Techno-Economic Model for Policy Assessment to Optimize Spectrum Frequency Utilization
Study Case: Frequency Fee for FWA and GSM Services in Indonesia

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Abstract: - Radio frequency spectrum is a limited resource, owned and regulated by government. Each telecommunication providers, which use radio frequency spectrum, has the obligation to pay frequency fee. Currently, frequency fee, called as "Biaya Hak Spektrum Frekuensi" (BHP-F), for the cellular and fixed wireless access (FWA) services are calculated based on the number of frequency spectrum channel that being used (aperture based). This method is considered obsolete for cellular and FWA services BHP-F, not only this method has technical problem but also calculation based on aperture is hampering the utilization of frequency spectrum. International telecommunication Union (ITU), through ITU-R SM 2012-2 recommends about BHP-F formula based on frequency spectrum spectral, which can promote the frequency spectrum utilization. The policy of changing BHP-F from aperture based to spectral based will affects in economic especially to GSM and FWA industries. The policy also will affect to government goals to increase frequency spectrum utilization and to have proper non-tax government income. To assessment this policy, we need proper model. This paper will propose a techno-economic model to evaluate the impact of the new policy. In this paper, we use cellular and FWA services as case study.

Key-Words: Frequency Fee, cellular and fixed wireless access services, utilization, techno-economic

1 Introduction

Radio frequency spectrum consists of bands of electro-magnetic frequencies. Those bands range from 9 kHz to over 275 GHz [1].

Spectrum has characteristics which make it unique as a resource. Spectrum is non-homogeneous in which different frequencies have different characteristics that make specific frequencies more suitable for certain uses. Spectrum is finite. Spectrum is non-depletable, using the spectrum today does not prevent use of spectrum tomorrow. It is non-storable. It cannot be stockpiled, spectrum not used today is lost forever. Different frequencies have different propagation, bandwidth and interference characteristics. The propagation of radio signals depends on the communications equipment in use, the time of day, time of year, solar activity, and topography and weather conditions. Lower frequency radio signals tend to propagate over long distances and penetrate some materials, while higher frequency signals are more suited to shorter range 'line-of-sight' applications. High powered signals propagate further than low powered signals. In general, the greater the bandwidth, the more information that can be transmitted in a given period. Interference reduces the quality of voice communication, reduces data rates and can even eliminate the communications connection. Some spectrum uses are more susceptible to interference than others. Interference depends, in part, on the technology used and more sophisticated equipment can improve receiver performance [2].

There is four (4) actor that involved with spectrum. Regulator manage the allocation of spectrum, provider has right to use spectrum from license, user use spectrum to make communication with other user and industry support user and provider to have equipment that can make a communication with spectrum. Provider and user utilize spectrum. Utilization of spectrum can be looked in three dimension : frequency dimension, space dimension and time dimension.[5].

The concept of frequency spectrum can be easier to understand by illustrate it in 3-dimesion that consist of frequency, space, and time as shown in Fig.1. In the FDM technology, the spectrum is separated by frequency and in the TDM technology, spectrum is separated by the time, but in the CDMA technology, spectrum is not separated by frequency and time.

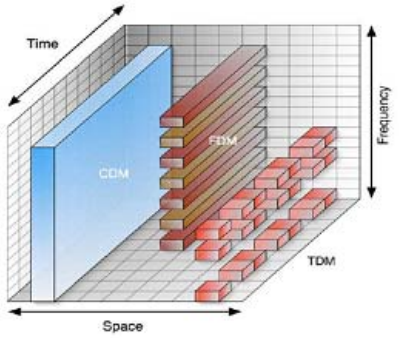

Fig. 1 Frequency Spectrum Dimension

Level of usage in frequency spectrum called as spectrum utilization. ITU through ITU-R SM.1046-2 define frequency spectrum utilization as below [3]:

$$U = B \cdot S \cdot T \quad (1)$$

Where U is frequency spectrum utilization, B is frequency bandwidth , S is geometric space (usually area) and T is time.

The Efficiency of spectrum utilization is stated as relative spectrum efficiency (RSE) [3] as below:

$$RSE = SUE_a / SUE_{std} \quad (2)$$

Where RSE is spectrum relative efficiency, SUE_{std} is SUE from standard system, and SUE_a is taken from field measurement.

As limited resource, government regulated the use of frequency spectrum in Cellular and FWA service. Providers need frequency spectrum to deliver services to users. To make demand and supply balance, the frequency spectrum was managed efficiently by government [4]. Government regulate frequency spectrum right of use. The providers who have the right of use must pay frequency fee [5].

There is some method for the government to collect spectrum fee[4]:

a. Based on spectrum management cost. Consist of direct and indirect cost.
   1. Direct cost. For example, they include: the cost of staff time in the frequency assignment process, site clearance, interference analysis when it can be directly associated with a particular class of service – keeping the public news and entertainment channels clear, ITU and regional international consultation that is specific to an identifiable group of users.
   2. Indirect cost. The cost of the spectrum management functions used to support the administration's frequency assignment process and the overhead of operating the administration's spectrum management procedures. They represent costs that cannot be identified as attributable to specific services or licensees such as general international consultation, for example with the ITU and regional groups, propagation research covering many frequency bands and services, general spectrum monitoring, interference investigations arising from the complaints of rightful users and the cost of support staff and equipment.

b. Based on user's gross income. A fee can be charged based on a percentage of the gross income of a company. The value of the gross income used in the fee calculation must be directly related to the company's use of the spectrum to avoid difficulty in the accounting and auditing processes.

c. Based on Incentives fee. An incentive fee attempts to use price to achieve spectrum management objectives and hence to provide some incentive to use the spectrum efficiently. Various elements of spectrum usage may be taken into consideration in the development of an approach or a formula (e.g. population density, bandwidth, frequency band, coverage area, exclusivity, power) and different formulae may be required for different frequency bands and services.

d. Based on Market. Market is given an opportunity to determine spectrum fee. This method is usually called as auction. The provider that has highest bid, has right to use spectrum.

2 BHP-F Formulation for FWA and GSM Services Today and Problem

BHP-F formulation for GSM and FWA today is based on aperture and the pricing is based on AIP (Administrative Incentives Price) where government decide basic price based on band type, bandwidth, channel location, access technology and transmission power [7].

Spectrum fee in Indonesia is called as "Biaya Hak Pengguna Frekuensi" BHP-F where is taken of the following [6].

a. the type of a radio frequency;
b. the width of the band and or the channel of the radio frequency;
c. the extent of the scope;
d. the location;
e. the market interest.

The formula of BHP as below .

$$BHP = \left(\frac{lb * HDLP * b + lp * HDDP * p}{2} \right) \quad (3)$$

Where :

- HDDP is reference Value of Power
- HDLP is reference Value of Bandwidth
- p is EIRP, power of transmitter (dBm)
- b is bandwidth used in kHz
- Ib is bandwidth Index
- Ip is Power Index

HDDP and HDLP are determined based on the classification on band frequency and geographical zone. HDDP and HDLP is in rupiahs unit. Geographical zone consist in five (5) zone. Determination of bandwidth index (Ib), and power index (Ip) is based on the type of radio communication services, and geographical district zone in Indonesia taking into account the economic and population growth factors.

For satellite networks (space segment), since it covers whole country, the zone is assumed as Zone 3 (average zone). BHP of a radio frequency spectrum is calculated per each station and each RF channels. To know more how BHP of a radio frequency work, can be shown in this example.

a. Example 1.
A station uses GSM-900, bandwidth 200 kHz, power 53 dBm, type of transceiver as transmitter, location in zone 1 , the BHP of radio frequency is

$$BHP = \left(\frac{8.79 * 11772 * 200 + 4.2 * 109481 * 53}{2} \right) = 45 \text{ B IDR}$$

b. Example 2.
A station used GSM-900, bandwidth 200 khz, power 0 dBm, type of transceiver as receiver, location in zone 1 :

$$BHP = \left(\frac{8.79 * 11772 * 200 + 4.2 * 109481 * 0}{2} \right) = 21 \text{ B IDR}$$

This BHP-F formula has some weakness as follows:

2.1 No incentives fee between high and low frequency
Type service that be categorized on mass service such as broadcasting and cellular communication has high competition and profit. Interference and propagation on lower frequency is better than higher frequency. Lower frequency is scarcity also. HDDP and HDLP on UHF band has single value. There is no incentives price for higher frequency that make mass service provider choose higher frequency to fix scarcity problem. In this below, is HDLP and HDDP parameter table on UHF band.

Table 1. HDDP and HDLP lookup table in UHF band

	Band	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
HDLP	UHF	11,772	9,418	7,063	4,709	2,354
HDDP	UHF	109,481	87,585	65,688	43,792	21,896

2.2 Not reflect of opportunity cost
Spectrum use of right in cellular communication service is national right. It means that provider that have a right to use spectrum have exclusive right that make another provider can not use the spectrum. On non economical zone, some spectrum has not used cause cost of CAPEX reason because the fees is calculated per each station and each RF channels. It make spectrum can not efficient to use because there is opportunity to use that can not be used (opportunity cost).

2.3 Not Proportional
In apparatus fee system, fees is calculated per each station and each RF channels. For provider that uses more bandwidth not usually pay more higher. In this below, provider J that use 30 MHz pay lower than provider K that use only 20 MHz for national right. It make not proportional for other provider because the right is same.

Table 2. BHP-F on 2007

Technology	User	BW (Mhz)	BHP-F (Rp)	BHP-F / BW (Rp/MHz)
CDMA-450	A	15	7,771,933,560	518,128,904
CDMA-800	B	14.76	48,310,547,876	3,273,072,349
	C	14.76	36,485,030,866	2,471,885,560
	D	9.84	38,835,940,774	3,946,741,949
	E	4.92	2,953,073,559	600,218,203
CDMA-1900	F	12.5	30,339,683,534	2,427,174,683
GSM 900 / GSM 1800	G	80	1,331,215,092,932	16,640,188,662
	H	65	736,531,891,098	11,331,259,863
	I	30	328,389,937,561	10,946,331,252
	J	30	24,647,702,466	821,590,082
	K	20	74,167,162,639	3,708,358,132
TOTAL		296.78	2,659,647,996,865	8,961,682,043

2.4 Not Technology Neutral

lb and lp index still categories service related with technology such as below. It will make difficult cause technology of communication is rapid development.

Table 3. Cellular and WLL service

Type of service		lb	lp
Cellular FDMA (AMPS. NMT)	Base + out station	8.210	0.630
Cellular TDMA (GSM,DCS & PCS)	Base + out station	8.790	4.200
Cellular DS-CDMA (IS95)	Base + out station	3.400	11.710
WLL FDMA	Base + remote/out station	1,360	0,110
WLL TDMA	Base + remote/out station	0,230	0,490
WLL DS-CDMA	Base + remote/out station	0,070	0,490

The weaknesses make spectrum utilization only optimal in some area especially in economic area that shown as below. It is happened because the providers have not obligation to pay their spectrum right opportunity.

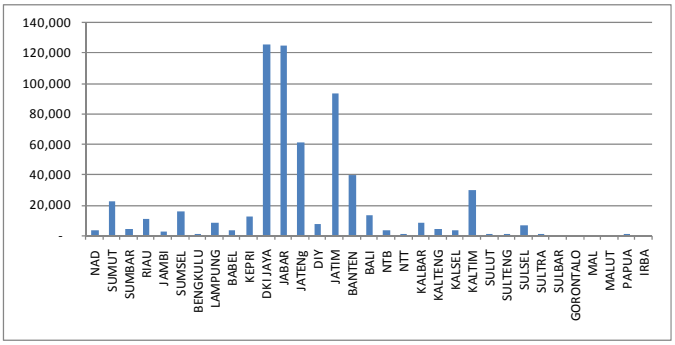

Fig. 2. Channel utilization per province

3 ITU Recommendation For Frequency Fee

BHP-F using aperture based for GSM and FWA services is not suitable anymore today because cannot promote spectrum utilization. Today, the formulation of frequency spectrum is based on the opportunity to utilize spectrum. Many country today, use frequency fee calculation based on bandwidth and spectral. ITU-T recommends ITU-R SM. 2012-2 that can promote optimalization on frequency spectrum utilization. ITU-R SM. 2012 – Economic aspects of spectrum management, was issued in 1998. In that recommendation, ITU proposed, An analytical model for calculating license fees on the basis of specified incentives that are designed to promote efficient spectrum use[7].

This model was developed in the framework of the BDT Asia and Pacific Project on Spectrum Validation and Licensing, Bangkok, 2000. The study focuses on a specific method of spectrum fee calculation. The model is derived from the conceptual base that there is a distinct need to price spectrum and that the pricing of spectrum resources should reflect more than administrative convenience[7].

The purpose of this model is to increase spectrum utilization efficiency. It is designed to introduce non-discriminatory access to the spectrum for various categories of users, stimulate the use of less congested (particularly – higher) frequency bands, stimulate harmonized development of radio communication services throughout the country, and cover the cost of spectrum management. It includes the consideration of the phased development and/or maintenance of spectrum management and monitoring facilities and reimbursement of expenditures of a national telecommunication administration including its international activities within ITU[7].

The proposed spectrum payment algorithm includes the following steps[7]:

a. Determination of annual expenditures of the State on management of actually used spectral resource and determination of the common value of the annual payments for all spectral resources.
b. Determination of the value of the spectral resource used by each radio station and, through their summation, by all stations registered in a national Spectrum Management Database.
c. Determination of the price for a unit of the spectral resource.
d. Determination of the annual payment for a specific user on a differential and non-discriminatory basis, determined from the actual value of used spectral resource.

3.1 Expenditures and Income of A State Concerning Spectrum Management.

The total amount of the annual payments for spectral resource C_{an}, to be collected from all users where they come from share of the sum that is necessary for covering expenditures of the State on all national and international spectrum management activities, net income of the State, if applied and etc.

3.2 Determination of The Used Spectral Resource Value

The second step is to determine the spectral resource value used by each user and then – by all users. For any i-th frequency assignment (from their total amount n incorporated in the national database) the three-dimensional value of the spectral resource, denoted as Wi, . This spectral resource is multiply from frequency resource, territorial resource and time resource.

3.3 Determination of a time resource used by an emission.

A time resource Ti used by i -th emission is determined as not more than one year and for each frequency assignment represents a fraction of time related to one year, determined in that or another way, during which the radio transmitter operates in accordance with terms set out in the relevant license.

For example, if particular TV transmitter in accordance with terms of its license is operating only 16 h per a day throughout the whole year, than: Ti = 16/24 = 0.67 year. If another transmitter (for example an HF one used for geological expedition), in accordance with terms of its license can operate totally only 3 months per year, then: Ti = 3/12 = 0.35 year.

3.4 Determination of a territorial resource used by an emission.

A territorial resource Si used by i -th emission is determined by the territory actually occupied (covered) by the emission in accordance with certain criteria (km2), and weighting coefficient which depends on the j-th category of the territory actually occupied by the emission and also number of categories.

The number of categories m and the relevant values of the weighting coefficients bj should be set out by a national telecommunications administration. These categories can take into account density of population and/or level of economic (industrial and/or agricultural) development of various regions of a country.

3.5 Determination of a frequency resource used by an emission.

A frequency resource Fi used by i-th emission is determined by necessary bandwidth of the emission (MHz), calculated in accordance with Recommendation ITU-R SM.1138, taking into account that an occupied bandwidth of an emission should be equal to its necessary bandwidth (Recommendation ITU-R SM.328-9)

3.6 Determination of weighting coefficients.

General weighing coefficient can be presented from takes into account commercial value of the spectrum range used, taking into account social factor, takes into account features of transmitter location, takes into account the complexity of spectrum management functions and other coefficient (coefficients) which can be introduced by an administration reflecting its specific needs.. Another weighting coefficient is exclusiveness of the frequency assignment.

3.7 Price for The Qualified Unit of The Used Spectral Resource

Then it is possible to determine the price of Δ Can for a qualified unit of the spectral resource where it present as units of a national currency/(MHz · km2 · 1 year)

3.8 Annual Fees for Particular Frequency Assignment

According to equation above the price Δ Can for the qualified unit of the spectral resource is determined. Equation above gives the value of the spectral resource Wi used for a particular i-th frequency assignment. Based on this, the amount of the annual payment Ci from the specific user of the spectrum for this frequency assignment can be determined

4 Techno-Economic Modeling

The changing of frequency fee policy from aperture based to bandwidth and spectral based will impact to the industry and spectrum utilization. Government has the obligation to manage spectrum more efficient in any region and make healthy industry competition. Before change the policy, government must analysis impact of the new policy. Because this policy is related with technical and economic, Government must use techno-economic model to ensure that their policy will have lower risk.

Techno-economic model proposed in this research is adopted from TERA (Techno-Economic Results from ACTS)[8]. Illustration of the model is shown as below:

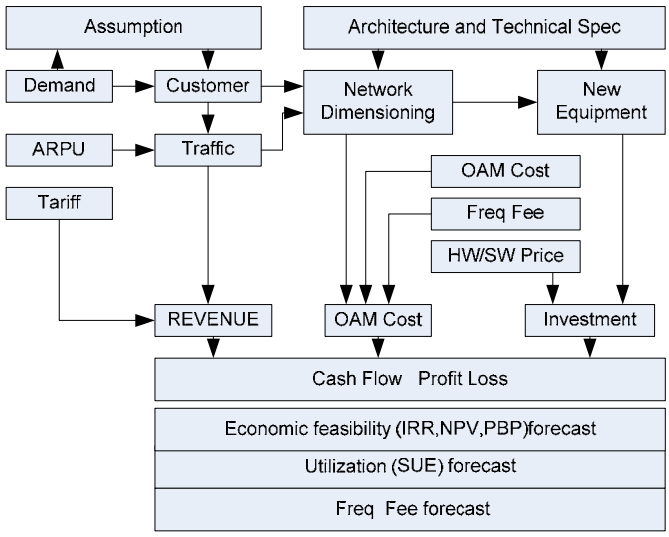

Fig. 3. Techno-Economic Model for Policy Analysis

4. 1 Demand Forecast

Input of this model is came from customer forecast for five year later. This forecast is illustrated as probability of customer that provider can reach.

4.2 Define ARPU and Tariff

Customer consumption each user is came from ARPU data. We use same tariff and type of traffic for all providers. From this input, this model will produce data of traffic each mount and each Provence.

4.3 Calculation of Traffic

We use ITU-R M.1390 – Methodology for the calculation of IMT-2000 terrestrial spectrum requirements to calculation of traffic. This traffic data will be used to define network architecture and equipment [8].

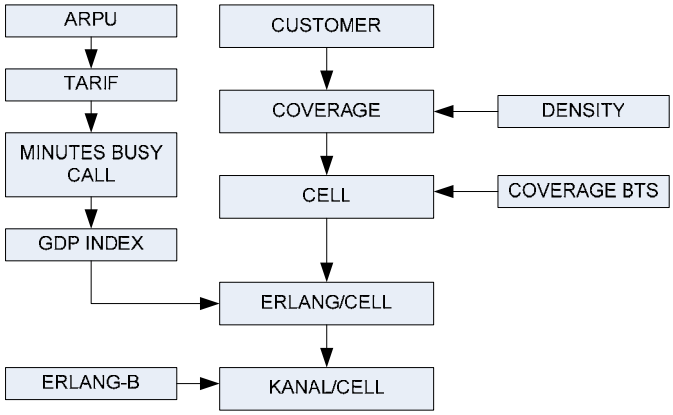

Fig. 4. Traffic Calculation Model

4.4 Network Architecture and Equipment List

We can define network architecture and equipment list. This architecture and equipment list will define CAPEX and also OPEX related with network dimensioning. In this step, we will have information about the use of frequency band, bandwidth, voice channel, erlang consumption and system capacity.

4.5 Network Dimension

Network dimension is the provider's requirement about equipment and network fee to provide telecommunication services. In the network dimension, equipment being considered is TRX, BTS, BSC, and MSC.

4.6 Calculating Operational Cost Unit and Investment

Cost estimation is came from TRX, BTS, BSC and MSC equipment. Operational cost estimation usually consists of operational and maintenance cost, general and administration, salary, depreciation and BHP-F cost. In this paper, operational cost is focusing only on yearly operational cost for TRX, BTS, BSC, MSC, and network fee.

BTS maintenance consists of location and tower rents which will be different for each region and then will be calculated based on location. Network fee is calculated based on the distance between location to Jakarta and Mbps requirement.

4.7 Economic Feasibility Calculation and Utility Efficiency.

From cash flow and profit and loss calculation, economic feasibility calculation based on IRR (internal rate of return), where it is considered feasible if it is more than required MARR (Minimum Attractive Rate of Return). Other than economic feasibility, calculation of relative SUE (Spectrum Utilization Efficiency) is also executed to know the optimal spectrum level with enforcement of the new formulation.

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4.8 Scenario

Scenario to use this techno-economic model can be explained as follows:

a. Study period
   The study period will use 5 years with 2008 as the year -0.
b. Type of provider
   Provider type which will be included in this test is as follows:
   1. Mature provider. Providers have delivered services on all area.
   2. Semi Mature. Providers have delivered services only in the profitable area and plan to extend to the non-profitable area
   3. Beginner. Providers are newcomer and will deliver service in profitable area first.

   Data is considered feasible when IRR is more than 10%

c. Comparison of BHP-F formulation
   Old model and new model of BHP-F will be compared:
   a. Old model of BHP-F (OLD)
      This model is still in use and will be applied as comparison
   b. Based on Bandwidth (FLAT)
      This formula, BHP-F is evaluated based on bandwidth which is the total PNBP (government income non tax) in the year 2009 divided by total bandwidth. Value of PNBP in 2009 is considered as shadow price of GSM and FWA of GSM and FWA services in the current situation. In the next five years, value of BHP-F is assumed as

fixed. Formulation of this model is as follows:

$$BHP\text{-}F_1 = B \times Cost\ Unit \quad (4)$$

$$Cost\ Unit = PNBP\ BHP\text{-}F\ 2009 / B \quad (5)$$

Where B is the bandwidth (MHz) and Cost Unit is price per MHz.

c. Extended of ITU-R SM.2012-2. ITU through ITU-R SM.2012-2 introduce formula calculation BHP-F based on opportunity which will able to promote efficient use of spectrum. Basic idea of using this method is to calculate the spectral resources already in use. Combining with AIP, government has intervention power to set the price basis.

$$BHP\text{-}F_3 = \sum[\alpha_i \times P \times B \times S_i] \times 114 \quad (6)$$

$$P = [Log(275000) - Log(f)] \quad (7)$$

Where α is economic level index, P is spectrum index, B is the bandwidth (MHz), S is population coverage which has been served by provider (kilopops), i is each location where service exists, and f is frequency band (MHz) being used. Unit of α and S is as follows:
Unit cost is Rp 114, is calculated based on of PNBP BHP-F 2008 and it is assumed that all region has been serviced.

Government intervention to set special fee to certain region/location to induce the increase of spectrum utilities there. In Maluku, North Maluku, Papua, and West Irian Jaya provinces, the incentive is 50% discount, for NAD (Aceh) the incentive is 25%, for DKI Jakarta the discount is 10%.

5 Result

Testing is executed by executing IRR analysis to SUE and see the effect to BHP-F. Testing is executed in stages on each BHP-F formula starting from the old BHP-F formula until the developed ITU-R SM-2012-2 INCENTIVE to the 3 provider types. The result is as follows:

a. Beginner
SUE has maximum value for OLD formula and ITU-R formula but the best IRR is on OLD formula. It is happened because BHP-F only calculate base on channel for OLD formula so it make lower cost for provider if they use OLD formula.

OLD formula has better advantage for Beginner Provider because they only pay only number of channel that they have utilized. For government and their competitor, it is not advantage if use OLD formula because there is not opportunity cost on this formula. In this situation, ITU-R is the best choice because has better SUE, IRR and BHP-F than FLAT although have lower value than OLD formula.

b. Semi Mature
All probability of SUE have same value for all formula. The best IRR is on ITU-R Formula where has IRR between 0.16-0.17. In this type of provider, ITU-R is the best choice because has better SUE, IRR and BHP-F than another.

Table 4. Result of Beginner Provider

BEGINNER		FORMULA		
		OLD	FLAT	ITU-R
SUE	MAX	0.8529	-	0.7576
	AVERAGE	0.5696	-	0.6271
	MIN	0.3472		0.4934
IRR	MAX	0.59	-	0.18
	AVERAGE	0.51	-	0.12
	MIN	0.36		0.10
BHP-F (Million Rp)	MAX	52,950	-	353,382
	AVERAGE	37,195	-	353,382
	MIN	20,346		353,382
FEASIBILITY		100.0%	0.0%	6.6%

Table 5. Result of Semi Mature Provider

SEMI MATURE		FORMULA		
		OLD	FLAT	ITU-R
SUE	MAX	41.1131	41.1131	41.1131
	AVERAGE	38.9632	38.9632	38.9632
	MIN	37.8341	37.8341	37.8341
IRR	MAX	0.15	0.16	0.17
	AVERAGE	0.14	0.16	0.16
	MIN	0.14	0.16	0.16
BHP-F (Million Rp)	MAX	214,065	177,712	164,881
	AVERAGE	213,853	177,712	164,036
	MIN	213,654	177,712	161,899
FEASIBILITY		100.0%	100.0%	100.0%

c. Result for Mature
All probability of SUE have same value for all formula. The best IRR is on FLAT and ITU-R Formula. The BHP-F is near one another for FLAT and ITU-R formula, but for OLD, the BHP-F is highest because mature provider hs utilized much channel. In this type of

provider, ITU-R is the best choice because has better SUE, IRR and BHP-F than another.

Table 6. Result of Mature Provider

MATURE		FORMULA		
		OLD	FLAT	ITU-R
SUE	MAX	14.9098	14.9098	14.9098
	AVERAGE	14.3428	14.3428	14.3428
	MIN	13.7135	13.7135	13.7135
IRR	MAX	0.29	0.31	0.31
	AVERAGE	0.28	0.30	0.30
	MIN	0.26	0.29	0.28
BHP-F (Million Rp)	MAX	1,966,134	1,066,275	1,081,540
	AVERAGE	1,911,446	1,066,275	1,081,540
	MIN	1,867,070	1,066,275	1,081,540
FEASIBILITY		100.0%	100.0%	100.0%

With three type of provider and three kind of formulation, we can conclude that ITU-R formula is the best choice as substitute of old formula because in this formula, have incentives factor that government can intervention to promote utilization on un economic area and have lower risk on economic feasibility.

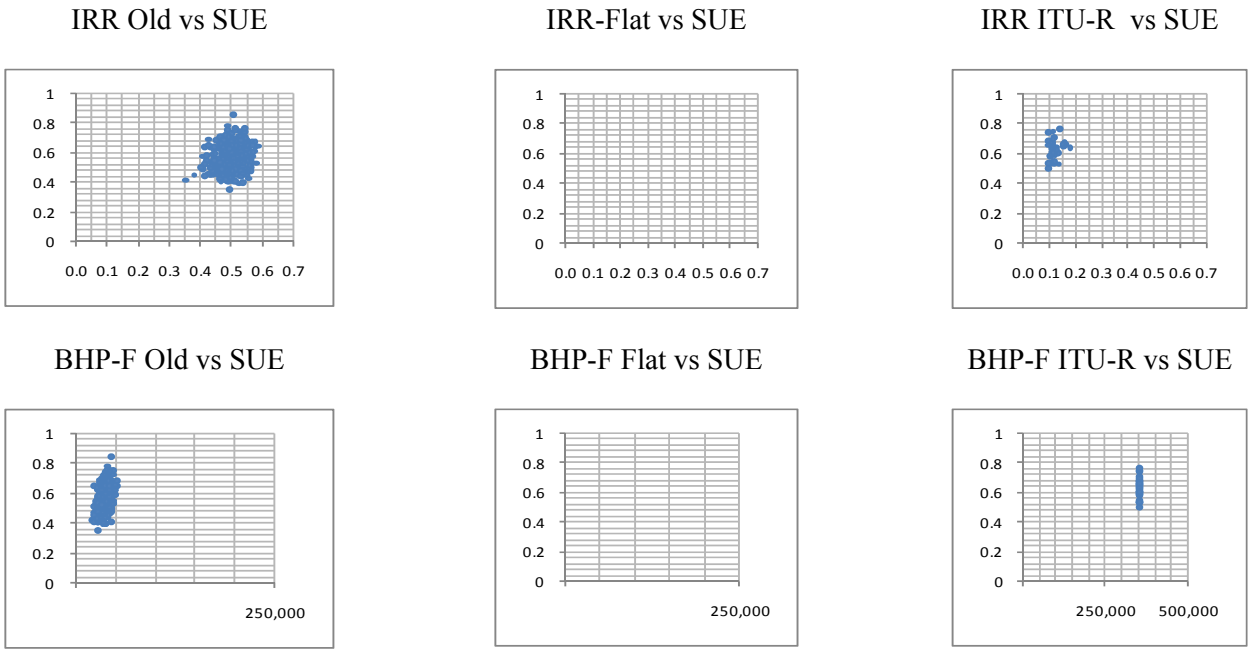

Fig 5. Result of Beginner

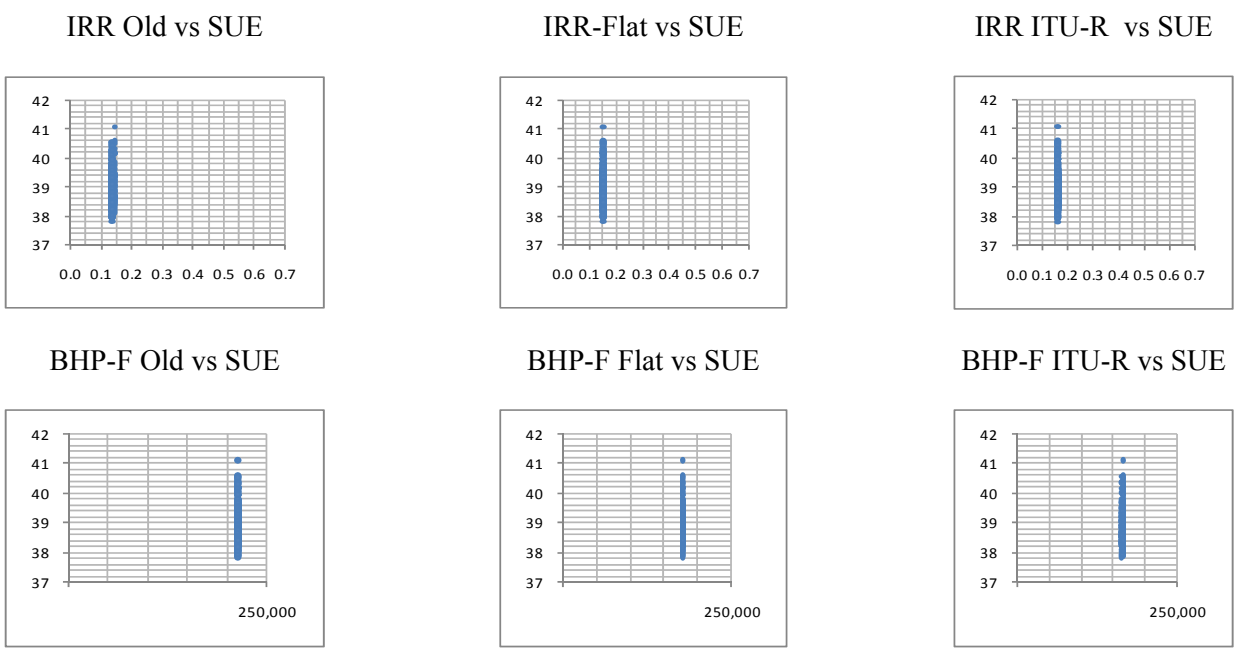

Fig. 6. Result of Semi-Mature

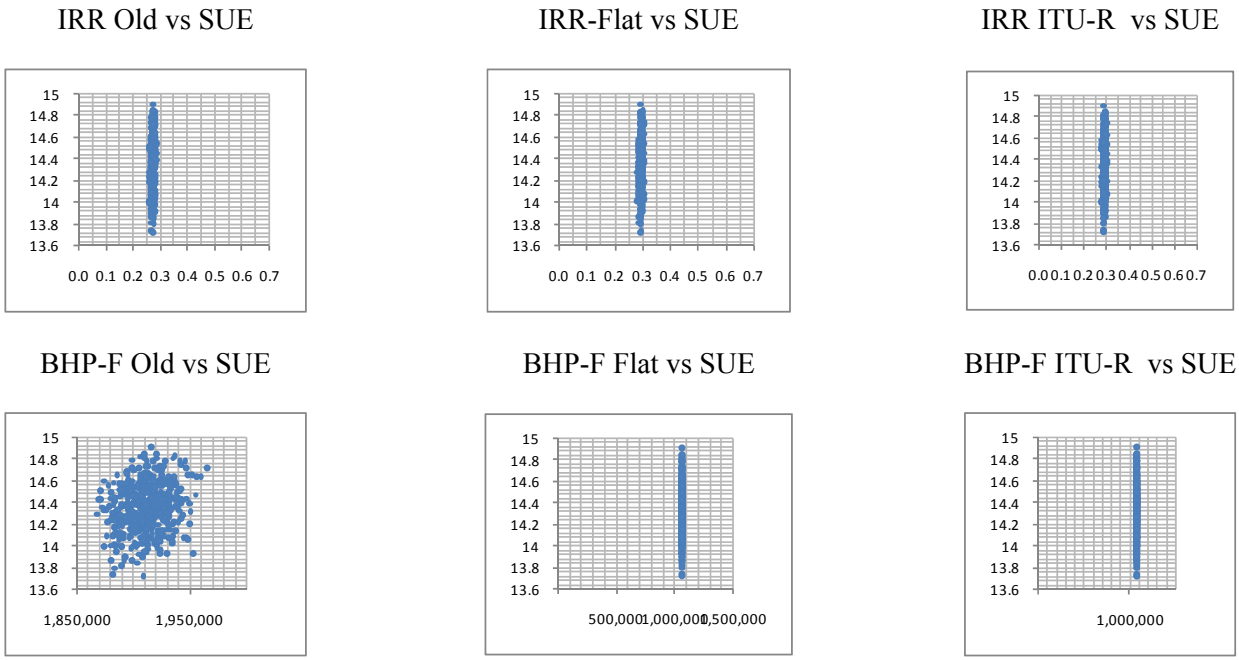

Fig. 7. Result of Mature

6 Conclusion

As a limited and critical resource, Government has to manage and regulate the frequency fee policy. The objective is to ensure that frequency spectrum has better utilization in all region. To reach the objectives, government must recommend to changing aperture based BHPF-F with a new BHP-F because aperture based BHP-F has been proven that cannot push to better utilization. This policy changing will affect in economic and in technical. By this model, government is able to obtain the best policy. In this case, formula from ITU has a lower risk economic impact and can reach better utilization than others.

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