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Article

Proposal of the Indonesian Framework for Telecommunications Infrastructure Based on Network and Socioeconomic Indicators

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Abstract: In Indonesia, there is still a disparity in telecommunications access, with most rural areas experiencing "no signal" or "blank spots." In contrast, urban areas enjoy modern and societally-beneficial technologies. A comprehensive framework is needed to address the disparity in telecommunications access between "rich" and "poor" groups in urban and rural/remote areas, respectively. This paper proposes a framework, built by the mathematical model, that can be used as a reference for the Indonesian government in constructing the nation's telecommunications infrastructure. The framework categorizes Indonesian administrative regions into four grids: Grid #1: "fostered" districts; Grid #2: "developing" districts; Grid #3: "developed" districts; and Grid #4: "independent-advanced" districts. To determine where each district falls in these grids, we propose a novel statistical approach using 17 indicators involving a telecommunications network and socioeconomic factors. The proposed framework results in a grid visualization of 7232 districts in Indonesia. Finally, as this paper is replete with academic research approaches and mathematical model perspectives, it is expected that the results may be a valuable input to the development of the country's telecommunications policy.

Keywords: telecommunications; policy; regulation; mathematical model; network; socioeconomic; Indonesia; framework; infrastructure

Citation: Situmorang, A.C.; Suryanegara, M.; Gunawan, D.; Juwono, F.H. Proposal of the Indonesian Framework for Telecommunications Infrastructure Based on Network and Socioeconomic Indicators. *Informatics* **2023**, *10*, 44. https://doi.org/10.3390/informatics10020044

Academic Editor: Alessandro Pozzebon

Received: 19 February 2023
Revised: 21 April 2023
Accepted: 22 April 2023
Published: 12 May 2023

1. Introduction

Poverty and isolation are two facets of the digital divide that cause a disparity in telecommunications access. Access to essential information and communication technologies in developing countries creates a significant divide between "rich and poor" and "urban and rural/remote areas." It is more expensive and difficult to deliver services in rural areas compared to metropolitan areas; moreover, feasible plans and solutions are often lacking. Blank signal spots sometimes arise in impoverished urban neighbourhoods. However, these areas are not geographically isolated and can be "reached" using a standard business plan or access strategy if the market is liberalized (supply and demand). In contrast, rural areas often experience neglect with or without liberalized markets, as they are perceived to carry higher risks and lower returns on capital. They are naturally the last to be served unless interventions occur. On the other hand, innovation is required in the telecommunications industry to stimulate the rapid development of technology (technology push) while meeting societal needs (market pull) [1,2].

Unfortunately, Indonesia is facing the above-mentioned condition. In the field of infrastructure provision, there is disagreement over which telecommunications infrastructure was constructed first. In view of this predicament, a few questions arise. Is the telecommunications infrastructure being constructed in geographically isolated and socioeconomically depressed regions in order to attract residents and stimulate economic growth [3,4]? Or is the telecommunications industry following the provider/business approach, whereby they wait until the region is economically viable before investing in infrastructure [5,6]?

This situation requires a framework that can serve as a regulatory reference, particularly in determining the region's category for telecommunication infrastructure. Therefore, both options ("was" and "should be" constructed first) are tailored to each district as a geographically specific policy proposal.

This paper proposes a framework that can be used as a reference for the Indonesian government in constructing the nation's telecommunications infrastructure. It was developed on the basis of the International Telecommunication Union (ITU) framework, which has become the global standard for ensuring universal access to telecommunications over the past 13 years [3]. Our proposed framework classifies Indonesian administrative regions into four grids: Grid #1: "fostered" districts; Grid #2: "developing" districts; Grid #3: "developed" districts; and Grid #4: "independent-advanced" districts.

To determine where a district falls in the framework, we develop a novel statistical approach using 17 indicators involving a telecommunications network and socioeconomic factors. The four indicators of a telecommunications network are the presence of optical distribution points (ODPs), coverage prediction/signal coverage (SigCov), traffic, and site quantity. Included among the thirteen socioeconomic indicators are electricity, education, buying and selling transactions, lodging, health facilities, financial activities, industrial capacity, tourism, mining and plantation business units, residential conditions, road access, regional finances, and population. Each indicator depicts the regionally specific factors or peculiarities or advantages or the local wisdom of a specific grid area. The proposed framework has resulted in a grid visualization of 7232 districts in Indonesia.

This paper suggests a geographically specific policy proposal containing telecommunication networks and socioeconomic indicators to boost the equitable distribution of telecommunications access, as well as mutually reinforcing the increasing quality and quantity of telecommunications networks that will have a positive impact on socioeconomic indicators. Challenges are involved in connecting to rural areas, but the mobile industry must help bridge the coverage gap. The government and regulators can play in encouraging and enabling the investments and innovations needed to extend network coverage into rural areas through key roles: efficient, targeted, and transparent.

This paper brings not only recommendations to Indonesian telecommunications policymakers but also a set of theoretical contributions consisting of a state-of-the-art framework as well as a novel multi-stage statistical approach. Such a contribution can be further elaborated in future research and could therefore be replicated as recommendations to regulators in multiple developing nations.

The rest of this paper is organized as follows. Section 2 discusses the ITU framework for universal access while providing regulatory and district information for Indonesia. Section 3 presents our proposal, including how to elaborate upon this framework using a novel formulation of 17 indicators that focus on the telecommunications network and socioeconomic factors. Section 4 presents a visualization of the Indonesian grid framework, while the last section concludes the paper.

2. Theory

2.1. The Indonesian Profile and Policy Direction

Indonesia is the largest archipelagic nation, consisting of 16,056 islands, among which are the six major islands [7]. The demographic profile indicates a national population of 270.2 million people [8], with 60% of people residing on Java Island. The state administration structures the country into 34 provinces, 514 regencies/cities, 7232 districts, and 83,880 villages [9]. Figure 1 illustrates the number of districts within each Indonesian province.

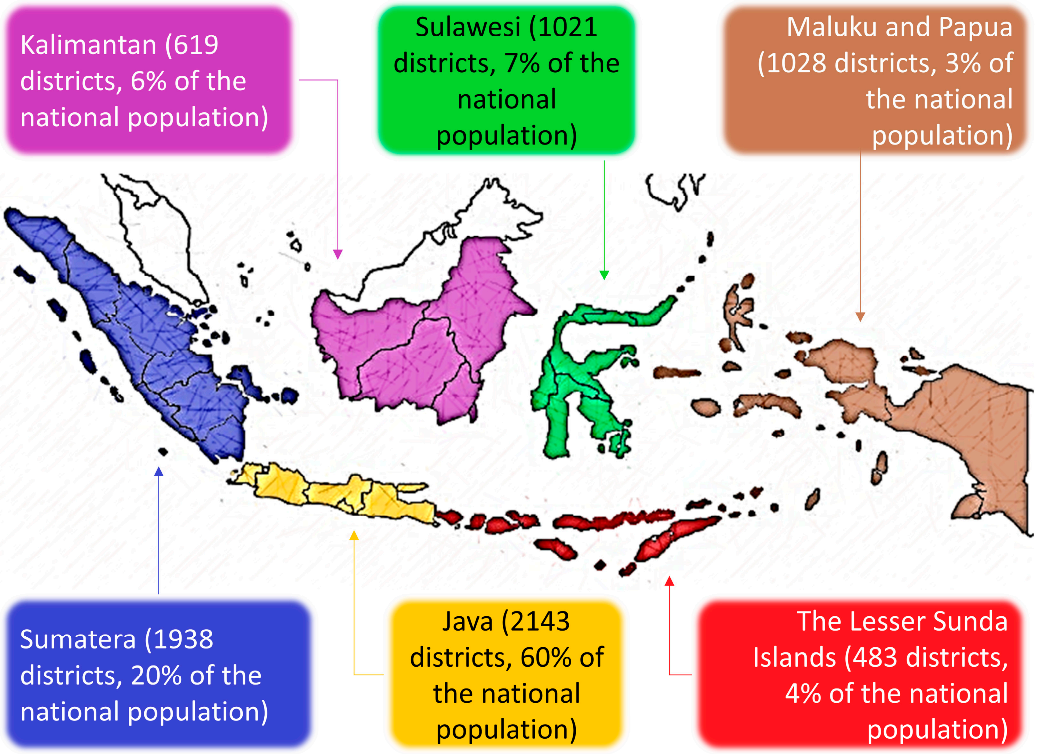


Figure 1. The Districts and Population Profiles of Indonesia's Six Major Islands.

Based on a 2021 report, 73.7% of the total population used the Internet, while active mobile networks reached 353.3 million people or 125.6% of the total population [10]. This figure relates to the Indonesian behaviour of subscribing to services on multiple devices for Internet-related activities. Despite these figures, there remain areas that lack 4G services [11] and areas with poor Internet quality. The average and median Internet speed in Indonesia still falls below the world's top ten [12–14] and 1530 villages in Indonesia still do not have signals (blind/blank spots) [15].

The speed goal for the Internet (mobile and fixed broadband) continues to be a national one. Even the goal for cable Internet coverage in homes/households/families by 2024 concerns only 30 percent of all homes/households/families. As a result, Indonesia will not have established a coverage speed per household until the year 2024, as shown in Figure 2. Once all households have access to telecommunications signals, the amount of traffic per household can be increased until reaching a future goal.

The government may conduct an intervention consisting of facilitating the telecoms infrastructure [16]. In line with the mandate of the Indonesian government regulation No. 46 of 2021, the mobile network operator (MNO), the Central Government, and Local Governments may provide facilities for use by MNOs at reasonable charges in the form of land, buildings, and/or passive telecoms infrastructure. The execution of the provision of facilities may utilize the state budget, the regional revenue and expenditure budget, and other sources of funding in compliance with applicable laws and regulations. The Central Government and Regional Governments assist MNOs in developing their telecommunications infrastructure in a transparent, accountable, and efficient way in compliance with applicable laws and regulations. Facilitation and/or convenience include but are not limited to the granting of right of way, access to buildings and areas, charges based on reasonable costs and ensuring business certainty, rental rates and/or use of assets owned by the Central Government or Local Government, as well as technical standardization and telecommunications technology. In providing facilitation and/or convenience, local governments and/or authorized agencies must coordinate with the minister. Furthermore, MNOs in organizing telecommunications networks can cooperate with passive infrastructure providers. Passive infrastructure includes culverts/ducts, towers, poles, cable holes/manholes, and/or other passive infrastructure. The provision of passive infrastructure can be carried out by the Central Government and/or Regional Governments, state-owned enterprises and/or regional-owned enterprises, privately owned enterprises, and/or legal entities or other parties determined by the Minister. Cooperation is carried out at a fair and cost-based utilization price. Price rates for passive infrastructure utilization are established by the suppliers of passive infrastructure in consideration of national efficiency, market conditions, positive economic consequences, and community interests. If the price of passive infrastructure utilization does not comply with the regulations, the Minister establishes a maximum rate that passive infrastructure providers must adhere to. Moreover, MNO may lease its telecommunication network to other MNOs and non-MNOs (service operators, etc.). Telecommunication network leasing (capacity, network systems, and other support systems) is outlined in a written contract and carried out in accordance with the contract in a fair, reasonable, and non-discriminatory manner.

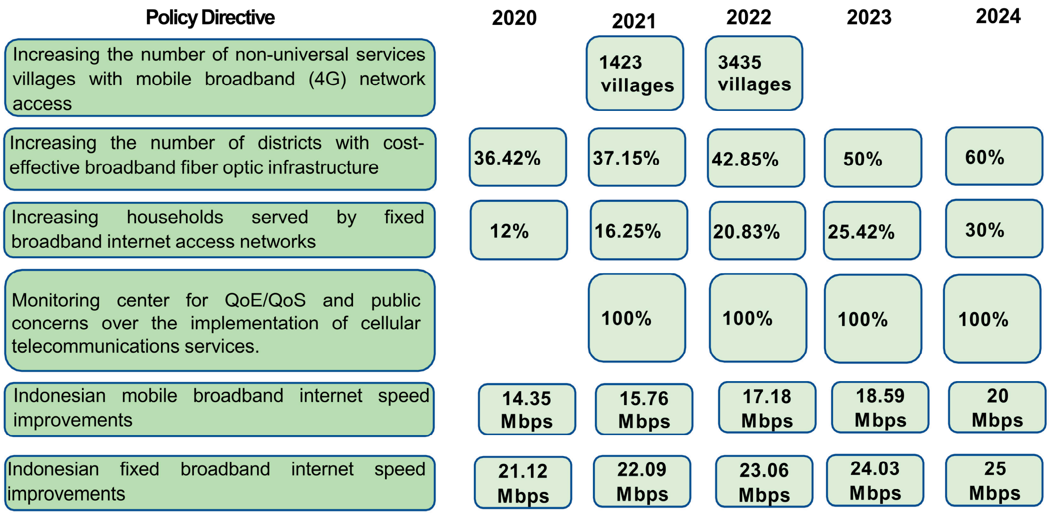


Figure 2. Policy Direction in Telecommunications for the Years 2020–2024, derivative of [17].

Later in this proposed framework, we actually propose a kind of new intervention in the form of interim regulations that stipulate the use of secondary technologies based on non-interference and non-protection (ITU Radio Regulation article 4.4). This access equalization solution applies to terrestrial peripheral technologies, for example, orthogonal frequency division multiplexing (OFDM) 5.8 GHz band, whose technical parameters may exceed the maximum value of the operational technical provisions (antenna gain, conducted power, RF power, bandwidth, frequency, radio pattern envelope, etc.) in Indonesia's universal telecommunications service area which belongs to grid category #1. If the area is commercially developed into the above category (grid #2 or #3 or #4), then this special condition class permit policy no longer applies.

Details of the regulations and policies of Indonesian telecommunications can be found in Appendices A–D (Supplementary Material Files S1−S4). Supplementary Material Files S1 details Indonesian telecommunication regulation and government action (compiled based on various references: [10,17–29] and provide 7 figures (Figures S1–S7)). Supplementary Material Files S2 details the implementation of the Universal Service Obligation (USO) in Indonesia (with reference to [30] and provide 1 figure (Figure S8)). Supplementary Material Files S3 details the Palapa Ring Project as the national infrastructure policy (compiled based on various references: [31,32] and provide 1 figure (Figure S9) as well as 1 table (Table S1)). Supplementary Material Files S4 details the strategic plan of the Ministry of Communication and Information (KOMINFO) (compiled based on various references: [17,33] and provide 2 figures (Figures S10 and S11) as well as 1 table (Table S2)).

2.2. Connectivity and Society

In the international arena, there are Sustainable Development Goals (SDGs), specifically SDG 9 "Build resilient infrastructure, promote sustainable industrialization and foster innovation". Figure 3 displays a correlation graph between the SDG score, the ICT Development Index (IDI) score, and the IMD digital competitiveness score of 50 countries as part of the SDG accomplishment accelerator. The graph demonstrates that an increase in a country's ICT capabilities will correspond with the achievement of certain SDGs. The highest-scoring countries in ICT are those with high levels of ICT investment and innovation, as well as high levels of economic prosperity, literacy, and the ability to use digital technology. The proposed 17 grid-forming indicators include this.

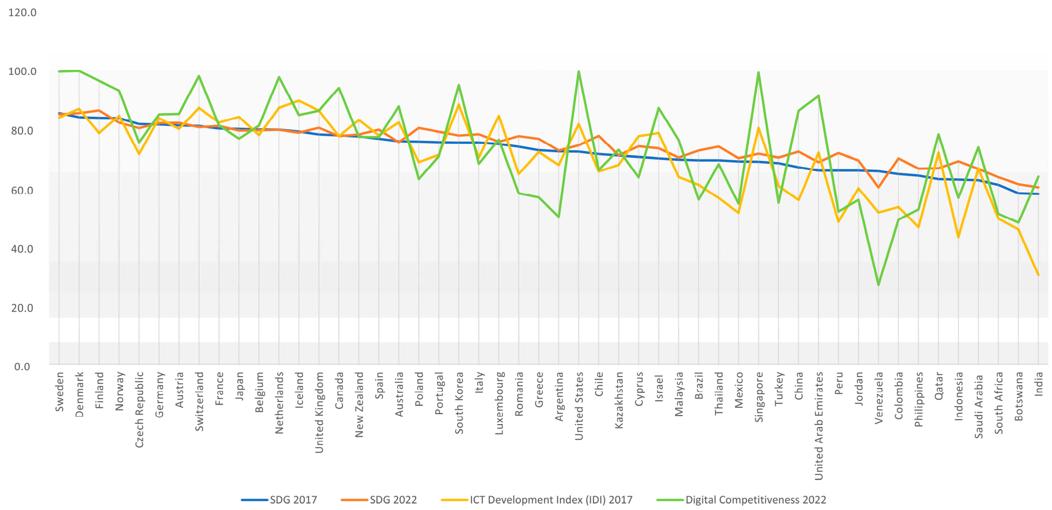
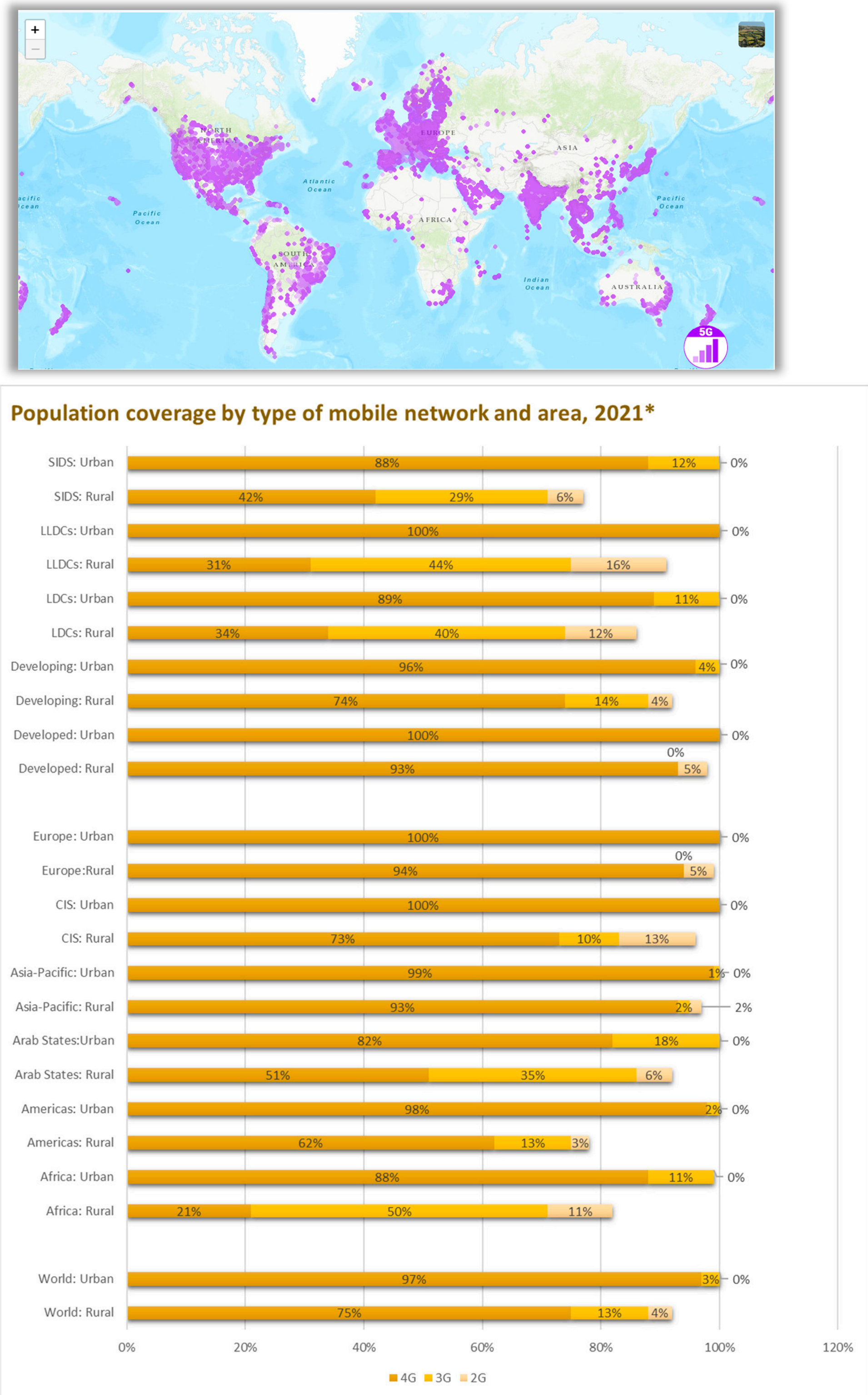


Figure 3. SDG, IDI, and Digital Competitiveness Scores by Country [34–36]. Reprinted/adapted with permission from Ref. [37]. 2022, IMD World Digital Competitiveness Ranking: IMD World Competitiveness Center, Switzerland.

It is believed that the benefits of Internet access are so significant that it is almost essential in the current period. It cannot be denied that the Internet is useful. For instance, Internet purchasing eliminates time-consuming activities such as long-distance travel, rush hour, and traffic congestion; hence, the time saved might be considered an enhancement in life quality. In addition, Internet access is a requirement for current scientific studies. In the past, scientists and graduate students were required to spend months in libraries and archives to locate the necessary content. This time has been reduced to a few weeks, if not hours, thanks to the Internet. In addition, the COVID pandemic changed the habit of most people using the Internet. Based on these arguments, it would appear that the benefits of Internet access significantly outweigh the hazards, making it an indispensable component of our life.

However, as shown in Figure 4, most of the world's population is covered by a mobile-broadband signal, but there are still blind areas [38–40]. In most developing nations, mobile broadband (3G or higher) is the primary and often only means of accessing the Internet [41]. It is a necessary condition, but it is not sufficient, as potential users encounter numerous obstacles to connectivity. In Indonesia, there are still indigenous villages seeking to preserve their culture without outside interference, such as telecommunications equipment and signals. One such example is that of Wae Rebo, as shown in Figure 5. Wae Rebo is a remote and secluded traditional village in Manggarai Regency, East Nusa Tenggara. Waerebo Village itself is 1200 years old and has entered the 20th generation where 1 generation is 60 years old. The Wae Rebo people still maintain a way of life according to the culture and traditions passed down by their ancestors. Moreover, even in developed countries such as the United States, 7% of Americans do not use the Internet [42]. Therefore, while nearly every urban area in the globe is covered by a mobile broadband network, there are still significant gaps in rural areas.



*ITU estimate, where the values for 2G and 3G networks show the incremental percentage of population that is not covered by a more advanced technology network. Moreover, only 92% rural area worldwide covered by cellular signal (75% 4G, 13% 3G, and 4% 2G).

Figure 4. 5G Coverage Map Worldwide Year 2023 and Population Coverage by Type of Mobile Network and Area Year 2021, Original Mapping from [43] and Redrawn from [41].

Figure 5. Wae Rebo Isolated Kampoeng—Original Photos from [44,45].

2.3. ITU Framework of Universal Access

The Telecommunications Access Framework provides an observational perspective on how to geographically expand the telecommunications access considering people's opportunity to obtain telecommunications. In 2002, a framework was developed to explore the universal accessibility of telecommunications in rural areas while mapping telecommunications access disparities. Sabater et al. [46] initiated pioneering research and published a framework entitled, "Telecommunications and Information Services for the Poor: Toward a Strategy for Universal Access" in 2002. Stern and Townsend [47] introduced the gap model in 2006, modifying the dimensions (x and y axes) of the framework. Formerly influenced by poverty and geographical isolation, the revised dimensions were influenced by availability/supply and needs/demand, thereby triggering market efficiency, market gaps, and access gaps. This model best explains the impact of market forces, regulatory decisions, and financial constraints on the growth of the telecommunications market, particularly in regions with lower incomes, higher costs, and unevenly distributed populations.

In 2009, Mayer et al. [48] streamlined the gap model framework by introducing the terms existing coverage, efficient market gap, and coverage gap (e.g., sustainable coverage gap and universal coverage gap) to the x and y axes. ITU and Intelecon-World Bank adopted the framework in the form of an ICT Regulation Tool Kit in 2010 [3] as a guide for global universal access. The ITU framework is considered to be the most applicable to Indonesia's situation as Indonesia has not established a per-household coverage speed target [49].

There is a connection between available access and service utilization. If there are routine users within the home, household penetration becomes effective. Household penetration is the amount of network access and reach that each person in the house uses on their own. On the other hand, a routine user uses a service whenever it is useful in daily life, as opposed to only in exceptional situations or emergencies. To become routine users, most individuals require the convenience of private services, which they will only acquire if they are accessible and affordable. There are stages in the process of achieving routine users, beginning with the deployment of infrastructure coverage, continuing with the development of public access and the provision of shared resources, and concluding with private access. This transition model from infrastructure coverage to routine use is applicable to both telephones and the Internet. However, there is a significant distinction between the telephone and Internet staircases: no qualification or skill is required to use a telephone, whereas using the Internet effectively requires specific levels of literacy, practice, and specialized skills (e.g., use of software, knowledge of English). In general, most people require or desire affordable telephone services, but not necessarily Internet access. Even in developed nations, large portions of the population do not wish to use the Internet for a variety of reasons. Younger people appear to have a much easier time acquiring the skills required to use the Internet, while older people frequently lack both the interest and necessary skills. Moreover, in developing nations with lower levels of education and less relevant content, there are more barriers to Internet usage, even in places where it is accessible and affordable.

2.4. Telecommunication Indicators on the Framework

While a profile of the telecommunication network is required to provide information on the current access position, the socioeconomic profile is required to provide information to the investor in the telecommunication infrastructure, such as infrastructure readiness (road), population, purchasing power, etc. ITU DataHub provides 11 connectivity concerns, where our three indicators are included in it, as shown in Table 1. Moreover, the quantity of mobile cellular (2G/3G/4G) sites gives cross-validation into coverage prediction. This does not necessarily mean the districts with cellular transmitting antennas, where residents are served by telecommunications signals. It could be that the signal is on the roof of the house but does not penetrate the house.

Table 1. Telecommunication Connectivity Indicators.

Our Telecommunication Network Indicators	SDG Indicators *	ITU Connectivity Concerns [50]	Our Data Source
The presence of optical distribution points (ODPs)	-	Backbone/core infrastructure	MNOs
Coverage prediction/signal coverage (SigCov)	9.c.1. Proportion of population covered by a mobile network.	Access	MNOs
Traffic	-	Quality of service (QoS)	OOKLA crowdsourcing
The quantity of mobile cellular (2G/3G/4G) sites	-	-	MNOs

* with SDG unique number/identity code.

2.5. Socioeconomic Indicators on the Framework

Table 2 overviews the related socioeconomic literature. The list of countries addressed is limited to Indonesia, India, Malaysia, Thailand, and Korea (Rep. of). Furthermore, Kosmas (2015) in "Modelling Complex Telecom Investments: A System of Systems Approach" considers interdependent systems such as competitor analysis, budget allocation, capital, and operational expenses (CAPEX + OPEX), demand forecast, and network externalities [51]. Most theoretical analyses of the impact of infrastructure on economic growth and development outcomes may be found in growth theory and the recent literature on economic geography. Straub (2008) identifies an additional avenue by which infrastructure investments can create growth effects: economies of scale and scope [52]. Moreover, the results of Snieska's empirical test (2009) demonstrated that the model for evaluating the impact of infrastructure must incorporate regionally specific factors/peculiarities/local wisdom [53].

Table 2. Socioeconomic indicators.

Propose Indicators	SDG Indicators *	Country Report [50] from ITU Indicators	Indicators from Research Paper	Our Data Source
Electricity	7.1.1. Population with access to electricity.	The proportion of households with electricity in Indonesia and Thailand is 99%.	Investor CAPEX [51,52].	Statistics Indonesia
Education	-	Education is needed to possess several ICT skills.	OPEX [51].	Statistics Indonesia

Table 2. *Cont.*

Propose Indicators	SDG Indicators *	Country Report [50] from ITU Indicators	Indicators from Research Paper	Our Data Source
Buying and Selling Transactions	-	-	Balancing market to achieve revenue [51].	Statistics Indonesia.
Lodging	-	-	Demand forecast [51].	Statistics Indonesia.
Health Facilities	3.8.1. Coverage of essential health services.	-	Reciprocal impact on infrastructure. [52]	Statistics Indonesia.
Financial Activities	8.10.1a Number of banks.	-	Demand forecast [51].	Statistics Indonesia.
Industrial Capacity	-	-	Reciprocal impact on infrastructure [52].	Statistics Indonesia.
Tourism	-	-	Reciprocal impact on infrastructure [52].	Statistics Indonesia.
Mining and Plantation Business Units	-	-	Reciprocal impact on infrastructure [52].	Statistics Indonesia.
Residential Conditions	11.1.1 Slums.	-	Demand forecast [51].	Statistics Indonesia.
Road Access	-	-	Investor CAPEX [51,52].	Statistics Indonesia.
Regional Finance	-	-	Pricing [51].	Ministry of Finance and Statistics Indonesia.
Population	-	Demographic trends are rising in Indonesia, India, Malaysia, Thailand, and Korea (Rep. of).	Demand forecast [51].	Ministry of Internal Affairs.

* With SDG unique number/identity code.

2.6. Regulatory Comparisons with Other Countries

Table 3 shows the regulation comparison among five countries. Municipal network initiatives are part of the digital strategies and broadband plans [50]. Some countries have adopted these. However, to accelerate the provision of broadband services, applications, and infrastructure, we suggest the area classification (four grids) to make development priority targets clearer in any country.

Table 3. Regulation comparison [50].

Regulation	Indonesia	India	Malaysia	Thailand	Korea (Rep. of)
Regulatory Incentives for Telecom/ICT Operators	2022: No, there are no targeted incentives.	2022: Yes, for other operators.	2021: Yes, for all operators (including virtual operators).	2022: Yes, for facility/infrastructure operators.	2021: No, there are no targeted incentives.
Spectrum Licenses Technology-Neutral	2022: Some.	2022: Yes.	2021: Yes.	2022: Yes.	2021: Some.
Mechanisms for Assigning 4G Spectrum	2018: Auction.	2020: Auction.	2020: First come, first served/spectrum allocated as part of the license.	2020: Auction.	2020: Auction.

Table 3. *Cont.*

Regulation	Indonesia	India	Malaysia	Thailand	Korea (Rep. of)
ICT Policy that Includes Broadband Exists	2016: Indonesia Broadband Plan. https://kominfo.go.id/content/detail/6859/program-prioritas-konektivitas-pita-lebar/0/pp_broadband (accessed on 5 January 2023)	National Digital Communications Policy, 2018. https://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf (accessed on 5 January 2023) National Broadband Mission 2019. https://dot.gov.in/national-broadband-mission (accessed on 5 January 2023)	2021: 11th Malaysia Plan. http://www.skmm.gov.my/Sectors/Broadband/National-Broadband-Initiative.aspx (accessed on 5 January 2023)	2022: National Digital Economy and Society Development Plan and Policy. www.mdes.go.th (accessed on 5 January 2023)	2021: The Sixth Master Plan for National Informatization to Realize Intelligent Information Society. https://www.msit.go.kr/web/msipContents/contentsView.do?cateId=_tsta5511&artId=1557222 (accessed on 5 January 2023)
The Timeframe and the Name for the Implementation of the National Broadband Policy	2014–2019: Indonesia National Broadband Plan. www.bappenas.go.id (accessed on 8 January 2023)	Every 5 years: BharatNet. www.bbnl.nic.in (accessed on 8 January 2023)	March 2010: National Broadband Initiative. https://www.mcmc.gov.my/sectors/broadband/national-broadband-initiative (accessed on 8 January 2023)	2019–2037: Digital Economy. https://www.onde.go.th/ (accessed on 8 January 2023)	2013: Ultra Broadband Convergence Network. http://www.kcc.go.kr (accessed on 8 January 2023)
Goals of National Broadband Plan	Promote the adoption of broadband services and applications.	Build nation-wide broadband infrastructure.	Build nation-wide broadband infrastructure.	Promote the adoption of broadband services and applications.	Promote the provision of public services using broadband.
Internet Access Is Recognized as a Legal Right	2022: Yes	2022: No.	2021: No.	2022: No.	2021: Yes.
Has Your Country Established Any Other Financing Mechanisms (e.g., Special Rural Access Concessions, Tax Incentives, etc.) for the Provision of Universal Service/Access?	2022: Yes.	2022: Yes.	2021: No.	2022: No.	2021: No.
Financing of National Broadband plan	2022: Universal service fund (USF).	2022: Universal service fund.	2021: Universal service fund.	2022: Universal service fund.	2010: Government grants of other direct financial subsidies.

Table 3. *Cont.*

Regulation	Indonesia	India	Malaysia	Thailand	Korea (Rep. of)
Projects Financed by USFs	2022: Connecting local government offices.	2022: Connecting persons with disabilities.	2016: Multi-purpose telecentres.	2022: Connecting persons with disabilities.	N/A
Municipal Network initiatives	2022: Yes.	2022: Yes.	N/A	2022: No.	2021: No.
Managing Authority of USF	2022: Regulatory Agency.	2022: Regulatory Agency.	2021: Regulatory Authority.	2022: Regulatory Authority.	N/A

In addition, there are other lessons to be learnt from implementing a broadband plan, such as establishing a central hub that connects all parties/institutions involved in implementing a broadband plan as a focal point connecting to all related parties/institutions, task delegation, support from the highest-ranking officials and having it put in regulation, concurred indicators for implementation and monitoring-evaluation, multi-stakeholder active participation, dynamic plans, maintaining the momentum, and a context which relates to national agenda to create urgency.

3. The Proposal

3.1. The Proposed Framework

Table 4 presents a comparison between some previous works [3,46–48] on telecommunications access frameworks and the proposed model. Compared to the preceding framework, the state of the art is the contextualization of the proposed model into quantitative indicators so that they can be measured and mapped.

Table 4. A Comparison between Previous Works [3,46–48] on Telecommunications Access Frameworks and this Paper.

	Sabater	Stern	Mayer	ITU	Proposed Model
Framework Name	Telecommunications & Information Services for the Poor.	The Gaps Model.	Coverage Gap Analysis Framework.	Distinctions within the Access Gap.	Indonesian Framework for Telecommunications Infrastructure based on Network and Socioeconomic Indicators.
Reference	[46]	[47]	[48]	[3]	-
Proposed Year	2002	2006	2009	2010	2023
Dimensions	Poverty and geographical isolation.	Needs and availability, area, and household.	Demand and supply.	Household and geographical reach.	Socioeconomic reach (demand or needs) and geographical reach (supply or availability of telecommunications networks).
Number of Grid Categories	5	5	3	4	4

Table 4. *Cont.*

	Sabater	Stern	Mayer	ITU	Proposed Model
Concept	People who can afford it can have personal access in their homes. Fewer resources and increasingly difficult geographic locations can lead to market inefficiency and access gaps.	Penetration is concentrated in high-income and low-cost regions. In inefficient market locations, a market gap begins to develop, leading to an access gap in areas where costs are high, and income is low.	A model that divides locations into existing coverage areas, market efficiency gaps, and coverage area gaps (sustainable and universal).	Communities flourish when they are situated in areas with access coverage and networks. Nevertheless, flourishing communities can be situated in market efficiency gaps, smart subsidy zones, and access gap zones.	In the Indonesian context, there are district areas that are already modernising or could be developed rapidly (Grid #4), developed areas (Grid #3), developing areas (Grid #2), and underdeveloped/non-commercial/blank spot areas (Grid #1).
Framework Benefits	Providing equal access to ICTs is now a universal principle.	It is becoming a universal concept to expand ICT access for all. This concept is a model proposal in Latin America that connects market forces, regulatory decisions, and finance to the growth of the telecommunications market, particularly in high-income, low-cost, and population-dense areas.	It is becoming a universal concept to facilitate equal access to ICT. This principle has been applied to the development of ICT infrastructure in Africa by means of market profiling and the deployment of fiber optic infrastructure.	Equal ICT access is a universal concept that is included in the ICT Regulation Toolkit.	It is a universal principle to provide equitable ICT access, which can be applied to fit the Indonesian context.

In principle, the Indonesian Framework for Telecommunications Infrastructure adheres to the International Telecommunication Union's (ITU) zone-based reference [3]; however, this research replaces the term "zone" with "Grid." In this conceptualization, each grid is a specific categorization of a district in Indonesia. Figure 6 presents the proposed Indonesian Framework for Telecommunications Infrastructure. Furthermore, Supplementary Material File S7 provides the abbreviation. Table S3 in Supplementary Material File S7 shows the abbreviation or variable definition for Figure 6 (The Proposed Indonesian Framework for Telecommunications Infrastructure).

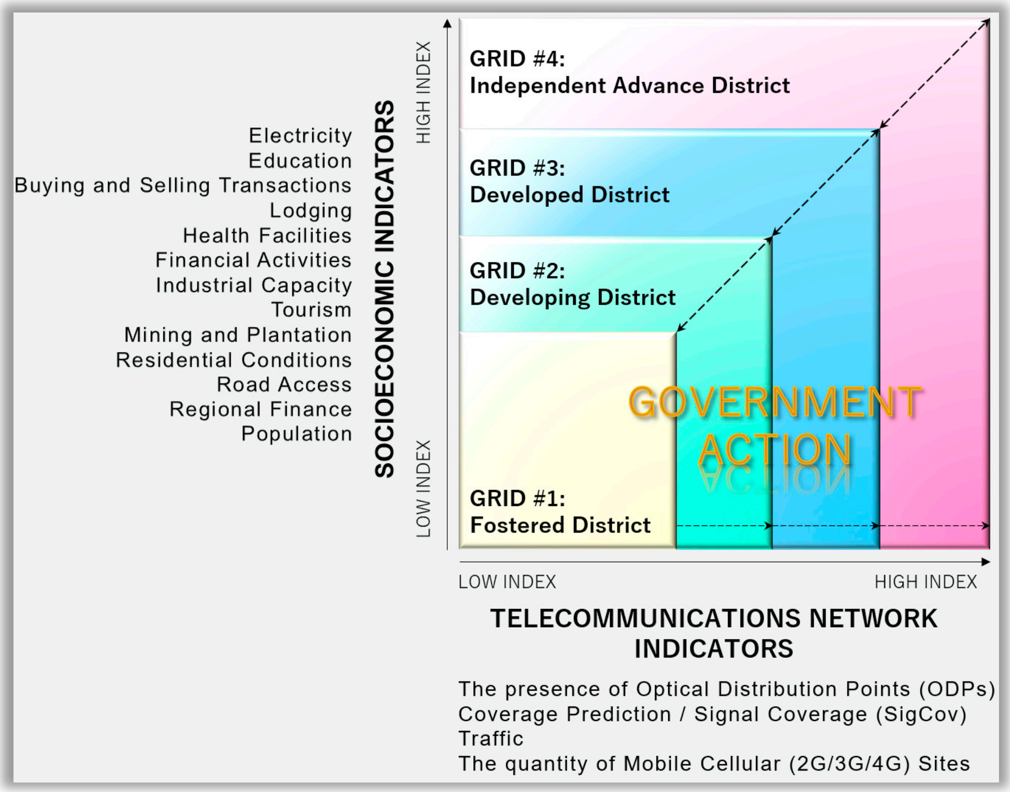


Figure 6. The Proposed Indonesian Framework for Telecommunications Infrastructure (developed from the Sabater Framework [46], Stern [47], Mayer [48], and ITU [3]).

The main purpose of the framework was to serve as a reference for the Indonesian government in constructing the nation's telecommunications infrastructure. In this framework, each district is categorized as either Grid #1, Grid #2, Grid #3, or Grid #4. By considering a district's assigned grid categorization, the government can take action using an approach in accordance with that grid category.

As seen in Figure 6, the framework is structured with an x axis of "telecommunications networks" and a y axis of "socioeconomic" indicators. On each of the axes, Grid #1 correlates with a low grid-reference index, while Grid #4 correlates with a high grid-reference index. The "telecommunications networks" axis is composed of four indicators, such as the presence of optical distribution points and traffic, while the "socioeconomic" axis is composed of 13 indicators, such as electricity and population. In Section 3.2, we will explain how these 17 indicators assist in formulating the grid-reference index on the basis of a novel statistical approach.

Table 5 provides an overview of each grid and the regulatory actions that the Indonesian government may take. Furthermore, digital literacy is only included in Grid #1. The blank spot area of a communication signal will attain digital literacy. In areas (grid #2/#3/#4) where telecommunications signal already exists, there are already individuals who are digitally literate.

Table 5. Definition of each Grid and Associated Government Actions.

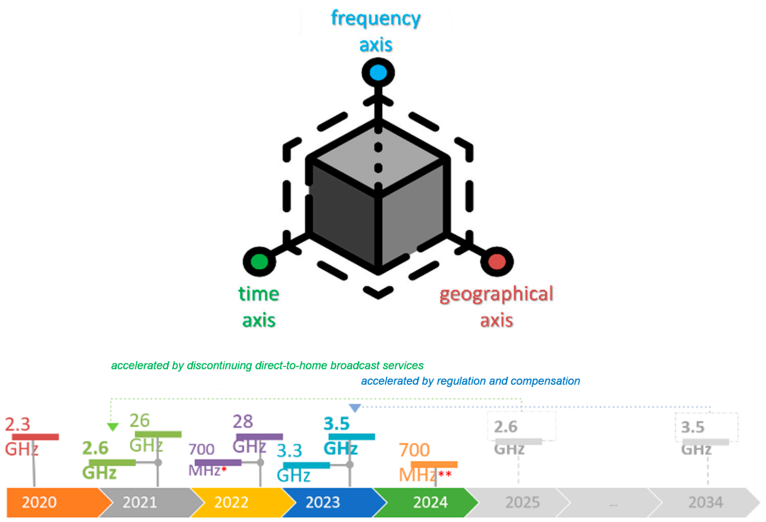
Grid	Definition	Government Action
Grid #1: Fostered District	In fostered districts, the backhaul network is not yet available, and several environmental factors complicate its construction. Due to the relatively low potential for traffic demand and relatively high operational costs, backhaul networks leading to the access network on Grid #1 are more likely to be constructed and managed by the government.	The government should develop policy actions to provide telecommunications access. These actions include schemes such as special subsidies or incentives; private telecommunications providers are tasked with connecting the network on Grid #1 to the national cellular network and promoting digital literacy.
Grid #2: Developing District	Developing districts are development areas with relatively low demand potential, which telecommunications operators evaluate from an economic standpoint. Grid #2 is less desirable due to the large deficit margin between the potential for obtaining demand traffic and the estimated cost of building and an operating telecommunications infrastructure.	In Grid #2, the backhaul network is not yet available; therefore, the government should play an active role as an enabler or facilitator in providing a backhaul network. For a backhaul network, optical fiber or microwave links should be prioritized. On the access side, a base transceiver station (BTS) is constructed by the telecommunications provider after the government provides the backhaul. The backhaul and constructed BTS infrastructure must be usable by a variety of telecommunications providers, such as cellular operators and Internet service providers (ISPs). For mobile services, the government can assist by establishing a clear legal umbrella for inter-operator roaming and spectrum sharing, allowing the multi-operator radio access network (MORAN) and multi-operator core network (MOCN) schemes to be implemented without the risk of becoming entangled in legal disputes.
Grid #3: Developed District	Grid #3 areas are those where backbones and backhauls are available but remain under the control of a small number of network administrators, making access difficult.	In Grid #3, the government (both central and regional) must provide incentives in the form of regulatory cost relaxation and affirmative policies, such as encouraging open access to existing backbone/backhaul networks or passive infrastructure sharing. In addition, telecommunications providers are encouraged to build on Grid #3 by committing to coverage and service quality (QoS).
Grid #4: Independent Advanced District	Independent advanced districts are modern areas in which high demand, backbone, and backhaul penetration are sufficiently pervasive. In this type of district, competition is sufficiently robust for telecommunications service providers to provide excellent service.	For Grid #4, there does not need to be a coverage development commitment, but there should be a QoS commitment. Therefore, regulators should ensure that operators maintain a high QoS.

The assessment of low demand potential in grid #2 is based on the framework's socioeconomic axes. In addition, for the future research and implementation, we suggest employing the blue ocean and/or cost leadership strategy [54] to reach "low demand potential" in grid #2. The Blue Ocean strategy is a strategy that takes MNO companies out of the red ocean of bloody (risky environment of ruthless) competition that occurs in high demand potential by building a market sector where there are no competitors yet, making the term competition obsolete. Practically, the Indonesian government has started encouraging MNOs to improve their performance by modernizing the spectrum regulation in the Omnibus Law on Job Creation (Act No.11 Year 2020). Moreover, the government started considering regulatory incentives for regions to build ecosystems so that collaboration is created between MNOs and non-mobile network operator companies. Please see Supplementary Material File S1 (compiled based on various references: [10,17–29] and provide 7 figures (Figures S1–S7) for political, practical, and analytical (MNOs level playing field) details.

3.2. Validation and Benefit of the Framework

To validate and to verify the consistency of the framework, we collect our data from the Ministry of Communication and Informatics (based on MNOs data), OOKLA crowdsourcing (based on mobile broadband user data), Statistics Indonesia (based on per inhabitants' national survey), Ministry of Finance (related to regional finance), and Ministry of Internal Affairs (population). These data collections show that these are well adapted to the different sizes of districts or whether it helps differentiate conditions in urban, semi-urban, or rural areas.

The benefit of a framework may refer to the results' interpretation. For example, 5G deployment requires frequencies. Since the radio frequency spectrum is a limited natural resource, its utilization must be optimized. The ideal usage of the radio frequency spectrum resembles a "totally charged cube" on three axes, including the frequency domain, the geographic domain, and the time domain. Figure 7 depicts the timetable plan (time axis) for the provision of a 5G band (frequency axis) in Indonesia. While this research's result "Grid Indonesia" illustrates the geographical axis. This geographic specific proposal could adapt to any country.



YEAR	BAND	BAND TYPE	BANDWIDTH POTENTIAL	BROADBAND TECHNOLOGY
2020	2.3 GHz	Mid Band	30 MHz	Mobile Broadband
2021	2.6 GHz	Mid Band	190 MHz	Mobile Broadband
	26 GHz	High Band	1000 - 3250 MHz	Mobile Broadband
2022	700 MHz *	Low Band	45 MHz (FDD)	Mobile Broadband (1st Phase)
	28 GHz	High Band	2000 MHz	Fixed Broadband
2023	3.3 GHz	Mid Band	100 MHz	Mobile Broadband
	3.5 GHz	Mid Band	200 MHz	Mobile Broadband
2024	700 MHz **	Low Band	45 MHz (FDD)	Mobile Broadband (2nd Phase)

*) rural
**) urban, waiting for broadcasting analogue switch off

Frequency Division Duplex (FDD): frequency modes that pair frequency for uplink with frequency for downlink

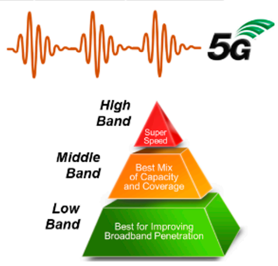


Figure 7. The Three Axes of the Radio Frequency Spectrum Flexibility Policy Philosophy.

In addition, the strategy for completing blank spot villages in Indonesia can be implemented if the regional government, the Ministry of Communication and Informatics, and the MNOs collaborate. Local administrations are responsible for making proposals to regions and potential communities. The mission of the Ministry of Communication and Informatics (MCI) is to map blank spot locations, give mapping documents covering non-3T areas that are still blank spots and need to be optimized, and provide regional options to MNOs for constructing BTS or optimizing the quality of service in mapping documents. The role of the cellular network operators is to construct a BTS or to optimize the network's quality based on the selected region. Telecommunications network operators (APJATEL) are responsible for providing the backbone. Further policy and regulatory instrument suggestions are shown in Table 6. For more details on the grid-based implementation approach, please see Supplementary Material File S4 which compiled based on various references: [17,33] and provide 2 figures (Figures S10 and S11) as well as 1 table (Table S2).

Table 6. Recommendations for Policy and Regulatory Instruments.

No.	Instruments for Policy and Regulation	Explanation	Grid*			
			#1	#2	#3	#4
1.	Infrastructure sharing.	From passive infrastructure to open access for telecommunications networks, operators are expected to share their network capacity with other operators in a fair manner.	☑	☑		
2.	It is feasible to have a neutral host that constructs networks in rural areas to be rented to telecommunications companies, such as cellular operators and ISPs.	This neutral host could be created by local entrepreneurs in partnership with the local government (*Pemda*) because, based on the number of entrepreneurs in Jakarta, developing a network in this region may be deemed unprofitable due to the national consumer profile. The local businesses or local governments who are more concerned with the requirements of the local community would have a different perspective, and it is believed that the on-net revenue from cellular operators or ISPs that rent their network capacity is sufficient.	☑	☑	☑	
3.	Reorientation of development commitments within telecom network operating licenses.	As of now, the development commitment is still based on the MNOs' business strategy. It emphasizes economic factors in terms of demand potential. Governments should determine the places to be developed, notably in grid #3 and grid #2′s priority grid.		☑	☑	
4.	Utilization of a more adaptable radio frequency spectrum, such as by permitting spectrum leasing.	Since the development of most national MNOs is concentrated in metropolitan cities, rural frequency permits have not been optimized. Under such conditions, a spectrum leasing program for neutral hosts at the local level temporarily utilizing the allocation of frequencies of national cellular operators based on government-approved business-to-business (B2B) agreements is feasible. In this spectrum leasing model, the frequency right-of-use fee (*BHP*) is not required to be billed twice, as the frequency permit is still associated with the national mobile operator.	☑	☑		

Table 6. *Cont.*

No.	Instruments for Policy and Regulation	Explanation	Grid*			
			#1	#2	#3	#4
5.	Reducing regulatory costs to lower rural development costs.	*BHP* frequency, *BHP* telecommunications, and USO payments are regulatory fees of the central government's non-tax state revenue (*PNBP*) that are directly associated with telecommunications providers. In addition, there are tower taxes, telecommunication tower building permission (*IMB*) fees, etc., imposed by municipal governments. The rationalization of such components might be seen as a means of promoting rural development. It requires careful calculation so that it is not classified as a state loss, for instance, by converting *PNBP* deposits into the obligation to build a number of new BTS on grids #1 and #2 ("pay or play") or by calculating the tax increases from telecommunications providers after rationalizing the components of these regulatory costs.	☑	☑		
6.	Encouraging the active participation of local governments in providing support, particularly access to passive infrastructure and territorial planning.	Since the regional spatial plan (*RTRW*) preparation stage, local governments have been encouraged to involve MNOs, particularly cellular operators, in planning candidates for the placement of telecommunication towers that are in line with network planning on the cellular operator side. The objective is to ensure that the BTS construction is optimal in terms of coverage, electrical power supply, and environmental safety.	☑	☑	☑	☑
7.	Scheme for asymmetrical interconnection	It is feasible to apply a higher termination rate to rural communications due to the higher operational and development costs associated with rural locations.	☑	☑		
8.	Subsidizing the subscription prices for rural residents' telecommunications services.	Providing rural residents with government subsidies so that retail rates for communication services in these areas can be reduced. On the other hand, telecom companies may guarantee that a portion of their income comes from government subsidies. This will at the very least reduce network running costs.	☑	☑		
9.	5G densification.	Utilization of public utilities (electric poles, bus stops, traffic lights, streetlights, etc.) for 5G feature optimization (enhanced mobile broadband (eMBB), ultra-reliable low-latency communication/URLLC, massive machine type communication (mMTC)). This necessitates coordination between ministries and institutions (K/L).				☑

* Background colors in the Table represent grid identity that are related to grid visualisation result as shown in Section 4 where yellow = grid #1, green = grid #2, blue = grid #3, pink = grid #4.

3.3. Determining Grids Based on 17 Indicators

We developed a novel statistical approach based on 17 indicators consisting of 4 telecommunications networks and 13 socioeconomic indicators. Prior to data collection, it is required to justify the data requirements. The reference is to stakeholders in telecoms deploying access networks. The Association of Indonesian Cellular Telecommunication Operators (ATSIs) was selected as the telecom's operators' umbrella organization (when the research started, there were still 7: Telkomsel, XL Axiata, Indosat, Hutchison 3 Indonesia, Smart Telecom, Smartfren Telecom, and Net1 Indonesia). In its statement to the government, ATSI emphasized two things that are fundamental to the commitment:

- Availability of services to suit the public's needs for 4G technology-based telecommunications' connectivity.

- In public facilities such as village government centres, economic activity centres (markets), industrial centres, health facilities, and educational places, locals can utilize the availability/coverage of telecoms access services using 4G technology.

In addition, according to the results of a pro bono consultation with OpenSignal's international crowdsourcing, there are three aspects that influence the network experience:

- The number of cells/sites will provide information on the network capacity (Mbps).
- Quantity of subscribers if two networks share the same spectrum, but only one has a large subscriber base, in which case the network with the larger subscriber base will often have a poorer network experience due to the increased network load.
- Type of transportation network: networks with enough spectrum but inadequate transport networks will provide a bad user experience.

If the perspectives of these 5G actors are reduced to empirical datasets, then the data gathering requirements can be categorized into two major groups: telecommunications' network dimensions and socioeconomic potential dimensions. Telecommunication networks include optical distribution points (ODPs), signal coverage (SigCov), traffic, and the number of sites as operator considerations for network optimization or new network construction. Socioeconomic potential, comprising electricity, community activity centres, business fields, residential conditions, regional finances, and population, as a factor for commercial service providers to provide profitable services. Since the objective is to develop a telecommunications access infrastructure, we determined that the four variables comprising the telecommunications network (4 × 20% = 80%) have a contribution or weight equivalent to the socioeconomic potential (1 × 20% = 20%), as depicted in Figure 8.

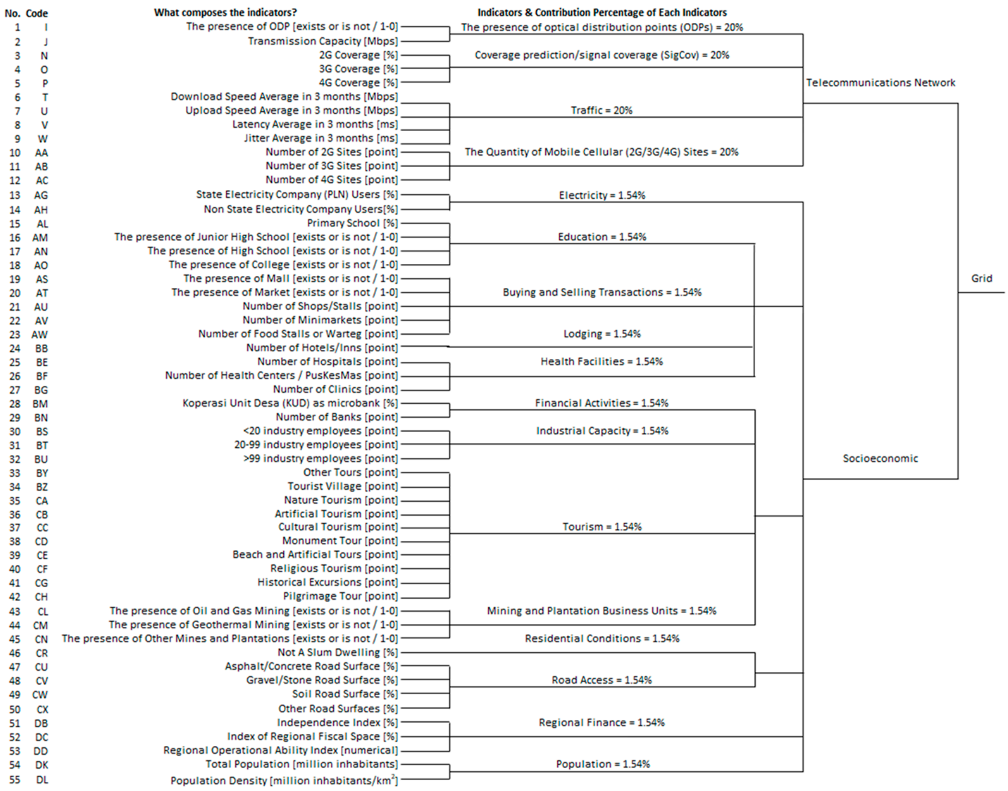


Figure 8. Dendogram.

In the dendogram shown in Figure 8, 17 indicators are merged with the percentage of contribution. After acquiring the values of telecommunications network dimensions and socioeconomic potential dimensions, the following correlation matrix is applied to the data. On the basis of these indicators, a multi-stage statistical modelling approach assists in determining whether a district falls into the grid-reference index, the so-called G1, G2, G3, and G4. The correlation of these indexes ultimately determines the corresponding grid. Table 7 shows the correlation matrix between these indicators. For example, if a district has a grid-reference index G1 for a telecommunications network and G2 for socioeconomics, then it is categorized as Grid #2.

Table 7. Correlation Matrix.

		The Grid-Reference Index of Telecommunications Network Indicators			
		G1	**G2**	**G3**	**G4**
The Grid Reference-Index of Socioeconomic Indicators	**G1**	Grid #1	Grid #2	Grid #2	Grid #2
	G2	Grid #2	Grid #2	Grid #3	Grid #3
	G3	Grid #2	Grid #3	Grid #3	Grid #4
	G4	Grid #2	Grid #3	Grid #4	Grid #4

Note: Background colors in the Table represent grid identity that are related to grid visualisation as shown in Section 4, where yellow = grid #1, green = grid #2, blue = grid #3, pink = grid #4.

Table S3 in Supplementary Material File S7 shows an abbreviation or variable definition for Table 7 (Correlation Matrix) and its explanation.

Matrix mathematical functions can also be used to demonstrate the process. If "G(i)" is socioeconomic and "G(j)" is the telecommunication network, then

$$\begin{aligned} G(x) &= G(i).\,G(j) \\ &= \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} . \begin{bmatrix} J_1 & J_2 & J_3 & J_4 \end{bmatrix} \\ &= \begin{bmatrix} I_1\,J_1 & I_1\,J_2 & I_1\,J_3 & I_1\,J_4 \\ I_2\,J_1 & I_2\,J_2 & I_2\,J_3 & I_2\,J_4 \\ I_3\,J_1 & I_3\,J_2 & I_3\,J_3 & I_3\,J_4 \\ I_4\,J_1 & I_4\,J_2 & I_4\,J_3 & I_4\,J_4 \end{bmatrix} \\ &= \begin{bmatrix} \text{"Grid \#1"} & \text{"Grid \#2"} & \text{"Grid \#2"} & \text{"Grid \#2"} \\ \text{"Grid \#2"} & \text{"Grid \#2"} & \text{"Grid \#3"} & \text{"Grid \#3"} \\ \text{"Grid \#2"} & \text{"Grid \#3"} & \text{"Grid \#3"} & \text{"Grid \#4"} \\ \text{"Grid \#2"} & \text{"Grid \#3"} & \text{"Grid \#4"} & \text{"Grid \#4"} \end{bmatrix} \end{aligned}$$

There is a 1–3–5–7 pattern variation for the grid.

Moreover, Table 7 shows the correlation matrix, while Table 8 shows sixteen combinations of the 4 × 4 matrix and pseudocode applications.

Table 8. Sixteen Combinations of 4 × 4 Matrix and Pseudocode Applications Adapted from [55].

Column / Row	A	B	C	
	Telco Network	**Socioeconomic**	**Final Grid**	**Pseudocode Application**
2	G1	G1	#1	=IF(AND(A2=1;B2=1);1;IF(AND(A2=2;B2=2);2;IF(AND(A2=3;B2=3);3;IF(AND(A2=4;B2=4);4;IF(AND(A2≥2;B2≥2);IF(AND(A2≥3;B2≥3);4;3);2)))))
3	G1	G2	#2	=IF(AND(A3=1;B3=1);1;IF(AND(A3=2;B3=2);2;IF(AND(A3=3;B3=3);3;IF(AND(A3=4;B3=4);4;IF(AND(A3≥2;B3≥2);IF(AND(A3≥3;B3≥3);4;3);2)))))
4	G1	G3	#2	=IF(AND(A4=1;B4=1);1;IF(AND(A4=2;B4=2);2;IF(AND(A4=3;B4=3);3;IF(AND(A4=4;B4=4);4;IF(AND(A4≥2;B4≥2);IF(AND(A4≥3;B4≥3);4;3);2)))))
5	G1	G4	#2	=IF(AND(A5=1;B5=1);1;IF(AND(A5=2;B5=2);2;IF(AND(A5=3;B5=3);3;IF(AND(A5=4;B5=4);4;IF(AND(A5≥2;B5≥2);IF(AND(A5≥3;B5≥3);4;3);2)))))
6	G2	G1	#2	=IF(AND(A6=1;B6=1);1;IF(AND(A6=2;B6=2);2;IF(AND(A6=3;B6=3);3;IF(AND(A6=4;B6=4);4;IF(AND(A6≥2;B6≥2);IF(AND(A6≥3;B6≥3);4;3);2)))))
7	G2	G2	#2	=IF(AND(A7=1;B7=1);1;IF(AND(A7=2;B7=2);2;IF(AND(A7=3;B7=3);3;IF(AND(A7=4;B7=4);4;IF(AND(A7≥2;B7≥2);IF(AND(A7≥3;B7≥3);4;3);2)))))
8	G2	G3	#3	=IF(AND(A8=1;B8=1);1;IF(AND(A8=2;B8=2);2;IF(AND(A8=3;B8=3);3;IF(AND(A8=4;B8=4);4;IF(AND(A8≥2;B8≥2);IF(AND(A8≥3;B8≥3);4;3);2)))))
9	G2	G4	#3	=IF(AND(A9=1;B9=1);1;IF(AND(A9=2;B9=2);2;IF(AND(A9=3;B9=3);3;IF(AND(A9=4;B9=4);4;IF(AND(A9≥2;B9≥2);IF(AND(A9≥3;B9≥3);4;3);2)))))

Table 8. *Cont.*

Row \ Column	A	B	C	
	Telco Network	**Socioeconomic**	**Final Grid**	**Pseudocode Application**
10	G3	G1	#2	=IF(AND(A10=1;B10=1);1;IF(AND(A10=2;B10=2);2;IF(AND(A10=3;B10=3);3;IF(AND(A10=4;B10=4);4;IF(AND(A10≥2;B10≥2);IF(AND(A10≥3;B10≥3);4;3);2)))))
11	G3	G2	#3	=IF(AND(A11=1;B11=1);1;IF(AND(A11=2;B11=2);2;IF(AND(A11=3;B11=3);3;IF(AND(A11=4;B11=4);4;IF(AND(A11≥2;B11≥2);IF(AND(A11≥3;B11≥3);4;3);2)))))
12	G3	G3	#3	=IF(AND(A12=1;B12=1);1;IF(AND(A12=2;B12=2);2;IF(AND(A12=3;B12=3);3;IF(AND(A12=4;B12=4);4;IF(AND(A12≥2;B12≥2);IF(AND(A12≥3;B12≥3);4;3);2)))))
13	G3	G4	#4	=IF(AND(A13=1;B13=1);1;IF(AND(A13=2;B13=2);2;IF(AND(A13=3;B13=3);3;IF(AND(A13=4;B13=4);4;IF(AND(A13≥2;B13≥2);IF(AND(A13≥3;B13≥3);4;3);2)))))
14	G4	G1	#2	=IF(AND(A14=1;B14=1);1;IF(AND(A14=2;B14=2);2;IF(AND(A14=3;B14=3);3;IF(AND(A14=4;B14=4);4;IF(AND(A14≥2;B14≥2);IF(AND(A14≥3;B14≥3);4;3);2)))))
15	G4	G2	#3	=IF(AND(A15=1;B15=1);1;IF(AND(A15=2;B15=2);2;IF(AND(A15=3;B15=3);3;IF(AND(A15=4;B15=4);4;IF(AND(A15≥2;B15≥2);IF(AND(A15≥3;B15≥3);4;3);2)))))
16	G4	G3	#4	=IF(AND(A16=1;B16=1);1;IF(AND(A16=2;B16=2);2;IF(AND(A16=3;B16=3);3;IF(AND(A16=4;B16=4);4;IF(AND(A16≥2;B16≥2);IF(AND(A16≥3;B16≥3);4;3);2)))))
17	G4	G4	#4	=IF(AND(A17=1;B17=1);1;IF(AND(A17=2;B17=2);2;IF(AND(A17=3;B17=3);3;IF(AND(A17=4;B17=4);4;IF(AND(A17≥2;B17≥2);IF(AND(A17≥3;B17≥3);4;3);2)))))

Note: Background colors in the Table represent grid identity that are related to grid visualisation as shown in Section 4, where yellow = grid #1, green = grid #2, blue = grid #3, pink = grid #4.

Table 9 lists and explains the detailed statistical formula for the 17 indicators. The four indicators for the telecommunications network are indicators 1–4, while the rest are socioeconomic indicators. G(x) in Table 9 represents the grid function x, where x is an independent variable affected by 49 indicators based on 17 postulates and a correlation matrix. A threshold is a proposition of the author that is supported by reference justification. Table S3 in Supplementary Material File S7 (compiled based on various references: [3,46–48,54] and also contain 1 table (Table S3)) shows an abbreviation or variable definition for Table 9 (postulate to determine the grid-reference index G1, G2, G3, and G4).

Supplementary Material File S5 contain 1 figure (Figure S12) and 4 tables (Table S4 until S7) provides details of the data processing for the telecommunication networks indicator, while Supplementary Material File S6 contain 13 tables (Table S8 until S20) provides details for socioeconomic indicators. The algorithmic processes of methodology are presented in Supplementary Material File S8 (with reference to [56] and provide 1 figure (Figure S13).

Table 9. Postulate to Determine the Grid-Reference Index G1, G2, G3, and G4.

Indicator	Indicator Name	Postulate to Determine the Grid-Reference Index G1, G2, G3, G4	Explanation
1	Telecommunications Network: The presence of optical distribution points (ODPs)	G1 = 0 Mbps, 0 Mbps < G2 < 1000 Mbps, 1000 Mbps ≤ G3 < 2048 Mbps, G4 ≥ 2048 Mbps. $G(x) = \begin{cases} 1 & , x = 0 \\ 2 & , 0 < x < 1000 \\ 3 & , 1000 \leq x < 2048 \\ 4 & , x \geq 2048 \end{cases}$ G(x) = IF(x = 0;1; IF(x < 1000;2; IF(x <= 2048; 3; 4)))	G1 if there is no fiber optic network distribution point (ODP) or the transmission capacity is 0 Mbps. G2 if ODP has a maximum transmission capacity of 1 Gbps. G3 if an ODP has a transmission capacity between 1000 Mbps and 2048 Mbps (or 1000 E1 [57]). G4 if the transmission capacity of ODP is greater than 2048 Mbps [58] (for 5G deployment).

Table 9. *Cont.*

Indicator	Indicator Name	Postulate to Determine the Grid-Reference Index G1, G2, G3, G4	Explanation
2	Telecommunications Network: Coverage prediction/signal coverage (SigCov)	Mean aggregates: $\overline{x} = \frac{\sum_{i=1}^{n} x_i + \ldots + x_n}{n}$ Filtering: If the data column N = {2G Coverage}, O = {3G Coverage}, and P = {4G Coverage}. Then G1 = 0; 0 < G2 $\leq$ 33.3; 33.3 < G3 $\leq$ 66.7; G4 > 66.7 $G(x) = \begin{cases} 1 & , x = 0 \\ 2 & , 0 < x \leq 33.3 \\ 3 & , 33.3 < x \leq 66.7 \\ 4 & , x > 66.7 \end{cases}$ G(x) = IF(x > 66.7; 4; IF(x > 33.3; 3; IF(x > 0; 2; 1)))	G1 when there is no signal for communication. G2 when the average signal coverage reaches approximately one-third of the grid region. G3 when the average signal coverage reaches between one-third and two-thirds of the grid region. G4 when the average signal coverage reaches between two-thirds and the entire grid. After calculating the aggregate of the N-O-P set's average data using the desktop analysis coverage prediction (SigCov) [11], this grid is categorized.
3	Telecommunications Network: Traffic	Mean aggregates: $\overline{x} = \frac{\sum_{i=1}^{n} x_i + \ldots + x_n}{n}$ Filtering: If the data column T = {DL speed average in 3 months}, U = {UL speed average in 3 months}, V = {latency average in 3 months}, and W = {jitter average in 3 months}. Then G1 = 0; 0 < G2 $\leq$ 33.3; 33.3 < G3 $\leq$ 66.7; G4 > 66.7 $G(x) = \begin{cases} 1 & , x = 0 \\ 2 & , 0 < x \leq 33.3 \\ 3 & , 33.3 < x \leq 66.7 \\ 4 & , x > 66.7 \end{cases}$ G(x) = IF(x > 66.7; 4; IF(x > 33.3; 3; IF(x > 0;2;1)))	G1 if no traffic is present. G2 if the average traffic volume does not exceed one-third of the maximum throughput capacity. G3 if the average traffic is between one-third and two-thirds of the throughput capacity. G4 if the traffic volume averages two-thirds of the maximum throughput capacity. After calculating the aggregate average of T-U-V-W data [59], this grid is categorized.
4	Telecommunications Network: The quantity of mobile cellular (2G/3G/4G) sites	Weighting: If the data column AA = {2G BTS}, AB = {3G NodeB}, and AC = {4G eNodeB}. Then G(AA, AB, AC) = 0.3AA + 0.2AB + 0.5AC Filtering: G1 = 0; G2 $\leq$ 12.90; 12.91< G3 $\leq$ 63.60; G4 $\geq$ 63.61 $G(x) = \begin{cases} 1 & , x = 0 \\ 2 & , x \leq 12.90 \\ 3 & , 12.91 < x \leq 63.60 \\ 4 & , x \geq 63.61 \end{cases}$ G(x)= IF(x $\geq$ 63.61; 4; IF(x $\geq$ 12.91; 3; IF(x > 0;2;1)))	G1 if there is no 2G BTS/3G NodeB/4G eNodeB pole with a null representation. G2 if between 1 and 13 site antennas exist (equivalent to a cut point of 12.9). G3 if 14–64 site antennas are present (worth 12.91–63.60). G4 if more than 64 site antennas are present (more than 63.60 cut points). After calculating the weighting of the AA-AB-AC dataset, this grid is categorized [60,61]. For data profiling information, there are 1044 blank spot areas; if the remainder (6188 out of 7232) is divided by 3, the normal distribution cut points are 12.9 and 63.6.
5	Socioeconomic: Electricity	Total: $x = \sum_{i=1}^{n} x_i + \ldots + x_n$ Filtering: If the data column AG = {electricity users from state electricity companies (PLN)}, and AH = {electricity users are not from state electricity companies (personal/private/non-PLN)}. Then G1 $\leq$ 80; 80< G2 $\leq$ 90; 90< G3 $\leq$ 95; G4 > 95 $G(x) = \begin{cases} 1 & , x \leq 80 \\ 2 & , 80 < x \leq 90 \\ 3 & , 90 < x \leq 95 \\ 4 & , x > 95 \end{cases}$ G(x) = IF(x > 95; 4; IF(x > 90; 3; IF(x > 80; 2; 1)))	G1 if less than 80% of households have electricity. G2 if 80–90% of households have electricity [62]. G3 if 90–95% of households have electricity [62]. G4 if more than 95% of households have electricity. After calculating the total number of electricity consumers using the AG and AH sets, this grid is categorized.

Table 9. *Cont.*

Indicator	Indicator Name	Postulate to Determine the Grid-Reference Index G1, G2, G3, G4	Explanation
6	Socioeconomic: Education	Filtering: If the data column AL = {elementary school}, AM = {junior high school}, AN = {high school}, and AO = {college}.Then $x = \{AL, AM, AN, AO\}, x \in \{0, 1\}$ G4~AO = 1; G3~AN = 1; G2~AM = 1; G1~AO = AN = AM = 0 $G(x) = \begin{cases} 1 & , x = \{1,0,0,0\} \cup \{0,0,0,0\} \\ 2 & , x = \{1,1,0,0\} \\ 3 & , x = \{1,1,1,0\} \\ 4 & , x = \{1,1,1,1\} \end{cases}$ G(AM, AN, AO) = IF(AO = 1; 4; IF(AN = 1; 3; IF(AM = 1; 2; 1))) or If AO = 1 Then Gx = 4 Else If AN = 1 Then Gx = 3 Else If AM = 1 Then Gx = 2 Else Gx = 1	G1 if there is no junior high school, high school, or college. G2 if at least one junior high school exists. G3 if at least one high school exists. G4 if at least one college is present [63].
7	Socioeconomic: Buying and selling transactions	Mean aggregates: $\overline{x} = \frac{\sum_{i=1}^{n} x_i + \ldots + x_n}{n}$ Filtering: If the data column AS = {the existence of mall}, AT = [64], AU = {number of shops or stalls}, AV = {number of minimarkets}, and AW = {number of food stalls or *warteg*}. Then G1 ≤ -0.44; $-0.43 \leq$ G2 ≤ 0; $0.01 \leq$ G3 ≤ 0.36; G4 ≥ 0.37 $G(x) = \begin{cases} 1 & , x \leq -0.44 \\ 2 & , -0.43 < x \leq 0 \\ 3 & , 0.01 < x \leq 0.36 \\ 4 & , x \geq 0.37 \end{cases}$ G(x) = IF(x > 0.36; 4; IF(x > 0; 3; IF(x > −0.44; 2; 1)))	G1 if the transaction size falls within the bottom quartile (≤ -0.44). G2 is between -0.43 and 0. G3 when between 0.01 and 0.36. G4 when on the rightmost quartile (≥ 0.37). After calculating the arithmetic mean of the AS–AT–AU–AV dataset, this grid is categorized. The concept of equal weighting for the location of economic activity is significant because it places emphasis on the size of transactions [65]. Due to the normalization of different units, the minus value occurs at the quartile cut point.
8	Socioeconomic: Lodging	Filtering: If the data column BB = {quantity of hotels/inns}, then G1 = 0; 1 $\leq$ G2 < 10; 10 $\leq$ G3 < 50; G4 $\geq$ 50. $G(x) = \begin{cases} 1 & , x = 0 \\ 2 & , 1 \leq x < 10 \\ 3 & , 10 \leq x \leq 50 \\ 4 & , x > 50 \end{cases}$ G(x) = IF(x < 1; 1; IF(x < 10;2;IF(x < 50; 3; 4)))	G1 if no hotel or inn is available. G2 if 1–9 hotels/inns are present. G3 if there are 10–49 hotels/inns. G4 if there are $\geq$ 50 hotels/inns. Scaling with cut points of 10 and 50 accounts for the granularity of the data and the fact that "the quality of employees, the season, and the concentration of competition in tourist destinations contributed most to the success of the lodging industry [66]".

Table 9. *Cont.*

Indicator	Indicator Name	Postulate to Determine the Grid-Reference Index G1, G2, G3, G4	Explanation
9	Socioeconomic: Health facilities	Filtering: If the data column BE = {number of hospitals}, BF = {number of health centres or *puskesmas*}, and BG = {number of clinics}. Then $x = \{\mathrm{BE},\ \mathrm{BF},\ \mathrm{BG}\};\ x \in \mathrm{N}$ $G(x) = \begin{cases} 1 & ,x = \{0,0,0\} \\ 2 & ,(BE = 0) \cup ((BF \geq 1) \cap (BG \geq 1)) \\ 3 & ,BE = 1 \\ 4 & ,BE > 1 \end{cases}$ or $x = \{BE, BJ\},\ x \in N$ $BJ = BF + BG$ $G(x) = \begin{cases} 1 & ,x = \{0,0\} \\ 2 & ,(BE = 0) \cup (BJ > 0) \\ 3 & ,BE = 1 \\ 4 & ,BE > 1 \end{cases}$	G1 if no health facilities are available. G2 if at least one clinic and/or health centre is present. G3 if only one hospital exists. G4 if there are multiple hospitals. The grid-based categorization of BE–BF–BG health facilities [67] takes into account the differences in clinical practice between urban and rural hospital clinics, community health centres, and private practices.
10	Socioeconomic: Financial activities	Filtering: If the data column BM = {percentage of *KUD*}, and BN = {number of banks}. Then $x = \{\mathrm{BM},\ \mathrm{BN}\};\ x \in \mathrm{N}$ $G(x) = \begin{cases} 1 & ,x = \{0,0\} \\ 2 & ,x = \{1,0\} \\ 3 & ,(BM \leq 1) \cup (BN = 1) \\ 4 & ,(BM \leq 1) \cup (BN > 1) \end{cases}$ or G(BM,BN) = IF(BN > 1; 4; IF(BN = 1; 3; IF(BM = 1; 2; 1)))	G1 if there is neither a microbank nor a bank. G2 if there is at least one microbank. G3 if there is a single bank. G4 if there is more than one bank. Regarding the categorization of the grid, banks and microbanks are the formal institutions that engage in financial activities, including the storage of funds [64]. An Indonesian cooperative, a so-called *Koperasi Unit Desa (KUD)*, is a microbank in this context.
11	Socioeconomic: Industrial capacity	Filtering If the data column BS = {<20 persons}, BT = {20–99 persons}, and BU = {>99 persons}. Then $x = \{\mathrm{BS},\ \mathrm{BT},\ \mathrm{BU}\};\ x \in \mathrm{N}$ $G(x) = \begin{cases} 1 & ,\ x = \{0,0,0\} \\ 2 & ,(\mathrm{BS} \geq 1) \cup (\mathrm{BT} = 0) \cup (\mathrm{BU} = 0) \\ 3 & ,(\mathrm{BS} \geq 0) \cup (\mathrm{BT} \geq 1) \cup (\mathrm{BU} = 0) \\ 4 & ,(\mathrm{BS} \geq 0) \cup (\mathrm{BT} \geq 0) \cup (\mathrm{BU} \geq 1) \end{cases}$ G(BU, BT, BS) = IF(BU $\geq$ 1; 4; IF(BT $\geq$ 1; 3; IF(BS $\geq$ 1.2; 1)))	G1 if no industry is able to absorb workers. G2 if the industry employs fewer than twenty people. G3 if it is a medium-sized industry employing 20–99 people. G4 if it is a large-scale industry with more than 99 employees. The categorization of the industrial capacity grid takes into account the number of employees [68] with scaling cut points of 20 and 99 individuals.
12	Socioeconomic: Tourism	Total: $x = \sum_{i=1}^{n} x_i + \ldots + x_n$ Filtering: If the data column BY = {other tours}, BZ = {tourist village}, CA = {nature tourism}, CB = {artificial tourism}, CC = [69], CD = {monument tour}, CE = {beach and artificial tours}, CF = {religious tourism}, CG = {historical excursions}, and CH = {pilgrimage tour}. Then G1 = 0; G2 $\leq$ 2; G3 $\leq$ 5; G4 > 5 $G(x) = \begin{cases} 1 & ,x = 0 \\ 2 & ,x \leq 2 \\ 3 & ,\ x \leq 5 \\ 4 & ,x > 5 \end{cases}$ G(x) = IF(x = 0; 1; IF(x $\leq$ 2; 2; IF(x $\leq$ 5; 3; 4)))	Default to G1 if no form of tourism can be created. If there are one or two tourist attractions, use G2. Use G3 if three to five tourist attractions are present. Use G4 if there are more than five tourist attractions. Multiple tourism variants (BY, BZ, CA, CB, CC, CD, CE, CF, CG, and CH) and locations will influence the economic growth [70–72].

Table 9. *Cont.*

Indicator	Indicator Name	Postulate to Determine the Grid-Reference Index G1, G2, G3, G4	Explanation
13	Socioeconomic: Mining and plantation business units	Filtering: If the data column CL = {the existence of oil and gas mining}, CM = {the existence of geothermal mining}, and CN = {the existence of other mines and plantations}. Then x = {CL, CM, CN}; x ∈ N $G(x) = \begin{cases} 1 & ,x = 0 \\ 2 & ,(\mathrm{CL}=0)\cup(\mathrm{CM}=0)\cup(\mathrm{CN}=1) \\ 3 & ,(\mathrm{CL}=0)\cup(\mathrm{CM}=1)\cup(\mathrm{CN}\geq 0) \\ 4 & ,(\mathrm{CL}=1)\cup(CM\geq 0)\cup(CN\geq 0) \end{cases}$ G(CL, CM, CN) = IF(CL = 1; 4; IF(CM = 1; 3; IF(CN = 1; 2; 1)))	If there is no mining and plantation business unit, G1 should be used. G2 should be used if a plantation business unit exists. G3 if a geothermal mining business unit exists. G4 if an oil and gas mining business unit exists. Grid categorization is based on the fact that island nations rely on CL-CM-CN mining and CN plantations for economic growth [69].
14	Socioeconomic: Residential conditions	Filtering: If the data column CR = {not a slum dwelling}, then G1 ≤ 90; 90 < G2 ≤ 95; 95 < G3 ≤ 99; G4 > 99. $G(x) = \begin{cases} 1 & ,x \leq 90 \\ 2 & ,90 < x \leq 95 \\ 3 & ,95 < x \leq 99 \\ 4 & ,x > 99 \end{cases}$ G(x) = IF(x > 99; 4; IF(x > 95; 3; IF(x > 90; 2; 1)))	G1 if the proportion of non-slum settlements is 90%. G2 if the proportion of non-slum settlements falls between 90 and 95%. G3 if the percentage of non-slum settlements ranges from 95 to 99%. G4 if greater than 99% of all settlements are not slums. The scaling with cut points 90, 95, and 99 takes into account the granularity of the data (the majority is greater than 90 percent) where residential conditions are closely related to road access as an investment factor [73].
15	Socioeconomic: Road access	Filtering: If the data column CU = {asphalt/concrete road surface}, CV = {gravel/stone road surface}, CW = {soil road surface}, and CX = {other road surfaces}. Then x = {CU, CV, CW, CX}; x ∈ N $G(x) = \begin{cases} 1 & ,\mathrm{x} = \{0,0,1,1\} \\ 2 & ,\mathrm{x} = \{0,1,1,1\} \\ 3 & ,(\mathrm{CU}<100)\cup(\mathrm{CV}\geq 0)\cup(\mathrm{CW}\geq 0)\cup(\mathrm{CX}\geq 0) \\ 4 & ,(\mathrm{CU}=100)\cup(\mathrm{CV}\geq 0)\cup(\mathrm{CW}\geq 0)\cup(\mathrm{CX}\geq 0) \end{cases}$ G(CU,CV,CW,CX) = IF(CU = 100; 4; IF(CU < 100; 3; IF(CV ≤ 100; 2; 1)))	G1 for non-commercial. G2 for low commercial. G3 for medium commercial. G4 for high commercial. The state of road access (CU, CV, CW, and CX) is considered to be an investment factor [73]. Adding together the data for asphalt/concrete road surface, gravel/stone, soil, and others yields a total of 100%.
16	Socioeconomic: Regional finance	Mean aggregates: $\overline{x} = \frac{\sum_{i=1}^{n} x_i + \ldots + x_n}{n}$ Filtering: If the data column DH = {z-score mean index}, then G1 ≤ −0.671; −0.671< G2 ≤ 0; 0 < G3 ≤ 0.671; G4 > 0.671. $G(x) = \begin{cases} 1 & ,x \leq -0.671 \\ 2 & ,-0.671 < x \leq 0 \\ 3 & ,0 < x \leq 0.671 \\ 4 & ,x > 0.671 \end{cases}$ G(x) = IF(x > 0.671; 4; IF(x > 0; 3; IF(x > −0.671; 2; 1)))	G1 if the average index is below −0.671. If the average index is between −0.671 and 0, G2 is denoted. If the average index is between 0 and 0.671, G3 is used. G4 is assigned if the average index exceeds 0.671%. This grid is categorized after calculating the aggregate average data on the potential and financial independence of a region that has been normalized to account for different units [74–77].
17	Socioeconomic: Population	Filtering: If the data column DK = {population}, and DL = {population density}. Then G1 < 250; 250 ≤ G2 ≤ 499; 500 ≤ G3 ≤ 999; G4 ≥1000. $G(x) = \begin{cases} 1 & ,x < 250 \\ 2 & ,250 \leq x \leq 499 \\ 3 & ,500 \leq x \leq 999 \\ 4 & ,x \geq 1000 \end{cases}$ G(x) = IF(x < 250; 1; IF(x < 500;2;IF(x < 1000; 3; 4)))	G1 if the population density is less than 250 people per square kilometre. G2 if there are between 250 and 499 inhabitants per square kilometre. G3 if there are between 500 and 999 inhabitants per square kilometre. G4 if the number of people per square kilometre is less than 1000. Population is closely related to the number of residents and the number of residents per km^2 (area), which can be used to calculate the population's maximum density [78].

4. Visualization Results

Table 10 and Figure 9 provide the visualization results after applying the proposed formula to the 7232 districts in Indonesia. Table 10 indicates that there are a total of 585 districts (8.1%) in Grid #1, 2458 districts (33.9%) in Grid #2, 2999 districts (41.5%) in Grid #3, and 1190 districts (16.5%) in Grid #4.

Table 10. Results of Correlation Matrix of 7232 Districts in Indonesia.

		The Indicators of Telecommunications Network				Total
		G1	**G2**	**G3**	**G4**	
	G1	Grid #1 = 585 (8.1%)	Grid #2 = 188 (2.6%)	Grid #2 = 102 (1.4%)	Grid #2 = 39 (0.5%)	914 (12.6%)
Socioeconomic Indicators	**G2**	Grid #2 = 384 (5.3%)	Grid #2 = 1600 (22.1%)	Grid #3 = 652 (9.0%)	Grid #3 = 163 (2.3%)	2799 (38.7%)
	G3	Grid #2 = 116 (1.6%)	Grid #3 = 1016 (14.0%)	Grid #3 = 1039 (14.4%)	Grid #4 = 381 (5.3%)	2552 (35.3%)
	G4	Grid #2 = 29 (0.4%)	Grid #3 = 129 (1.8%)	Grid #4 = 409 (5.7%)	Grid #4 = 400 (5.5%)	967 (13.4%)
Total		1114 (15.4%)	2933 (40.6%)	2202 (30.4%)	983 (13.6%)	7232 (100%)

Note: Background colors in the Table represent grid identity that are related to grid visualisation as shown in Figure 9, where yellow = grid #1, green = grid #2, blue = grid #3, pink = grid #4.

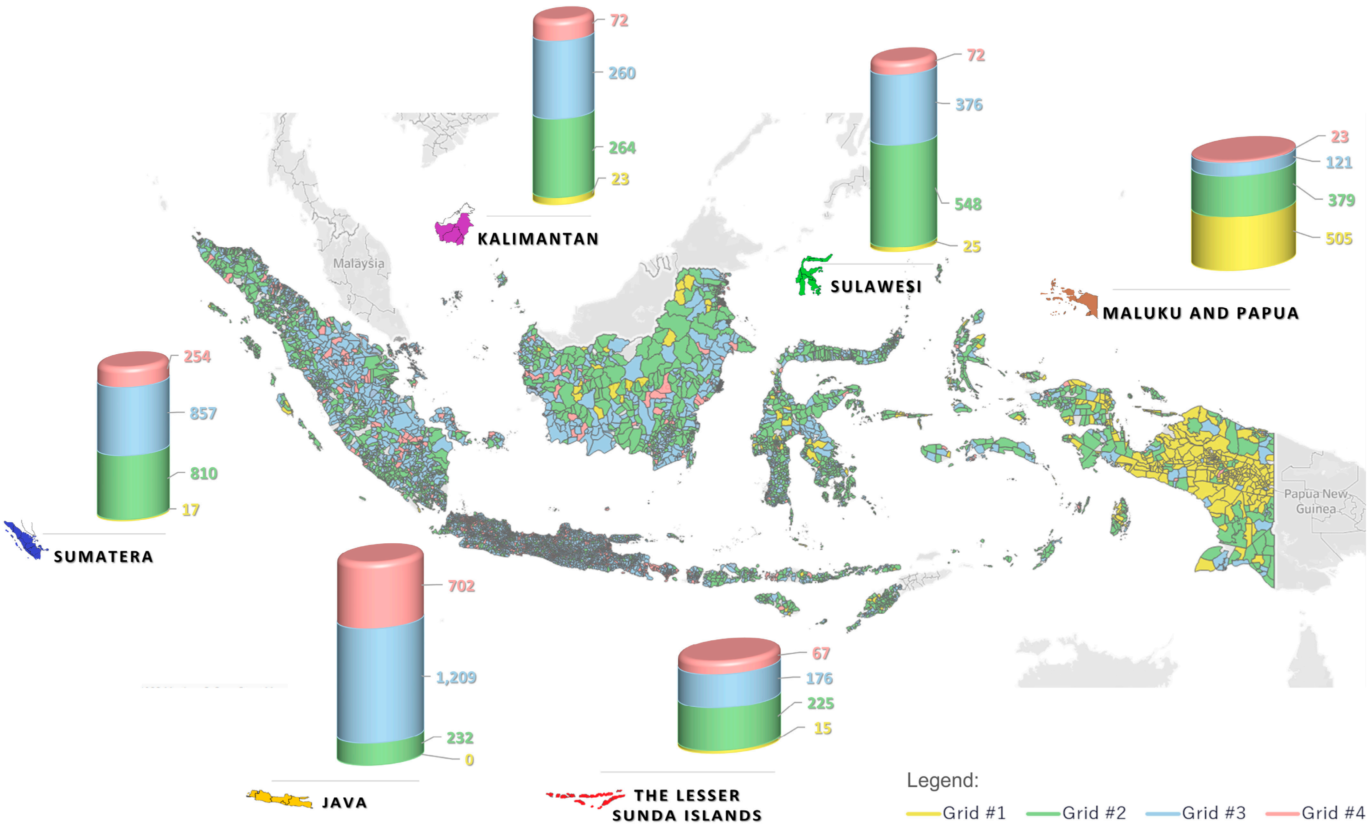


Figure 9. Grid Visualization of Indonesia.

Related to Figure 1, Figure 9 illustrates the 34 provinces grouped into the six major islands of Indonesia. The six major islands are Sumatera, Java, Kalimantan, Sulawesi, the Lesser Sunda Islands, as well as Maluku and Papua. In total, there are 7232 districts consisting of 585 Grid #1 districts, 2458 Grid #2 districts, 2999 Grid #3 districts, and 1190 Grid #4 districts.

Sumatera Island has 10 provinces, namely the Riau Islands, Bangka Belitung Island, Lampung, Bengkulu, South Sumatera, Jambi, Riau, West Sumatera, North Sumatera, and Aceh. There are 1938 districts on this island, counting 17 Grid #1 districts, 810 Grid #2 districts, 857 Grid #3 districts, and 254 Grid #4 districts, as illustrated in Figure 9.

Java Island has six provinces named Banten, East Java, Yogyakarta, Central Java, West Java, and Jakarta. There are 2143 districts on this island, none of which are Grid #1 districts, but 232 districts are Grid #2, 1209 districts are Grid #3, and 702 districts are Grid #4, as illustrated in Figure 9.

Kalimantan Island has five provinces named North Kalimantan, East Kalimantan, South Kalimantan, Central Kalimantan, and West Kalimantan. The number of districts on this island is 619, among which 23 districts are Grid #1, 264 districts are Grid #2, 260 districts are Grid #3, and 72 districts are Grid #4, as illustrated in Figure 9.

Sulawesi Island has six provinces named West Sulawesi, Gorontalo, Southeast Sulawesi, North Sulawesi, Central Sulawesi, and South Sulawesi. The number of districts on this island is 1021, among which 25 districts are Grid #1, 548 districts are Grid #2, 376 districts are Grid #3, and 72 districts are Grid #4, as illustrated in Figure 9.

The Lesser Sunda Islands comprise three provinces, namely East Nusa Tenggara (NTT), West Nusa Tenggara (NTB), and Bali. The number of districts on this island is 483, among which 15 districts are Grid #1, 225 districts are Grid #2, 176 districts are Grid #3, and 67 districts are Grid #4, as illustrated in Figure 9.

The Maluku and Papua Islands have four provinces named West Papua, Papua, North Maluku, and Maluku. The number of districts on this island is 1028, among which 505 districts are Grid #1, 379 districts are Grid #2, 121 districts are Grid #3, and 23 districts are Grid #4, as illustrated in Figure 9.

As demonstrated in Tables 11 and 12, the following conclusions were drawn from the validation results. Supplementary Material File S8 contain 1 figure (Figure S13) provides information on the verification procedures used to confirm the results. The accuracy ranges from 89 to 95.5%.

Table 11. Confusion Matrix.

		Actual Value (Correct Answer)			
		Positive		Negative	
		DKI Jakarta	Nation-wide Random Sampling	DKI Jakarta	Nation-Wide Random Sampling
Predicted Value (Model)	**Positive**	42	56	2	0
	Negative	0	7	0	0

Table 12. Accuracy and Error Rate Percentage.

	DKI Jakarta	Nation-Wide Random Sampling
Accuracy	95.5%	89%
Error Rate	4.5%	11%

5. Conclusions

This paper proposes a framework that can serve as a guide for the Indonesian government when constructing the nation's telecommunications infrastructure. The framework was designed to categorize the districts of the Indonesian administrative region into four grids: Grid #1: "fostered" districts; Grid #2: "developing" districts; Grid #3: "developed" districts; and Grid #4: "independent-advanced" districts. To determine which grid a district falls into, we developed a novel multi-stage statistical approach involving 17 indicators of telecommunications network and socioeconomic factors. This paper's application of the proposed framework yields a grid representation of 7232 districts distributed across Indonesia's six major islands.

This framework was applicable on a global scale for future work seeking to resolve the issues of disparity in access to telecommunications between the "rich and poor" groups in "urban and rural/remote" locations. With the assistance of this grid framework, telecommunications signals can be made available in all regions, thereby enhancing the global economy's efficiency and competitiveness, allowing for improved public service delivery (such as health and education) while providing the underprivileged with new employment and income opportunities. The comparison between study topics and important findings are presented in Table 13.

Table 13. Research questions and key observations.

No.	Research Questions	Key Observations
1.	Is the telecommunications infrastructure being constructed in geographically isolated and socioeconomically depressed regions in order to attract residents and stimulate economic growth?	This situation requires a framework that can serve as a regulatory reference, particularly in determining the region's category for telecommunication infrastructure.
2.	Or is the telecommunications industry following the provider/business approach, whereby they wait until the region is economically viable before investing in infrastructure excellence?	

The concepts of connectivity and digital development encompass many variables, perspectives, and areas of emphasis. In order to summarize the many variables that contribute to connectivity and digitalization, we propose a framework that can be used as a reference for the Indonesian government for constructing the nation's telecommunications infrastructure. Since this paper is full of academic research approaches and mathematical model perspectives, we expect that the results of our work will become valuable input for further policy development in Indonesia. As such, the creation of such policies will be enriched by an academic perspective, completing the typical socio-political considerations of policy development.

It is also believed that our proposed framework has a very significant and potentially practical impact that could be replicated in multiple developing countries where millions of people are not yet covered by mobile telecommunications services. We truly expect that our findings will benefit not only academic communities but also all people including operators and regulators who work in infrastructure sectors.

6. Future Studies

As potential future research avenues, we might:

1. Propose that Grid #5 might be defined as having 100% household penetration. The number of grids proposed in this manuscript is four. Hence, there is no Grid #5. However, if the term affordability is added to a new grid, specifically Grid #5, we think it is not required, as it has already been included into the socioeconomic dimension. Affordability is related to the total purchasing power of the population. While Quality of Service (QoS) relates to the telecommunication signal traffic, such as downlink speed, uplink speed, throughput/bit rate, and jitter. Grids #1–#4 indicate whether a district is fostered, developing, developed, or independent advanced. If Grid #5 exists, it must have superior conditions than Grid #4 (independent advanced).
2. Suggest employing the Blue Ocean and/or cost leadership strategy [54] to reach "low demand potential" in grid #2 for the future research and implementation. The assessment of the low demand potential in grid #2 is based on the framework's socioeconomic axes. The Blue Ocean strategy is a strategy that takes cellular companies out

of the red ocean of bloody (risky environment of ruthless) competition that occurs in high demand potential by building a market sector where there are no competitors yet, making the term competition obsolete. We can begin by defining market segments, developing canvas methodologies, developing customer levels, and devising answers to probable implementation difficulties.

3. Investigate technology trends, such as low-Earth-orbiting satellites and small-scale mesh networks, to see whether these technologies may challenge any of this paper's underlying assumptions.

Additionally, access networks (cellular) are supported by the existence of transport network transmission pipelines. The adoption of the most advanced features of new technologies (5G and beyond) as well as meeting the demands of a growing population are both possible if the huge transport network capacity is unrestricted. Satellite technology is a speedy means of providing telecommunications access, however, it results in significant OPEX. Satellite transponders are also attached; however, they cannot be modified until the satellite's lifespan has expired.

It is considered that optical fiber networks may provide the highest quality broadband access compared to other backbone network infrastructure technologies [79]. On the upstream side of Indonesian digital infrastructure development, there are the backbone layer (optical fiber), middle mile layer (high throughput satellite, hot backup satellite), and last mile layer (2G BTS, 3G NodeB, 4G eNodeB, 5G NR). Therefore, the scope of this research is limited to terrestrial optical fiber and excludes satellites and other backbone infrastructure technologies.

We have previously given some thought to both terrestrial and non-terrestrial technologies. Due to rental price reasons and the anticipated development of transmission capacity, we chose fiber optics. In the future, the use of existing very small-aperture terminal (VSAT) can be converted into fiber optic cores (terrestrialization) as an extension point to fishbone/fronthaul last mile.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/informatics10020044/s1, Figure S1: Existing Government Action in Indonesia; Figure S2: Modernizing Spectrum Regulation in Omnibus Law on Job Creation (Act No.11 Year 2020); Figure S3: The Proportion of Indonesian Subscribers for Each Service Provider (in Millions), Redrawn from [28]; Figure S4: Indonesian MNOs Free Cash Flow (FCF); Figure S5: Indonesian MNOs Profitability of Return on Investment (RoI); Figure S6: Indonesian MNOs Profitability of Net Profit Margin (NPM); Figure S7: Indonesian MNOs Regulatory Cost are Increasing; Figure S8: Analogy of economic and non-economic areas/USO regions in Indonesian telecoms development; Figure S9: Palapa Ring Fiber Optic Telecommunications Network [31]; Figure S10: Strategic Plan Programs Year 2020–2024, translated into English from [17]; Figure S11: Indonesian 5G Roadmap Resume in The Thirteen 5G Pilot Project Cities; Figure S12: Number of Sites and Cutpoint; Figure S13: Algorithm Flowchart; Table S1: Optical Fiber Network as Backbone [31]; Table S2: The thirteen 5G Pilot Project Cities Grid Proposal; Table S3: Variable Definition for Figure 6 and Tables 7–10 of The Manuscript; Table S4: Optical Distribution Points (ODPs) Data Processing Example; Table S5: Coverage Prediction/Signal Coverage (SigCov) Data Processing Example; Table S6: Traffic Data Processing Example; Table S7: The Quantity of Mobile Cellular (2G/3G/4G) Sites Data Processing Example; Table S8: Indicator 5: Electricity Data Processing Example; Table S9: Indicator 6: Education Data Processing Example; Table S10: Indicator 7: Buying and Selling Transactions Data Processing Example; Table S11: Indicator 8: Lodging Data Processing Example; Table S12: Indicator 9: Health Facilities Data Processing Example; Table S13: Indicator 10: Financial Activities Data Processing Example; Table S14: Indicator 11: Industrial Capacity Data Processing Example; Table S15: Indicator 12: Tourism Data Processing Example; Table S16: Indicator 13: Mining and Plantation Business Units Data Processing Example; Table S17: Indicator 14: Residential Conditions Data Processing Example; Table S18: Indicator 15: Road Access Data Processing Example; Table S19: Indicator 16: Regional Finance Data Processing Example; Table S20: Indicator 17: Population Data Processing Example; File S1: Indonesian Telecommunication Regulation and Government Action; File S2: Service Obligation (USO) in Indonesia; File S3: Palapa Ring Project as the National Infrastructure Policy;

File S4: Strategic Plan of/for The Ministry of Communication and Informatics (KOMINFO); File S5: Telecommunication Networks Indicators Data Processing; File S6: Socioeconomic Indicators Data Processing; File S7: Abbreviation; File S8: Methodology's Algorithmic Processes.

Author Contributions: Conceptualization, A.C.S. and M.S.; methodology, A.C.S.; software, A.C.S.; validation, A.C.S., M.S. and D.G.; formal analysis, A.C.S.; investigation, A.C.S.; resources, A.C.S.; data curation, A.C.S.; writing—original draft preparation, A.C.S.; writing—review and editing, A.C.S., M.S. and F.H.J.; visualization, A.C.S.; supervision, M.S. and D.G.; project administration, A.C.S.; funding acquisition, M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research including the APC was funded by UNIVERSITAS INDONESIA, grant Publikasi Terindeks Internasional Quartile-2 (PUTI Q2) No. NKB-702/UN2.RST/HKP.05.00/2022.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The complete grid category for 7232 Indonesian districts as a result of our novel framework can be accessed in the Intellectual Property (copyright No. EC002022107232 date 15 December 2022) document [33].

Acknowledgments: Denny Setiawan from the Ministry of Communication and Informatics of the Republic of Indonesia is acknowledged for his assistance with this study.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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