Maintenance Task Optimization of the BTS using RCM and LCC Methods

Rd Rohmat Saedudin, Judi Alhilman, and Tatang Mulyana

***Abstract*—To fulfill and to afford the best service for customers, the corporation needs to build the main infrastructure which is base transceiver stations (BTSs). The construction is purposed to make a wider network area in order to gain a good coverage to all Indonesian customers. Although the amount of BTS is growing, the equipment for supports will eventually have a damage session caused by continuous usage. This results in lost revenue for the corporation. To overcome this problem, the reliability centered maintenance (RCM) method is applied in order to get effective maintenance task and appropriate maintenance interval for BTS which works well to the functions, has a good availability, and reduces the potency of inappropriate maintenance and incorrect time of maintenance activity. It is necessary to determine optimum retirement age and the number of optimum maintenance site crew based on minimum life cycle cost (LCC) method. Based on data processing, the RCM method is used to the components in transmission subsystems for seven components which are GPON LINK, FIBER OPTIC, OMUX, RL NODE, RMJ MODULE, INFRATEL LINK, and RL NEC. Those include schedule on conditions and the other two components, which are IDU and E1 comprise the Run to failure schedule. Based on life cycle cost calculation, the smallest total LCC is IDR 54,467,056,568.00 with the optimum retirement age is 5 years and the optimum number of maintenance site crew is 5. The contributions of the paper take in the task and schedule maintenance identification, and the maintenance crews, optimum costs and economic life of each component.**

***Index Terms*—Life cycle cost, maintenance interval, maintenance task, reliability centered maintenance**

I. Introduction

IN the business of cellular telecommunication, the growth of customers of telecommunication cellular should be balanced with development of infrastructures. The main purposes of the business are to fulfill the company's customer needs and to provide the best service. PT XYZ is one of the provider companies which builds infrastructure to keep upright the growth of the telecommunication customers in term of telecommunication services.

Manuscript received July 24, 2015. This work was supported by the Telkom University under Partnership Research Grant.

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Over time, the number of customers grows rapidly. One of efforts to fulfill the customers' need in terms of infrastructure development is to build new BTSs. The purpose of developing the BTS is to make the networks widespread so that they can be reached by all customers throughout Indonesia. Based on the data, in 2003, it was built 4,820 BTS and there were 69,905 BTSs across Indonesia in 2013. This indicates that the company seriously fulfills the customer's needs. Although the number of the BTS is reproduced, the equipment will definitely be damaged if it is continuously used. It causes profit lost if the damage occurs to the BTS or if the BTS is downtime. Base on the data of downtime, the level of downtime of the BTSs in Bandung from January until December 2011 is shown in TABLE I.

Downtime causes revenue loss to the company due to malfunction of BTSs and no service to the customers, Therefore, it needs an effective maintenance task that can make the BTSs continue to operate in accordance with its function with good availability. Moreover, it is also required to reduce the potential for inaccuracy types of the maintenance activities and the error in the maintenance interval.

TABLE I
TOTAL DOWNTIME OF BTS IN BANDUNG FROM JAN-DEC 2011

Month	Total Downtime (Hours)
January	131.82
February	143.03
March	197.30
April	510.57
May	150.22
June	163.97
July	248.55
August	141.11
September	208.58
October	233.33
November	854.71
December	158.82

To achieve that requirement, in this paper, reliability centered maintenance (RCM) method is considered for BTS maintenance. The RCM method can give a maintenance task or suitable treatment for the BTS and also the appropriate maintenance interval to execute the maintenance activities. In addition, it is important to determine the optimum retirement age and the number of maintenance site crew to maintain the BTS based on minimum LCC method.

In this paper, the determination of effective maintenance task is conducted with two types of measurement: quantitative and qualitative measurement. Based on system breakdown structure, the output of the quantitative measurement is mean time to failure (MTTF) and mean time to repair (MTTR) of every BTS subsystem. To get the effective maintenance task, in this paper, the RCM method is demonstrated through quantitative measurement.

In recent years, the technological development in general and the spread on the territory of antennas for mobile phones have urged a state of widespread public concern repeatedly the social alarm verge. The need for a greater territorial coverage of mobile telephone service, due to the continuous request of users and to the presence of more operators in the market, has resulted in an intensification of the installations that not only make to a progressive decrease the power radiated from individual installations but also require that they be placed closer to homes with consequent concern of the population for their own health. In the case of BTS situated in the city areas, the technical choices are considerable various [1].

Reducing the power consumption of base transceiver stations (BTSs) in mobile communications networks is typically achieved through energy saving techniques, where they can also be combined with local power generators to create a hybrid power system (HPS). Such a system has reduced power consumption and operational cost, without taking the advantage of real-time energy management. In [2], Diamantoulakis has introduced the smart HPS that can facilitate energy consumption scheduling (ECS) via an intelligent connection to the power grid.

The increase of the base transceiver station (BTS) in most urban areas can be traced to the drive by network providers to meet demand for coverage and capacity. In traditional network planning, the final decision of BTS placement is taken by a team of radio planners; this decision is not fool proof against regulatory requirements. In [3], an intelligent based algorithm for optimal BTS site placement has been proposed.

A Base Transceiver System (BTS) is a system in a mobile communication network that houses radio receivers and is used for wireless communication between users and network providers that is under the control of Base Switching Controller (BSC) and then the exchange [4]. The power consumption of wireless access networks has become a major economic and environmental issues, providing dedicated power supply for cell sites is one of the major issues for mobile communication system. In particular, base stations cause more than 80% of the operator’s power consumption, which makes the design of base station a key element for determining both the environmental impact of wireless networking and the operational expenditure. Utilizing renewable energy sources such as the solar, wind and bio – fuels as an alternative energy would be the ultimate solution to the mobile telecommunication industry [5].

Optimal signal coverage has always been a fundamental issue for cellular network operators. Other issues related to capacity, quality of service and cost efficiency are also rapidly gaining prominence. In order to determine signal coverage, network engineers usually rely mainly on two dimensional (2D) terrain maps and rather simple empirical propagation-prediction models. In this paper, a framework which provides a more efficient and cost effective network coverage optimization for a dense urban environment is investigated. 3D Geographic Information System (GIS) of the study area is developed. The signal propagation-prediction tool based on ray-tracing coupled with the 3D geo-information is used to model the radio signal coverage for the Base Transceiver Stations for one of the mobile phone operators licensed to provide mobile phone services in Kenya. To determine the best locations of the BTSs for optimal signal coverage of the study area, spatial analysis tools in GIS are employed. Comparing the proposed methodology with classical methods demonstrates that this spatial analysis approach can be used to optimize mobile signal coverage in any dense urban environment without resorting to lengthy field measurements thus minimizing on costs of wireless network planning [6].

The rapid growth of the mobile telecommunication sectors of many emerging countries creates a number of problems such as network congestion and poor service delivery for network operators. This results primarily from the lack of a reliable and cost effective power solution within such regions. Okundamiya [7] has presented a comprehensive review of the underlying principles of the renewable energy technology (RET) with the objective of ensuring a reliable and cost-effective energy solution for a sustainable development in the emerging world. The grid-connected hybrid renewable energy system incorporating a power conversion and battery storage unit has been proposed based on the availability, dynamism, and techno economic viability of energy resources within the region. The proposed system’s performance validation applied a simulation model developed in MATLAB, using a practical load data for different locations with varying climatic conditions in Nigeria.

The paper by Afefy [8] has described the application of reliability-centered maintenance methodology to the development of maintenance plan for a steam-process plant. The main objective of reliability-centered maintenance is the cost-effective maintenance of the plant components inherent reliability value. Applying of the reliability-centered maintenance methodology shows that the main time between failures for the plant equipment and the probability of sudden equipment failures are decreased. The proposed labor program is carried out. The results show that the labor cost decreases from 295200 $/year to 220800 $/year (about 25.8% of the total labor cost) for the proposed preventive maintenance planning. Moreover, the downtime cost of the plant components is investigated. The proposed PM planning results indicate a saving of about 80% of the total downtime cost as compared with that of current maintenance. In addition, the proposed spare parts programs for the plant components are generated. The results show that about 22.17% of the annual spare parts cost are saved when proposed preventive maintenance planning other current maintenance once. Based on these results, the application of the predictive maintenance should be applied.

PT. XYZ is a company engaged in telecommunications services which customers spread throughout Indonesia [9]. In order to meet consumer needs, companies must always keep the reliability of telecommunication devices such as tool is the Base Transceiver Station (BTS). BTS has a very important role in the process of telecommunication, so if the Base stations damage, it would result in down time that will affect the company. Based on historical data, corrective maintenance for BTS tool in 2013 reached 16% of the overall total corrective maintenance telecommunications equipment. This happens because there are frequent sudden damages to the appliance. Maintenance managers have not been able to calculate the cost of maintenance needs to ensure performance tool because it could not predict the condition of these tools. Additionally, the tool will undergo aging and increased hazard rate, so that the calculation of the economic life of the unit and the optimal amount of maintenance crews need to be done. To determine the economic life of the unit and the optimal amount of maintenance crews in this paper used the method Life Cycle Cost (LCC) and to simplify the calculation, then made an application LCC calculation. The output of this application is to estimate useful life of components and estimate the optimal amount of maintenance crews.

The combination of more data-hungry devices and higher service expectations on the part of users has led to inevitably high global mobile data traffic which in turn translates in to huge impact on the environment. In order to analyze and minimize the impact on environment from whole activities (initial to final process), Life cycle assessment (LCA) helps in achieving carbon credits [10]. Carbon Credits provide an efficient mechanism to reduce the greenhouse gas emissions by monetizing the reduction in emissions. In order to protect ourselves, our economy, and our land from the adverse effects of climate change, we must reduce emissions of carbon dioxide and other greenhouse gases. Life-cycle assessment (LCA) is the methodology which can be used to consider carbon footprint or we can say that considering the impact on CO2 emissions. This paper discussed the approach of LCA of wireless BTS which can help the telecom operators to reduce the carbon footprints of Wireless mobile communication networks.

The first step is identifying the function and the performance standard of the subsystems. The performance standard will acquire a functional failure that causes the failure of a subsystem. From the functional failure, it will be obtained the failure mode that causes occurrence of the functional failure. The failure mode can be caused by weather, disasters, or the occurrence of defects in components within the subsystem that will bring impact or failure effect.

The failure effect itself is divided into three groups: local, system, and plant. It will cause failure consequences. The failure consequences will greatly effect to determination of maintenance task. Life cycle cost analysis is then used to achieve minimum total cost along life time period of the BTS. Life cycle costs are summation of sustaining cost and acquisition cost.

In this paper, the retirement age and the number of maintenance site crew are combined in order to achieve minimum life cycle cost. According to [11], the maintenance is to ensure that physical assets continue to do as required by users. From [12], the maintenance is divided into two groups, i.e. preventive and corrective maintenance. The classification of maintenance is shown in Fig. 1.

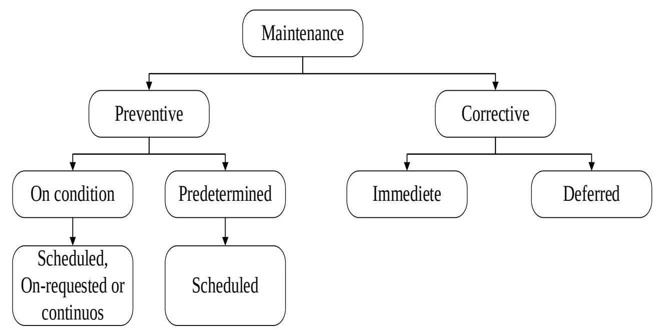

Fig. 1. Maintenance classification.

According to [12], the preventive maintenance is defined as maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of the equipment. The corrective maintenance is maintenance carried out after fault recognition and intended to put the equipment into a state in which it can perform a required function.

According to [13], reliability is defined to be the probability that a component or system will perform a required function for a given period of time when used under stated operating conditions. The reliability value of a component or system is usually expressed in terms of probability, with value of R (reliability) between 0-1. MTTF is an average time or expectation of failure of a component or system that operates under normal conditions. According to [13], if the rate of failure of a component or system is not related to the life cycle and other characteristics in the history of its use, then used a statistical distribution is exponential (failure rate is constant) expressed by the parameter λ. If the rate of failure depends on life cycle, then normal statistical distribution and weibull distribution are used. An exponential distribution equation is demonstrated in (1), the normal distribution is displayed in (2), and the weibull distribution is shown in (3).

$$MTTF = \int \mathrm{R(t)dt} = \frac{1}{\lambda} \quad (1)$$

$$F(t) = \Phi\left(\frac{t-\mu}{\sigma}\right) \quad (2)$$

$$MTTF = \eta . \Gamma\left(1 + \frac{1}{\beta}\right) \quad (3)$$

II. RCM AND LCC METHODS

According to [1], a RCM is a process used to determine the maintenance requirements of any physical asset in its operating context. The main objective of the RCM is to preserve system function by identifying the failure mode and prioritize it, and then selecting the effective preventive maintenance. According to [11], there are 7 stages in the RCM, they are:

1. Selection of systems and information collection. In the selection of system, a system that will be selected is a system that has a high frequency of corrective maintenance, the high cost and greatly affect to the process on the environment.
2. Definition of system boundaries. Definition of the system boundaries is to find out what is included and not include in the system.
3. System description and functional diagram block (FDB). Once the system is selected, and then the system wills describe for identifying and documentation the important details of the system.
4. Determination of function and functional failure. Functions can be defined as what is done by equipment that is user expectations. Functions related to the problem of speed, output, capacity, and quality of products. Failure can be defined as the inability of equipment to do what is expected by the user. The functional failure can be defined as the inability of equipment to fulfill its function in the performance standard which can be received by users.
5. Failure Mode and Effect Analysis (FMEA). The failure mode is a condition that can lead to functional failure. If the failure mode is already known it is possible to determine the impact of failure that describes what will happen when the failure mode occurs, and then used to determine the consequences and decide what will be done to anticipate, prevent, detect, or correct it.
6. Logic Tree Analysis (LTA). Logic Tree Analysis is a qualitative measurement to classify failure mode. Failure mode can be classified into four categories, they are: a. Safety Problem (A category). Failure mode has consequences to injure or threaten someone; b. Outage Problem (B category). Failure mode can shut down the system; c. Minor to Investigation Economic Problem (C category). Failure mode has no impact on system and the impact is relatively small and can be ignored; d. Hidden Failure (D category). Failure mode can't be known by the operator.
7. Task Selection. Task Selection is done to determine the maintenance tasks that are likely to be applied and select the most efficient task for each failure mode.

According to [11], the preventive maintenance will take before the failure happens. In the RCM, preventive maintenance is divided into three categories, i.e. schedule on-condition tasks, scheduled restoration task, and discard tasks. Scheduled on-condition tasks entail for potential failure, so that action can be taken to prevent the functional failure or to avoid the consequences of the functional failure. Scheduled on-condition tasks are technically feasible if, (a) it is possible to define a clear potential failure condition, (b) the P-F interval is reasonably consistent, (c) it is practical to monitor the item at intervals less than the P-F interval, and (d) the net P-F interval is long enough to be of some use (in other words, long enough for action to be taken to reduce or eliminate the consequence of the functional failure). Fig. 2 shows a P-V Curve [11].

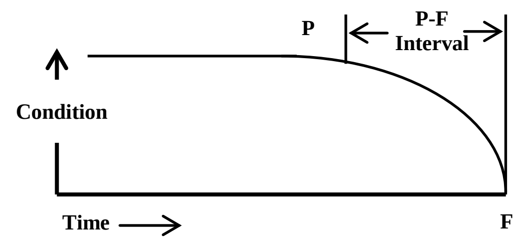

Fig. 2. P-F Curve [9]

Scheduled on-condition task should be performed at intervals less than the P-F interval. In practice, usually to determine the frequency for maintenance task, it can be used as the reference is half the P-F interval. Hence, the equation used to determine the interval scheduled on-condition task is as follows.

$$PM = \frac{1}{2} x P - F\ Interval \quad (4)$$

Scheduled Restoration Task is an existing component of recovery efforts periodically with aims to restore the system to its original condition. This action is done if on-condition task is not allowed to do. The scheduled restoration task can be done when the system is not operating and is generally performed in the workshop, so that it always affects production activities and requires more power than the on-condition task.

Scheduled Discard Task is an activity that is most cost-effective among the three preventive tasks. This is because the scheduled discard tasks require replacing components before the system regardless of the age limit condition. This activity is done in the hope of resilience of the system failure will recover after replacing old components with new components.

Life cycle cost is summations of cost estimate from inception to disposal either equipment or project depends on study analysis and estimates of total cost of ownership [14]. The purpose of LCC analysis is to choose the most effective cost approximately so that the cheapest cost term ownership is achieved from some alternatives. In this research, life cycle cost model is shown as Fig. 3.

Maintenance Cost is affected by repair cost and the number of maintenance site crew. Shortage Cost is a cost which has to spent because the equipment waiting for repair as effect of insufficient maintenance site crew. Acquisition Cost is a cost which has to spend on initial purchase of equipment or system. Acquisition Costs are summation of purchasing cost and population cost.

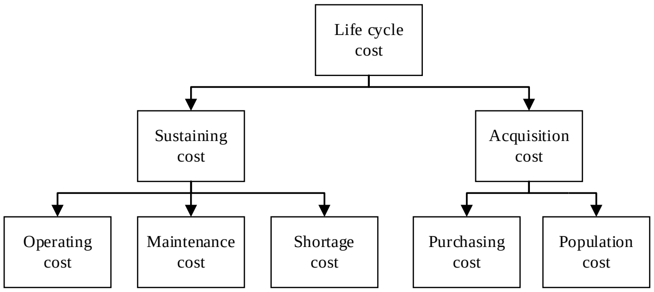

Fig. 3. Life Cycle Cost Mode

TABLE II
TOTAL DOWNTIME EVERY COMPONENT OF THE TRANSMISSION BTS SUBSYSTEM

Component	Total Downtime/Year (Hour)
GPON LINK	154,230.000
FIBER OPTIC	103,103.000
OMUX	177,249.000
RL NODE	21,979.000
RMJ MODULE	32,093.000
INFRATEL LINK	17,597.000
E1	0.671
IDU	46,490.000
RL NEC	0.587

Purchasing Cost is a total cost to purchase all equipment needed in system. Every different retirement age results in differences of annual purchasing cost. In annual purchasing cost calculation, it is important to consider interest rate. Population Cost is a cost which has to spend every period as the cost of ownership of equipment. Population Cost is calculatesd by multiplying annual equivalent cost with the number of population in system.

III. RESULT AND DISCUSSION

In this paper, the first step is selecting the components on critical subsystem that will be carried out with quantitative and qualitative measurement using RCM. Based on the results of surveys and interviews, subsystems that have a critical level are the transmission subsystems. The transmission subsystem has a high level of critical because if that subsystem is down, the BTS will not be able to cover the nearby customers. The amount of downtime every component on the BTS transmission subsystems can be seen in TABLE II.

After the determination of the critical subsystems, it will be measured quantitatively. In the quantitative measurement performed to obtain parameters of reliability and maintainability. The reliability of the parameters is represented by the MTTF, while the maintainability parameters are represented by the MTTR. Results of quantitative measurements can be seen in TABLE III. After obtained the MTTF and MTTR parameters, then the qualitative measurement is done by using RCM. Results from these measurements are maintenance tasks and intervals of maintenance for transmission subsystem. Results of qualitative measurements by RCM can be seen in TABLE IV.

TABLE III
RESULTS OF QUANTITATIVE MEASUREMENT

Component	MTTF (Hour)	MTTR (Hour)
GPON LINK	795.876	13.360
FIBER OPTIC	124.934	12.888
OMUX	741.770	5.542
RL NODE	1,350.900	5.619
RMJ MODULE	4,050.680	0.856
INFRATEL LINK	109.711	0.239
E1	19,008.000	0.223
IDU	7,588.030	1.139
RL NEC	621.517	0.195

TABLE IV
RESULTS OF QUANTITATIVE MEASUREMENT

Component	Preventive Maintenance Category	Proposed Task	Initial Interval (hour)
GPON LINK	Scheduled on-condition task	Monitoring VSWR and DC power	397,938.0
FIBER OPTIC	Scheduled on-condition task	Monitoring cable physical and optical power	62,467.0
OMUX	Scheduled on-condition task	Monitoring VSWR, DC and optical powers	370,885.0
RL NODE	Scheduled on-condition task	Monitoring VSWR and DC power	675,450.0
RMJ MODULE	Scheduled on-condition task	Monitoring VSWR and DC power	2,025,340.0
INFRATEL LINK	Scheduled on-condition task	Monitoring VSWR and DC power	39,370.0
E1	Run to failure	-	-
IDU	Run to failure	-	-
RL NEC	Scheduled on-condition task	Monitoring VSWR and DC power	310,758.5

Total life cycle cost is computed by summation of sustaining cost and acquisition cost. Sustaining cost is a cost which has to spend along operation of equipment. Sustaining cost consists of annual operating cost, annual maintenance cost, and annual shortage cost. Annual Operating Cost is a cost which has to spend to operate equipment or system every year during life period of equipment. During operation of BTS, the cost spent includes operating labor cost and energy cost. Operating cost calculation shown as TABLE V.

TABLE V
OPERATING COST

Operating Name	Cost (IDR)
Energy	3,079,296,000,000.00
Labor	1,478,400,000,000.00

Total Cost: 12 months x 88 man x IDR.700,000.00 x 2 shift

Annual maintenance cost is a cost which has to spend to maintain the equipment in period of time. Maintenance Cost consists of maintenance labor cost and repair cost is presented in TABLE VI.

Calculation above shows for retirement age 1 years and maintenance site crew (M = 1). Shortage Cost is a cost which has to spent because the equipment waiting for repair as effect of insufficient maintenance site crew. Annual shortage cost is affected by the number of maintenance site crew and probability of unit in waiting lines. Calculation of shortage cost for (n =1 years) and (M = 1 to 5) is shown in TABLE VII.

TABLE VI
MAINTENANCE COST

Maintenance Name	Cost (IDR)
Maintenance	3,436,161,685.56
Maintenance Labor	180,000,000.00

Total Cost: 12 months x IDR15,000,000.00 = IDR 3,616,161,685.56

TABLE VII
SHORTAGE COST

M	Pr0,0	Annual Shortage Cost (IDR)	Total Unit	Total Annual Shortage Cost (IDR)
1	0.949	38,425,486.90	68	2,617,108,827.00
2	0.950	37,506,998.99	48	1,808,487,761.00
3	0.951	37,476,175.20	28	1,048,873,296.00
4	0.951	37,475,595.07	4	157,143,045.00
5	0.952	37,475,586.28	5	185,506,021.00

Potential Revenue: IDR 2.094.065.81
Queuing (day): 17 (for all, exception for M=1)

TABLE VIII
ANNUAL PURCHASING COST

N	A/P, 12%, n	Annual Purchasing Cost (IDR)	Total (IDR)
1	1.120	1,344,000,000.00	118,272,000,000.00
2	0.592	710,037,736.00	62,483,320,755.00
3	0.416	499,618,777.00	43,966,452,347.00
4	0.329	395,081,324.00	34,767,156,474.00
5	0.277	332,891,678.00	29,294,467,693.00
6	0.243	291,870,862.00	25,684,635,866.00
7	0.219	262,941,283.00	23,138,832,911.00
8	0.201	241,563,410.00	21,257,580,049.00
9	0.188	225,214,667.00	19,818,890,654.00
10	0.177	212,380,997.00	18,689,527,735.00
11	0.168	202,098,485.00	17,784,666,694.00
12	0.161	193,724,169.00	17,047,726,882.00
13	0.156	186,812,634.00	16,439,511,804.00
14	0.151	181,045,495.00	15,932,003,589.00
15	0.147	176,189,088.00	15,504,639,707.00

Unit Price: IDR 1,200,000.00
Total of BTS: 88

TABLE IX
BOOK VALUE

Retirement Age	Salvage Value (IDR)	Book Value (IDR)
1	1,080,000,000.00	1,192,0000,000.00
2	972,000,000.00	1,169,600,000.00
3	874,800,000.00	1,134,960,000.00
4	787,320,000.00	1,089,952,000.00
5	708,588,000.00	1,036,196,000.00
6	637,729,200.00	975,091,680.00
7	573,956,280.00	907,846,264.00
8	516,560,652.00	835,499,014.00
9	464,904,587.00	758,942,752.00
10	418,414,128.00	678,942,752.00
11	376,572,715.00	596,153,325.00
12	338,915,444.00	511,132,355.00
13	305,023,899.00	424,354,046.00
14	274,521,509.00	336,220,075.00
15	247,069,359.00	247,069,359.00

Purchasing Cost: IDR 1,200,000.00

Purchasing Cost is a total cost to purchase all equipment needed in BTS system. In this paper, the purchasing cost consists of all initial cost in constructing BTS as shown in TABLE VIII.

Book value calculation is used to determine value of equipment in the end years of use according to equipment's life estimate. In this calculation assumed that BTS have 10% depreciation every year and life estimates is 15 years. Book value calculation is shown as TABLE IX.

Population cost is a cost which has to spend every period as the cost of ownership of equipment. Population Cost is calculated by multiplying annual equivalent cost with the number of population in system. TABLE X presents an annual population cost. Life cycle cost is calculated after all cost before gained. Life cycle cost of the BTS for each retirement age and maintenance site crew is shown as

TABLE X
ANNUAL POPULATION COST

Retirement Age	Annual Equivalent Cost (IDR)	Annual Equivalent Population Cost (IDR)
1	800,000.00	704,000,000.00
2	30,400,000.00	2,675,200,000.00
3	65,040,000.00	5,723,520,000.00
4	110,048,000.00	9,684,224,000.00
5	163,804,000.00	14,414,752,000.00
6	224,908,320.00	19,791,932,160.00
7	292,153,756.00	25,709,528,768.00
8	364,500,986.00	3,076,086,733.00
9	441,057,248.00	38,813,037,817.00
10	521,057,248.00	45,853,037,817.00
11	603,846,675.00	53,138,507,439.00
12	688,867,645.00	60,620,352,758.00
13	775,645,954.00	68,256,843,939.00
14	863,779,925.00	76,012,633,356.00
15	952,930,641.00	83,857,896,451.00

Population: 88

TABLE XI. Determination of optimum retirement age and the number of maintenance site crew is decided based on the minimum life cycle cost. According to life cycle cost calculation, the optimum retirement age is 5 years and the number of maintenance site crew is 5 with total annual life cycle cost IDR 54,476,056,568.00

TABLE XI
TOTAL LIFE CYCLE COST

N	M=1 (IDR)	M=2 (IDR)	M=3 (IDR)
1	129,766,966,827	129,138,345,761	128,558,731,296
2	76,671,190,206	76,028,812,525	75,462,120,724
3	61,982,107,708	61,322,635,696	60,758,149,203
4	57,585,891,671	56,905,260,294	56,341,892,215
5	57,754,644,740	57,047,916,174	56,485,371,866
6	60,507,615,985	59,768,808,344	59,206,683,966
7	64,946,496,785	64,168,383,595	63,606,,067,124
8	70,587,757,853	69,761,634,792	69,198,227,429
9	77,138,963,285	76,254,378,928	75,688,592,131
10	84,408,432,452	83,452,880,381	82,882,898,853
11	92,263,521,766	9,122,092,601	90,645,392,789
12	100,609,266,502	99,464,260,465	98,877,370,780
13	109,376,493,953	108,106,997,981	107,505,182,857
14	118,514,735,597	117,096,174,352	116,473,018,936
15	127,987,767,559	126,391,445,906	125,738,311,231

Population: 88

TABLE XI
CONTINUED

N	M=7 (IDR)	M=8 (IDR)	M=9 (IDR)
1	128,490,825,831	128,708,465,562	128,926,066,443
2	75,065,971,910	75,287,445,868	75,508,881,682
3	60,013,006,144	60,238,694,749	60,464,345,853
4	55,214,401,882	55,444,720,499	55,675,002,211
5	54,938,165,965	55,173,567,522	55,408,932,739
6	57,199,011,585	57,439,989,229	57,680,931,114
7	61,093,606,156	61,340,695,826	61,587,750,509
8	66,132,855,634	66,386,637,787	66,640,387,052
9	72,018,167,756	72,279,260,257	72,540,334,156
10	78,551,184,014	78,820,098,635	79,089,177,821
11	85,595,176,763	85,868,986,767	86,146,804,130
12	93,161,924,979	93,322,628,015	93,609,958,219
13	103,505,813,417	101,102,943,474	101,400,265,051
14	114,331,392,198	109,163,586,840	109,457,039,855
15	123,681,230,615	118,205,614,202	117,732,763,763

Population: 88

TABLE XI
CONTINUED

N	M=10 (IDR)
1	129,766,966,827
2	76,671,190,206
3	61,982,107,708
4	57,585,891,671
5	57,754,644,740
6	60,507,615,985
7	64,946,496,785
8	70,587,757,853
9	77,138,963,285
10	84,408,432,452
11	92,263,521,766
12	100,609,266,502
13	109,376,493,953
14	118,514,735,597
15	127,987,767,559

Population: 88

IV. CONCLUSION

Based on the results of the measurements using RCM method, the obtained maintenance tasks for critical components in the transmission subsystem were 7 scheduled on-conditions and two were run to failure. Based on the results quantitative measurement, it was obtained interval maintenance for each component in accordance with the maintenance task on these components: GPON LINK its maintenance interval 397,938 hours, FIBER OPTICS 62,467 hours, OMUX 370,885 hours, RL NODE 675,450 hours, RMJ MODULE 2,025,340 hours, INFRATEL LINK 39,370 hours, and RL NEC 310,758.5 hours. The components E1 and IDUs did not have interval maintenance because the maintenance task was run to failure. Based on life cycle cost calculation, the minimum life cycle cost minimum was IDR 54,476,056,568.00 with retirement age optimum was 5 years and the optimum number of maintenance site crew was 5. The paper contributions were as follow: the task and schedule maintenance known, the maintenance crews, optimum costs and economic life of each component.

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