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FINANCIAL ESTIMATION ON STREET LIGHTING USING LED TECHNOLOGY

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Abstract

Light emitting diode (LED) technology has been widely used for street lighting. However, this implementation needs a large amount of initial investment which makes it costly. The replacement of sodium lamps with LED technology requires a comprehensive budget analysis. This research aims to calculate the probability of cost and energy reduction in the process of street lighting replacement by using LED technology. The sample in this research is Jalan Soekarno Hatta (Soekarto Hatta street) as long as 1,470 meters with a total of 54 poles. Based on our analysis, although the initial investment is relatively higher (twice as much of that of the conventional lighting) the use of LED technology is highly recommended as it is more economical in a long term. The cost of lamp replacement decreases by 51% during its time of use. This result shows that the use of LED technology in street lighting is more efficient and has a relatively lower operating expense.

Keywords: Light-Emitting Diode (LED), Investment analysis, LCCA, Street lighting.

1. Introduction

Street lighting systems are one of the subsystems of the whole lighting systems used by human beings. Public street lighting is a vital facility required by people to navigate, increase safety and comfort, support a conducive environment, and provide environmental aesthetics at night. Street lighting is also needed to support economic activities and mobility of the people at night. The appropriate and sufficient lighting in a particular location of the street is crucial in creating safety for the people [1]. The system of street lighting has a lot of positive impacts on the lives of people [2]. The increasing number of activities conducted at night requires better street lighting because it can minimize the crimes at night [3]. Currently, most of the street lighting use the conventional system with mercury or sodium lamps, requiring high electrical power [4]. This conventional system requires high operating and maintenance cost because the mercury or sodium lamps are easily damaged. Even though the spare parts of these lamps are relatively inexpensive, their durability is poor. Therefore, lamp replacement is often made. Now, there are light emitting diode (LED) lamps which provide more energy efficiency than the conventional ones [5]. LED bulbs are considered the best choice because their power consumption (watt) is relatively lower and their lifespan is longer [6,7]. Therefore, the lamp replacement using LED lamps is the most realistic action. In the future, LED lamps will be more appropriate to be used because LED technology offers better lighting, a higher level of efficiency, and better cost-effectiveness in the long run [8].

The lamp replacement using LED technology has several benefits. LED lamps provide more energy efficiency as they need lower power consumption and have a longer lifespan up to 50,000 hours, making these lamps the best choice for the time being [9-11]. However, the drawback of this technology is its higher initial investment. Several previous studies were conducted by some researchers worldwide, studying the high initial investment of replacing the conventional lamps with LED lamps [12-14]. This high initial investment perhaps becomes the primary barrier of using LED technology [15]. Creating efficient management helps the government to establish the project of energy efficiency related to the financial feasibility [16]. Identifying available technologies and analyzing costs and benefits can be done by simulating some scenarios in several cities [17].

The replacement project of public street lighting with a better alternative may require considerable investment. Nonetheless, it may have many advantages in the investment process, which are a relatively short payback period and promising investment. Investment analysis needs to be done to see the benefits of every investment because investment is strongly influenced by such factors as uncertainty or risk. The high level of uncertainty has a negative impact on any investment [18]. The increasing uncertainty can increase the value of options but can hinder new investment invested [19]. Investors should conduct investment evaluation and consider uncertainty factors by using several technologies in different levels of uncertainty [20]. Likewise, in the process of replacing street lighting with LED technology, the uncertainty factors affecting investment in Indonesia include the price of the component due to a change in interest rate and government policies regarding basic electricity tariffs (TDL). The increase in component price of approximately 10% per year and the basic electricity tariffs that often occur in Indonesia will also increase the amount of investment that will be invested subsequently; thus, supporting the opinions of some researchers, uncertainty has a negative effect on investment and can hinder the new investment invested [18, 19]. The purpose of this research is to calculate the possibility of cost and energy savings in the process of replacing the conventional street lighting with LED technology. This paper described in traditional methodologies such as Net Present Value (NVP), Internal Rate of Return (IRR) to analyze the viability of the project and to evaluate all the costs, Life-Cycle Cost Analysis use NVP associated with the project during its lifetime. Traditional methodologies only influenced by the cost that is used at the time and ignore the actions of management, strategic options, flexibility and uncertainty [21, 22]. Uncertainty factors that can affect investment in lamp replacement can be used as meaningful input for policymakers in the city of Bandung, Indonesia. The government is expected to be able to anticipate fluctuations in basic component prices by determining a fixed interest rate, a low import duty tax, and the determination of the basic electricity tariff that does not change significantly. Also, the results of the calculation are expected to be a strategic recommendation for the process of replacing other public street lightings in the city of Bandung in order that the further investment costs can be predicted in a more extended period.

2. Method

2.1. Primary framework

The framework used in this study is shown in Fig. 1. In short, the framework was initiated by literature study. Then, it is followed with data collection as well as analysis and calculation. Based on the analysis and calculation step, we can conclude whether the suggested ideas are appropriate or not to be implemented.

2.2. Research location

The location of this research is at Soekarno Hatta Street (1,470 meters long) which has the intersections of Buah Batu Street until Ibrahim Adjie Street and Cijagra Street until Buah Batu Street. This street is one of the longest streets in Bandung, Indonesia. Soekarno Hatta Street was chosen as the research sample because it is the only street in Gedebage area which still uses conventional street lighting and its magnitude of illumination is the lowest compared to others. Consequently, Soekarno Hatta Street consumes a huge amount of energy, yet the lighting level is smaller than that in other streets in the Gedebage area, Bandung. Also, as the primary arterial road in Bandung with the status of a State/National Road, Soekarno Hatta Street requires special attention in its lighting planning because this street is long, broad and wide. Thus, this street requires a proper and energy-efficient lighting system.

2.3. Data collection

The data were collected from direct surveys to the field and from the Public Works Agency of Highways and Irrigation, specifically from the Technical Implementation Unit (UPT) of Public Street Lighting (PJU) of the Republic of Indonesia. The data include the road class, the standard of unit price for goods, electricity bill list, types of lamps used street lighting, and the type and shape of the pole.

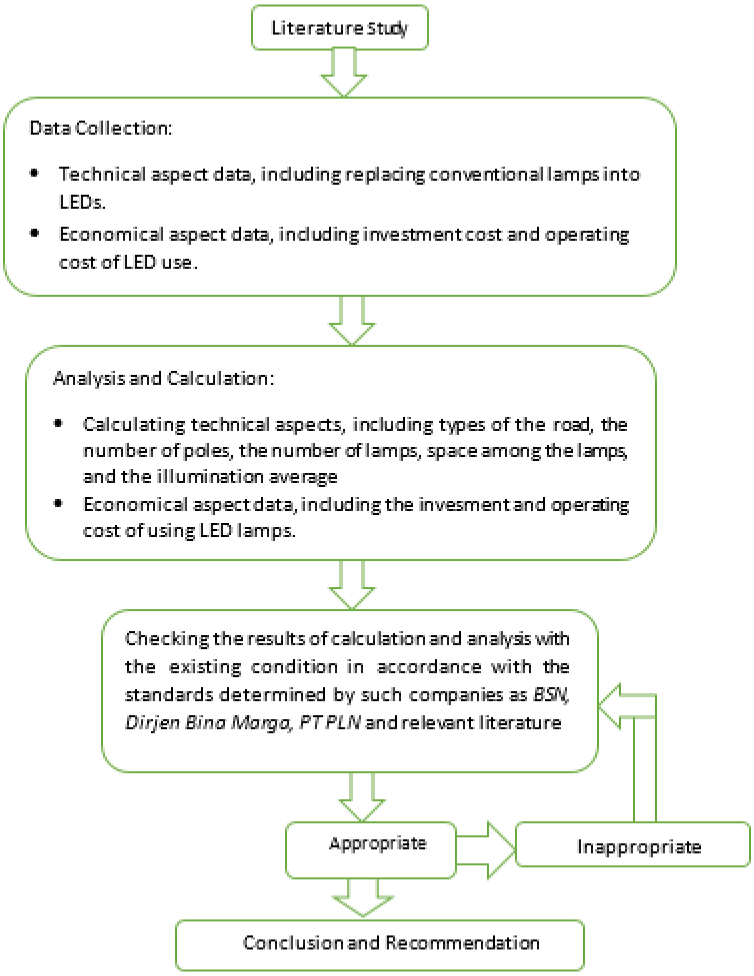

Fig. 1. Framework used in this study.

2.4. Formulation of financial estimates using Life Circle Cost Analysis

Some of the analysis methods which can be used to measure the performance level of a product or material are *Life Cycle Cost Analysis (LCCA), Benefit-to-cost Ratio, Interval Rate of Return, Net Benefit, Payback, and Multi-attribute Decision analysis*. In this research, the method used to analyze the economic value of public lamp replacement considers the lifespan of the lamp using *Life Cycle Cost Analysis (LCCA), Benefit-to-cost Ratio and Internal Rate of Return*. LCCA is one of the economic calculation methods to evaluate the use of all costs of a project. LCCA is useful to use when we get alternative projects or jobs with the same performance requirements, but have different initial costs and operating costs. So, we have to compare to choose an alternative project or job that has maximum savings. With LCCA, we can also determine the cost of ownership or initial investment, operating cost, maintaining cost, and disposing cost. Besides, LCCA is used to determine the lowest cost of a project and is used for various investment decisions in evaluating the relative costs of an investment. In this study, two forms of calculations were used in the LCCA method, namely: (1) life cycle costing and (2) parameter supplementary costing.

2.4.1. Life Cycle Costing (LCC)

Life cycle costing is calculated based on the number of future costs and current costs of a project during its life cycle [8]. The calculation process in street lighting project uses data including costs which are measured based on the lifespan of each product, the rate of product replacement, and the period of the project. The equation for the LCC is written as follows:

$$LCC = PC + \sum_{1}^{N} \frac{(OC)}{(1-r)t} \tag{1}$$

2.4.2. Calculation of parameter supplementary

2.4.2.1. Calculation of Electricity Consumption

Electricity Consumption (EC) is the total electricity consumption calculated from the multiplication of the number of street lighting, the power of each lighting, and the duration of lamp usage in one day, divided by 1000. The EC equation is written as follows:

$$EC = \frac{N\ x\ W\ x\ OH}{1000} \tag{2}$$

2.4.2.2. Calculation of Energy Saving

Energy Saving (*ES*) is calculated using the difference in value between the total energy consumption used at this time and total energy consumption after the lamp replacement process is carried out. The ES equation is written as follows:

$$ES = EC_{(\text{Existing})} - EC_{(\text{Retrofitting})} \tag{3}$$

2.4.2.3. Calculation of bill saving

This calculation is the multiplication between energy saving and power basic rate. Below is its equation.

$$BS\ =\ ES\ x\ ET \tag{4}$$

2.4.2.4. Calculation of operating cost

This is the total cost of the entire street lighting replacement. The equation is as follows.

$$OC\ =\ N\ x\ W\ x\ OH\ x\ ET \tag{5}$$

3. Results and Discussion

This research started with the survey and data collection of street lighting in Gedebage area, Bandung, Indonesia. Geographically, Bandung is divided into six areas. This research focuses on Gedebage whose protocol roads (arterial roads) are taken based on the map of Bandung city shown in Fig. 2. On that map, the characteristics of the arterial road are marked yellow. The arterial streets in the Gedebage area consist of six streets, namely Soekarno Hatta Street, Terusan Buah

Batu Street, Cipagalo Street, Marga Cinta Street, Ciwastra Main Street, and Terusan Kiaracondong Street. However, in this study, we only sampled Soekarno Hatta Street. The replacement process of 54 points are explained in the side of the research is shown in Fig. 3.

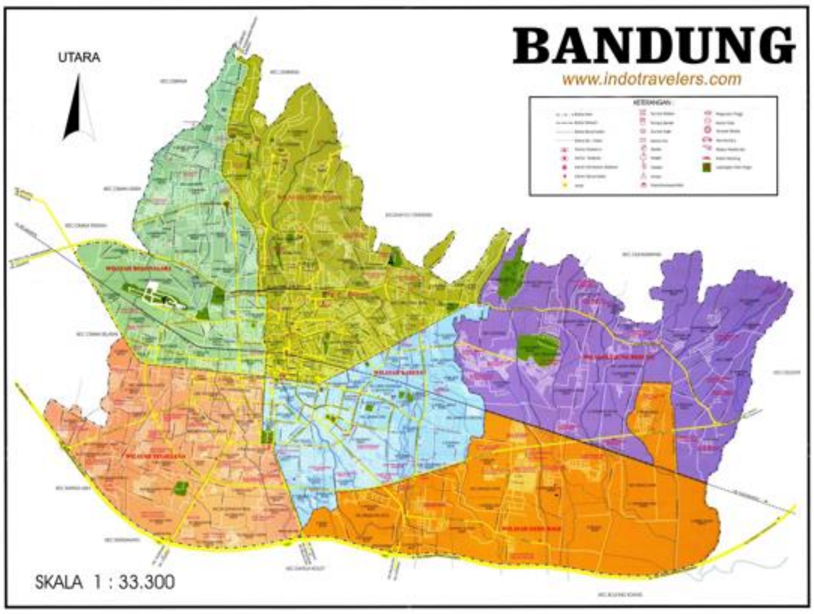

Fig. 2. The map of six areas in Bandung.

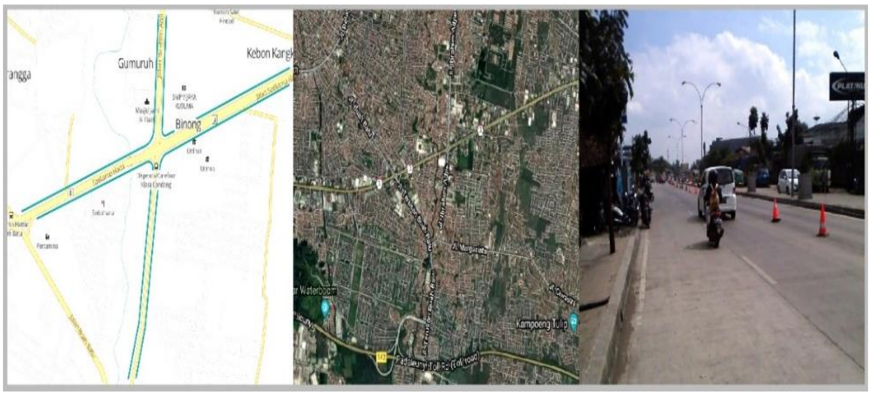

Fig. 3. The field of street lighting replacement using LED technology.

The process of street lighting replacement using LED lamps was carried out on Soekarno Hatta street sections (starting from Buah Batu Street to Ibrahim Adjie Street and from Cijagra Street to Buah Batu Street) of 1,470 meters long or 54 poles. Soekarno Hatta Street still uses conventional street lightings with the type of SOX 135W 164V BY22d 1SL / 12, causing many complaints from road users about the damage of those lamps. Besides, the use of conventional lamps has many disadvantages, one of them is the inefficient energy usage, resulting in high electricity expenses. This study attempts to calculate the initial investment costs and future investments using traditional method (NVP and IRR) in the process of redesigning the replacement of street lighting along 1,470 meters with a total of 54 poles using LED lamps.

Before calculating the initial investment costs, we made a design of street lighting replacement using LED lamps. The first step was to identify street conditions (length of the street, number of poles, number of lamps, the average distance among poles, and the average illumination). The information of street length was obtained with the help of Google map application. Table 1 shows the identification of street conditions to be analyzed. From that table, it is known that the average street illumination is smaller than the standard lighting quality according to the type or classification of road functions determined by the National Standardization Agency (BSN) contained in (SNI): 7391: 2008. Thus, this condition requires repairmen and replacement so that the function of the Soekarno Hatta Street as a primary arterial road can be realized. The primary arterial road is an arterial road on a regional scale at the national level.

Table 1. Identification of street conditions in Gedebage area.

No.	Street Name	Street Length (meter)	Number of Poles (unit)	Number of Lamps (unit)	Average distance among poles (meter)	Average illumination (lux)
1	Jl. Soekarno Hatta	5500	136	272	40,44	3
2	Jl. Terusan Buah Batu	1000	64	128	15,63	9,86

Table 2 shows the comparison of specifications and prices of street lighting between the conventional (existing) and the LED lamps (type BPR372 120 Watt/ 220 Volt). From table 2, it is shown that the electrical power, illumination, and basic price of the lamp may affect the energy consumption, thus affecting the electrical expenses.

Table 2. Comparison of specification and price between conventional and LED lamps.

Variable Input	Conventional lamp	LED
Distance of pole to the road	1,80 m	1,80 m
Minimum illumination criterion	5 lx	5 lx
Uniformity	0,10	0,10
Type of lamp	SOX 135W 164V BY22d 1SL/12	LED BPR372 120 Watt/ 220 Volt
Manufacturer	Philips	Philips
Lamination flux	22,600 lm	14,560 lm
Type of pole	Single Row	Single Row
Power	135 W	128 W
Distance among poles	30 – 55 m	30 – 55 m
Height of poles	10 – 13,50 m	10 – 13,50 m
Price of lamps	387.600	6.937.857 (Complete with armature)

The next step was to calculate the initial and annual costs of the existing lamps based on the observation on the street lights at 54 points whose type of lamp is Philips SOX 135W 164V BY22d 1SL/12. The total electrical power (P_{total}) consumed is shown in Table 3. That amount of power was supplied by PT PLN (State-Owned Electrical Company) with the tariffs class of P-1/TR and power limit of 5,500 VA. Based on the regulation of Ministry of Energy and Mineral Resources of the Republic of Indonesia number 31 the year 2014 regarding the electrical tariff for government offices and street lighting[23], provided by PT PLN, the tariffs with power limit of 5,500 VA is IDR 1,076/kWh. In reality, the lamps at Soekarno Hatta Street operate 12 hours daily. Table 3 shows the energy level efficiency resulted from replacing the conventional lamps with LED lamps. The level of efficiency is 52% and the decrease in annual electrical expense is IDR 39,303,014.4. This condition benefits either the society or the government so the replacement project is a must thing to do.

Table 3. Comparison of energy consumption between conventional and LED lamps.

Type of lamp	Total of power consumption (kW)	Operating hour (hour/day)	Consumption of electrical power (kWh)		
			In 1 day	In 1 month	In 1 year
Philips SOX 135W 164V BY22d 1SL/12.	324 KW	12 hours	209.952	6.298.560	75.582.720
LED type BGP353, 120 W/220V	155,52 KW	12 hours	100.776,96	3.023.308,8	36.279.705,6
Estimated energy saving for a year (kWh)					39.303.014,4
Percentage of energy saving for a year					52%

The budget calculation for the replacement of street lighting using LED lamps started with the planning of time and cost of investment, continued by analyzing the prices of unit work, namely 1) cost of labors (workers); 2) cost of equipment and material needed for the replacement in the area; and 3) tax. The estimation of the initial investment for replacing the lamps at Soekarno Hatta Street using a LED type of BPR372 120Watt/220Volt, adjusted to the price in the analysis period, i.e., December 2017. The estimated initial investment is IDR 1,594,327,216. This result shows that the initial investment for this replacement project using LED lamps is quite high. However, the energy efficiency produced by LED lamps is higher where the total power consumption decreases from 324 KW to 155.52 KW.

The replacement of street lighting using LED lamps has an advantage as it has lower operating expense. Table 4 shows the decrease in operating expense after installing the LED lamps. The decrease in operating expense supports the opinion of some experts stating that the replacement of the conventional lamps with LED lamps will result in lower operating expense as the LED lamps may function up to 100,000 hours, have a relatively smaller size, and have a faster response in the switching mechanism [24, 25]. Thus, there is no need to perform lamp replacement quite often. This condition reduces operating expense up to IDR 229,047,234 or 51% during its lifespan (with basic electrical tariffs of IDR 1,049/kWh and power limit of 1,300W). From the calculation above, it is shown that the total life-cycle cost (LCC) of using LED lamps is higher than that of the conventional lamps with the difference of IDR 707,427,756 or 56%. However, LED lamps provide more energy efficiency which will reduce the annual expense of electricity. Thus, using LED lamps are more economical, effective, efficient, and profitable in a long term. Using LCC, we can also determine the amount of investment fund for 10, 20, or 30 years to come.

Table 4. Main characteristics of the project.

Input variables	Conventional lamp: SOX 135W 164V BY22d 1SL/12	LED BPR372 120 Watt/ 220 Volt
Lifespan of the lamp (hour)	5,000 – 10,000	50,000 – 100,000
Energy consumption (Watt)	135	120
E average (lux)	3	14,71
Operating hour (hour)	12	12
Number of poles	54	54
Total energy consumption (kW)	324	155.52
Price of lamp (IDR)	387,600	6,937,857
Initial investment (IDR)	886,899,460	1,594,327,216
Basic electrical tariffs (kWh)	1,049 kWh	1,049 kWh
Daily electrical tariffs (IDR)	209,952	100,776.96
Annual electrical tariffs (IDR)	75,582,720	36,279,705.6
Annual Saving (IDR/year)	39,303,014.5	
Average illumination (lux)	3	17.05
Operating expense (IDR)	440,479,296	211,430,062
Difference in operating expense (IDR/year)	229,047,234 (51%)	
Number of lamp replacement in 50,000 – 100,000 hours	20X	1X
Cost of lamp replacement in 50,000 - 100,000 hours (IDR)	418,608,000	374,644,278
Total cost in 50,000 – 100,000 hours (IDR)	440,479,296	211,430,062

Feasibility of replacing investments with LED determined based on the results of the Net Present value calculation of an Annuity. In this study, the value of the initial investment is the total value of the budget plan the cost for replacing SOX lamps to LED of IDR 1,594,327,216, cash inflows are the amount of replacing electricity bills per year of IDR 453.496.320. Calculation of eligibility replacing investment with LED is shown in Table 5.

Table 5. Total NPV, IRR and B/C Ratio of replacement projects with LED technology.

n	NVP	IRR	B/C
1	173,085,459.281	8,04%	1,27
2	339,131,989.561		
3	498,500,561.558		
4	651,371,660.631		
5	797,925,772.139		
6	938,523,866.800		
7	1,072,751,727.973		
8	2,202,754,432.376		
9	1,326,747,874.009		
10	1,445,868,210.949		
11	1,560,115,443.196		
12	1,669,489,570.750		

Economic analysis is carried out to calculate the feasibility study for making decision [26, 27]. Specifically, it is used for understanding how the condition after replacing lights using LED lamps. The initial process was to make a calculation using the cost and benefit method (NVP, IRR, and B/C Ratio). Table 6 shows the results of the NPV calculation from the first to the twelfth year. The calculation results show that the LED replacement project has an IRR of 8.04%, based on the eleventh year total NVP of IDR 1,560,115,443.196, and with B/C Ratio of 1.27 and the simple payback time (SPT) is 11,3 years. Figure 4 in order showed the simple payback time replacement project using LED.

Table 6. Calculation of net present value of annuity (i = 4.25%).

No.	Cash inflow	Annuity	A	P
1	453.496.320	180.485.359	0,959	173,085,459.281
2	453.496.320	180.485.359	1,879	339,131,989.561
3	453.496.320	180.485.359	2,762	498,500,561.558
4	453.496.320	180.485.359	3,609	651,371,660.631
5	453.496.320	180.485.359	4,421	797,925,772.139
6	453.496.320	180.485.359	5,200	938,523,866.800
7	453.496.320	180.485.359	5,947	1,072,751,727.973
8	453.496.320	180.485.359	6,664	2,202,754,432.376
9	453.496.320	180.485.359	7,351	1,326,747,874.009
10	453.496.320	180.485.359	8,011	1,445,868,210.949
11	453.496.320	180.485.359	8,644	1,560,115,443.196
12	453.496.320	180.485.359	9,250	1,669,489,570.750

From these results, it can be concluded that the replacement project is feasible. The investment period of this LED lamp is projected to be 20 years because the average age of LED armatures is two decades. Where, the LED replacement process is carried out every 11 years, where the lifetime of LED lamps reaches an average of 50,000 hours or 11 years with 12 hours per day usage.

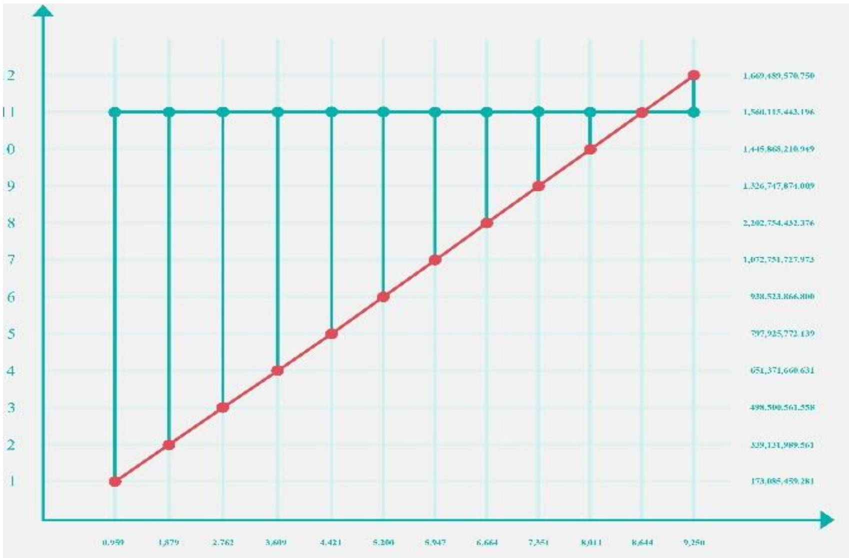

Fig. 4. The simple payback time replacement project.

Based on our analysis using one of the primary arterial roads in Bandung as a sample, it is shown that the initial investment of lamp replacement project with LED technology is huge. With ten primary arterial roads in Bandung, the costs needed to replace the entire street lighting with LED technology are even bigger. This evidence reinforces the research result] stating that the initial investment for the lamp replacement project using LED technology is high [9]. In addition to the high cost, energy consumption is also high [11]. The economic performance of the systems was evaluated using a simple payback time [5].

The lamp replacement project on one of the streets in Bandung requires IDR 1,594,327,216, but the annual operational costs decrease by IDR 229,049,234. This result proves that the light replacement project using LED lamps can reduce the operating costs. Also, this result supports the previous studies stating that LED lamps are believed to be the best choice because, in addition to the lower power (watt) consumption, they also have longer life [6, 7]. The uncertainty factors which can affect investment in each country are different, depending on the policies of the government. In Indonesia, one of the factors of the uncertainty affecting investment in the street lighting replacement process is the government's policy on basic electricity tariffs. This evidence reinforces the result of the previous study, stating that the policy of basic electricity tariffs can affect energy investment in Iran [28]. The cost saving of lamp replacement project using LED technology in Italy is influenced by uncertainty in electricity price and forms of multi-stage investment [15]. The factor of investment uncertainty is influenced by technological innovation and changes in a country's laws [20].

One of the limitations in this study is that, the process of calculating the possibility of cost and energy savings in the process of replacing street lighting using LED technology does not include the risk of uncertainty in investment, so the next study is to compare the possibility of cost savings and energy replacement with traditional methods and real options.

4. Conclusions

Replacement of street lighting with LED technology has been conducted in this study. The findings on the research site show that the existing condition of street lighting below the lighting standard in Indonesia; however, the absorption of energy produced is higher. The street lighting system with LED technology carried out on the Soekarno Hatta road can be said to be good, because E (average) = 14.17 lux (as shown in Table 6), where it shows the average strong lighting of the road lighting in accordance with SNI for street lighting. Likewise, for luminance and even illumination of street lighting are in accordance with SNI standards. LED technology has been the right choice in the replacement project of street lighting because it reduces cost, consumes less power, and has a longer life cycle. Also, LED technology is environmentally friendly and has a better illumination. Regardless of those aspects, the high initial investment of LED technology becomes the primary barrier for people to utilize it. Thus, there should be an adequate evaluation model to support the investment in this field. The high initial investment of LED technology, two until four times of the conventional technology, requires us to identify the probability of cost reduction of the replacement implementation. Therefore, the further research may conduct cost reduction analysis in the light replacement project, so that the amount of money for the initial investment of using LED technology can be minimized. The implementation of LED technology in the city of Bandung can provide cost saving in the annual electrical expense of the local government. This result can be used as an input for the government to conduct energy efficiency program by replacing the high-illuminating lamps with the energy-saving lamps such as LED lamps. This research is expected to give input to the local government of Bandung in determining the policy related to the improvement of public services, especially the policy of public street lighting.

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