Comparative Analysis of Equipment Cost Structure Optimizing Methods

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***Abstract*—**Four optimizing methods of equipment cost structure were detailedly analyzed based on their theories. The strengths and weaknesses of the four optimizing methods were analyzed and compared each other. And the characteristics of system dynamics were introduced. It was found that the weaknesses of the four optimizing methods were just made up by the characteristics of system dynamics. It was put forward that system dynamics is better than the four methods in optimizing equipment cost structure at the moment. This viewpoint not only enriches the categories of optimizing methods for equipment cost structure, but also explores a new way for optimizing equipment cost structure in practice.

1 Introduction

Equipment cost structure optimizing [1] is an improving process of its configuration benefit on condition that the total equipment cost is finite, to achieve the system harmonious and high efficient constantly, and to develop the "value surplus" due to diseconomy of structure. Its essence is optimizing the internal proportion of equipment cost expenditure. In view of equipment life cycle cost management, optimizing equipment cost structure is one of the efficacious methods in improving its economy and military benefit, as well as a immanent request of current equipment development [2].

2 Analysis of Optimizing Methods for Equipment Cost Structure

Optimizing the structure of equipment cost means distributing the cost logically, it mostly consists of two contents [1]. One is for a certain equipment system, how to distribute its development cost, stock cost, operational and support cost based on the immanent relation of each part in life cycle cost. The other is how to distribute the macroscopical development cost, stock cost, operational and support cost as well as the distribution inverse proportion among all the armed services. At present, optimizing methods for equipment cost structure mostly include intuitive analysis method, systemic analysis method, proportional parameter method and utility function method.

2.1 Intuitive Analysis Method

Intuitive analysis method [1,3] (named experiential analysis method too) is a longitudinal analysis method. It mostly depends on the wisdom of experts and the practical experiences of human, analyses the historical data (the main structure data of equipment cost in the previous years) longitudinally, summarizes the change laws of equipment cost structure, makes the inverse proportion relation among each cost certain, distributes the equipment cost structure this year based on the data and results that finds out from the logical equipment cost structure at present, in order to seek an optimal structure for equipment cost. Intuitive analysis method works on historical data, hangs qualitative analysis and quantitative analysis together to show the change law of equipment cost structure itself, then works out the proportion of various expenditure by weighted average method, and defines the logical distribution structure according to next year's reality so as to reduce the subjective factors, increase the objective factors and ensure the conclusion no doubtful.

Although, intuitive analysis method shows the change law of equipment cost structure itself, it would go against the external environment working on equipment cost structure. It is difficult to find new references for new situation because intuitive analysis method has rest on experience analysis stage. There are researchers advanced some applicative policy advice depend on historical data which introduced from the foreign army. However, different countries have different reform direction and specific target, which leads equipment cost structure take on some certain difference, and it is caused by the effect of data availability, reliability and time lag that horizontal comparison is unable to show our national conditions and

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our military characteristics as well as control the direction of optimizing equipment cost structure in mid-long term. Therefore, demonstration analysis method should be introduced into intuitive analysis method for studying problems such as the interrelationship of equipment cost structure in and out of China to develop the research category of intuitive analysis method.

2.2 Systemic Analysis Method

System principle emphasizes studies problems from the global aspect, pays attention to global function. When using systemic analysis method, firstly, setting a goal of army's modernization construction. It should not emphasize a part and disobey the whole when define the whole structure, and system principle is use to achieve maximum global function, strive for winning maximum military economic benefit. Secondly, analyzing and determining system factors according to ordinal principle. Concretely, analyzing the main component factors of national defense scientific research and development cost, equipment purchase expenditure, equipment scientific research expenses and equipment maintenance management cost systemically so as to find their laws, characteristics and relationships. Then arrange them in order of primary-secondary sequence, importance and priority. We should determine the logical distribution proportion on equipment cost structures of land army, navy, air force and armed services as well as their status and effects in future wars, and make them to achieve coordinated development. At last we should find out a new balance-cost proportion rationalization for the system. For instance, if we use equipment life cycle cost management to raise development cost and improve the reliability, the maintenance and support cost will reduce heavily. Using this method, the equipment cost structure might jump to a better and newer stable state, make the equipment cot system to produce more military economic benefit.

Modeling (such as linear programming model [3]) is an useful means of systemic analysis method, and theorists have advised to analyze equipment cost structure by system theory, but it is very difficult to quantify the system target all the time. So it is impossibility to set up an effective model for systemic analysis method, and we just can use its research approach. This is not only a pity for the systemic analysis method, but also a main reason why systemic analysis method can not be made deep research on optimizing the structure of equipment cost.

2.3 Proportional Parameter Method

Proportional parameter method aspires after the best combination of battle effectiveness factors based on army's strategic policy, aims at improving army's cooperative engagement capability and raising the military economic benefit, counts different proportional parameters in multi-levels, makes equipment cost structure to achieve optimal. Proportional parameter method which is used widely, does not need plenty of practical experience or professional knowledge as expert method and analogy method, and collecting data, determining variable, analyzing relation, establishing cost estimate model are the key points, and its main approaches are illustrated in Figure 1 [3].

In view of the whole army, proportional parameters was figure out among development cost, equipment purchase expenditure and operational and support cost, between the armed services and the special force in different theater. The more the proportional parameters, the more optimal the equipment cost structure. Although, proportional parameters may be figure out by AHP, Delphi method, etc, it is very hard to determine the proportional parameter because of strong subjectivity.

2.4 Utility Function Method

Utility function method works by seeking the mathematical extremum [1, 4], it is illustrated in Figure 2 with a budget constraint line and an equal product curve group. Suppose the equipment cost has two structures (such as development cost and purchase expenditure) expressed x_1 and x_2, and the utility function expressed $U = U(x_1, x_2)$. The equal utility curve is convex to the origin because there has been a law of diminishing marginal utility in military economic field. U_1, U_2, U_3 respectively represent three different utility levels, and $U_3 < U_2 < U_1$. The budget of equipment cost expressed AB, Q is a tangent point for AB and U_2, M, N are the intersectant points for AB and U_3, and F is in U_3, E is in U_1.

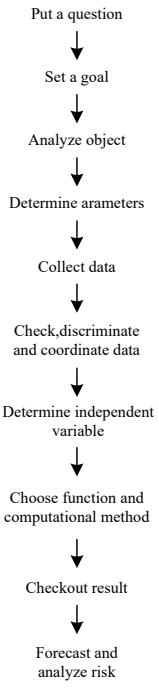

Figure 1. Proportional parameter method's main approachs

In a certain period, the quantity of equipment cost is invariable, so all the equipment expenditure should be in $\triangle 0AB$ which is inside of AB (include AB). On utility level, $U_1 > U_2 > U_3$, but U_1 is outside of AB, it is an impossibility. F is inside of AB, but the equipment cost

is not sufficient used because $U_3 < U_2$ on utility level for F. Also, M, N are not proper, and they could be improved by the Pareto. Q is in U_2, so $Q > M, N, F$ on utility level, moreover, Q is in AB, and Q is a tangent point of U_2 and AB, so here the equipment cost structure is the Pareto optimal, namely the equipment cost structure is optimal, and the best structure is $x_1 = x_{10}$, $x_2 = x_{20}$. Although D is in U_2, it is impossible in the budget of equipment cost at present.

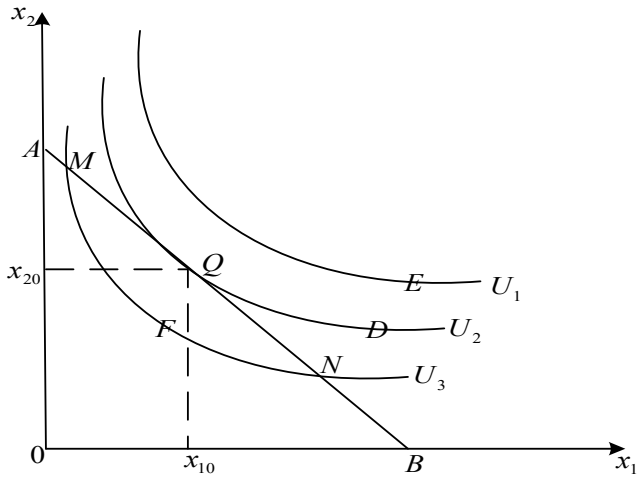

Figure 2. The optimal equipment cost structure

When there is multi-structure (three or n), its optimizing way is the same as two structures, namely multi-dimensional (three or n) equal utility curved surface instead of equal utility curved, but the optimizing process is much more complex, and the best optimizing point is the tangent point of budget flat surface and equal utility curved surface.

3 A Comparison of Optimizing Methods for Equipment Cost Structure

It is clearly illustrated in Table 1 that the emphases of the above four methods are different, and each of them has strengths and weaknesses. So we should extensive use modern economic methods and systemic scientific methods to find out the correlative factors which affect equipment cost structure, make the research on optimizing equipment cost structure be modeling principle, describe and simulate the function of equipment cost structure, put up systemic simulation with computers, and achieve the optimizing aim in the end.

System Dynamics [5,6] (SD for short) praised "stratagem and policy laboratory" is an important branch of system science and management science, it is a cross-subject of communicating natural science and social science. The model simulation of SD is a structure-function simulation, and it can be used for doing researches on a variety of complex system such as social system, economic system, ecological system and their combined system. SD sets up models with flow-graphs, it has mature and normative modeling methods, a simulation language (DYNAMO), simulation softwares and many peculiar strengths: (1) SD is able to work in the condition of data lacking because it emphasizes that systemic mode mostly lies on its inner dynamic structure and feedback mechanism; (2) SD is accomplished in dealing with the problems of multi-dimensional, nonlinear, multi-level and time-varying, etc, and equipment cost structure just has these problems; (3) SD is able to transform the factors which unable to be quantified into math-physical and statistic expression, and finally show the numerical numeration and simulation result; (4) SD studies complex system problems based on the computer simulation technique, hangs quality and quantification together, spirals and gradually deepens, investigates the dynamic development of system; (5) SD models can be used as a policy simulation platform all the while. These strengths just make up the weaknesses of the four optimizing methods above. Further more, Luo [7], Zhang [8] and Zhang [9] have respectively set up the system dynamics' model on control of equipment life cycle cost. The simulation experiments have shown that it is an available way of studying in control of equipment life cycle cost using SD. Therefore, not only in theory, but also in practical modeling, using SD to optimize equipment cost structure is better than intuitive analysis method, systemic analysis method, proportional parameter method and utility function method, it is worthy discussing deeply and researching further.

TABLE I. Strengths and Weaknesses Comparison of Equipment Cost Structure Optimizing Methods

Optimizing Methods	Strengths	Weaknesses
Intuitive analysis method	Working on historical laws and experiences, hanging qualitative analysis and quantitative analysis together, simple and convenient.	Hard to get data, control the direction of optimizing equipment cost structure in mid-long term and no references for new situation, more subjective than objective.

Systemic analysis method	Paying attention to global function, distinguishing the order of, and adjusting the imbalance inverse proportion of all distribution structure endlessly.	Hard to quantify the system target, so it is impossibility to set up an effective model for systemic analysis, and we just can use its research approach.
Proportional parameter method	Counting different proportional parameters in multi-levels.	Complicated model, hard to estimate the parameter, many bad effect of people's subjectivity.
Utility function method	Showing the optimizing steps clearly.	Staying at theoretical analysis and qualitative analysis, unable to quantify, and many qualification.

4 CONCLUSION

Choosing a suitable method is the key of equipment cost structure optimization, also, it is an important premise of controlling the life cycle cost effectively, increasing the benefit of equipment cost and improving the battle effectiveness of weapon equipment. This paper advises that system dynamics is better than each of the current four methods in optimizing equipment cost structure. But the concrete measures and detailed approaches of optimizing equipment cost structure are not discussed deeply this time, it will be analyzed soon.

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REFERENCES

1. R. X. Wei and Y. H. Tang. Management of equipment cost. Beijing: National Defense Industry press, 2004.
2. T. Y. Lv, and M. Z. Wu, "Explore and analyze the way of optimizing equipment cost of American army," Military Economic Research, pp. 51-52, March 2010.
3. B. Tian. A Study on Structure Optimization Methods for Military Spendings. Wuhan: Naval University of Engineering, 2008.
4. H. Y. Gao. Western economics (microscopic part). Beijing: Renmin University of China press, 2004.
5. E. Suryani, S. C. Chou, and C. H. Chen, "Rir passenger demand forecasting and passenger of electronic capacity expansion: a system dynamics frame work," Expert Systems with Applications, Vol. 37, pp. 2324-2339, March 2010.
6. Y. G. Zhong, X. J. Jia, and X. Li. System Dynamics. Beijing: Science press, 2009.
7. F. Luo, X. M. Luo, and S. Y. Zhang, "Application of systemics' model on control of fife cycle cost of weapon and equipment," Journal of the Academy of Equipment Command & Technology, Vol. 16, pp. 16-20, February 2005.
8. D. Zhang, F. Luo, and X. M. Luo, "The macroscopical controlof the life cycle cost of the equipments based on system dynamics' model," Journal of National University of Defense Technology, Vol. 27, pp. 110-114, March 2005.
9. S. Y. Zhang, Q. B. Guan, and S. X. Feng, "Simulation of equipment LCC control based on SD," Computer Simulation, Vol. 23, pp. 11-13, July 2006.