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Review of system contribution rate evaluation

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Abstract

In order to better evaluate the role of weapons and equipment in the whole system and promote the development of weapons and equipment, the research on the contribution rate of equipment system has become an important step in the process of equipment research. This paper briefly analyzes the significance and purpose of studying the contribution rate of the system, summarizes and arranges it according to the current main research methods, divides it into architecture model, system capability model and system efficiency model according to the analysis model, describes each model respectively, and points out some problems existing in this research method, And some descriptions of the development trend are made, which provides a reference for the relevant research of the system contribution rate.

Keywords

System contribution rate; evaluation method; architecture; system capability; system effectiveness.

1. Introduction

Modern warfare is a multi-army joint operation under the condition of informationization. Only by improving the combat capability of the system and establishing a complete system of weapons and equipment can we promote the integration and complementation of the performance of various types of weapons and equipment, and give full play to the best combat effectiveness of weapons and equipment [1].

The term contribution rate first appeared in the category of economics, and it is described as the ratio of contribution to output. By constructing the index of contribution rate, it can be used to analyze the role of various economic factors on the economy in the process of economic growth and influence, and draw corresponding conclusions. With the development of society, the term contribution rate has different effects and development in different fields. Such as environment, health, medical care, education.

The concept of system contribution rate was originally proposed by President Xi at the 2014 All-Army Equipment Work Conference, emphasizing "adhering to the idea of system construction, taking the contribution rate to the combat system as the evaluation criterion, and considering and arranging the development of weapons and equipment." The contribution rate of the equipment system is the key problem that needs to be solved to optimize the structure of weapon equipment and improve the efficiency of weapon equipment construction. Therefore, the system contribution rate of equipment has become an important research direction. From the initial single architecture model to the complex network architecture model, and the division of the system only according to the physical structure, to the division of the system according to the equipment capability, to the division of the system according to the efficiency, it shows that the system contribution rate has been fully developed.

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2. Research status

At present, the research on the contribution rate of the equipment system mainly focus on three aspects: the evaluation of the contribution rate of the equipment system structure, the evaluation of the contribution rate of the equipment system capability, and the evaluation of the contribution rate of the equipment system efficiency. In addition to these aspects, in recent years, the research on the contribution rate of the system based on the combat ring theory has also increased.

2.1. Equipment Architecture Contribution Rate Model

The most basic system model is the equipment architecture contribution rate model, which is shown in Figure 1. The model is mainly divided into three layers, the top layer is the equipment system layer, the middle layer is the single system layer, and the bottom layer is the equipment layer. Taking the example given in [3] as an example, the top layer is the entire electronic equipment system, the middle layer is composed of various systems such as early warning detection system, communication system, weapon equipment system, the bottom layer is the specific equipment in the various system.

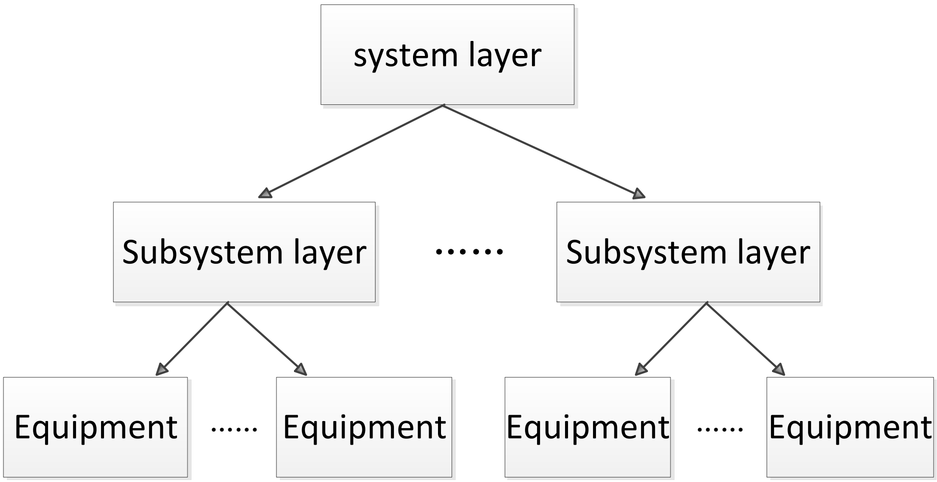

Figure 1: Architecture contribution rate model

Reference [4] pointed out that since the equipment system is affected by various aspects such as combat tasks and military and political guidance ideas, the connection between various levels is not only a one-to-many connection, but a more complex many-to-many connection. Therefore, the equipment system model of the network structure can better express the connection relationship between different levels than the traditional tree structure equipment system model.

Reference [5] proposes a fault tree-based analysis and evaluation method to analyze the contribution rate of equipment. This method is to study the influence of the failure probability of the bottom layer on the failure probability of the top layer. By studying the relationship between the failure probability of the top layer and the failure probability of the lower layer in the system, the importance of the bottom layer to the top layer can be obtained. So, its result can be regarded as the contribution rate of the bottom layer to the top layer.

Through the analysis of the above research results, it can be concluded that the simple architecture model has been unable to adapt to the current combat system with a variety of equipment. Each type of equipment will have different effects through different combinations, and one type of equipment is commanded by multiple sets of command systems, so the many-to-many network structure will become the main direction of future research.

However, due to the complexity of the network structure, the contribution rate evaluation method for a certain equipment will not be able to evaluate its contribution rate with the

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evaluation method of single system. Therefore, finding a suitable evaluation method for evaluating networked architecture will become a difficult problem to be overcome in the future.

2.2. Equipment system capability contribution rate model

The equipment system capability model is based on the capability displayed by the system during combat, by studying the contribution rate of a certain capability in the entire system and judging what the capability that affects the combat system is based on the results obtained. In addition, the system model can also be applied to the contribution rate of a single capability of the equipment to the capability of entire equipment. The system model is shown in Figure 2.

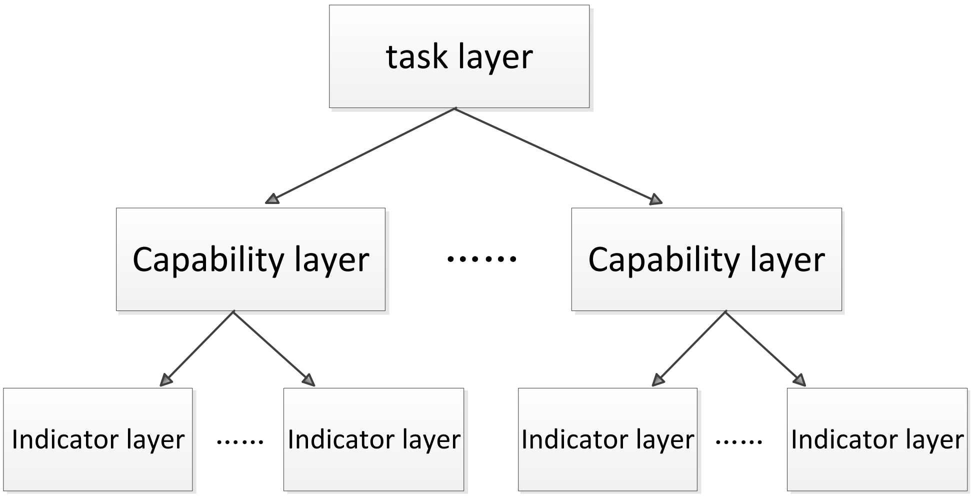

Figure 2 : System Capability Contribution Rate Model

References [6-21] all use the system capability model. For example, the capabilities involved in the References [6] are only three types of early warning, command and control, and fire strikes, but these three capabilities are evaluated by a variety of indicators. According to the actual ability of the equipment, these indicators are given a good, medium and poor evaluation, and then the contribution rate of each index item is obtained according to the commonly used contribution rate calculation formula (1).

$$\text{system contribution rate} = \frac{\text{contribution rate after equipment replacement}}{\text{contribution rate before equipment replacement}} - 1 \quad (1)$$

Next, the weight distribution is obtained through the contribution rate percentage of each indicator, and then the overall contribution rate is obtained according to formula (2). When establishing the weight distribution, the subjective weighting method is often used, and the attribute weight is determined according to the subjective importance of decision makers and experts to each attribute.

$$\text{system contribution rate} = \sum_{1}^{\text{number of abilities}} \text{Ability weight given by experts} * \left(\frac{1}{\text{Number of indicators}} \sum_{1}^{\text{Number of indicators}} \text{contribution rate of this indicator}\right) \quad (2)$$

The calculation method of the system contribution rate mentioned in the literature [8] is similar to that of the reference [6,7], both of which are calculated based on the contribution rate of a single equipment. In addition, the reference [8] also proposed a calculation formula for a large number of the same equipment, that is, the contribution rate of each same equipment is weighted and averaged, and the weight is given by experts. Reference [9] emphatically describes the comparison process of the gray target comparison method and gives specific examples, and analyzes the advantages and disadvantages of various equipment system contribution rate evaluation methods.

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The Belief Rule-Base mentioned in the reference [10] is also mentioned in other literatures on the contribution rate. For example, the reference [11,12,13] all construct the Belief Rule-Base to analyze contribution rate.

The Belief Rule-Base is composed of a large number of IF-THEN models. 'IF' is a limited condition composed of simulation experiments, objective conditions, and expert experience. When an event satisfies the conditions of 'IF', it can be concluded that the 'THEN' The conclusions contained and the extent to which that conclusion is credible. Then, multiple conclusions are aggregated through the evidence inference algorithm, and finally the contribution rate of the system can be obtained. However, most of the parameters in the Belief Rule-Base are given by experts and are highly subjective, the reference [10,11] use the differential evolution algorithm to optimize the parameters of the Belief Rule-Base.

Reference [14] uses the AHP to calculate the system contribution rate. The AHP is to establish an evaluation table for each index under the same ability through different experts, and then obtain the judgment matrix of the ability. Then, the maximum eigenroot of the matrix and the corresponding eigenvector are obtained, and finally the average value of each eigenvector is obtained to obtain the weight vector of the capability. According to the same method, the weight vectors of other abilities are obtained. Finally, the result of multiplying the weight vectors of each ability by their respective weights is the contribution rate of the system. Reference [15] adopts the fuzzy AHP, which is similar to AHP in that it analyzes the contribution rate of the system by constructing a matrix. Reference [16] also used the AHP to analyze the system contribution rate.

Reference [18] is based on the relationship between equipment system configuration, system capabilities, combat tasks and mission requirements, and determines the quality function from the demand set to the metric set to expand a quantitative decomposition matrix. Then, the weight of the metric set is determined according to the quantitative decomposition matrix, and the ability and efficiency are evaluated according to the approximation ideal solution ranking method. Finally, according to the evaluation results, whether the total efficiency change of the sub-system is included or not, the evaluation value of the system contribution rate is given. The method used in reference [19] is fuzzy clustering and entropy weight method to calculate expert weight and index weight. Reference [20] simplifies some details from a practical point of view, and can quickly calculate the contribution rate of indicators under the current system. Reference [21] pointed out the influence of time change and real scene change on expert weight, and proposed a method suitable for avionics system contribution rate evaluation, and solved the time weight vector through artificial intelligence algorithm.

Through the analysis of the above research results, it can be concluded that how to objectively evaluate the emergence of the overall capability of the equipment system has become a key research direction for the equipment system. Since there are different required capabilities in different equipment systems, and the index content of each capability is also different, the evaluation of the emergence of the overall capabilities of the equipment system will yield different results. Therefore, finding a method that can be used to evaluate the overall capability will be a problem that needs to be overcome in studying the capability model of the system. In addition, because the artificial intelligence algorithm has a good optimization effect on the parameters in the evaluation method, the combination of the research system contribution rate evaluation method and the artificial intelligence algorithm will become the focus in the future.

2.3. Equipment System Efficiency Contribution Rate Model

The equipment system effectiveness model is basically similar to the system capability. The third level of the effectiveness model is the efficiency of completing subtasks, while the third level of the capability model is more specific capability indicators. The model works by studying various aspects of the equipment.Then the relative contribution rate of the equipment in the whole system can be calculated by using formula (3).

$$\text{system contribution rate} = \frac{\text{efficiency after equipment replacement}}{\text{efficiency before equipment replacement}} - 1 \quad (3)$$

Reference [22] analyzes and studies the advantages and disadvantages of the simulation test and the actual installation test, and then proposes a system contribution rate evaluation method based on the integrated maturity test, which opens up a new idea for the study of the system contribution rate. Reference [23] achieved a rapid evaluation of the contribution rate of the system, but it still needs to be refined in details.Reference [18, 24] combine the system capability model with the efficiency model, and then use a comprehensive evaluation method to obtain the efficiency contribution rate and capability index contribution rate of the two models, and finally obtain the contribution rate of the entire system. Reference [25] introduced the content of neural network to build a system efficiency model, and the weights were continuously adjusted through artificial intelligence algorithms. Then the optimal weight combination is obtained, which will make the result of the system contribution rate optimal.

In the process of evaluating the contribution rate of the system, the literature [26] built a deep-level evaluation model based on deep learning such as SDAE+Softmax, which can better ensure the accuracy of the evaluation results. In addition, the model can also describe the internal characteristics of complex systems well. References [27,28] also use artificial intelligence algorithms to build a system efficiency model in the process of studying system efficiency, which makes the evaluation of system efficiency more accurate. Reference [29] builds a detailed system performance model from the actual situation, adding a variety of necessary calculation indicators, so that the contribution rate of each indicator of the entire equipment is more specific and has a better realistic background.

Through the analysis of the above research results, it can be seen that combining two different system models to obtain a more complete evaluation system will help to better evaluate the contribution rate of equipment, which will become an important research direction.In addition, the use of artificial intelligence algorithms to assist in the construction of the system model will also help to improve the accuracy of the evaluation effect, and make the final system contribution rate result more accurate. This will also become an important direction for the contribution rate of future research systems.

2.4. Modeling based on combat ring system

The combat ring theory is a system network model proposed by Tan Yuejin and other researchers based on the OODA theory. The model is composed of four nodes: reconnaissance, decision-making, influence, and target. The basic combat unit composed of these four types of nodes is shown in Figure 3. Each node contains one or more weapons and equipment, and the more types of weapons a node contains, the higher the stability of the node. It means that when one type of equipment is affected by interference, there will be other types of equipment to complete the task of the node.

The content studied in the reference [30-39] is based on the theory of combat ring to carry out the research on the contribution rate of the system.Reference [30] converts the probability of the network connection loop of the combat ring into the solution of network reliability under the condition of random node failure after the combat ring is networked.Then, the Monte Carlo method based on DFS (depth-first search algorithm) is used to solve the reliability of the combat loop network, that is, the effectiveness value of the combat loop network is obtained.

Reference [31] adopted the calculation method based on information entropy to obtain the contribution rate of the system. This paper improves the calculation formula of the system

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contribution rate, and adds the concepts of the risk factor of the equipment life cycle and the cost of the equipment to the contribution rate formula.

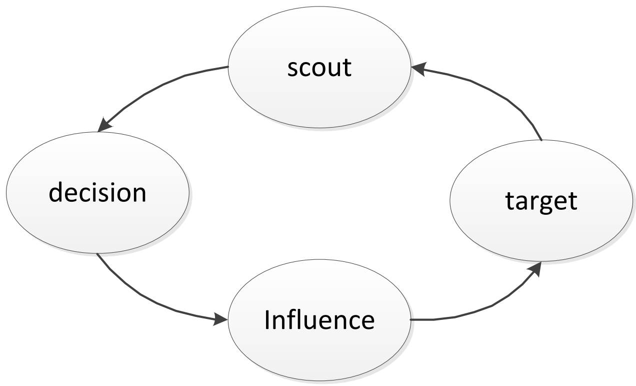

Figure 3: Basic unit of combat ring

Reference [32] adopts the system contribution rate evaluation method based on self-information to realize the evaluation and calculation of the combat effectiveness of the system, which improves the credibility of the evaluation results.

References [33, 34] have proposed to use the Monte Carlo method to calculate the system contribution rate after the battle ring is networked, which provides a new method for the study of the system contribution rate.

References [35] combines the combat ring theory with the research on the attribute contribution rate of a single equipment, and points out that this research idea can be used to evaluate the contribution rate of weapon equipment systems that perform a single task. This paper provides a new application idea for the study of system contribution rate.In the references [36], a combat link similar to the combat ring network is constructed, and then the weights in the link nodes are determined based on the improved CRITIC method and the contribution rate of each node is obtained. Finally, it can get the contribution rate of the entire network system.

Reference [37] describes the basic model and basic problems of the contribution rate of the fighter system based on the OODA loop, and also briefly describes the confrontation process of the system.Reference [38] considers the impact of space-time factors on the combat ring network, and improves the evaluation content of the system contribution rate, which has obvious practical significance.Reference [39] proposed a multi-task-oriented system contribution rate calculation method, which provided a theoretical basis in the face of a multi-task equipment system.

The research on the contribution rate of the system based on the combat ring is an important direction of the research on the contribution rate of the system. It can well show the connection between each node and the process required to complete the task objective.The difficulty of its research is that when the nodes between multiple combat loops form a new combat loop to operate jointly with the original combat loop, the calculation of the contribution rate of the shared nodes is complicated.

3. Conclusion

Through the reading of the system contribution rate literature in recent years, it is realized that with the complicated real conditions, the simple tree evaluation model can no longer meet the evaluation needs of the rapidly developing equipment system. The networked evaluation model will become a key direction of future research. In addition, the application of artificial

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intelligence algorithms will help to build more reasonable evaluation models, as well as process parameters involved in optimizing evaluation.

References

[1] H.W. Lv, Q.C. Wu, W. Zhang Equipment System Contribution Evaluation Based on Gray Evidence Theory[J]. Journal of Academy of Military Transportation, 2017,19(5): 22-27.
[2] C.K. Luo, Y.X. Chen, H.C Xiang. Review of the evalution methods of equipment's contribution rate to system-of-systems[J]. Systems Engineering and Electronics, 2019, 41(8): 1789-1794.
[3] B. Zhou, D.P Kong, H.D. Qiao, Evaluation method of SoS contribution degree for electronic information equipment[J].Aerospace Electronic Warfare, 2019,35(01):19-23.
[4] Y.Q. You, J. Jiang, J.B. Sun, et al. Evidential network-based evaluation method of contribution to weapon system-of-systems[J]. Systems Engineering and Electronics,2019, 41(8): 1780-1788.
[5] C.K. Luo, Y.X. Chen, Z. Ke, et al. Evaluation method of aviation equipment's structure contribution rate to system-of-systems based on fault tree analysis[J]. Journal of National University of Defense Technology, 2021, 43(1): 155-162.
[6] G.W. Zheng, S.Y. Dong, Evaluation Method of Contribution Rate for Large Caliber Naval Gun System[J]. Command Control & Simulation, 2020, 42(4): 66-72.
[7] T.L. Liu, T.P. Zhang, P. Gao, Contribution rate assessment method of wartime equipment system based on structural equation model[J]. Military Operations Research and Systems Engineering, 2020, 34(2): 39-45.
[8] X. Li, X. Fu, H.W. Lv, Contribution Rate Evaluation of Radar Equipment Capability Enhancement of Anti-missile Early Warning System[J]. Ordnance Industry Automation, 2020, 39(9): 22-24, 44.
[9] X.Q. Wu, Y. Yang, Y. Zhou, Research of Evaluation Method for Equipment Contribution Rate to System of System[J]. Astronautical System Engineering Technology,2021,5(3):21-27.
[10] Y.L. Meng, G.M. Chen, R.F. Han, Contribution Rate Assessment of Equipment System Capability in Early Warning Counter Attack Combat[J]. Fire Control & Command Control, 2019, 44(7): 27-32.
[11] Y. He, Research on Capability Contribution of Anti-missile Weapon Systems based on RIMER[D]. National University of Defense Technology, 2016.
[12] W.Y. Chen, B.Z. Zhang, L.C. Shi, Research on Evaluation of Contribution Rate of a New Intelligent Armoured Combat System to Army Weapon System-of-systems[J]. Acta Armamentarii, 2018, 39(9): 1841-1849.
[13] C.K. Luo, Y.X. Chen, Y.M. Zhang, Evaluation of Equipment Contribution Rate to System-of-systems Based on Hybrid Parameter Evidential Network[J]. Acta Armamentarii, 2018, 39(12): 2488-2496.
[14] B.C. Lou, Helicopter System Contribution Evaluation based on AHP[J]. Helicopter Technique, 2020,(01):6-10+14.
[15] D.L. Guan, X.H. Wu, G. Chang, Contribution Ratio Evaluation for Naval Battle Group Information System Based on Fuzzy-AHP Method[J]. Command Control & Simulation, 2019, 41(3): 122-127.
[16] L. Wang, B. Li, Z.A. Qiu, Evaluation of System Contribution Rate for Air-to-Air Missile Weapon System[J]. Aero Weaponry ,2021 ,28 (1) : 20-25.
[17] H.G. Yan, Z.Y. Lu, L. Wang, Application of System Contribution Rate Assessment in Equipment Life Cycle[J]. Journal of Academy of Armored Force Engineering, 2019,33(2):28-32.
[18] M. Lin, X.B. Li, Y.F. Wang, Capability-effectiveness evaluation of contribution ratio to system-of-systems based on QFD and combination weights TOPSIS[J]. Systems Engineering and Electronics,2019,41(8): 1802-1809.
[19] D.T. Wei, X.D. Liu, W. Xu, Evaluation of Equipment System of Systems Contribution Rate Based on Entropy Weight Group Analysis[J]. Journal of Information Engineering University, 2021, 22(1):107-111, 128.
[20] J.B. Zhang, Evaluation of the System Contribution Rate of the American Alebock Destroyer in the Formation Cooperative Air Defense Operation[J]. Marine Electric, 2021, 41(8): 38-42.
[21] X. Zhou, F. He, X.Y. Gu, Dynamic comprehensive evaluation with weight evolution for system contribution rate of avionics systems[J]. Systems Engineering and Electronics, 2020,42(8): 1740-1750.
[22] J.H. Song, L. Li, Q.S. Guo, Research on Weapon Equipment System Contribution Rate Evaluation Method[J]. Fire Control & Command Control, 2019, 44(3): 107-111.

[23] J.M. Miao, B.Z. Shen, G.W. Jia, An Assessment Method of Contribution of Equipment System based on Degree of Mission Completion[C]// Proceedings of the 8th China Command and Control Congress, Ordnance Industry Press,2020:589-593.

[24] X.J. Wang, Y.F. Guan, Research on Contribution Rate of Anti-cluster UAV Equipment System Based on TOPSIS Method and Simulation Method[J]. Air & Space Defense, 2021, 4(1): 33-40.

[25] S.N. Chen, A. Zhang, F. Gao, Equipment Contribution Rate to System-of-Systems Evaluation Method Based on Deep Belief Networks[J]. Command Control & Simulation, 2021, 43(4): 26-31.

[26] X.J. Yin, X.F. Hu, S.M. Guo, Evaluation Method of the Contribution Rate to SoS Based on SDAE + Softmax Model[J]. Fire Control & Command Control,2021,46(6):7-11.

[27] Z.Y. Ji, H.K. QI, Machine Learning Method Application in Effectiveness Evaluation of Anti-ship Missile Weapon System in Battlefield Environment[C]// Proceedings of the 9th China Command and Control Congress, Ordnance Industry Press, 2021: 551-557.

[28] Z.Y. Ji, Y. Chen, P.Z. Shen, Decision Tree Integration Method Application in Effectiveness Evaluation of Anti-Ship Missile Weapon System[J]. Modern Defence Technology, 2021, 49(4): 15-23, 34.

[29] W.Q. Wang, H.G. Ren, Z.C. Gao, Evaluation of System Contribution Rate of Helicopter-borne Air-to-air Missile[J]. Journal of Projectiles, Rockets, Missiles and Guidance, 2021, 41(3): 100-104.

[30] C. Zhou, B.L. Shang, B.F. Song, E.Q. Ke, Y.Z. Wang, Aviation armament system of systems contribution evaluation based on operation loop. Acta Aeronautica et Astronautica Sinica,2022,43(02):314-325.

[31] D.J. Yue, J. He, X.H. Zhou, W. Zhang, Assessment of Contribution ratio to System-of-system of GPS jamming Equipment in Anti-patrol Operation. [J]. Electronics Optics & Control,2021,28(07):21-25.

[32] C.K. Luo, Y.X. Chen, X. Hu, Evaluation Method of Equipment's Contribution Rate to System-of Systems Based on Operation Loop and Self-Information Quantity[J]. Journal of Shanghai Jiao Tong University, 2019, 53(6): 741-748.

[33] G.X. Fang, Y.J. Tan, M. Zhang, Evaluation of relative contribution rate of missile weapon system-of systems based on combat ring[J]. Systems Engineering and Electronics, 2020, 42(8): 1734-1739.

[34] C. Zhou, B.F. Song, B.L. Shang, Armament system of systems contribution evaluation based on operational network reliability[J]. Systems Engineering and Electronics, 2021, 43(7): 1875-1883.

[35] L. Wang, B. Li, Z.A. Qiu, Evaluation of System Contribution Rate for Air-to-Air Missile Weapon System[J]. Aero Weaponry, 2021, 28(1): 20-25.

[36] D.X. Zhang, C. Wang, J.L. Guo, Improved Evaluation Method of Contribution Ratio of CRITIC System Based on Structure and Function[J]. Fire Control & Command Control,2021,46(6):39-46.

[37] L. Yang, H.Y. Han, Q.T. Yuan, D. Zhang, H.Q. Chen, S. Xiao, Contribution Rate of Fighter System of Systems Effectiveness Based on the OODA Loop[C]// Selected papers on complex systems engineering.,2019:190-195.

[38] Q.L. Chen, C.K. Luo, Y. Liu, Y.M. Zhang, Evaluation Method of Technical Contribution Rate of U.S. Aircraft Carrier Combat System-of-Systems Considering the Influence of Time and Space[J]. Modern Defence Technology,2021,49(03):21-29.

[39] X.Y. Xie, Y.D. Chen, X.N. Zhao, Evaluation Method of Integrated Weapon Equipment's Contribution Rate to System-of-Systems Based on Operation Loop[J]. Missiles and Space Vehicles,2020(3) :122-126.

[40] T.L. Yao, Q.W. Hu, Z.Y. Qi, Soft Computing-based Assessment Method of Contribution Rate of Small Arms and Equipment System[J]. Acta Armamentarii, 2019, 40(5): 938