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Effectiveness Evaluation of Wartime Equipment Maintenance Support Based on Bayesian Network

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Abstract. Starting with the definition of wartime equipment maintenance support effectiveness, the paper deeply analyses the difference between equipment maintenance support effectiveness and equipment maintenance support capability. Based on Bayesian network theory and experts experience knowledge in the field of equipment maintenance, an evaluation model of wartime equipment maintenance and support effectiveness is established, which takes equipment command efficiency, equipment maintenance efficiency and supply efficiency as main evaluation indicators. Based on Netica software, the Bayesian network for evaluating the effectiveness of wartime equipment maintenance support is constructed. The gradient descent method is used to learn network parameters. Finally, the feasibility of the model is proved by a practical case.

1. Introduction

Wartime equipment maintenance support system is a complex system. Its evaluation is a multi-attribute problem, which is affected by many factors such as battlefield environment, combat objects, support deployment and operational command. At present, the evaluation of maintenance support system is mostly capacity evaluation, but the evaluation of wartime effectiveness is not enough. But from the actual operation, commanders often pay more attention to the effectiveness of equipment maintenance support in wartime, so as to make decision on the operational plan. Because the completion probability of maintenance support task is an important factor to consider the effectiveness of equipment maintenance support effectiveness evaluation. Bayesian network theory can be used to objectively evaluate the effectiveness of wartime equipment maintenance support and provides an important basis for selecting and optimizing maintenance support strategies.

2. Overview of Bayesian Network

Bayesian network is based on probability theory and Bayesian theory. It integrates graph theory knowledge, and has mathematical rigor and intuitive expression. It establishes probability reasoning method based on graph. It is an important tool to solve the uncertainty problem.

Bayesian network is a graphical model which describes the probability relationship between variables or nodes and makes inference. It can be expressed as:

$$B =< G, \theta > \tag{1}$$

1) G=<V, A>denotes a directed acyclic graph. V is the set of nodes in the network V={V1, V2, ... Vn}. A denotes a set of directed edges between nodes. Directed edges in Bayesian networks indicate

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that there is a direct probability dependence between two nodes, and the degree of dependence depends on the conditional probability.

2) The parameters are conditional probability distributions associated with each variable. They are expressed by conditional probability tables, where $P(V_i \mid P_a(V_i))$ represents conditional probability between the node V_i and its parent $P_a(V_i)$.

With the conditional probability distribution of nodes, network structure and nodes, Bayesian network can calculate the joint probability of all nodes in the network, and the probability of other nodes'value can be calculated according to the prior probability and the value of some nodes. The node V_i (i = 1 , 2 , 3,...) can be obtained from the chain rule of probability theory. The joint probability is:

$$P(V_1, V_2, \cdots, V_n) = \prod_{i=1}^{n} P(V_i \mid B(V_i)) \tag{2}$$

Netica is a special software for solving Bayesian network problems. It has rich and powerful functions. It can create Bayesian network structure with intuitive graphical interface. It can use various methods to learn network structure and network parameters. Therefore, the author uses Netica software to build and simulate Bayesian network model.

3. Bayesian Network for Effectiveness Evaluation of Wartime Equipment Maintenance Support

3.1. Topological Structure of Evaluation Model

Maintenance and support effectiveness of equipment in wartime refers to the ability of equipment maintenance and support system to accomplish specified tasks under the predetermined or prescribed operational environment and the consideration of organization, strategy, tactics, survivability and threat, or the effective degree of equipment maintenance and support system used to perform specific maintenance and support tasks to achieve the desired objectives. The effectiveness of wartime equipment maintenance support is the ability of the maintenance support system to accomplish the maintenance support tasks entrusted to it by the battlefield, while the maintenance support capability of wartime equipment refers to the ability of the equipment maintenance support system to repair the damaged equipment to the specified state under the battlefield conditions. Therefore, in the effectiveness evaluation of equipment maintenance support in wartime, the first step is to evaluate the probability of completion of equipment maintenance support tasks, and to evaluate the role of equipment maintenance support system, and even the impact on the whole combat process.

Under combat conditions, the equipment maintenance force is organized according to the command of the superior, and repairs the damaged equipment by the mode of accompanying or fixed-point support. At the same time, because equipment maintenance is a consumptive behavior, the necessary spare parts must be replenished in time to complete the task smoothly, so supply support is also an important part of equipment maintenance. Based on the analysis of the operation of wartime equipment maintenance and support system and consulting experts in the field of equipment maintenance and support, the main factors affecting the effectiveness of wartime equipment maintenance and support are as follows:

Effectiveness of equipment command: including command cecision effectiveness, command operational effectiveness, information support effectiveness.

Effectiveness of equipment maintenance: including technical support effectiveness, equipment rescue effectiveness, equipment repair effectiveness.

Effectiveness of supply support: including equipment preparation effectiveness, field transceiver effectiveness, field supply effectiveness.

In wartime equipment maintenance and support effectiveness and its impact indicators all adopt a three-level evaluation system, which consists of three levels: high, medium and low, and its effectiveness decreases in turn. As shown in Figure 1, nine kinds of indicators, such as command and decision-making effectiveness, can be obtained by collecting data and comparing evaluation criteria.

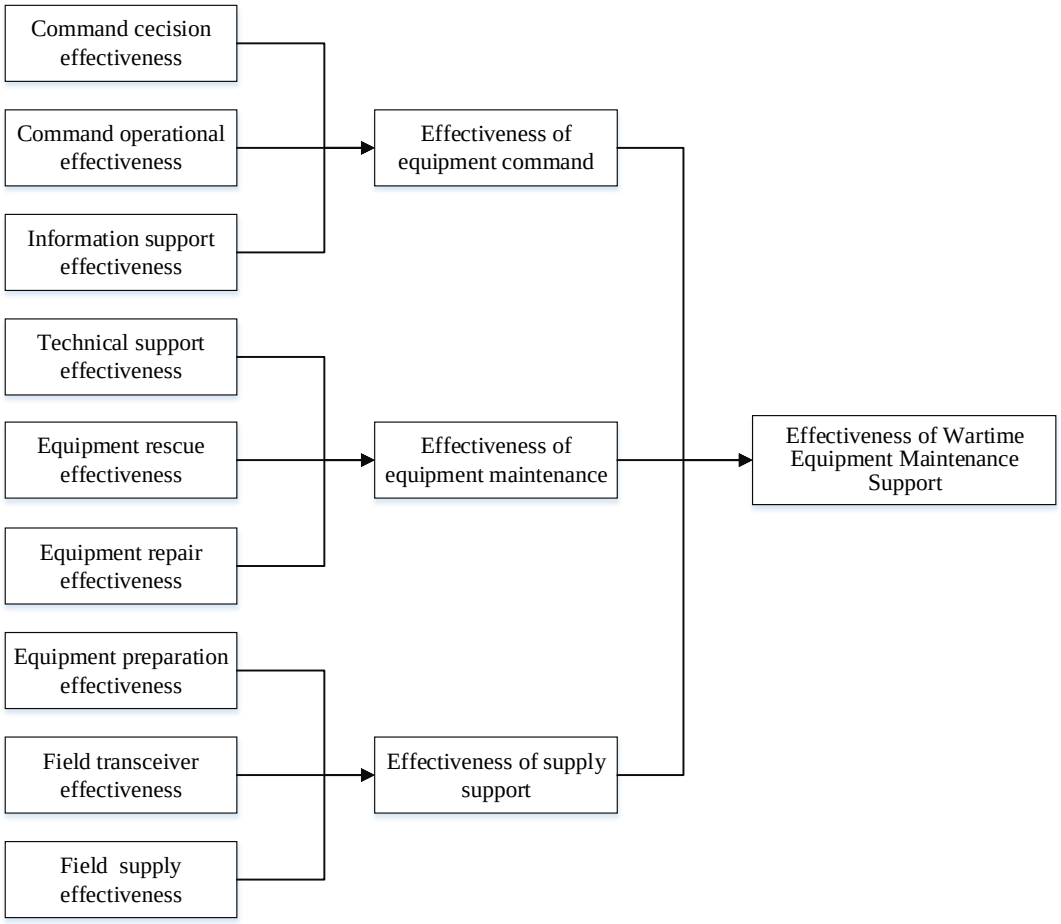


Figure 1. Example of a figure caption.

3.2. Network parameters of evaluation model

Bayesian network parameters can be determined by statistical analysis of prior data or experimental data and machine learning method. Experts in related fields can also be invited to estimate the probability. When the data is incomplete or there are errors in the data, it is difficult to learn the data. Expert estimation will make the network parameters affected by strong subjective factors, which will lead to deviation from the objective reality. The author uses the combination of the two methods, based on historical data, combined with expert revision.

Experts in the field of equipment maintenance and support corrected the evaluation data of previous combat drills, eliminated the wrong data, supplemented the missing data, and obtained the sample data set. Due to space constraints, only the first-level indicator sample data sets are listed here, including 13 different types of sample data, such as equipment command efficiency, equipment maintenance efficiency, supply support efficiency, etc.

Table 1. Sample data of Bayesian network parameter learning.

No.	Effectiveness of equipment command	Effectiveness of equipment maintenance	Effectiveness of supply support	Effectiveness of Wartime Equipment Maintenance Support
1	High	High	High	High
2	High	High	Middle	High
3	High	Middle	High	Middle
4	High	Middle	Middle	Middle

5	High	Middle	Low	Middle
6	High	Low	Middle	Low
7	Middle	High	Middle	Middle
8	Middle	Middle	High	Middle
9	Middle	Middle	Middle	Middle
10	Middle	Low	Middle	Low
11	Middle	Low	Low	Low
12	Low	Middle	Middle	Middle
13	Low	Middle	High	Middle

Using Netica software, the Bayesian network structure of wartime equipment maintenance support effectiveness evaluation is established, and the gradient descent method is used to learn the above sample data, and the probability distribution of each node is obtained, as shown in Figure 2.

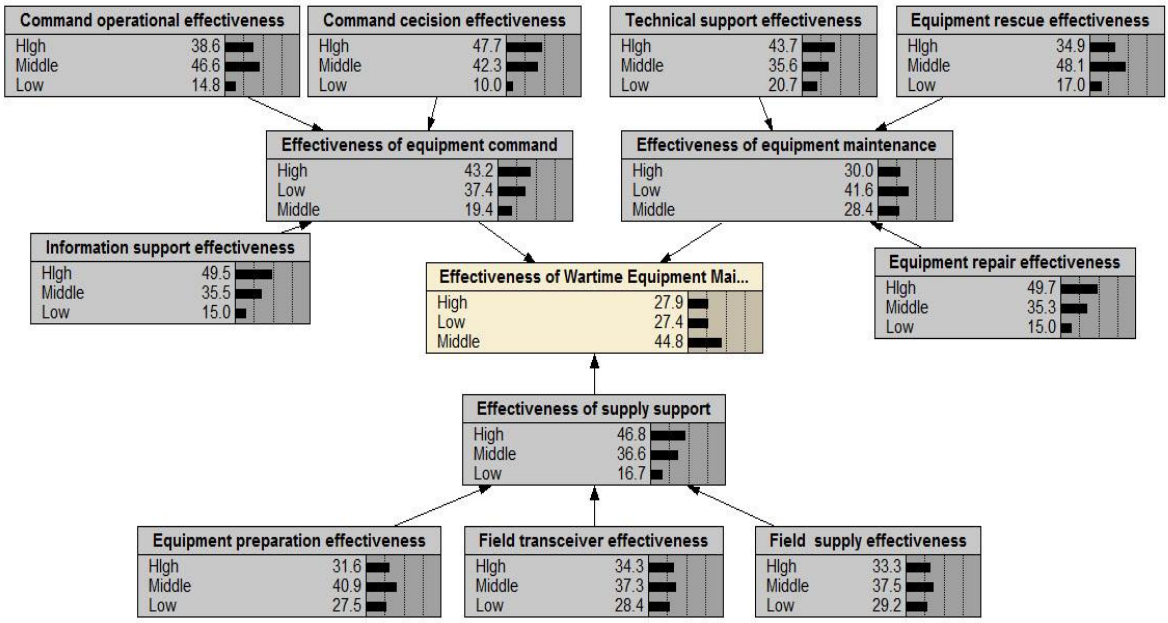


Figure 2. Bayesian network structure.

4. Demonstration of Effectiveness Evaluation Model of Wartime Equipment Maintenance Support

Taking the first-level index in the evaluation model of wartime equipment maintenance and support effectiveness as an example, taking the data collected from a synthetic brigade of the Army as the test sample and comparing with the evaluation criteria for expert evaluation, the equipment command efficiency, equipment maintenance efficiency and supply support efficiency level are obtained, which are taken as the test sample data as shown in Table 2.

Sample data are input into Bayesian network, and the effectiveness evaluation results of wartime equipment maintenance support are obtained as shown in Table 3. Experts in related fields score the wartime equipment maintenance and support effectiveness indicators according to the scoring criteria, and the weighted evaluation result is 90 points, the efficiency grade is high, which is in good agreement with the evaluation result of Bayesian network model. Thus, the Bayesian network evaluation model established in this paper can accurately evaluate the effectiveness level of wartime equipment maintenance support.

Table 2. Testing samples for effectiveness evaluation of wartime equipment maintenance support

Index category	Effectiveness of equipment command	Effectiveness of equipment maintenance	Effectiveness of supply support
Evaluation results	Middle	High	High

Table 3. Test results of effectiveness evaluation of equipment maintenance support in wartime

Evaluation grade	High	Middle	Low
Probability	37.2%	31.7%	31.1%

5. Conclusion

Based on Bayesian network theory, the author evaluates the effectiveness of wartime equipment maintenance support, establishes the Bayesian network structure according to expert experience, uses gradient descent method to learn Bayesian network parameters, obtains the probability distribution of Bayesian network nodes, realizes the effective evaluation of wartime equipment maintenance support efficiency, and improves the effectiveness of equipment maintenance system and chooses wartime equipment. Maintenance support strategy provides decision-making basis.

References

[1] Liu Changtai, Du Xiaoming, Li Feng. Effectiveness evaluation index system of equipment maintenance support [J]. Sichuan Journal of Military Engineering, 2009, 30 (10): 120-123.
[2] Jiao Yue, Li Deyi. A new method for evaluating the effectiveness of CaI system [J]. System Engineering Theory and Practice, 1998, 56 (12): 68-73.
[3] Liu Wei, Jia Xisheng, Hu Qiwei, et al. [J] Research on the effectiveness and evaluation index system of wartime equipment maintenance support [J]. Journal of Ordnance Engineering College, 2010, 22 (6): 1-6.
[4] Chen Fujian, Liu Benmin, Guo Zhongyin, et al. Reliability model of road traffic system based on Bayesian analysis [J]. Journal of Tongji University (Natural Science Edition), 2011 (2): 220-225.
[5] Hu Xin. Risk analysis of high-speed railway Karst Tunnel Based on Bayesian network [D]. Xiangtan: Hunan University of Science and Technology, 2014.
[6] Tian Fuping, Wenbo, Zheng Pengpeng. Bayesian Network-based Operational Target Assessment [J]. Firepower and Command Control, 2017, 42 (2): 79-82.
[7] PEARL J. Fusion propagation and structuringin belief netWorks[J]. Artificial Intelligence, 1986, 29(3): 241-288.
[8] PEARL J. Belief networks revisited[J]. Artificial Intelligence, 1993, 59(1): 49-56.
[9] DARWICHE A. A differential approach to inference in Bayesian networks[C]//Proceedings of the 16th coferenceon uncertainty in artificial intelligence. San Francisco: Morgan Kaufman, 1995: 1146-1152.
[10] Shi Zhifu, Zhang An. Bayesian Network Theory and Its Application in Military System [M]. Beijing: National Defense Industry Press, 2012:54-76.
[11] Du Yuanwei, Shifangyuan, Yang Na. Bayesian Network Construction Method Based on Relative Inference of Fusion Experts [J]. Computer Engineering and Application, 2016, 52 (22): 105-112.
[12] Sun Zhaolin, Yang Hongwen, Hu Weidong. Situation estimation method based on Bayesian network [J]. Computer application, 25 (4): 745-747.

[13] Du Xiaoming, Guping, Gaolu, et al. Effectiveness evaluation of equipment support based on Simulation [M]. Beijing: National Defense Industry Press, 2017:1-10.
[14] Nielsen S H, Nielsen T D. Adapting Bayes networkst-ructures to non-stationary domains[J]. InternationalJour-nal of Approximate Reas-oning, 2008, 49(2): 379-397.
[15] Bressan G M, Oliveira V A, Hruschka J R E R, et al. Using Bayesian networks with rule extraction to inferthe risk of weed inf-estation in a corn-crop[J]. Eng-ineering Applications of Artificial Intelligence, 2009, 22(4/5): 579-592.