THEORY RESEARCH AND ENGINEERING APPLICATIONS ON THE ANALYSIS AND EVALUATION FOR DEVELOPMENT RISK OF AIRCRAFT

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Keywords: *Development risk, index system, next-generation advanced combat aircraft, Analytic Hierarchy method*

Abstract

The features of aircraft design determine the higher risk of aircraft design. Development risk is an important index in the program management and scheme evaluation and optimal selection of aircraft design as well as aircraft top-level design. In this paper, the basic theory on the analysis and evaluation of development risk for aircraft is investigated. Firstly, the flowchart of analysis and evaluation process on development risk is presented. Then, combining with the development project of next generation advanced combat aircraft in China, risk analysis and evaluation for the development of next generation advanced combat aircraft is investigated. The flowchart of the risk evaluation for the aircraft's development is proposed. The multi-hierarchy index system for development risk of next generation advanced combat aircraft is presented. Risk rankings are divided according to the risk matrix. By applying Analytic Hierarchy Process (AHP) and comprehensive fuzzy evaluation method into the field of risk evaluation, a method of risk evaluation for aircraft development is proposed. Illustrated with next generation advanced combat aircraft, the process of risk evaluation for the development of next generation advanced combat aircraft is detailed described. The engineering applications for the analysis theory of risk studied in the development of aircraft product are also described.

1 Introduction

The development of new higher technology equipments as Next-generation advanced combat aircraft, Launch vehicle, Spacecraft etc is a large-scale, complex system engineering project. The features and characteristics of aircraft design determine the higher risk of aircraft design. Development risk is an important index in the project management and scheme evaluation and optimal selection of aircraft design as well as aircraft top-level design. Firstly, the basic theory on the analysis and evaluation of development risk for aircraft is investigated and the flowchart of analysis and evaluation process on development risk is presented in this paper. Then, combining with the development project of next generation advanced combat aircraft, risk analysis and evaluation for the development of next generation advanced combat aircraft is investigated. The flowchart of the risk evaluation for the aircraft's development is proposed. The multi-hierarchy index system for development risk of next generation advanced combat aircraft is presented. Risk rankings are divided according to the risk matrix. By applying Analytic Hierarchy Process (AHP) and comprehensive fuzzy evaluation method into the field of risk evaluation, a method of risk evaluation for aircraft development is proposed. Illustrated with next generation advanced combat aircraft, the process of development risk's evaluation for the combat aircraft is detailed described. The engineering applications for the theory of risk evaluation studied in the development of aircraft product are also described.

2 Basic theory of Risk Evaluation

2.1 Type of Development Risk

According to the consequence introduced by the risk event to the development project of aircraft, the development risk of risk is divided into three kinds of type: performance risk, cost risk, schedule risk. According to the source of development risk for aircraft, the development risk of aircraft is divided into six kinds of type: technology risk, cost risk, schedule risk, talented man risk, supported risk, external risk. Technology risk, cost risk and schedule risk are primary risks.

2.2 Evaluation Process of Development Risk

The flowchart of analysis and evaluation process on development risk is illustrated as figure 1.

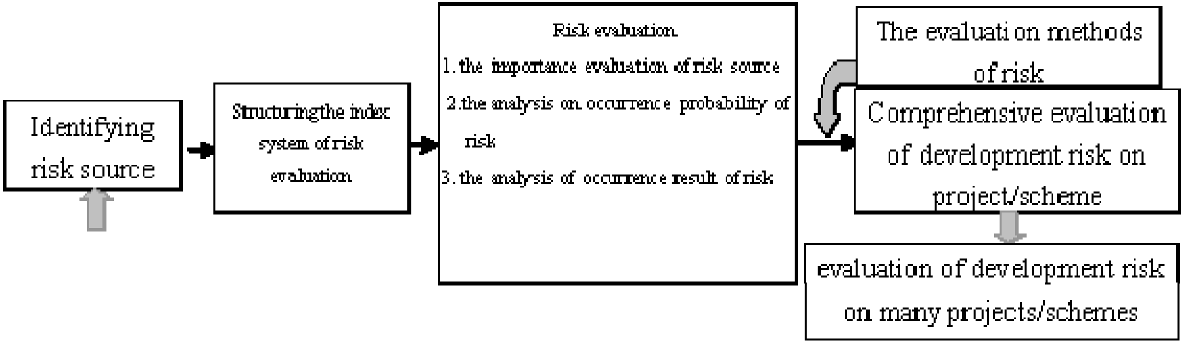

Figure 1 The flowchart of analysis and evaluation process on development risk

2.3 Content of Risk Analysis and Evaluation

The primary content of the analysis and evaluation on development risk of aircraft include five parts: risk identification, structuring the index system of risk evaluation, the research of technology on risk evaluation, comprehensive evaluation of risk, development risk's evaluation/decision of multi-project/scheme.

3 Evaluation of Development Risk for Next-Generation Advanced Combat Aircraft

3.1 Index System of Risk Evaluation for Next-Generation Advanced Combat Aircraft

The evaluation of development risk for next-generation advanced combat aircraft involves many systems, indexes and multiple risk factors. When we evaluate development risk for next-generation advanced combat aircraft, we need firstly know the characteristics and key technology during the process of design and manufacture of next-generation advanced combat aircraft. Through analyzing the features of next-generation advanced combat aircraft, according to the divided types of development risk[2-3] and the basic principle of structuring the index system of risk evaluation and the theory of system engineering, the author use the step-by-step delaminating method from exterior to interior, cursory to particularity, universal to partial, to establish the index system of development risk's evaluation. According to multi-hierarchy step-by-step structure from objective level, sub-objective level, principle level, system level to technology level, the index system of development risk's evaluation on next-generation advanced combat aircraft is divided into five levels, four factors level.

The multi-hierarchy index system for development risk of next generation advanced combat aircraft is illustrated as Figure 2. Through analyzing the 4S basic performance required to be possessed by next-generation advanced combat aircraft, the author determined the key technology fields in system-level which include six fields. Every field includes many detailed technologies which are omitted in this paper. The correlations between principle level and system level as well as system level and technology level is not shown here.

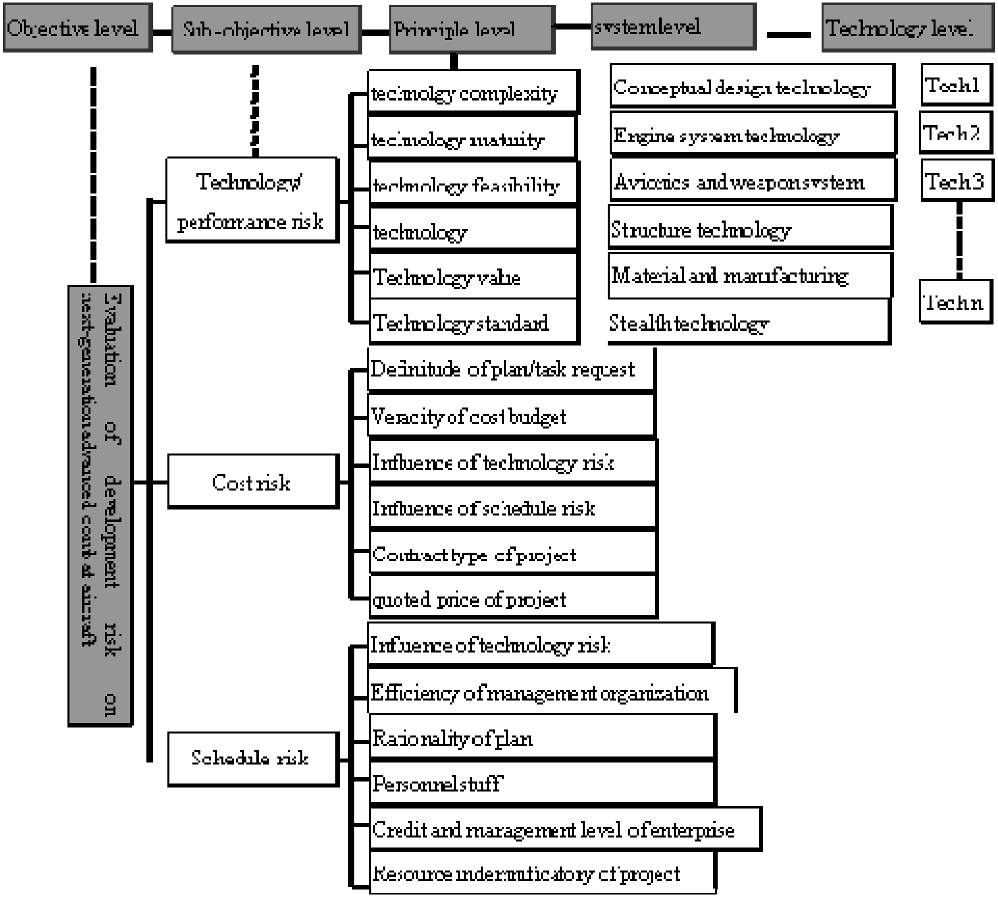

Figure 2 Multi-hierarchy index system for development risk of next generation advanced combat aircraft

3.2 Risk Rankings

Risk rankings are divided with risk matrix method in America which is introduced into risk evaluation of aircraft in China. Risk ranking is divided into five levels: high, less high, middle, lower, low[1].

3.3 Index Weights of Risk Evaluation

The evaluation of development risk on aircraft involved many influence factors. The method of AHP is used to determine the weights of risk factors and indexes. The detailed process on AHP is omitted here.

3.4 Fuzzy Comprehensive Evaluation of Development Risk for Next-Generation Advanced Combat Aircraft

Considering many factors has fuzziness and uncertain, the method of combining AHP with fuzzy comprehensive evaluation is used to evaluate the development risk of aircraft in this paper. According to the principle of AHP and fuzzy comprehensive evaluation, the authors determine the weights of every risk factor and index, construct the evaluation matrix of individual factor. The analysis result for the technology field of conceptual design and engine system in system level is shown as table 1.

Table 1 Investigation and analysis of risk factors in fifth level

System level factor	Risk factor in technology level	Evaluation result of risk factor to risk rankings				
		high L	ess high	middle	lower	low
conceptual design field	Technology 1	0.1	0.1	0.15	0.25	0.4
	Technology 2	0.05	0.05	0.15	0.25	0.5
	Technology 3	0.05	0.1	0.15	0.15	0.55
	Technology 4	0.5	0.3	0.1	0.05	0.05
	Technology 5	0.1	0.2	0.5	0.15	0.05

Engine syetem field	Technology 1	0.1	0.2	0.4	0.2	0.1
	Technology 2	0.05	0.05	0.1	0.2	0.6
	Technology 3	0.1	0.1	0.1	0.2	0.5
	Technology 4	0.5	0.3	0.1	0.05	0.05
	Technology 5	0.4	0.3	0.2	0.1	0
	Technology 6	0	0.1	0.15	0.25	0.5

The individual Evaluation matrix for Conceptual design D_1 and engine system D_2 is respectively are

$$R_1=\begin{bmatrix} 0.1 & 0.1 & 0.15 & 0.25 & 0.4 \\ 0.05 & 0.05 & 0.15 & 0.25 & 0..5 \\ 0.05 & 0.1 & 0.15 & 0.15 & 0.55 \\ 0.5 & 0.3 & 0.1 & 0.05 & 0.05 \\ 0.1 & 0.2 & 0.5 & 0.15 & 0.05 \end{bmatrix}$$

$$R_2=\begin{bmatrix} 0.1 & 0.2 & 0.4 & 0.2 & 0.1 \\ 0.05 & 0.05 & 0.1 & 0.2 & 0.6 \\ 0.1 & 0.1 & 0.1 & 0.2 & 0.5 \\ 0.5 & 0.3 & 0.1 & 0.05 & 0.05 \\ 0.4 & 0.3 & 0.2 & 0.1 & 0 \\ 0 & 0.1 & 0.15 & 0.25 & 0.5 \end{bmatrix}$$

The model of Fuzzy comprehensive evaluation is

$$B_{ijk}=A_{ijk}\circ R_{ijk}=(b_{ijk1},b_{ijk2}..,b_{ijkx}\ldots b_{ijkm})$$

The comprehensive evaluation outcome for all technology factors in all kinds of technology fields or subsystem level is

$$B_4=\begin{bmatrix} B_{1,4} \\ B_{2,4} \\ B_{3,4} \\ B_{4,4} \\ B_{5,4} \\ B_{6,4} \end{bmatrix}=\begin{bmatrix} 0.1575 & 0.15 & 0.21 & 0.165 & 0.3175 \\ 0.1975 & 0.1775 & 0.1725 & 0.165 & 0.2875 \\ 0.06 & 0.11 & 0.104 & 0.266 & 0.46 \\ 0.1005 & 0.18 & 0.1768 & 0.2165 & 0.3262 \\ 0.0144 & 0.086 & 0.1852 & 0.2116 & 0.5028 \\ 0.05 & 0.1225 & 0.1775 & 0.2125 & 0.4375 \end{bmatrix}$$

Technology risks for conceptual design field belongs to five rankings (high, less high, middle, lower, low) are respectively 15.75% 、15%、21%、16.5%、31.75%.

Through down-to-top step-by-step comprehensive evaluation, the development risk for the project of next-generation advanced combat aircraft (top-level objective) is calculated.

The evaluation outcomes for technology risk, cost risk and schedule risk belonged to different risk rankings in risk evaluation is

$$\begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix}=\begin{bmatrix} 0.107 & 0.143 & 0.174 & 0.248 & 0.328 \\ 0.095 & 0.162 & 0.179 & 0.267 & 0.297 \\ 0.132 & 0.154 & 0.160 & 0.263 & 0.291 \end{bmatrix}$$

The evaluation outcome for development risk on the aircraft project is

$$B=AR=A\begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix}=(0.11 \quad 0.152 \quad 0.172 \quad 0.258 \quad 0.308)$$

The final result shown that the development risk of next-generation advanced combat aircraft belongs to five risk levels (high, less high, middle, lower, low) are respectively 11 %, 15.2%, 17.2%, 25.8%, 30.8%. According to the rule of biggest degree, the risk level of the aircraft project belongs to low risk level when comprehensively considering technology risk, cost risk, and schedule risk. The project is a better and feasible project.

4 Conclusions

In this paper, the basic theory on the analysis and evaluation of development risk for aircraft is investigated firstly and the flowchart of analysis process on development risk is presented. Then, risk analysis and evaluation for the development of next generation advanced combat aircraft is investigated. The flowchart of risk evaluation and multi-hierarchy index system of development risk for the aircraft are proposed. Engineering applications for risk evaluation theory studied and the process of development risk's evaluation for next-generation advanced combat aircraft is detailed described by applying Analytic Hierarchy Process (AHP) and comprehensive fuzzy evaluation method into the field of risk evaluation.

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