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The Feasibility of Eco-Bricks as Recycled Products in Yogyakarta Waste Bank

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ABSTRACT IN ENGLISH

Plastic waste is an inorganic waste that can pollute the environment and is difficult to decompose. Recycling of plastic waste has not been widely used because the selling price is not too high. So, plastic waste is simply thrown away then ends up in the landfill and reducing soil fertility. Eco-brick is the product solution for plastic waste management. The Kamulyan waste bank searched to accommodate and reuse plastic waste into eco-bricks which greatly assists the management of plastic waste in Yogyakarta. This research was conducted to determine the economic feasibility of the eco-bricks as the product of recycling activity. The research method used the Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Internal Rate of Return (IRR) for analyzing the economic feasibility of investment activities carried out by the Kamulyan Waste Bank. The results were feasible for NPV with positive values at Rp 1.331.313 and 9,32% as the rate of return for IRR. The BCR was not feasible cause the BCR was lower than the standard value. Recycling activities provide direct benefits in the form of net profit derived from the sale of recycled products of Rp 1.741.421 from 2020 to 2021. The indirect benefits were being able to reduce the accumulation of plastic waste PET bottles and sachets in Yogyakarta by 0.008% and reducing plastic waste management costs of Rp 1.069.636,84.

1. INTRODUCTION

Plastic waste is an inorganic waste that needs some years to dissolve. The bottles of plastic water are predicted to dissolve completely for 500 years [1]. On the other hand, plastic has been required in households and businesses. Indonesia is the top country that contributes to producing plastic waste. The estimated plastic waste produced annually in Indonesia is 7.8 million tons and 4.9 million tons of plastic waste reportedly cannot be managed [2]. Plastic has become everyone's needs in the usual ways and its consumption is increasing but its waste has been managed poorly [3]. Indonesia has a low rate of plastic recycling cause some plastic types have low value and the recycling systems aren't well-established for all kinds of plastic types [4]. The matters of plastic recycling in Indonesia need some actions to reduce plastic waste.

There are some actions to plastic recycling in households that are managed by waste banks as a formal sector. The waste bank is a community that manages household waste collectively [5]. Waste bank's activities are mainly sorting, distributing, and selling the collective waste from households. Waste banks become institutions that can gain economic value from waste management. Because not all household waste can be sold into the market and recycled products can gain more value. Therefore, there are more activities related to making recycled products. Waste banks can generate income from the activities of recycling household waste into recycled products.

One of the products in the waste bank for recycling plastic waste is eco-bricks. Eco-bricks have been made mostly from polyethylene terephthalate (PET) bottles and plastic waste as a filling [6]–[8]. Eco-bricks become a solution to reduce plastic waste into new products that could be new materials in construction[6], [7], [9]. Although eco-bricks can be the solution to managing some plastic waste, the economic value of eco-bricks has not been analyzed yet. There is consideration of the important role of waste banks in recycling PET bottle waste [10]. An example of eco-bricks can be seen in Figure 1, the hexagonal type and triangle type of eco-bricks that are produced in the waste bank.

a b

Figure 1 – (a) Hexagonal Type of Eco-Bricks; (b) Triangle Type of Eco-Bricks

As one of the provinces that promote tourism, the Special Region of Yogyakarta could have the risk of increased waste generated. The data from the National Waste Management Information System (SIPSN) in Figure 2 indicated that plastic waste in Yogyakarta was the third largest. The provided data were only the waste composition in Yogyakarta and Bantul Regency for the Special Region of Yogyakarta [11]. Yogyakarta contributed more plastic waste than the Bantul regency.

If waste banks can manage plastic waste properly, the plastic waste that goes to landfills could be reduced. There were some problems in the Piyungan landfill with waste management. The communities around the Piyungan landfill are against the poor management that caused problems like leachate [12], [13]. Plastic waste composition was found second largest in the Piyungan landfill [14]. The largest waste contributor region in the Piyungan landfill was Yogyakarta, then followed by Sleman and Bantul [15]. Yogyakarta became the largest contributor due to the limitation of area. Almost all the waste generated in Yogyakarta entered landfills. Piyungan landfill also has a high risk of hazard and should be closed soon [16].

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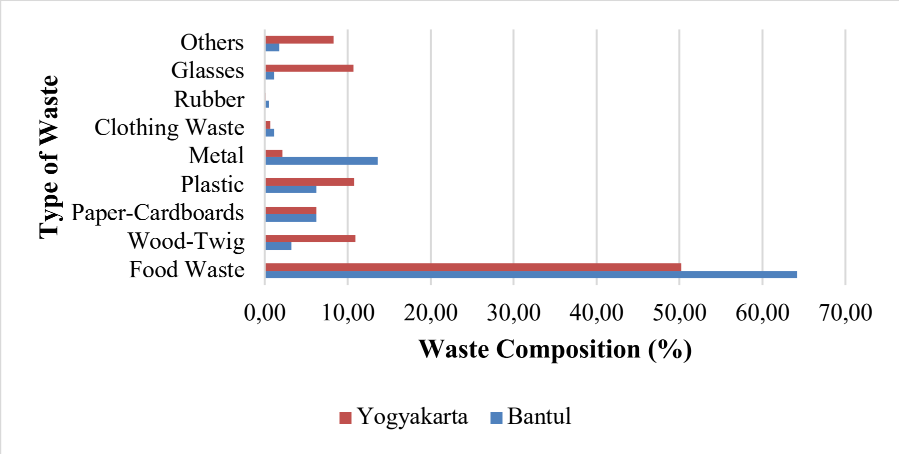

Figure 2 – The Waste Composition of Yogyakarta and Bantul Regency in 2020 [11]

The feasibility of eco-bricks in the waste banks has not been examined yet. There was research about waste banks as a formal sector in plastic waste management [17], [18] but the research only discussed the waste simulation and material flow. The other research focused on simulation in the informal sector of plastic waste management [19]. The previous research on plastic waste management's feasibility just examined the benefits in the informal sector [20]. There was a need to observe eco-bricks commercialization as plastic waste recycling products. The feasibility methods that could be used were Cost Benefit Ratio (BCR), Net Present Value (NPV), and Interest Rate of Return (IRR).

Waste banks have a role in reducing plastic waste with eco-bricks. The benefit of eco-bricks can manage plastic waste in households but there are not many waste banks adopted eco-bricks as a solution to recycled activities. This research was conducted in Yogyakarta which became the largest contributor of waste in the Piyungan landfill. It is important to understand the feasibility of eco-bricks in the waste banks. Waste banks can generate income from activities of recycling household waste into recycled products. Kamulyan Waste Bank is the most active waste bank that produces eco-bricks in Yogyakarta. Kamulyan Waste Bank was still producing recycled products even in the pandemic condition. Regarding the economic benefits that came from eco-bricks, it needed to be examined for operational purposes. The purpose of this research was to determine the feasibility analysis of eco-bricks in the Kamulyan waste bank. The feasibility analysis was mainly come from the economic value of eco-bricks in waste banks. The feasibility of eco-bricks was conducted on the first channel in the previous research about plastic waste open loop diagrams [21].

2. METHOD

2.1 Research Object

The research objects were the eco-bricks management in Yogyakarta's waste bank. Research data were gathered from some sources that related to eco-bricks management from households until the buyers of eco-bricks based on the previous research's first channel about plastic waste management's open loop diagram [21]. The data were gathered with observations, interviews, and government data about plastic waste in Yogyakarta.

2.2 Data Collection

This research gathered initial data to identify the value that was gained from each actor in the first channel of the diagram [21]. The initial data were gained with snowball sampling to capture data about eco-bricks management in Yogyakarta. The methods for collecting the data were interviews and surveying waste banks around Yogyakarta. There were not many waste banks in Yogyakarta that were active in managing the waste even before the pandemic began. Kamulyan Waste Bank located in Brontokusuman RW 20-22, Yogyakarta was the most productive waste bank that managed plastic waste into eco-bricks. Kamulyan Waste Bank also had its Standard Operation Procedure (SOP) for producing eco-bricks [22]. The data would become a network diagram with value gained for each actor. The other data gathered was the cash flow of eco-bricks management in Kamulyan waste bank through interviews with the manager of the waste bank. This data would be calculated using the feasibility analysis method.

2.3 Data Processing with Feasibility Analysis

Eco-bricks could be the future solution for sustainable construction. It would be used in home architecture and could replace conventional bricks [23]. The market feasibility for commercializing eco-bricks as products was required in Bangladesh, and the awareness of using eco-bricks was increased [24]. The rising awareness of eco-bricks was found in Indonesia which became a paving construction material [25]. On the other side, the waste bank could generate profit as

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a formal provider of eco-bricks in the plastic waste management chain. It would be encouraged to determine the feasibility of eco-bricks in the Kamulyan waste bank.

The methods of feasibility analysis to calculate eco-bricks management were Net Present Value (NPV), Internal Rate of Return (IRR), and Cost Benefit Ratio (BCR). NPV was a method to understand the present worth of the eco-bricks in the waste bank. IRR was a method to know the return rate of eco-bricks production that happened in the waste bank. BCR was used to understand the feasibility from the benefit perspective of eco-bricks production in the waste bank. These methods were used in the informal sector of plastic waste management [20]. The formula for each method can be found as:

$$NPV = -Ao + \sum_{t-1}^{n} \frac{At}{(1+r)^t} \tag{1}$$

Where:
A_0 = the expenditure in the year of observation
A_t = the cash flows in the year of observation
r = the interest rate
n = the number of years of observation [20]

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \, x \, [i_2 - i_1] \tag{2}$$

Where:
i_1 = the low discount rate
i_2 = the high discount rate
NPV_1 = the NPV for i_1
NPV_2 = the NPV for i_2 [20]

$$BCR = \frac{Benefit}{Cost} \tag{3}$$

Where:
Benefit = the total of benefit (which is direct and indirect)
Cost = the total cost, if BCR is more than 1 then the investment is feasible [26]

3. RESULT AND DISCUSSION

3.1 The Network Diagram of Economic Value in The Channel

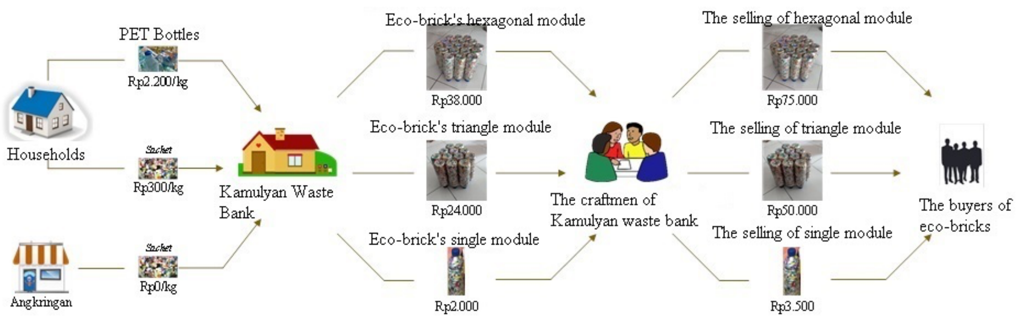

Figure – 3 The network diagram that formed from each actor in the channel

In Figure 3, we can see that the raw material of eco-bricks came from households and angkringan. PET bottles and plastic sachets were the main raw materials for eco-bricks. The plastic sachets that came from angkringan were free of charge. The collecting point was in Kamulyan waste bank. After that, Kamulyan waste bank produced three types of eco-brick which were hexagonal modules, triangle modules, and single modules. Each type of eco-brick had its production cost. The production cost for the eco-bricks hexagonal module was Rp 38.000, the triangle module was Rp 24.000, and the single module was Rp 2.000. Kamulyan Waste Bank has craftsmen who will make the eco-bricks as the requested type by buyers. The craftsmen of eco-bricks were active members of the Kamulyan waste bank. The price of each eco-brick type was different. The price for an eco-bricks hexagonal module was Rp 75.000, a triangle module was Rp 50.000, and a single module was Rp 3.500. Another value of each node in the channel can be seen in more detail in Figure 3.

3.2 Eco-bricks Volume

The main material in the eco-brick came from PET bottles in 600 ml and shredded plastic sachets. PET bottles mainly came from households. Plastic sachets came from households and angkringan. The weight of PET bottles in 600 ml was 14 grams and for plastic sachets was 260 grams to produce one single module eco-brick. Kamulyan Waste Bank has PET bottles that waste as many as 1,85 kg once every two weeks. The total PET bottles waste collected in the Kamulyan waste bank was 264 bottles every month. The members of Kamulyan Waste Bank were 25 persons. So, the average PET bottle waste generated from each household was 10 bottles.

The plastic sachets waste generated from households and angkringan. The total plastic sachets waste from households was 1,6 kg. This plastic sachets waste came from 2-3 members of Kamulyan waste banks once every two weeks. The average plastic sachet waste generated from each household was estimated at 1,2 kg. The total plastic sachets generated from angkringan were 70 sachets once every week and the total weight was 280 grams. The angkringan did not take any charge for the plastic sachets waste. The amount of main material derived from the Kamulyan waste bank for each month can be found in Table 1.

Table 1 – The Amount of Main Material for Eco-bricks per Month

The source of plastic waste	Average amount per month	Main material of eco-bricks
Households	10	PET bottles (pieces)
	1200	Plastic sachet (grams)
Angkringan	280	Plastic sachet (grams)

3.3 The Eco-bricks' Profit Calculation

Kamulyan Waste Bank had sold some type of eco-bricks module. The profits of eco-bricks need to be calculated first to become data for the next feasibility calculation. The production cost for single and triangle modules can be found in Table 2. The production from 2020 to 2021 sold eco-bricks triangle modules and single modules. The eco-brick triangle module sales were ordered from the Yogyakarta Environment Department and were sold for Public Green Open Space in Kadipaten, Kraton, Yogyakarta. The total production cost for the triangle module was Rp 39.056 and the single module was Rp 2.109.

Table 2 – The production cost for eco-bricks

Cost Variables	Triangle Module	Single Module
PET bottle waste (600 ml)	Rp 369,6 (12 bottles)	Rp 30,8 (1 bottle)
Plastic sachets waste	Rp 936 (3.120 grams)	Rp 78 (260 grams)
Silicon glue	Rp 13.750	-
The labor cost of craftsman	Rp 24.000	Rp 2.000
Total	Rp 39.056	Rp 2.109

The data of the profit calculation can be observed in Table 3. The production cost from Table 1 will be used to calculate the net profit for each module of eco-bricks. The triangle module was sold for 32 modules and the single module was for 1.000 modules. It could be seen that the total net profit for two years of production was Rp 1.741.421.

Table 3 – The profits of eco-bricks in the Kamulyan waste bank

Eco-brick type	Sales amount	Production cost for an eco-brick module	The price	Total production cost	Gross profit	Net profit
Triangle Module	32	Rp 39.056	Rp 50.000	Rp 1.249.779	Rp 1.600.000	Rp 350.221
Single Module	1.000	Rp 2.109	Rp 3.500	Rp 2.108.800	Rp 3.500.000	Rp 1.391.200
Total				Rp 3.358.579	Rp 5.100.000	Rp 1.741.421

3.4 The Eco-bricks' Net Present Value

The Net Present Value (NPV) calculation was needed to provide information to investors on the current net value of eco-bricks. The interest rate that was used for calculation was 9,23% in 2020 [27] and 8,59% in 2021 [28]. The data that were needed for NPV's calculation can be observed in Table 4. In 2020, Kamulyan Waste Bank sold triangle module eco-bricks. Then in 2021, single module eco-bricks were sold.

Table 4 – Data for calculated eco-bricks NPV in Kamulyan waste bank

	Total production cost		**Gross profit**		**Net profit**	
Eco-bricks' type	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
Triangle module	Rp 1.249.779	-	Rp 1.600.000	-	Rp 350.221	-
Single module	-	Rp 2.108.800	-	Rp 3.500.000	-	Rp 1.391.200
Total	Rp 1.249.779	Rp 2.108.800	Rp 1.600.000	Rp 3.500.000	Rp 350.221	Rp 1.391.200

The NPV for eco-bricks can be seen in Equation 4. The NPV resulted in Rp 1.331.313. NPV was more than 0 and positive so the investment on eco-bricks was feasible.

$$Eco - bricks\ NPV = -\text{Rp}169.000 + \frac{\text{Rp}350.221}{(1+0{,}0923)^1} + \frac{\text{Rp}1.391.200}{(1+0{,}0859)^2} = \text{Rp}\ 1.331.313 \quad (4)$$

3.5 The Eco-bricks' Internal Rate of Return

Internal Rate of Return (IRR) was used to understand the feasibility of the cash flow rate of return. IRR was used to explain the investment in a rate. The calculation of IRR needed data on NPV. The low discount rate for calculation was 8,59% [28] and the high discount rate was 9,23% [27].

$$Eco - bricks\ IRR = 8{,}59\% + \frac{Rp1.179.695}{Rp1.179.695 - Rp151.617}\ x\ [9{,}23\% - 8{,}59\%] = 9{,}32\% \quad (5)$$

The result of the IRR calculation was 9,32%. This rate from the result was more than the interest rate in 2020 and 2021. The result of IRR explained that eco-bricks production in the waste bank was feasible.

3.6 The Eco-bricks' Benefit-Cost Ratio

The direct benefit of the Benefit-Cost Ratio (BCR) can be found in the net benefit from Table 3. The indirect benefit of BCR is calculated from the waste reduction in Yogyakarta. The data for indirect benefit were generated from the weight of eco-bricks that were produced and the reduction of plastic waste that was recorded. The weight for each type of eco-brick can be found in Table 5. The hexagonal module needed 19 single module eco-bricks and the triangle module needed 12 single module eco-bricks.

Table 5 – The Weight of Eco-bricks Produced in Kamulyan Waste Bank

Eco-brick type	**The number of single eco-brick**	**The weight of PET bottles is 600 (grams)**	**The weight of plastic sachets (gram)**	**Total weight (gram)**
Hexagonal module	19	266	4940	5206
Triangle module	12	168	3120	3288
Single module	1	14	260	274

The triangle module and single module were sold in 2020 until 2021. The sales amount for each eco-brick type is found in Table 3. The sales amount could be determined by the plastic waste volume that was managed by Kamulyan Waste Bank. The volume of managed plastic waste can be seen in Table 6. The total plastic waste that turned into eco-bricks was 379,216 kg for two years.

Table 6 – The managed plastic waste volume

Eco-brick type	Plastic waste volume in 2020 (kg)	Plastic waste volume in 2021 (kg)	Total (kg)
Triangle module	105,216	0	105,216
Single module	0	274	274
	Total		379,216

The indirect benefit of eco-bricks could reduce the plastic waste volume. The data on plastic waste generation was from the Yogyakarta Environment Department. The total plastic waste reduced in Table 7 was from the computation of the total managed plastic waste volume with eco-bricks in Table 6.

Table 7 – Indirect Benefit Calculation

Indirect Benefit	2020	2021	Total
Total of plastic waste generated (kg)	2.260.228,56	2.282.435,04	4.542.663,6
Total of plastic waste reduced with eco-bricks (kg)	105,216	274	379,216

The costs of waste management in Yogyakarta can be seen in Table 8. The data source of the waste management cost was also coming from the Yogyakarta Environment Department. The cost component was for one year of operation. Cause the eco-bricks data were gained for two years then the cost component was for 2020 and 2021. The total cost of waste management for two years was Rp 12.813.314.750. This data was required to calculate the indirect benefit of eco-bricks.

Table 8 – The Costs Component of Waste Management in Yogyakarta

Costs component	2020	2021
Cleaning workers' salaries	Rp 2.950.215.000	Rp 2.932.415.250,00
Fuel costs for waste transportation equipment	Rp 925.219.000,00	Rp 935.310.000,00
Waste management machine maintenance	Rp 27.000.000,00	Rp 28.000.000,00
Health insurance costs for cleaning workers	Rp 130.080.500,00	Rp 131.075.000,00
Cultural heritage area waste transport services	Rp 2.200.000.000,00	Rp 2.228.000.000,00
Cost of temporary garbage dump cleaning	Rp 160.000.000,00	Rp 166.000.000,00
Total cost	Rp 6.392.514.500,00	Rp 6.420.800.250,00
	Rp 12.813.314.750,00	

The indirect benefit of eco-bricks was calculated from the data in Table 6 and Table 7. First, the percentage of plastic waste reduction was calculated from the total plastic waste reduction with eco-bricks to the total plastic waste generated. The percentage of plastic waste reduction was 0,008%.

$$Percentage\ of\ plastic\ waste\ reduction\ = \frac{Total\ of\ plastic\ waste\ reduction\ with\ eco-brick}{Total\ of\ plastic\ waste\ generated} x100\%$$
$$= \frac{379{,}216}{4542663{,}6} x100\% = 0{,}008\% \tag{6}$$

The percentage of plastic waste reduction would be the data for calculated plastic waste management indirect benefit. This indirect benefit would be added with a direct benefit for eco-bricks BCR calculation. The indirect benefit of eco-bricks was Rp 1.069.639,840. The direct benefit of eco-bricks was Rp 1.741.421, which was from net profit of eco-bricks in Table 1. The cost for eco-bricks BCR calculation was from the total production cost in Table 1, which was Rp 3.358.579.

$$Plastic\ waste\ management\ indirect\ benefit\ = Rp\ 12.813.314.750{,}00\ x\ 0{,}008\% = Rp\ 1.069.639{,}840 \tag{7}$$

$$Eco-bricks\ BCR = \frac{Benefit}{Cost} = \frac{Rp\ 1.069.639{,}840 + \text{Rp}\ 1.741.421}{\text{Rp}\ 3.358.579} = 0{,}84 \tag{8}$$

The BCR calculation resulted in 0,84 which indicated that eco-bricks were not feasible. Most of the activities in the waste bank are voluntary. The waste bank's activities are solely based on communities. If the communities are aware of the environment's condition and worsening pollution then the waste banks' activities will be more active and varied. Because of the economic value returns from managing household waste are not much likely to gain profit. Cause the reverse value of plastic waste management lower than expected.

3.7 Discussion

This research on eco-bricks NPV resulted in a positive impact. It determined the Kamulyan waste bank's eco-bricks were feasible to operate. The other research resulted in negative on the first year but turned positive in the fourth year [25]. The cost of the eco-bricks craftsmen was relatively high cause the methods were used hand-made. The comparison of eco-bricks production cost for paving products was Rp 3.226,57 per piece [25]. It was more expensive than the Kamulyan waste bank's eco-bricks. The eco-bricks IRR was also positive. It resulted in the feasibility of eco-bricks production. The other research did not use IRR for feasibility [25].

On the other hand, the BCR of eco-bricks was not feasible in the Kamulyan waste bank. The PET bottle value of one kilogram was Rp 2.200 and plastic sachets waste was Rp 300/kg. Mostly plastic sachets waste was devalued because the technology for recycling it was too expensive or the actors that could recycle it were a few near Yogyakarta. The direct benefits of eco-bricks were too low. The actors in the formal sector of plastic waste management were suffering cause all the activities in the waste bank now purely came from their members and the active members were a few.

The indirect benefit of plastic waste management could not be acquired easily. The data on plastic waste that flows in the rivers and sea could not be reached. The other data on plastic waste in the informal sector could not be obtained. The limitation of this research was on the formal sector. Kamulyan Waste Bank also needs some support from the Yogyakarta Environment Department to promote their eco-bricks so that sales can increase. The support for their activities could be added value that can reduce waste in Yogyakarta. The waste banks that have good management in Yogyakarta used their funding to open saving and loan associations (cooperation). The number of waste banks with savings and loan associations was a few in Yogyakarta. Future research could use the indirect data of plastic waste management to calculate BCR. The other suggestion was eco-bricks feasibility as construction products in parks or open public places.

4. CONCLUSION

Feasibility for eco-bricks in the Kamulyan waste bank was conducted with NPV, IRR, and BCR methods. The NPV for eco-bricks was Rp 1.331.313 then it concluded positive and more than 0. The IRR for eco-bricks was 9,32%. The result from IRR was feasible cause this rate was higher than in 2020 and 2021. The eco-bricks BCR resulted in 0,84. The BCR was not feasible cause it had lower than 1. The BCR was lower than 1 because the data for indirect benefit could not be obtained. Eco-bricks had feasibility with the results from NPV and IRR methods but not with the BCR method. This research was limited in economic feasibility method and the observed data came from Kamulyan waste bank. Further research could use Life Cycle Cost (LCC) to examine eco-bricks as recycled products to reduce plastic waste. The other research should simulate the use of eco-bricks in construction products in an open park and calculate the feasibility analysis as the plastic waste recycled products.

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