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# Valuation of 5G mmWave Fixed Wireless Access in Residence Area: Analysis of Real Option for Wireless Broadband Service in Kota Wisata Cibubur Using Decision Tree and Black Scholes Model

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**ABSTRACT**

Fixed Wireless Access (FWA) is one of the popular use cases in 5G, expected to replace conventional internet service. However, investing in a telecommunications project requires massive capital, so careful planning is usually required. In general, investments are valued by the standard Net Present Value (NPV) method. When the NPV is positive, the project is profitable. However, the NPV possibly will not be as expected due to uncertainty in the future. One of these is the number of subscribers. This research proposes using Real Option (RO) to analyze the FWA project with an uncertainty of the number of subscribers and compare it to the standard NPV method. From the result of the research, the standard NPV method produces a positive Expected NPV of $153,176. However, there is a 33% possibility that the NPV will be -$406,246. By using the decision tree in RO to evaluate the project, the managers have an option to delay the project from one to three years and eliminate negative NPV resulting in the Expected NPV of $250,038, $216,842, and $188,371. Using Black Scholes Model to delay the project from one to three years also results in a higher Expected NPV of $220,668, $209,593, and $219,428.



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## 1. INTRODUCTION

Data or internet services have become a crucial need for most people. In the pandemic, work from the home policy has become inevitable. Demand from residents results in subscriber increase. One of the most anticipated use cases of 5G is Fixed Wireless Acces (FWA). FWA is a concept of delivering broadband internet through wireless technologies. It offers robust internet service similar to an internet service provider (ISP) and offers cheaper costs to deploy [1][2].

Before deploying telecom infrastructure, operators usually analyze costs and revenue [3]. The techno-economic analysis is usually used to determine the technological and economic factors. Net Present Value (NPV) is a standard tool to value the project [4]. The project is deployed if the NPV is positive and vice versa [5].

Some assessment in telecommunications projects from [6][7] is the modeling of 5G techno-economic of different radio technologies analysis with three demand scenarios to predict the need to upgrade the 5G network. The NPV was earned in cities in Indonesia for six years. From [8], a case study of FWA in the residence area shows only the requirement of different technologies (Base Station type) and the expenditure (CAPEX and OPEX) to deploy the FWA. All of the research mentioned above mentions that the project is deployed right away if it is considered profitable. In reality, many uncertain factors like the adoption of technology, the number of subscribers, network performance, and others result in the NPV being far from projected. Some projects may seem risky if deployed right away, even if they seem profitable in the assessment. Therefore, we propose a method to evaluate the FWA with options to make or abandon some choice concerning the investment of the FWA, whether to delay or deploy it right away. This method is called Real Option (RO).

This research aims to use RO to analyze the FWA project. Users will know better the uncertainty of implementing the FWA project. By doing so, users can minimize the risk of negative NPV [9] and make the best decision whether to wait or abandon the project [10].

## 2. METHOD

### 2.1. Location of Research

Kota Wisata Cibubur is located on Transyogi road, Gunung Puteri district, Bogor regency, West Jawa province, Indonesia. It covers a total area of 480 hectares and consists of 11,512 households and stores. Fig.1 shows the map of its location.

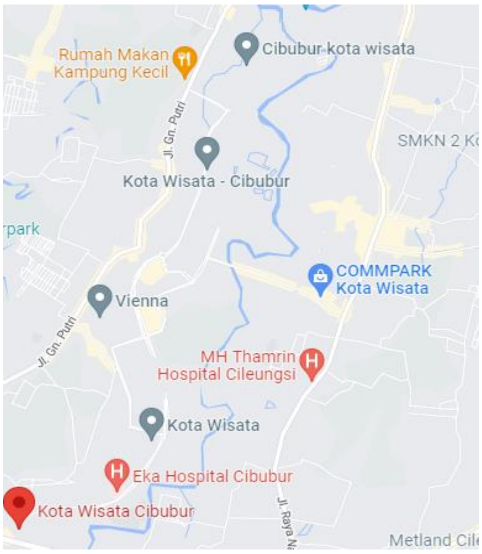


**Fig. 1.** Map of Kota Wisata Cibubur (source: google map)

### 2.2. Household Subscriber Forecast and Traffic Forecast

The number of customers is estimated using the Bass model shown in Eq. (1) [11]. $N(t)$ is the number of residential customers in a year $(t)$. $M$ is the number of current customers. The value of $p > 0$ is the coefficient of innovation, and $q \geq 0$ is the coefficient of imitation. Considering Indonesia as a developing country, the value of $p = 0.0267$ and $q = 0.3356$ [8][12]. In this research, the number of customers using FWA is assumed to be in three scenarios as in the previous techno-economic research, namely the high number of customers, moderate number of costumer, and low number of customers. $N(t)$ is included in the high number of customers, the moderate number of customers is 60% of $N(t)$, and the low number of customers is 60% of the number of moderate customers [6][13]. Assume the probability scenario for each number of costumer, namely $Pa$, $Pb$, and $Pc$, are considered to have relatively the same value, as shown in Table 1.

$$N(t) = M \frac{1 - e^{-t(p+q)}}{1 + \frac{q}{p} e^{-t(p+q)}} \tag{1}$$

The traffic forecast is a data service demand in a kilometer square shown in Eq. (2). $G(t)$ is the traffic demand. $\rho$ is the population density of 1,365 per km square for West Java, and $Nmd$ is the number of days in a month equal to 30 days. $Ndh$ is the number of busy daily hours equal to 9 hours [8]. $\varphi(t)$ is the percentage of active users in a time range (100%). $Dk$ is are by the average monthly demand equal to 500 GB per month [7][14].

$$G(t) = \rho \frac{8}{Ndh.Nmd} \cdot \frac{1}{3600} \varphi(t).Dk \tag{2}$$

**Table 1**. Probability of subscriber scenario

| No | Subscriber Scenario | Probability |
|---|---|---|
| 1 | High | $Pa$ = 0.33 |
| 2 | Moderate | Pb = 0.34 |
| 3 | Low | Pc = 0.33 |

### 2.3. Network Necessity

Network necessity aims to determine the number of base stations needed based on coverage and capacity requirements[15]-[17] for the mmWave 28 GHz frequency with a bandwidth of 400 MHz [18][19]. Calculating the coverage requirement is obtained by using $A = \pi r^2$, where $r$ is the circle's radius. The propagation model used is 3GPP 38.901 [20]. Eq. (3) shows the capacity requirement. $N(site)$ is the number of sites. $N(cell)$ is the number of cells. $Spectrum(eff)$ is the efficiency of the spectrum 14 bps/Hz/Cell (FDD UL-FR2, $\mu = 120$) for 28 GHz mmWave [21]. The value of the network necessity parameter is shown in Table 2 [22][23].

$$Cap(sys) = BW(MHz) \times N(site) \times N(cell) \times Spectrum(eff) \tag{3}$$

**Table 2**. Network necessity parameter

| No | Parameter | Value |
|---|---|---|
| 1 | Frequency | 28 GHz |
| 2 | Antenna sector | 3 |
| 3 | Bandwidth | 400 MHz |
| 4 | Spectrum Efficiency | 14 |
| 5 | Average cell throughput | 6,464 Mbps |
| 6 | Average site throughput | 19,392 Mbps |
| 7 | Range | 0.1 km |
| 8 | Coverage | 0.259 km$^2$ |

### 2.4. CAPEX and OPEX Requirements

Capital Expenditure (CAPEX) is the funds by a company to acquire, upgrade, and maintain physical assets [24]. Operational Expenditure (OPEX) is the expense required to function after the project is deployed [25]. Table 3 shows the infrastructure deployment cost to calculate the total CAPEX and OPEX [8][26].

**Table 3**. Base station deployment cost

| BS type | Cost type | CAPEX | OPEX |
|---|---|---|---|
| 5G micro mmWave | New site | $25,400 | $7,400 |

### 2.5. Revenue and Cash Flow

Customers' spending earns revenue, and we propose the subscription fee is $20 per month for this service. Each year's total revenue is shown in Eq. (4) [27]. $REV(y)$ is the revenue in year $y$. $N$ is the number of subscribers, and $M$ is the variable of customers to continue using the service. Assuming that customers continue using FWA after the project is deployed, $M = 1$. Cash flow is determined by CAPEX and OPEX, shown in Eq. (5) [27].

$$REV(y) = NU.12.M \tag{4}$$

$$\begin{aligned} CF(d)(y) &= -CAPEX(d) if\ y = 0 \\ &= REV(y) - OPEX if\ \ 0 < y \leq |Y| \end{aligned} \tag{5}$$

### 2.6. Net Present Value (NPV)

NPV is a tool to determine whether a project is worth investment. The project is considered profitable if the NPV is positive [28]. The project is not profitable if the NPV is negative [29]. This research considers

CAPEX in 2022, and subscribers will grow and produce revenue next year. $NPV$ value is shown in Eq. (6) [28]. $CF$ is cash flow, and $R$ is the discounted factor. In this research the value of $R = 0.1$ [8].

$$NPV = \sum_{k=0}^{k=n} \frac{CFi}{(1+R)^i} \tag{6}$$

Because there are three scenarios of the number of subscribers, the Expected $NPV(ENPV)$ will be shown in Eq. (7). $CFa$ is the cash flow of a high number of subscribers. $CFb$ is the cash flow of the number of moderate subscribers. $CFc$ is the number of the low subscriber.

$$ENPV = Pa\ x \sum_{k=0}^{k=n} \frac{CFai}{(1+R)^i} + Pb\ x \sum_{k=0}^{k=n} \frac{CFbi}{(1+R)^i} + Pc\ x \sum_{k=0}^{k=n} \frac{CFci}{(1+R)^i} \tag{7}$$

### 2.7. Valuation of 5G mmWave FWA Using Option to Delay the Project by One to Three Years

By deploying CAPEX in the year 2022, there is a probability that the NPV will result negatively because of the low number of subscribers in the next year. Consider that there is an option to delay the project and learn about the market or test the service. It means the CAPEX is not used in 2022. The project will be deployed if it results in a positive NPV or will be delayed in 2023-2025.

To evaluate the FWA project, we propose using Real Options analysis. Real Option (RO) is a way to make or abandon a choice or option concerning an investment evaluating an investment. There are three ways to determine the value of RO: using the Black Scholes model, the decision tree, and the Monte Carlo simulation. In this research, we use the decision tree and Black Scholes model to determine the value of the FWA project if we have the option to delay the project from one to three years [30][31].

The decision tree in the Real option represents the actual actions a company can make whether to expand or abandon the operation. By using Eq. (6), negative NPV means abandoning the project. Fig. 2 shows the scenario and action.

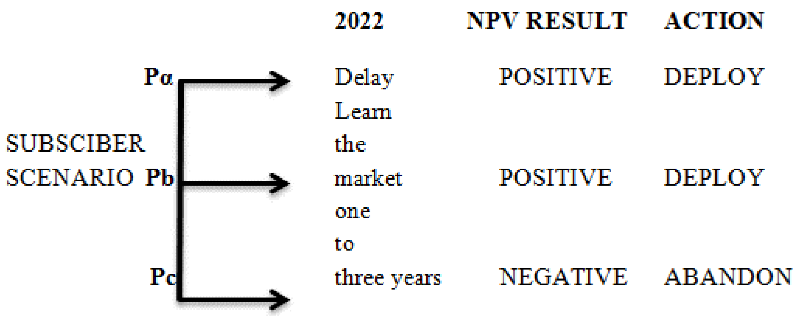


**Fig. 2** Decision tree scenario and action

The decision tree in Fig. 2 is to determine the Expected $NPV(ENPV)$ [32][33] of the FWA project by using Eq. (7). Then, we compare the $ENPV$ that gives the option to delay the project to study the market for one to three years and abandon the project if the result shows a low number of subscribers. Hence, the cash flow of a low number of subscribers is zero. Table 4 shows the details of different scenarios with learning the market for one year.

**Table 4**. The action of different scenarios with learning the market for one year

| Year | Subscriber Scenario | | |
|---|---|---|---|
| | **High** | **Moderate** | **Low** |
| 2022 | Learn | Learn | Learn |
| 2023 | Deploy network | Deploy network | Abandon |
| 2024 | Cash Flow | Cash flow | 0 |
| . | . | . | . |
| . | . | . | . |
| 2029 | Cash Flow | Cash Flow | 0 |

The second method to evaluate the FWA project is by using the Black Scholes model shown in Eq. (8) [34]-[36]. $V$ is the option's value. $X$ is CAPEX. $t$ is time to delay the project. $\sigma$ is project uncertainty. $r$ is the risk-free interest rate. We assume the value of $r$ is 6 %. $S$ is the present value of the project. $N$ is Normal cumulative distribution [37]-[40].

$$\mathrm{V} = \mathrm{S} \cdot \mathrm{N(d1)} - \mathrm{X} \cdot \mathrm{e}^{-rt}.N(d2) \tag{8}$$

$$d1 = \frac{ln\frac{S}{X} + \left(rt + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}} \tag{9}$$

$$d2 = d1 - \sigma\sqrt{t} \tag{10}$$

The uncertainty of each number of subscribers is shown in Eq. (11). $Eo$ is the ENPV in the year zero or 2022, and $Eys$ is the NPV of each scenario in the considered CAPEX. Because there are only two data hence $n = 2$, the uncertainty can be simplified in Eq. (12).

$$\sigma s = \sum_{k=0}^{k=n} \frac{(Eys - Eo)^2}{n-1} \tag{11}$$

$$\sigma = P\alpha(Ey\alpha - Eo)^2 + Pb(Eyb - Eo)^2 + Pc(Eyc - Eo)^2 \tag{12}$$

## 3. RESULTS AND DISCUSSION

### 3.1. Number of Subscribers

Using the Bass model from Eq. (1) results in the number of FWA subscribers shown in Table 5. In 2022 the project deployed it started to gain subscribers from 2023. The result shows in the high subscriber scenario in Table 5. The value of the average subscriber scenario number is 60 % of the high subscriber scenario, and the value of the low subscriber scenario number is 60 % of the moderate subscriber number. By 2028, there is a 33% probability that the subscriber of the FWA will be 4200 households, 34 % probability it will be 2520 households, and 33 % probability it will be 1512 households.

**Table 5.** Number of subscribers for each scenario

| Year | Subscriber Scenario | | |
|---|---|---|---|
| | **High** | **Moderate** | **Low** |
| 2022 | Deploy | Deploy | Deploy |
| 2023 | 359 | 216 | 130 |
| 2024 | 837 | 503 | 302 |
| 2025 | 1456 | 874 | 525 |
| 2026 | 2230 | 1338 | 803 |
| 2027 | 3154 | 1893 | 1136 |
| 2028 | 4200 | 2520 | 1512 |

### 3.2. Demand and Network Requirements

Using Eq. (2) and Eq. (3) will result in the requirement of Base Stations shown in Table 6**.** Table 6 shows the number of base stations needed to deploy FWA in Kota Wisata Cibubur based on coverage and capacity. The total demand of the FWA is 5,617 Mbps; hence from the capacity perspective, the number of base stations needed is three base stations. However, it will not cover all the residential areas. Seventeen base stations need to be deployed to cover the whole area.

**Table 6**. Total demand and network requirement

| Parameters | Value |
|---|---|
| Coverage area | 4.8 km² |
| Total demand | 5,617 Mbps |
| Average cell capacity | 6,464 Mbps |
| Average site capacity | 19,392 Mbps |
| Coverage of base station | 0.259 km² |
| Number of BS by capacity | 3 |
| Number of BS by coverage | 17 |

### 3.3. CAPEX and OPEX Requirements

CAPEX and OPEX Requirements are the total cost to deploy and maintain the FWA service. The OPEX is used in the early deployment, and the OPEX is a yearly cost for six years of FWA operations. From Table 6, the number of Base Stations needed is 17, and by using the cost of deployment in Table 3 and the requirement of CAPEX and OPEX are shown in Table 7.

**Table 7.** The requirement of CAPEX and OPEX

| Parameters | Value |
|---|---|
| Number of BS | 17 |
| Total CAPEX | $482,600 |
| Total OPEX | $140,600 |

### 3.4. Cash Flow and NPV of Each Scenario

In this research, CAPEX is deployed in the early year, which is 2022. The project is deployed and considered the year zero or the start of the project; hence the cost of the project is –CAPEX. The revenue is determined by using the number of subscribers of each scenario in Table 5 and using Eq. (4). Using Eq. (5), the Cash Flow of each scenario is shown in Table 8.

**Table 8.** Cash flow of each scenario

| Year | Subscriber Scenario | | |
|---|---|---|---|
| | High | Moderate | Low |
| 2022 | -CAPEX | -CAPEX | -CAPEX |
| 2023 | -$54,440 | -$88,760 | -$109,400 |
| 2024 | $60,280 | -$19,880 | -$68,120 |
| 2025 | $208,840 | $69,160 | -$14,600 |
| 2026 | $394,600 | $180,520 | $52,120 |
| 2027 | $616,360 | $313,720 | $132,040 |
| 2028 | $867,400 | $464,200 | $222,280 |

From Table 8, the FWA project will result in a positive NPV with both moderate and a high number of subscribers. This condition means that the project is profitable if it has at least a moderate number of subscribers. However, the low number of subscribers will result in a negative NPV, and the project will have a loss. The value of ENPV is $153,176. The result of ENPV shows that the project has a positive ENPV. It means the project is considered a valuable project. However, there is a 33 % probability that the project could have a negative NPV, so it is risky if CAPEX is deployed in 2022, as shown in Table 9.

**Table 9.** NPV of each scenario

| | Subscriber Scenario | | |
|---|---|---|---|
| | High | Moderate | Low |
| Probability | 33 % | 34 % | 33 % |
| NPV | $816,484 | $52,362 | -$406,246 |

### 3.5. Real Option (RO) Analysis

Using the decision tree method, the ENPV of the project if it has the option to wait and abandon the project if the result is low subscribers from one to three years shown in Table 10**.** It shows that by waiting from one to three years, the ENPV value is greater than the ENPV value where there is no option to delay the project. Using the method shown in Fig. 2, negative NPV means abandoning the project, delaying the project from one to two years, considered profitable even if there are a moderate number of subscribers because the NPV value is positive. Delaying the project for three years also shows greater ENPV value than having no option to wait or delay. However, it will become riskier as a moderate number of subscribers will result in a negative NPV. Hence the project will be profitable if only it has a high number of subscribers. This condition will give the manager more consideration about the FWA project and what kind of action to minimize the risk of loss.

Table 11 shows the option to wait or delay the project from one year to three years, which shows the value of ENPV by only using the standard NPV method. It means that the option to wait or delay the project is considered more valuable than no option at all. However, it only shows the value of the ENPV. Because there are three probabilities of the subscriber number, Black Scholes Model does not show whether each probability in the number of the subscriber has a risk of negative NPV.

**Table 10.** NPV result and ENPV given option to wait and abandon the project using Decision Tree

| Subscriber Scenario | Value Option to Wait | | |
|---|---|---|---|
| | 1 Year | 2 Years | 3 Years |
| LOW | Negative | Negative | Negative |
| MOD | Positive | Positive | Negative |
| HIGH | Positive | Positive | Positive |
| ENPV | $250,038 | $216,842 | $188,371 |

**Table 11.** ENPV was given the option to wait using Black Scholes Model

| | Option to Wait | | |
|---|---|---|---|
| | 1 Year | 2 Years | 3 Years |
| ENPV | $220,668 | $209,593 | $219,428 |

## 4. CONCLUSION

In some real cases of a telecommunication project, the project could be delayed and need some time to research before deployment. In this case, evaluating an FWA project using a decision tree and the Black Scholes model is effective. Based on the result, the option to delay the FWA project using decision three and the Black Scholes model shows a greater ENPV value than the standard NPV method. It means it is profitable to have an option to delay the project. The Black Scholes model is easy to use; however, it only shows the final ENPV value. It does not give information about the risk of each subscriber scenario

Using the decision tree method also results in a greater ENPV value. It also shows the value of each probability in the number of subscribers. Because of this, managers get more input about the risk included in the FWA project. Information about this risk is beneficial to arranging contracts, funds, and legal aspects of the FWA project and minimizing loss in the FWA project.

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