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Using MDM and random walk for analyzing the combined influencing strength of Risk-DSM

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Abstract: In the complex R&D process, changes from function and component may cause uncertainties. To solve the problem, the paper builds Multi-domain Matrix (MDM) of "function-component-risk" to identify risk factors and its potential relationship. Taking the results of MDM as input, the paper uses random walk algorithm to analyze the influencing strength between different risk factors. Further, the paper calculates the combined influencing strength based on direct and indirect risk propagation. An industrial example is provided to illustrate the proposed model. Results indicate that the change of function and component can discover the risk factors and its potential relationship, and the indirect influencing is very important when measuring the combined influencing strength.

Keywords: Multi-domain Matrix (*MDM*)*, random walk algorithm, change propagation, Risk- DSM*

1 Introduction

R&D project is a complex system involving project, process and organization management, complexity and uncertainty are the most prominent feature (Yang et al., 2015). As the primary source of uncertainty of project, complexity has been extensively explored in the literature (Qazi et al., 2016). The uncertainty will produce additional costs and affect project performance if managers fail to address it (Shenhar, 2001). Moreover, the complexity and uncertainty derive principally from its sophisticated function and multitudinous components of projects (Eckert et al., 2016; Koh et al., 2012). Therefore, the change of function and components will bring high risk, which dramatically increases the difficulty of project management (Ackermann et al., 2014).

So, to identify risks in R&D projects and determine the relationship between different risk factors, we present an innovative approach to analyze the risks using extend-MDM (E-MDM). The paper has three key contributions to practice: 1) it presents the "function-component-risk" E-MDM to identify risk factors and determine its potential relationship; 2) taking the analyzing results of MDM as input, the paper uses random walk algorithm to calculate the influencing strength; 3) the paper analyzes the influencing strength based on direct and indirect risk propagation and then calculates the combined influencing strength through all possible propagation paths.

2 The calculation of initial Risk-DSM based on MDM

The DSM proposed by Steward (1981) is a powerful structural method to represent the elements comprising a system and their dependencies (Yang et al.,2015).The MDM is an extension of DSM modeling in which two or more DSM models in different domains are represented simultaneously, each single-domain DSM is on the diagonal of the MDM, and the off-diagonal blocks are Domain Mapping Matrix (DMM) (Eppinger & Browning, 2012). The DMM is a (typically) non-square matrix mapping the domain of one DSM to the domain of another DSM (Eppinger & Browning, 2012).

In this paper, the Risk-DSM (R_DSM) implements the risk factors involved in R&D project and the relationship between different risk factors. We builds upon the E-MDM of "function-component-risk" to determine the R_DSM and analyze the risk factors. As shown in figure 1, the MDM consists of three essential parts: functional DSM (F_DSM), component DSM (C_DSM) and the risk DMM (R_DMM).

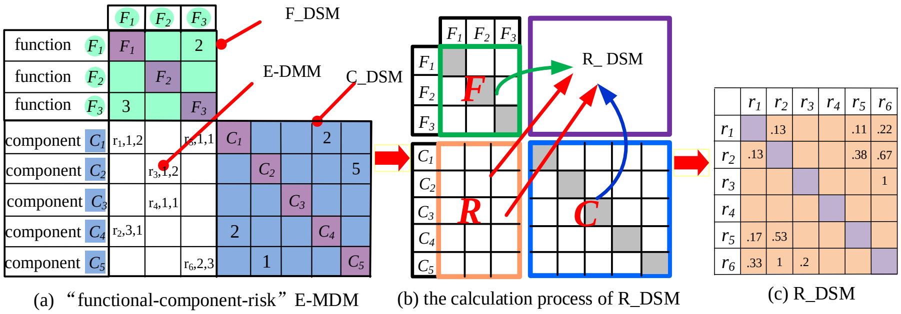


Figure 1. The calculation of initial R_DSM

The model of F_DSM/ C_DSM describes the functional/componential changes and its relationship in R&D projects; the R_DMM reflects the risk factors arising from functional or component changes and shows the relationship between functional/componential changes and risk factors. It can be seen from the R_DMM that risk may be caused by functional or componential changes, and the traditional DMM cannot describe these two changing relationships.

So, the paper builds the E-DMM, as shown in figure 1, each element in E-DMM can contain three parts, $E-DMM(r_i,\alpha,\beta)$ r_i is the risk factor, α is the impact relationship between risk and functional changes (Column) and β is between risk and component changes (row). For instance, $(r_1,1,2)$ reflects the degree of risk factors are affected by functional changes (F_1) is 1, and affected by componential changes (C_1) is 2.The paper uses the value ranging from 1 to 5 to quantify the intensity of relationship. The higher the value, the stronger the impact relationship.

3. Using random walk to calculate the influencing strength between different risk factors

The random walk method, a recent innovation, can be used to deduce the influencing strength. The basic idea is to simulate the process that a random walker wanders into the network. The walker starts the journey at random from one of the functions or components that have a risk in history. Then, in each step, the walker may either move at random to a neighboring node or start a new journey with a certain probability.

The R_DSM is a square matrix with diagonal entries representing risk factors and off-diagonal $entries(i, j)$ representing the influencing strength between different risk factors. In the R_DSM, the elements of column represent instigating risk, and the row represent the affected risk. The paper studies the influencing relationship of risks (R_DSM) through functional and component change, and the initiated R_DSM is elicited from the MDM.

Based on the results of the analysis, the paper uses random walk developed by (Gan et al., 2014) to measure the influencing strength between different risk factors. However, the random walk method only studies the relationship between two layers, as the figure 2 shows, the paper calculates the influencing strength of function and component on R_DSM respectively.

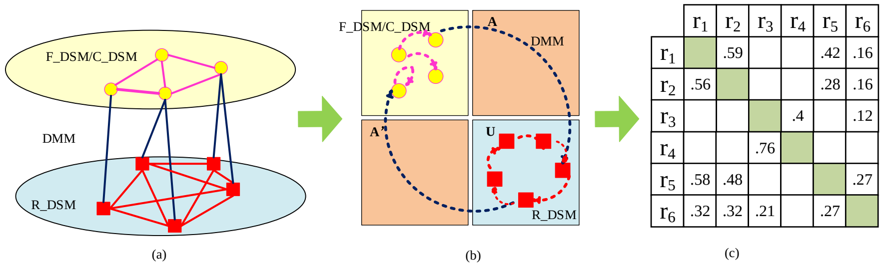


Figure 2. The calculation R_DSM using random walk

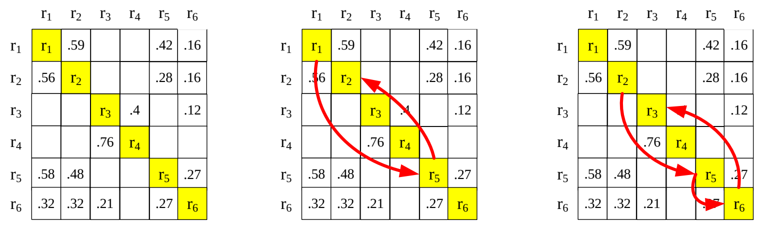
Therefore, based on restart random walk algorithm, the influencing strength resulting from functional change is calculated to be R_DSM_F; then, we can use the similar approach to calculate the value resulting from the component change as R_DSM_C. Hence the integrated influencing strength resulting from the change of function and component can be calculated as formula 1.

$$R\_DSM(i, j) = 1 - [1 - R\_DSM_F(i, j)] \times [1 - R\_DSM_C(i, j)] \qquad (1)$$

4. Analyzing the influencing strength based on direct and indirect risk propagation

4.1 The direct and indirect propagation

The traditional risk analysis mainly focuses on the direct influencing between risk factors. In fact, the influencing relationship between different risk factors is not only directly related but also indirectly influenced by many possible and potential paths. As shown in figure3, the influencing strength from r_1 to r_2 including the direct influencing strength (0.56) and the indirect influencing strength from r_1 to r_2 through intermediate risk r_5 (0.58×0.28).



(a) The direct influencing strength

(b) The influencing strength through an intermediate risk

(c) The influencing strength through two intermediate risks

Figure 3. The example of direct and indirect influencing strength

4.2 The combined influencing strength DSM

The combined influencing strength is defined as the integrated influencing strength of all possible change propagation paths. We assume that the changes would not transmit appreciably beyond three steps, which is a reasonable assumption based on previous research (Koh et al., 2012; Giffin et al., 2009; Clarkson et al., 2004). Therefore, analyzing the combined influencing strength through direct, one and two intermediate risk factors.

(1) The direct influencing strength

As shown in figure3 (a), the $R\_DSM(i, j)$ represents the direct influencing strength risk j on risk i , so the direct influencing strength can be calculated as formula 2.

$$RS^1(i,j) = R\_DSM(i,j) \qquad (2)$$

(2) The influencing strength through an intermediate risk

As shown in figure3 (b), the indirect influencing strength of risk j on risk i through an intermediate risk p $RS^2(i,j)$ can be calculated as formula 3.

$$RS^2(i,j) = 1 - \prod_{p=1}^{N_c} (1 - RS_p^2(i,j)) = 1 - \prod_{p=1}^{N_c} [1 - \mathrm{DSM}(p,j) \times \mathrm{DSM}(i,\mathrm{p})] \qquad (3)$$

Where $i \neq j, i, \ j \neq p$, p is the intermediate risk from j to i and N_c is the number of all conventional risk factors on the path from j to i .

(3)The influencing strength through two intermediate risks

As shown in figure3 (c), the influencing strength of risk j on risk i through two common risk factors, p and q , $RS^3(i,j)$ can be calculated as formula 4.

$$RS^3(i,j) = 1 - \prod_{p,q=1}^{N_c} (1 - RS_{p,q}^3(i,j)) = 1 - \prod_{p,q=1}^{N_c} [1 - DSM(p,j) \times DSM(q,p) \times DSM(i,q)] \qquad (4)$$

Where, $i \neq j; i, j \neq p, q$, p and q are the intermediate risks from j to i , N_c is the number of all conventional risk factors on the path from j to i .

So, the combined influencing strength risk j on risk i $CRS(i, j)$ can be calculated as formula 5. $CRS(i, j)$ is defined as the integrated influencing strength of all possible paths.

$$CRS(i,j) = RS^1(i,j) \cup RS^2(i,j) \cup RS^3(i,j) = 1 - \prod_{z=1}^{3}(1 - RS^z(i,j)) \qquad (5)$$

5. An illustrative example

The following case study will illustrate how the model and methodology developed in the preceding sections can be applied in a real-work setting. Based on the research and development of smart-phones, the paper investigates the change of function and component in the project, identify risk factors and determine the potential relationship between different risk factors. Analyzing the change of function and component in the smart-phones projects, the paper builds the E-MDM of "function-component-risk" as shown in figure 4(a).

F_DSM

E-DMM

C_DSM

		F_1	F_2	F_3	F_4	F_5						
processor change	F_1	F_1				1						
display screens change	F_2		F_2									
resolution change	F_3	3	1	F_3		4						
zoom change	F_4	2			F_4	2						
price change	F_5	1	2			F_5						
operating system	C_1			r_6,3,2		r_7,2,4	C_1	2			2	3
hardware system	C_2	r_3,1,3					2	C_2	1		2	2
radio frequency	C_3		r_8,2,3		r_1,4,3		3	1	C_3			
mould	C_4			r_5,1,2				1		C_4		1
testing	C_5	r_4,3,2							4		C_5	
industrial design	C_6					r_2,4,2	2			2		C_6

(a) "functional-component-risk" E-MDM

	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
r_1	r_1	.67	.38	.5		.5	1	
r_2		r_2	.08	.25	.22	.22	.44	.33
r_3	.25	.39	r_3	.33	.67	.33	.68	.25
r_4	.67	.25		r_4			.13	.67
r_5		.41	.22	.19	r_5		.17	.04
r_6		1	.46	.66		r_6	.5	.13
r_7		.67	.68	.51	.08		r_7	.17
r_8			.25		.13	.5	1	r_8

(b) R_DSM

Figure 4. The calculation of initial R_DSM of smart-phones R&D

Based on the initial influencing relationship using MDM, the random walk gives the quantification of influencing strength between risk factor, as shown in figure 5(a). The paper analyzes the combined influencing strength affected by direct and indirect propagation through one and two common risk factors, shown in figure 5 (b) and (c).

	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
r_1	r_1	.50	.46	.12	.15	.15	.21	.16
r_2	.29	r_2	.41	.36	.18	.17	.28	.02
r_3	.18	.41	r_3	.53	.18	.18	.16	.03
r_4	.11	.13	.29	r_4	.09	.14	.18	.03
r_5	.07	.27	.26	.18	r_5	.21	.06	.01
r_6	.11	.28	.29	.22	.23	r_6	.22	.07
r_7	.30	.33	.46	.40	.14	.28	r_7	.07
r_8	.24	.11	.08	.02	.06	.08	.10	r_8

(a) The direct influencing strength

	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
r_1	r_1	.66	.66	.53	.35	.37	.42	.21
r_2	.44	r_2	.64	.60	.36	.39	.44	.12
r_3	.38	.58	r_3	.66	.35	.37	.39	.10
r_4	.25	.37	.45	r_4	.22	.27	.29	.08
r_5	.23	.44	.45	.41	r_5	.32	.25	.06
r_6	.31	.50	.53	.49	.35	r_6	.37	.12
r_7	.47	.61	.68	.65	.37	.46	r_7	.16
r_8	.31	.30	.29	.18	.16	.18	.21	r_8

(b) The influencing strength through an intermediate risk

	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8
r_1	r_1	.72	.71	.55	.39	.41	.46	.22
r_2	.53	r_2	.71	.64	.40	.43	.49	.13
r_3	.44	.67	r_3	.69	.38	.41	.44	.12
r_4	.27	.39	.51	r_4	.26	.29	.33	.10
r_5	.24	.47	.48	.44	r_5	.34	.27	.08
r_6	.33	.53	.56	.51	.38	r_6	.40	.14
r_7	.53	.66	.73	.67	.39	.49	r_7	.19
r_8	.31	.30	.29	.18	.16	.18	.21	r_8

(c) The influencing strength through two intermediate risks

Figure 5. The results of analyzing the influencing strength in the smart-phone projects

From the calculation results can be seen, the combined influencing strength DSM fluctuated whether indirect propagation is considered, such as, the direct influencing strength of r_1 on r_2 is 0.29, and the value is 0.44 through an intermediate risk, and the value is 0.53 through two intermediate risks. The numerical results indicate whether indirect propagation is taken into account when analyzing influencing strength between risk factors has a significant impact on the influencing strength. Therefore, in measuring the influencing strength between different risk factors, the indirect relationship is very important, because the true and combined influencing strength would surely be affected by intermediate risks.

6. Conclusion

To assist managers in facing risks caused by the change of function and components, the paper analyzes the risk factors using the E-MDM of "function-component-risk". On the basis of identifying risk factors and determining the potential relationship deriving from the change of function and component, we use random walk algorithm to analyze influencing strength. Moreover, the paper analyzes the influencing strength based on direct and indirect risk propagation and calculates the combined influencing strength between different risk factors through all possible paths. The validity of the model and algorithm is verified by a research on development of smart-phones.

Nevertheless, the approach has also some limitations that are outlined in the following. Since this is a mathematical deductive approach, we had to make a few assumptions. For instance, we calculate the R_DSM based on the E-MDM of "function-component-risk" and analyze the risk factors deriving from the change of function and component. In reality, there may also be many other changing factors that may lead to risk, such as, design changes and environmental factors. For further analysis and evaluation, the more detailed and practical changing factors that may lead to risk should be concerned. Moreover, random walk enriches the theory and application of risk, is an interesting issue worth to be studied further.

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