Accredited Ranking SINTA 2
Decree of the Director General of Higher Education, Research, and Technology, No. 158/E/KPT/2021
Validity period from Volume 5 Number 2 of 2021 to Volume 10 Number 1 of 2026

Published online on: **http://jurnal.iaii.or.id**

JURNAL RESTI
(Rekayasa Sistem dan Teknologi Informasi)
Vol. 6 No. 3 (2022) 403 - 411 ISSN Media Electronic: 2580-0760

Interdependency and Priority of Critical Infrastructure Information (Case Study: Indonesia Payment System)

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Abstract

The sturdy and reliable payment system is one of the most important systems in the digitalization era, especially in the pandemic COVID-19 period. As part of Critical Infrastructure Information (CII), a strategy to protect the payment system is needed to reduce risks that may arise. But the author's best knowledge, in Indonesia, no reference describes the interdependency of the CII sector that could be used as input on strategy making for reducing the risk on all CII sectors which are influencing the payment system. This research uses the Fuzzy-based DANP (FDANP) Framework based on a multi-expert perspective on inter-sector influences to identify the interdependency and priority of the CII sector with a case study on the payment system. The contribution of this research is to provide information about the interdependency and priority of the CII sector. The findings of this research show that 5 sectors that have an influence on other sectors with a case study of the payment system and the information and communication technology sector, the energy and mineral resources sector, and the financial sector are the three major sectors that must be paid more attention to because they have an impact on many sectors.

Keywords: *Critical infrastructure information, FDANP framework, interdependency, multi-expert perspective, payment system*

1. Introduction

The COVID-19 pandemic has caused many community activities to be carried out through online media and almost all the devices we have are now connected to the digital world. This happened in the education sector through online learning, the financial sector through increasing online shopping activities as well as increasing the use of technology by Micro, Small, and Medium Enterprises (MSMEs), the business and government sectors with the implementation of work from home (WFH) policies, and so on. Based on a survey by the Indonesian Central Statistics Agency (BPS) [1], during COVID-19, 31% of respondents reported a rise in online buying activity, 28% suffered a decrease, and the rest reported no change. Regarding MSMEs, based on research results by Harianto [2] it is known that around 63.9% of MSMEs that carry out activities using conventional strategies (offline systems) more than a 30% drop in sales turnover and around 3.8% of MSMEs that carried out activities with a digitalization strategy (online system) such as smartphones connected to the internet, there has been an increase in sales turnover. The increase in digital transactions certainly encourages the need for a secure and reliable payment system.

One of the advantages of a safe and dependable payment system, according to the World Bank [3], is that it contributes to financial stability by lowering risks connected with financial transactions, allowing the smooth flow of payments, and ensuring the efficient operation of financial markets. To answer these challenges and provide a payment system that is solid, reliable, all-mobile, fast, and secure, Bank Indonesia issued the Bank Indonesia Book: Navigating the National Payment System in the Digital Era which is the pouring of the Indonesia Payment System Blueprint 2025 where MSMEs are the initial focus on drafting one of the initiatives. Digital innovation is intended to provide sustainable access to the formal economy and finance for 62.9 million MSMEs and 91.3 million unbanked people [4].

In [5], it is stated that the Government establishes an agency or institution that has strategic electronic data that must be protected. That agency or institution belongs to the government administration sector (S1), the energy and mineral resources sector (S2), the transportation sector (S3), the financial sector (S4), the healthcare sector (S5), the information and communication technology sector (S6), the food sector (S7), the defense sector (S8), and other sectors as

Accepted: 28-04-2022 | Received in revised: 26-06-2022 | Published: 30-06-2022

determined by the President. These eight sectors, which are then called critical information infrastructure (CII), have interdependencies. For example, if there are problems with electricity supply and the internet, it will have an impact on the disruption of the payment system.

Interdependence is a two-way interaction in which the status of one infrastructure affects or is influenced by the state of another [6]. Interdependency is divided into four main classes, namely, logical interdependency, cyber interdependency, geographic interdependency, and physical interdependency [7]. It is important to understand interdependencies, especially to protect critical infrastructure.

Researchers around the world conduct research on the interdependency of Critical Infrastructure (CI) or CII sectors, both with the aim of identifying interdependencies and creating a framework or method that can be used to identify CI/CII interdependencies, such as [8] which identifies interdependencies in CI sector in India using the MICMAC method, [9] which performs modeling and assessing CI interdependencies using a Bayesian network, [10] which creates a framework for analyzing CI dependencies with time-based method, [11] which make a model to conduct CI interdependency assessment using Probabilistic Risk Assessment (PRA), [12] which makes a technique for exploring interdependence and importance using the Analytic Network Process (ANP) and Decision Making Trial and Evaluation Laboratory (DEMATEL), [13] who developed a method to analyze the influential relationship of CI using rough-fuzzy, DEMATEL, and ANP, and [14], [15] who used fuzzy theory, DEMATEL, and ANP to establish a mechanism for measuring interdependency and priority of CI. The several methods used to identify the interdependence of the CI sector in these studies, the method designed by [14], namely Fuzzy DEMATEL ANP (FDANP) is the latest, and from the results of the study, it is known that FDANP gets better results than the previous method. However, to the author's best knowledge, in Indonesia, there are no references that explain the interdependency of the CII sector, including those related to the payment system.

In this study, the interdependency of the CII sector was identified by focusing on the point of view of the payment system using the Fuzzy-based DANP (FDANP) framework. Fuzzy-based DANP Framework is a hybrid method that combines fuzzy logic theory, DEMATEL, and ANP designed by Jui-Sheng Chou and Citra S. Ongkowijoyo in [14], [15] which is used to determine interdependence between sectors based on a multi-expert perspective. Assessments from experts related to the influence of one sector on other sectors will be used as input which will then be processed using the FDANP method to obtain interdependency between sectors. The result of this study can be used to formulate policies and strategies used to keep the CII sector especially related to this payment system operating properly and in a safe condition.

The remaining of this paper is structured as follows: Section 2 the methodology used in this research, Section 3 the research results and discusses the use of research results and the next research, and Section 4 describes the conclusions of the research.

2. Research Methods

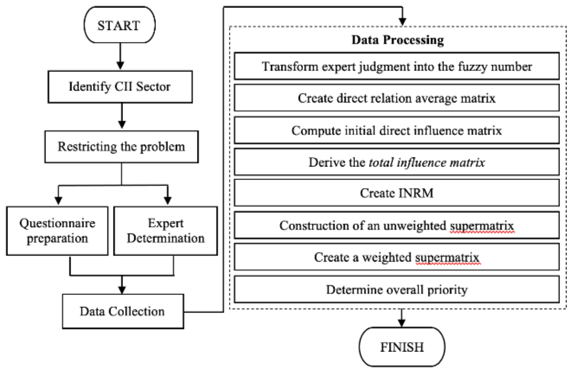


Fig. 1. Research process

The research process in Fig. 1 is explained as follows:

Step 1. Identify Critical Infrastructure Information Sector

In [14], it is stated that an important first step to determining the interdependency of the CII sector is to define the CII sector and sub-sectors which will be the limits of the problem analysis. In this study, only the identification of the CII was carried out. This is because the urgency at this time is to know the interdependency of the vital information infrastructure sector as stated in the introduction.

The identification of the CII sector is carried out through a literature study by studying the policies related to CII. Based on the results of the literature study conducted, information was obtained that in [5], it was stated that the Government established agencies or institutions that have strategic electronic data that must be protected. The agency or institution is an agency or institution that belongs to the following sectors: (1). Government administration sector, (2). Energy and mineral resources sector, (3). Transportation sector, (4). Financial sector, (5). Healthcare sector, (6). Information and communication technology sector, (7). Food sector, (8). Defense sector, and (9). Other sectors as determined by the President.

Apart from these regulations, until this research was conducted, no regulations or decisions have been found that stipulate additions to the sector. Thus, the eight sectors, hereinafter referred to as the CII sector, are sectors that will be processed to determine their interdependency.

DOI: https://doi.org/10.29207/resti.v6i3.4051

Step 2. Restricting the problem

The wave of digitalization in Indonesia over the last few years and the pandemic conditions that have made most of the community's activities carried out online have caused a large need for payments to be made safely, quickly, and easily. This of course requires a solid and reliable payment system. With the publication of the Buku Bank Indonesia: Menavigasi Sistem Pembayaran Nasional di Era Digital, the Blueprint for the Indonesian Payment System 2025 which aims to answer challenges in the financial sector in the digital era, this research will focus on knowing the interdependency of 8 CII sectors based on their inter-relationships with the payment system.

Before taking data, it is necessary to determine the sectors and sub-sectors that will be the problem analysis's limit, determine the linguistic membership function that will be used to measure the direct influence, and determine the Likert scale and the membership of the Trapezoidal Fuzzy Number (TFN) for the degree of the direct influence scale. This research only uses sectors and does not use criteria or sub-sectors, because, to the author's best knowledge, no document describes the CII sub-sector from each sector.

Step 3. Questionnaire Preparation

This research questionnaire was made in two versions, an offline survey created using a spreadsheet file and an online survey created using an online survey application. The questionnaire asks about how much influence one sector has on other sectors while still considering its relationship to the payment system.

Step 4. Expert Determination

Experts are selected based on the relevance of their field of work to the issues raised. The selected experts come from various fields of specialization, namely regulators, academia, and industry. The researchers used 3-18 experts as was done in [12], [14]–[23]. In this research, the experts involved were 3 people.

Step 5. Data collection

There are several methods used to collect data, namely through direct interviews as conducted on [23], and filling out questionnaires as conducted on [12], [14]–[23]. In this study, data collection was carried out in two options, face-to-face interviews and an online survey to fill out the prepared questionnaires. Experts are asked to assess how much influence one sector has on other sectors while still considering its relationship to the payment system. The influence rating used is presented in Table 1.

Step 6. Data Processing

The steps of data processing using FDANP were carried out based on [14], as follows:

Step 6.1. Transform expert judgment into the fuzzy number

Translate the linguistic terms into a Likert scale, then carry out the defuzzification process using the specified TFN membership function. The defuzzification method used is as in formula 1.

$$F(d_{ij}) = \frac{[b_0-c]+[b_1-c]}{\{[b_0-c]+[b_1-c]\}-\{[a_0-d]+[a_1-d]\}} \quad (1)$$

In the defuzzification of all linguistic terms, the values of c and d are the same. The values a_0 and b_0 are the maximum values when the membership function is zero while a_1 and b_1 are the values at the extreme limits of each linguistic term when the membership function is one.

The Likert scale, the TFN, and the Crisp Value for each of these sizes are presented in Table 1. TFN is determined based on Fig. 2. Meanwhile, Crisp Value is obtained through the defuzzification process using formula 1, which was based on Fig. 2, with the values $c = 0$ and $d = 10$. The values a_0, a_1, b_0, and b_1 are the TFN values for each influence rating. For example, for moderate influence, the values $a_0 = 3$, $a_1 = 4$, $b_0 = 7$, and $b_1 = 6$ so that by using formula 1, the crisp value for moderate influence is 0.500. The calculation is carried out for all influence ratings. Transform expert judgments into fuzzy numbers, it is done by translating each influence rating in the matrix into a crisp value.

Table 1 TFN and crips value specified for the degree of influence

Influence Rating	Likert	TFN	Crips Value
Very High Influence	4	(8,9,10,10)	0,870
High Influence	3	(6,7,8,9)	0,708
Moderate Influence	2	(3,4,6,7)	0,500
Low Influence	1	(1,2,3,4)	0,292
No Influence	0	(0,0,1,2)	0,130

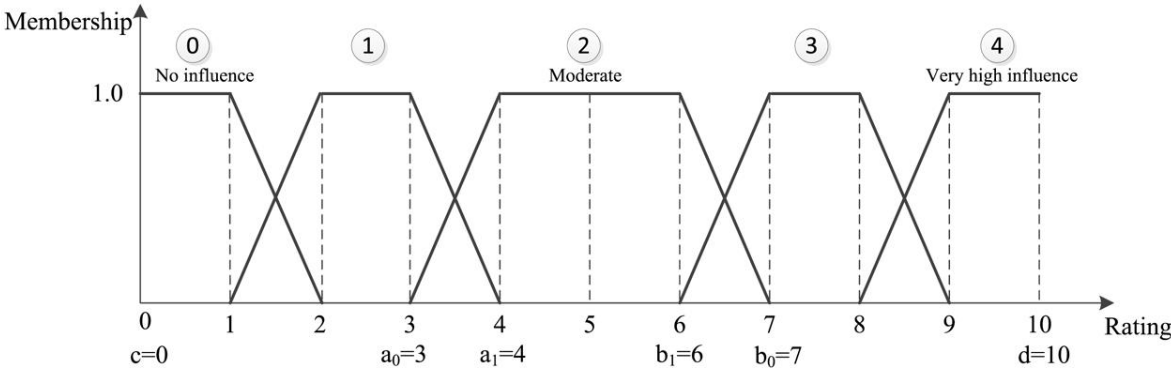
Step 6.2. Create a direct relation average matrix

The transformed matrix for each expert is then processed by calculating the average of each component of the transformed matrix from all the experts so that it gets a direct relation average matrix D. The mean in all cases of matrix D is:

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1j} & \cdots & d_{1n} \\ \vdots & & \vdots & & \vdots \\ d_{i1} & \cdots & d_{ij} & \cdots & d_{in} \\ \vdots & & \vdots & & \vdots \\ d_{n1} & \cdots & d_{nj} & \cdots & d_{nn} \end{bmatrix}$$

Step 6.3. Compute the initial direct influence matrix

Matrix D is then used to get the initial direct influence matrix X by normalizing it using formula 2 and formula 3.



Source : J. S. Chou and C. S. Ongkowijoyo [14]
Fig. 2. Trapezoidal fuzzy membership

$$X = s.D \tag{2}$$

$$s = min\left[1/\max_i \sum_{j=1}^{n}|d_{ij}|, 1/\max_j \sum_{i=1}^{n}|d_{ij}|\right] \tag{3}$$

Step 6.4. Derive the total influence matrix

The next process is to calculate the total influence matrix using formula 4.

$$T = X + X^2 + X^3 + X^4 + X^5 + \cdots + X^k = X(I - X)^{-1} \tag{4}$$

where, $T = [t_{ij}]_{n\times n}$ for $i, j = 1,2,\cdots,n$ and $(I - X)(I - X)^{-1} = I$.

Next is to calculate d_i which is the sum of each row and r_i which is the sum of each column of the T matrix using formula 5 and formula 6.

$$d_i = (r_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}, \tag{5}$$

$$r_i = (c_j)_{n\times 1} = (c_j)'_{1\times n} = \left[\sum_{j=1}^{n} t_{ij}\right]'_{1\times n}, \tag{6}$$

where d_i reflects the total of criterion i 's direct and indirect (higher-order) effects on the other criteria. While r_i shows the number of direct and indirect effects of other criteria on criteria j.

Then calculate the value of $(d_i + r_i)$ to determine the level of influence given and received and the value of $(d_i - r_i)$ where a positive value indicates that the sector is the sector that affects and for negative values indicate that the sector is the sector that is affected as described in [12]. When $i = j$, $(d_i + r_i)$ is a measure of one's ability to exert and receive influence.

Step 6.5. Create INRM

INRM is a visualization of the influence between sectors. The coordinates of the INRM are created using the values of $(d_i + r_i)$ as the X-axis and the values of $(d_i - r_i)$ as the Y-axis of matrix T, where the matrix T can be divided into a matrix T_D based on the sectors and matrix T_C based on the sub-sectors. Matrix T_C can be derived as in formula 7.

$$\boldsymbol{T}_C = \begin{array}{c c} & \begin{array}{cccc} \overset{C_1}{C_{11}\ldots C_{1m_1}} & \overset{C_1}{C_{11}\ldots C_{1m_1}} & \overset{\cdots}{\cdots} & \overset{C_n}{C_{n1}\ldots C_{nm_n}} \end{array} \\ \begin{array}{c} C_1\ C_{11}, C_{12}, \vdots, C_{1m_1} \\ C_2\ C_{21}, C_{22}, \vdots, C_{2m_1} \\ \vdots \\ C_n\ C_{n1}, C_{n2}, \vdots, C_{nm_n} \end{array} & \begin{bmatrix} T_C^{11} & T_C^{12} & \cdots & T_C^{1n} \\ T_C^{21} & T_C^{22} & \cdots & T_C^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_C^{21} & T_C^{22} & \cdots & T_C^{2n} \end{bmatrix} \end{array} \tag{7}$$

Meanwhile, the visualization of the level of influence is shown by arrows connecting two points/sectors.

Step 6.6. Construction of an unweighted supermatrix

The initial step in ANP is to create an unweighted supermatrix. For example, T_C^{12} (formula 8), the general form of the unweighted supermatrix is $W_{21} = (T_C^{\propto 12})'$, where $'$ denotes the transposition, so W_{21} (formula 11 from formula 10) is the normalized matrix T_C^{12}'s transpose. To get the normalized matrix T_C^{12} you can use formula 9.

$$T_C^{12} = \begin{array}{c c c} & \begin{array}{ccccc} c_{21} & \cdots & c_{2j} & \cdots & c_{2m_2} \end{array} & \\ \begin{array}{c} c_{11} \\ \vdots \\ c_{1i} \\ \vdots \\ c_{1m_2} \end{array} & \begin{bmatrix} t_{11}^{12} & \cdots & t_{1j}^{12} & \cdots & t_{1m_2}^{12} \\ \vdots & & \vdots & & \vdots \\ t_{1i}^{12} & \cdots & t_{ij}^{12} & \cdots & t_{im_2}^{12} \\ \vdots & & \vdots & & \vdots \\ t_{m_11}^{12} & \cdots & t_{m_1j}^{12} & \cdots & t_{m_1m_2}^{12} \end{bmatrix} & \begin{array}{l} \rightarrow t_1^{12} = \sum_{j=1}^{m_2} t_{1j}^{12} \\ \vdots \\ \rightarrow t_i^{12} = \sum_{j=1}^{m_2} t_{ij}^{12} \\ \vdots \\ \rightarrow t_{m_1}^{12} = \sum_{i=1}^{m_2} t_{m_1j}^{12} \end{array} \end{array} \tag{8}$$

where, $t_i^{12} = \sum_{j=1}^{m_2} t_{ij}^{12}$, i $= 1,2,3,\cdots,m_1$

$$T_C^{\propto 12} = \begin{array}{c c} & \begin{array}{ccccc} c_{21} & \cdots & c_{2j} & \cdots & c_{2m_2} \end{array} \\ \begin{array}{c} c_{11} \\ \vdots \\ c_{1i} \\ \vdots \\ c_{1m_2} \end{array} & \begin{bmatrix} t_{11}^{12}/t_1^{12} & \cdots & t_{1j}^{12}/t_1^{12} & \cdots & t_{1m_2}^{12}/t_1^{12} \\ \vdots & & \vdots & & \vdots \\ t_{1i}^{12}/t_i^{12} & \cdots & t_{ij}^{12}/t_i^{12} & \cdots & t_{im_2}^{12}/t_i^{12} \\ \vdots & & \vdots & & \vdots \\ t_{m_21}^{12}/t_{m_1}^{12} & \cdots & t_{m_1j}^{12}/t_{m_1}^{12} & \cdots & t_{m_1m_2}^{12}/t_{m_1}^{12} \end{bmatrix} \end{array} = \begin{bmatrix} t_{11}^{\propto 12} & \cdots & t_{1j}^{\propto 12} & \cdots & t_{1m_2}^{\propto 12} \\ \vdots & & \vdots & & \vdots \\ t_{1i}^{\propto 12} & \cdots & t_{ij}^{\propto 12} & \cdots & t_{im_2}^{\propto 12} \\ \vdots & & \vdots & & \vdots \\ t_{m_11}^{\propto 12} & \cdots & t_{m_1j}^{\propto 12} & \cdots & t_{m_1m_2}^{\propto 12} \end{bmatrix} \tag{9}$$

$$\begin{array}{cccc} \overset{C_1}{C_{11}\ldots C_{1m_1}} & \overset{C_1}{C_{11}\ldots C_{1m_1}} & \overset{\cdots}{\cdots} & \overset{C_n}{C_{n1}\ldots C_{nm_n}} \end{array}$$

DOI: https://doi.org/10.29207/resti.v6i3.4051

$$W = \begin{array}{c} \begin{array}{cc} & C_{11} \\ C_1 & C_{12} \\ & \vdots \\ & C_{1m_1} \\ & C_{21} \\ C_2 & C_{22} \\ & \vdots \\ & C_{2m_1} \\ \vdots & \vdots \\ & C_{n1} \\ C_n & C_{n2} \\ & \vdots \\ & C_{nm_n} \end{array} \end{array} \begin{bmatrix} W_{11} & W_{11} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix} \quad (10)$$

$$W_{21} = \begin{array}{c} \\ c_{21} \\ \vdots \\ c_{2j} \\ \vdots \\ c_{2m_2} \end{array} \begin{array}{c} \begin{array}{ccccc} c_{11} & \cdots & c_{1j} & \cdots & c_{1m_1} \end{array} \\ \begin{bmatrix} t_{11}^{\propto 12} & \cdots & t_{i1}^{\propto 12} & \cdots & t_{m_1 1}^{\propto 12} \\ \vdots & & \vdots & & \vdots \\ t_{1j}^{\propto 12} & \cdots & t_{ij}^{\propto 12} & \cdots & t_{m_1 j}^{\propto 12} \\ \vdots & & \vdots & & \vdots \\ t_{1m_2}^{\propto 12} & \cdots & t_{im_2}^{\propto 12} & \cdots & t_{m_1 m_2}^{\propto 12} \end{bmatrix} \end{array} \quad (11)$$

W_{ij} is the major eigenvector representing the effect of the criteria in the jth cluster relative to those in the i-cluster, where C_n denotes the nth cluster, and C_{nm} is the mth criterion in the nth cluster. If the ith cluster is unaffected by the jth cluster, then $W_{ij} = [0]$

In [14], the unweighted supermatrix W is obtained from matrix T_C which is the total influence matrix for the criteria or sub-sectors. However, because this research does not use criteria or sub-sectors, the matrix $T_C = T$. So to get matrix W, matrix T is normalized so that the number of each row is equal to 1, which is symbolized by matrix $T^{\propto}$. Then matrix $T^{\propto}$ is transposed to produce matrix W as an unweighted supermatrix.

Step 6.7. Create a weighted supermatrix

The total influence matrix T_C and matrix T_D for the n dimensions are calculated using the DEMATEL method (in Step 6.5.). Then matrix T_D is normalized using formula 12.

$$T_D = \begin{bmatrix} t_{11}/d_l & \cdots & t_{1j}/d_1 & \cdots & t_{1n}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{1i}/d_i & \cdots & t_{ij}/d_i & \cdots & t_{in}/d_i \\ \vdots & & \vdots & & \vdots \\ t_{n1}/d_n & \cdots & t_{nj}/d_n & \cdots & t_{nn}/d_n \end{bmatrix} = \begin{bmatrix} t_{11}^D & \cdots & t_{1j}^D & \cdots & t_{1n}^D \\ \vdots & & \vdots & & \vdots \\ t_{i1}^D & \cdots & t_{ij}^D & \cdots & t_{in}^D \\ \vdots & & \vdots & & \vdots \\ t_{n1}^D & \cdots & t_{nj}^D & \cdots & t_{nn}^D \end{bmatrix} \quad (12)$$

The weighted supermatrix W_w is calculated using the normalized matrix T_D and the unweighted supermatrix W based on formula 13.

$$W_w = \begin{bmatrix} t_{11}^D \times W_{11} & t_{21}^D \times W_{12} & \cdots & \cdots & t_{n1}^D \times W_{1n} \\ t_{12}^D \times W_{21} & t_{22}^D \times W_{22} & \vdots & & \vdots \\ \vdots & \cdots & t_{ij}^D \times W_{ij} & \cdots & t_{ni}^D \times W_{in} \\ \vdots & & \vdots & & \vdots \\ t_{n1}^D \times W_{n1} & t_{2n}^D \times W_{n2} & \cdots & \cdots & t_{nn}^D \times W_{nn} \end{bmatrix} \quad (13)$$

This research does not use criteria or sub-sectors, so matrix $T_D = T$. To get matrix W_w, matrix T is normalized using formula 12, then each element of matrix T that has been normalized is multiplied by each element of matrix T.

Step 6.8. Determine overall priority

The overall priority is calculated using the limiting process method by iterating the weighted supermatrix W_w until the supermatrix converges and becomes a stable supermatrix. After that, the stable supermatrix is utilized to construct a global priority vector known as the "weight". If there are N supermatrixes and the limiting supermatrix is not the only one, the average supermatrix value is derived by adding up the N supermatrixes and dividing by N.

3. Results and Discussions

From the research flow described in section 2, the result for data collection is shown in Table 2.

The results for each stage of data processing are as follows.

Step 6.1. Transform expert judgment into the fuzzy number

From Table 2, as described in section 2, expert judgment transform into the fuzzy number using Table 1, and the result of this step is shown in Table 3.

Table 2 Fuzzy number for 1st expert

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,00	0,13	0,13	0,13	0,13	0,13	0,13	0,29
S2	0,29	0,00	0,87	0,87	0,71	0,71	0,13	0,13
S3	0,13	0,13	0,00	0,29	0,29	0,29	0,13	0,29
S4	0,29	0,50	0,87	0,00	0,29	0,29	0,13	0,13
S5	0,13	0,13	0,13	0,13	0,00	0,13	0,13	0,13
S6	0,50	0,87	0,87	0,87	0,71	0,00	0,13	0,50
S7	0,13	0,13	0,13	0,13	0,13	0,13	0,00	0,13
S8	0,29	0,29	0,29	0,50	0,13	0,29	0,13	0,00

Step 6.2. Create a direct relation average matrix

From the result in step 6.1. for all experts, create a direct relation average matrix D as described in section 2. The matrix D, as shown in Table 4, is the output of the fuzzy process.

Table 3 Direct relation average matrix *D*

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,00	0,50	0,50	0,62	0,50	0,45	0,45	0,62
S2	0,48	0,00	0,82	0,68	0,64	0,76	0,45	0,52
S3	0,50	0,57	0,00	0,55	0,62	0,62	0,57	0,50
S4	0,55	0,57	0,75	0,00	0,68	0,62	0,50	0,57
S5	0,43	0,45	0,45	0,43	0,00	0,50	0,45	0,52
S6	0,62	0,76	0,76	0,75	0,64	0,00	0,45	0,75
S7	0,45	0,45	0,45	0,45	0,57	0,52	0,00	0,52
S8	0,55	0,57	0,57	0,62	0,45	0,68	0,38	0,00

Step 6.3. Compute the initial direct influence matrix

The initial direct influence matrix X is shown in Tabel 5.

Table 4 The initial direct influence matrix *X*

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,00	0,11	0,11	0,13	0,11	0,09	0,09	0,13
S2	0,10	0,00	0,17	0,14	0,14	0,16	0,09	0,11
S3	0,11	0,12	0,00	0,12	0,13	0,13	0,12	0,11
S4	0,12	0,12	0,16	0,00	0,14	0,13	0,11	0,12
S5	0,09	0,09	0,09	0,09	0,00	0,11	0,09	0,11
S6	0,13	0,16	0,16	0,16	0,14	0,00	0,09	0,16
S7	0,09	0,09	0,09	0,09	0,12	0,11	0,00	0,11
S8	0,12	0,12	0,12	0,13	0,09	0,14	0,08	0,00

DOI: https://doi.org/10.29207/resti.v6i3.4051

Table 5 Expert Judgment for Importance of CII Sector

Expert	Degree of importance CII Sector								
1st expert	**Sector**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
	S1	0	N	N	N	N	N	N	L
	S2	L	0	VH	VH	H	H	N	N
	S3	N	N	0	L	L	L	N	L
	S4	L	M	VH	0	L	L	N	N
	S5	N	N	N	N	0	N	N	N
	S6	M	VH	VH	VH	H	0	N	M
	S7	N	N	N	N	N	N	0	N
	S8	L	L	L	M	N	L	N	0
2nd expert	**Sector**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
	S1	0	M	M	VH	M	M	M	H
	S2	L	0	H	L	M	H	H	H
	S3	M	VH	0	M	H	H	VH	M
	S4	M	M	M	0	VH	H	VH	VH
	S5	L	M	M	L	0	M	H	H
	S6	M	H	H	M	M	0	M	VH
	S7	M	M	M	M	VH	H	0	H
	S8	M	H	H	M	M	VH	M	0
3rd expert	**Sector**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
	S1	0	VH	VH	VH	VH	H	H	VH
	S2	VH	0	VH	VH	H	VH	M	H
	S3	VH	H	0	VH	VH	VH	H	H
	S4	VH	H	VH	0	VH	VH	M	H
	S5	VH	H	H	VH	0	VH	M	H
	S6	VH	H	H	VH	H	0	H	VH
	S7	H	H	H	H	H	H	0	H
	S8	VH	H	H	VH	H	VH	M	0

Step 6.4. Derive the total influence matrix

The total influence matrix T as shown in Table 6 and the sum of influence which is represented by the value of $d_i + r_i$ and $d_i - r_i$ as shown in Table 7 are the output of the DEMATEL process.

Table 6 The total influence matrix T

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,45	0,58	0,63	0,62	0,60	0,60	0,50	0,61
S2	0,63	0,57	0,78	0,73	0,72	0,75	0,57	0,68
S3	0,58	0,63	0,57	0,65	0,66	0,67	0,55	0,63
S4	0,62	0,66	0,75	0,58	0,71	0,71	0,57	0,67
S5	0,49	0,52	0,56	0,54	0,45	0,56	0,45	0,54
S6	0,69	0,75	0,82	0,78	0,76	0,65	0,61	0,77
S7	0,51	0,54	0,58	0,56	0,58	0,58	0,38	0,56
S8	0,58	0,62	0,67	0,66	0,62	0,67	0,51	0,52

Table 7 Sum of influences

Sector	d_i	r_i	$d_i + r_i$	$d_i - r_i$
S1	4,5915	4,5490	9,1405	0,0424
S2	5,4261	4,8700	10,2962	0,5561
S3	4,9321	5,3478	10,2799	-0,4157
S4	5,2650	5,1238	10,3888	0,1412
S5	4,1089	5,1143	9,2233	-1,0054
S6	5,8349	5,1799	11,0148	0,6551
S7	4,2874	4,1298	8,4172	0,1576
S8	4,8541	4,9854	9,8396	-0,1313

Step 6.5. Create INRM

The values of $d_i + r_i$ and $d_i - r_i$ and the total influence matrix T are then used to create IRNM. IRNM as presented in Fig. 3 is created to show which sectors are affected by that sector. For example, for the government administration sector, it can be seen in the figure that the sector affects the transportation and financial sectors. The shape of the arrows shows how much the sector affects other sectors as explained in Section 2. Fig. 3 shows that of the eight sectors, only 5 sectors have an influence on other sectors with a case study of the payment system. This condition can be caused by two possibilities, namely the transportation sector, the healthcare sector, and the food sector that do not affect other sectors at all or, these sectors affect other sectors, but the level of influence is very small (below the threshold) so it does not appear in IRNM. This is also by following the explanation in Section 2 that a positive $d_i - r_i$ value indicates that the sector is an influencing sector and a negative $d_i - r_i$ value indicates that the sector is affected.

Step 6.6. Construction of an unweighted supermatrix

This step is the initial step of the ANP process. As described in section 2, for the ANP process, we need to construct an unweighted supermatrix W with the result from the DEMATEL process and an unweighted supermatrix W for this research as shown in Table 8.

Table 8 The unweighted supermatrix W

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,10	0,12	0,12	0,12	0,12	0,12	0,12	0,12
S2	0,13	0,11	0,13	0,13	0,13	0,13	0,13	0,13
S3	0,14	0,14	0,12	0,14	0,14	0,14	0,14	0,14
S4	0,14	0,13	0,13	0,11	0,13	0,13	0,13	0,14
S5	0,13	0,13	0,13	0,13	0,11	0,13	0,14	0,13
S6	0,13	0,14	0,14	0,13	0,14	0,11	0,13	0,14
S7	0,11	0,11	0,11	0,11	0,11	0,10	0,09	0,10
S8	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,11

Step 6.7. Create a weighted supermatrix

The weighted supermatrix W_w as described in section 2 as shown in Table 9.

Table 9 The weighted supermatrix W_w

Sector	S1	S2	S3	S4	S5	S6	S7	S8
S1	0,01	0,01	0,02	0,02	0,02	0,02	0,01	0,01
S2	0,02	0,01	0,02	0,02	0,02	0,02	0,01	0,02
S3	0,01	0,02	0,01	0,02	0,02	0,02	0,01	0,01
S4	0,02	0,02	0,02	0,01	0,02	0,02	0,01	0,02
S5	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
S6	0,02	0,02	0,02	0,02	0,02	0,01	0,02	0,02
S7	0,01	0,01	0,02	0,01	0,02	0,01	0,01	0,01
S8	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,02

Step 6.8. Determine overall priority

The overall priority was calculated and **Error! Reference source not found.** 10 shows the result. From table 6, it can be seen that the three most influential sectors are the information and communication technology sector, the energy and mineral resources sector, and the financial sector. That sector must be paid more attention to because they have an impact on many sectors.

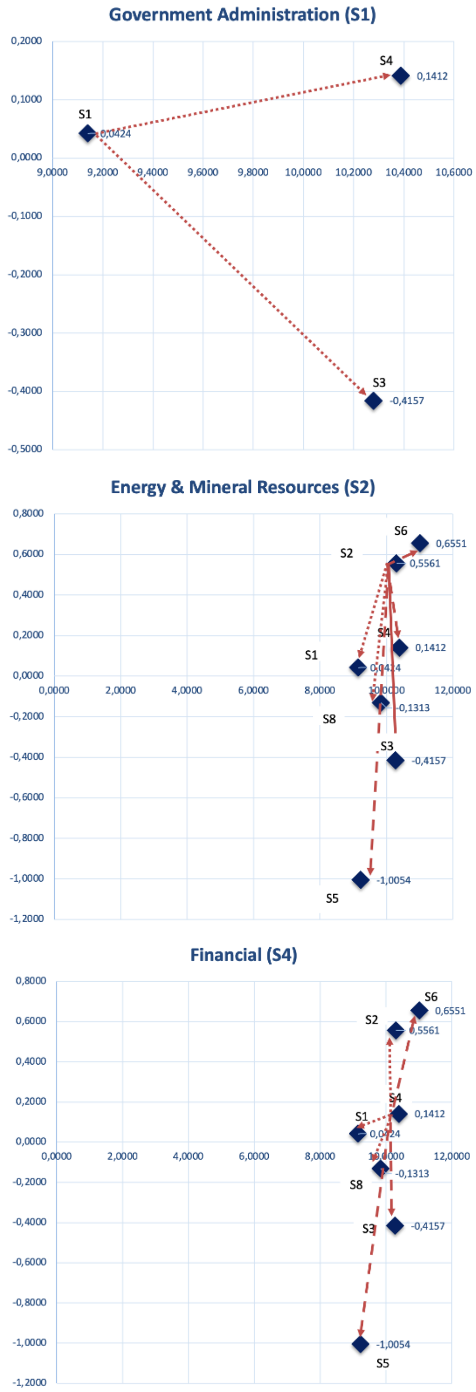
The most influential sector is the energy and mineral resources sector and the least influential sector is the healthcare sector. In the actual situation that happened in Indonesia, related to this research, the energy and mineral resources sector is indeed a very influential sector, especially for the payment system. This is evidenced by the blackout Jakarta incident in 2019 where the energy supply stopped and caused people to be unable to use the payment system to meet their needs. As for the healthcare sector itself, we know that since 2020 in Indonesia there has been a Covid-19 pandemic that has had a wide impact on people's lives. However, this does not affect the operation of the payment system in Indonesia. Even in the worst conditions of the Covid-19 pandemic, people can still use the payment system to meet their needs

Table 10 Ranking of CII Sector

Sector	Local Weight	Ranking
S1	0,1168	6
S2	0,1378	2
S3	0,1257	4
S4	0,1338	3
S5	0,1050	8
S6	0,1482	1
S7	0,1089	7
S8	0,1238	5

From the information presented in Fig. 3, we can see that for the case study of the payment system, the sectors that have an influence value above the threshold on other sectors are the government administration sector, the energy and mineral resources sector, the financial sector, the information and communication technology sector, and the defense sector which has varying degrees of influence. This information, coupled with the information in **Error! Reference source not found.**, can be used to formulate policies and strategies used to keep the CII sector especially related to this payment system operating properly and in a safe condition.

This research only describes a small part of the interdependency of the CII sector that should be known. To get an overall picture related to the interdependency of the CII sector, it is necessary to conduct further research with other case studies. In addition, it is also necessary to define the CII sub-sectors of each CII sector and then conduct research on the interdependencies between these sub-sectors. Knowing the interdependency of the CII sector and sub-sector as a whole can help related parties to maintain the CII.



DOI: https://doi.org/10.29207/resti.v6i3.4051

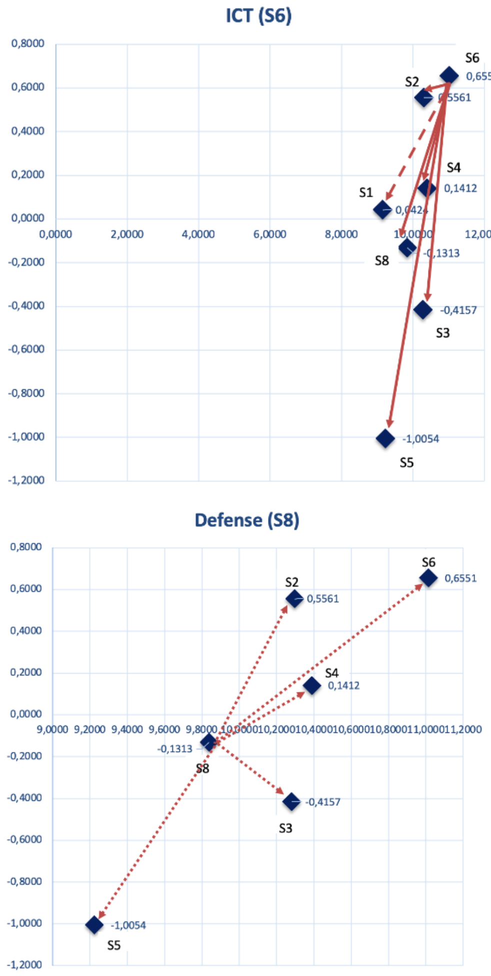


Fig. 3. IRNM

4. Conclusion

This research uses FDANP based on a multi-expert perspective on inter-sectoral effects to identify the interdependency of the CII sector with case studies on the payment system. The influence assessment from the experts is processed and produces IRNM and CII sector rankings. The results show that for the payment system case study, five sectors have an influence value above the threshold on other sectors, namely the government administration sector, the energy and mineral resources sector, the financial sector, the information and communication technology sector, and the defense sector. The information and communication technology sector, the energy and mineral resources sector, and the financial sector are the three major sectors that should be paid more attention to for the payment system case study because they have an impact on many sectors.

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