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An Optimize and Adaptive Modeling for Sugarcane Harvesting and Transportation

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***Abstract*: This paper discusses sugarcane harvesting and transportation system to provide an appropriate quality and number of sugarcanes for the mill. The objectives of this research were to optimize transportation cost and sugarcane quality to produce at the mill. Harvesting and transportation system was analyzed descriptively using Business Process Modeling Notation (BPMN). A Fuzzy Subtractive Clustering (FSC) algorithm was applied to find sugarcane distribution centers for transportation to the mill. Non-dominated Search Genetic Algorithm (NSGA) II and LINMAP (Linear Programming Technique for Multidimensional Analysis of Preference) algorithm were applied to find feasible solutions to optimize sugarcane transportation cost and quality. The main contribution of the paper was formulating new transportation system and optimizing transportation cost and sugarcane quality. This paper successfully found 4 regions as distribution centers with each specific characteristic for transportation system. The best solution was found with specific number of transportation mode and scheme to minimize transportation cost and maximize sugarcane quality to process at the mill.**

Keywords: Fuzzy subtractive clustering, NSGA II, Optimization, Sugarcane, Transportation.

I. Introduction

This research considers an adaptive and optimization model in solving transportation problems for sugar agroindustry. The adaptive modelling is required to covers uncertainty and imprecision variables of the problem descriptions. In an adaptive approach in optimization, the dynamical changes of actual parameter of the real world are applied as the input and constraints for the optimization model [1], [2]. An optimization model is a mathematical procedure to allocate scarce resources optimally. The optimization model on this research is focused on formulating the problems and develop alternative solutions to achieve an optimum transportation problem in sugarcane.

Harvesting and transportation activities in sugar industry hold the important role to ensuring the availability and the quality of sugarcane for the mill. Sugarcane harvesting and transportation are also the prior operations affect productivity and the quality in producing sugar for consumer. Refers to Ref. [3], 60% of industry's total costs comes from cultivation and transportation activities. Therefore, this is an opportunity in reducing cost through an optimization modeling.

Harvesting and transportation in sugar agroindustry problems have many objectives to be optimized. Some of these objectives may conflict each other which makes the process in finding solutions is full of complexity and uncertainty [4]. Harvesting and transportation system in sugar agroindustry has a highest priority to evaluate and essential to discuss. Further, challenges in harvesting and transportation model of sugarcane becomes more complex, uncertainties and imprecise which affect decision-making process for cost minimization and improving the raw material quality [5], [6].

In sugarcane transportation, it should deal with perishable and seasonal product, challenging in moving a right amount of the right product to the right place at the right time and minimize yield loss [7]. Besides that, sugarcane transportation activity is an attempt to maintain the amount of sugar that goes into the mill in accordance with the required quality and time. Some uncertainties and imprecisions parameters which have to be noticed of the sugarcane transportation are sugarcane quality, total reducing sugar (TRS) within transportation, distance of the farm to the mill facility, availability and capacity of the transportation mode and sugar mill warehouse capacity [3], [8].

In previous research, the uncertainty and imprecision variables in harvesting and transportation are assumed as precisely known and set equal to nominal value [8]. These assumptions are incomplete and unfeasible to define as an approximation that will greatly affect the efficiency [8]. Therefore, a multi-objective model deal with uncertainty and imprecision variable is proposed to represent the real world problem of the sugarcane harvesting and transportation activities [8], [9]. A multi-objective model may have uncertainty and imprecise levels to achieve objectives with respect to constraints, therefore it is a challenging for analysts to modelling the problem. In this context, this research proposed a multi-objective problem solves using soft computing method to accommodate the uncertainty and imprecision parameters. Seek to answers this challenge, optimization and adaptive modelling is applied in this problem. As far of author knowledge, there are no previous research that considers developing distribution center to assist the optimization problem in transportation cost and product quality. This research offers a new approach to solve similar problems.

The objectives of this research are to identify sugar agroindustry's harvesting and transportation system, to analyze and develop a sugarcane transportation system through developing distribution center and optimize sugarcane transportation cost and quality. In the remainder of the paper, we briefly mention formulation and mathematical model to answering the objectives in section 2. Thereafter, in section 3 describes result and discussion of the model validation. Finally, in section 4 we conclude the results and deliver recommendations.

II. Research Method

A. Research Framework

The framework of the research is organized by 3 sections, system analysis, transportation system modelling and optimization. The complexity of the sugarcane transportation and distribution is analyzed and depicted in a Business Process Model Notation (BPMN). A Fuzzy Subtractive clustering (FSC) is applied for determining the distribution center and region of harvesting of the sugarcane. At the final stage, an optimization model is developed to minimize transportation cost and maximize sugarcane quality with considering previous stage in distribution center scheme for transportation. NSGA II technique is applied in optimization to deliver feasible solutions. A LINMAP (Linear Programming Technique for Multidimensional Analysis of Preference) is applied to mention the ideal solutions of the pareto front of the feasible solutions provided by NSGA II result. Seek to find the optimize result with considering the real-world condition, this research considers a case study for data acquisition. This research considers a sugarcane plantation and mill at the West Java, Indonesia as the case study. Finally, to solve the research objective, the research framework is depicted in Figure 1.

B. Research flow and modelling

1) System analysis and identification for sugarcane harvesting and transportation.

The system identification and analysis are the first step of a system methodology approach to identify limitation and overall stakeholder's requirements in the system. In this case, sugarcane harvesting, and transportation is the limitation of the system.

The system modelling is required to describe the system definition and limitation. In this case, sugarcane harvesting, and transportation business modelling will be described in a Business Process Model Notation (BPMN) diagram. BPMN is required to obtain the overall system workflow, stakeholder and system entities relations also define the problem and limitation of the research graphically. This research apply BPMN due to enables to assist in developing the model in the system [10].

2) Model formulation to find region centre for sugarcane transportation.

Sugarcane transportation and harvesting system define as a network or a graph model, which consist of Vertices (***V***) and Edge ***(E)***. For answering the second objective of the research in determining Regions (R), it is necessary to find potential Region centers at the field. This problem is possible to be solved by a clustering algorithm. In this context, the transportation and harvesting system is defined as a weighted graph. In this case, the **V** of the model is defined as location of each farm while **E** as a Weight of the graph. A weight function (*w*) ***E***→ **R** is defined to assigns a weight on each Edge [11].

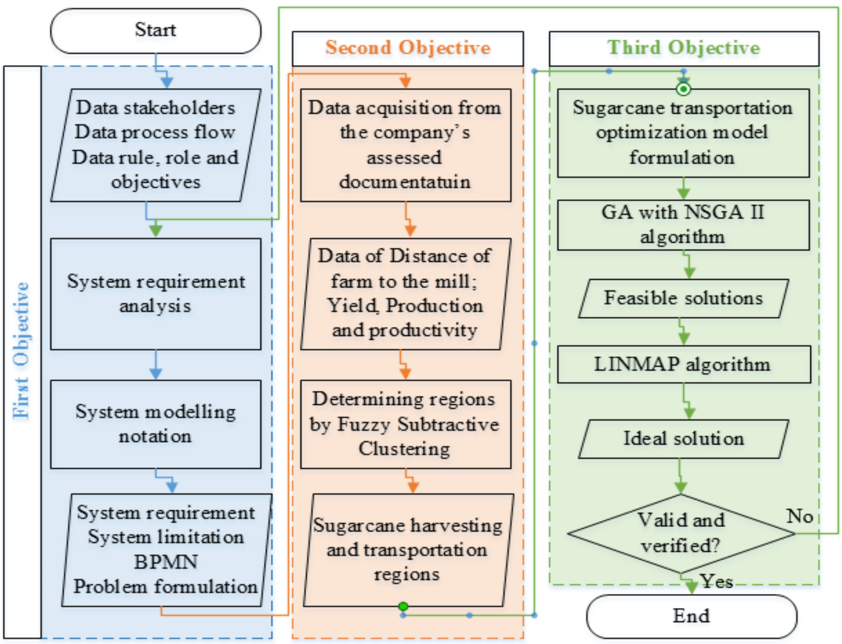

Figure 1. Research framework

To find a region center *(R)* through vertices and edges {***V***, ***E***}, it needs to adopt a cluster fitness function. It is required to find a center of the cluster for a given input of graph based on the similarity. We define vertices (***V***) as a data set of farm location {$V_1, V_2 \dots V_j$} while Edge (***E***) is dataset of weight factor in determining Region {$E_1, E_2 \dots E_i$}. To find a location of the Regions, we need to find maximum ***E*** or weight of the graph of a **V** (location). The formulation in determining a region center position *(R_j)* in the sugarcane field is defined in Equation 1-6.

$$\text{Region (R) network} = \{\boldsymbol{V}, \boldsymbol{E}\} \quad (1)$$

$$\text{Region position } (R_j) = \text{Max } |\boldsymbol{V}| \quad (2)$$

Subject to:

$$\text{Max } \boldsymbol{E} \rightarrow |\boldsymbol{V}| \quad (3)$$

$$\boldsymbol{E} \geq 0 \ \forall \ \boldsymbol{R} \quad (4)$$

$$\boldsymbol{V} = \{\boldsymbol{V_1}, \boldsymbol{V_2} \dots \boldsymbol{V_j}\} \quad (5)$$

$$\boldsymbol{E} = \{\boldsymbol{E_1}, \boldsymbol{E_2} \dots \boldsymbol{E_i}\} \quad (6)$$

Previous research proposed algorithm to find maximum edge or maximum weight of the weighted graph, moreover this case requires to apply the density measure to accommodate the uncertainty variables. The density measure is proposed since the input weight of the Edge (***E***) is an uncertainty and imprecision variables which found in sugarcane transportation and harvesting to define possible region centers. These are involve distance of farm to the mill (X_{c1}); sugarcane yield and sugar content (X_{c2}); sugarcane quality (X_{c3}); wide of farm (X_{c4}); number of sugarcane production of a farm (X_{c5}); sugarcane productivity in a farming area (X_{c6}).

In a density measurement seek to find a higher density than a previous preset threshold [12]. The density measure is a special case of the decision problem to find location of the Region. To measuring density and to accommodate uncertainty and imprecision variables in determining location of the transportation's region, Fuzzy Subtractive Clustering (FSC) is proposed to solve the problem.

3) Fuzzy Subtractive Clustering modelling for this research

Fuzzy Subtractive Clustering (FSC) is an unsupervised algorithm to determine areas in a variable that has higher density than another points [13], [14]. A fuzzy based clustering acts in improving the accuracy, considering uncertainty and imprecision parameters and leads to a precise decision-making environment [15]. This algorithm seeks to reduces computational complexities and performs a better distribution of cluster centers than any clustering algorithms.

In determining Region centers position which considers maximum weight factor of the potential Region is described in following step. The input data as Edge (**E**) in the formulation are normalized. Suppose that X_{cd} represents as data input, X_{Min} is a minimal value of X and X_{Max} is maximal value of X, therefore the formula to normalized data X is described at Equation 7.

To seek a cluster point in FSC, the first step is calculating the density of each data (n) which the feature space is normalized. The data densities are used to calculate potential cluster point which is defined. by the Equation 8.

Where $\|X_{cd} - X_{bd}\|$ donates the Euclidian distance, X_{bd} assumed as first location of cluster center. In this problem, variable r is a radius to measure the potential point which commonly define as 0.3 [13]. Finally, *Dc* donates potential cluster data point of the data *c*.

After the potential of every dataset point has been found, the data point with the highest potential value is selected as the first cluster center. Assumed X_{bd} as the first location of cluster center and D_1 is the first cluster potential value, then to revise a new potential value is found by the Equation 9.

Suppose r_g is a positive constant value which has higher value than r since it is folded by Squash factor and define as 1.25 [13]. In the Fuzzy Subtractive Clustering, it also defines the reject ratio and accepted ratio to evaluate the potential cluster value. In this research accept ratio is set 0.5 and reject ratio is set as 0.15. The FSC algorithm works in determining cluster center by decreasing another data point's potential value. This method affected those previous points among a potential cluster are impossible to be the next cluster center.

$$X_{cd} = \frac{Xcd - XMind}{XMaxd - XMind} \quad (7)$$

$$R = \sum_{k=1}^{n} e^{-4\left(\frac{||Xcd - Xbd||}{r}\right)} \quad (8)$$

$$R_i = D_i - D_1 * e^{-4\left(\frac{||Xcd - Xbd||}{r_g^{\,2}}\right)} \quad (9)$$

4) Multi-objective Sugarcane Harvesting and Transportation optimization

This paper applied Genetic Algorithm (GA) to optimize transportation modes allocation in minimizing transportation cost and maximize sugarcane quality. GA is powerful for optimization, as show in [16] and [17]. The idea of GA for transportation and allocation has also applied in [18] which the result is satisfied. As we know that GA solutions is found through population in chromosome representation. In this case, chromosome representation for GA solution is defined as transportation mode allocation in every region at a certain time. The number of region (*Ri*) has been found at the previous stages as the distribution center. The constraint of the transportation mode should be appropriate with available truck and trailer to fulfil the requirement of sugar mill and enable to transporting all harvested sugarcane at the field. Chromosome matrices representation in this model is described at Table 1.

Region (R_i) is a result of the farm cluster by FSC method as aforementioned. Number of Truck (*NT*) and number of Trailer (*NL*) in every region and in an appropriate time are the optimal solution for transportation mode allocations which considering transportation cost and the quality and yield of the transported sugarcane. To obtain these solutions, the multi-objective models are described mathematically by Equation 14 and Equation 15.

Minimizing the transportation cost is obtained by the whole cost of transportation which respect to the distance (*D*). The transportation cost is calculated through fuel consumptions (*TC*), time of transportation (*TT*) and drivers pay. The time of transportation (*TT*) is determined through the distance and average velocity of the mode in full capacity.

Maximizing yield of the sugarcane is obtained through average yield loss in specific time of transportation (*TT*) and enable of total capacity to transport to the mill. As we know, sugarcane is a perishable product that possible find a sugar content loss during transportation after harvesting to milling time [4], [19]. Therefore, it needs to allocate truck and trailer optimally to a specific region for minimizing transportation cost and maximizing sugar content/ quality of the sugarcane.

The constraints of the model are mentioned as follows:

1. All allocated mode transportation (AM_{ij}) must be able to transport all harvested cane in region *i* in an appropriate time of transport (Rit_{ij}), as mentioned below.

$$\sum_{i=1}^{i} truck\ capacity \times RitTruck_{ij} \times RPt_{ij} < total\ harvested\ sugarcane\ at\ region\ i \quad (10)$$

2. All harvested and transported sugarcane in all regions (R_i) must fulfilled with factory's requirements in an appropriate time, as mentioned below.

$$\sum_{i=1}^{I} Ri \geq Millcapacity_j \quad (11)$$

3. Time of transportation (*TT*) is obtained by distance (*D*) and average velocity of transportation mode (*v*), as mentioned below.

$$TT_{ij} = \frac{D_{ij}}{\bar{v}_{ij}} \quad (12)$$

4. Sugar content loss (YL_{ij}) is occurred specifically as defined below.

$$YL_{ij} = Y_{ij} - (delay_{ij} \times decay_{ij}) \quad (13)$$

To accommodate GA solutions, this paper applied population size with 100, crossover 0.9 and permutation 0.1. The mathematical model and constraints are applied in the Java NetBeans Desktop using MOEA framework version 2.1 (available from http://www.moeaframework.org/) to solving problems using NSGA II.

5) Non-dominated Search Genetic Algorithm (NSGA) II formulation

According to Equation 14 and 15, a solution point *p* is accepted if only if there are no solutions better than *p* with respect to minimize y_{ij} and maximize z_{ij} . Due to multi-objective optimization problem, a Pareto front should be defined. A pareto front for this case is defined as a set optimal solution which respect to the objective function (P_{ym}, P_{zn}) as detailed at Equation 16.

Suppose P_{ym} as a set of minimizing y_{ij} solution, while P_{zn} for a set of minimizing z_{ij} as describe in Equation 17 - 19. To obtain a dominated search, NSGA II algorithm is applied, a solution P_{ym} should be better than P_{ym*} (the solution before P_{ym} is found) in case minimization and P_{zn} should be better than P_{zn*} for maximization as is described in equation 19 and 20.

6) LINMAP model to find the best solution

A Pareto front solution is generated by NSGA II with 2 objectives possible to provide feasible solutions. An ideal solution should be found among possible solutions (F_{ij}). In this step, LINMAP (Linear Programming Technique for Multidimensional Analysis of Preference) algorithm is applied to find the ideal solution of the Pareto front.

The LINMAP algorithm searches the best solution which has a minimum distance to the ideal solution (F_j^{ideal}). Therefore, each solution distance (D_i) is found through Equation 21.

Region	Number of allocated trucks to sugar mill *j*	Number of allocated Trailer to sugar mill *j*
R_1	NT_{1j}	NL_{1j}
R_2	NT_{2j}	NL_{2j}
R_i	NT_{ij}	NL_{ij}

Table 1. Chromosome representation

Min transportation cost (y) =
$$\sum_{i=1}^{I}\sum_{j=1}^{J} NT_{ij} \times D \times TC_{ij} + NT_{ij} \times TT_{ij} \times S_{ij} + NL_{ij} \times D \times TC_{ij} + NL_{ij} \times TT_{ij} \times S_{ij} \quad (14)$$

Max sugar content (z) =
$$\sum_{i=1}^{I}\sum_{j=1}^{J} (NT_{ij} \times Truckcap_{ij}) \times Y \times tt \times YL_{ij} + (NL_{ij} \times Tlailercap_{ij}) \times Y \times tt \times YL_{ij} \quad (15)$$

$$\text{Optimize } Y_{ijk} \text{ and } Z_{ijk} = [(P_{y1}, P_{z1}), (P_{y2}, P_{z2}) \ldots (P_{ym}\ P_{zn})] \quad (16)$$

$$P_{ym} \in y_{ij} \quad (17)$$

$$P_{zn} \in z_{ij} \quad (18)$$

$$Pym \leq Pym^* \quad (19)$$

$$Pzn \geq Pzn^* \quad (20)$$

$$D_{i+} = \sqrt{\sum_{j=1}^{n} \left(F_{ij} - F_j^{ideal}\right)^2} \quad (21)$$

III. Result and Discussion

A. Sugarcane harvesting and transportation system.

Sugarcane harvesting and transportation involves stakeholders to ensure sugarcane transportation to the mill in the right quality and in the right time. The sugarcane harvesting and transportation system should be described specifically to realize stakeholders and their responsibilities in ensuring the business is running well. There are 4 main stakeholders involve in the system, involve farmers, field and harvesting management unit, transportation mode management and sugar mill. These stakeholders have own role in the system which is described in a Business Process Modeling Notation (BPMN) as depicted at Figure 2.

Farmers hold an important role in sugarcane cultivation, manage the quality and handle harvesting. In completing these activities, farmers are also assisted by the field and harvesting management unit (FHM) of the sugar mill to ensure a highest quality and yield of sugarcane for the mill. In the daily activities, farmers and FHM unit predict the possible productions of the sugarcane manually and recommends action and appropriate time to handling the productivity improvement to increase the production performance. In harvesting season, transportation mode unit organizes the harvesting schedule, allocate harvester machine, and allocate number of transportation mode for each farm with respect to the scheduling.

Due to many farms to be harvested and uncertainty condition, the transportation mode and resource allocation is found in inefficiency condition [20], [21]. Sugar mills calculate their demand daily, report it to each unit and ask for fulfill it in appropriate time. Unfulfilled of mill capacity and lowest sugarcane quality affect the sugar mill efficiency and it is possible to loss profit [22], [23]. Therefore, an effective management to allocate transportation modes efficiently is required to provide.

The transportation and harvesting of sugarcane have an important role in sugar industry. This research considers an uncertainty and imprecision of decision-making parameters in transportation and harvesting activities. To optimize this problem, a determination of loading station or Region centers is applied to improve the effectivity in transportation.

This stage is required to minimize total cost of transportation, ensure the uncertainty distance, decrease the imprecision of total reducing sugar, also to maximize uncertainty quality and sugarcane freshener. Determining Region centers for sugarcane farming in transporting to the mill has successfully applied by previous research as found in Ref. [24], [25] for reducing total cost and increase the efficiency.

To accommodate the uncertainty and imprecision of decision-making parameters, Fuzzy Subtractive Clustering algorithm is proposed to determining Region centers of the sugarcane field. The uncertainty and imprecision parameters that will be considered in this model are the uncertainty of distance, sugarcane productivity, wide of farm, and number of cane production for each region, yield of sugar and sugarcane quality and sugar content. The data acquisition is provided by a case study at the sugarcane field and sugar mill at West Java, Indonesia.

The next step, it requires to optimize modelling of transportation and harvesting. In this optimization model, it needs to maximize quality of sugarcane and minimize transportation cost based on constraints in the following formulation. In this optimization model, due to multi-objective optimization in Genetic Algorithm which describe in Elitist NSGA II by Pareto front is formulated. A case study is applied in the optimization model to easily describe formulation as define in section formulation and mathematical model. At the end of the discussion, this research delivers an ideal solution to achieve an optimize transportation cost and sugarcane quality to produce at sugar mill. In the following sections, the stage of algorithm and solutions are revealed.

B. Determine position of regions center at the sugarcane fields.

Determining a Region center in sugarcane field considers some important factor which are uncertainty and imprecision variables. This research assume that in developing a Region centers has to consider 6 uncertainty factors involve distance of farm to the mill (X_{i1}); yield of sugar in a sugarcane(X_{i2}); Wide of farm (X_{i3}); Production of a farm(X_{i4}); Productivity of cane in a farming wide(X_{i5}); and quality of cane (X_{i6}). As the examples of variable which is obtained from 72 sugarcane plantations in the field as dataset are summarized at Table 2.

Fuzzy Subtractive Clustering is an unsupervised algorithm which has no default number in determining number of cluster or Region center. To determine Region center positions in the FSC algorithm, some value must be defined. As following of the formulation and mathematical model of FSC, this research applies ***r*** = 0.3, accept ratio 0.5, reject ratio 0.15 and squash factor 1.25, as refer to Ref. [13].

Fuzzy Subtractive Clustering determine possible region center of 72 sugarcane plantation points. By a series process of using an unsupervised algorithm of FSC, it is concluded that there are 4 regions center to develop. At the beginning of analysis, all features must identify each maximum and minimum value. The FSC algorithm has been defined at the equations 7 – 9 to define the region center in the field. Therefore, the region center and its feature's data are detailed at the Table 3.

The model has succeeded to find 4 Region centers which considers of uncertainty and imprecision variables in the transportation and harvesting of sugarcane. There are 17 farms as member of region 1, 20 farms in the Region 2, 9 farms in the Region 3 and 27 farming in the Region 4 as depicted in Fig. 3. The concept of this region centers that each farm members are transported and collected their sugarcane production into region centers which means it is acted as the distribution centers.

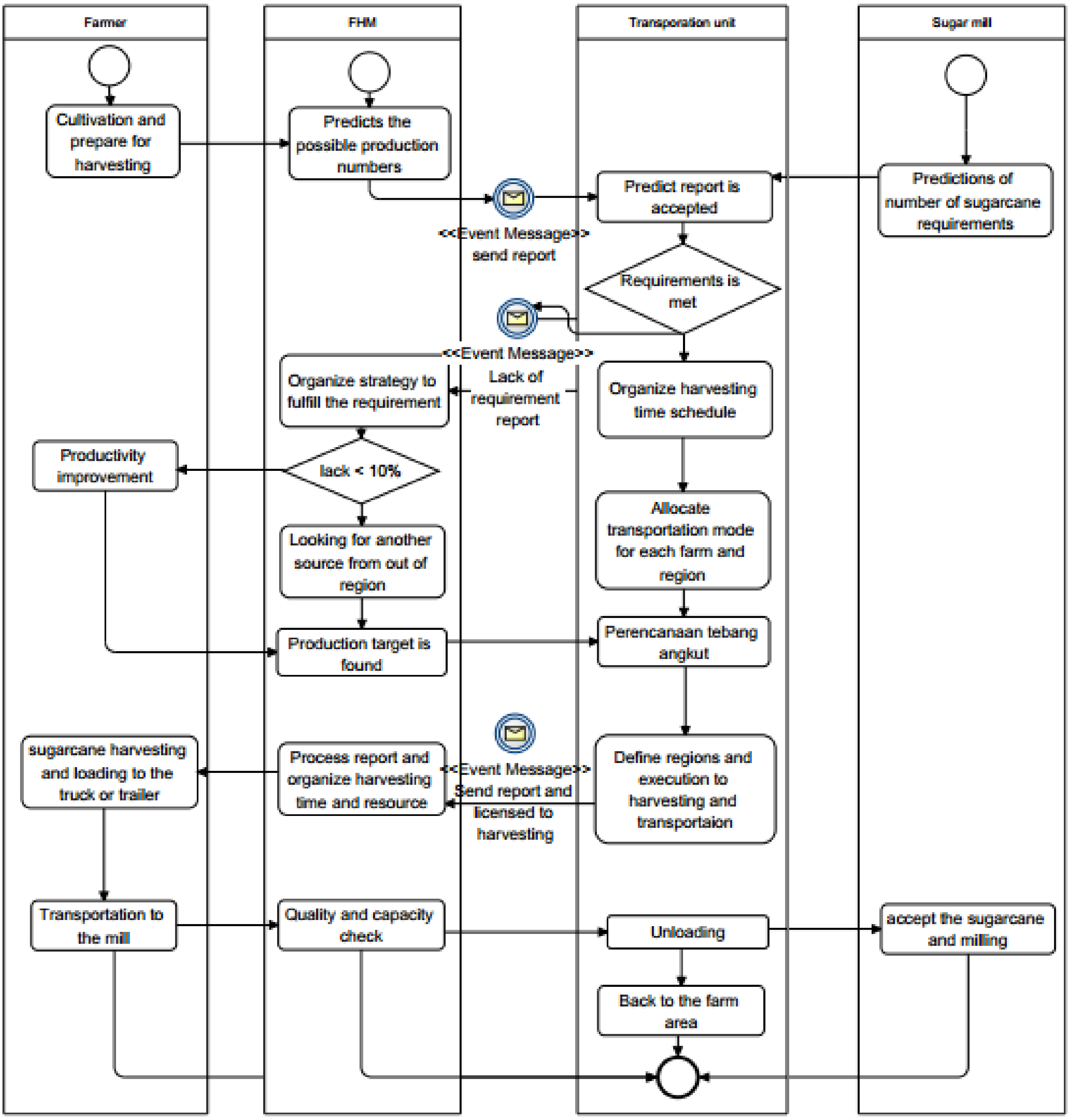

Figure 2. BPMN model for sugarcane transportation and harvesting system.

No	Name of Farm	Distance (Km)	Yield (%)	Wide (ha)	Production (quintal)	Productivity (quintal/ha)	Quality (%)
1	Awilarangan	5	8.3000	41	24,763	604	95.050
2	Barugbug	14	7.0000	14	9,172	670	88.600
3	Batu Goong A	14	7.0000	53	32,915	626	95.400
4	batu Goong B	14	7.0000	40	23,507	589	95.400
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
70	Wanasasi B	50	7.4400	13	8,156	655	93.675
71	Wanasasi T	50	8.3700	66	39,318	599	95.420
72	Wanasuta	50	7.5450	19	10,317	558	96.200

Table 2. Example of the dataset for determining sugarcane fields region's

No	Region centers	Distance to mill (Km)	Yield (%)	Wide (ha)	Production (quintal)	Productivity (quintal/ha)	Quality (%)
1	Kepuh utara	50	7.17	31.247	20,264.68	630.706	94.56
2	Pasir Banteng	10	7.80	107.450	73,183.35	679.924	95.36
3	Peundey	50	7.64	86.459	48,381.50	560.649	94.23
4	Siki	14	7.00	36.479	22,074.47	599.322	93.44

Table 3. Result of FSC model for region center

Objective 1	Objective 2	NT_{11}	NL_{11}	NT_{21}	NL_{21}	NT_{31}	NL_{31}	NT_{41}	NT_{41}
32,290,000	105,981	10	6	16	31	10	6	38	6

Table 4. Best solution

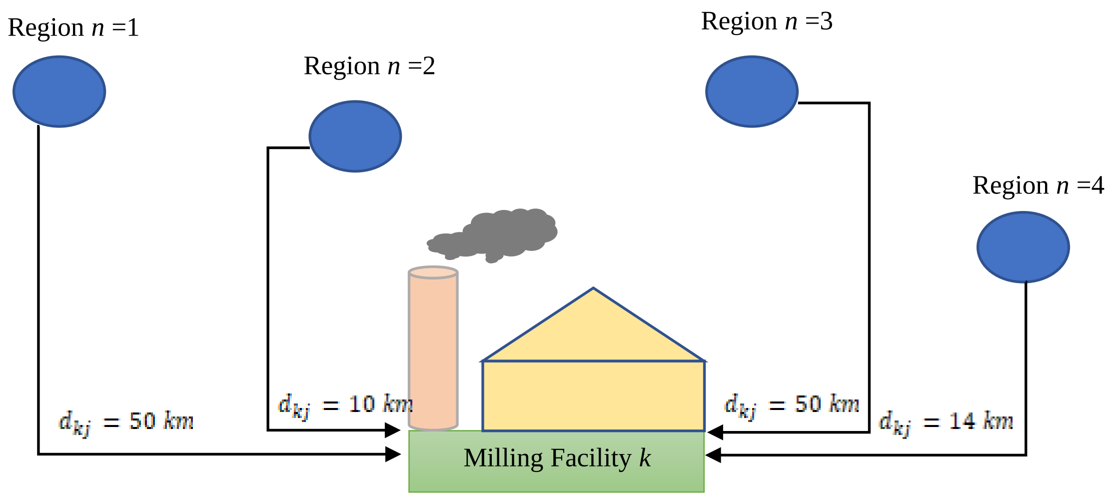

Figure 3. Framework of transportation for sugarcane with determining Region center

C. Multi-objective optimization

This paper solves multi-objective sugarcane transportation through MOEA framework, which is coded in the Java NetBeans, Windows 10 with RAM 4 GB. As mentioned in the last section, we have 4 regions with specific characteristic as distance (*d*), yield (*y*) and number of productions to formulate the multi-objective for minimize transportation cost and maximize sugarcane quality. The schematic operations of the transportation system is depicted at Figure 3.

In solving the problem, this paper assumes that the average velocity of the transportation mode is 40 Km/hour, the average truck capacity is 7 Tons while trailer 15 Tons and the specific sugarcane yield is based on result of clustering analysis by FSC as has mentioned at Table 2. The summarization of the yield loss from the data analysis of the sugarcane yield and sugar content in transportation up to 0.0188765 per hour in average. Besides that, this paper assumes the transportation cost is IDR 10,000 and IDR 15,000 for each kilometer of transportation of truck and trailer, respectively. The driver salary is set to IDR 3,000/Hour and IDR 5,000/Hour for truck and trailer, respectively. Assumptions are applied to find feasible solutions.

Since we found 4 regions center of fields, therefore there are 8 decision variables of the problem. The decision variables obtain the number of allocated trucks and trailer for each region in appropriate time, for minimum cost of transportation and maximum yield of the sugarcane. Java NetBeans with MOEA Framework fire well to find solutions of the optimization model. The result show that the model recommends 100 feasible solutions to allocate trailer and truck for optimizing transportation cost and sugarcane quality. The solutions of minimizing transportation cost (objective 1) and maximizing sugarcane quality (objective 2) is depicted in a Pareto front as shown at the Figure 4.

Transportation donates highest cost in logistic activities of the business [26], and the product quality is the first parameter to maintain consumer trust. This paper successfully optimizes these issues. Based on the result of the models, we found there are 100 feasible solutions using Genetic Algorithm that depicted in a pareto Front.

The objective 1 in case to minimize sugarcane transportation cost is optimum in range IDR 27,000,000 to IDR 35,000,000. Objective 2 maximize sugarcane quality or sugarcane yield, the value between 5,500 to 8,500. Figure 4 shows a positive correlation, that sugarcane cost will be increase if the quality of the sugarcane also increases and vice versa. Moreover, this paper provides the best solutions of the 100 feasible solutions. Therefore, decision-maker is possible to find the best combinations of sugarcane quality and the transportation cost for operations at the sugar industry.

To obtain the best solution among 100 feasible solutions, LINMAP is applied. the best solution among pareto solutions is the solution which has a minimum Euclidian distance value with the ideal solution in pareto front. Finally, the best solution for allocating the number of truck trailer into regions is detailed in Table 4. Decision-maker for this case may set the number of truck (NT_{ij}) and the number of trailer (NL_{ij}) for each region -*i* and sugar mill -*j* based on Table 4 to minimize transportation cost and maximize sugarcane quality to transport for the mill.

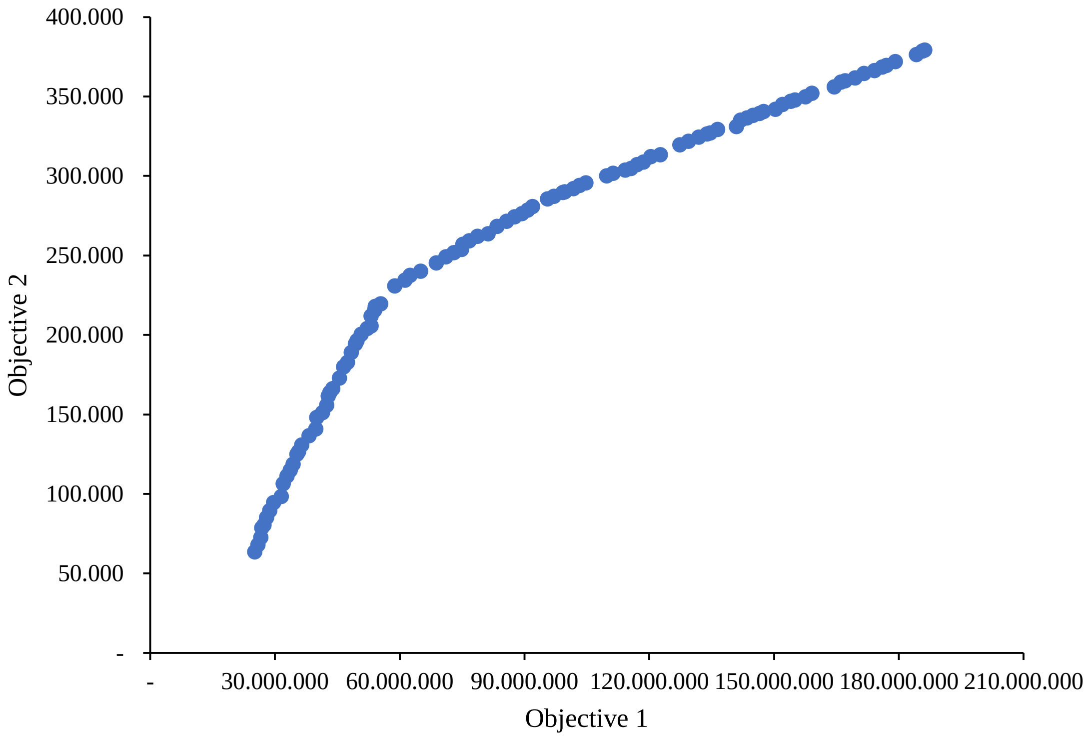

Figure 4. Pareto front of feasible solutions

IV. Conclusion and Recommendations

This research considers an optimization model to minimize transportation cost and maximize sugarcane quality. Developing distribution center to assist the optimization, four distribution centers is found. This paper successfully finds an optimal solution through NSGA II algorithm. The solution recommends number of trailer and truck allocations for each distribution centers to fulfil the efficient transportation cost and maximize sugarcane quality. The uncertainty parameters are considered to formulate and solve the problem.

For further research, seek to find an operational implementation of the model, a decision support system is required to developed. The decision support system considers uncertainty variables and optimization model is necessary to assists decision-maker in the industry.

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