

FAHP-BASED SINGLE-MOUNTED FIRE STRIKE CAPABILITY MODELING STUDY

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Abstract: Modern war forms are constantly evolving, and new types of weapons are emerging one after another, but the ground assault force represented by tanks and armored vehicles is still the main combat equipment. This paper focuses on the tanks and armored vehicles with fire strike capability, builds the index system of single-mounted fire strike capability, determines the weight of the indexes by using fuzzy analytic hierarchy process (FAHP), establishes the assessment model of the single-mounted fire strike capability of the ground assault force, improves and optimizes the real-war maneuver, makes the maneuver effect close to the real war, and provides support for the realization of the autonomous search, decision-making and striking against the enemy targets.

Keywords: FAHP; Single-mounted firepower; Assessment indicator system; Strike capability

1 INTRODUCTION

Modernized war patterns are constantly evolving, and quantitative maneuver of the combat process is needed before the initiation of combat. Single-mounted weapon system is the basic unit of simulation, and its data accuracy is directly related to the accuracy of the results of the maneuver, so the maneuver should be a combat single-mounted autonomy to attempt the combat mission as the goal, to achieve the effect of autonomous search and decision-making to strike the enemy target. In this paper, based on the effect of single-mounted weapon system strikes in the actual war environment, the degree of destruction caused to the target from the discovery of the target to the launch of one or more rounds of artillery shells within a unit of time, as a basis for evaluating the strength of single-mounted fire striking capability of the ground assault force, the fuzzy analytic hierarchy process (FAHP) is used to evaluate the various stages of tank combat from discovering the target to tracking and aiming at the target to destroying the target, to establish a set of assessment models of the single-mounted fire striking capability of the ground assault force, to enhance the realism of combat simulation, and to assist the commanders of the basement armored detachments in simulating the war process and decision-making [1-2].

2 SINGLE-MOUNTED FIREPOWER STRIKE CAPABILITY AND ITS CHARACTERISTICS

Single-mounted fire strike capability is a modern military force with strong fire destructive capability, coordinated operation capability, rapid reaction capability battlefield adaptability, and is one of the important forces in modern war. Specifically, single-mounted fire strike capability refers to the ground assault force in different combat environments, the use of a single vehicle's artillery, machine guns, information equipment, reconnaissance equipment, fire control systems, protective devices, maneuvering devices, and other types of weaponry on the target to implement the ability to fire strike, which mainly contains the fire destruction capability, coordinated operation capability, rapid reaction capability, battlefield adaptability, as shown in Figure 1.

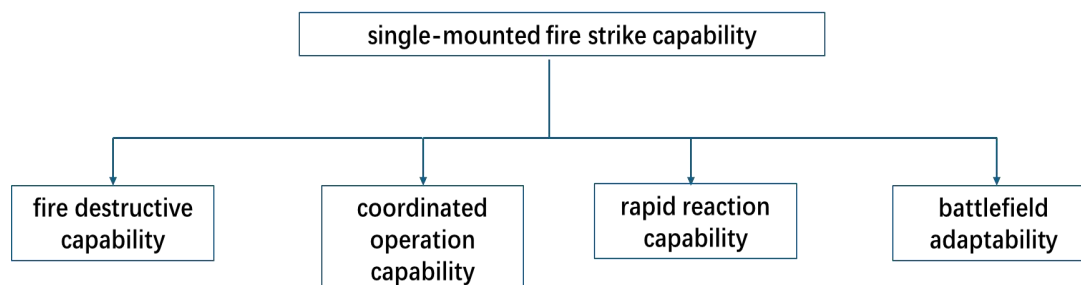


Figure 1 Schematic of Single-Mounted Fire Strike Capability

3 INDICATOR SYSTEM FOR ASSESSING THE FIRE-STRIKE CAPABILITY OF SINGLE-MOUNTED WEAPON SYSTEMS

Single-mounted equipment refers to the main weaponry on a single vehicle of the ground assault force, which directly determines the fire-strike capability of a single vehicle. The establishment of the indicator system is the fundamental

work of assessing the fire strike capability, as the evaluation standard of the single-mounted fire strike capability of the ground assault force, it has an important status in the assessment, which is directly related to the rationality and accuracy of the assessment results. Therefore, when constructing the index system, it needs to be subdivided into multiple aspects in order to comprehensively integrate the single-mounted strike capability [3-4].

This paper takes tanks as the main body to study the single-loaded fire strike capability, tanks as the main fire assault equipment on the ground at present, the factors affecting the fire strike capability of the region, personnel, environment, equipment situation, etc., but the general analysis, the main determining factors are the three aspects of projectile striking effect, shooting time, and probability of destruction. Therefore, the first-level evaluation index of firepower striking capability can be divided into projectile striking effect, shooting response time, and probability of destruction. Each level of evaluation indicators can be divided into a number of sub-indicators, i.e., secondary evaluation indicators (see Figure 2), of which the first-level evaluation indicators of the effectiveness of projectile strikes can be divided into the type of artillery shells, caliber of artillery, protection capabilities, environmental factors; the first-level evaluation indicators of the firing response time can be divided into the detection capability, the fire control system, the tracking ability; the first-level evaluation indicators of the probability of destruction can be divided into: the shooting mode, the distance, the quality of the combatants, the mobility ability. The probability of destruction can be divided into: firing mode, distance, quality of combatants, maneuvering ability.

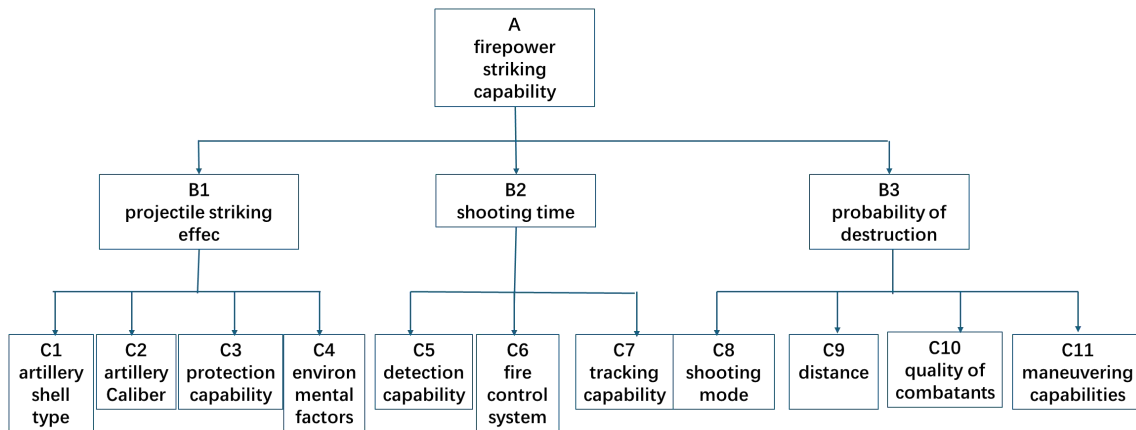


Figure 2 Indicator System for Single-Mounted Fire Capability

4 SINGLE-MOUNTED FIRE STRIKE CAPABILITY ASSESSMENT MODEL BASED ON FAHP

FAHP is a decision analysis method that combines qualitative and quantitative, and is widely used in decision problem analysis, prioritization, and performance evaluation in various fields. The FAHP-based operation loop capability analysis integrates the detection, decision-making, and striking in the operation loop into the process of striking the target caused by a single-mounted weapon system, and a comprehensive and objective evaluation is used to assess the capability of single-mounted fire strikes. In the single-mounted fire strike capability model, to determine the weight of each factor on the target, the following methods can generally be used:

(1) Establish single-mounted fire strike capability indicator system: according to the operational requirements and single-loaded fire strike capability indicator system, the single-loaded fire strike capability indicator system is divided into three levels, as shown in Figure 2.

(2) Determine the weight of each level of indicators: according to the single-mounted fire strike capability indicator system, establish the single-mounted fire strike capability evaluation indicator system, for the target A, through the two-by-two comparison of the factors B₁, B₂, B₃ and select the scale as in Table 1, the establishment of the matrix A-B; similarly for the B₁, B₂, B₃, respectively, the establishment of the judging matrix B₁-C, B₂-C, B₃-C, where, a_{ij} denotes the relative importance of the ith factor to the jth factor.

Table 1 Scales and Their Meanings

Scale	Meaning
1	Both elements are of equal importance
3	One element is slightly more important than the other
5	One element is significantly more important than the other
7	One element is more strongly important than the other
9	One element is more important than the other extreme
2, 4, 6, 8	If the difference between the two elements is in between, take the middle value

reciprocal If the ratio of the importance of elements i and j is a_{ij} , then the ratio of the importance of elements i and j is $a_{ij}=1/a_{ji}$

(3) Calculate the weights of the factors based on the fuzzy judgment matrix and normalize the w_i

$$w_i = \frac{\left(\prod_{j=1}^n r_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^n \left(\prod_{j=1}^n r_{ij}\right)^{\frac{1}{n}}}$$

The consistency test is calculated based on the characteristic root $\lambda_{\max} = \frac{R_w \cdot W}{W}$ of the judgment matrix to verify whether the calculated weights are in line with the objective reality, and the judgment criterion is: $CI = \frac{\lambda_{\max} - n}{n-1}$, when the consistency ratio $CR = \frac{CI}{RI} < 0.1$, it means that the relative importance of each factor to the goal is consistent, so that the consistency test is passed. RI is the random consistency index, which is a pre-calculated value depending on the number of guidelines.

(4) Determine the weight of each factor: according to the principle of fuzzy comprehensive judgment, establish the single-level judgment matrix in the single-unit fire strike capability index system, that is, the comprehensive judgment matrix of the single target.

(5) Calculate fuzzy sets $B_x = W_x \cdot R_x$, let $R = (B_1, B_2, B_3)^T$

(6) Further single-mounted fire strike capability target tier evaluations: $H=W \cdot R$

(7) According to the impact system of evaluation indicators, you can establish the evaluation set V , such as Table 2, according to $V = \{100,90,80,60,0\}$, to find the comprehensive evaluation score: $S=H \cdot V^T$, according to the score to determine the single-loaded fire strike capability.

Table 2 Single-mounted Fire Strike Capability Evaluation Set

Degree of target damage	Attack and destroy	Loss of firepower and mobility at the same time	Loss of firepower capability	Loss of mobility	In good condition
Damage index	100	90	80	60	0

5 SIMULATION CASE ANALYSIS

5.1 Case Analysis

In a position attack red-blue confrontation process, the Blue Army in the front of the position sent a certain type of infantry fighting vehicle to carry out reconnaissance alert strike mission. At a certain moment, the enemy vehicle stands still in the bunker, scouting the battlefield situation, obtaining data through sensors, including artillery type, caliber, effective range, speed, carrying ammunition, position and other information.

The concrete evaluation method is divided into three steps: single index analysis to determine the impact of factors on the degree of damage alone; The multi-factor comprehensive influence result is analyzed, and the formula is summarized to link each influence factor and comprehensively evaluate the single-load firepower strike capability.

5.2 Single-mounted Fire Strike Capability Assessment

According to the degree of influence of evaluation indicators, the evaluation set can be established: $V = \{v_1, v_2, \dots, v_m\}$, m is the total number of evaluation grades. Referring to the domestic and foreign common evaluation grading, we can define the evaluation set of single-mounted fire strike capability of ground assault force as follows: $V = \{\text{intact, loss of fire and mobility, loss of fire capability, loss of mobility, intact}\}$.

Experts in the field of armored chassis, firepower, and systems are invited to study and judge the evaluation indexes of the ground assault force at all levels. Each factor level has a certain influence on the evaluation indicators of the evaluation set, which can be expressed by the affiliation function R_i . Define the affiliation of factor u_i to evaluation level v_j as r_{ij} , then the single factor evaluation set of u_i is $R_i = (r_{i1}, r_{i2}, \dots, r_{im})$. Judging each factor, the fuzzy relationship matrix $R=(r_{ij})_{m \times n}, i=1, 2, \dots, m; j=1, 2, \dots, n$ can be constructed from the factor set U to the evaluation set V . Based on

the evaluation index system of Fig. 1, the weights of each index are determined, and the resulting judgment matrix is shown in Tables 3 to 6.

Table 3 Judgment Matrix of A-B and Corresponding Weight Vector W

A	B ₁	B ₂	B ₃	W
B ₁	1	2	1/3	0.249
B ₂	1/2	1	1/3	0.157
B ₃	3	3	1	0.594
$\lambda_{\max} = 3.05$ CR=0.027<0.1				

Table 4 Judgment Matrix of B₁-C and Corresponding Weight Vector W₁

B ₁	C ₁	C ₂	C ₃	C ₄	W ₁
C ₁	1	3	4	5	0.540
C ₂	1/3	1	3	3	0.255
C ₃	1/4	1/3	1	1/2	0.088
C ₄	1/5	1/3	2	1	0.117
$\lambda_{\max} = 4.15$ CR=0.049<0.1					

Table 5 Judgment Matrix of B₂-C and Corresponding Weight Vector W₂

B ₂	C ₅	C ₆	C ₇	W ₂
C ₅	1	4	3	0.630
C ₆	1/4	1	2	0.219
C ₇	1/3	1/2	1	0.152
$\lambda_{\max} = 3.11$ CR=0.053<0.1				

Table 6 Judgment Matrix of B₃-C and Corresponding Weight Vector W₃

B ₃	C ₈	C ₉	C ₁₀	C ₁₁	W ₃
C ₈	1	2	3	3	0.453
C ₉	1/2	1	2	3	0.289
C ₁₀	1/3	1/3	1	1/2	0.107
C ₁₁	1/3	1/3	2	1	0.151
$\lambda_{\max} = 4.04$ CR=0.012<0.1					

According to the calculation results, it can be seen that the consistency ratio of each judgment matrix $CR < 0.1$, which fully meets the consistency test requirements. The single-factor indicators affecting the single-mounted fire strike capability are evaluated by 10 experts respectively, and the corresponding affiliation r_{ij} is calculated. r_{ij} is the ratio of the number of times the indicator u_i is rated as v_j to the total number of experts, and the evaluation results are shown in Table 7.

Table 7 Expert Evaluation Results

r_{ij}	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
100	0.2	0.3	0.1	0	0	0.3	0.3	0.3	0.5	0.1	0.4
90	0.3	0.4	0.2	0.2	0.2	0.4	0.3	0.5	0.4	0.4	0.4
80	0.3	0.2	0.3	0.4	0.5	0.2	0.2	0.2	0.1	0.3	0.1
60	0.2	0.1	0.3	0.2	0.2	0.1	0.2	0	0	0.1	0.1
0	0	0	0.1	0.2	0.1	0	0	0	0	0	0

Based on the evaluation of each factor by the expert members, a fuzzy evaluation judgment matrix is obtained:

$$R_1 = \begin{bmatrix} 0.2 & 0.3 & 0.3 & 0.2 & 0 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0 \\ 0.1 & 0.2 & 0.3 & 0.3 & 0.1 \\ 0 & 0.2 & 0.4 & 0.2 & 0.2 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.2 & 0.5 & 0.2 & 0.1 \\ 0.3 & 0.4 & 0.2 & 0.1 & 0 \\ 0.3 & 0.3 & 0.2 & 0.2 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.3 & 0.5 & 0.2 & 0 & 0 \\ 0.5 & 0.4 & 0.1 & 0 & 0 \\ 0.1 & 0.1 & 0.3 & 0.1 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 & 0 \end{bmatrix}$$

Fuzzy sets for each indicator layer:

$$B_1 = W_1 \cdot R_1 = (0.193 \quad 0.305 \quad 0.289 \quad 0.016 \quad 0.012)$$

$$B_2 = W_2 \cdot R_2 = (0.286 \quad 0.260 \quad 0.389 \quad 0.178 \quad 0.063)$$

$$B_3 = W_3 \cdot R_3 = (0.352 \quad 0.445 \quad 0.167 \quad 0.042 \quad 0)$$

Get:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} 0.193 & 0.305 & 0.289 & 0.016 & 0.012 \\ 0.286 & 0.260 & 0.389 & 0.178 & 0.063 \\ 0.352 & 0.445 & 0.067 & 0.042 & 0 \end{bmatrix}$$

Based on the results of the Tier 1 evaluation, further single-mounted fire strike capability target tier evaluations were conducted:

$$H = W \cdot R = (0.326 \quad 0.354 \quad 0.216 \quad 0.094 \quad 0.013)$$

$$V = \{100, 90, 80, 60, 0\}$$

Finding the comprehensive evaluation score: $S = H \cdot V = 75.67$

According to the evaluation results, in accordance with the principle of maximum affiliation, it can be seen that the single-loaded fire-strike capability of the ground assault equipment is evaluated to be able to cause the enemy to lose its fire-strike capability, which indicates that the fire-strike capability of the evaluated ground assault equipment is high.

6 CONCLUSION

This paper establishes a single-mounted fire strike capability assessment model of ground assault force based on FAHP, which is an effective military assessment tool for scientific assessment and control of military systems and can be used to improve the combat simulation software such as weapon projection and computer simulation, which can make the results of the projection closer to the actual combat and assist the commanders to make correct decisions, which can help to improve the combat effectiveness. At the same time, this model is based on tanks and armored vehicles to study the single-armor fire strike capability, after the model is established, through experimental analysis and modification of its parameters, it can assess the purpose of the air, sea and long-range fire strike capability, and this model is combined with artificial intelligence to realize the weapon system autonomy to carry out combat tasks, and to promote the weaponry to the intelligent progress.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCE

- [1] Zhou Liyao, Liu Xiaofang, Wang Yaguang, et al. Assessment of missile equipment fire strike capability based on improved FAHP. 2022.
- [2] Zhao Manyun, Zhang Lei. Composite FAHP's assessment method of missile brigade's overall NBC defense capability. *Firepower and Command and Control*, 2022, 47(11): 5.
- [3] Li Suying, Tian Ya, Wu Yongli. Research on risk assessment of railroad engineering projects based on FAHP model. *Journal of Railway Engineering*, 2019, 36(7): 8.
- [4] Zhang Yaolong, Ruan Yongjun, Li Zhen. Research on the assessment of synthetic brigade's equipment guarantee capability based on topable cloud. *Command Control and Simulation*, 2021, 43(6): 71-77.