Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):208-215

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

An evaluation of new-type ammunition support capability based on the gray-extension goodness

ZHAO Zhi-ning[1,2], SHI Quan[1], Tang Jian[3], CHE Yan-lian[4], MEI Qi- yi[2], MA Guo-jiang[2], YIN Yan[5], FENG Xing-hua[4], YUAN Qing-hai[4] and BAI Wen-rui[6]

[1]Mechanical Engineering College，Shijiazhuang, China
[2]Artillery Training Base of the General Staff, Xuanhua, China
[3]Bethune Medical NCO College of PLA Shijiazhuang, China
[4]Nanjing Artillery Academy of PLA Nanjing, China
[5]Deskbound Information Center, Beijing, China
[6]NBS Defense Beijing, China

ABSTRACT

New-type ammunition, as an important part of weapon system, is one of the most important composition factors of army battle effectiveness. How to confirm the question whether the new-type ammunition supports capability can meet the requirements of the rules is a complicated problem. On the basis of analyzing the factors affecting the new-type ammunition support capability, the article constructs an evaluation index system, containing 6 secondary indicators, totally 20 underlying index, such as staff efficiency, storage, transportation, loading and unloading capacity, management efficiency and self-supply ability. The comprehensive index weight is determined based on the gray-fuzzy thought and Analytic Hierarchy Process (AHP), on basis of which the extension evaluation model of the new-type ammunition support capability is further constructed. This model is used to carry out an overall evaluation of the new-type ammunition support capability. The evaluation results show that the model is an effective method of evaluating new-type ammunition support capability, which can be used to guide the support capability construction of the new-type ammunition support unit.

Key words: New-type Ammunition, Support Capability, Gray- fuzzy, Extension Goodness, Evaluation
CLC Number：TP207；N945.1 **Document Code**：A

INTRODUCTION

With the development of science and technology, more and more high and new technology has been widely used in the field of ammunition; a variety of new-types of ammunition arises and put into the battlefield, which produces enormous military benefits. New ammunition has the characteristics of intelligentization, accuracy and powerful attack ability. Despite its huge military benefits, the new-type ammunition also has some problems such as complex structure, high costs, high requirements for storage, etc. How to evaluate and improve the new-type ammunition support capability is a very important topic of research, which can put the essence, accuracy and quickness of the new ammunition support into effect, not only meeting the requirements of the combat unit, but also avoiding the waste of important resources. [1, 2]

Based on this background, this article, taking the new-type ammunition support capacity as the research object, constructs the new-type ammunition support capability index by analyzing the factors influencing the new support capability and repeatedly consulting relevant experts, and puts forward an evaluation model of new-type ammunition support capability based on extension goodness, so as to implement an effective assessment and guidance of building the new-type ammunition support capacity.

I. Analysis of the factors influencing the new-type ammunition support capability

To build a scientific and reasonable index system is an important procedure and foundation of evaluation. On the basis of making an in-depth analysis of the factors influencing the informatization construction of equipment support capability, following the principle of constructing the index related system, such as systematicness, timeliness, mutual exclusivity, completeness and normalization, etc.[3-5]. Through making investigation & research and consulting relevant experts, a system of evaluation index (figure 1), totally consisting of 6 secondary indexes, 26 a tertiary index is constructed.

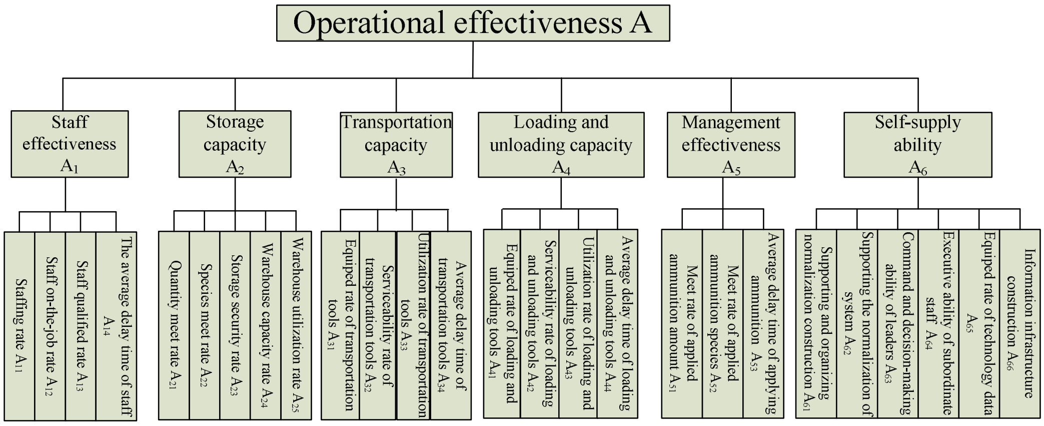

Figure 1 evaluation index system of the new-type ammunition support capability construction

This article selects staff efficiency, storage, transportation, loading and unloading capacity, management efficiency and self-supply ability of 6 secondary indexes, 26 level tertiary indicators to establish a new-type ammunition support capability evaluation index system. The method of index data acquisition is shown as Table 1, among which some quantifiable tertiary indexes are defined as follows:

$$\text{Staffing rate } A_{11} = \frac{\text{Existing number of permanent staff}}{\text{Rated number of staff}} \times 100\% \qquad (1)$$

$$\text{staff on-the-job rate } A_{12} = \frac{\text{The number of on-the-job personnel}}{\text{Existing number of permanent staff}} \times 100\% \qquad (2)$$

$$\text{staff qualified rate } A_{13} = \frac{\text{The number of people evaluated better than good}}{\text{The number of on-the-job personnel}} \times 100\% \qquad (3)$$

$$\text{quantity meet rate } A_{21} = \frac{\sum_{i=1}^{N_E} \min\begin{pmatrix}\text{The standard magnitude of Ammunition } i \text{ reserve,} \\ \text{The actual capacity of Ammunition } i\end{pmatrix}}{\sum_{i=1}^{N_E} \text{The standard magnitude of Ammunition } i \text{ reserve}} \times 100\% \qquad (4)$$

$$\text{species meet rate } A_{22} = \frac{\text{Number of species meeting minimum reserves}}{\text{Number of species to be provided}} \times 100\% \qquad (5)$$

$$\text{warehouse utilization rate } A_{25} = \frac{\text{Current usage area of warehouse}}{\text{Total usage area of warehouse}} \times 100\% \qquad (6)$$

Table 1 Index calculation method

index	Calculation method	index	Calculation method
A_{11}	equation（1）	A_{41}	equation（1）
A_{12}	equation（2）	A_{42}	equation（3）
A_{13}	equation（3）	A_{43}	equation（6）
A_{14}	0-1	A_{44}	0-1
A_{21}	equation（4）	A_{51}	equation（4）
A_{22}	equation（5）	A_{52}	equation（5）
A_{23}	0-1	A_{53}	0-1
A_{24}	0-1	A_{61}	0-1
A_{25}	equation（6）	A_{62}	0-1
A_{31}	equation（1）	A_{63}	0-1
A_{32}	equation（3）	A_{64}	0-1
A_{33}	equation（6）	A_{65}	equation（1）
A_{34}	0-1	A_{66}	0-1

As shown in Table 1, the qualitative indexes shall be quantified by applying Delphi method, and the specific value is determined by experts' investigation and evaluation, and the value range is 0-1.

II. Research of the new-type ammunition support capability evaluation model

2.1 The determination of index weight

2.1.1 Establishing the matrix fuzzily evaluating the importance of factors

The article changes the former method to solve index weight, and uses Delphi, fuzzy evaluation and gray correlation method to build gray-fuzzy evaluation model so as to solve the index weight.

Applying Delphi method, a certain number of experts are invited to evaluate the importance of the new-type ammunition support capability indexes, the questionnaire on the Delphi method shown as Table 2. Then the suggestions from all members are collected to make a percentage statistical summary. According to the statistical results, the fuzzy evaluation matrix on importance degree of each index factor can be structured. The evaluation model is divided into four fuzzy levels, and the specific evaluation sets:

$$U = \begin{Bmatrix} \text{very important } U_1, & \text{important } U_2 & , \\ \text{average } U_3, & \text{not important } U_4 & \end{Bmatrix}$$

Table 2 Delphi questionnaire

index	Very important	important	ordinary	Not important
A_{ij}				

Requirements: as long as the sign "○"is filled in one important degree column for every index, other item shall be blank.

For example, the investigation statistics for the storage capacity index factors are conducted among experts, who made evaluation on each indicator, and the final statistical summary is as follows:

$f(A_{21}) = (40,30,20,10)$ $f(A_{22}) = (30,50,20,0)$

$f(A_{23}) = (20,40,40,0)$ $f(A_{24}) = (0,20,30,50)$

$f(A_{15}) = (10,30,50,10)$

Taking the evaluation of A_{21} index factor for example, 40% of the experts considered the quantity meet rate as "very important", 30% "important", 20%"average", and 10% "not important".

If the single factor evaluation set is taken as a matrix consisting of lines, the fuzzy comprehensive evaluation matrix of A_1 shall be:

$$Z = \begin{bmatrix} 40 & 30 & 20 & 10 \\ 30 & 50 & 20 & 0 \\ 20 & 40 & 40 & 0 \\ 0 & 20 & 30 & 50 \\ 10 & 30 & 50 & 10 \end{bmatrix}$$

In the similar way, the fuzzy evaluation matrix about the importance of other indicators at various levels can be acquired in turn by applying evaluation set, the expert assessment, and the final statistical summary.

2.1.2 Solving index weights by using gray correlation

Within each level indicators, taking the important degree of each index evaluation sets as a sequence, the gray correlation degree of each index importance is solved, and the gray correlation degree is the measure degree of each index importance, and then normalization processing is implemented to acquire each index weight.

1） within the each layer index system, the evaluation sets of each index can be marked as $x_i(k)$, comparing sequence [6,7] is constructed in turn.

$$x_i = \left\{ x_i(k) \middle| k = 1, 2, \cdots, 4 \right\} \tag{7}$$

2） the evaluation criterion is given, namely, reference sequence x_0

$$x_0 = \left\{ x_0(k) \middle| k = 1, 2, \cdots, 4 \right\} \tag{8}$$

x_0 is optimal value of all indexes, the maximum value of this index from all plans is selected when the index is “efficiency-type” (the greater the value, the more optimal);the minimum value is selected when the index is “cost-type”(the smaller the value, the more optimal)

3）Confirm

$\Delta_i(k) = \left| x_0(k) - x_i(k) \right|$ $(i = 1, 2, \cdots, m)$, $\underset{i}{Min}\,\underset{k}{Min}\,\Delta_i(k)$ and $\underset{i}{Max}\,\underset{k}{Max}\,\Delta_i(k)$ 。

4）Select $\rho = 0.5$, Solve correlation coefficient $\xi_i(k)$

$$\xi_i(k) = \frac{\underset{i}{Min}\,\underset{k}{Min}\left|x_0(k) - x_i(k)\right| + \rho\,\underset{i}{Max}\,\underset{k}{Max}\left|x_0(k) - x_i(k)\right|}{\left|x_0(k) - x_i(k)\right| + \rho\,\underset{i}{Max}\,\underset{k}{Max}\left|x_0(k) - x_i(k)\right|} \tag{9}$$

5） to solve correlation degree γ_i

$$\gamma_i = \frac{1}{4}\sum_{k=1}^{4} \xi_i(k) \tag{10}$$

The greater correlation degree reveals that the index importance is greater.

6） to solve weight

The importance the each index, with the expression of correlation degree, normalizing each layer index, the each index weight ω_i can be acquired.

$$\omega_i = \frac{\gamma_i}{\sum_{i=1}^{n} \gamma_i} \tag{11}$$

n refers to the number of index within each layer.

The storage capacity of index is taken as an example to make an analysis:

Table 3 Fuzzy relations comparison and reference sequence of important degree

Reference series X_0	40	50	20	0
Quantity meet rate	40	30	20	10
Species meet rate	30	50	20	0
Storage security	20	40	40	0
Storage capacity	0	20	30	50
Utilization rate of warehouse	10	30	50	10

Table 4 gray correlation coefficient，gray correlation degree and weight of index

	1	2	3	4	γ_i	ω_i
$\xi_1(k)$	1	0.56	1	0.71	0.8175	0.2359
$\xi_2(k)$	0.71	1	1	1	0.9275	0.2677
$\xi_3(k)$	0.56	0.71	0.56	1	0.7075	0.2042
$\xi_4(k)$	0.38	0.45	0.71	0.33	0.4675	0.1349
$\xi_5(k)$	0.45	0.56	0.46	0.71	0.5450	0.1573

Table 4 shows tertiary index weight that storage capacity belongs to shall be:

$$\omega_i = (0.2359, 0.2677, 0.2042, 0.1349, 0.1573)$$

Each index weight of the new-type ammunition support capability index system can be successively acquired as shown in Table 5.

Table 5 the new-type ammunition support capability index system weight

Secondary index	weight	Tertiary index	weight
A_1	0.1956	A_{11}	0.0528
		A_{12}	0.0431
		A_{13}	0.0489
		A_{14}	0.0508
A_2	0.1562	A_{21}	0.0368
		A_{22}	0.0418
		A_{23}	0.0319
		A_{24}	0.0211
		A_{25}	0.0246
A_3	0.1659	A_{31}	0.0461
		A_{32}	0.0426
		A_{33}	0.0409
		A_{34}	0.0363
A_4	0.1451	A_{41}	0.0375
		A_{42}	0.0402
		A_{43}	0.0381
		A_{44}	0.0293
A_5	0.1423	A_{51}	0.0473
		A_{52}	0.0461
		A_{53}	0.0489
A_6	0.1949	A_{61}	0.0325
		A_{62}	0.0347
		A_{63}	0.0361
		A_{64}	0.0294
		A_{65}	0.0317
		A_{66}	0.0305

2.2 Constructing the evaluation model of extension goodness

The method of extension goodness refers to the way of evaluating the extent that an object is good or bad in the case of weighting the measuring conditions. Correlation function is established to operate interval and interval sets, realizing the quantification of qualitative index. [8, 9]. The basic steps are:

(1) Determine the matter-element to be evaluated

For the target of evaluation M_j, the value of evaluation index can be expressed in form of matter-element R：

$$R_j = (N_j, C, V_j) = \begin{bmatrix} N_j & c_1 & V_{j1} \\ & c_2 & V_{j2} \\ & \vdots & \vdots \\ & c_n & V_{jn} \end{bmatrix} \qquad (12)$$

In formula, R_j is the matter-element of M_j， N_j is the name of M_j， V_{ji} is the quantitative value of c_i， namely, the concrete value of evaluation index c_i .

(2) Determining the classical domain and joint domain
N_{0j} is used to signify j evaluation levels, the quantitative value scope of evaluation index c_i at all levels is $V_{0ji} = \langle a_{0ji}, b_{0ji} \rangle$, $i = (1, 2, \cdots, n)$, $j = (1, 2, \cdots, m)$; n is the number of evaluation index, m is the number of evaluation level; the matter-element of classical domain can be expressed as follows:

$$R_{0j} = \begin{bmatrix} N_{0j} & c_1 & V_{0j1} \\ & c_2 & V_{0j2} \\ & \vdots & \vdots \\ & c_n & V_{0jn} \end{bmatrix} = \begin{bmatrix} N_{0j} & c_1 & \langle a_{0j1}, b_{0j1} \rangle \\ & c_2 & \langle a_{0j2}, b_{0j2} \rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{0jn}, b_{0jn} \rangle \end{bmatrix} \tag{13}$$

The matter-element R_p consisting of total N_p of evaluation level N_{0j} is named as the matter-element of joint domain, $V_{pi} = \langle a_{pi}, b_{pi} \rangle$ is the qubit range of matter-element of joint domain about evaluation index c_i , the matter-element can be expression as:

$$R_p = \begin{bmatrix} N_p & c_1 & V_{p1} \\ & c_2 & V_{p2} \\ & \vdots & \vdots \\ & c_n & V_{pn} \end{bmatrix} = \begin{bmatrix} N_p & c_1 & \langle a_{p1}, b_{p1} \rangle \\ & c_2 & \langle a_{p2}, b_{p2} \rangle \\ & \vdots & \vdots \\ & c_n & \langle a_{pn}, b_{pn} \rangle \end{bmatrix} \tag{14}$$

From above $V_{0ji} \subseteq V_{pi}$ can be concluded.

(3) Establishing correlation function to calculate the degree of qualification
Correlation function describes the extent that something is of certain characteristics in form of quantification, establishing the correlation function $k_i(x)$ about $c_1(M), c_2(M), c_3(M), \cdots c_n(M)$.

1) if $c_i(M)$ is expressed by an interval X_{0i} , getting:

$$k_i(x) = -\frac{\rho(x, X_{0i})}{|X_{0i}|} \qquad i = 1, 2, 3, \cdots n \tag{15}$$

Thereunto, $|X_{0i}|$ is the length of interval, $\rho(x, X_{0i})$ is called distance, signifying the distance between x and the interval $X_{0i} = \langle a, b \rangle$:

$$\rho(x, X_{0i}) = \left| x - \frac{a+b}{2} \right| - \frac{1}{2}(b-a) \tag{16}$$

(4) Calculating goodness
The qualification degree of the evaluation target M_j about each index c_1 , c_2 , $c_3 \ldots c_n$ is:

$$k(M_j) = (k_{1j}, k_{2j}, \ldots k_{nj})^T \quad j = 1, 2, \cdots m \tag{17}$$

Weight coefficient distribution is $W = \{w_1, w_2, w_3, \cdots w_n\}$,

Therefore, the goodness value of M_j is:

$$C\left(M_j\right)=Wk\left(M_j\right)=\left(w_1,w_2,\ldots w_n\right)\left(k_{1j},k_{2j},\ldots k_{nj}\right)^T$$
$$=\sum_{i=1}^{n}w_ik_{ij}\quad,\left(j=1,2,3\ldots m\right) \tag{18}$$

According to the principle of maximum membership: $C_{0q}\left(M_j\right)=\max\left[C_{0i}\left(M_j\right)\right]$, so the evaluation target M_j is N_{0q} level.

III. The evaluation of the new-type ammunition support capability construction in a unit as an example
Taking a new-type ammunition support unit as an example, we evaluate its new-type ammunition support capability.

(2) Setting the threshold value at all levels of tertiary index:
Evaluation level can be divided into four levels: unqualified, ordinary, good and excellent, accordingly, each underlying index for the four levels of threshold (interval is given) is shown as Table 6.

Table 6 the table of threshold value of each index at all levels

Two levels index	Three level index	Unquanli-fication	ordinary	good	excellent	value
A_1	A_{11}	0-0.6	0.6-0.8	0.8-0.9	0.9-1	0.82
	A_{12}	0-0.75	0.75-0.85	0.85-0.95	0.95-1	0.79
	A_{13}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.81
	A_{14}	0-0.7	0.7-0.8	0.8-0.9	0.9-1	0.76
A_2	A_{21}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.80
	A_{22}	0-0.75	0.75-0.85	0.85-0.95	0.95-1	0.75
	A_{23}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.81
	A_{24}	0-0.6	0.6-0.7	0.7-0.8	0.8-1	0.74
	A_{25}	0-0.6	0.6-0.75	0.75-0.85	0.85-1	0.79
A_3	A_{31}	0-0.7	0.7-0.8	0.8-0.95	0.95-1	0.87
	A_{32}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.85
	A_{33}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.88
	A_{34}	0-0.6	0.6-0.75	0.75-0.85	0.85-1	0.84
A_4	A_{41}	0-0.6	0.6-0.7	0.7-0.85	0.85-1	0.86
	A_{42}	0-0.7	0.7-0.8	0.8-0.95	0.95-1	0.87
	A_{43}	0-0.7	0.7-0.8	0.8-0.95	0.95-1	0.76
	A_{44}	0-0.8	0.8-0.85	0.85-0.95	0.95-1	0.90
A_5	A_{51}	0-0.7	0.7-0.8	0.8-0.9	0.9-1	0.81
	A_{52}	0-0.6	0.6-0.8	0.8-0.95	0.95-1	0.76
	A_{53}	0-0.6	0.6-0.75	0.75-0.9	0.9-1	0.82
A_6	A_{61}	0-0.7	0.7-0.8	0.8-0.95	0.95-1	0.80
	A_{62}	0-0.6	0.6-0.75	0.75-0.85	0.85-1	0.76
	A_{63}	0-0.6	0.6-0.7	0.7-0.85	0.85-1	0.77
	A_{64}	0-0.6	0.6-0.75	0.75-0.9	0.9-1	0.71
	A_{65}	0-0.7	0.7-0.8	0.8-0.9	0.9-1	0.80
	A_{66}	0-0.6	0.6-0.7	0.7-0.85	0.85-1	0.82

(3) Evaluation results calculated
The data are put into the formula（15）、（16）, getting the correlation degree of each index relative to each level.

$$k(x)=\begin{bmatrix} -0.3667 & -0.1000 & 0.2000 & -0.8000 \\ -0.0533 & 0.4000 & -0.6000 & -3.2000 \\ -0.0125 & -0.2000 & -0.4000 & -2.8000 \\ -0.0857 & 0.4000 & -0.4000 & -1.4000 \\ \cdots & \cdots & \cdots & \cdots \\ -0.2833 & -0.7000 & 0.4667 & -0.5333 \\ -0.1833 & 0.2667 & -0.2667 & -1.9000 \\ -0.1428 & 0.0000 & -0.0000 & -1.0000 \\ -0.3667 & -1.2000 & 0.2000 & -0.2000 \end{bmatrix}$$

From the formula（18）, the goodness value of evaluation object can be acquired as follows:

$$C = (-0.3018, -0.1553, 0.1104, -0.1031)$$

According to the maximum membership principle, maximum: 0.1104, so the support capability of the new-type ammunition support unit shall be: good.

It can be seen from the evaluation results that the support capability of the new-type ammunition support unit is being in good condition, and there is room for further improvement to make its support capacity achieve excellent level, that is to say, there exists some weak aspects that need improving, which involves the determination of weak indexes. It can be comprehensively considered from two aspects of index weight and index values to determine the new-type ammunition support capability weak aspects [10], which is the future direction of researching the new-type ammunition support capability.

CONCLUSION

How to determine the new-type ammunition support capacity construction level? This article puts forward a evaluation model of extension goodness on the basis of constructing a new-type ammunition support capability evaluation index system, realizing the effective evaluation of the new-type ammunition support capacity of a unit, which lays a good foundation for further determining the weak points existing in the support capacity, and finally provides an effective guidance for improving the construction level of the new-type ammunition support capacity of a unit.

REFERENCES

[1] Dai Xiangjun, Luo Feng, Zhang Zhihui, etc. *Journal of Logistics Engineering and Management*, **2010**, 32 (11) : 70 - 71,73.
[2] Zhao Donghua Zhang Huaizhi, Huang Yingke. *Journal of Sichuan Armaments Factories*, **2011**, 32 (7) : 137-138.
[3] Wang Yingluo. Systems engineering [M]. Beijing: Mechanical Industry Publishing House, **1999**.
[4] Xu Hongming. A Study of Vessel Crew Fitness Capricious Hierarchy Gray Comprehensive Evaluation [D]. Dalian: Dalian Maritime University, **2007**.
[5] Guo Qisheng,etc. Introduction to Equipment Effectiveness Evaluation [M]. National Defense Industry Press, **2005**.
[6] Yin Jian, Feng Ledong, Wang Zhongyi. *Journal of Command, Control and Simulation*, **2009**, 31 (3) : 65-67.
[7] Huang Renquan, Li Weimin, Zhou Xiaoguang. *Ordnance Industry Automation* , **2009**, 28 (6) : 94-96.
[8] Yang Kun, Wang Ruijin, Yang Lei. *Military Strategy and System Engineering*, **2007**, 21(1): 77-80
[9] Xuan Kecheng. A study of New-type Ordnance Equipment Support Capacity Evaluation Index System [D]. Shijiazhuang: Ordnance Engineering Academy, **2008**.
[10] Bai Xianghua, Tao Fenghe, Jia Changzhi, etc. *Computer Engineering*, **2011** ,37((16) :, 267-269.