Risk Analysis and Evaluation Process of PDM Project Based on Fuzzy Analytic Hierarchy

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Abstract. Based on the comprehensive analysis of the major risk factors of PDM project, this paper establishes risk evaluation index system. In addition, it determines the weight of various indexes by adopting the thought of quantifying the expert’s opinions and applying the fuzzy analytic hierarchy process and evaluates the enterprise risk in PDM project by using fuzzy synthetic evaluation method. It provides bases for the enterprise to make decisions about PDM project and take risk control measures.

Introduction

Product data management (PDM) is a kind of software frame (or data platform) developed with the software technology as the basis, the product as the core and the distributed network, subordinated structure, graphic user interface and database management technology as a base. It can realize the integrated management of data, process and resources in relation to products [1]. As the key of production and operation management of an enterprise, product data have become an important content and support of implementing informational project such as ERP. However, from the PDM implementation effect in recent years, it can be seen there is still a high failure rate. Therefore, it has very important research value to study the key successful factors of implementing PDM project, establishing risk management strategy, control the risk in the life cycle of the PDM project. Learning from foreign scholars’ research on software project risk results provides an important basis for risk analysis and evaluation of PDM project. Hao (2011) [2] Proposed software project risk management system and the system for a more in-depth research; Zafar(2015) [3] shows an application of the metrics in an environment of multiple projects of software development with the goal of analyzing its applicability and utility as support tool for decision-making and risk monitoring during project life cycle; Janjua (2016) [4] contacted 14 experts of 6 different countries through an open ended questionnaire to take their opinion about software project effective risk management and results indicated that to measure the effectiveness of risk management, it must be viewed in broader context of project success; Otto B(2012) [5] proposes how to evaluate and implement the business benefit of product data management (PDM), aiming to understand the "means - end relationship" between PDM and product data. In method selection, the paper adopts fuzzy analytic hierarchy process (FAHP). Introducing the thought and method of fuzzy mathematics to analytic hierarchy process (AHP) can combine qualitative analysis with quantitative analysis effectively, which provides scientific and feasible methods for multi-target risk evaluation of medium and large-size project on certain condition [6,7].

Risk Factor Analysis and Evaluation Index System of PDM Project

PDM project risk refers to the existence of the influencing factors like the uncertainty of external environment and conditions themselves, the difficulty and complexity of PDM project and the PDM project organization and its stakeholders failing to foresee or control the risks correctly makes the PDM project fail to reach the expectation and thus brings about the possibility of loss. It mainly includes quality risk, expense risk, schedule risk, management risk, human resource (HR) risk and purchase risk etc.
(1) Quality risk. The quality of PDM software product refers to the using value and attributive of software and the quality of project work, which is the guarantee of realizing the product value. Quality risk is mainly determined by factors like the reliability of software product and the satisfaction of project work.

(2) Expense risk. As PDM project is invested flexibly, and the expense is estimated flexibly, the change of external environment will cause some risks of capital need beyond the plan. The main factors affecting the risk of expense are the correctness of estimation and budget, the expense control ability and the expense support, etc.

(3) Schedule risk. PDM project involves many employees and departments. The environment is complicated and the schedule has a big elasticity. The major influencing factors of schedule risk mainly includes the correctness of schedule and the control ability of schedule, etc.

(4) Management risk. Management risk mainly refers to that affects the coordination of constituents of projects. The implementation of PDM project will certainly result in reform and the reform may encounter the obstruction. How to reduce the obstruction, capability of reforming and capability of organization management is related to the rationality of management system.

(5) Human resource (HR) risk. PDM project team is usually made up of enterprise party, PDM software support provider and consultant. Therefore, how to coordinate the project participants is the key factor to affect the risk of project. HR risk index mainly includes the stability of employee team, the adequacy of HR and the quality and capability of project employees.

(6) Purchase risk. Purchase risk refers to what affects the project implementation owing to improper selection of PDM product, and contract administration disorder, etc. The rationality of purchase plan, the normalization of purchase procedure and the completeness of purchase contract are the major influencing factors of the risk.

According to the risk analysis of the PDM project above, the paper constructs the risk index system of PDM project based on the scientific, systematisms, comprehensiveness, convenience, feasibility, and the combination of quantitative and qualitative principle, as is shown in Figure 1.
Risk Evaluation of PDM Project

Step 1: Construct Fuzzy Consistent Matrix

According to the index system in Diagram 1, compare the same layer of various factors subordinated to (or influencing) various factors of the above layer by comparison between each two factors and construct fuzzy consistent matrix $R = (r_{ij})_{66}$. In order to describe the relative importance of any two indexes in the above layer quantitatively, 0.1-0.9 scale method is adopted as Table 1.

Table 1. 0.1-0.9 Scale method.

| Compare Factor Ui with Uj | The evaluation value of Ui |
|---------------------------|---------------------------|
| extremely important       | 0.9                       |
| very important            | 0.8                       |
| obviously important       | 0.7                       |
| slightly important        | 0.6                       |
| equal                     | 0.5                       |
| slightly unimportant      | 0.4                       |
| obviously unimportant     | 0.3                       |
| very unimportant          | 0.2                       |
| extremely unimportant     | 0.1                       |

The fuzzy evaluation matrix $R$ of the important degree of Factor U1, U2,…, U6 through comparison is shown in Table 2.
Table 2. Fuzzy evaluation matrix $R$ of PDM project.

|          | U1  | U2  | U3  | U4  | U5  | U6  |
|----------|-----|-----|-----|-----|-----|-----|
| quality risk | R11 | R12 | R13 | R14 | R15 | R16 |
| expense risk | R21 | R22 | R23 | R24 | R25 | R26 |
| schedule risk | R31 | R32 | R33 | R34 | R35 | R36 |
| management risk | R41 | R42 | R43 | R44 | R45 | R46 |
| HR risk | R51 | R52 | R53 | R54 | R55 | R56 |
| purchase risk | R61 | R62 | R63 | R64 | R65 | R66 |

**Step 2: Calculate the Weight of Evaluation Index**

According to fuzzy consistent matrix, solve the weight $\omega_i$ of each factor and make the single rank. The computational formula is as below:

$$\omega_i = \frac{1}{6} - \frac{1}{2a} + \frac{1}{6a} \sum_{k=1}^{6} r_{ik}, i = 1, 2, \cdots, 6$$ (1)

In these formulas, 6 is the order of fuzzy matrix, $a$ is the parameter to meet $a \geq (6 - 1)/2$.

**Step 3: Determine Fuzzy Evaluation Set and Evaluate the Grade Subordination Degree**

The fuzzy evaluation set refers to the set of the evaluation value given to the evaluation object under one evaluation index. The paper adopts 5-level evaluation system and the fuzzy evaluation set $V = \{\text{the risk is very high, the risk is slightly high, the risk is ordinary, the risk is slightly low and the risk is low}\}$ to form fuzzy evaluation matrix of factor $U_i (i=1,\ldots,6)$

$$E_i = \begin{bmatrix} e_{11} & e_{12} & e_{13} & e_{14} & e_{15} \\ e_{21} & e_{22} & e_{23} & e_{24} & e_{25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ e_{k1} & e_{k2} & e_{k3} & e_{k4} & e_{k5} \end{bmatrix}$$ (2)

Hereinto, $k$ is index $k$ of factor $U_i$, $e_{kj} (j = 1, \cdots, 5)$ is the subordinate degree of index $k$ to the evaluation $V_j$ of Level $j$. The value of should be determined according to the following method: make statistics of the score result by utilizing Delphi method and get that there are $Q_{ik1}$ of Level $V1$ evaluations, $Q_{ik2}$ of Level $V2$ evaluations, $\ldots$, $Q_{ik5}$ of Level $V5$ evaluations for index $U_{ik}$, then

$$e_{kj} = \frac{Q_{ikj}}{\sum_{j=1}^{5} Q_{ikj}}$$ (3)

**Step 4: Make Single Hierarchy Fuzzy Comprehensive Evaluation**

According to the marks of experts and supervisors to each index, apply the above method of constructing the fuzzy consistent matrix of various factors to construct the fuzzy consistent matrix of various factors. Through calculation, get the single-hierarchy comprehensive evaluation vector of Factor $U_i$. The computational formula is:

$$U_i = \omega_{ik} \cdot E_i$$ (4)

Hereinto, $\omega_{ik}$ is the weight vector of various indexes of Factor $U_i (i=1,\ldots,6)$.

Determine the factor evaluation result of single-hierarchy comprehensive evaluation vector by adopting maximum subordinate degree principle. That is, when $a_i = \max[a_1, a_2, \cdots, a_5]$, it can be deemed that the comprehensive evaluation grade of the factor is Grade $i$. 

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Step 5: Make Multi-hierarchy Fuzzy Comprehensive Evaluation

Firstly, construct the fuzzy evaluation matrix $E = \{U_1, U_2, U_3, U_4, U_5, U_6\}$ between the PDM project risk $U$ and the evaluation set $V$, and then utilize the weight $\omega_i$ of various factors to calculate the whole risk $U$ of the PDM project. The computational formula is as below:

$$ U = \omega_i \cdot E $$

At last, determine the risk of PDM project according to the maximum subordinate degree principle.

**Examples of Application**

In the marketing process, enterprises often need to comprehensively evaluate suppliers’ product quality, productivity, product structures and sales situations, and enterprise market influences, etc., which requires the fuzzy evaluation system [11-12]. Take the index shown in Diagram 1 as the example, and apply the fuzzy analytic hierarchy process to the fuzzy comprehensive evaluation of PDM project risk of Y enterprise.

(1) Construct questionnaire and employ experts to give marks. Calculate fuzzy consistent matrix and weight of various factors and codes by using fuzzy analytic hierarchy process. Make Parameter $\alpha = (6 - 1) / 2$, the computational result is shown in Table 3.

| factor layer         | index layer                                         | weight |
|----------------------|-----------------------------------------------------|--------|
| quality risk         | the reliability of software product                 | 0.54   |
|                      | the satisfaction of implementing the work           | 0.46   |
| expense risk         | the correctness of estimation and budget            | 0.38   |
|                      | the expense control ability                         | 0.34   |
|                      | the expense support                                 | 0.28   |
| schedule risk        | the correctness of schedule                         | 0.48   |
|                      | the schedule control ability                        | 0.52   |
| Management risk      | the reform capability                               | 0.40   |
|                      | the organization management capability              | 0.28   |
|                      | the rationality of management system                | 0.32   |
| HR risk              | the stability of employee team                      | 0.36   |
|                      | the adequacy of HR                                  | 0.32   |
|                      | the quality and capability of employees             | 0.32   |
| purchase risk        | the rationality of purchase plan                    | 0.36   |
|                      | the normalization of purchase procedure             | 0.30   |
|                      | the completeness of purchase contract               | 0.34   |

(2) Get the fuzzy evaluation matrix $E_i$ according to the marks to the possibility of the single factor risk given by the evaluation group made up of project decision maker and related experts.
Table 4. Fuzzy evaluation matrix of each code risk of PDM project.

| index level | name of matrix | The risk is very high | The risk is slightly high | The risk is ordinary | The risk is slightly low | The risk is very low |
|-------------|----------------|-----------------------|--------------------------|---------------------|------------------------|---------------------|
| the reliability of software product | E1 | 0.00 | 0.07 | 0.26 | 0.47 | 0.00 |
| the satisfaction of implementing the work | | 0.34 | 0.53 | 0.13 | 0.00 | 0.02 |
| the correctness of estimation and budget | E2 | 0.00 | 0.33 | 0.54 | 0.13 | 0.00 |
| the expense control ability | | 0.00 | 0.20 | 0.47 | 0.27 | 0.06 |
| the expense support | | 0.00 | 0.00 | 0.00 | 0.20 | 0.80 |
| the correctness of schedule | E3 | 0.06 | 0.20 | 0.40 | 0.34 | 0.00 |
| the schedule control ability | | 0.13 | 0.33 | 0.54 | 0.00 | 0.00 |
| the reform capability | E4 | 0.00 | 0.00 | 0.27 | 0.47 | 0.26 |
| the organization management capability | | 0.40 | 0.53 | 0.07 | 0.00 | 0.00 |
| the rationality of management system | | 0.26 | 0.40 | 0.27 | 0.07 | 0.00 |
| the stability of employee team | E5 | 0.00 | 0.13 | 0.20 | 0.33 | 0.34 |
| the adequacy of HR | | 0.07 | 0.27 | 0.06 | 0.00 | 0.00 |
| the quality and capability of employees | | 0.34 | 0.60 | 0.06 | 0.00 | 0.00 |
| the rationality of purchase plan | E6 | 0.06 | 0.34 | 0.34 | 0.20 | 0.06 |
| the normalization of purchase procedure | | 0.00 | 0.06 | 0.20 | 0.40 | 0.34 |
| the completeness of purchase contract | | 0.20 | 0.47 | 0.26 | 0.06 | 0.00 |

(3) The sheer level fuzzy comprehensive evaluation

Table 5. Single-hierarchy fuzzy comprehensive evaluation.

| factor layer | comprehensive evaluation vector | level of risk |
|--------------|---------------------------------|---------------|
| quality risk | (0.1564 0.2816 0.2002 0.2538 0.1080) | The risk is slightly high. |
| expense risk | (0.0000 0.1934 0.3650 0.1972 0.2444) | The risk is ordinary. |
| schedule risk | (0.0964 0.2676 0.4728 0.1632 0.0960) | The risk is ordinary. |
| management risk | (0.1952 0.2764 0.2140 0.2104 0.1040) | The risk is slightly high. |
| HR risk | (0.1312 0.3252 0.1104 0.1188 0.1224) | The risk is slightly high |
| purchase risk | (0.0896 0.3002 0.2708 0.2124 0.1236) | The risk is slightly high |

(4) Make multi-hierarchy fuzzy comprehensive evaluation

\[
U = \alpha U \cdot E = [0.16 \ 0.10 \ 0.18 \ 0.20 \ 0.24 \ 0.12].
\]

\[
= [0.1564 \ 0.2816 \ 0.2002 \ 0.2538 \ 0.1080 \ 0.0000 \ 0.1934 \ 0.3650 \ 0.1972 \ 0.2444 \ 0.0964 \ 0.2676 \ 0.4728 \ 0.1632 \ 0.0960 \ 0.1952 \ 0.2764 \ 0.2140 \ 0.2104 \ 0.1040 \ 0.1312 \ 0.3252 \ 0.1104 \ 0.1188 \ 0.1224 \ 0.0896 \ 0.3002 \ 0.2708 \ 0.2124 \ 0.1236].
\]

(5) Analysis of evaluation result. According to the risk evaluation result of PDM project in Table 5, it can be known that the quality risk, management risk, HR resource risk and purchase risk are slightly high, and the expense risk and schedule risk are ordinary. According to the result of multi-hierarchy fuzzy comprehensive evaluation and the maximum subordinate degree principle, the whole risk of PDM software project is slightly high. The risk of the project is at a high level. Therefore, project risk should be prevented carefully, especially from quality, management, HR and purchase risks.
Conclusion

As the fundamental management contents of manufacturing enterprises, product data is emphasized all the time. However, the failure rate of PDM projects is found to be very high after investigating several enterprises. Therefore, the research on the risk of implementing PDM project has great theoretical and practical significances. In the risk evaluation of PDM project, this paper establishes fuzzy snapper evaluation model through constructing risk evaluation index system for PDM project. It makes comprehensive analysis of enterprise risk in PDM project qualitatively and quantitatively and thus overcomes the restriction of other risk evaluation methods that can only evaluate single risk qualitatively or quantitatively. Therefore, the evaluation result is more objective and rational, which provides a scientific basis for the decision-maker to make risk analysis before conducting PDM project as well as providing a certain reference for the enterprise to carry out project risk prevention.

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