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Risk Evaluation Model in Food Supply Chain Using Integration grey-DEMATEL-ISM

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ABSTRACT

The food supply chain has a complex structure because it is a perishable product and involves many stakeholders. Because of this complexity, the food supply chain will confront a few sorts of risks. This study means to create a risk assessment model in the food supply chain. Pareto analysis was used to identify risks based on the responses of 5 experts from companies and academics in the food sector. Then, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method based on grey system theory was utilized to evaluate the causal relationship between identified risks in the food supply chain. Furthermore, the grey-DEMATEL method was developed by combining it with the Interpretive Structural Modeling (ISM) method which can construct and visualize the relationship between risks into a graphic diagram. By integrating the three methods, three critical risks are found is lack of skilled labor, legal and regulatory, and communication failures. The results of this study can help companies to formulate risk mitigation strategies that have been identified in the food supply chain. This research can be expanded by verifying the data statistically using the system dynamics modeling (SDM) method or other statistical methods.

Keywords: Decision-Making Trial and Evaluation Laboratory (DEMATEL), Food Risk, Grey system theory, Interpretive Structural Modeling (ISM), Supply Chain Risk

INTRODUCTION

The development of the business world today is not only competing between companies but has grown to be between supply chains (Perevozova et al., 2020; Vonderembse, Uppal, Huang, & Dismukes, 2006; W. Yu, Chavez, Jacobs, & Feng, 2018). On the other hand, today's supply chains are becoming more vulnerable to natural disasters and man-made disturbances (Soni & Jain, 2011). Therefore, supply chain management is a major component of a competitive strategy to increase a company's productivity and profitability (Gunasekaran, Patel, & McGaughey, 2004).

Supply chains are generally complex, indicated by the number of activities that are usually spread across several functions or in several parts and sometimes can occur over a long period of time (Arshinder, Kanda, & Deshmukh, 2008). This also applies to the food supply chain, indicating that the food supply chain is more complex than the supply chain for manufacturing or other services because food is a commodity for human consumption and is a perishable product. In addition, the overall structure and function of the food supply chain are very broad, involving many stakeholders such as farmers, producers, processors, and consumers (Rizou, Galanakis, Aldawoud, & Galanakis, 2020; Salah, Nizamuddin, Jayaraman, & Omar, 2019). Based on this, the increasing complexity and involvement of many suppliers, service providers, and end consumers in the supply chain will result in the emergence of risks in the food supply chain (Arshinder, Kanda, & Deshmukh, 2011).

The risk of a poor food supply chain can result in a negative response from consumers so that the frequency of product purchases will be reduced (H. Yu, Legendre, & Ma, 2021). One of the best ways to address risk in food products is through the supply chain with a risk-based management approach (Uyttendaele, Boeck, & Jacxsens, 2016). Risk assessment is one of the three parts of the risk analysis process, which also includes risk management and risk communication. The ultimate goal of the risk assessment process is to estimate the likelihood of a risk occurring and this may be based on qualitative and/or quantitative information (Wang, Li, & Shi, 2012). Therefore, this study creates a risk model for the food supply chain in the SMEs industry. This study uses a combination of grey system theory and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) to determine cause and effect relationships on risk criteria and Interpretive Structural Modeling (ISM) to compile and visualize the relationship between risks into graphic diagrams. There have been no studies using an integration of these three methods in a food supply chain risk assessment model.

LITERATURE REVIEW

Supply Chain Risk Management is defined as a risk mitigation process achieved through collaboration, coordination, and implementation of risk management tools between partners, ensuring sustainability combined with increased long-term supply chain profitability (Faisal, 2013). This research more focus on food supply chain risks. Food supply chains can contribute to the economy of a country and are needed for citizens. Awareness of managing food supply chain risks is becoming a significant local and global issue. There are several studies that focus on food supply chain risks.

(Wu & Hsiao, 2021) evaluates the risks that occur in the cold chain and provides improvement strategies using the failure mode and effect analysis (FMEA) approach. (Rathore, Thakkar, & Jha, 2021) investigated the risks involved in the food grain supply chain in India and proposed risk mitigation using failure mode effect analysis (FMEA) and fuzzy VIKOR. (Wahyuni, Vanany, Ciptomulyono, & Purnomo, 2020) using Bayesian Network model to identify risks in the food manufacturing process. (Kumar, Kumar, Kumar, & Song, 2021) presented the fuzzy-best worst methodology (F-BWM) to analyze risk mitigation strategies. However, some of these studies still have not considered the relationship between risks that occur in the food supply chain. So that in this study we will consider the relationship between risks in the food supply chain.

RESEARCH METHOD

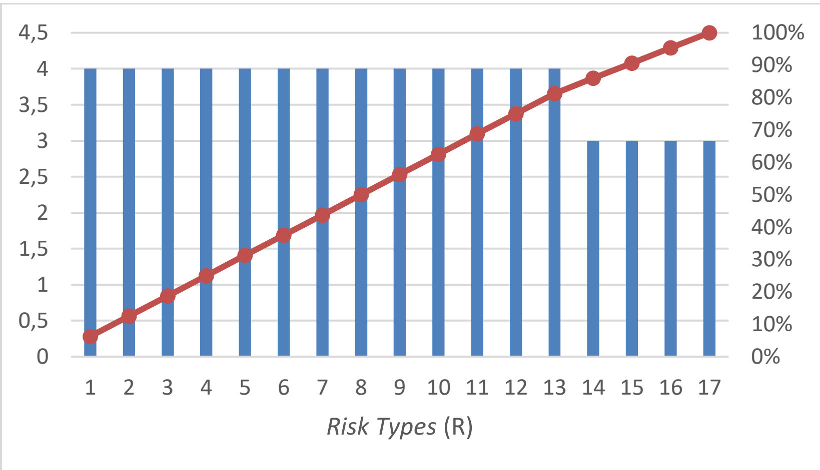
Primary data collection was carried out by literature study, interviews, and questionnaires by food industry professionals and academic experts. The results of literature studies and interviews with experts are risk identification.

Risk selection in the food supply chain

To recognize and decide the relationship between the risk of FSCs, an overview was finished by food industry experts and academic experts. This 4 expert respondent comes from the SME food industry XYZ in Balikpapan city and 1 from academic expert. The average experience of each expert in the food industry is 5-10 years.

Furthermore, a list of risks identified based on Yes/No is given to decision makers or experts to identify important risks in the food supply chain through filling out a questionnaire. Pareto analysis is used to identify the most important risks in the food supply chain. This study uses the theory of Pareto analysis where the vital few (major risk) is 80% based on the frequency of election while the useful many (minor risk) is 20% which is also based on the frequency of election. Pareto diagrams obtained from 4 expert respondents can be seen in **Figure 1**.

Figure 1. Pareto chart of food supply chain risk



In Figure 1, the major risk in the food supply chain is 80%, while the minor risk is 20%. So based on this, 13 risk categories will be selected which are considered the most important in the food supply chain. Among the 17 risks proposed from the literature and interviews in this study, the number of responses to the risks considered the most important is 4 with risk categories from R1 to R13. Meanwhile, the identified risks are not important, the number of responses is 4 with risk categories from R14 to R17.

Based on the Pareto analysis, data on the 13 most important types of risk in the food supply chain will be analyzed further. These risks include the COVID-19 pandemic (R1), environmental risks (R2), laws and regulations (R3), demand (R4), changing customer tastes (R5), poor customer relationships (R6), supply (R7), inventory (R8), capacity (R9), failure of machines, equipment, and facilities (R10), lack of skilled labor (R11), communication failure (R12), and failure in IT System (R13).

Risk assessment using the grey-DEMATEL method

***Building a direct relationship matrix* (DRM)**
A pairwise correlation matrix was built with the assistance of well-qualified assessment from the experts and utilizing 5 grey level scales. To conquer the equivocalness of human abstract decisions, this study utilizes a linguistic rating scale based on grey numbers displayed in **Table 1.** To assess the relationship between risks in the food supply chain, each expert will make a 13x13 linguistic DRM. And then the value of linguistic variables will be changed to a grey linguistic scale for each DRM expert. Initial DRM acquired from Expert-1 is introduced in **Table A1** in Appendix.

Find average grey relation matrix
The average grey relation matrix will be obtained by using Equation (1) from direct grey relation matrix. Then, use Equations (2)-(6) to convert the grey value into a crisp value which will later be used in the DEMATEL method and crisp relation matrix will be presented in **Table A2** in Appendix.

Obtaining the cause and effect relationship
By using Equations (7) and (8), the normalized direct-relation matrix will be obtained. Furthermore, using Equation (9) will be calculated to obtain the total-relation matrix (T), will be shown in **Table A3** in Appendix. Then, using Equations (10) and (11) it is used to get the risk groups in the cause-effect category using the data set (D_i-R_j) which presented in **Table 2**.

Risk assessment using the grey-DEMATEL-ISM method
After assessing the risk criteria using grey-DEMATEL, it will proceed to the risk assessment stage using the ISM method. This method procedures are discussed below:

Changing the total-relation matrix from DEMATEL to the initial reachability matrix of ISM.
The relationship between risks is shown by looking at the value of the risk criteria against other risks to the threshold value (α). Based on this, a value of 0 is used if the value in the TRM is less than the average value (α) of the TRM. Then, the value of 1 is used if the value in TRM is more than or equal to the average value (α) of TRM. Conversion of matrix TRM into initial reachability matrix is shown in **Table B1** in Appendix B.

Check transitivity and determine the final reachability matrix.
The next step is to examine the transitivity by looking at the relationship between the risk criteria. For example, if the risk of R1 is related to the risk of R2 and R2 is related to R3, then R_1 is related to R_3, so k_{13} = 1. After all transitivity has been checked, the final reachability matrix (K') has been formed. The final reachability matrix can be seen in **Table B2** in Appendix B. The part of the matrix that is italicized, is the change in value after transitivity is done.

Defines reachability set and antecedent set
Reachability set (RS_i) of system elements is a set of elements associated with columns, where all elements in row i of the final reachability matrix are 1. The antecedent set (AS_i) of system elements is the set of elements associated with rows, where all the element in

column i of the final reachability matrix is 1. The reachability set and the antecedent set can be seen in Table B4 in Appendix B.

Arrange elements of the hierarchical structure
Where the elements that appear in the reachability set and the antecedent set are selected to be the intersection set (ISi). The order of elements starts from level 1, which is placed at the top of the hierarchy. The selected elements are elements that have the same reachability set and intersection set in the final reachability matrix. The process in this iteration is terminated when all element levels have been defined. The iteration process can be seen in **Table B3** in Appendix B.

Create a risk relationship diagram
Arrangement of elements ordered from level one which is placed at the top of the diagram. The final ISM model obtained is shown in **Figure 2**

Table 1. Grey linguistic scale (Bhatia & Srivastava, 2018)

Linguistic term	Grey numbers	Influence score
No influence	(0, 0)	0
Very low influence	(0, 0.25)	1
Low influence	(0.25, 0.5)	2
High influence	(0.5, 0.75)	3
Very high influence	(0.75, 1.0)	4

$$\bar{a}_{ij} = \frac{\sum_{k=1}^{H} a_{ij}^{k}}{H} \quad (1)$$
$$\underline{\tilde{P}}_{ij}^{k} = \left(\underline{P}_{ij}^{k} - \min_{j} \underline{P}_{ij}^{k}\right) / \Delta_{min}^{max} \quad (2)$$
$$\tilde{\bar{P}}_{ij}^{k} = \left(\bar{P}_{ij}^{k} - \min_{j} \bar{P}_{ij}^{k}\right) / \Delta_{min}^{max} \quad (3)$$
$$\Delta_{min}^{max} = \max_{j} \overline{P}_{ij}^{k} - \min_{i} \underline{P}_{ij}^{k} \quad (4)$$
$$Q_{ij}^{k} = \frac{\left(\underline{\tilde{P}}_{ij}^{k}(1-\underline{\tilde{P}}_{ij}^{k}) + (\tilde{\bar{P}}_{ij}^{k} \times \tilde{\bar{P}}_{ij}^{k})\right)}{\left(1-\underline{\tilde{P}}_{ij}^{k} + \tilde{\bar{P}}_{ij}^{k}\right)} \quad (5)$$
$$R_{ij}^{k} = \min_{j} \underline{\tilde{P}}_{ij}^{k} + Q_{ij}^{k} \Delta_{min}^{max} \quad (6)$$
$$M = k \times A \quad (7)$$
$$k = \frac{1}{\max \sum_{j}^{n} a_{ij}} \quad 1 \le i \le n \quad (8)$$
$$T = M(I - M)^{-1} \quad (9)$$
$$R_{j} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = \left[t_{ij}\right]_{1\times n} \quad (10)$$
$$D_{i} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = \left[t_{ij}\right]_{n\times 1} \quad (11)$$

Notation	Description
$\underline{P}_{ij}^{k}$	Low gray value on gray number
$\overline{P}_{ij}^{k}$	High gray value on gray number
$\underline{\tilde{P}}_{ij}^{k}$	Lower gray value on the normalized gray number
$\tilde{\bar{P}}_{ij}^{k}$	Upper gray value on the normalized gray number

Δ_{min}^{max}	The difference between the normalized maximum upper gray value and the normalized minimum lower gray value
Q_{ij}^{k}	Normalized crisp value
$\bar{a}_{ij}$	Average relation matrix
M	Normalized direct-relation matrix
A	Crisp relation matrix
T	Total relation matrix
R_j	The sum of the values in the columns of the total relation matrix
D_i	The sum of the values in the rows of the total relation matrix

RESULTS AND DISCUSSION

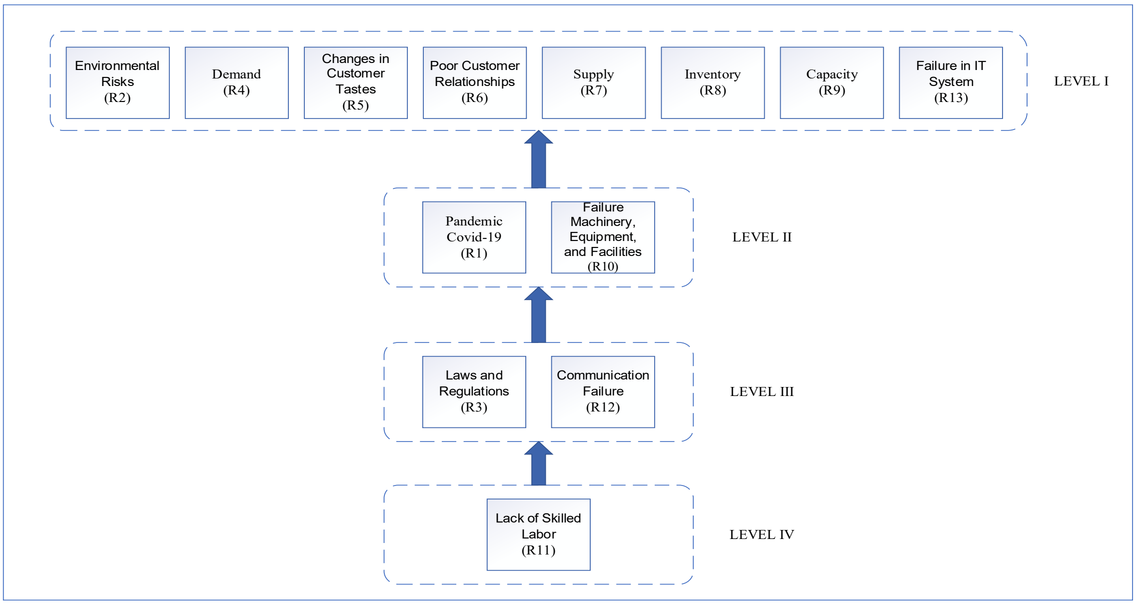
Table 2 shows that there are 7 risk categories that are included in the cause group, and there are 6 risk categories that are included in the effect group.

Table 2. Risk group based (D_i-R_j)

Cause Group	D_i-R_j	Effect group	D_i-R_j
R1	1.6447	R5	-1.5237
R3	1.5524	R4	-1.3622
R11	0.9913	R6	-1.0187
R12	0.5016	R9	-0.8472
R13	0.3556	R7	-0.3414
R10	0.3073	R8	-0.3270
R2	0.0674		

The result of this stage is a causal relationship between risk criteria. Based on data from (Di-Rj) the COVID-19 pandemic (R1), Laws and Regulations (R3), Lack of Skilled Labor (R11), Communication Failure (R12), Failure in IT System (R13), Failure Machinery, Equipment, and Facilities (R10), and environmental risks (R2) are grouped into categories of risk causes. Part of the effect group is changes in customer tastes (R5), demand (R4), poor customer relationships (R6), capacity (R9), supply (R7), and inventory (R8).

Figure 2. ISM Model



A four-level model was obtained using the ISM method. Lack of skilled labor (R11) is a risk that is at level 4 which can be seen in Figure 2. This risk has an important role because it affects all other risks that are above the risk in the model. If depicted in a tree, then the risk of a lack of skilled labor (R11) is the root of creating the risk of the entire food supply chain. So the involvement of the workforce is an important risk in the food supply chain risk.

At level 3, there are two risks that are directly affected by the risk of a lack of skilled labor (R11) namely: laws and regulations (R3) and communication failure (R12). The first is the relationship between the lack of skilled labor and laws and regulations. This happens because the lack of skilled labor can result in violations of regulations and policies against the government. So the result in a reduced image and good name of the company among the surrounding community. Second, the lack of skilled labor can affect communication between workers or between departments within the company. If the worker is unable to communicate the work and the results of the work he produces to other workers, it will result in several problems such as misunderstandings between the transportation, storage, and delivery of raw materials or finished products.

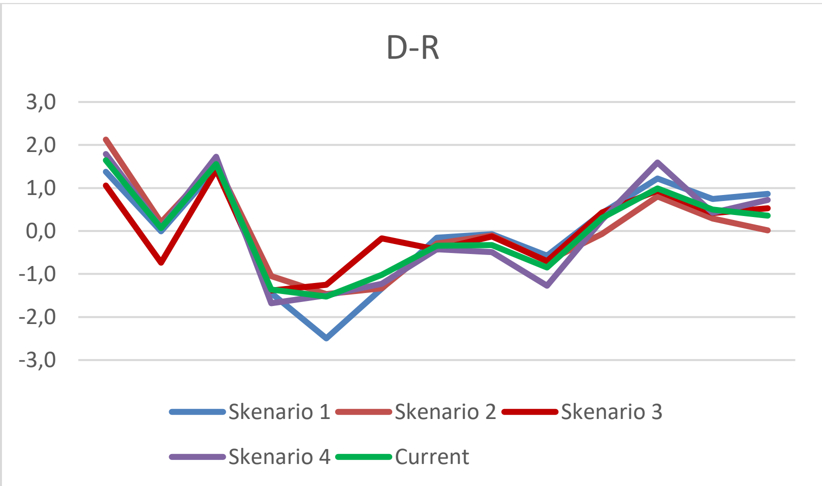
At level 2, there are two risk criteria, namely the risk of the COVID-19 pandemic (R1) and the risk of machine or equipment failure (R10) which are directly affected by laws and regulations risks (R3) and communication failures (R12). Laws and regulations risk (R3) affects the COVID-19 pandemic (R1). This means that government laws and regulations take part in increasing or decreasing the rate of spread of the COVID-19 virus. Thus, the higher the risk of violating these laws and regulations, the higher the potential for workers and customers to be exposed to the COVID-19 virus. Furthermore, the risk of communication failure (R12) affects the risk of machine or equipment failure (R10). This happens because if one of the workers makes a mistake in providing information to the next job it will result in the failure of the machine used. Such as giving incorrect information for the input limit of a raw material that is not in accordance with the standards of the machine or equipment, it will increase the potential for failure of the machine or equipment used.

There are 8 risk criteria that are at the top of the ISM model or at level 1. The risk criteria are environmental risk (R2), demand (R4), changes in customer tastes (R5), poor customer relationship (R6), supply (R7), inventory (R8), capacity (R9), and IT system failure (R13). The eight risk criteria are directly affected by the risk of the COVID-19 pandemic (R1) and the risk of machine or equipment failure (R10). These eight criteria will directly affect the risk of the food supply chain.

As previously explained, several important risks were found based on the ISM model and a proposed risk mitigation strategy will be provided. The results of the model reveal that the lack of skilled labor (R11) gets the highest level in the model. Therefore, to manage and reduce these risks, the company needs to conduct training programs to develop the skills and skills of workers in a sustainable manner. This will significantly reduce the risk of the food supply chain. The risk that is at level 3 is law and regulations risk (R3). Companies in making strategic decisions need to consider laws and regulations in order to minimize food supply chain risks. In addition, to mitigate this risk, the SME must apply a management style that is participative to laws and regulations. And the SME needs to always update the latest information related to laws and regulations. The next level 3 risk is the risk of communication failure (R12). To deal with the risk of communication failure, the SME can plan to invest in a good communication infrastructure in order to avoid communication failures, such as equipment or an application that can help deliver information accurately and quickly.

Sensitivity analysis
This study also analyzes the difference in ratings in different scenarios to verify the robustness of the results and the results of the analysis can be seen in Figure 3. Sensitivity analysis was carried out to verify the robustness of the research results by giving all respondents the same weight and the highest weight for one of the respondents. The ratings on most of the risk criteria are not affected by variations in the weights assigned to each expert in different scenarios. Although there are some deviations between the different scenarios, the overall relationship can maintain its consistency. Thus, no bias was observed in the results and indicates that the results are consistent across the four experts.

Figure 3. Sensitivity analysis on the value of Di-Rj



CONCLUSION

The food supply chain can contribute to the economy of a country and is needed by its citizens, so good food is very necessary. This research provides an assessment of the company's food risk and risk mitigation strategies. The grey-DEMATEL method can find a causal relationship between the identified risks. There are seven risks that are included in the cause group and there are six risks that are included in the effect group. Risks that are in the cause group, namely: R1, R3, R11, R12, R13, R10, and R2. Then, risks that are in the effect group, namely: R5, R4, R6, R9, R7, and R8.

The grey-DEMATEL-ISM method can map the relationship between the identified risk criteria. This method maps risk criteria based on a level scale. Where in this study there are four levels in the structure of the ISM model. It was found that the lack of skilled labor is at level four, so it can be concluded that the lack of skilled labor is the most critical risk and is a risk that can affect other risks. In addition, law and regulations risks, and communication failures are at level three in the ISM model, these risks are also a concern because they can affect other risks at lower levels.

All the results obtained about the relationship between each of these risks are expected to help reduce the risk that is influenced by other risks. In the end, it is expected to help the company in determining the strategy to be taken in reducing risk.

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The authors would like to thank the industry for providing the opportunity and for being willing to fill out a questionnaire for the purposes of this research.

DECLARATION OF CONFLICTING INTERESTS

There are no conflict interests in the completion of this article.

Appendix A

Table A1. *Direct-relation matrix* from *expert* 1

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1	0	1	2	3	4	2	1	3	1	1	1	1	2
R2	1	0	1	4	4	3	1	4	1	1	1	1	2
R3	4	3	0	4	4	3	1	1	1	1	1	1	1
R4	4	2	2	0	4	4	2	1	1	1	1	1	1
R5	0	2	1	3	0	1	1	1	1	3	1	1	1
R6	0	2	2	2	2	0	1	1	2	1	1	1	1
R7	2	1	2	1	3	3	0	2	2	2	1	1	1
R8	3	3	2	1	3	2	1	0	2	2	1	1	1
R9	0	1	2	3	4	2	2	2	0	1	1	1	1
R10	0	2	2	2	4	2	2	2	2	0	1	1	1
R11	2	2	2	2	4	3	1	1	1	1	0	1	1
R12	0	1	1	4	4	2	2	2	2	1	1	0	1
R13	0	2	3	2	4	3	2	2	2	1	1	1	0

Table A2. Crips relation matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1	0	0.4449	0.4625	0.8849	0.4007	0.4375	0.4125	0.5625	0.3676	0.4531	0.3333	0.2188	0.3510
R2	0.5822	0	0.3042	0.5822	0.5139	0.5139	0.4531	0.6875	0.5221	0.2969	0.4167	0.2188	0.5536
R3	0.8849	0.6289	0	0.7336	0.5478	0.8194	0.6875	0.4531	0.6765	0.2625	0.2102	0.2969	0.3125
R4	0.5417	0.5547	0.4196	0	0.8194	0.4007	0.4531	0.4531	0.6765	0.2625	0.25	0.2188	0.1971
R5	0	0.0714	0.0192	0.6579	0	0.2847	0.3750	0.2969	0.5221	0.3375	0.3333	0.2188	0.4732
R6	0	0.3000	0.0729	0.8092	0.5478	0	0.4125	0.2321	0.5993	0.0179	0.2898	0.2625	0.2740
R7	0.5417	0.4063	0.3438	0.3229	0.4375	0.5139	0	0.5313	0.5993	0.2625	0.3693	0.4531	0.5536
R8	0.1544	0.6289	0.4196	0.25	0.4007	0.3272	0.5313	0	0.6765	0.3036	0.3693	0.4531	0.5536
R9	0	0.4063	0.4196	0.8092	0.6667	0.5139	0.5625	0.6094	0	0.5625	0.3693	0.4125	0.3510
R10	0	0.5221	0.0913	0.3553	0.2537	0.3272	0.5625	0.2969	0.7537	0	0.2898	0.4531	0.5536
R11	0.2243	0.7537	0.5417	0.4309	0.3672	0.4007	0.4125	0.4125	0.3320	0.4125	0	0.6875	0.4732
R12	0	0.4063	0.4625	0.8092	0.3672	0.4007	0.4531	0.6094	0.5221	0.1875	0.4489	0	0.4732
R13	0	0.4805	0.6473	0.6579	0.2266	0.3272	0.5313	0.4531	0.5221	0.6875	0.3693	0.6094	0

Table A3. Total relation matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1	0.1438	0.3173	0.2595	0.4452	0.3250	0.3035	0.3260	0.3359	0.3649	0.2520	0.2362	0.2370	0.2826
R2	0.2283	0.2649	0.2494	0.4226	0.3511	0.3246	0.3443	0.3662	0.3989	0.2428	0.2585	0.2497	0.3231
R3	0.2951	0.3875	0.2300	0.4958	0.3990	0.4040	0.4143	0.3737	0.4652	0.2624	0.2577	0.2852	0.3226
R4	0.2136	0.3201	0.2457	0.3180	0.3741	0.2923	0.3235	0.3154	0.3955	0.2223	0.2210	0.2301	0.2571
R5	0.0918	0.1842	0.1378	0.3105	0.1810	0.2028	0.2353	0.2170	0.2859	0.1790	0.1770	0.1756	0.2256
R6	0.1013	0.2225	0.1513	0.3461	0.2734	0.1713	0.2494	0.2195	0.3073	0.1398	0.1784	0.1857	0.2060
R7	0.2139	0.3104	0.2457	0.3747	0.3264	0.3136	0.2664	0.3335	0.3932	0.2285	0.2434	0.2719	0.3119
R8	0.1583	0.3321	0.2492	0.3513	0.3123	0.2814	0.3338	0.2504	0.3937	0.2280	0.2373	0.2661	0.3057
R9	0.1479	0.3211	0.2595	0.4472	0.3717	0.3231	0.3580	0.3521	0.3266	0.2738	0.2504	0.2746	0.2951
R10	0.1163	0.2879	0.1816	0.3261	0.2621	0.2514	0.3066	0.2642	0.3689	0.1619	0.2049	0.2433	0.2786
R11	0.1803	0.3668	0.2781	0.3971	0.3250	0.3074	0.3348	0.3265	0.3685	0.2520	0.1957	0.3097	0.3096
R12	0.1415	0.3066	0.2575	0.4268	0.3144	0.2931	0.3255	0.3371	0.3778	0.2113	0.2486	0.2020	0.2941
R13	0.1521	0.3357	0.2950	0.4294	0.3118	0.3020	0.3570	0.3349	0.4019	0.2928	0.2512	0.3038	0.2449

Appendix B

Table B1. Initial reachability matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1	1	1	0	1	1	1	1	1	1	0	0	0	0
R2	0	1	0	1	1	1	1	1	1	0	0	0	1
R3	1	1	1	1	1	1	1	1	1	0	0	1	1
R4	0	1	0	1	1	1	1	1	1	0	0	0	0
R5	0	0	0	1	1	0	0	0	1	0	0	0	0
R6	0	0	0	1	0	1	0	0	1	0	0	0	0
R7	0	1	0	1	1	1	1	1	1	0	0	0	1
R8	0	1	0	1	1	0	1	1	1	0	0	0	1
R9	0	1	0	1	1	1	1	1	1	0	0	0	1
R10	0	1	0	1	0	0	1	0	1	1	0	0	0
R11	0	1	0	1	1	1	1	1	1	0	1	1	1
R12	0	1	0	1	1	1	1	1	1	0	0	1	1
R13	0	1	1	1	1	1	1	1	1	1	0	1	1

Table B2. Final reachability matrix

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
R1	1	1	0	1	1	1	1	1	1	0	0	0	*1*
R2	0	1	*1*	1	1	1	1	1	1	*1*	0	*1*	1
R3	1	1	1	1	1	1	1	1	1	*1*	0	1	1
R4	0	1	0	1	1	1	1	1	1	0	0	0	*1*
R5	0	*1*	0	1	1	*1*	*1*	*1*	1	0	0	0	*1*
R6	0	*1*	0	1	*1*	*1*	*1*	*1*	1	0	0	0	*1*
R7	0	1	*1*	1	1	1	1	1	1	*1*	0	*1*	1
R8	0	1	*1*	1	1	*1*	1	1	1	*1*	0	*1*	1
R9	0	1	*1*	1	1	1	1	1	1	*1*	0	*1*	1
R10	0	1	0	1	*1*	*1*	1	*1*	1	1	0	0	*1*
R11	0	1	*1*	1	1	1	1	1	1	*1*	1	1	1
R12	0	1	*1*	1	1	1	1	1	1	*1*	0	*1*	1
R13	*1*	1	1	1	1	1	1	1	1	1	0	1	1

Table B3. Level partition

Iterasi	Risiko	Reachability Set	Antecedent Set	Intersection	Level
1	R1	1,2,4,5,6,7,8,9,13	1,3,13	1,13	
1	R2	2,3,4,5,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,12,13	1
1	R3	1,2,3,4,5,6,7,8,9,10,12,13	2,3,7,8,9,11,12,13	2,3,7,8,9,12,13	
1	R4	2,4,5,6,7,8,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,4,5,6,7,8,9,13	1
1	R5	2,4,5,6,7,8,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,4,5,6,7,8,9,13	1
1	R6	2,4,5,6,7,8,9,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,4,5,6,7,8,9,13	1
1	R7	2,3,4,5,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,12,13	1
1	R8	2,3,4,5,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,12,13	1
1	R9	2,3,4,5,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	2,3,4,5,6,7,8,9,10,12,13	1
1	R10	2,4,5,6,7,8,9,10,13	2,3,7,8,9,10,11,12,13	2,7,8,9,10,13	
1	R11	2,3,4,5,6,7,8,9,10,11,12,13	11	11	
1	R12	2,3,4,5,6,7,8,9,10,12,13	2,3,7,8,9,11,12,13	2,3,7,8,9,12,13	
1	R13	1,2,3,4,5,6,7,8,9,10,12,13	1,2,3,4,5,6,7,8,9,10,11,12,13	1,2,3,4,5,6,7,8,9,10,12,13	1
2	R1	1	1,3	1	2
2	R3	1,3,10,12	3,11,12	3,12	
2	R10	10	3,10,11,12	10	2
2	R11	3,10,11,12	11	11	
2	R12	3,10,12	3,11,12	3,12	
3	R3	3,12	3,11,12	3,12	3
3	R11	3,11	11	11	
3	R12	3,12	3,11,12	3,12	3
4	R11	11	11	11	4

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