A system design for cocoa beans transportation of premium products.

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Abstract. Premium chocolate product such as praline, chocolate bars, confectionery, and chocolate drink need a premium quality of cocoa beans. Scarcity of sources and less quality in the existing cocoa beans supply chain affecting a sustainable production and increase operational cost. Improvement in cocoa supply chain which is consisting of farmers-farmers group- transporter/logistic provider- agro industry will provide cocoa beans availability and optimum operational cost of premium product-agro industry. Transportation sector which support supply chain has an important role for ensuring the distribution of cocoa beans delivery in time. The source availability and transportation mode are the requirements that analyzed in Business Process Modelling (BPMN) to minimize transportation cost and maximize quantity of cocoa bean demand. The formulation of those will be optimized by Goal Programming. The results is deviation of transportation cost 2,083 rupiahs per kilogram when supply meets the agro industry demand and there is no deviation of transportation unit when using six unit of truck. It's reveal that the availability of cocoa bean to meet agro industry demand will give cost efficiency.

1. Introduction

As a third cocoa producer in the world, Indonesia's cocoa has a high melting point as a special characteristic which used by national and international cocoa industry for blending process. Predominantly by smallholder crop with total land 1,686,178 hectare or percentage of 97.6% and productivity about 0.8 ton/ha. This production does not sufficient to provide national processing industry and international demand. Our cocoa bean quality still has less grade than Ivory Coast and Ghana as the first and second cocoa producer in the world. Global market mainly in Europe, our cocoa beans has less quality due to contain high acidity, less of flavored precursor compounds, low level of butter which cause automatic detention about 15% from average international price of cocoa beans. Therefore, we have to drive and improve good agricultural, handling and manufacturing processes to produce high quality export of processed cocoa products.

Source of availability is an important factor in producing food and non-food cocoa-based products such as cocoa powder, cocoa bar, cocoa compound, candy, ice cream, cake, emulsifier, and other personal and pharmacy products. Fulfillment of industry demand through the existing supply chain which consist of farmer, local collector, trader/exporter, and agro industry comprise collecting of cocoa beans, sortation, fermentation, drying, packaging, and storage to get uniformity size and quality. Scarcity and lack of source in right time, quantity, quality, and also this long existing supply chain affect delay in processing and increase operational cost.

Effectiveness and efficiency in distribution and cocoa trading will improve cocoa supply chain from upstream (farmers) to downstream (agro industry) and enhance sharing margin for farmer. The directly purchase of cocoa beans by agro industry increase farmers' share price about 95% of total margin in Donggala District Central Sulawesi Province (KPPU 2009), with involving farmer, farmers' group, transporter and agro industry-a direct supply chain.

The continuous distribution can be achieved by supporting of transportation system in right time, quantity, quality, cost, and type. Transportation as a bridge between farmers and agro industry will assist a distance and infrastructure problem by providing capacity mode, right schedule, besides the availability of supply. On-time delivery of cocoa beans with conformity of quantity and quality will give an efficiency transportation cost.

The objective of this study are reducing transportation cost and optimize supply of cocoa beans in right time, quantity and quality which consider quantity of mode, capacity of supply, production cost of cocoa beans and shipment cost to agro industry. Several study in cocoa distribution and transportation system will be present in section 2, current condition of cocoa supply chain and problem formulation can be seen in section 3, methodology which are used in this study will be explain in section 4, result in section 5, conclusion and discussion in section 6.

2. Related Work

Transportation and distribution of cocoa bean still use traditional mode where farmers sell their harvest to local collector, then continuing the market mechanism to trader, exporter or cocoa agro industry (1). The challenge of transportation and distribution system are complexity of supply chain where each stakeholder has their own objective, consumer preferences of delivery in-time and satisfaction of mode, conformity and combination of pathway along the supply chain and capacity of mode which affect transportation cost, government regulation, and governance of green transportation to reduce pollution (2). In (3) research emphasize that infrastructure of logistic is very important for vertical-integrated industry, which is fully depend on raw material.

According to (4), composition of transportation mode as one of routing strategy and tactical decisions which has impact on shipping frequency, delivery capacity, and coverage area. Determination of transportation mode and its unit number as an input for transportation and distribution system of Crude Palm Oil in PT. XYZ is studied by (5), with minimum transportation cost of fruit fresh bunch as an objective. Coordination between agro industry demand and producer supply, inventory in trader/exporter warehouse are such a preventive solution for distortion of supply demand called Bullwhip Effect phenomenon (6). Other study by (7), mentioned the accuracy of those factor, price fluctuations, and batch order are an important input for production planning improvement of minimizing Bullwhip Effect. In order to anticipate this kind of phenomenon, (8) proposed coordination contract between cassava farmer and Biofuel industry in China. This coordination to make sure the availability of supply which is depend on uncertainty harvest, as a risk and benefit factor in biofuel supply chain.

Determine distribution path from supplier to industry based on the chosen optimum path through shortest path method (9), optimization with linier and non-linier programming, Branch and Bound Algorithm (10) or matrix saving (11).

3. Problem Formulation

3.1. Current condition

The existing cocoa supply chains involve local collectors and traders that affect cocoa beans supply to industry demand. It could be happen due to export demand and/or other industries with high price. This pattern give impact in lack and scarcity of agro industry supply and increase operational cost such as transportation and distribution. Fulfillment of raw material from another source or producer should take times, add transportation route and also cost. In (12) also said that distance, transportation mode, delivery time, consistency of quality, and quantity of cocoa beans will affect cost efficiency and

supply effectiveness. According to this requirements, transportation becomes one important determining advantage of Indonesia cocoa beans.

3.2. A system design of cocoa beans transportation by Goal Programming Method

Redesign of cocoa supply chain with farmer's group and agro industry as a stakeholder is expected enhance cocoa beans supply to industry. In order to achieve that objective, we need transportation system which involve the availability of supply, industry demand, shipping capacity, scheduling, on-time delivery and these factor will reduce transportation cost. Farmers group should provide and comply the cocoa beans demand, which is delivering with the appropriate capacity and number of mode. The objective of this system design are delivering of cocoa beans in right time, quantity and quality to fulfill agro industry demand and reducing transportation cost. The fulfillment of cocoa beans is facilitated by capacity and number of mode, meanwhile transportation cost is affected by production cost of cocoa beans, shipping cost, and quantity of shipped cocoa beans. In order to achieve these objective, goal programming is used to get the optimum solution.

Where Parameters:

C_{prod} = production cost of cocoa beans of farmers' group i (Rp/ton)

K = capacity of mode (ton)

C_{trans} = transportation cost from farmers' group i to agro industry j (Rp/ton)

D_j = cocoa beans demand of agro industry j (ton)

C^{tot} = total transportation cost from farmers' group i to agro industry j (Rp/ton)

And decision variables:

Q_{ij} = amount of cocoa beans shipped from farmers' group i to agro industry j (ton)

M_{ij} = number of mode from farmers' group i to agro industry j (unit)

In this study, a system design of transportation has maximum number of mode, cocoa beans production at farmers' group, and demand of agro industry.

Parameters:

K_i = cocoa beans production of farmers' group i (ton)

M^{max} = maximum number of mode (unit)

Decision variables:

Q_{ij} = amount of cocoa beans shipped from farmers' group i to agro industry j (ton)

M_{ij} = number of mode from farmers' group i to agro industry j (unit)

Table 1. Notation of transportation system.

Notation	Description
C_{prod}	production cost of cocoa beans of farmers' group i (Rp/ton)
K	capacity of mode (ton/unit)
C_{trans}	transportation cost from farmers' group i to agro industry j (Rp/ton)
K_i	cocoa beans production of farmers' group i (ton)
D_j	cocoa beans demand of agro industry j (ton)
M_{ij}	number of mode from farmers' group i to agro industry j (unit)
M^{max}	maximum number of mode (unit)
Q_{ij}	amount of cocoa beans shipped from farmers' group i to agro industry j (ton)
C^{tot}	total transportation cost from farmers' group i to agro industry j (Rp/ton)

Assumption:
1. The shipped cocoa beans to agro industry are in premium quality,
2. Sortation and storage time at farmers' group are not counting
3. Capacity of mode is same
4. Type of mode is same
5. Q_{ij} and M_{ij} are non-negative variable and integer

Goal:
1. Maximum fulfillment of cocoa beans supply :

$$\sum_{i=1}^{I}\sum_{j=1}^{J} KM_{ij} \geq D_{ij} \quad (1)$$

i = {1,2,3,.....,I}
j = {1,2,3,.....,J}
i, j ∈ Z

2. Minimum of transportation cost :

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij} \sum_{i=1}^{I} C_{prod} + \sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij} \sum_{i=1}^{I}\sum_{j=1}^{J} C_{trans} \leq C^{tot} \quad (2)$$

i = {1,2,3,.....,I}
j = {1,2,3,.....,J}
i, j ∈ Z

Constraints:
1. Number of mode :

$$\sum_{i=1}^{I}\sum_{j=1}^{J} M_{ij} \leq M^{\max} \quad (3)$$

2. Availability of cocoa beans :

$$\sum_{j=1}^{J} Q_{ij} \leq K_i \quad (4)$$

3. Amount of cocoa beans shipped :

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij} \geq D_j \quad (5)$$

i = {1,2,3,.....,I}
j = {1,2,3,.....,J}
i, j ∈ Z

Fulfillment of cocoa beans to agro industry being maximized by number and capacity of transportation mode (1), minimum transportation cost from farmers' group to agro industry consist of production cost of cocoa beans and shipping cost are less than total transportation cost (2). This system design of transportation is limited by number of used mode for shipping cocoa beans (3), cocoa beans production at farmers' group (4), and demand of agroindustry (5).

4. Methodology

4.1. Identification System

System identification as a needs analysis of cocoa beans transportation system which consist of system boundary/scoping, objectives, stakeholder, resources, rules, operation condition, desirable and undesirable inputs, desirable and undesirable outputs, opportunity and threat. These element being

analyzed in relation with farmer's group and agro industry activities (use case) along this system. The availability of cocoa beans, production cost and transportation cost are from survey .

4.2. Business Process Model and Notation (BPMN)

Relation and connectivity between processes being depict literally in graphics to give a detail analysis of the system. A system design of transportation which is involving stakeholder, information, and processes based on the existing condition of cocoa beans supply chain which re-engineered through directly supply chain from farmer's group to agro industry, will show in BPMN 2.0.

4.3. A system design for Cocoa Beans Transportation by Goal Programming

A system design for cocoa beans transportation are shipping cocoa beans directly with certain quantity from farmer's group to agro industry. The amount of shipped cocoa beans to agro industry are based on the availability supply in each farmers' group. Input variables are used in goal programming method to optimize this system design. The constraints of number of mode, availability of cocoa beans and amount of cocoa beans shipped are used to get minimum deviation of the number of modes and transportation cost which is an optimum solution.

The first objective (1) which aim to fulfill agro industry demand should give minimum deviation of number of modes through goal constraints $\sum_{i=1}^{I}\sum_{j=1}^{J} KM_{ij} - d_1^+ + d_1^- = D_j$, and second objective (2) which aim to reducing transportation cost through minimum deviation of $\sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij} \sum_{i=1}^{I} C_{prod} + \sum_{i=1}^{I}\sum_{j=1}^{J} Q_{ij} \sum_{i=1}^{I}\sum_{j=1}^{J} C_{trans} - d_2^+ + d_2^- = C^{tot}$. The optimum result will achieve by minimum deviation of number of modes and transportation cost $d_1^- + d_2^+$ as goal function.

5. Result and Discussion

5.1. Identification System

System identification as a needs analysis of cocoa beans transportation system which consist of farmer's group and agro industry as stakeholders, quantity of shipped cocoa beans to agro industry with production cost and number of modes with transportation cost are input for this system which should efficiently meet agro industry demand as an objective. Cocoa beans from farmer's group are delivered to agro industry directly with a certain capacity as a system boundary/scoping. These element being analyzed in relation with stakeholder activities (use case) along this system.

5.2. Business Process Analysis (BPMN)

Analysis of a system design for cocoa beans transportation is based on agro industry demand of cocoa beans that should be fulfilled from the availability of cocoa beans in farmers' group, then being delivered by using transportation mode. The capacity of modes should meet quantity of shipped cocoa beans. The analysis process using BPMN which is presented in figure 1:

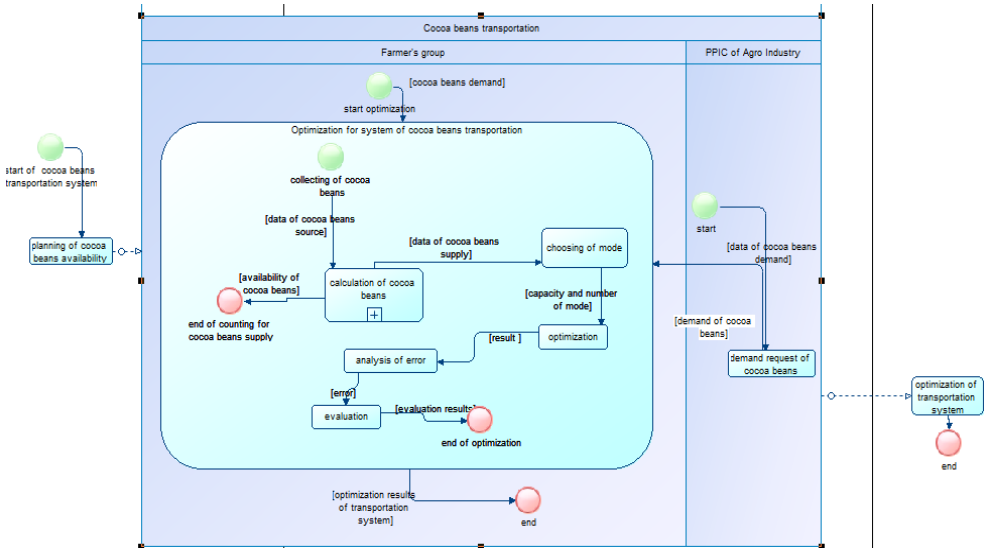

Figure 1. Analysis process of system design for cocoa beans transportation in BPMN.

5.3. Design Transportation

Cocoa beans are collected at farmers' group which is an origin point of this system. Each farmers' group supply to several agro industry in order to fulfill demand capacity in right time, quantity and quality. The illustration of this system design are seen in Figure 2 :

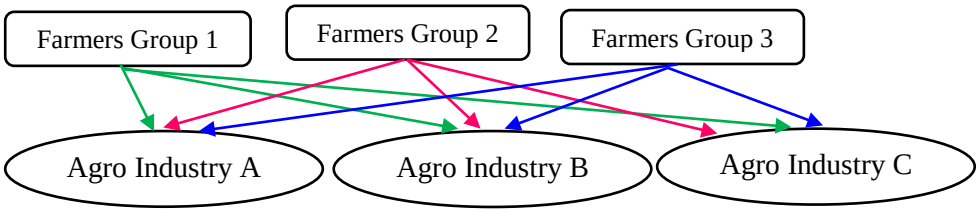

Figure 2. Process of cocoa beans shipping.

We use an illustration of cocoa beans supply demand in Banten Province, which farmers in Pandeglang district are member of three farmers' group which supply their cocoa beans to three agro industry in Tangerang district. The production of cocoa beans at each farmers' group is 120 tons and demand of each agro industry about 105-120 tons. Each farmers' group supply for each agro industry.

Estimation of transportation cost is based on 60% of cocoa bean price. An average price of cocoa beans is 20,000 – 32,000 rupiahs per kilogram, then we estimate transportation cost is about 12,000 – 20,000 rupiahs per kilogram. The estimation cost which used as a maximum total transportation cost for this system design is 20,000 rupiahs per kilogram or equal to 20,000,000 rupiahs per ton.

In order to fulfill of each agro industry demand 105 ton, we use maximum truck of six unit with capacity 20 ton per truck – for equation (1). According to minimum transportation cost, we use production cost of cocoa beans about 150,000 rupiahs per ton and shipping cost is 100,000 rupiahs per ton, with the maximum total transportation cost is 20,000,000 rupiahs for each ton – for equation (2).
By using goal programming method and solver, optimization of the maximum fulfillment of cocoa beans is represented by minimum deviation of the number of modes which are used for delivering agro industry demand. And also for transportation cost is represented by minimum deviation of transportation cost. The result is zero for deviation of the number of mode and 2,083,333 – 3,333,333 rupiahs per ton or equal to 2,083 – 3,333 rupiahs per kilogram for deviation of transportation cost. The satisfying result from this optimization is 2,083 rupiahs per kilogram.

6. Conclusion

A system design for cocoa beans transportation of premium products, the fulfillment of cocoa beans demand by farmers' group and efficiency of total transportation cost are solved by goal programming method. Minimum deviation shows the satisfy result of goal constraints. The differences of demand give a deviation of transportation cost about 10.42 – 16.67% with 10.42% is the satisfy result, meanwhile the use of six truck do not give any deviation.

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