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Customized Production Project Risk Management with Analytic Hierarchy Process

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Abstract

Based on the PMBOK risk management frame, this paper collects the potential risk factors of the customized project of company T with Delphi method. After several rounds of research, we get 22 level three factors from the original 6 level one factor. Then we filtrate all the 22 level three factors to identify the TOP10 factors with Analytic Hierarchy Process (AHP). This method is qualitative and quantitative. The project manager can find out the critical factors quickly. It's very helpful to analyze and solve issues during project management.

Keywords

Customized Production Project, Risk Management, Research on Critical Factors, Analytic Hierarchy Process, Lean Production, Delphi Method

1. Introduction

As a brand new production mode, customized production aims to produce customized products under acceptable cost and time line. Enormous investment is also required for the new technology and equipments. The internal and external environment changes very quickly as well. The risk happens everywhere, which is believed that a valid risk management is very critical to the success of the project [1]. While the current risk management effect depends on the experience of the project manager. All the arrangements and decisions made under this situation are very subjective. Besides, it's very difficult to find out and focus on the most critical factors when all of them come to you in the same time. There is a big challenge to transfer the risk management knowledge to your peers as well. It

is a big waste to the company.

This paper uses AHP to calculate the weight of each critical factor and rank them. It's quantitative and qualitative which can help avoid the subjective decisions. It's also very easy for the project managers to find out the important factors to help improve the efficiency of the project risk management. The project management knowledge with the AHP can be stored and transferred as well.

2. Literature Review

In the 1960s, risk management becomes a subject. The purpose of the traditional risk management is to decrease the negative effect to the business operation and sustainable development. The primary strategy is to avoid or transfer the risk [2] [3]. Insurance is the most important tool in this period. The risk management research focus on the credits risk and financial risk [4]. The Global Association of Risk Professionals (GARP) established in 1996. It drives the establishing and perfecting of the certification and qualification examination system. The GARP is accepted and recommended by the financial industry in many countries. It becomes the principle standard to measure the risk management ability of the employee. In the same year, Project Management Institute (PMI) issues the first edition of PMBOK. Risk management is one of the nine knowledge field and never been removed since that [5] [6]. Project risk is defined as an uncertain event or condition by PMBOK the 5th edition. It will create positive effect or negative effect to the project objective once happened. The target of project risk management is to enhance the percentage and effect of the positive events and lower them on the negative events. The risk management is divided into six processes by PMBOK risk management frame. They are plan the risk management, identify the risk, implement qualitative risk analysis, implement quantitative risk analysis, plan the risk response and control the risk [7].

AHP (Analytic Hierarchy Process) is suggested by Professor T.L. Saaty from University of Pittsburgh in the early 1970s. It's an easy and flexible quantitative decision-making method to qualitative questions. It can divide various factors from complicated problems into different levels to make them more systematical [8].

According to the subjective judgment of the objective reality, the AHP combines the expert advice and analysis judgment effectively. First of all, make quantitative description of the importance between different factors in the same level. Then calculate each factor's weight of importance. At last, rank the factor based on the weight of importance. The AHP combines the qualitative and quantitative analysis, flexible and systematical to deal with different kinds of problems, which help it get widely attention and application quickly.

3. Identify Risk Factors

Based on the six processes of risk management in the PMBOK, we identify the critical factors of customized production projects with Delphi. In the first round

open research, we identify the secondary factor from A1 plan the risk management、A3 implement qualitative risk analysis、A4 implement quantitative risk analysis、A5 plan the risk response and A6 control the risk. We get 11 secondary factors. In the second round evaluation research, we identify the secondary factor from A2 identify the risk and identify the third factor from 11 secondary factors in the meantime. It totally takes 3 rounds. We get 7 secondary factors and 22 third factors from original 6 primary factors. Establish the critical factor evaluation system of customized production project. See Table 1.

4. Rank Risk Factors with AHP

4.1. AHP Procedure

In order to find out the top 10 critical risk factors, this paper analysis all the 22 risk factors with AHP, below is the procedure:

1) Create hierarchy structure model
2) Construct comparison matrix

Table 1. Critical factor evaluation system of customized production project.

Primary factors	Secondary Factors	Third Factors
A1 Plan the risk Management	C1 Support of Stakeholders	
	B1 Arrange time and resource for the risk management activity	C2 Cost and schedule activities
		C3 Establish risk contingency reserve using method
	B2 An accepted risk estimation basis	C4 Define the risk probability and influence
		C5 Risk classification
A2 Identify the risk	C6 Risk description format	
	C7 Risk identification method and technology	
	C8 Risk triggering condition	
A3 Implement qualitative risk analysis	C9 Risk attitude of the group and the other stakeholders	
	B3 Create risk rating rules	C10 Risk priority ranking
		C11 Risk urgency evaluation
A4 Implement quantitative risk analysis	B4 Implement the risk quantified result	C12 Quantification risk priority list
		C13 Probability to fulfill the project objective
	C14 Quantitative analysis method	
A5 Plan the risk response	C15 Determine the risk response responsible individual	
	B5 Create risk response actions	C16 Negative risk response
		C17 Positive risk response
CA6 Control the risk	B6 Risk reevaluate	C18 Identify new risk
		C19 Existing risk reevaluate
		C20 Cancel outdated risk
	B7 The validity of the control process	C21 Comply with the risk management policies and procedures
		C22 Adjust cost/schedule contingency reserve

3) Check consistency

4) Calculate the final weight value.

4.2. Create Hierarchy Structure Model

In order to create hierarchy structure model, we need to define the target layer, standard layer and decision layer. The target of this paper is to find out the critical factor of customized production project, so the target layer is effective risk management (A). Because the paper is based on the PMBOK risk management, so the 6 processes (plan the risk management, identify the risk, implement qualitative risk analysis, implement quantitative risk analysis, plan the risk response and control the risk) are the standard layer (B1-B6). At last, we use the 22 risk factors from Delphi as the decision layer (C1-C22). See below Figure 1.

4.3. Construct Comparison Matrix

In order to construct comparison matrix for AHP, we need to compare the importance of each factor in the same group. According to the interview information with the industry experts, we get the comparison value. We compare the factor i with the factor j in the same group, and mark them from 1 to 9. 1 means factor i is as important as factor j, 3 means factor i is a little more important than factor j, 5 means factor i is obviously more important than factor j, 7 means factor i is intensely more important than factor j, 9 means factor i is extremely more important than factor j, the other number means the importance is between its

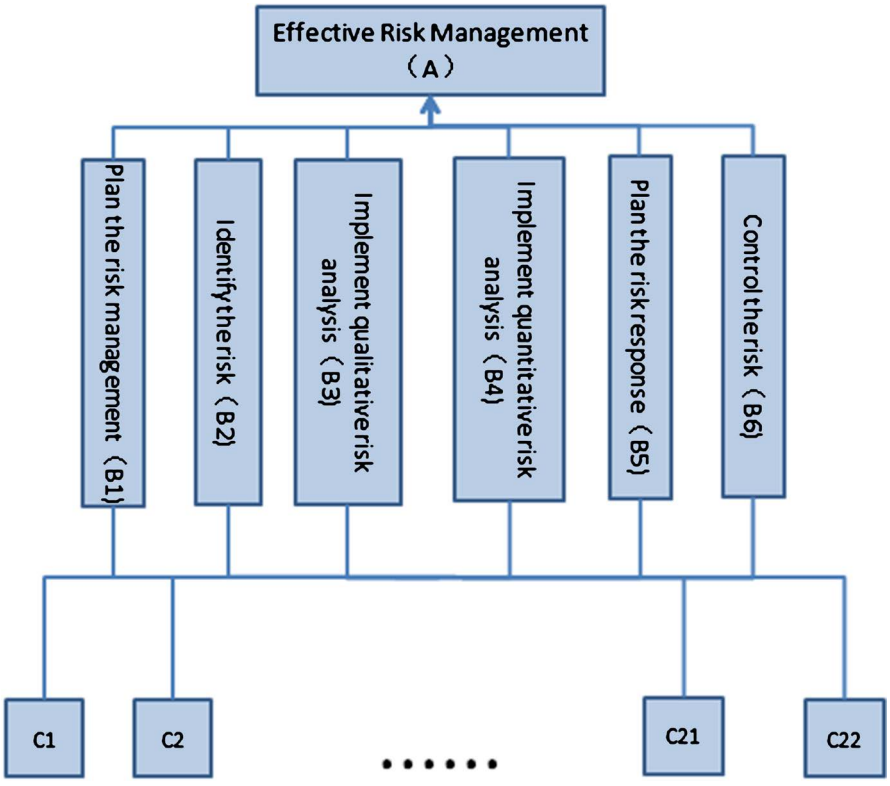

Figure 1. Hierarchy structure model.

front number and the latter number. The importance of j to i is the reciprocal of the importance of i to j. See Table 2 for the definition of each scale number.

After summarized all the information, we get the below comparison matrix: Table 3 is the comparison matrix between decision layer C1 to C5 of the standard layer B1; Table 4 is the comparison matrix between decision layer C6 to C8 of the standard layer B2; Table 5 is the comparison matrix between decision layer C9 to C11 of the standard layer B3; Table 6 is the comparison matrix between decision layer C12 to C14 of the standard layer B4; Table 7 is the comparison matrix between decision layer C15 to C17 of the standard layer B5; Table 8 is the comparison matrix between decision layer C18 to C22 of the standard layer B6; Table 9 is the comparison matrix between standard layer B1 to B6 of

Table 2. Definition of each scale number for the comparison matrix.

Scale aij	Definition
1	factor i is as important as factor j
3	factor i is a little more important than factor j
5	factor i is obviously more important than factor j
7	factor i is intensely more important than factor j
9	factor i is extremely more important than factor j
2, 4, 6, 8	the importance is between its front number and the latter number
reciprocal	When compare j to i,the aji = 1/aij

Table 3. Decision layer comparison matrix of standard layer B1.

	C1	C2	C3	C4	C5
C1	1	7	5	5	3
C2	1/7	1	1/3	1/2	1/3
C3	1/5	3	1	3	3
C4	1/5	2	1/3	1	1/3
C5	1/3	3	1/3	3	1

Table 4. Decision layer comparison matrix of standard layer B2.

	C6	C7	C8
C6	1	1/3	1/7
C7	3	1	1/5
C8	7	5	1

Table 5. Decision Layer Comparison Matrix of Standard Layer B3.

	C9	C10	C11
C9	1	1/5	1/3
C10	5	1	3
C11	3	1/3	1

Table 6. Decision layer comparison matrix of standard layer B4.

	C12	C13	C14
C12	1	3	5
C13	1/3	1	3
C14	1/5	1/3	1

Table 7. Decision layer comparison matrix of standard layer B5.

	C15	C16	C17
C15	1	3	5
C16	1/3	1	3
C17	1/5	1/3	1

Table 8. Decision layer comparison matrix of standard layer B6.

	C18	C19	C20	C21	C22
C18	1	3	7	1/3	5
C19	1/3	1	5	1/5	3
C20	1/7	1/5	1	1/7	1/3
C21	3	5	7	1	5
C22	1/5	1/3	3	1/5	1

Table 9. Standard layer comparison matrix of target layer A.

	B1	B2	B3	B4	B5	B6
B1	1	1/3	3	5	1/3	1/5
B2	3	1	3	5	1/3	1/5
B3	1/3	1/3	1	3	1/5	1/7
B4	1/5	1/5	1/3	1	1/7	1/9
B5	3	3	5	7	1	1/3
B6	5	5	7	9	3	1

the target layer A.

After we get the comparison matrix, we calculate the relative weight Wi of factor i to the upper layer. The formula for Wi as below:

$Wi = Qi/Qa$, and $Qi = \left(\prod_{j=1}^{n} Cij\right)^{\frac{1}{n}}$, Cij is the importance scale of factor i to factor *j*.

$$Qa = /\left(i,\ j = 1, 2, \cdots n\right)$$

This paper use YAAHP to run the AHP calculation. Table 10 to Table 16 are the relative weight result of all the factors.

Table 10. Relative weight result of target layer A.

Effective risk management consistency ratio of the judgment matrix: 0.0028; the weight to the target: 1.0000; λ_{max}: 6.0179							
effective risk management	Plan the risk management	Identify the risk	Implement qualitative risk analysis	Implement quantitative risk analysis	Plan the risk response	Control the risk	Wi
Plan the risk management	1	0.6703	1.4918	2.2255	0.6703	0.4493	0.1367
Identify the risk	1.4918	1	1.4918	2.2255	0.6703	0.4493	0.1562
Implement qualitative risk analysis	0.6703	0.6703	1	1.4918	0.4493	0.3012	0.098
Implement quantitative risk analysis	0.4493	0.4493	0.6703	1	0.3012	0.2019	0.0657
Plan the risk response	1.4918	1.4918	2.2255	3.3201	1	0.6703	0.2181
Control the risk	2.2255	2.2255	3.3201	4.953	1.4918	1	0.3253

Table 11. Relative weight result of standard layer B1.

Plan the risk management consistency ratio of the judgment matrix:0.0126; the weight to the target:0.1367; λ_{max}:5.0563						
Plan the risk management	C1 Support of Stakeholders	C2 Cost and schedule activities	C3 Establish risk contingency reserve using method	C4 Define the risk probability and influence	C5 Risk classification	Wi
C1 Support of Stakeholders	1	3.3201	2.2255	2.2255	1.4918	0.3525
C2 Cost and schedule activities	0.3012	1	0.6703	0.8187	0.6703	0.1197
C3 Establish risk contingency reserve using method	0.4493	1.4918	1	1.4918	1.4918	0.2014
C4 Define the risk probability and influence	0.4493	1.2214	0.6703	1	0.6703	0.1405
C5 Risk classification	0.6703	1.4918	0.6703	1.4918	1	0.1859

Table 12. Relative weight result of standard layer B2.

Identify the risk consistency ratio of the judgment matrix: 0.0000; the weight to the target: 0.1562; λ_{max}: 3.0000				
Identify the risk	C6 Risk description format	C7 Risk identification method and technology	C8 Risk triggering condition	Wi
C6 Risk description format	1	0.6703	0.3012	0.1721
C7 Risk identification method and technology	1.4918	1	0.4493	0.2567
C8 Risk triggering condition	3.3201	2.2255	1	0.5713

Table 13. Relative weight result of standard layer B3.

Implement qualitative risk analysis consistency ratio of the judgment matrix:0.0000; the weight to the target:0.0980; λ_{max}:3.0000				
Implement qualitative risk analysis	C9 Risk attitude of the group and the other stakeholders	C10 Risk priority ranking	C11 Risk urgency evaluation	Wi
C9 Risk attitude of the group and the other stakeholders	1	0.4493	0.6703	0.212
C10 Risk priority ranking	2.2255	1	1.4918	0.4718
C11 Risk urgency evaluation	1.4918	0.6703	1	0.3162

Table 14. Relative weight result of standard layer B4.

Implement quantitative risk analysis consistency ratio of the judgment matrix: 0.0000; the weight to the target: 0.0657; λ_{max}: 3.0000				
Implement quantitative risk analysis	C12 Quantification risk priority list	C13 Probability to fulfill the project objective	C14 Quantitative analysis method	Wi
C12 Quantification risk priority list	1	1.4918	2.2255	0.4718
C13 Probability to fulfill the project objective	0.6703	1	1.4918	0.3162
C14 Quantitative analysis method	0.4493	0.6703	1	0.212

Table 15. Relative weight result of standard layer B5.

Plan the risk response consistency ratio of the judgment matrix: 0.0000; the weight to the target: 0.2181; λ_{max}: 3.0000				
Plan the risk response	C15 Determine the risk response responsible individual	C16 Negative risk response	C17 Positive risk response	Wi
C15 Determine the risk response responsible individual	1	1.4918	2.2255	0.4718
C16 Negative risk response	0.6703	1	1.4918	0.3162
C17 Positive risk response	0.4493	0.6703	1	0.212

Table 16. Relative weight result of standard layer B6.

Control the risk consistency ratio of the judgment matrix: 0.0057; the weight to the target: 0.3253; λ_{max}: 5.0256						
Control the risk	C18 Identify new risk	C19 Existing risk reevaluate	C20 Cancel outdated risk	C21 Comply with the risk management policies and procedures	C22 Adjust cost/schedule contingency reserve	Wi
C18 Identify new risk	1	1.4918	3.3201	0.6703	2.2255	0.2663
C19 Existing risk reevaluate	0.6703	1	2.2255	0.4493	1.4918	0.1785
C20 Cancel outdated risk	0.3012	0.4493	1	0.3012	0.6703	0.0869
C21 Comply with the risk management policies and procedures	1.4918	2.2255	3.3201	1	2.2255	0.3386
C22 Adjust cost/schedule contingency reserve	0.4493	0.6703	1.4918	0.4493	1	0.1296

4.4. Check Consistency

After we calculate the weight of each factor, we need to check the consistency of the comparison matrix. Calculate the consistency ratio CR of each matrix. If the CR is less than 0.1, it's acceptable. Otherwise, we need to rerun the comparison matrix. We can get the CR from the below formula.

$$CR = \frac{CI}{RI}, CI = \left(\lambda_{\max} - n\right)/\left(n-1\right),$$

The RI can be found from Table 17 based on the latitude n (the quantity of factors).

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AQ)i}{n \times Qi},$$

$(AQ)i$ is the product of a row matrix and a column matrix. Row matrix is the row *i* of the comparison matrix, column matrix is the relative weight matrix of the comparison matrix. Qi is from the relative weight calculation in chapter 4.3.

We can get the CR of each comparison matrix from Table 10 to Table 16 and they are all less than 0.1, which is acceptable to the consistency check. Table 18 is the summary of all the CR.

4.5. Calculate the Final Weight Value

Multiply the relative weight of each factor by the relative weight of corresponding standard layer. We can get the final weight of all the 22 factors, rank them in descending order, we get the below final weight list of all the factors, Table 19.

Table 17. Random consistency index value of RI.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.28	1.32	1.41	1.45

Table 18. CR value of the comparison matrix.

	B1	B2	B3	B4	B5	B6	A
CR	0.0126	0.0000	0.0000	0.0000	0.0000	0.0057	0.0028

Table 19. Final weight list of all the factors.

factor	weight	ranking
C21 Comply with the risk management policies and procedures	0.1101	1
C15 Determine the risk response responsible individual	0.1029	2
C8 Risk triggering condition	0.0893	3
C18 Identify new risk	0.0866	4
C16 Negative risk response	0.069	5
C19 Existing risk reevaluate	0.0581	6
C1 Support of Stakeholders	0.0482	7
C10 Risk priority ranking	0.0462	8
C17 Positive risk response	0.0462	9
C22 Adjust cost/schedule contingency reserve	0.0422	10
C7 Risk identification method and technology	0.0401	11
C11 Risk urgency evaluation	0.031	12
C12 Quantification risk priority list	0.031	13
C20 Cancel outdated risk	0.0283	14
C3 Establish risk contingency reserve using method	0.0275	15
C6 Risk description format	0.0269	16
C5 Risk classification	0.0254	17
C9 Risk attitude of the group and the other stakeholders	0.0208	18
C13 Probability to fulfill the project objective	0.0208	19
C4 Define the risk probability and influence	0.0192	20
C2 Cost and schedule activities	0.0164	21
C14 Quantitative analysis method	0.0139	22

With the AHP, we can calculate the weight value of all the 22 factors. Ranking them in descending order, we can get top 10 factors as the risk management critical factors. AHP combines the qualitative and quantitative analysis, the project manager can find out the critical factors quickly. It's very helpful to analysis and solves problems during project management.

5. Management Enlightenment

Top 10 critical factors belong to Plan the risk management, Identify the risk, Implement qualitative risk analysis, Plan the risk response and Control the risk. Besides, Plan the risk response and Control the risk are particularly important, they include 7 of 10 critical factors. Project manager can pay extra attention to them.

The weight value of top two factors is obviously bigger. Comply with the risk management policies and procedures as the NO.1 critical factor means it's very important to ensure the risk management policies and procedures are well executed and complied during the whole risk management cycle. Only in this way we can provide theoretical basis to the other risk management activities. Besides, we should determine the responsible individual for each risk, only when the responsible individual take his own responsibility, follow the risk management policies and procedures, the risk can be well managed.

According to the top 10 critical factors, we can identify the top 10 risks. For example, No.3 critical factor is Risk triggering condition. The corresponding risk is the structure failure. When the product is manufactured, it's very difficult to tell whether there is a structure issue. But the customers are the professional players. They are much stronger and faster than the amateurs which means the sticks will be broken after several shoots. And broken sticks in the professional level will affect the brand reputation. In order to manage this risk, we should take actions in advance to describe the triggering condition of the structure failure.

As we can see from the final weight list of the factors, the weight of the last five factors are much lower. Which means it will not have too much influence to the whole project. So we don't need to spend too much resource on them. Just need to review them in a certain period.

6. Conclusion

In this paper, based on the six processes of risk management, we identify the critical factors of customized production projects with Delphi. We get 7 secondary factors and 22 third factors from original 6 primary factors, and establish the critical factor evaluation system of customized production project. Then we calculate the weight of all the factors from critical factor evaluation system with AHP. After ranking them in descending order, we get top 10 critical factors. They are C21, C15, C8, C18, C16, C19, C1, C10, C17 and C22. With the top 10 critical factors list, project manager can manager each factor specifically, which

will improve the efficiency of project management.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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