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The Evaluation Model of R&D Project Supply Chain Risk Conduction Based on Probability ID

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Abstract. For the effective management of SC risk, risk conduction characteristic needs to be evaluated quantitatively. Based on classic energy theory, the probability influence diagram of R&D project supply chain risk conduction was established from topology layer, functional layer and numerical layer, the applicability of which was analyzed as well. Considering the decision-making aspect, the evaluation frame of R&D project supply chain risk conduction was designed finally.

Keywords: research & develop project supply chain, risk conduction, probability influence diagram, evaluation.

1. Introduction

Cooperative Research & Develop (R&D for short) was defined as the associated innovative dealing between corporations, scientific research institutes and higher educational institutes[1]. The acquirement of associated innovative fruit means the finish of R&D project, so R&D has typical characteristics of project supply chain such as extensive participants, one-off and temporality, which determines the participants would pay more attention to self-behalves and take a cautious attitude against risks in the background of the further cooperative proceed cannot be insured. However, this kind of short-term oppositional cooperative relations between participants[2-3] would prick up the high-risk characteristic of project. Because of the direct or indirect interest relations between economic systems, the phenomenon of risk conduction was prevalent[4]. With a view to the increasingly extrusive dynamic conductive characteristic of risk which resulted from the affinity of R&D project supply chain participants[5], the whole project risk cannot be managed effectively by solely review the risk of certain node corporation.

The current released research fruits of risk conduction emphasized particularly on the essential theories, which were primarily applied to the areas of corporation risk and financial risk management[6-7], the effective model and method of quantitative research on risk conduction were still lacking. The recognition and evaluation of risk conduction are one of the most important steps of project supply chain risk management, considering the uncertainty of risk conduction, the R&D project supply chain risk conduction evaluation model was established by probability influence diagram theory, the applicability of the model was discussed, and the R&D project supply chain risk conduction evaluating frame based on probability influence diagram was advanced.

2. Basic Theory of Probability Influence Diagram

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Influence Diagrams(ID) is a kind of effective graphic denotative language of complicated uncertain decision-making problem, as well as a effective tool of assistant modeling, uncertain token and reasoning[8], the mathematic definitions are as follows[9].

2.1. Definition 1

An influence diagram G is a directed acyclic graph which composed of node set N and directed arc set A, $G=(N,A)$. Node sets can be divided into chance node set C, decision node set D and value node set V, namely $N=(C,D,V)$, each node i in the graph has corresponding range Ω_i and its mappings, which are Π_i, d_i, U according to the type of node separately.

2.2. Definition 2

The influence diagram which only has chance node and certain node goes by the name of probability influence diagram.

The directed arc between chance node which represent stochastic(or certain) variable and certain node denotes the possible existent probability pertinence;

The numerical value appended to each node are its value and the conditional probability which depended on the possible states of anterior nodes.

A possible estimating order of the joint probability distributions was showed in the probability influence diagram, with which the probability can be ratiocinated and the conditional independence between varieties can be verdict[10]. The probability influence diagram can express the probability relations and information flows between varieties vividly, which can be built through aim-oriented conformation method, as well as be evaluated.

3. The Evaluation Model of R&D Project Supply Chain Risk Conduction

3.1. Restriction of model

Numerous scholars had explained the mechanism of risk conduction from various angles, of which the energy theory is the extensively accepted one. The principle of energy theory can be generalized as follows:

Each participants of R&D project is an intact system, which has the characteristics as self-organize, self-adapt, self-adjust and centralized risk release, so the risk can be dissolved to a certain extent. However, if all kinds of risk energy in system reach to a certain "critical value", the risk would cannot be dissolved by node corporation, and the risk energy would released and exported intensively, then the dynamic risk conduction be formed.

The aforementioned theory can be described in mathematic formula (1):

$$f(R_1,R_2,...R_n)>R_c \tag{1}$$

here R_i indicates different kinds of risk, $i\in(1,2,...n)$, $f(R_1,R_2,...R_n)$ means the dissolved risk energy, while R_c indicates the critical value.

Based on the energy theory, the risk conduction of R&D project is chosen as research object, the conductive effect formed by risk energy breaching the critical value is taken as objective event, to investigate what events would arouse this aftermath, and the probability of risk conduction will be calculated.

3.2. The structure of probability diagram

3.2.1. The Topology Layer

There are several factors can influence risk energy, in this paper we consider that R&D project risk conduction mostly depends on the risk-resist effort and risk-resist ability of node corporation as well as unpredictable environmental factor. The risk management and managers incarnates the former two factors separately, so the influential factors can be divided into three second-class factors as management, manpower and environment, which can be ulteriorly broken down into fourteen first-class factors, described as TAB 1.

Tab. 1: Influential factors of r&d project supply chain risk conduction

First-class	Second-class	
Cushion Plan x_1	Plan y_1^1	Management y_1
Substitute Plan x_2		
Channel of Information x_3	Organization y_1^2	
Operational Efficiency x_4		
Control System x_5	Control y_1^3	
Control Measure x_6		
Complement Coordination x_7	Coordination y_1^4	
Contradiction Coordination x_8		
Group Stability x_9	Manpower y_2	
Personnel Ability x_{10}		
Personnel Responsibility x_{11}		
Fluctuation of Market x_{12}	Environment y_3	
Political Condition x_{13}		
Natural Condition x_{14}		

In TAB 1, it can be seen that cushion plan will influence the schedule and charge risk, the substitute plan will influence the functional risk; keep the channel of information expedite and improve the operational efficiency can shorten the reactive time of project participants; follow the risk control system and measures can reduce the risk quantity; do complement and contradiction coordination well also can reduce the potential risk conduction probability. All of above are regarded as management factors which can be done before the risk conduction happens.

Therefore the formula (1) can be further extended as formula (2):

$$f(R_i, x_j) > R_c \tag{2}$$

here R_i indicates different types of risk, $i \in (f, s, c)$ represents the functional risk, schedule risk and cost risk separately. $i \in (1,2,...14)$, $f(R_i, x_j)$ means the risk energy dissolved by influential factor x_j, while R_c still indicates the critical value.

The analysis of risk conduction can be started from single type. The object-oriented formation method[11] was adopt to construct influence diagram, starting analysis from the object event node "risk conduction"(RC), the cause to which is risk energy exceeds conductive critical value. The probability of this event cannot be estimated directly, therefore object event should be decomposed until the probabilities of all borderline nodes can be estimated directly, and then the topology layer of risk conductive influence diagram is structured, as Fig 1 shows.

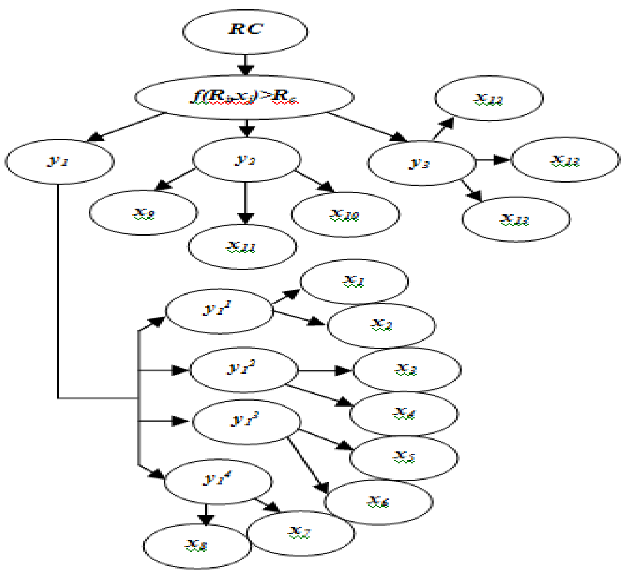

Fig. 1: Single type risk conductive influence diagram

3.2.2. The Functional Layer and Numerical Layer

The relations between state variable nodes were reflected by functional layer, and from the angle of tough extent these relations can be divided into three kinds: independent relation, part-correlative relation and complete correlative relation. From the analysis of each influential factors in Tab1, the relations between the influential factors were represented as independent relation, namely that each first-class influential factors has no influence to others, as well as arise second-class influential factors and then lead to certain effect independently. For the sake of identifying this relation directly in topology layer, the triangle within symbol "i" was introduced to describe independent relation, take Fig 2 for example.

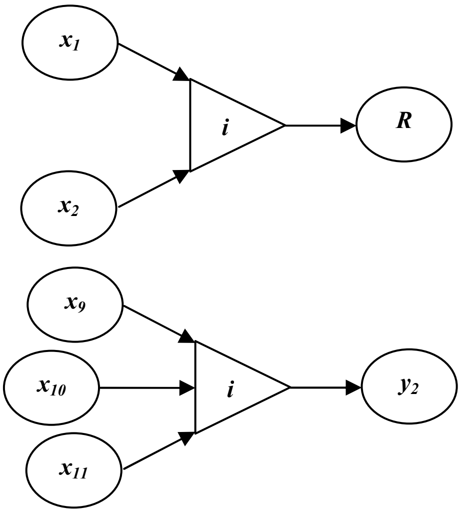

Fig. 2: The independent relation between first-class influential factors

The conformation of independent relation not only reflects the different influential mechanism of different influential factors, but also reduces the complexity of numerical calculation.

The independent relation between second-class influential represents different risk mode, namely that the risk conduction may be aroused by management, manpower and environment independently or jointly, the quantity of risk node should be a synthesis of each risk mode. However, because of the different dimension, this synthesis is not simply addition, certain combined quomodos existed according to different risk types. Concretely analyzing, the cost risk can be added directly, the schedule risk should be functional combined by allowed overlaps or remaining in the plan of schedule flow and the most complicated performance risk should be synthesized after some transformation to cost risk and schedule risk. So, there are two kinds of the risk quantity synthetical mode: direct addition and functional combination, as Fig 3 shows.

The numerical layer includes the concrete information of various possible states of risk node. In the influence diagram of R&D project risk conduction, numerical layer should includes the probability of first-class influential factors "p", the probability of second-class influential factors be aroused by first-class influential factors "p'", and the influential quantity to risk node "c".

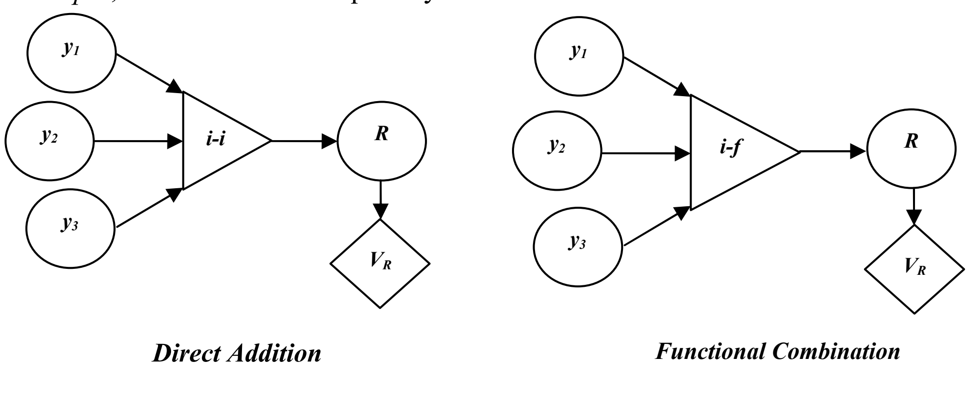

Fig. 3: Synthetical mode of risk quantity

3.2.3. Evaluation of Model

Take the influence diagram of R&D project risk conduction showed in Fig1 as an example, the influence to risk conduction by influential factor "manpower" was analyzed.

Given the probabilities p_1, p_2, p_3, which represents the first-class influential factor group alteration, personnel ability deficiency and personnel irresponsibility separately, $p_1^{'}$, $p_2^{'}$, $p_3^{'}$ represents the probabilities of second-class influential factor human error resulted from first-class influential factors separately, the cost risk quantity caused by first-class influential factors are c_1, c_2, c_3, then the probability of second-class influential factor "human error" can be calculated as formula (3):

$$P_h = 1-(1-p_1p_1^{'})(1-p_2p_2^{'})(1-p_3p_3^{'}) \tag{3}$$

The risk quantity of "human error" can be added directly, as formula (4):

$$R_h = p_1p_1^{'}c_1 + p_2p_2^{'}c_2 + p_3p_3^{'}c_3 \tag{4}$$

by the same way the cost risk quantity caused by other second-class influential factors can be calculated.

Given the probabilities of improper management measures and environment change are P_m and P_e, the cost risk quantity caused by them are R_m and R_e separately, the cost risk quantity aroused jointly can be represented as formula (5):

$$R = P_hR_h + P_mR_m + P_eR_e \tag{5}$$

Since there is a critical risk value R_c. When $R > R_c$, the risk quantity is more than the critical value, the risk conductive effect shaped. When $R < R_c$, the risk quantity is less than the critical value, the risk conductive effect would be held up.

Take the decision of risk manager into consideration, due to the transform characteristic of risk types, even the risk quantity of single type exceeds the critical value, the risk may not be conducted definitely. For instance, the function of R&D project product is the most important, for which the schedule and cost usually be sacrificed by project initiator, so the functional risk quantity would be reduced and the risk conductive effect be held up. In this way, a synthetical evaluation must be introduced. Only when the synthetical risk quantity of functional risk, schedule risk and cost risk exceeds the endurable ability of decision maker, the certain type risk would be conducted. Therefore, a decision node should be added to realize the synthetical evaluation of different risk types, as Fig 4 shows.

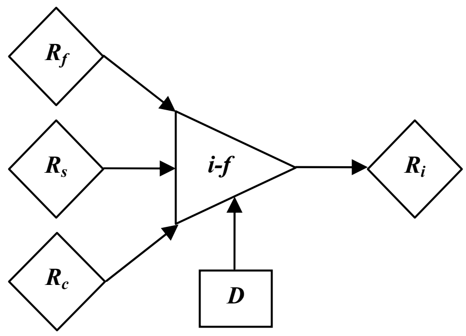

Fig. 4: Synthetical evaluation with decision node

Then the condition of risk conduction transformed to formula (6):

$$R_i > R_c^{'}, \; R_c^{'} = g(R_f, R_s, R_c) \tag{6}$$

here R_i represents quantity of different risk types, $i \in (f,s,c)$ represents the functional risk, schedule risk and cost risk separately. $R_c^{'}$ is the function of R_f, R_s and R_c, as well as the synthetical critical value after the introduction of decision node.

3.3. Analysis of model

3.3.1. The applicability

Influence diagram has its unique superiority in the research on project risk supply chain conduction. There are three kinds of nodes in influence diagram: decision node, chance node and value node, which according to decision node, risk node and loss node separately in the research on project supply chain risk[12]. Influence diagram analyzes the system depicted from topology layer, functional layer and numerical layer, the intuitionistic structure was revealed in topology layer, the structure of accurate functional relations between nodes in system was revealed in functional layer, and numerical layer expatiates quantitatively from operative lay. In the evaluation of R&D project supply chain risk conduction, the topology layer, functional layer and numerical layer according to the influence to risk node of influential factors, the relations between nodes and concrete data.

3.3.2. Data collection

The probabilities distributing of first-class and second-class influential factors can be acquired from statistical data in a certain period, the influential value to risk quantity comes from both statistical data and numerical calculation. Something worth noticing is that the thorough acquirement of information can improve the precision of evaluation. So there is a concept of information value to be derivated. Given the decision node set $D=\{d_1,d_2,......d_m\}$, the probability of influential factors set $P=\{p_1,p_2,......p_n\}$, the influential quantity set $C=\{c,c,......c_n\}$, the state according to influential factors is $s_i(p_i,c_i)$, so the influence to risk quantity can be calculated as formula (7):

$$V=f[s_i,d(s_i)]=f[p_i,c_i,d(s_i)] \tag{7}$$

if spending M_I can get the concrete information of state $S_I(P_I,C_I)$, then the formula (7) would be transformed to formula (8):

$$V^{'}=g[s_I,d(s_I)]=g[p_I,c_I,d(s_I)] \tag{8}$$

and the information value IV is:

$$\begin{aligned}IV&=V-V^{'}-M_I\\&=f[p_i,c_i,d(s_i)-g[p_I,c_I,d(s_I)]-M_I\end{aligned} \tag{9}$$

when $IV>0$, the acquirement of information would help the decision-making and can reduce the risk quantity.

3.3.3. Simplification of application

In the application of model, according to the different stages and risk types, the evaluating process can be simplified to a certain extent. For instance, in the demonstrate stage and plan stage, the schedule risk is mainly beared by general agent, so the risk conductive effect can be dismissed. In the conduction of functional risk at the same stage, the influence from market fluctuation can be dismissed, so this node in influent diagram can be deleted.

4. The Frame of R&D Project Supply Chain Risk Conductive Evaluation

The risk conductive evaluation is the basis of risk management decision. In section 3.3.3 the evaluating method of single type risk conduction was established. However, because of the invert characteristic between different types, the evaluation of single influence diagram could not be taken as the decisive reference, and a synthetical evaluation(SE) method of different stages and risk types is needed.

The steps of synthetical evaluation can be defined as follows, the frame of which is showed as Fig 5.

a. Carving the whole project up to different stages, recognizing corresponding risk types;

b. Structuring probability IDs according to different stages and risk types, simplifying the models;

c. Collecting data, evaluating the influence diagrams;

d. Evaluating these influence diagrams synthetically.

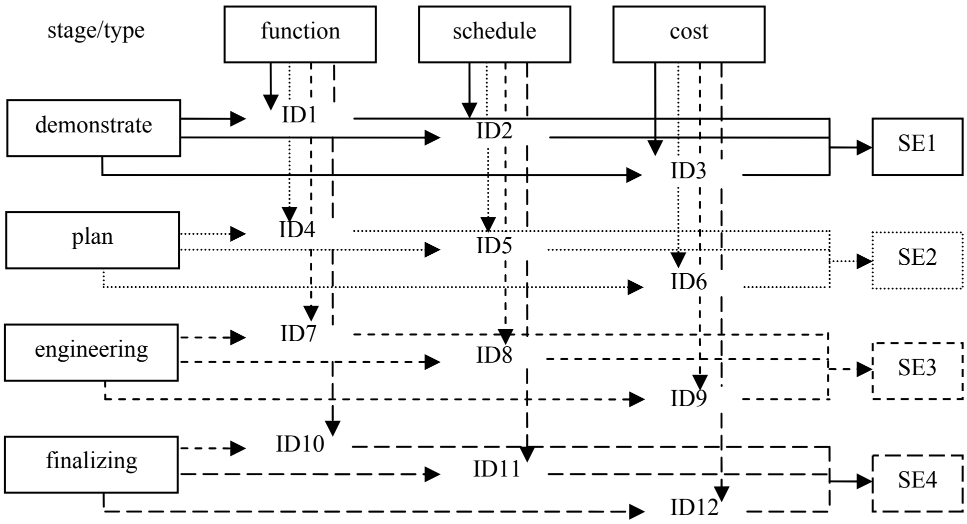

Fig. 5: Frame of R&D project supply chain risk conductive evaluation

5. Conclusion

The application of probability influence diagram to the evaluation of R&D project supply chain risk conduction was discussed, and the problem of model construction was resolved. On one hand, the influence diagram theory was proved useful in the evaluation of supply chain risk conduction, which overcomes the weakness of lack of quantitative method. On the other hand, the establishment of risk conduction evaluation frame set a foundation to the application of model. Finally, the analysis of information value in data collection step and the synthetical evaluating method of multi-type risk will be next research aspect.

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