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A proposal for the regulation of the spectrum usage fee in 5G private network using fuzzy AHP

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Abstract — This study evaluates the types of regulation models for the Indonesia spectrum usage fee or *Biaya Hak Pengguna* (BHP) frequency in 5G private network technology that are most suitable to implement in Indonesia. This will be done by implementing the fuzzy analytical hierarchy process (F-AHP) method. This method accommodates the opinions of telecommunications experts from mobile network operators (MNOs), regulators, vertical industries, and telecommunications consultants through a series of scientific steps to produce weights for each type of alternative solution offered. By taking the given criteria into account, the results show that the proposed model most suitable to implement in Indonesia is the one that uses unlicensed 5G frequencies. This model involves vertical industries that do not use licensed frequencies established by the government, using unlicensed frequencies to develop 5G technology for their own use. The implementation of this model is expected to encourage the optimization of regulation for spectrum usage fees in 5G private network technology owned by the government, providing opportunities for vertical industries to develop 5G technology on private networks independently without relying on existing MNOs. This can stimulate innovation and technological progress in Indonesia to support Industry 4.0.

Keywords – fuzzy analytical hierarchy process, F-AHP, 5G, 5G private network, industry 4.0, triangular fuzzy number

I. Introduction

The manufacturing industry is crucial to Indonesia's national economic expansion. This industry is capable of producing up to 17.34% of the country's GDP in the second quarter of 2021, placing it fifth among G20 members [1]. The Indonesian government has established objectives for the industry through the implementation of the "Making Indonesia 4.0" national master plan program [2]. These goals include positioning Indonesia as one of the world's top ten largest economies by 2030 and driving economic growth through exports. Other objectives involve increasing labor productivity levels above labor cost levels and allocating 2 % of the GDP to research and development (R&D) as well as technological innovation.

Through a number of programs that support the Making Indonesia 4.0 master plan, the Indonesian government is working to achieve its goals by encouraging digital transformation in the industrial sector. The objective is to integrate significant breakthroughs into the industrial automation, connection, information, and communication value chains. Therefore, as this technology delivers faster data rates and lower latency, the adoption of 5G private networks in industrial organizations is essential.

The successful implementation of a 5G private network requires appropriate health and safety regulations to ensure the implementation process can run smoothly. Several previous studies have discussed regulations for implementing 5G technology. In the study [3], regulations for 5G implementation in developing countries are discussed. Studies [4] and [5] provide examples of regulations for 5G in European countries, while studies [6] and [7] discuss the situation in China, which also focuses on user orientation. A study [8] emphasizes the impact of 5G regulations on mobile operators. Studies [9] and [10] have started preliminary research on the existence of private networks in 5G technology by evaluating private LTE and 5G at a frequency of 3.5 GHz, but they only discuss the technical aspects related to payment equations in that country without discussing the regulations and factors that underlie the decision making regarding those regulations.

Meanwhile, studies [11], [12] determine specific locations for implementing 5G technology in several countries and provide a techno-economic feasibility assessment. These studies only identify potential locations for 5G technology development based on expert assessments, quantitative measurements, and techno-economic feasibility studies using the AHP method [13] but have not proposed regulations related to 5G BHP in specific geographic locations or private networks. A study on the obstacles to Industry 4.0 is discussed in [14]. This study highlights the obstacles to the implementation of Industry 4.0 in India, develops a framework for a comparative ranking analysis of these obstacles, and proposes a methodology for the industry using the Fuzzy Analytical Hierarchy Process (F-AHP). The study found that infrastructure is the biggest obstacle and ranks first, investment ranks second, technology, including 5G, ranks third, and legal obstacles, including regulations, have roughly the same scale and rank fourth [15].

Based on previous studies, the researchers propose regulations as a reference for regulators, MNOs, and vertical industries that will be applied to 5G private network technology related to BHP regulations in Indonesia, specifically in industrial areas. This research is important as an initial step to support the era of Industry 4.0.

A. 5G Private Network

5G technology is highly suitable for the current development and changes in industries, especially in Industry 4.0. Industry 4.0 requires communication technology that meets specific industrial needs with regard to network infrastructure, timing, heterogeneity, safety, and security. The utilization of this technology is based on several requirements, such as industry-specific cycle times and production processes. Typically, the utility and food industries require a cycle time of around 100 ms. Automotive and heavy equipment production requires a cycle time of around 10 ms, while motion control applications require very low latency, less than 1 ms [16] and [17].

Regulations are required to control the Spectrum Usage Fee for 5G technology in certain geographic locations and served privately in order to facilitate the deployment of the aforementioned. Regulations in this area have never been prepared, much less with the objectives broken down into several criteria and various approaches.

The 5G private network in the manufacturing industry in industrial areas is believed to provide better overall connectivity with various benefits and improved services for users of limited geographic networks [18]. The 5G private network is likely to be the best choice for many companies in the world, especially for industrial sectors such as factories, remote offices, and terminals [19].

Regulators control the frequency spectrum that the 5G private network will employ in order to make the most use of this finite resource. The three categories of wireless frequency spectrum are unlicensed, licensed, and shared licenses. The distribution of wireless frequency spectrum varies by nation, but the goal is to have a balanced distribution across all categories to support emerging technologies and needs while minimizing radio interference [19].

A 5G private network can be built on shared, unlicensed, or licensed spectrum. Unlicensed spectrum is usable worldwide at 2.4 GHz and 5 GHz, according to the International Telecommunication Union (ITU). Any company is able to operate 5G private networks in unlicensed spectrum, like the UNII-3 band used for Wi-Fi, for instance, MulteFire.

These frequencies, which are normally free, play a significant role in our digital economy. The majority of the spectrum that has been licensed is granted to mobile network operators, who can subsequently license their spectrum to any end-user business [20].

B. Vertical Industries

Vertical industries, in the context of 5G technology, refer to specific sectors or domains of economic activity that utilize and benefit from the capabilities and applications enabled by 5G networks. These industries encompass a wide range of sectors, including manufacturing, automotive, transportation, media, energy, healthcare, agriculture, etc. However, for the case of this study, we focus on the manufacturing industry, in which industry can use 5G technology for a variety of applications to enhance its operations and processes [21].

C. Fuzzy Analitycal Hierarchy Process (F-AHP)

An automated decision-support system (DSS) will be used in this study. DSS is a system that can offer communication and problem-solving abilities for issues that have semi-structured and unstructured situations. Although decision-help system (DSS) applications are frequently created to help a specific problem, they can also be used to assess possibilities or alternatives. DSS employs a variety of techniques, particularly when dealing with cases involving numerous criteria, such as the one examined in this study. The analytical hierarchy process (AHP) is one illustration [18]. Thomas L. Saaty developed AHP in the 1970s as a hierarchical approach to solving complicated multi-criteria problems. Decomposition, comparison judgment, and logical consistency are three ideas that must be comprehended in order to use the AHP approach to solve a problem [22].

The AHP method and fuzzy ideas are combined to create the ranking technique known as F-AHP. A method using a fuzzy approach known as F-AHP was developed to address the shortcoming of AHP, which is criteria that have more subjective features. The degree of membership in F-AHP is determined by a triangular fuzzy number [23].

There are a number of requirements that must be met before new laws can be proposed for BHP implementation in 5G private networks. AHP is an appropriate method for establishing standards based on professional opinions. To evaluate criteria and assign weight values, AHP creates a hierarchy. The decomposition of the entire problem into related components is depicted in Fig. 1 as a hierarchical structure. The hierarchical structure in the proposed study will resemble that in Fig. 1.

The criteria are shown in Table 1, while the alternate solutions are shown in Table 2.

Table 1: Criteria Used in Research

No.	Criteria
1	Spectrum usage fee (BHP)
2	Number of Subscribers
3	Non-Tax State Revenue (Penerimaan Negara Bukan Pajak / PNBP)
4	Investment
5	Technology Roadmap
6	Private Network
7	Regulation

Table 2: Alternative Solutions

No.	Alternative solutions
1	Spectrum rental by MNOs (BHP is paid by MNOs. MNOs have frequencies that are leased to vertical industries.)
2	Unlicensed 5G frequencies (Vertical industries have no obligation to pay BHP because they use unlicensed frequencies.)
3	Vertical industries have their own spectrum (BHP is paid by vertical industries).

The researcher will conduct interviews with experts after establishing the hierarchical structure; the primary data will be gathered by questionnaires and in-depth interviews with expert responders who can provide correct information [24]. Experts in telecommunications and 5G technology are interviewed and questionnaires are distributed. Table 4 provides information on the experts.

Table 3: List of Experts

No.	Professional Affiliation	Number
1	Ministry of Communication and Information Technology	3
2	MNOs	3
3	Vertical Industry	2
4	Telecommunication Consultant	2
Total		10

The experts will use comparative judgment to provide assessments of the relative importance of two aspects: either one criterion and another criterion or a criterion and an alternative.

II. Research Method

The goal of this study is to use the F-AHP approach to determine the best 5G private network for the BHP regulatory model for Indonesia. The invention of the F-AHP approach, which works by assigning weights to a problem that has been organized into a hierarchy, is the major method employed in this study. The purpose of solving the challenge is to reach the top of the hierarchy. The primary goal of this research is to identify several options. In this investigation, seven different criteria (Table 1) and three different solutions (Table 2) have been developed:

1) Spectrum rental by MNOs, where BHP is paid by MNOs. MNOs have frequencies that are leased to vertical industries.
2) Using unlicensed 5G frequencies (vertical industries have no obligation to pay BHP because they use unlicensed frequencies).
3) Vertical industries have their own spectrum. In this case BHP is paid by vertical industries.

Then, experts or respondents in the telecommunications field from the Ministry of Communication and Information Technology, MNOs, vertical industries, and telecommunications consultants will compare the criteria at the same level on a scale of 1 to 9. Experts' judgments in the comparison of the criteria, however, are very subjective. To promote impartiality, fuzzy logic is employed to substitute the scales of 1 to 9 as the evaluation scale in the AHP approach. The scale is replaced with a fuzzy triplet number.

The following are several steps taken in F-AHP [14]:

1) Designing a hierarchical structure
   This process entails mapping the problem into a hierarchical structure by establishing the desired outcome, which is the regulation of 5G private network BHP. As indicated in Table 1 and Fig. 1, this step shows the influencing criteria. The spectrum usage fee (BHP), the number of subscribers, non-tax state revenue (PNBP), investment, technology roadmap, private network, and regulation are the criteria. Meanwhile, three alternative options are given, as indicated in Table 2. An agreement among experts was obtained to identify the criteria and alternative solutions, and the distribution of specialists is displayed in Table 4. In-depth interviews were used to acquire primary data.
2) Forming a fuzzy relative importance matrix for each level.

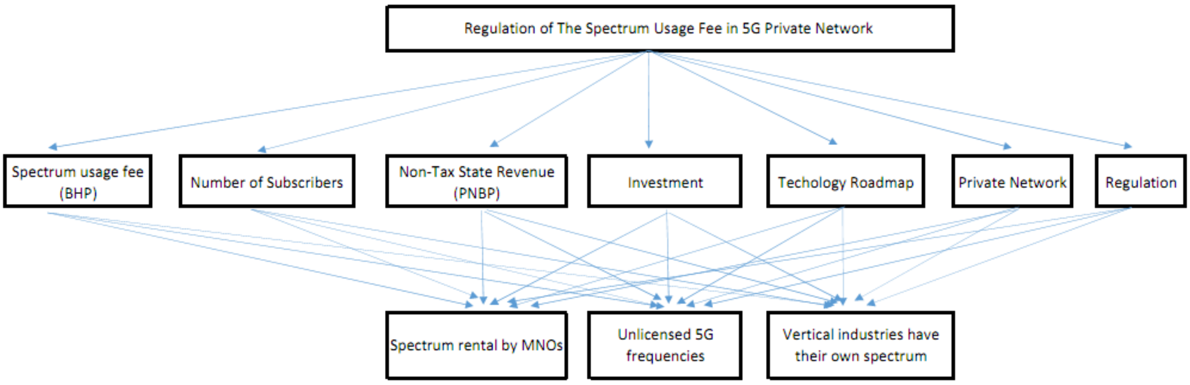

Fig. 1: BHP 5G private network regulatory hierarchy structure.

The relevance matrix for each level is generated using a scale of 1 to 9, which is then translated to fuzzy numbers. Triangular fuzzy numbers (TFN) used in this investigation is shown in Fig. 2.

Table 4: Scale of Fuzzy Relative Importance

Relative Importance	Fuzzy Scale	Explanation
$\tilde{1}$	$(1,1,1)$	Equally important
$\tilde{3}$	$(3-\alpha),3,(3+\alpha)$	Slightly more important
$\tilde{5}$	$(5-\alpha),5,(5+\alpha)$	Quite important
$\tilde{7}$	$(7-\alpha),7,(7+\alpha)$	Very important
$\tilde{9}$	$(9-\alpha),9,(9+\alpha)$	Extremely important
$\tilde{2}$, $\tilde{4}$, $\tilde{6}$, $\tilde{8}$	$(x-\alpha),x,(x+\alpha)$	Intermediate level of importance between the two values above

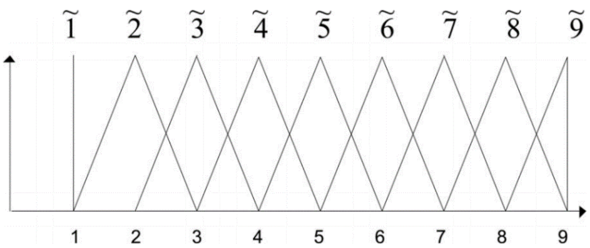

Fig. 2: Triangular fuzzy number (TFN).

TFN can be denoted by (l, m, u), where $l \leq m \leq u$. l and u respectively, indicate the low and high values of a TFN. If two TFNs are $M_1 = (l1, m1, u1)$ and $M_2 = (l2, m2, u2)$, then we have the following mathematical operations [25]:

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (1)$$

$$M_1 \odot M_2 = (l_1 l_2, m_1 m_2, u_1, u_2) \quad (2)$$

$$(\lambda, \lambda, \lambda) \odot (l_1, m_1, u_1) = (\lambda l_2, \lambda m_2, \lambda u_2) \text{ with } \lambda > 0, \lambda \in \mathbf{R} \quad (3)$$

$$(l_1, m_1, u_1)^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \quad (4)$$

3) Creating a matrix of pairwise comparisons based on the results of the survey
The aim of creating a matrix of pairwise comparisons $\tilde{D}$ in fuzzy AHP is to quantify the relative importance or preference of each criterion or alternative with respect to one another. By obtaining survey data and conducting pairwise comparisons, we can derive the degree of importance or preference between each pair of criteria or alternative.

$$\tilde{D} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & (1,1,1) \end{bmatrix}$$

Where $\tilde{a}_{ij} \times \tilde{a}_{ji} = 1$; i and $j = 1, 2, \ldots, n$. $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is TFN and $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$.

4) Calculating the fuzzy synthetic extent (S) value
Let $X = \{x_1, x_2, \ldots, x_n\}$ represent a set of objects, and $U = \{u_1, u_2, ..., u_m\}$ denote a set of goals. We apply extent analysis to each object for every individual goal. This results in m extent analysis values for each object, which can be denoted as follows:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m; i = 1, 2, \ldots, n \quad (5)$$

If the extent analysis values of the i-th object for m goals are denoted as $M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m$, the fuzzy synthetic extent value for the i-th object is defined expressed by 6:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \quad (6)$$

where:

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \quad (7)$$

and,

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}\right)^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}\right)^{-1} \quad (8)$$

5) Determining the possibility degree of $S_j = (l_j, m_j, u_j) \geq S_i = (l_i, m_i, u_i)$
This step aims to identify the degree of possibility that $S_j = (l_j, m_j, u_j)$ is greater than or equal to $S_i = (l_i, m_i, u_i)$. S_j and S_i values can be compared using 9:

$$V(S_j \geq S_i) = \begin{cases} 1, & \text{if } m_j \geq m_i \\ 0, & \text{if } l_i \geq u_j \\ \frac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)} & \text{for others} \end{cases} \quad (9)$$

Fig. 3 illustrates $V(S_j \geq S_i)$ for the scenario where $m_j < l_i < u_j < m_i$. In this case, d corresponds to x-coordinate of the highest intersection point between S_j and S_i. It is important to obtain both $V(S_j \geq S_i)$ and $V(S_i \geq S_j)$ values to accurately compare S_i and S_j.

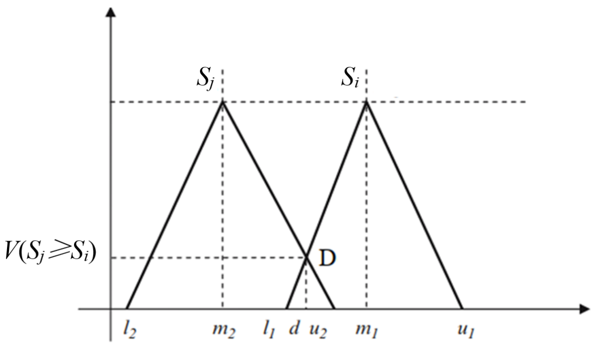

Fig. 3: The intersection between S_j and S_i.

6) Determining the minimum degree of possibility and deriving the weight vector
The minimum degree of possibility, denoted as d' for $V(S_i \geq S_j)$ with $i, j = 1, 2, \ldots, k$, can be obtained using equation 10. Subsequently, the weight vector W' can be calculated based on equation 11.

$$V(S \geq S_1, S_2, \ldots, S_k) = V\left[(S \geq S_1), \text{ and } (S \geq S_2), \text{ and }, \ldots, \text{ and } (S \geq S_k)\right] = \min V(S \geq S_i); i = 1, 2, \ldots, k. \quad (10)$$

The weight vector is derived based on the assumption that $d'(A_i) = \min V(S_i \geq S_k)$, $k = 1, 2, \ldots, n$ and $k \neq i$. Then, the weight vector can be defined as follows:

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \quad (11)$$

where n represents the total number of elements.

7) Determining the relative weights
The relative weights of each dimension can be calculated by normalizing the weight vector using 12.

$$d(A_i) = \frac{d'(A_i)}{\sum_{i=1}^{n} d'(A_i)} \quad (12)$$

for $i = 1, 2, \ldots, n$.

III. Results and Discussion

The F-AHP analysis was performed on the criteria to determine the weight values of each criterion and potential solutions for each criterion. In total, there are eight F-AHP analyses. The same stages are used for F-AHP analysis at the criteria and alternative solution levels.

As an example, consider the following stages of analysis at the criterion level: The first step is to arrange the pairwise comparison into a matrix, as illustrated in Table 5. The values in the matrix represent geometric averages of respondents' answers to pairwise comparisons in the questionnaire.

Next, calculate the fuzzy synthetic extent (S) value, which is obtained by using 6, after previously calculating $\sum_{j=1}^{n} \tilde{a}_{ij}$ and $\left[\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1}$ using 7 and 8, as shown in Table 6.

The fuzzy synthetic extent (S) values are shown in Table 7. The next step is to construct the priority vector by calculating the degree of possibility of $S1 \geq S2$. For example, **C1** has the vector $S_1 \geq (S_2, S_3, S_4, S_5, S_6, S_7)$ as shown in Table 8. The vector weights are then normalized by dividing each weight element by the vector's total value, and the normalizing result will produce a new cumulative value of 1 (one) (Table 9). For $V(S_1 \geq S_2)$, since the values of $m_1 \geq m_2$ and $u_2 \geq l_1$ are not fulfilled, it is obtained using the following formula:

$$V(S_1 \geq S_2) = \frac{0.121 - 0.146}{(0.083 - 0.146) - (0.201 - 0.121)} = 0.170$$

Using the same method for $(S_1 \geq S_3)$, $(S_1 \geq S_4)$, $(S_1 \geq S_5)$, $(S_1 \geq S_6)$, $(S_1 \geq S_7)$, we get the following values: 1.000; 0.177; 0.183; 0.781; 0.512. Next, we determine the ordinate value, d', which is:

$$d'(S_1) = \min(0.170; 1.000; 0.177; 0.183; 0.781; 0.512) = 0.170$$

Table 5: Matrix of Comparisons

	C1	C2	C3	C4	C5	C6	C7
C1	$(1, 1, 1)$	$(0.4, 0.5, 0.7)$	$(1.1, 1.3, 1.9)$	$(0.3, 0.4, 0.6)$	$(0.3, 0.3, 0.5)$	$(0.8, 1, 1.3)$	$(0.4, 0.5, 0.7)$
C2	$(1.4, 2.2, 2.6)$	$(1, 1, 1)$	$(3.1, 4, 5.1)$	$(0.8, 1, 1.5)$	$(1.2, 1.5, 2)$	$(1.1, 1.4, 2.1)$	$(0.8, 1, 1.4)$
C3	$(0.5, 0.8, 0.9)$	$(0.2, 0.2, 0.3)$	$(1, 1, 1)$	$(0.4, 0.5, 0.8)$	$(0.2, 0.3, 0.4)$	$(0.4, 0.6, 0.8)$	$(0.3, 0.4, 0.6)$
C4	$(1.7, 2.5, 3.5)$	$(0.7, 1, 1.3)$	$(1.3, 2.1, 2.5)$	$(1, 1, 1)$	$(1, 1.3, 1.8)$	$(1.4, 2, 2.6)$	$(1.4, 1.9, 2.7)$
C5	$(2.2, 3, 4)$	$(0.5, 0.7, 0.8)$	$(2.5, 3.7, 4.4)$	$(0.6, 0.8, 1)$	$(1, 1, 1)$	$(1.5, 2.1, 2.7)$	$(1.3, 1.6, 2.3)$
C6	$(0.7, 1, 1.3)$	$(0.5, 0.7, 0.9)$	$(1.2, 1.7, 2.3)$	$(0.4, 0.5, 0.7)$	$(0.4, 0.5, 0.7)$	$(1, 1, 1)$	$(0.6, 0.8, 1.2)$
C7	$(1.4, 2, 2.3)$	$(0.7, 1, 1.3)$	$(1.6, 2.5, 3.1)$	$(0.4, 0.5, 0.7)$	$(0.4, 0.6, 0.8)$	$(0.8, 1.3, 1.6)$	$(1, 1, 1)$

Table 6: Calculating Fuzzy Synthetic Extent Value

	$\sum_{j=1}^{n} \tilde{a}_{ij}$		
	l	m	U
C1	0.52	0.63	0.86
C2	1.19	1.54	1.98
C3	0.39	0.49	0.65
C4	1.17	1.58	2.02
C5	1.17	1.52	1.89
C6	0.63	0.81	1.05
C7	0.81	1.09	1.36
$\left[\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right]$	5.87	7.66	9.81
$\left[\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right]^{-1}$	9.81	7.66	5.87

Table 7: Fuzzy Synthetic Extent (S_i)

	S_i		
	l	m	U
C1	0.053	0.083	0.146
C2	0.121	0.201	0.337
C3	0.040	0.063	0.111
C4	0.119	0.206	0.344
C5	0.120	0.198	0.322
C6	0.064	0.106	0.180
C7	0.083	0.143	0.231

The ordinates for the other criteria, **C2** through **C7**, are acquired in the same manner as **C1**, yielding ordinate data for all criteria, as shown in Table 8.

The alternative solutions offered consist of spectrum rental by MNOs (BHP is paid by MNOs), using unlicensed 5G frequencies, and vertical industries having their own spectrum. So that the results are obtained as shown in Table 9.

The final results are shown in Table 10. In the 5G BHP regulations for private networks, the weight denotes the model's priority level. It can be observed that the model with the most weight is the one that uses unlicensed 5G frequency, specifically, the model in which vertical industries do not utilize the licensed frequency specified by the government but prefer to develop the 5G private network technology that will be employed. The second recommendation is for MNOs to employ a spectrum leasing model, in which vertical industries lease the frequency spectrum used in the manufacturing industry they develop to MNOs. The least recommended model is one in which vertical industries have their own spectrum, specifically their own frequency, and it is clear that vertical industries must build their own 5G private network with BHP, which is paid directly to the regulator by the vertical industry.

The usage of unlicensed 5G frequencies might have an influence on Indonesian telecommunications regulations. This is due to the fact that unlicensed 5G frequencies lack official government permits and are not subject to the same laws or restrictions as licensed frequencies.

The usage of unlicensed 5G frequencies by vertical industries such as businesses or other organizations may create interference or interruption to current telecommunications networks. Telecommunication networks that have been set up by the government have frequency restrictions and are controlled to minimize interference across networks so that the use of unlicensed frequencies can disrupt existing networks and create discomfort for users.

Furthermore, the use of unlicensed 5G frequencies on private networks may limit MNOs' ability to use the same frequencies for their networks. This can have an impact on MNO network quality, speed, and user experience.

However, the usage of unlicensed 5G frequencies on private networks may create opportunities for vertical industries to develop 5G technologies on private networks independently without relying on current MNOs. This may encourage creativity and technical growth in Indonesia.

To address this issue, regulators can create laws severely regulating the use of unlicensed 5G frequencies and ensuring that their usage does not impair existing telecommunications networks. Regulators can also control the technical standards that unlicensed 5G frequency users must meet, such as security and privacy requirements that vertical industries must meet. This can ensure that the deployment of 5G unlicensed frequencies on private networks does not negatively impact consumers or current telecommunication networks.

Table 8: Vector Value Comparison

	$S1 \geq$	$S2 \geq$	$S3 \geq$	$S4 \geq$	$S5 \geq$	$S6 \geq$	$S7 \geq$
$S1$		1.000	0.752	1.000	1.000	1.000	1.000
$S2$	0.170		0.000	1.000	0.987	0.379	0.653
$S3$	1.000	1.000		1.000	1.000	1.000	1.000
$S4$	0.177	0.977	0.000		0.963	0.375	0.638
$S5$	0.185	1.000	0.000	1.000		0.393	0.668
$S6$	0.781	1.000	0.529	1.000	1.000		1.000
$S7$	0.512	1.000	0.264	1.000	1.000	0.722	
$d(S1)$	0.170	0.977	0	1	0.963	0.376	0.638

Table 9: Normalized Vector Weights

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Weights	0.041	0.237	0.000	0.242	0.233	0.091	0.155

Table 10: Determination of Consensus on Alternative Solutions

	Weights	First option	Second option	Third option	With Weighting		
					First Alternative Solution	Second Alternative Solution	Third Alternative Solution
Spectrum usage fee (BHP)	0.04	0.30	0.35	0.36	0.01	0.01	0.01
Number of Subscribers	0.24	0.17	0.25	0.57	0.04	0.06	0.14
Non-Tax State Revenue (*Penerimaan Negara Bukan Pajak / PNBP*)	–	0.54	0.46	–	–	–	–
Investment	0.24	0.30	0.36	0.34	0.07	0.09	0.08
Technology Roadmap	0.23	0.35	0.65	–	0.08	0.15	–
Private Network	0.09	0.01	0.6	0.39	0.00	0.05	0.04
Regulation	0.15	0.59	0.41	–	0.09	0.06	–
TOTAL					0.30	0.43	0.27

IV. CONCLUSION

Determining the most appropriate regulation model for a spectrum usage fee (BHP) for 5G private network technology to be implemented in Indonesia is an important agenda that requires support from regulators. This study has accommodated the assessment of experts using the F-AHP method, which aims to determine the most recommended model. The results of this study are models using unlicensed 5G frequencies, namely models where vertical industries do not use licensed frequencies set by the regulator. Instead, they prefer to use unlicensed frequencies to develop the 5G technology to be used. The results are expected to provide an overview of the model and appropriate regulations for future use.

Furthermore, the adoption of the spectrum usage fee regulation on 5G private network technology can improve the investment climate, allowing for the equitable distribution of telecommunications services. Users of telecommunications services will certainly provide a challenge to regulatory regimes that can satisfy regulators, vertical businesses, and MNOs.

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