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Case Study: Optimisation of Federal Land Development Authority Jengka Supply Chain Management Using P-Graph Approach

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Establishment of biomass supply chain is preliminary stage for biomass energy production especially in proposing potential processing plant location. Most of the relevant biomass is produced in abundance in agriculture sector. In Malaysia, biomass supply is obtained mainly from oil palm plantation which governed under Federal Land Development Authority. Biomass supply chain deals with harvesting, storage, pretreatment and transportation. Low energy density of biomass combined with availability of biomass that is widely distributed contributes huge constraints to the problem. To address this issue, P-graph modelling is used as the methodology to solve combinatorial complexity of the biomass supply chain in Federal Land Development Authority Jengka. Few possible locations for building new biomass processing plant and storage hubs were introduced in the optimisation problem. Existing plant mills, hubs and possible plant locations were interconnected to create a network. Fuel consumption for transportation was calculated by taking into account the road profiles of the routes in Jengka. The resulting solution from Accelerated Branch and Bound algorithm in P-graph shows that the optimal solution is through building new plant in location 1, 2 and 4 for a profit of 77.35 M MYR/y (18.3 M €/y).

1. Introduction

Biomass is biological material derived from living, or recently living organisms. In the context of biomass for energy, it is often used to refer to plant based material. Supply chain refers to steps to get goods or services from the supplier to the customer. Management of biomass supply chain should consider local constraints such as geographical factor and available infrastructure (Gold and Seuring, 2011). The extensive infrastructures are necessary for harvesting, transportation, storage and processing. Selecting the best location for processing facility is equally important to optimise the route of transporting the biomass (Lakovou et al., 2010). This is to decrease the consumption of fuel which will eventually leads to reduction of operating cost and enable energy production of biomass to compete with other fossil fuels. Besides, less fuel will cause less emission of carbon dioxide to the atmosphere which is directly linked to the transportation distance to the degree of vicinity of biomass site and conversion plant.

Federal Land Development Authority (FELDA) has launched a number of private corporate entities where FELDA Global Ventures Holding is considered to be the world's largest plantation operator with 811,140 ha of oil palms, mainly across Peninsular Malaysia, but also including other parts of Malaysia and the world. According to FELDA Global Group (2010), from 15.3 Mt of fresh fruit branch (FFB), 12.053 Mt of biomass comprises of empty fruit branch (EFB), mesocarp, palm shells and oil palm trunk is produced in Malaysia. The abundance source of oil palm biomass can be utilised and developed properly to meet the demand in bio-power generation. Adverse effect of fossil fuel resources on environment leads to search for alternative sustainable sources such as biomass (Lam and Lim, 2014). Oil palm biomass has sustainable and low carbon characteristics where it is cheaper to convert into energy. In some cases transitional fuel is

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favoured when usage of fuel is unavoidable while green energy is being developed. In a study conducted by Ng et al. (2014), the industrial waste oil integrated biofuel or Energy Pack provides solution to waste management in industry. However, emissions of heat–trapping gases such as carbon dioxide should be considered to reduce negative impact on global warming. This issue needs to be mitigated carefully by optimising the supply chain management (Lam et al. 2010).
This article evaluates the potential for achieving environmental and economic benefits through utilising the waste from oil palm biomass processing based on Jengka region. The number of biomass processing plants and their locations in Jengka are considered.

2. Applied Methods

P-graph tool is applied to identify the new biomass processing facilities. It is a framework which represents an unambiguous complex structure of a process network synthesis with a graph-based model and applied efficient combinatorial algorithms (Klemeš et al., 2010). The algorithms have been validated as mathematically rigorous which is based on set of axioms in selecting the optimal solutions (Varbanov and Friedler, 2008). P-graph aids in structural optimisation by removing infeasible solutions from the possible networks that do not satisfy the axioms (Friedler et al., 1992). In this study, P-graph is used to solve the optimisation problem in such a way to minimise transportation cost of biomass.

3. Case Study

In Jengka, there are a total of 64,117.05 ha for oil palm plantations with eight palm oil mills for processing. However, only one bio-oil plant is built for power generation from biomass in Jengka 8. There is a possibility for higher demand for biomass processing in the future which leads to this research study. The geographical distribution of plant mills can be referred in Figure 3.

3.1 Data Extraction

Information on amount of FFB processed in palm oil mills was obtained from respective FELDA Public Summary which in accordance with Roundtable on Sustainable Palm Oil (RSPO) requirement. A total of 41 % of biomass which consist of 5.5 % of palm kernel shell, 22 % of EFB and 13.5 % of mesocarp fibre are produced from processed FFB. Eleven possible locations for building the new biomass processing plant were initially chosen around Jengka area. Each location has been analysed based on demands from targeted customers and availability of route infrastructures.
The availability of road facilities is one of the most important aspects in determining the location of the plant. The chosen plant has to be easily accessible as large amount of biomass are required to be transported for processing. In this work, possible locations are determined based on few factors. Based on the survey conducted, road profiles of six main routes in Jengka area is observed by using cycleroute.org application. Bandar Pusat Jengka which is the main city in FELDA Jengka is used as a reference location which is indicated as “B” point from the several existed oil palm mills referred as “A” point. Based on the result, the average of ascent road is 383.43 m while average of descent road in FELDA Jengka is 373.35 m. The study of road profiles are an important key in utilising the fuel consumption as ascending roads consume higher amount of fuel as compared to descending roads. The figure below shows the road profile of the main road which is from Jengka 18 to Bandar Pusat Jengka.

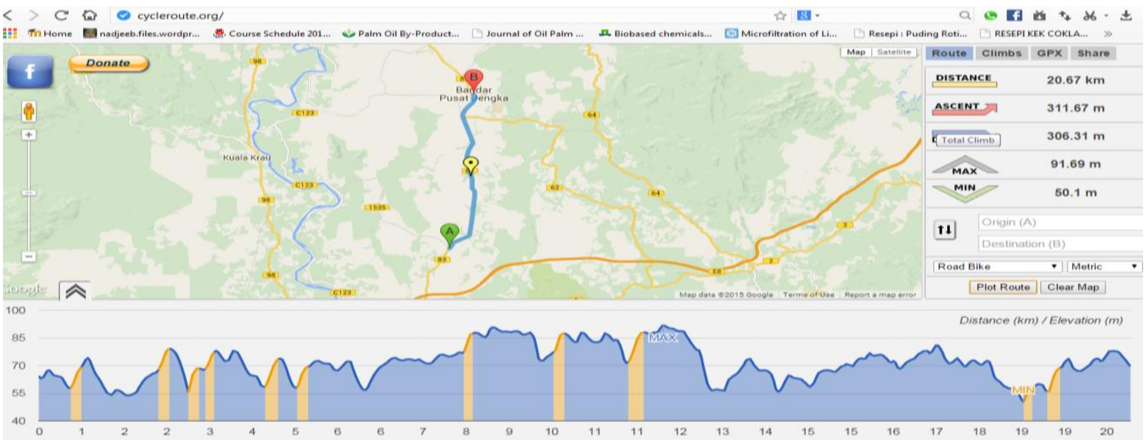

Figure 1: Road profile of main road from Jengka 18 to Bandar Pusat Jengka

Three intersections are identified as possible locations to build the biomass processing plant. These three plants are located in Jengka 12, Jengka 18 and Bandar Jengka. In Jengka 18, the intersection has a combination of main road and normal road while intersections of Bandar Pusat Jengka and Jengka 12 consist of main roads and normal roads. Main road has an advantage compared to normal roads as they are well maintained and usually bigger in size which eases transportation. Nevertheless, it is located close to the city and might be prone to heavy traffics compared to other options.

Plant Mills and general facilities owned by FELDA need electrical supply for daily operations. Instead of consuming electricity from Tenaga Nasional Berhad (TNB) which is the main energy provider in Malaysia, energy generated from the biomass processing plant can be utilised by FELDA. In this way, operational cost of FELDA can be reduced. In fact the settlers in FELDA development lands can be benefited from power generation by obtaining electricity at a lower price. By analysing these factors, the initial options have been reduced to five potential locations based on the reasoning provided in Table 1:

Table 1: Summary of proposed plant characteristics

No	location	Palm mill	Intersection	Road infrastructure Properties: Main road	Road infrastructure Properties: Minor road	High population density	Town accessibility (< 15 km)	Decision
1	Padang Piol	✓	X	X	✓	X	X	Rejected
2	Kota Gelangi	✓	X	✓	✓	X	X	Rejected
3	Jengka 8	✓	X	✓	✓	✓	✓	Accepted
4	Intersection Jengka 12	X	✓	X	✓	✓	✓	Accepted
5	Jengka 21	✓	X	X	✓	X	X	Rejected
6	Intersection Bandar Jengka	X	✓	✓	✓	✓	✓	Accepted
7	Equidistant between Jengka 14,15 and 16	X	X	✓	✓	✓	✓	Accepted
8	Equidistant between Jengka 16,18 and 23	X	X	X	✓	✓	✓	Rejected
9	Intersection Jengka 18	✓	✓	✓	✓	✓	X	Redundant [Choice: Intersection]
10	Jengka 18	✓	X	✓	✓	✓	X	
11	Jengka 3	✓	X	✓	✓	X	X	Rejected

Few storage hubs which act as biomass collection points from different palm mills are introduced in this optimisation problem. The hubs are interconnected with existing palm mills and proposed plant locations to create a network. The locations of the storage hubs can be referred in Figure 3. The distances from palm mills to hubs as well as hubs to proposed plant locations are acquired from Google Maps. The cost of fuel required for transporting biomass is calculated for each distance.

3.2 Supply chain with P-graph modelling

The inputs for the optimisation model are based on the following assumptions:

a) The raw material is represented by supply of biomass from existing palm mills in FELDA Jengka. The cost of the raw material is based on the market value of oil palm biomass in Malaysia.

b) Operating costs in this study are referred to cost of fuel for transporting facilities. The average fuel consumption is assumed as MYR 0.39/ km t biomass by taking road profiles into consideration.

c) The intermediate materials denote the storage hubs which are the collection point of biomass from various plant mills.

d) The proposed locations of the plant are depicted by final products in P-graph. The revenues from the plant are results of selling produced heat (or/and) power to the customers.

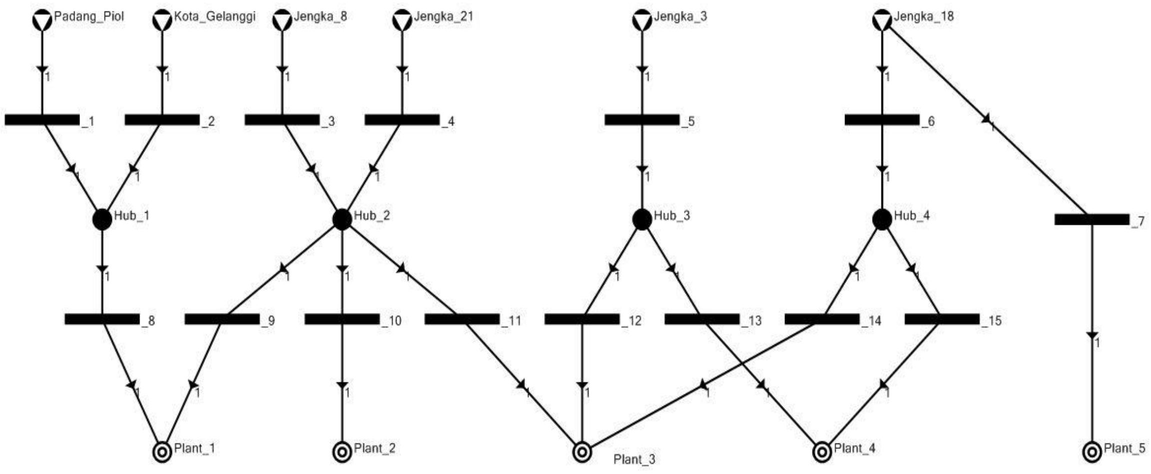

Figure 2: P-graph modelling for Jengka supply chain optimization problem

3.3 Results

The result from the P-graph ABB optimisation algorithm shows that the total profit is MYR 77.35 M/y (18.3 M €/y) by building plant 1, 2 and 4. However, networks through operating unit 7, 9, 11, 12 and 14 were not chosen in the solution. Plant 3 and 5 which are linked to these operating units are eliminated completely. The gross profit from plant 1, 2 and 4 are MYR 19.44 M/y, MYR 34.58 M/y and MYR 36.10 M/y whereas the total net profit for plant 1, 2 and 4 are MYR 17.76 M/y, MYR 30.00 M/y and MYR 31.42 M/y.

Plant 4 has the highest gross and net profit compared to other plants as it consumes largest amount of biomass to generate product. The cost of fuel consumption of the transportation facilities is less due to shorter distances involved for the route to plant 4. From the obtained solution, Plant 4 is the best choice as it produces the most products with reduced cost of fuel consumption.

4. Conclusion

Based on the results from P-graph modelling, possible locations for building new biomass processing facility in FELDA Jengka are plant location 1, 2 and 4. Plant 1 is located close to palm mill Jengka 8 and hence has the potential to supply heat and power to the mill and surrounding village through cogeneration. Conversely, Plant 2 and 4 can be used as power generation plant to supply electricity to households in the villages nearby. Plant 2 is strategically located at an intersection, which provides good access to transportation.

On the other hand, Plant 4 is situated in highly populated area which is surrounded by 3 FELDA villages and also has an advantage in terms of transportation as it is closer to the main road. As an overall, Plant 1, 2 and 4 have good accessibility to the town which is within 15 km but further from the congested area. Another alternative other than P-graph, GAMS which is specifically designed for modelling linear, non-linear and mixed integer optimisation problems can also be used in handling process synthesis problems for future work.

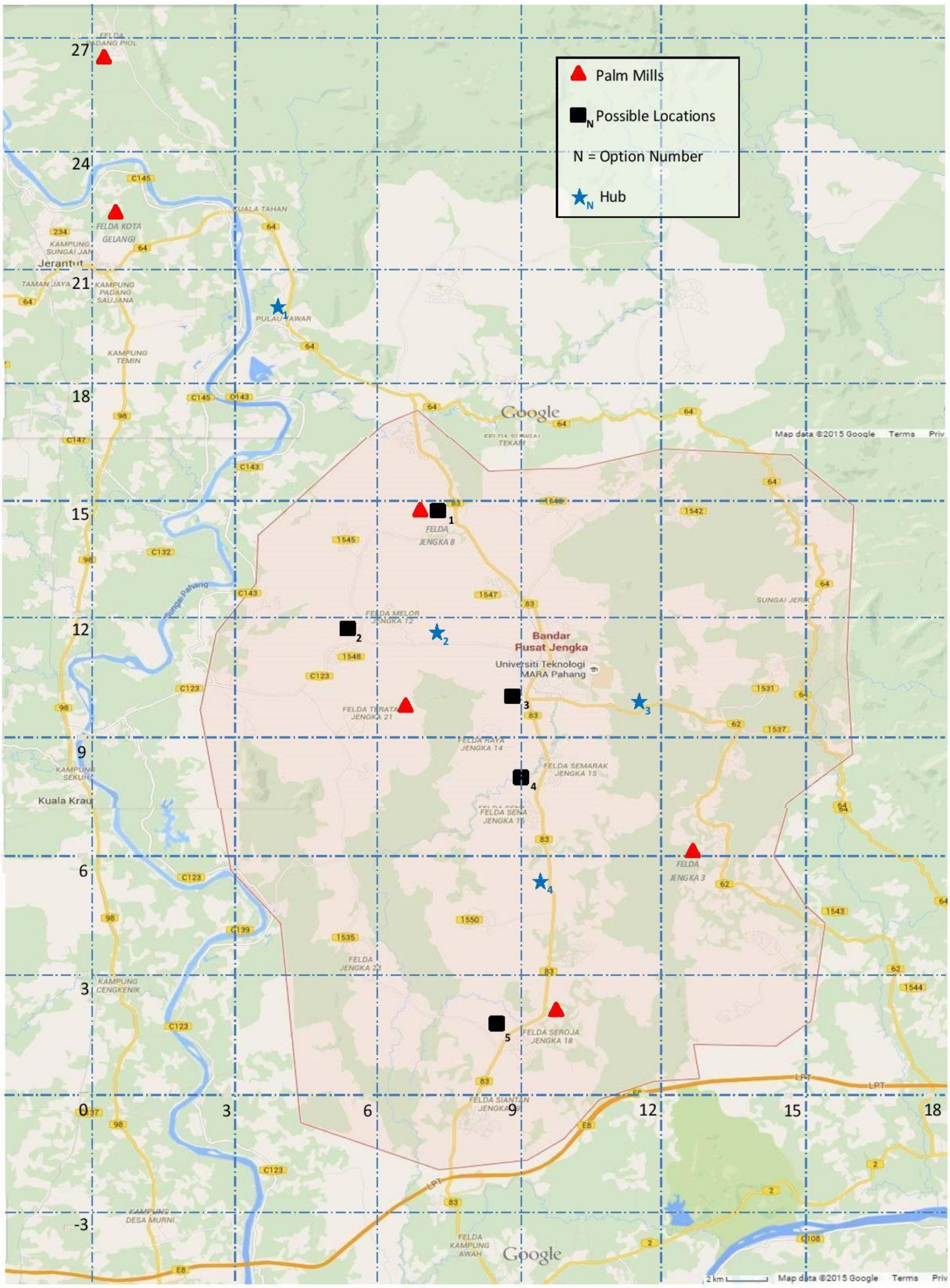

Figure 3: Locations of existing palm mills, potential hubs and plants

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