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A Systematic Literature Review on the Traditional NPV Model and Its Improved Versions

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ABSTRACT

Based on the analyses of the usage scenarios and limitations of the traditional NPV model, this paper aims to introduce and compare three kinds of the most practical and representative versions of the improved NPV models. In this study, the traditional NPV model is first introduced; followed by analyses of its main defects, such as low flexibility, inability to quantify the value of options, and changes in discount rates that may lead to errors in results. Therefore, three improved NPV models are introduced including Max-NPV, Fuzzy NPV and DNPV. The development background, reasoning logic and application scenarios of each of the three modified models were demonstrated in detail. In the end, some feasible suggestions are given including how to select appropriate modified NPV in reality as well as the matters needed to pay attention to application. This paper could provide useful reference for the NPV related study in the future.

Keywords: *Traditional NPV, Max-NPV, Fuzzy NPV, DNPV, Application*

1. INTRODUCTION

The traditional NPV method has many problems and limitations, such as "unable to quantify the future uncertainty", "unable to make timely adjustment according to the change of decision" [1] and so on. Therefore, great efforts have been made to develop new versions of NPV, and many new modified NPV models of great value and practical significance have emerged. In this paper, three typical models are selected for analysis of research progress, namely Max-NPV, Fuzzy NPV and DNPV.

Firstly, Max-NPV is a model to optimize the project, which is based on maximizing the net present value [2]. It was established in 1922, then with a long term development, it has become a relative completed system for solving the imperfect projects. Secondly, Fuzzy NPV is a reanalysis method of NPV combined with fuzzy mathematics [3], like fuzzy set. This method improves the traditional NPV in terms of cash flow calculation. It provides a theoretical basis for the net present value of uncertain conditions in reality. Thirdly, DNPV is to conduct risk assessment of a project without considering the discount rate, and obtain the risk result of each part of the project which is the variability of cash flow [4]. Therefore, it is convenient for decision-makers to control risks and make investment decisions.

Each of the above three models is designed for the different real-world scenario. Three perspectives of "maximizing net present value", "quantifying uncertainty with fuzzy mathematics" and "cash flow variation with risk" [5] are taken into account in the three models, respectively. Based on previous studies, this paper analyses the popular explanation and feasibility of the three mentioned models, in order to provide different perspectives and references for further modification and optimization of NPV model.

The reminder of this paper is organized as follows: Section 2 reviews the significance of traditional NPV model and its defects in practice; Section 3 introduces the Max-NPV model and different usage scenarios; Section 4 introduces the concept and application of Fuzzy NPV model; Section 5 ends with the analysis and exploration of DNPV method.

2. TRADITIONAL NPV METHOD

2.1. Introduction of the traditional NPV

The Net Present Value (NPV) is how much money we can make over the life of the project given the time value of money (inflation depreciation). In more general terms, what is the maximum annual interest rate we can afford if we take out a loan to invest in the project [6, 7].

NPV method has the most extensive and difficult application scope among the various enterprise valuation methods currently used, and has the highest requirements for financial and business sensitivity [8]. Marchioni and Magni [9] also proposed that the reliability of a valuation model depends on its compatibility with NPV.

2.2. Limitations of the traditional NPV model

The traditional NPV method does not consider the value of options brought about by uncertainty. For projects with high uncertainty and irreversibility [10], although the NPV is easy to calculate and highly manoeuvrable, the existing NPV method has serious defects in cash flow and risk estimation, discount rate determination and option consideration, which affect investment decisions [11]. The application of NPV method in actual corporate financial decision-making requires targeted changes and upgrades in combination with different environments and situations.

2.2.1. Neglect of choice

The traditional NPV method contains an assumption: once a certain investment is decided, it cannot be changed during the life of the project, no matter how the environment it faces changes. In reality, most investment projects have some degree of flexibility in management and adjustment. D. Bogataj and M. Bogataj [12] put forward the view that this flexibility is manifested in the fact that managers need to make judgments and decisions based on actual conditions during the project's duration, such as postponement, abandonment, and expansion. The existence of this management option will have an impact on the cash flow of the project, which in turn will affect the effect of investment decisions.

Therefore, when using the NPV method to evaluate investment projects, the value of the option must be considered [13], that is, the value of the project should be equal to the general NPV plus the value of a certain option.

2.2.2. Changes of discount rate

Another assumption implied in the traditional NPV rule is that the risk is constant during the life of a given investment project. However, the risk degree of cash flow in the life of the project cannot be consistent, so the NPV calculated according to this and the investment decision will certainly have a great deviation [14]. Reflected in the design and calculation of valuation models, the discount rate will change over the lifetime. Once the discount rate changes drastically due to some unexpected situations [15], the calculated NPV will be disconnected from the actual situation and cannot reflect the real value of the underlying investment project.

3. MAX-NPV METHOD

3.1. Introduction of the Max-NPV

Max-NPV Project Scheduling Problem was presented in 1970 by Russell [16]. It is used to optimize the project schedule. The net present value is decided by both client defrays and the cost of project.

Therefore, if the schedule is arranged too fast, it is bound to increase the investment of resources and increase the cost. In addition, too fast progress will cause the fracture of capital flow and increase the financing cost. On the contrary, if the schedule is too slow, there is a risk that the project will be delayed and the owner will be punished for not delivering the project according to the time stipulated in the contract. Therefore, how to reasonably arrange the progress of the project is directly related to the benefits of the project.

3.2. Max-NPV at different conditions

The Max-NPV project scheduling problem can be divided into two categories which are resource-free and resource-constrained problem [17]. The resource-free problem can use exact algorithm to optimize which means it is easier. Resource-constrained project scheduling problem is a classic problem in construction projects. It is NP-hard problem which means it needs to use heuristic algorithm to solve. The early studies are limited but Dayanand and Padman induce the contract payment into Max-NPV project adjustment problem for the first time, and the project payment input model is formed, which optimizes the payment arrangement and the project schedule to maximize the net present value of the project [18, 19]. Since the project payment schedule problem is a combinatorial optimization problem, Dayanand and Padman developed a two-stage intelligent optimization algorithm for this problem [20].

3.3. The contrast of Max-NPV and the traditional NPV

Max-NPV is based on the conventional NPV but it must be used in the specific contract payment mode to optimize the schedule [18, 19]. Compared with the conventional NPV, the Max-NPV emphasizes on the arrangement to get the max NPV. It is because that in practical application, whether the capital or other resources is not fixed, the owner can adopt a lot of tools like the loan, borrowing, and purchase which means the more flexible schedule can get more net present value than the conventional NPV. And Max-NPV must depend on a set of accurate tools to calculate the best arrangement. The conventional NPV is based on the determinate cash flow but Max-NPV on the uncertain future. Therefore, the Max-NPV is more practical in the reality.

3.4. The application of the Max-NPV

In the early time, the Max-NPV is focused on to achieve the shortest time limit for a project or the minimum of the project cost.

With relatively high interest rates and expensive financing costs, however, especially for capital-intensive projects, NPV maximization is more in line with the goal of profit pursuit of enterprises. In addition, in the implementation process of the project, it is inevitable to involve the inflow and outflow of cash. The inflow of cash represents the payment by the owner, while the outflow of cash represents the cost caused by manpower, equipment, and raw materials. From the contractor's point of view, he hopes to get the payment from the owner as soon as possible and at the same time postpone the payment of expenses as late as possible, to effectively increase his own net present value and maximize the net present value of the project.

4. FUZZY NPV METHOD

4.1. Introduction of Fuzzy NPV

Fuzzy NPV is another method of the expanded NPV method commonly based on mathematical fuzzy sets and fuzzy functions. The fuzzy set is an important concept in fuzzy mathematics, which refers to the whole of something with certain attributes as a fuzzy collection.

Because of the uncertainty of the conditions, and to make the Fuzzy NPV easier to understand and calculate, Maravas and Pantouvakis [21] introduced the three-dimensional model of the Fuzzy NPV diagram as a means of visualizing the uncertainty when studying and calculating the Fuzzy NPV in the cost-benefit analysis (CBA). The hypothesis of this method is real and intuitive, and the mathematical complexity is low, and it is easy to be computerized.

In traditional NPV, for example, what is the cost from start to finish, and how much investment is appropriate for the specific project at the exact time. In real life, however, many things do not provide an exact figure. The advantage of Fuzzy NPV is that all the uncertain cases can be considered, and the relevant model can be established for accurate calculation.

4.2. Application of Fuzzy NPV

There have been many experts and scholars in the study of different Fuzzy NPV. Although the concept of Fuzzy NPV is the same, there are many different fuzzy conditions or use different fuzzy mathematical theorems to study it.

For example, Chrysafis and Papadopoulos [22] cited Fuzzy NPV in the project evaluation. Fuzzy NPV can deal with uncertainty and a fuzzy environment in the investment analysis well. The method can consider various factors and increase the flexibility of decisions in the project execution. It compensates for the defect that traditional NPV cannot make decisions during the project life cycle because of the asymmetric planning and execution stages of the project life cycle. They used stochastic calculus to simulate randomness and fuzzy set theory to simulate uncertainty. As for the algorithm, they cited Klir and Yuan's [23] theorem, fuzzy set principle and fuzzy algorithm attributes, Sfiris and Papadopoulos's [24] proof of non-discontinuous fuzzy estimation, and deduced the net value of fuzzy possibilities and the upper and lower probability of fuzzy through NPV formula. Finally, a flexible method of Fuzzy NPV is proposed to evaluate the actual investment. They believe that this approach enables flexible assessment of various types of projects, such as construction, transformation, and reform.

Meanwhile, Nazeri [25] also proposed an evaluation method of project constraints with Fuzzy NPV. The biggest advantage of this method is that it contains the smallest possible value, the bigger of the two possible values, and the maximum possible values.

In the decision of the investment market, Sun [26] introduced fuzzy numbers and risk weight (VLR) into the net present value to establish another new model. In the process of calculating NPV, the traditional NPV formula is modified appropriately and the relevant data is fuzzy treated. It is found that this method can reflect the investment decision of the objective market more accurately and provide a more accurate reference for investors. Compared with the traditional NPV method, this model can be more devoted to the market changes, and can effectively control the risk, and avoid the loss of the unanticipated Fuzzy NPV analysis of multi-project and multi-cycle combinations.

5. ANALYSIS AND EXPLORATION OF DNPV METHOD

5.1. Introduction of DNPV

Espinoza, Morris [27] and Espinoza [28] introduced the decoupled net present value (DNPV) method. It combines multiple concepts of prospect theory and deterministic equivalence method to better explain standard financial concepts (such as Utility theory) did not capture investor behaviour. Prospect theory is a theory introduced by Kahneman and Tversky [29] to describe uncertain decision-making. The main feature of CEM is the separation of the time value of money (represented by the risk-free interest rate) and risk. In order to better analyse the project, use the cost of risk to identify and evaluate the project, pay attention to the characteristics of cash flow, to assess the risk of investment, especially to price the risk of lower-than-expected cash flow, so as to represent investors in assuming such risks compensation. Then formulate a set of valuation framework including the calculation of expected value, the discount of the risk-free rate to the result, and the control of risk cost. The main advantage is that the risk cost of DNPV depends on the project and is independent of the risk appetite of investors. It can better structure concessions and redistribute risks among stakeholders.

It is similar to the previous paragraph, the main function of DNPV is to reduce the processing of uncertain expected cash flow and combine risk assessment with risk price, making it an indicator to evaluate the performance and value of the project, when the project risk and time value of funds. When grouping together, one of heuristic methods, probabilistic methods and/or stochastic methods can be used. Probability and stochastic methods are used to price risk. The DNPV method is used to directly link risk management and financial performance. The results obtained represent the true value of investment opportunities, in other words, DNPV combines the two valuation rules of financial indicators and risk indicators to provide investors with in-depth consideration of different risk sharing mechanisms and establish appropriate conditions for risk integration to ensure that investors can obtain maximum returns.

5.2. Applications of DNPV

5.2.1. Agriculture

In order to better prove the versatility of DNPV, many researchers mainly used greenhouse pepper cultivation as an example. In the process of planting, pepper faces the basic risks of pests and diseases to peppers, as well as the natural risks of climate change and water resources, as well as economic risks caused by price changes such as discount rates. In order to deal with these problems, Espinoza proposed application methods including methods, decision trees [30]; and introduced analysis combining with critical analysis to evaluate decisions, and evaluated the value of risk as a cost, which is convenient for decision makers. Following is the sensitivity analysis that combined with the value of options through probability analysis, the value of risk is evaluated as a cost, which is convenient for managers to make investment decisions. When the DNPV method is used to quantify the risk and combined with the decreasing gamma discount function, it is found that DNPV is not affected by the discount reducing function, and all risks are correctly and accurately analyzed which the results more accurate.

5.2.2. Natural ecology

For the carbon credits royalty's estimation, the first step is assumed that the overspending risks of capital expenditure and operating expenditure are the same. Further to calculate the additional risk cost by combining the negotiated price of carbon credit and the amount of methane collected. Using the DNPV method by analyzing cost and revenue to calculate that 32% of the carbon credit revenue should be paid to the city as royalties as an additional benefit.

6. CONCLUSION

Through a comprehensive analysis of the traditional NPV method, several dynamic factors affecting the calculation result of traditional NPV method are listed: the value of the option in the project process is not considered, and the inconsistency of the risk degree of cash flow in the life of the project is not considered.

This paper analyzes three kinds of improved NPV and draws the following conclusions:

Firstly, in Max-NPV, it focuses on how to arrange the project schedule to achieve the maximum net present value or minimum the loss of NPV. Therefore, it has more practical significance than the conventional one. Secondly, in Fuzzy NPV, it provides a solution to cash flow accounting under many uncertain conditions. Therefore, the introduction of three-dimensional and triangle fuzzy numbers in Fuzzy NPV makes it more precise and cover a wider range, allowing NPV to be accurately accounted for or compared under more uncertain conditions. Third, in DNPV, the risk cost of DNPV depends on the project and is independent of the risk appetite of investors, the accuracy of the risk cost calculation is directly related to the accuracy of the cash flow distribution profile, and finally allows technical experts to seamlessly integrate the project risk assessment into the project finance valuation.

In summary, the analytical perspectives and conclusions provided in this paper can be used to further study other types of NPV versions not mentioned in this paper. This paper is worthy of being used as a reference for the solution of traditional NPV optimization problems in the future.

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