

Evaluation of Communication Command Effectiveness Based on Fuzzy Analytic Hierarchy Process

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Abstract. Forces carries out the task to improve effectiveness of communication command, is the important guarantee of communication support ability to ascend, the fuzzy analytic hierarchy process (AHP) to evaluate communication command efficiency, to a certain degree of communication security work guide role. This paper established the hierarchy communication command effectiveness evaluation index system. Combine and fuzzy comprehensive evaluation and analytic hierarchy process (AHP), this paper proposes a communication command effectiveness evaluation model based on fuzzy analytic hierarchy process (AHP), according to the characteristics of communication command effectiveness evaluation index and fuzzy complex assessment and objective assessment results are drawn.

Introduction

Construction and utilization of information system have profound influence on army combat mode. Traditional empirical command which cannot meet the demand of information warfare is replaced with intelligent command mode supported by information technology means. Communication command effectiveness can only be comprehensively improved by relying on information system, giving full play to functional advantages of information system in communication command, realizing real-time, integrated and transparent command, and improving command decision-making to be more scientific. However, there are still some problems in communication command through information system platform, and these problems restrict the full play of command effectiveness. Therefore, scientific evaluation methods shall be used in quantitative evaluation of communication command effectiveness based on information system, in order to provide a basis for improving communication command effectiveness through scientific application of information system.

Application of AHP in evaluation of communication command effectiveness

Establish an evaluation index system

Communication command effectiveness relies on organic operation of multiple factors and the overall effectiveness can be affected by situational awareness, command and control capability, and communication support capability etc in mission area. This is the target layer. A four-level index system can be obtained by decomposing communication command effectiveness model and the general target of communication command effectiveness layer by layer based on information system according to analytic hierarchy process (AHP), and the index system structure is shown in figure 1.

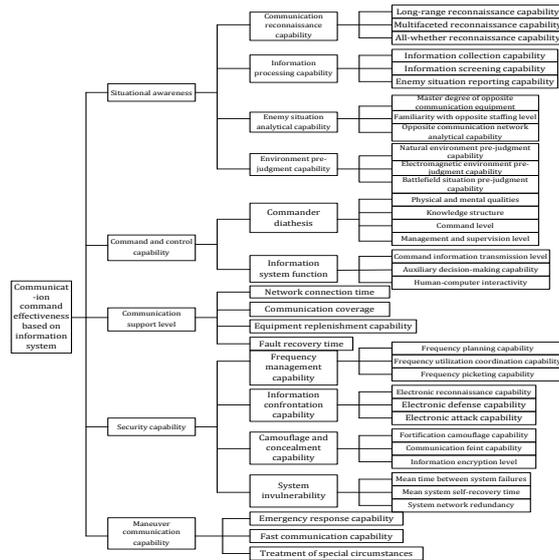


Fig. 1. Evaluation index system for communication command effectiveness based on information system

Construct judgment matrix for each level of indexes

Establish factor sets of each level, compare between two factors and assign values according to T. L. Satty’s 1-9 scale method to denote importance degrees to each other, as shown in table 1.

Table 1 Index weight scale by AHP

Value	Meaning
1	Index i is equally important with index j
3	Index i is slightly more important than index j
5	Index i is obviously more important than index j
7	Index i is certainly more important than index j
9	Index i is absolutely more important than index j
2, 4, 6 and 8 are other available medians; if index i is less important than index j, the value is 1/v, where v is 1-9	

Calculate weight vectors of matrix

In AHP, characteristic roots method is the most widely used in weight calculation. Suppose judgment matrix A and equation

$$A\mathbf{w} = \lambda_{\max} \mathbf{w} \tag{1}$$

Where λ_{\max} is the maximum characteristic root of judgment matrix A, and can be the required weight vector after normalization processing by vector W obtained by calculating the equation.

Consistency test of judgment matrix

To avoid illogical misjudgment, consistency of judgment matrix A shall be tested: Firstly, calculate C.I.(consistency index) of the matrix

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

Then, look up average random consistency index R.I. (random index) corresponding to the matrix. See details in table 2.

Table 2 R.I. of 1~15-order positive reciprocal matrix R.I.

Matrix order	1	2	3	4	5	6	7
R.I.	0	0	0.52	0.89	1.12	1.26	1.36
Matrix order	8	9	10	11	12	13	14
R.I.	1.41	1.46	1.49	1.52	1.54	1.56	1.58

Calculate C.R.(consistency ratio)

$$C.R. = \frac{C.I.}{R.I.} \tag{3}$$

When $C.R. < 0.1$, the consistency of judgment matrix A is feasible; and when $C.R. \geq 0.1$, judgment matrix A shall be corrected appropriately.

Table of comparison of relative importance among all levels of indexes and their weights

Table 3 Table of comparison of relative importance among second-level indexes and their weights

Index	Index Score	Situational awareness	Command and control capability	Communication support level	Security capability	Maneuver communication capability	Weight
Situational awareness		1	1	2	1	1/2	0.1992
Command and control capability		1	1	1	2	1	0.2289
Communication support level		1/2	1	1	1	2	0.1992
Security capability		1	1/2	1	1	1	0.1734
Maneuver communication capability		2	1	1/2	1	1	0.1992

Note: consistency test result is 0.0800, the maximum characteristic root is 5.3582, and the overall target weight is 1.

Table 4 Table of comparison of relative importance among third-level indexes under situational awareness index and their weights

Index	Communication reconnaissance capability	Information processing capability	Enemy situation analytical capability	Environment pre-judgment capability	Weight
Communication reconnaissance capability	1	1/3	1/3	1/2	0.1045
Information processing capability	3	1	2	4	0.4764
Enemy situation analytical capability	1/2	3	1	1	0.2382
Environment pre-judgment capability	1/4	2	1	1	0.1810

Note: consistency test result is 0.04946, the maximum characteristic root is 4.132, and the overall target weight is 0.1992.

Table 5 Table of comparison of relative importance among third-level indexes under command and control capability index and their weights

Index	Commander diathesis	Information system function	Weight
Commander diathesis	1	1/2	0.3333
Information system function	2	1	0.6667

Note: consistency test result is 0.0000, the maximum characteristic root is 2.0000, and the overall target weight is 0.2289.

Table 6 Table of comparison of relative importance among third-level indexes under communication support capability index and their weights

Index	Network connection time	Communication coverage	Equipment replenishment capability	Fault recovery time	Weight
Network connection time	1	2	1/3	3	0.2470
Communication coverage	1/2	1	1/3	1/2	0.1116
Equipment replenishment capability	3	3	1	4	0.5087
Fault recovery time	1/3	2	1/4	1	0.1327

Note: consistency test result is 0.0788, the maximum characteristic root is 4.2104, and the overall target weight is 0.1992.

Table 7 Table of comparison of relative importance among third-level indexes under security capability index and their weights

Index	Frequency management capability	Information confrontation capability	Camouflage and concealment capability	System invulnerability	Weight
Frequency management capability	1	4	2	5	0.5101
Information confrontation capability	1/4	1	1/3	1	0.1091
Camouflage and concealment capability	1/2	3	1	2	0.2669
System invulnerability	1/5	1	1/2	1	0.1141

Note: consistency test result is 0.0101, the maximum characteristic root is 4.0268, and the overall target weight is 0.1743.

Table 8 Table of comparison of relative importance among third-level indexes under maneuver communication capability index and their weights

Index	Emergency response capability	Fast communication capability	Treatment of special circumstances	Weight
Emergency response capability	1	2	3	0.5499
Fast communication capability	1/2	1	1	0.2402
Treatment of special circumstances	1/3	1	1	0.2098

Note: consistency test result is 0.0036, the maximum characteristic root is 3.0037, and the overall target weight is 0.1992.

Table 9 Table of comparison of relative importance among fourth-level indexes under communication reconnaissance capability index and their weights

Index	Long-range reconnaissance capability	Multifaceted reconnaissance capability	All-whether reconnaissance capability	Weight
Long-range reconnaissance capability	1	2	3	0.5499
Multifaceted reconnaissance capability	1/2	1	1	0.2402
All-whether reconnaissance capability	1/3	1	1	0.2098

Table 10 Table of comparison of relative importance among fourth-level indexes under information processing capability index and their weights

Index	Information collection capability	Information screening capability	Enemy situation reporting capability	Weight
Information collection capability	1	3	5	0.6370
Information screening capability	1/3	1	3	0.2583
Enemy situation reporting capability	1/3	1/5	1	0.1047

Note: consistency test result is 0.0370, the maximum characteristic root is 4.0000, and the overall target weight is 0.0949.

Table 11 Table of comparison of relative importance among fourth-level indexes under enemy situation analytical capability index and their weights

Index	Master degree of opposite communication equipment	Familiarity with opposite staffing level	Opposite communication network analytical capability	Weight
Master degree of opposite communication equipment	1	1/3	1/5	0.1095
Familiarity with opposite staffing level	3	1	1/2	0.1090
Opposite communication network analytical capability	5	2	1	0.5816

Note: consistency test result is 0.0036, the maximum characteristic root is 3.0037, and the overall target weight is 0.0475.

Table 12 Table of comparison of relative importance among fourth-level indexes under environment pre-judgment capability index and their weights

Index	Natural environment pre-judgment capability	Electromagnetic environment pre-judgment capability	Battlefield situation pre-judgment capability	Weight
Natural environment pre-judgment capability	1	1/2	2	0.2857
Electromagnetic environment pre-judgment capability	2	1	4	0.5714
Battlefield situation pre-judgment capability	1/2	1/4	1	0.1429

Note: consistency test result is 0.0000, the maximum characteristic root is 3.0000, and the overall target weight is 0.0361.

Table 13 Table of comparison of relative importance among fourth-level indexes under commander diathesis index and their weights

Index	Physical and mental qualities	Knowledge structure	Command level	Management and supervision level	Weight
Physical and mental qualities	1	1/5	1/3	2	0.1259
Knowledge structure	5	1	2	3	0.4878
Command level	3	1/2	1	2	0.2743
Management and supervision level	1/2	1/3	1/2	1	0.1120

Note: consistency test result is 0.0660, the maximum characteristic root is 4.1763, and the overall target weight is 0.0763.

Table 14 Table of comparison of relative importance among fourth-level indexes under information system function index and their weights

Index	Command information transmission level	Auxiliary decision-making capability	Human computer interactivity	Weight
Command information transmission level	1	1/2	1/3	0.1574
Auxiliary decision-making capability	2	1	1/3	0.2493
Human computer interactivity	3	3	1	0.5936

Note: consistency test result is 0.0516, the maximum characteristic root is 3.0536, and the overall target weight is 0.1526.

Table 15 Table of comparison of relative importance among fourth-level indexes under frequency management capability index and their weights

Index	Frequency planning capability	Frequency utilization coordination capability	Frequency picketing capability	Weight
Frequency planning capability	1	3	4	0.6144
Frequency utilization coordination capability	1/3	1	3	0.6284
Frequency picketing capability	1/4	1/3	1	0.1172

Note: consistency test result is 0.0707, the maximum characteristic root is 3.0735, and the overall target weight is 0.0885.

Table 16 Table of comparison of relative importance among fourth-level indexes under information confrontation capability index and their weights

Index	Electronic reconnaissance capability	Electronic defense capability	Electronic attack capability	Weight
Electronic reconnaissance capability	1	2	1/2	0.2970
Electronic defense capability	1/2	1	1/3	0.1634
Electronic attack capability	2	3	1	0.5396

Note: consistency test result is 0.0088, the maximum characteristic root is 3.0092, and the overall target weight is 0.0189.

Table 17 Table of comparison of relative importance among fourth-level indexes under camouflage and concealment capability index and their weights

Index	Fortification camouflage capability	Communication feint capability	Information encryption level	Weight
Fortification camouflage capability	1	3	7	0.6586
Communication feint capability	1/3	1	4	0.2628
Information encryption level	1/7	1/4	1	0.0786

Note: consistency test result is 0.0311, the maximum characteristic root is 3.0324, and the overall target weight is 0.0463.

Table 18 Table of comparison of relative importance among fourth-level indexes under system invulnerability index and their weights

Index	Mean time between system failures	Mean system self-recovery time	System network redundancy	Weight
Mean time between system failures	1	2	4	0.5584
Mean system self-recovery time	1/2	1	3	0.3169
System network redundancy	1/4	1/3	1	0.1220

Note: consistency test result is 0.0176, the maximum characteristic root is 3.0183, and the overall target weight is 0.0198.

Consistency test results of the above judgment matrixes are smaller than 0.1, and thus these matrixes have passed the test.

Evaluation of communication support effectiveness in joint operations by fuzzy comprehensive evaluation method

Establish evaluation standards

Set ranges of all grades of variable values as: 0—0.4 (poor), 0.4—0.6 (general), 0.6—0.8 (good), and 0.8—1.0 (excellent). Thus, evaluation grade matrix is:

$$P = \begin{pmatrix} 0.9 \\ 0.7 \\ 0.5 \\ 0.2 \end{pmatrix} \quad (4)$$

Calculate membership values

Conduct normalization processing of expert comments, and calculate membership of evaluation index sets, as shown in table 19.

Table 19 Table of membership of evaluation index set

Index	Comment	Membership			
		Excellent	Good	General	Poor
	Long-range reconnaissance capability	0.1458	0.5833	0.2083	0.0625
	Multifaceted reconnaissance capability	0.1875	0.6458	0.1250	0.0417
	All-whether reconnaissance capability	0.3333	0.5208	0.0417	0.1042
	Information collection capability	0.2080	0.1458	0.7917	0.0417
	Information screening capability	0.0625	0.1042	0.3958	0.4375
	Enemy situation reporting capability	0.0417	0.0625	0.5417	0.3542
	Master degree of opposite communication equipment	0.3333	0.6250	0.0208	0.0208
	Familiarity with opposite staffing level	0.2083	0.6042	0.0208	0.1667
	Opposite communication network analytical capability	0.1667	0.5625	0.1667	0.1042
	Natural environment pre-judgment capability	0.1458	0.5833	0.1667	0.1042
	Electromagnetic environment pre-judgment capability	0.1857	0.5625	0.1875	0.0625
	Battlefield situation pre-judgment capability	0.2292	0.6250	0.1458	0.0000
	Physical and mental qualities	0.2083	0.6458	0.1042	0.0417
	Knowledge structure	0.1042	0.5000	0.2292	0.1667
	Command level	0.0625	0.6042	0.3125	0.0208
	Management and supervision level	0.1667	0.5625	0.1875	0.0833
	Command information transmission level	0.1875	0.1458	0.5208	0.1458
	Auxiliary decision-making capability	0.0417	0.1875	0.6042	0.1667
	Human-computer interactivity	0.2708	0.3958	0.3125	0.0208
	Network connection time	0.2500	0.5625	0.1250	0.0625
	Communication coverage	0.0625	0.5833	0.2500	0.1042
	Equipment replenishment capability	0.4583	0.5208	0.0208	0.0000
	Fault recovery time	0.3750	0.5417	0.0208	0.0625
	Frequency planning capability	0.3333	0.5625	0.0625	0.0417
	Frequency utilization coordination capability	0.4792	0.4583	0.0417	0.0208
	Frequency picketing capability	0.4375	0.5000	0.0208	0.0417
	Electronic reconnaissance capability	0.2292	0.6042	0.0833	0.0833
	Electronic defense capability	0.1667	0.5208	0.2708	0.0417
	Electronic attack capability	0.3333	0.6250	0.0417	0.0000
	Fortification camouflage capability	0.1667	0.5417	0.1875	0.1042
	Communication feint capability	0.2500	0.5625	0.0625	0.1250
	Information encryption level	0.1875	0.5208	0.1458	0.1458
	Mean time between system failures	0.2708	0.5417	0.0000	0.1875
	Mean system self-recovery time	0.2917	0.5833	0.0833	0.0417
	System network redundancy	0.1042	0.5417	0.1875	0.1667
	Emergency response capability	0.3542	0.5000	0.1250	0.0208
	Fast communication capability	0.3125	0.4375	0.1667	0.0833
	Treatment of special circumstances	0.1875	0.6042	0.1875	0.0208

Establish fuzzy evaluation matrixes

Denote row vector of matrix R as R_i , element R_{ij} of which denotes membership of index to grade j, and matrix A_i is the weight of this level of indexes. Calculate value set of fuzzy comprehensive membership.

$$R_{11} = \begin{pmatrix} R_{111} \\ R_{112} \\ R_{113} \end{pmatrix} = \begin{pmatrix} 0.1458 & 0.5833 & 0.2083 & 0.0625 \\ 0.1875 & 0.6458 & 0.1250 & 0.0417 \\ 0.3333 & 0.5208 & 0.0417 & 0.1042 \end{pmatrix} \quad (5)$$

$$B_{11} = A_{11} \bullet R_{11} = \begin{pmatrix} 0.5499 \\ 0.2402 \\ 0.2098 \end{pmatrix}^T \bullet R_{11} = (0.1951 \quad 0.5851 \quad 0.1533 \quad 0.066) \quad (6)$$

$$B_{12} = A_{12} \bullet R_{12} = \begin{pmatrix} 0.6370 \\ 0.2583 \\ 0.1047 \end{pmatrix}^T \bullet \begin{pmatrix} 0.2080 & 0.1458 & 0.7917 & 0.0417 \\ 0.0625 & 0.1042 & 0.3958 & 0.4375 \\ 0.0417 & 0.0625 & 0.5417 & 0.3542 \end{pmatrix} \quad (7)$$

$$= (0.1530 \quad 0.1263 \quad 0.6632 \quad 0.1766)$$

$$B_{13} = A_{13} \bullet R_{13} = \begin{pmatrix} 0.1095 \\ 0.1090 \\ 0.5816 \end{pmatrix}^T \bullet \begin{pmatrix} 0.3333 & 0.6250 & 0.0208 & 0.0208 \\ 0.2083 & 0.6042 & 0.0208 & 0.1667 \\ 0.1667 & 0.5625 & 0.1667 & 0.1042 \end{pmatrix} \quad (8)$$

$$= (0.1561 \quad 0.4614 \quad 0.1014 \quad 0.0810)$$

$$B_{14} = A_{14} \bullet R_{14} = \begin{pmatrix} 0.2857 \\ 0.5714 \\ 0.1429 \end{pmatrix}^T \bullet \begin{pmatrix} 0.1458 & 0.5833 & 0.1667 & 0.1042 \\ 0.1857 & 0.5625 & 0.1875 & 0.0625 \\ 0.2292 & 0.6250 & 0.1458 & 0.0000 \end{pmatrix} \quad (9)$$

$$= (0.1805 \quad 0.5773 \quad 0.1755 \quad 0.0654)$$

$$B_1 = A_1 \bullet R_1 = \begin{pmatrix} 0.1045 \\ 0.4764 \\ 0.2382 \\ 0.1810 \end{pmatrix}^T \bullet \begin{pmatrix} 0.1951 & 0.5851 & 0.1533 & 0.0665 \\ 0.1530 & 0.1263 & 0.6632 & 0.1766 \\ 0.1561 & 0.4614 & 0.1014 & 0.0810 \\ 0.1805 & 0.5773 & 0.1755 & 0.0654 \end{pmatrix} \quad (10)$$

$$= (0.1631 \quad 0.3357 \quad 0.3879 \quad 0.1222)$$

Similarly, fuzzy comprehensive evaluation result of overall target can be obtained as follows:

$$B = (0.2717 \quad 0.4731 \quad 0.2182 \quad 0.0704) \quad (11)$$

Thus, comprehensive evaluation value is:

$$Q = B \bullet P = (b_1, b_2, \dots, b_m) \bullet \begin{pmatrix} 0.9 \\ 0.7 \\ 0.5 \\ 0.2 \end{pmatrix} = 0.6989 \quad (12)$$

Variable range of value Q is corresponding to grade 0.6—0.8 (good), which is the final evaluation result.

Through fuzzy calculation, the evaluation value of communication command effectiveness based on information system is 0.6989, and the evaluation result is “good”, which is basically in line with reality.

Conclusions

With information system, communication command effectiveness is significantly improved in army task execution and communication support capability is also substantially strengthened. However, with constant deepening of information construction, the key of being initiative in wars lies in high integration of information system utilization with communication command, so that army communication command mechanism can better adapt to application of information achievements and communication command effectiveness based on information system can be comprehensively improved.

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