1.000	0.550	0.449	0.550
15	0.457	0.336	1.000	0.716
16	0.553	1.000	0.382	1.000
17	0.556	0.714	1.000	0.556
18	0.457	0.457	1.000	1.000
19	0.702	1.000	0.440	0.702
20	1.000	1.000	0.528	0.528
21	0.553	0.382	1.000	0.382
22	1.000	0.714	0.556	0.556
23	0.556	0.556	1.000	0.714
24	0.561	0.719	1.000	1.000
25	1.000	0.376	0.376	1.000
26	0.376	1.000	0.547	0.547

Calculate the ultimate correlation degree of multi-level evaluation system.

By  $r_i = \sum_{j=1}^m X_j \xi_i(j)$ ,  $r_1 = 0.65315$ ,  $r_2 = 0.64329$ ,  $r_3 = 0.72128$ ,  $r_4 = 0.76301$ , and the order of the correlation degree is

$$r_4 > r_3 > r_1 > r_2$$

Therefore, the driver's driving skill is from high to low, which is driver 4, driver 3, driver 1 and driver 2.

It can be seen from the above calculation process and results that the traditional method of simple summation cannot highlight the importance of special skills required to drive a special vehicle, and the comparison of scores is inaccurate due to different orders of magnitude in the data. The multi-level gray comprehensive evaluation method overcomes these shortcomings and at the same time can reasonably change the weights of evaluation factors according to the actual situation, thereby highlighting the importance of certain assessment items and having the advantages of simple operation, high efficiency, less required data and clearly reveal the problem and so on. And with the help of computers, a large number of drivers can be evaluated, so it is an easy to implement method.

## 7. Conclusion

Using the analytic hierarchy process and the gray comprehensive evaluation method, the weight of the driving skill evaluation index system for the special vehicle driver is determined by means of data calculation tools. Finally, the evaluation model is established and the feasibility of the model is verified, which can provide an important basis for the assessment selection of special vehicle drivers. At the same time, it is of great practical significance to fully understand the current causes of the problems that restrict the quality of driver training, follow the rules of training, innovate group training mode, play a leading role in theory, and improve the practical training level of special vehicle drivers.

## References

- [1] Mingyu Yang, Chengyi Ruan, Yesheng Du. Causes of Traffic Accidents in Military Vehicles and Countermeasures [J]. Traffic Engineering and Technology for National Defense. 2007(4): 121-123.
- [2] Fei Li, Zhentao An, lilei Qi, et al. Evaluation of military driver 's suitability [J]. Journal of Ordnance Equipment Engineering. 2010, 31 (7): 71-74.
- [3] Huaren Zhou, Cheng Zhang, Song Mu. Comprehensive Evaluation Method and Its Military Application [M]. Peking: Tsinghua University Press, 2015
- [4] Sifeng Liu, Naiming Xie. Gray System Theory and Its Application [M]. Peking: Science Press, 2008 .
- [5] Zheng Tang, Chao Sun, Zongwei Liu, et al. Efficiency Evaluation of Hydroacoustic Countermeasure System Based on Gray Analytic Hierarchy Process [J]. Acta Armamentarii, 2012, 33 (4) : 432-436.
- [6] Huatang Shi, Rongbin Liao. Construction Organization Comparison and Selection Based on Gray AHP Method [J]. Highway Engineering, 2012, 12 (6): 161-165.
- [7] Fuliang Jiang, Keping, Zhou, Changshan Li, et al. Geological Environment Impact Assessment of Gypsum Mines Based on Analytic Hierarchy Process and Gray Comprehensive Evaluation [J]. China Safety Science Journal, 2009, 19(3): 125-131.