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An Optimized Supply Chain Model for Determination of Distribution Center and Inventory Level in A Coconut Water Agro-Industry

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ABSTRACT

As raw materials of agro-industries such as coconut water are perishable and made this commodity requires a special treatment in the entire supply chain. In addition for the sake of processing rule, the coconut water is required to incubate with duration of 4 to 5 days. With the dispersed area of availability consequently it needs to several distribution center (DC) available in the field to ensure the incubation process runs in a controllable manner. Therefore, firstly the identification factors that significantly influence the DC determination are acquired by using Relief dynamically from each component of transportation cost, operating cost and product features. Furthermore, this model supports for the determination of the number and location of optimal distribution centers based on fuzzy subtractive clustering. As a result, this model effectively determined distribution centers which is located in the region of nearest and lowest risk for handling and distribution. The inventory level determination was based on a deterministic model by considering the deterioration rate. With a real world case in a major coconut water nationally, the level of inventory acquired in each DC are ranged for 137.500 until 190.500, 15.000 until 20.000, and 160.000 until 184.000 units. For more powerful and useful impacts, it is necessary to further analysis on how to minimize the total cost.

Keywords: *Coconut, Factors, Distribution Center, Inventory Level*

1. INTRODUCTION

Coconut water as perishable raw industrial materials risk in reducing quality starting from harvesting to processing which refers to its metabolism processes. Referring to [1] result, Table 1 below shows the changes in physic-chemical coconut during the storage process during 6 to 7 days post-harvest. In fact, most of the coconut water industry do not have the raw materials warehouse to incubate them up to 4 until 5 days. This means their entire supply chain required special treatment to ensure the quality acceptable.

Table 1. Physico-Chemical Characteristics of Tender Coconut during Storage (27±2°C, 70±5% RH)

Storage Period (Day)	Volume of Water (ml)	pH	Total Sugars (g/100 ml)	Free Amino Acids (mg/100 ml)	Na (mg/100 ml)	K (mg/100 ml)
1	231,7	4,9	3,4	2	44,3	325,9
2	196,7	5,1	3,4	1	37,8	291,6
3	256,7	5,1	4,3	1,6	35,6	297,6
5	225	5,3	4,7	2,3	39	284,2
6	**273,3**	**5,1**	**4,6**	**2,7**	**41,2**	**291,6**
7	**230**	**5,1**	**4,5**	**3,2**	**44**	**303,6**
9	243,3	5,2	4,3	3,2	39,7	288,7
11	212	5,2	NE	NE	NE	NE
13	205	5,4	4,8	2,8	38,8	283,3

The challenge occur as currently warehouses only able to incubate up to two days before the processed. However, if the incubation carried out by each supplier, the coconut price will rise significantly due to the addition of warehouse construction cost. In our case, PT XYZ has 13 small suppliers that are spread throughout the diverse region. Therefore, to solve that problem, it is necessary to build distribution center to ensure that the incubation is doing well.

Based on the problems, it's necessary to determine the location of distribution centers and optimal inventory level. These problems are the key issues of distribution system, they involve quantitative and qualitative factors [2]. Although this case has been widely studied, but previous studies have focused on determining the location of a weighting factor, regardless of the nature of the agro-industrial raw materials that are easily damaged. So in this paper tries to address the challenges in the research [2], with a greater emphasis on product quality multi objectives especially accompanied by mapping the location of the supplier as a reference in determining the location of the distribution center.

Table 2. Factors of Determining Distribution Center

Quantitative Factors	Qualitative Factors
Construction Cost	Business Environment
Resource Cost	Labor Supply
Transportation Cost (Logistic Capacity, Transportation Rate, Distance, Road Condition, And Traffic Management)	Product Feature (Deteriorating Rate)
Operating Cost	Services
	Competition Environment
	Policy Environment

Therefore this work aims to identify significant factors, to determine of distribution centers and inventory levels of young coconut for agro industrial coconut water industry. Focus on the factors that significantly influence the selection of distribution center. Specifically, in this paper, the methodology used to solve problem is described in Section II, the factors that influence the selection, the determination of distribution centers and inventory levels in Section III, and conclusion in Section IV.

II. METHODOLOGY

This research will be started with identifying sphere of coconut supply chain. This will be easier to limit the scope of the research to be conducted. Next is to identify the factors that are considered in the determination of distribution center. These factors then becomes an input in the calculation of fuzzy subtractive clustering to determine the number and location of distribution centers and scope area. And the final step is to determine the level of inventory levels for each distribution center (DC).

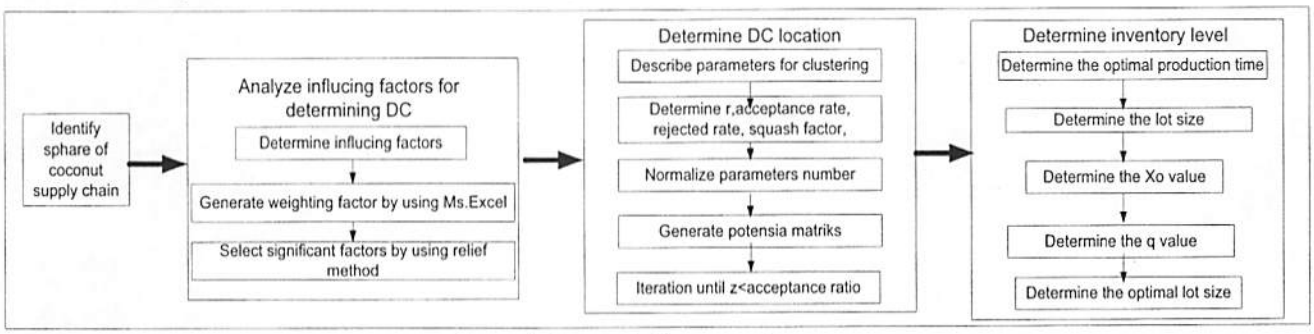

Figure 1. Research Framework

A. Recursive Elimination of Feature or Relief

Relief is one method for feature selection. This method was introduced by Kira and Rendell in 1992 which has advantages especially speed and accuracy [3]. The algorithm is quite simple, which do have information classified target data and calculated weighting by nearest miss and hit. In this case, relief is used to select the factors that significantly influence the selection of a Distribution Center (DC). Otherwise significant factors if they have a weight greater than threshold.

$$W[F_i] = P(F_i nearest\ miss) - P(F_i nearest\ hit) \qquad (1)$$

B. Fuzzy Substractrive Clustering

The idea of fuzzy clustering is to divide the data space into fuzzy clusters, each representing one specific part of the system behavior. After projecting the clusters into the input space, the antecedent parts of the fuzzy rules can be found. The consequent parts of the rules can then be simple functions. In this way, one cluster corresponds to one rule of the Tagaki Sugeno Kang model [4].

Table 3. Definition Parameters and Symbols

Symbol	Parameters	Data	Symbol	Parameters	Data
ε	reject ratio	0,35	q_A	Lot size upper limit	
$\overline{\varepsilon}$	accept ratio	0,7	q^*	Optimal lot size	
P_i	the potential value of data		q_B	Lot size bottom limit	
r_a	hyper sphere cluster radius	0,5	$I(t_1)$	The level of inventory at time t_1	
r_b	hyper sphere penalty radius	0,4	θ	Deterioration rate	
N	total number of data vectors,	13	C	Capacity rate	
W	Weighted factor		t_1	time when the stock reached a maximum	
$\|\|.\|\|$	Euclidian distance		K_o	Carrying capacity of MODA	
H	Squash factor	1,25	n	the amount of transportation required	

Referring to [5], the clustering in the fuzzy system is useful for reducing the dimension of fuzzy system rules while still representing the overall system. Clustering partitions a data set into several clusters where each data points in a cluster has more similarity than the one among the clusters. Further considering to [6] subtractive clustering method also extends the mountain method's criterion for accepting and rejecting cluster centers. This method uses data points as candidates for cluster centers [7]. The parameters of the subtractive clustering are Xi is the normalized data vector of both input and output dimensions defined as [6]:

$$x_1^i = \frac{x_1^i - \min\{x^i\}}{\max\{x^i\} - \min\{x^i\}} \qquad (2)$$

The subtractive clustering method works as follows. Consider a collection of n data points in dimensional space. Without loss of generality, the data points are assumed to have been normalized in each dimension so that they are bounded by a unit hypercube. Each data point is considered as a potential cluster center. The potential of data point xi is

$$P_i = \sum_{j=1}^{n} e^{\frac{-4\|x_i - x_j\|^2}{r_a^2}} \qquad (3)$$

After the potential of every data point has been computed, we select the data point with the highest potential as the first cluster center. Let x*1 be the location of the first cluster center and P1* be its potential value. We then revise the potential of each data point xi by the formula:

$$P_i = P_i - P_1 * e^{\frac{-4\|x_i - x_j\|^2}{r_b^2}} \qquad (4)$$

Where r_b is a positive constant. Thus, we subtract an amount of potential from each data point as a function of its distance from the first cluster center. The data points near the first cluster center will have greatly reduced potential, and therefore will unlikely be selected as the next cluster center. The constant r_b is effectively the radius defining the neighborhood which will have measurable reductions in potential. When the potential of all data points has been revised, we select the data point with the highest remaining potential as the second cluster center. This process continues until a sufficient number of clusters are obtained. In addition to these criterions for ending the clustering process are criteria for accepting and rejecting cluster centers that help avoid marginal cluster centers.

C. Inventory Model for Deterministic and Pherishable Product

In conducting the inventory management, the type of goods or products must also be a concern in determining the optimal policy. This is because not all types of products or durable goods (no damage) during the inventory that can refer to [9], the algorithms for determining inventory level are as follow:

1. Determine the optimal production time (t_1)
2. Determine the lot size that is sent to the buyer by the following equation.

$$I(t_1) = (1 - e^{-\theta.t_1})\frac{C}{\theta} \qquad (5)$$

3. Determine the Xo value, where:

$$X_o = I(t_1) \Big/ K_o \qquad (6)$$

4. Determine the q value of n-1 and n by using the equation:

$$n = \|X_o\| \qquad (7)$$

$$q_A = (n-1).K_o \quad n > 1 \tag{8}$$

$$q_B = n.K_o \tag{9}$$

5. Determine the optimal lot size (q*)

III. RESULT AND DISCUSSION

Coconut is an agricultural commodity that has been known in Indonesia since hundreds of years ago [8]. Therefore, the public has realized sphere of coconut supply chain is fixed even though there is no written law. The coconuts that has been harvested by farmers will be directly sold to middlemen in the garden district level. Furthermore, the transport of the garden to the warehouse while being the responsibility of the middleman. Furthermore, these middlemen mostly sell oil to the big cities and others sold to PT XYZ. The amount of oil that is collected each day is relatively stable, so the supply is deterministic. Furthermore PT XYZ take coconut water and then sterilized and packaged in drums. As for the filling of retail products carried by ABC Ltd. who are abroad and products marketed in the country. Broadly speaking coconut water industry supply chain can be seen in Figure 2 below. In this study focused on two stakeholder that sub-district level as suppliers and PT XYZ as the manufacture of coconut water.

Figure 2. Sphere of Coconut Water Industry

A. Identifying the Significant Factors Determining the Distribution Centers

According to [2], there are several considerations in determining the distribution center both qualitative and quantitative factors. These factors are then evaluated for their influence on the selection of DC with linkert scale which is 1 for no effect until 5 which shows a very influential. In this paper, we used hypothetical data that generated by the normal distributed random values by using Ms. Excel 2013. And then data is processed using equation 1. Relief with data and processing results can be seen in Table 4 below. From Table 4, using the threshold 4.0, the obtained 3 important factors to consider in the determination of the DC that is the transportation cost, operating cost and product features.

Table 4. Weighting Factors for Determining of Distribution Center

Expert	Construction Cost	Resource Cost	Transportation Cost	Operating Cost	Business Environment	Product Feature	Labor Supply	Services	Competition Environment	Policy	Decision
1	5	3	4	5	1	1	2	1	2	1	No
2	3	5	4	5	2	2	2	1	4	2	No
3	4	5	4	4	2	2	5	2	3	1	No
4	5	4	5	5	1	2	5	2	4	3	No
5	4	4	3	2	2	4	4	2	2	2	Yes
6	5	3	3	1	2	4	5	3	1	4	Yes
7	3	5	2	3	2	5	1	1	3	1	Yes
8	3	3	2	3	2	5	5	1	4	4	Yes
9	3	3	2	1	4	5	5	4	3	1	Yes
10	3	3	2	2	2	5	2	3	4	3	Yes
Weighted	**2,9**	**2,9**	**4,6**	**4,3**	**0,6**	**4**	**1,1**	**1,3**	**0,8**	**0,7**	

B. Determining Distribution Centers

Transportation costs include the cost of renting a transportation vehicle, fuel, and labor (both loading and unloading). The transportation cost are proportional to the distance (the distance between the supplier with a factory), but also considering the ease of access roads impassable. In this case, which includes distribution costs, is the distance and transportation costs. Operating costs include all costs incurred to store coconut for 4-5 days, which is comprised of overhead cost and holding cost. While the product features include the capacity and deteriorating rate of any suppliers. In detail the following table 5 is the data that is to be considered in determine of DC.

Table 5. Clustering Suppliers

Supplier	Distance to Factory (Km)	Transportation Cost (Rp)	Capacity	Deteriorating Rate (%)	Holding Cost (Rp)	Overhead Cost (Rp)
A	86,5	255867,0	2500	0,07	30000	8062
B	72,6	153766,8	8000	0,04	344000	6972
C	47,4	97454,4	5000	0,09	85000	8814
D	41,1	62965,2	8000	0,06	176000	5757
E	28,6	57343,0	5000	0,06	80000	11065
F	14,4	40276,8	2500	0,01	72500	12064
G	14,0	28028,0	2500	0,08	37500	13815
H	30,7	58207,2	8000	0,01	328000	13700
I	5,0	8165,0	2500	0,04	92500	10389
J	29,8	47441,6	16000	0,09	336000	5265
K	14,9	31185,7	16000	0,09	192000	6425
L	18,1	49177,7	8000	0,07	312000	14845
M	4,9	8638,7	16000	0,06	496000	7811

In principle, the method used to determine the DC is a clustering method. Considering to [5] that clustering define the classification of objects into different groups, or more precisely, the partitioning of a data set into subsets (clusters), so that the data in each subset shares some common features, often proximity according to some defined distance measure. Fuzzy subtractive clustering have been chosen because number clusters are not default before. As the optimum value of n clusters were obtained. This applying the assumption that with minimize the number of clusters, can be obtained the minimun number of expenses. Objective:

$$\min total\cos t = \min \sum_{i=1}^{n} K \qquad (10)$$

With a constraint on Table 5. As result, by using fuzzy subtractive clustering, there are three distribution centers, which colors are red, as in Sub district J which scope of supplier J,K, and M; in sub district I from supplier I and F; and the last distribution center located in sub district E from supplier A,B,C,D,E,G,H and L.

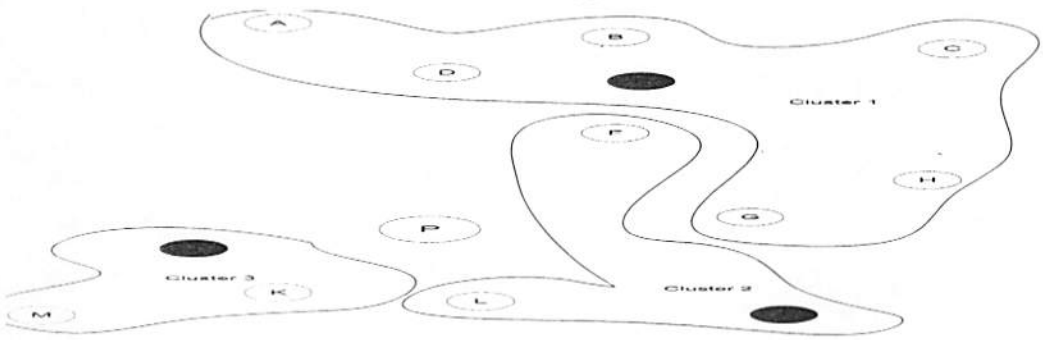

Figure. 4 Result of Fuzzy Subtractive Clustering

C. Inventory Level

As coconut is a perishable commodity, the inventory model should consider the deteriorate factors which subtract available stock, the ordered amount has to be greater than the number of requests. The assumptions used in this study are:

1. The demand, capacity and deterioration rate are deterministic with a fixed rate
2. Shortages are not allowed
3. Lead time is deterministic
4. The capacity of the suppliers and buyers can fulfilling the demand
5. All cost components are known with certainty and constant
6. The model developed only for a single supplier and a distribution center

By using the above assumptions and the data in Table 6 below hypothetic then the next can be calculated by using equation 5 to 9. The results of the calculations can be seen in Table 6, which shows the range of optimal lot size for each supplier. And then, in accordance with the clustering results, the information of inventory level for each distribution center are presented in Table 7.

Table 6. Data and Results of Calculation of Inventory Levels

Supplier	t_l (month)	C (unit)	Θ (%)	K_o (unit)	$I(t_l)$ (unit)	X_o	N	q_A (unit)	q_B (unit)
A	0,127	62500	0,07	2500	7902,322	3,161	4	7500	10000
B	0,143	200000	0,04	8000	28518,360	3,565	4	24000	32000
C	0,117	125000	0,09	8000	14548,269	1,819	2	8000	16000
D	0,153	200000	0,06	8000	30459,975	3,807	4	24000	32000
E	0,155	125000	0,06	8000	19285,185	2,411	3	16000	24000
F	0,137	62500	0,01	2500	8556,637	3,423	4	7500	10000
G	0,180	62500	0,08	2500	11169,387	4,468	5	10000	12500
H	0,148	200000	0,01	8000	29578,107	3,697	4	24000	32000
I	0,146	62500	0,04	2500	9098,407	3,639	4	7500	10000
J	0,174	400000	0,09	8000	69057,866	8,632	9	64000	72000
K	0,137	400000	0,09	8000	54463,542	6,808	7	48000	56000
L	0,142	200000	0,07	8000	28259,319	3,532	4	24000	32000
M	0,123	400000	0,06	8000	49018,898	6,127	7	48000	56000

Table 7. Inventory Levels in Distribution Centers

DC	q_A (unit)	q_B (unit)
1	137500	190500
2	15000	20000
3	160000	184000

IV. CONCLUSION AND RECOMMENDATION

Based on the result and discussion above, the conclusions to draw are how to determine appropriate the distribution centers (DC), the factors of the transportation cost, operating cost and product features were selected. Optimal conditions were achieved by building three DC which is located in the E, I, J with each inventory level acquired are ranged 137.500 until 190.500, 15.000 until 20.000, and 160.000 until 184.000 units respectively. It is necessary to further analyze incorporating other cost factors when determining inventory level with permitted narrower ranges. By implementing this model, enterprise may expect a safer and better product quality with a lower distribution risk. To fulfill a full engagement with current system it is necessary to investigate the social culture of coconut cultivation to ensure the supply chain performance sustainability.

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