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Crude Palm Oil Waste Treatment Facility with Carbon Tax Benchmarking

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Abstract

The Crude Palm Oil (CPO) market of Indonesia is growing, with a production of around 45.8 million metric tons in 2019. The forecasted domestic consumption will achieve 15 million metric tons in 2021. This number tends to increase due to the government policy that encourages the use of palm oil in biodiesel and renewable energy sources. Despite its positive benefit to the economy, CPO suffered from negative campaigns regarding sustainable development issues, particularly in CPO waste management of its derivative. One concern is regarding the availability of CPO waste treatment facility. The waste treatment facility should be located strategically considering various factors. This study proposed a mixed-integer linear programming model for the green facilities problem. The model is used to decide the facility location and allocation of CPO waste treatment by considering transportation cost, facilities development cost and emission cost as environmental factors.

Keywords Green Facility Location, Crude Palm Oil Waste Treatment, Mixed Integer Linear Programming

1. Introduction

Industries that survived the financial crisis, as well as the economic crisis caused by the Covid 19 pandemic in Indonesia, are agribusiness of staple food for surviving the important role in the supply of food (Nicola et al. 2020). The agribusiness sector includes several economic activities that have direct and indirect linkages in terms of meeting intermediate industrial raw materials. Direct linkages include the relationship of agricultural commodities as input raw materials as well as marketing and trade activities that market agro-industrial end products. Indirect interrelationships in the form of economic activities that provide other input raw materials outside agricultural commodities, such as chemicals, packaging materials, etc., along with economic activities related to trade and supply chain (Saragih 2000; Bappenas RI 2017). In connection with that, agroindustry in palm oil industry activities, where Indonesia is the world's number one oil producer in 2020, it is important to make the palm oil industry comply with the principles of sustainability and innovation in a unified global value chain system (Pacheco et al. 2017).

Crude Palm Oil (CPO) receives several negative responses due to CO_2 emissions generated during the production process. There is agreement about the emissions standards generated by industry, such as mentioned in ISO 14040 and ISO 14044. However, it is still debatable whether various energy sources which fossil fuels still dominant as energy sources to be included or excluded when measuring carbon footprints. In measuring carbon footprints, several factors that commonly considered, including the capital embodied in building and machinery, waste products in the production and consumption process, and utilization of energy generates emissions associated with production and the product used by the consumer. In the United Kingdom (UK), the Carbon Trust, the British Standards Institute and DEFRA have a mutual contribution to constructing a common methodology when calculating carbon footprints. Furthermore, the raw data to be used and data source when calculating the carbon footprint, within a context in Indonesia is an important issue to be solved.

Each manufacturing activities emphasis on sustainable systems should consider the environmental performance assessment of the supply chain. Life cycle analysis within the supply chain, enhance considering integrated environmental impacts assessment of the of a product or service, is widely applying environmental impact measurement approaches (Guinee 2002). As a paradigm, life cycle analysis within the supply chain has been applied across a range of manufacturing products, and to a lesser extent to fresh fruit and vegetables including oil palm, in particular, comparison of different modes of freight transport (Guinee 2002).

As a policy formulation by corporate and national level of oil palm agribusiness on how operational and supply chain management (SCM) methods can assist practical application of LCA results. The LCA of the oil palm industry consists of 4 stages: nursery, plantation management, harvesting and transport of fresh fruits, and extraction of CPO (Munasinghe et al. 2019).

Within the context of Indonesia, the oil palm industry has conducted Roundtable on the Sustainability of Palm Oil (RSPO) as well as Indonesian Sustainability Palm Oil (ISPO) mandatory of LCA paradigm. Ecological attributes are always attached to the global crude palm oil value chain; among others the threat of climate change due to carbon dioxide emissions should be considered in the decision making of production and consumption of crude palm oil products. It is a necessary but sufficient condition to ensure the carbon footprint in the supply chain of crude palm oil can be investigated due to the sustainability of crude palm oil.

Our research focuses on "How can palm oil plantations as an agribusiness system of palm oil-producing plantations implement carbon footprints through solving the problem of palm oil empty bunch waste treatment facilities into value-added derivative products?" The approach chosen in this study is the location-allocation facility with a P-Median instrument using Integer Linear Model Programming mathematical model.

1.1 Research Statement

A previous study conducted by Rajakal et al. (2021) explained a sustainable agro-industrial value chain with a mixed-integer linear program (MILP) model which takes profit, carbon footprint, and water footprint optimization of the expected increase in the demand for a particular agro-industrial product.

Our study proposed a mixed-integer linear programming model for the green facilities problem. The model is used to decide the facility location and allocation of CPO waste treatment by considering financial and environmental factors including emission cost, transportation cost, development cost as well.

2. Literature Review

Indonesia has oil palm plantation in large scale areas, namely in Sumatra and Kalimantan. Most of them are operated by smallholders plantation rather than large companies plantation. The smallholders plantation may apply traditional operating management due to their crops as well as their FFB waste products. One thing that should consider is about zero burning management upon the FFB waste products also peatland of oil palm estates. While the zero burning policy was enacted in 1997, variations in subsequent annual rainfall patterns relate to part of the hot spot frequency but current haze does not stem from exceptional weather (Ekadinata et al. 2013).

Steen (2002) suggests that there are four main approaches for the assessment of the environmental impact. When we consider risk assessment which is typically used to consider regulation and control mechanisms for hazardous materials or processes as part of environmental impact assessment, then risk management is used to ascertain the likely effects of a project and may be used to shape rules and operating conditions for a proposed development; environmental economics (e.g., cost-benefit analysis and willingness to pay/accept). Companies ought to make esteem for customers and make esteem for the environment to secure their competitive qualities and/or obtain competitive points of interest (Büyüksaatçı 2016).

When we develop the facilities of CPO waste treatment management, we should consider the whole life carbon (WLC) concept for decision-making assistance, correct project precision in terms of minimizing carbon emissions across the lifetime of the infrastructure (Hughes 2013).

The responsible of palm oil industry sustainability include the hazardous effluent to community, merely subject to illegal oil palm plantations as they do not have the location-allocation and preparation of an Environmental Protection and Management Plan with the aim of avoiding environmental damage as described in Articles 2, 3, and Article 9 of the Environmental Law. So that, the WLC concept figures out the necessary condition to build the facility by considering the zero emissions goals, which palm oil has to be implemented responsibly (Ramos 2020).

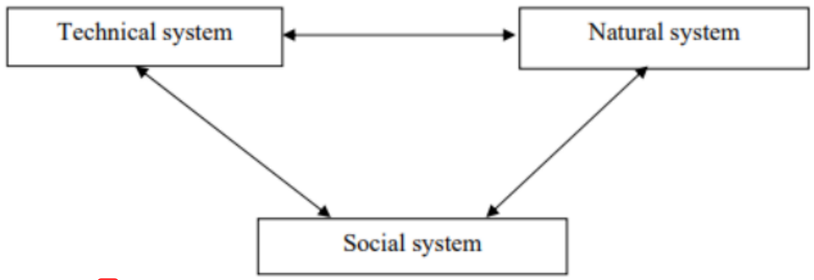

Figure 1. Impact factors evaluation combining scenarios for technique, environment, and human attitudes. (Source: Steen, 2002 p.150)

Environmental impact assessment does not only consider aspects of risk management assessment as explained in Figure 1. The evaluation of environmental impacts requires measurement across an interdependent system of carbon footprint which includes technical, natural, and social sub-systems. Another thing to consider in making economic decisions and environmental impacts is that the CPO waste treatment facility reduces carbon emissions in the lifetime of the facility. The environmental and social purpose that rely on issues such as costs related to energy and structure as well as pollution, noise, quality of life, fossil fuel crisis has all become significant for determining facility location problems (Farahani et al. 2010).

The assessment should cover the development's carbon emissions over its lifetime, accounting for its operational carbon emissions (both regulated and unregulated), its embodied carbon emissions, also any future potential carbon emissions 'benefits', post 'end of life, including benefits from reuse and recycling of building structure and materials (Pandey et al. 2011).

The sustainable of supply chain management should meet the growing public interest in global warming issues require guidelines for carbon footprint (CF) accounting for greenhouse gas (GHG) contents of animal and plant productions, such as crude palm oil as our concerned. Paksoy et al. (2010) considered the green effect on a closed-looped supply chain network and attempted to prevent more CO_2 gas emissions and empower the customers to use recyclable products through giving a little profit. They have presented distinctive transportation choices between models according to CO_2 emissions.

Bojarski et al. (2009) describe optimization and design planning supply chain considering economic and environmental concerns. The combination of CO_2 emissions and multi-modality in supply chain design is completely absent in the literature. However, integration of environmental issues and multi-modality is critical, as most of the literature suggests. Conducted by Hugo et al. (2005), who created a multi-objective enhancement approach for hydrogen systems, where they explored trade-offs between investment and greenhouse gas emissions.

Several of the models have been proposed in which the choice of mode of transportation as an option is included (Cordeau et al. 2006). Explored the impact of combining supply chains on lessening CO_2 outflows from transport with two conceivable modes, road and rail and appeared that a logistical mutualization is an effective approach to diminishing CO_2 outflows (Pan et al. 2009).

As part of the deepening of carbon zero emission in supply chain management, issues raised for follow-up, among others discussed about the type of modeling and programming binary model 0-1. For example, Santibanez-Gonzalez et al. (2011) presented a mixed-integer 0-1 model for solving feasible supply chain organize plan issues in the public sector. Chaabane, et al. (2009) proposed a multi-objective mixed-integer 0-1 model to determine the sustainable supply chain payback cycle over time in long-term.

Taking into consideration natural aspects, Ramudhin et al. (2008) proposed a mixed-integer 0-1 programming show for the GSC design for analyzing the effect of transportation, subcontracting, and generation exercises on the plan of a supply chain network. Amplified the past model considering life cycle evaluation (LCA) principles in expansion to the conventional material adjust constraints at each node within the supply chain.

In the tax carbon regime apply to ensure cost effectiveness in sustainability supply chain management, Yurimoto and Katayama (2002) created an algorithm for getting the ideal number and locations of public distribution centers in Tokyo with the point of decreasing the sum of truck CO_2 emissions to minimize logistics costs. The first-level costs included venture investment and initialization of the treatment plant. Chen and Fan (2012) created a bi-programming model to play down the general cost for raw materials and transportation as the second-level costs.

3. Methods

The most detailed approach to life cycle analysis is bottom-up or process analysis (Jansen and Thollier, 2006; van Engelenburg, Rossum, Block and Vringer, 1994). After describing the production network, the component activities required to produce, transport, consume and handle the waste associated with the product are assessed in terms of energy, physical inputs, emissions, and waste. A complete bottom-up life cycle analysis will cover from the cradle to the grave, and this can be a sizeable undertaking given the complexity and length of supply chains products.

An alternative approach to life cycle analysis is a top-down or Input-Output analysis which uses methods from economics and statistics to determine impacts through the formulation and use of matrices to determine energy and emissions. The input-Output analysis allows the impact of a complete production network to be calculated, although the accuracy for individual products is usually somewhat less than for the bottom-up approach (Van Engelenburg et al. 1994).

Mixed Integer Linear Programming (MILP) is often used for system analysis and optimization as it presents flexible and robust methods for solving large and complex problems such as industrial symbiotic cases and process integration. The many limitations make a problem more complex. This study considers three issues that consist of the logistics, environmental and economic side, by considering transportation costs, construction costs and carbon footprint costs (Samir et al. 2012).

A crude palm oil processing product produces waste that ecologically needs to be planned waste treatment facilities resulting from crude palm oil products. Environmentally friendly waste treatment facilities need to be built by considering variable decisions such as transportation costs, construction costs of environmentally friendly waste treatment facilities, and the cost of carbon emissions as a proxy of the carbon footprint, as presented in figure 2 below.

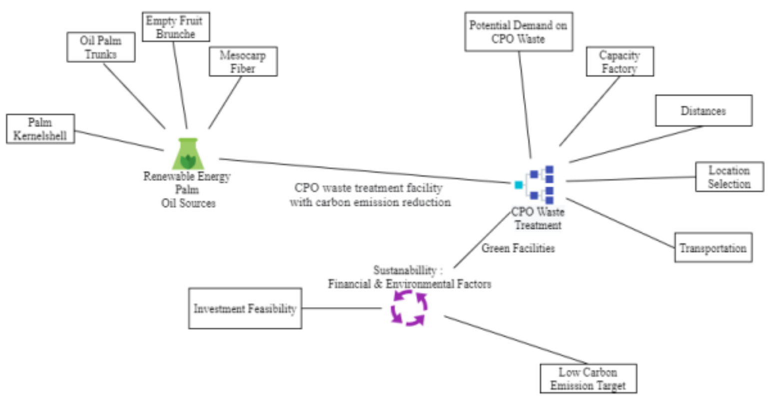

Figure 2. Theoretical Framework

Solving the P-Median model produces the optimal location to meet all existing demands with minimum transportation costs. However, this method only optimizes transportation costs following constraints. The P-Median method is part of mixed-integer linear programming that uses binary algorithms where the result is integer 0 or 1, indicating whether the location is selected. The P-Median method is included in the NP-Hard condition because it includes a discrete location model method or a condition to find the optimal solution that takes a short time.

The P-Median method is one type of location-allocation model that aims to determine the location of service facilities or service centers (supply centers) so that the level of service provided by the facility and the center to the demand point becomes optimal.

In this study determining green factory facilities, the P-median method takes into account not only transportation costs but also considers the development cost (based on manufacturing index in each candidate of the location of the facility) and the emission cost of the mode of transportation to be used.

Following is the mathematical model for the P-Median Mixed Integer Linear Programming method:

Sets:

I: crude palm oil manufacturer facility set

J: facility-candidate of green factory location set

K: transportation facility preference, used $k = \{1, 2\}$, 1 refers to light truck, 2 refers to heavy truck

Parameters:

h_i: total demand i, where i ∈ I (ton/month) (multiplicated by crude palm oil production, production efficiency)

P: number of facility candidates

d_{ij}: distance between location i ∈ I to j ∈ J (facility candidate location)

c_{ijk}: transportation costs facilities of k (data source from online data logistics company)

E_k: carbon dioxide emission (Kg CO_2 / km) of vehicle k ∈ K

ct: carbon tax per tonnage, a benchmark from UK the Carbon Trust

Cap_k: vehicle capacity k ∈ K

F_j: development cost (refers to manufacturing index in each facility candidate location)

FC_j: facility candidate capacity j ∈ J (ton/month)

ω_1: weighting factor of transportation cost

ω_2: weighting factor of development cost

ω_3: weighting factor of carbon dioxide emission cost

4. Data and Model

4.1 Data

This research utilizes data collected from the Association of Crude Palm Oil Producers of Indonesia (GAPKI) West Kalimantan Province as one of the biggest CPO producers, particularly 5 (five) major state-owned companies' plantations. Data references include production of CPO of 2018, transportation cost from a private logistic company, emission tax referenced by UK carbon tax 1USD per kilograms CO_2. Oil palm empty bunch waste calculated from the production of CPO multiply by 0.1 as CPO-waste produced.

In this study using AMPL software which is mathematical modelling used to solve problems with mathematical expression. AMPL has several solver options that will solve math problems (e.g., CPLEX and Gurobi). AMPL Language modelling is often used for troubleshooting optimization issues. The distance matrix between candidates for CPO waste treatment facilities located in West Kalimantan Province, Indonesia in table 1 below.

Table 1. Distance Matrix (kilometers)

Candidate Facility		PTPN XIII Kebun Gunung Meliau	PTPN XIII Kebun Rimba Belian	Pirsus 1 Parindu	PIR Ngabang	PTPN XIII Kembayan
		A	B	C	D	E
PTPN XIII Kebun Gunung Meliau	A	0	26.6	59.8	144	88.5
PTPN XIII Kebun Rimba Belian	B	26.6	0	54.5	109	83.1
Pirsus 1 Parindu	C	59.8	54.5	0	59.2	33.3
PIR Ngabang	D	114	109	59.2	0	80.9
PTPN XIII Kembayan	E	88.5	83.1	33.3	80.9	0

Source: authors' calculation

4.2 Model

Solving the P-Median model produces the optimal location to meet all existing demands with minimum transportation costs. However, this method only optimizes transportation costs by constraints. The P-Median method is part of mixed-integer linear programming that uses binary algorithms where the result is integer 0 or 1, indicating whether the location is selected. The P-Median method is included in the NP-Hard condition because it includes a discrete location model method or a condition to find the optimal solution that takes a short time.

The P-Median method is one type of location-allocation model that aims to determine the location of service facilities or service centers (supply centers) so that the level of service provided by the facility and the center to the demand point becomes optimal.

In this study determining green factory facilities, the P-median method considers not only transportation costs but also considers the development cost (based on manufacturing index in each candidate of the location of the facility) and the emission cost of the mode of transportation to be used.

Following is the mathematical model for the P-Median Mixed Integer Linear Programming method:

Sets:

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J: facility-candidate of green factory location set

K: transportation facility preference, used $k = \{1, 2\}$, 1 refers to a light truck, 2 refers to heavy truck

Parameters:

h_i: total demand i, where $i \in I$ (ton/month) (multiplicated by crude palm oil production, production efficiency)

P: number of facility candidates

d_{ij}: distance between location $i \in I$ to $j \in J$ (facility candidate location)

c_{ijk}: transportation costs facilities of k (data source from online data logistics company)

E_k: carbon dioxide emission (Kg CO_2 / km) of vehicle $k \in K$

ct: carbon tax per tonnage, a benchmark from UK the Carbon Trust

Cap_k: vehicle capacity $k \in K$

F_j: development cost (refers to manufacturing index in each facility candidate location)

FC_j: facility candidate capacity $j \in J$ (ton/month)

ω_1: weighting factor of transportation cost

ω_2: weighting factor of development cost

ω_3: weighting factor of carbon dioxide emission cost

The objective function (1) minimizes the number of demands divided by vehicle capacity multiplied by the cost of transportation using vehicles (k), namely, transportation cost. To measure the development cost containing manufacturing index in each facility candidate location multiplying facility candidate. As point out of this research in carbon dioxide emission cost counted the point of demands (h) divided by vehicle capacity (k), then multiplied by the distance between the point of demand, multiplied by emission carbon from the vehicle (k), thus, multiplied by the carbon tax. Each parameter would multiply by the weighting factors of each decision parameter.

The constraint equation (2) suggests if, there is demand at point (i) to one facility (j) using the variant of transportation (k). Equation (3) means the Number of Facilities to be built as much as P. Equation (4) ensures the decision of the location of facilities with location variables, that demand at the point (i) can only be met if the location of the facility (j) is chosen to be built (= 1). Equation (5) explains that the facility capacity in each candidate is multiplied by the candidate facility, which is greater than the choice of location of the facility X_j times the variable Y_{ijk}. Equations (6) and (7) describe this model using a binary algorithm where the result is an integer of, 0 or 1 indicating whether the location is selected.

Decision Variables:

$$X_j = \begin{cases} 1 & \text{If the facility is selected from a candidate location } j \in J \\ 0 & \text{if the facility is selected from the candidate's location.} \end{cases}$$

$$Y_{ijk} = \begin{cases} 1 & \text{If demand location } i \in I \text{ is served by } j \in J \text{ facility by transportation mode } k \in K \\ 0 & \text{If demand location from is served by the facility.} \end{cases}$$

Minimize: Transportation Cost + Development Cost + Emission Cost

Minimize: $$\omega_1 \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \frac{h_i}{Cap_k} * c_{ijk} + \omega_2 \sum_{j \in J} F_j * X_j + \omega_3 \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \frac{h_i}{Cap_k} * d_{ij} * E_k * ck * Y_{ijk} \quad (1)$$

Subject to

$$\sum_{i \in I} \sum_{j \in J} Y_{ijk} = 1 \qquad \forall i \in I; \forall k \in K \quad (2)$$

$$\sum_{j \in J} X_j = P \qquad \forall j \in J \quad (3)$$

$$\sum_{k \in K} Y_{ijk} - X_j \leq 0 \qquad \forall i \in I; \forall j \in J \quad (4)$$

$$\sum_{i \in I} \sum_{k \in K} h_i * Y_{ijk} \leq FC_j * X_j \qquad \forall i \in I; \forall j \in J \quad (5)$$

$$X_{ij} \in \{0,1\} \qquad \forall j \in J \quad (6)$$

$$Y_{ijk} \in \{0,1\} \qquad \forall i \in I; \forall j \in J; \forall k \in K \quad (7)$$

5. Result and Discussion

5.1 Result

As equation model (1) result by AMPL, it shows that C facility of plantation estate P=1 when no green facility development cost generated the transportation cost equal to 3,126,600 IDR both using heavy or light trucks as a transportation mode. The carbon footprint would be 692,304,000 IDR as tax charges.

```
#OBJECTIVE FUNCTION
minimize greenfacility: w[1]*TransportationCost + w[2]*DevelopmentCost + w[3]*EmissionCost;
subject to o1: (sum{i in I} sum{j in J} sum{k in K} h[i]/cap[k]*c[i,j,k]*Y[i,j,k] )= TransportationCost;
subject to o2: (sum{j in J} F[j]*X[j]) = DevelopmentCost;
subject to o3: (sum{i in I} sum{j in J} sum{k in K} h[i]/cap[k]*d[i,j]*e[k]*ct*Y[i,j,k]) = EmissionCost;

#CONSTRAINTS
subject to cons1 {i in I}: sum{j in J}  sum{k in K} Y[i,j,k] = 1;
subject to cons2 : sum{j in J} X[j] = P;
subject to cons3 {i in I, j in J}: sum{k in K} Y[i,j,k]-X[j] <= 0;
subject to cons4 {j in J}: sum{i in I, k in K} h[i]*Y[i,j,k] <= FC[j]*X[j];
```

Figure 3. P-median Green Facility Model

```
Gurobi 9.1.0: optimal solution; objective 1555110878
plus 1 simplex iteration for intbasis
ampl: display X,Y,EmissionCost,TransportationCost,DevelopmentCost;
X [*] :=
A  0
B  0
C  1
D  0
E  0
;

Y [*,*,M]
:   A   B   C   D   E    :=
A   0   0   0   0   0
B   0   0   0   0   0
C   0   0   0   0   0
D   0   0   0   0   0
E   0   0   0   0   0

 [*,*,N]
:   A   B   C   D   E    :=
A   0   0   1   0   0
B   0   0   1   0   0
C   0   0   1   0   0
D   0   0   1   0   0
E   0   0   1   0   0
;

EmissionCost = 692304000
TransportationCost = 3126600
DevelopmentCost = 859680000
```

Figure 4. Results with weight factor ω1=1, ω2=1, ω3=1, P=1

Figure 4 is the output that is generated on AMPL software for determining Crude Palm Oil Waste Treatment Facility if you decide to build one facility. It can be seen, C is 1 (one) means that the Crude Palm Oil Waste Treatment Facility is built around location C.

```
ampl: Gurobi 9.1.0: optimal solution; objective 334280394.1
14 simplex iterations
plus 1 simplex iteration for intbasis
X [*] :=
A  1
B  0
C  1
D  0
E  0
;

Y [*,*,M]
:   A   B   C   D   E    :=
A   1   0   0   0   0
B   0   0   0   0   0
C   0   0   0   0   0
D   0   0   0   0   0
E   0   0   0   0   0

 [*,*,N]
:   A   B   C   D   E    :=
A   0   0   0   0   0
B   1   0   0   0   0
C   0   0   1   0   0
D   0   0   1   0   0
E   0   0   1   0   0
;

EmissionCost = 332777000
TransportationCost = 1502900
DevelopmentCost = 1719360000
```

```
ampl: Gurobi 9.1.0: optimal solution; objective 1863057442
17 simplex iterations
plus 1 simplex iteration for intbasis
X [*] :=
A  0
B  0
C  1
D  1
E  0
;

Y [*,*,M]
:   A   B   C   D   E    :=
A   0   0   0   0   0
B   0   0   0   0   0
C   0   0   0   0   0
D   0   0   0   0   0
E   0   0   0   0   0

 [*,*,N]
:   A   B   C   D   E    :=
A   0   0   1   0   0
B   0   0   1   0   0
C   0   0   1   0   0
D   0   0   0   1   0
E   0   0   1   0   0
;

EmissionCost = 570959000
TransportationCost = 2578580
DevelopmentCost = 1289520000
```

Figure 5. Comparison of results with different weight factors

Figure 5 is a comparison output of the solve AMPL results. Where on the left with a weight factor ω1 = 1, ω2 = 0, ω3 = 1, while on the right with a weight factor ω1 = 1, ω2 = 1, ω3 = 1. It can be seen the difference in decisions on where the facilities will be built.

The estate plantation of P=2, with no development cost of a green facility of CPO waste management, occurs 2,578,580 IDR of transportation cost and 570,959,000 IDR of emission cost as a proxy of carbon footprint. Because P=2 gardens do not build environmentally friendly facilities for empty palm bunch waste produced, P=2 gardens use facilities C and D. While P=3 gardens, utilizing facilities A, D, E that create transportation costs 1,109,010IDR and emission costs as carbon footprint proxy of 245,560,000IDR, as mentioned in Table 1.

Table 2. Summary of results with weight factor ω1=1, ω2=1, ω3=1

P	Transportation Cost	Development Cost	Emission Cost	Facilities	Total
1	3,126,600	859,680,000	692,304,000	C	1,555,110,878
2	2,578,580	1,289,520,000	570,959,000	C,D	1,863,057,442
3	1,109,010	1,934,280,000	245,560,000	A,D,E	2,180,949,010
4	492,480	2,793,960,000	492,480	A,C,D,E	2,794,944,960
5	-	3,653,640,000	-	A,B,C,D,E	3,653,640,000

Source: Authors' calculation

The estate plantation of P=2, with the green facility of CPO waste management development cost, occurs 1,502,900IDR of transportation cost and 332,777,000IDR of emission cost as a proxy of a carbon footprint. Because P=2 gardens do not build environmentally-friendly facilities for empty palm bunch waste produced, P=2 gardens use facilities C and D. While P=3 gardens, utilizing facilities A, D, E that create transportation costs 954,874IDR and emission costs as carbon footprint proxy of 211,432,000IDR, as mentioned in Table 2.

Table 3. Summary of results with weight factor ω1=1, ω2=0, ω3=1

P	Transportation Cost	Development Cost	Emission Cost	Facilities	Total
1	3,126,600	859,680,000	692,304,000	C	1,555,110,878
2	1,502,900	1,719,360,000	332,777,000	A,C	2,053,639,900
3	954,874	2,149,200,000	211,432,000	A,C,D	2,361,586,874
4	462,394	3,008,880,000	102,385,000	A,C,D,E	3,111,727,394
5	-	3,653,640,000	-	A,B,C,D,E	3,653,640,000

Source: Authors' calculation

5.2 Discussion

P-median Green Facility model presents solutions for decision-makers in building a facility considering 3 main factors, namely transportation cost, development cost and emission cost. By using the P-Median model where input data is needed in the form of facility limitations obtained from the number of fresh fruit bunches production in Kalimantan province through data from the Indonesian Palm Oil Association 2016, the amount of demand obtained from the percentage of the amount of fresh fruit mark production (FFB), distance data between candidate's facilities (X_j) obtained from the calculation of google maps. After all input data is obtained, it is done computing green facility problem solving using AMPL software and produce a facility location that helps decision-makers in making decisions by weighted factors. Figure 6 is the result of if the candidate's facility is equal to 1.

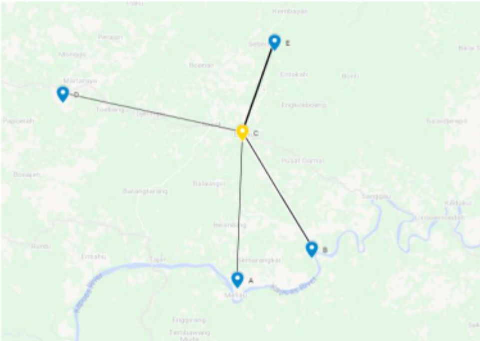

Figure 6. Illustration Facility Candidate of P = 1

Where located in "Pirsus 1 Parindu" estate plantation that can meet the demand of four other facilities. This study uses a characteristic demand to point approach with the development of the P-Median method that aims to produce an optimal distance between demand point and facility by considering the amount of waste output in each node so that waste CPO waste plant can be easier and cheaper because the distance is not too far from the facility. So, this research will produce optimal location in facilities in West Kalimantan Province as a place of Crude Palm Oil Waste Treatment.

6. Further Research

Ecological attributes that are the main topic of sustainability of palm oil business in Indonesia should consider the decision that oil palm plantations are also the most effective carbon plantations absorbing carbon compared to other vegetable oil production. In particular, West Kalimantan Province is the main producer of palm oil that has river flow and sea flow. In addition, further research that needs to be done is how green facility waste treatment of empty palm oil bunches that cost-effectively built utilizing multi modes of land and water transportation. Future research can also consider the integration of facility location with routing decisions using vehicle routing problems.

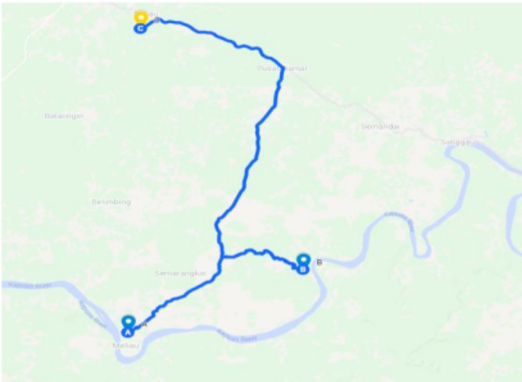

Figure 7. River transportation mode towards c by approach vehicle routing problem

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