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Research on Risk Assessment of R&D projects based on Bayesian decision theory

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***Abstract*—By discussing the characteristics of risk-based decision making and the advantages and disadvantages of expected value method, this paper puts forward that people should not only consider the principle of maximum (or minimum) expected value, but also consider the irretrievable consequences of one-off risk decision making. In order to solve the reliability problem of risk decision making, this paper puts forward a method to optimize the expected value.**

***Index Terms*—Research and development project, Risk assessment; Bayes' formula; Bayesian decision theory.**

I. Introduction

Research and development project refers to the research and development activities carried out by an organization within a specified time and budget. The central task is to carry out the research and development of a certain theory, technology, product and process. Because of the particularity of R&D industry and R&D process, there are many uncertain risk factors in the development cycle of R&D products. The existence of these risk factors often leads to the failure of R&D projects. According to a Standish Group survey of U.S. companies, only 28% of R&D projects are completed on time and within budget [1].

Risk management of research and development projects includes risk identification, risk assessment, risk response and risk monitoring, among which risk assessment is a very important part of risk management to ensure the success rate of research and development projects. Barry Boehm, the father of R & D project risk management, made pioneering work in the systematic definition and analysis of R & D project risk assessment. He quantified risks based on the impact of risks, so as to prioritize known risks and control risks [2]. This is the simplest and most applicable method used by research and development enterprises for project risk management at present. On this basis, many experts, scholars and enterprises also consider the risk controllability index in the risk equivalent.

At present, the theoretical system of risk management of R&D projects is not perfect, and the design and calculation of Bayesian network model is complicated, so it can not be widely used in the risk assessment of R&D projects. Based on this, this paper proposes a risk assessment method for R&D projects based on Bayesian risk decision theory. It conducts research on the theoretical basis of Bayesian probability formula, which is the most basic and fundamental basis of Bayesian theory. It greatly reduces the workload of model calculation, effectively makes up for the problem of low accuracy of prior probability, and improves the accuracy of risk assessment for R&D projects. It provides a simple and scientific method for risk assessment [3].

II. Risk Assessment and Bayesian Decision Theory

A. *Risk assessment*

Risk Assessment refers to the quantitative assessment of the impact and possibility of loss caused by a risk event on people's life, life, property and other aspects before or after the occurrence (but not yet over) [4]. That is to say, risk assessment is to quantify the possible degree of impact or loss caused by an event or thing.

From the perspective of information security, risk assessment refers to the assessment of the threats, weaknesses and impacts of information assets (that is, the information set possessed by an event or thing), as well as the possibility of risks brought by the combination of the three. As the basis of risk management, risk assessment is an important way for organizations to determine the needs of information security, which belongs to the process of information security management system planning. [8] discussed that In surgical planning and cancer treatment, it is crucial to segment and measure a liver tumor's volume accurately. Because it would involve automation, standardisation, and the incorporation of complete volumetric information, accurate automatic liver tumor segmentation would substantially affect the processes for therapy planning and follow-up reporting. Based on the Hidden Markov random field, Automatic liver tumor detection in CT scans is possible using hidden Markov random fields (HMRF-EM).

B. *Basis of Theory*

When making risk decisions, the decision maker can analyze the probability of risk occurrence by analogy according to the existing historical data when there is

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historical data. When there is no historical data or the historical data is insufficient, the decision maker will make a subjective judgment on the probability of future events according to the knowledge and experience of the experts. However, this is not enough to reflect the objective reality, then it is necessary to revise the probability of expert judgment, and Bayes theory is a scientific method to revise the prior probability.

The formula of Bayesian probability is as follows:

Let the sample space of test E be S,A is the event under E,the event groups $B_1, B_2, \mathrm{L}\ , B_n$ are a partition of the sample space S.Assuming that

$$P(B_k) > 0, P(A) > 0, k = 1, 2, \mathrm{L}\ , n.$$

Then,

$$P(B_k \mid A) = \frac{P(B_k)P(A \mid B_k)}{\sum_{k=1}^{n} P(B_k)P(A \mid B_k)}.$$

This formula is called the Bayesian formula where $P(A \mid B_k)$ is the prior probability and $P(B_k \mid A)$ is the posterior probability.

Simply put, Bayesian decision theory is to use prior probability and related conditional probability to get a posteriori probability, and make a decision based on the posteriori probability. Since the prior probability obtained by prior knowledge is not very accurate, the Bayesian decision method is to correct the prior probability and make the decision more perfect and scientific.

C. Bayesian decision making

Bayesian decision is to estimate some unknown states with subjective probability under incomplete information, then modify the probability with Bayesian formula, and finally make the optimal decision by using the expected value and correction probability [5]. Bayesian decision making is a risk-based decision making. Although the decision maker cannot control the changes of objective factors, he can grasp the possible conditions of their changes and various distribution probabilities, and make a choice by using the expected value. Bayesian decision-making is not to make the decision problem completely risk-free, but to increase the information through other ways to give decision-makers a better choice space. Since the decision maker's description of objective factors is uncertain, it will bring risks to the decision maker when making decisions. However, there is no case that all information is certain, especially in the sales market with high volatility.

Bayesian risk decisions are analyzed based on the prior distribution of event states and the loss function of consequences, and the decision rules with the least Bayesian risk are obtained through reasoning, which is the optimal risk decisions [6]. The following takes a random event Y as an example to illustrate how to make Bayesian decision [7-9].

Define a prior distribution function $\pi(\theta)$ and a decision function, then the corresponding loss function is $L(\theta, \delta, (Y))$, then, the risk function is defined as follows:

$$R(\theta, \delta) = E_\theta\left[L\left(\theta, \delta(Y)\right)\right] = \int_Y L\left(\theta, \delta(Y)\right) dP_\theta(Y).$$

It's called Bayesian posterior risk.According to the commutativity of integration order and Fatou lemma, it can be proved that when $\sup R(\delta) < \infty$, Bayesian decision function and Bayesian posterior decision function are equivalent. Therefore, it is necessary to seek Bayesian decision solution according to the posterior risk criterion.

III. RESEARCH AND DEVELOPMENT PROJECT RISK ASSESSMENT MODEL BASED ON BAYESIAN DECISION THEORY

For risk decision making, Bayesian network provides a more accurate and scientific decision-making method for risk decision makers, that is, following the Bayesian risk minimization principle. In R & D projects, due to the existence of many unclear risks and limited project manpower and material resources, we can only focus on controlling risk events with high probability of risk occurrence and big loss after risk occurrence, which is similar to the Bayesian risk decision-making theory, but here we need to find the biggest risks in Bayesian risk [6].

Since the risk assessment in the project is different from the risk analysis in the risk decision, it is necessary to re-establish the risk assessment model of the research and development project. The specific operation is as follows:

(1) Define prior probability distribution. Due to the late development of the R&D project, there is no relatively complete risk data, so experts can make judgments here.

(2) Given the relevant conditional probability parameters, and combined with the prior probability to calculate the corresponding posterior probability.

(3) Define the risk loss function (risk severity: refers to the degree of harm caused by the risk to the project). Due to the difference between risk assessment and risk decision of research and development projects, risk loss here will be defined according to the principles shown in Table 1, which is divided into 5 levels according to the degree of increase of project workload caused by risk. [10] discussed that Liver tumor division in restorative pictures has been generally considered as of late, of which the Level set models show an uncommon potential with the advantage of overall optima and functional effectiveness. The Gaussian mixture model (GMM) and Expected Maximization for liver tumor division are introduced. In the early liver division process Level set models are utilized

It should be noted that the criterion for determining risk severity in this paper is workload. In the risk assessment of the research and development project, the cost or other indicators can be used as the standard to measure, and the establishment of this standard should be based on the actual situation of the research and development organization, and there is no unified standard.

(4) The final Bayesian risk can be obtained by multiplying the Bayesian posterior risk probability with the corresponding risk severity level, and the risk is sorted according to the risk size for risk control.

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Table 1 Risk severity rating of R&D projects

Severity of Risk	Weight	Description
Very high	5	The additional workload for risk mitigation accounts for more than 30% of the original workload
Relatively high	4	The additional workload for risk mitigation accounts for more than 20% and less than 30% of the original workload
Medium	3	The additional workload for risk mitigation accounts for more than 10% and less than 20% of the original workload
Relatively low	2	The additional workload for risk mitigation accounts for more than 5% and less than 10% of the original workload
Very low	1	The additional workload for risk mitigation accounts for less than 5% of the original workload

IV. Conclusion

Risk management of R&D project is a very important work in the process of R&D and a very important factor related to the success or failure of R&D project. Risk management of research and development projects mainly includes the identification, assessment, response and control of project risks. That is, first of all, the project risks should be identified, the relationship between risks and the possibility, consequences and scope of influence of risks should be assessed, the risk response plan should be formulated according to the assessment results, and the risks should be tracked and controlled. The main purpose of research and development project evaluation is to quantify all kinds of risks that may be encountered in project development activities, estimate the possibility of risks and the degree of impact on the project development, prioritize risks, and provide basis and reference for the development of project risk management plan and risk monitoring. It can be seen that risk assessment plays a very important role in the risk management of research and development projects and is the key to the success or failure of risk management.

This paper mainly adopts the risk assessment model of R & D project based on Bayesian risk decision theory to evaluate the risk in R & D project. Practice has proved that this method is simple and effective, and easy to implement, which greatly reduces the workload of the model. The adoption of this model can effectively make up for the low accuracy of prior probability, improve the accuracy of risk assessment of research and development projects, and provide a more reliable basis for risk control.

The shortcoming of this method is that the acquisition of some data depends on expert knowledge and its robustness is relatively poor. In the next step, a more objective evaluation method based on actual data will be introduced by investigating the actual data of enterprises.

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