Risk Assessment of NPD Project Based on ANP

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Abstract
There are a lot of risks in new product development projects. It’s very important to assess these risks accurately for the success of these projects. This paper proposed a risk assessment approach of NPD projects based on analytic network process (ANP) method. The effectiveness of the approach is tested by an actual NPD project. The results show that the approach can reflect the complex relationship among the risk factors, and improve the accuracy of risk assessment.

Keywords: NPD Project, Risk Assessment, ANP

1. Introduction

New product development (NPD) is very important for enterprises, but it is full of risks. So it is one of the most important tasks of NPD project management to assess these risks accurately. In many companies, risk assessments of NPD project are simple and subjective, without using scientific assessment tools, and even quite part of companies don’t put risk assessment into the project management practice. This often leads to underestimate the risk of NPD projects, and brings losses or fails to achieve the expected results for those companies.

There are many methods for NPD project risk assessment, such as Failure Mode and Effect Analysis (FMEA), Decision Tree (DT), Analysis Hierarchy Process (AHP), Fuzzy Analysis (FA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Bayesian Approach, Data Envelopment Analysis (DEA), Grey Comprehensive Evaluation (GCE), Neural Network (NN), and so on. Carbone used FMEA to assess the important factors which affect NPD results in the automotive industry[1]. Lam applied AHP to analyze the key factors of conflict management in the NPD process [2]. Buyukozkan made a fuzzy analysis on NPD under uncertainty, and compared the choice of different NPD projects[3]. Kahraman analyzed the influencing factors and decisions by using TOPSIS [4]. Wang used TOPSIS to analyze the NPD risks and pointed out the advantages and disadvantages of this method[5]. Junxin Shen and Songjiang Wang used BP neural network method to assess the risk of BOT projects[6]. Chin applied bayesian approach to analyze and evaluate NPD risks, which can effectively solve the problem of dynamic assessment of NPD risks[7]. Feng XU apply Bayesian network to analyze the risk factors of software project[8].

Furthermore, some comprehensive risk analysis methods, such as Fuzzy Analytic Hierarchy Process (FAHP) and Gray Analytic Hierarchy Process (GAHP), can combine the advantages of different assessment methods, so they are applied to the research and practiced more and more recently. Li Xiaofeng established the multidimensional extension-matter-element model of comprehensive risk measure of enterprise technological innovation based on matter-element and extension set theories[9]. Bao GuoXian studied the FAHP assessment and decision-making of enterprise's technological innovation risks[10]. These methods have different advantages and can be applied in different situations, but these methods are hard to describe the multi-objective, multi-level, multi-elements and uncertainties characteristics of NPD project, and can not fully meet the needs of practical works in NPD project management.

Analytic Network Process (ANP) is an improved decision method based on AHP, which was proposed by professor Satty[11]. It not only retains the advantages of AHP, but also can be used to solve complex network-structure problems, which can not be dealt with by AHP. AHP assumes the elements in the same layer have no relationship each other, but it occurs rarely in the practice of NPD projects. In fact, risk factors are always interrelated. ANP method considers not only the relationship
between the lower elements and the upper elements, but also the correlations of the same layer elements. So it is very suitable for the risk assessment of NPD project. Therefore, this paper proposes a risk assessment approach of NPD project based on ANP method, to make a beneficial exploration on NPD project risk assessment.

2. Risk Assessment Based on ANP Method

A risk assessment approach based on ANP method is proposed in this section. The goal of this risk assessment approach is to evaluate and rank the risks in NPD projects, and get the final weight vector of the risk set. The risk assessment approach includes following steps:

2.1. ANP model construction

In general, an ANP model includes two parts: the control layer and the network layer. The criteria of the control layer are independent, but the element groups of network layer may interact mutually. And the elements in an element group also may influence each other. Fig. 1 shows a general ANP model. The criteria of control layer are K1, K2, ..., Km; the element groups of network layer are C1, C2, ..., CN; and the elements in each element groups are e1i, e2i, ..., eini, i=1,2,...,N.

![Figure 1. General ANP Model](image)

2.2. Building the weighed super-matrix

If the main criterion is ks and the secondary criteria are the element ejl (l=1, 2, ..., n) in element group Cj, it can get a judgment matrix by comparing the elements in Cj with each other according to their influence on ejl. To normalize the eigenvectors of the judgment matrix can get a weight vector $W(j1) = (w_{i1}^{j1}, ..., w_{in}^{j1})$. Similarly, we can get $W(jk)$, k=1,2,...,n.

Sets $W_{ij} = (W(j1), ..., W(jn))$, then the column vector of $W_{ij}$ is the priority vector, which means the influence degree of the elements (e1i, e2i, ..., eini) in Ci to the elements (ej1, ej2, ..., ejni) in Cj. If the elements in Ci have no influence on the elements in Cj, then $W_{ij}=0$. Thus, the super-matrix under the criteria of $K_t (t=1, 2, ..., n)$ is given by
Super-matrix just presents the extent of the mutual influence of the network elements. But it does not consider the mutual influence of element groups. So we can get a weighted super-matrix as follows: \( W = a_j \times W' \), where \( a_{ij} \) is the weight of the influence of element group i to the element group j, and \( \sum a_{ij} = 1 \). The relative weight matrix \( a_{ij} \) can be obtained by AHP method.

### 2.3. Calculate the final weight vector of the risk set

The value of the weighted super-matrix \( W \) refers to the first-stage priority, and the second-stage priority can be calculated further, and so on. Repeat the process till \( W^\infty = \lim_{k \to \infty} W^k \) exists, thus column p of \( W^\infty \) is the limit relative weight of element groups to element p under the criteria \( k \).

Hence, the limit super-matrix is:

\[
W^\infty = \begin{bmatrix}
W_{11}^\infty & W_{12}^\infty & \cdots & W_{1N}^\infty \\
W_{21}^\infty & W_{22}^\infty & \cdots & W_{2N}^\infty \\
\vdots & \vdots & \ddots & \vdots \\
W_{N1}^\infty & W_{N2}^\infty & \cdots & W_{NN}^\infty
\end{bmatrix}
\]

The elements in \( W^\infty \) are limit weight elements. Then we can put these elements into a column vector in order. The vector is the final result of the risk assessment.

### 3. An Example of Npd Project Risk Assessment Based on Anp Method

In this section, the risks of a NPD project in the consumer electronics manufacturer A are evaluated, for the illustrative purpose of the suggested approach.

#### 3.1. Identify NPD project risk factors

Usually NPD project process can be divided into several stages, such as decision stage, R&D stage, production stage, and marketing stage[12]. The risk factors in each stage are quite different, so it needs to identify the main risk factors in each stage firstly. For example, 18 main risk factors are identified in the decision stage of the company A, which are shown in table 1. These risk factors are classified into 3 types, which are environment factor, enterprise factor and project factor. For company A is a foreign manufacturer with very strong technical strength, there are 9 risk factors belong to environment factor in the decision stage.
### Table 1. Main Risk Factors of NPD Project at Decision Stage

<table>
<thead>
<tr>
<th>Risk scope</th>
<th>Risk index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>the impact of industrial policy (e11)</td>
</tr>
<tr>
<td></td>
<td>effect</td>
</tr>
<tr>
<td></td>
<td>macro-economic situation (e12)</td>
</tr>
<tr>
<td></td>
<td>the impact of relevant laws and regulations(e13)</td>
</tr>
<tr>
<td></td>
<td>the scale of intended market (e14)</td>
</tr>
<tr>
<td></td>
<td>the change of market demand (e15)</td>
</tr>
<tr>
<td></td>
<td>the acceptance degree of market to products (e16)</td>
</tr>
<tr>
<td></td>
<td>the demand degree of market to products (e17)</td>
</tr>
<tr>
<td></td>
<td>the accept time of market to products (e18)</td>
</tr>
<tr>
<td></td>
<td>the dependence of market on competitors' products (e19)</td>
</tr>
<tr>
<td>Enterprise</td>
<td>product positioning (e21)</td>
</tr>
<tr>
<td></td>
<td>the understanding of consumer demand (e22)</td>
</tr>
<tr>
<td></td>
<td>top managers' attention on the project (e23)</td>
</tr>
<tr>
<td></td>
<td>top managers' innovative consciousness (e24)</td>
</tr>
<tr>
<td></td>
<td>the science of decision (e25)</td>
</tr>
<tr>
<td></td>
<td>the sufficient degree of capital supply (e26)</td>
</tr>
<tr>
<td>Project</td>
<td>project cost control (e31)</td>
</tr>
<tr>
<td></td>
<td>project capital demand (e32)</td>
</tr>
<tr>
<td></td>
<td>the life cycle of new product (e33)</td>
</tr>
</tbody>
</table>

#### 3.2. ANP model development

Fig.2 shows the ANP model for NPD project risk assessment. The control layer only includes one NPD project risk component. And the network layer includes three first-class components: environment factor, enterprise factor, project factor, and their corresponding second-class components.

![Figure 2. ANP Model for NPD Project Risk Assessment](image)

As is shown in Fig.2, environment factor impact the enterprise factors and project factors, and enterprise factors impact project factors mutually. The internal factors (the second-class components) of the three components impact mutually.

#### 3.3. Procedure

The risk assessment model of NPD project has only one assessment goal (NPD project risk). All elements and element groups use their influence degree to NPD project risk as a criterion for comparison. According to table 1, a comparative matrix could be constructed based on the criterion of NPD project risk. The comparative matrices can be classified into two types: the comparative matrix of element groups and the comparative matrix of elements.
The comparative matrix of element groups with NPD project risk as the main criteria and environment factor as sub-criterion at decision stage can be constructed firstly, shown as table 2:

<table>
<thead>
<tr>
<th>Decision stage (environment factors)</th>
<th>Environment factors</th>
<th>Enterprise factors</th>
<th>Project factors</th>
<th>Normalized eigenvectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment factors</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.4067</td>
</tr>
<tr>
<td>Enterprise factors</td>
<td>1/2</td>
<td>1</td>
<td>3</td>
<td>0.3695</td>
</tr>
<tr>
<td>Project factors</td>
<td>1</td>
<td>1/3</td>
<td>1</td>
<td>0.2238</td>
</tr>
</tbody>
</table>

Similarly, we can obtain another two comparative matrixes of elements groups, which are the matrix with enterprise factor as sub-criterion and the matrix with project factor as sub-criterion. Then the judgment matrix J of first-class indexes (i.e. element groups) can be obtained by combining the normalized eigenvectors of the three comparative matrixes.

\[
J = \begin{bmatrix}
0.4067 & 0.4934 & 0.2211 \\
0.3695 & 0.3108 & 0.46 \\
0.2238 & 0.1958 & 0.3189
\end{bmatrix}
\]

Then it needs to calculate the judgment matrix for second-class indexes. There are three element groups, so there are the 9 judgment matrixes for second-class indexes. The calculation procedure is similar to the calculation of the judgment matrix of element groups. Thus we can get the super-matrix I for second-class indexes of NPD project risks at decision stage:

\[
I = \begin{bmatrix}
I_{11} & I_{12} & I_{13} \\
I_{21} & I_{22} & I_{23} \\
I_{31} & I_{32} & I_{33}
\end{bmatrix}
\]

Where I11 is the judgment matrix that reflects the interaction of the internal elements of environmental factor at the decision-making stage, I12 is the judgment matrix that reflects the interaction of the internal indexes of environment factor and enterprise factor, as others for similar meaning.

Multiplying the elements of I by the corresponding elements of J gives a weighted super-matrix:

\[
\tilde{I} = \begin{bmatrix}
0.4067I_{11} & 0.4934I_{12} & 0.2211I_{13} \\
0.3695I_{21} & 0.3108I_{22} & 0.46I_{23} \\
0.2238I_{31} & 0.1958I_{32} & 0.3189I_{33}
\end{bmatrix}
\]

As the super-matrix is column stochastic, it is directly transformed into the limit super-matrix \( \tilde{T} \).

\[
\tilde{T} = \lim_{t \to \infty} \tilde{T} = \lim_{t \to \infty} \begin{bmatrix}
0.4067I_{11} & 0.4934I_{12} & 0.2211I_{13} \\
0.3695I_{21} & 0.3108I_{22} & 0.46I_{23} \\
0.2238I_{31} & 0.1958I_{32} & 0.3189I_{33}
\end{bmatrix}
\]

The values of the approximate limit super-matrix are almost stable when the power of \( \tilde{T} \) is greater than 40.

Finally, the limit super-matrix \( \tilde{T} \) is normalized, and the final weight vector Q1 can be gotten:

\[
Q1 = (0.0745, 0.0527, 0.0708, 0.0420, 0.0427, 0.0289, 0.0277, 0.0277, 0.0277, 0.0624, 0.0553, 0.0594, 0.0594, 0.0735, 0.0844, 0.0844, 0.067).
\]
As shown in Fig 3, some project factors, such as the factor of cost control and capital demand, have the highest weight. And the factor of product life cycle lies in the sixth. That indicates the factors of project itself is the fundamental source of risk, if capital demand is too high, the NPD project has a higher failure probability which leads to higher risk; and if new product has some drawbacks itself, it will be difficult to accepted by the market, and cannot bring enough profit, which is also one of the important risk sources.

The weight of policy and laws and regulations lie in the 3rd and 5th position respectively, which indicates the limitation or encouragement of these factors can influence the success of project at some extent.

The enterprise factors are also important. Enterprises need to have enough innovation abilities, innovative atmosphere and innovative awareness to increase the successful probability of NPD project.

Most of factors with lower weight are environment factors, the scale of intended market and micro-economic situation are relatively more important, and the acceptance degree of market to products, the demand degree of market to products, the accept time of market to products, the dependence of competitors on products are relatively less important.

The weight vectors of risks at the R&D stage, production stage, and marketing stage can also be obtained according to the above steps.

4. Conclusions

This paper proposed a risk assessment approach of NPD projects based on ANP, which is suitable for the multi-objective, multi-level, multi-elements and uncertainties characteristics of NPD project. The effectiveness of the approach is tested. The results show that the approach can reflect the complex relationship among the risk factors and improve the accuracy and reliability of risk assessment.

In the future, in-depth study on some specific industries can be taken to improve and simplify the proposed risk assessment approach.

5. Acknowledgments

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7. References