Fuzzy Model for Distribution Route Determination of Horticultural Products

Aditia Ginantaka

***Abstract*— Route Determination could optimize logistics costs of distribution horticultural products. This study aims to analyze the logistics costs and design a models for distribution services. Some of horticulture producers in west java area have observed. Logistics cost was identified using activity based cost method and analize using Relief alghorithm. Fuzzy model have designed based on two variables such as roads condition and traffic loads. Defuzzyfication refers to the value of logistic vehicle speed then convert to the time of travel from one node to another on distribution routes. The route determination was performed using Kruskal alghorithm to find the most suitable route. The results of analysis showed that there was three variables affecting costs include the purchasing cost of horticultural products, packaging cost, and transportion cost. Fuzzy model designed to optimized transportation cost. This model succeeded to determine distribution route from case study to transport horticultural product from Bogor to Bekasi. The shortest recomendation route through more than 20 distribution nodes with the travel time for 213.4 minutes.**

***Keywords*— logistics, transport routes, Relief, fuzzy.**

INTRODUCTION

Horticultural commodities such as vegetables and fruits are perishable products. Product quality decrease rapidly after harvest. Therefore the appropriate product handling and distribution to consumers timely is should considered to achieve consumer satisfaction. Time becomes crusial aspect because time to transport depend on the shortest route that conecting all of distribution point [1]. Thus the problem that faced regarding the distribution is to take a decision about the route that could optimizes the distance of origin point to destination. Several factors that should considered in route determination is the distance to destination, time for delivery and delivery cost [2]. Distribution planning based on experience and intuition could not support proper handling. The producer often face several risk such as product quality below standard and the low performance of procurement process [1]. The inappropriate supply chain management in horticultural product could cause processing delays and the risk of product return [3].

Distribution system of food product should designed properly, because it could support the affordability of consumers on fresh product such as horticulture product. The availability and food security becoming strategic issue for government [4]. Determining the shortest route in distribution process becomes important due to it could expect the product that delivered arrive timely, minimizing fuel use and minimize operating cost, hence food product become more accessible by consumer. Proper route planing could affect efficiency in resource management, service level and client satisfaction. Besides that route planing could support supply chain mechanism in the supply of horticultural product as raw material for processing industries. The decision in planing of the postharvest handling, transportation requires a very careful process to reduce reduce product defect and preserve their value [5]. Thus logistical planning, transport and distribution should managed in order to faced the competition with other company [2], [6], [7].

Setting transport route based on shortest route has conducted in order to optimize transport that influenced by the distance between the location of the distribution point on meat supply process [8] and for recall product case [9] . There is two challenges to determine route planning for fresh product. The first is the complexity caused by specific product and process characteristics. The second one is the lack and precise information [10]. The real world condition could become information for decision support to predict and recomend a decision on route planning for product distribution process. Transport planning problems for distribute the horticulture product using highway require knowledge the characteristics of the road network, customer or demand points and the distribution centres (warehouses, depots, platforms, transit centres) [10]. Because uncertainty of information in real world that influencing route planning, fuzzy approach was chosen as appropriate method to analyze and give a recommendation to determine route of horticulture product distribution [6], [10], [11]. Delivery patterns was all demand points receive individual deliveries which has a linear delivery cost [1], [12].

This Approach was used in vehicle routing problem that assume vagueness of each variable in the model [6]. Fuzzy approach also conducted to develop decision support system for traffic control centre [13]. The decision created based on data that gathered from information from real condition that represented in several linguistic variable. The uncertanty information have to measured not only qualitative but quantitative as well. The values were expressed in words, thus it could use as knowledge representation about real world condition. Input data in Fuzzy logic system could set at scalar value [14]. Fuzzy scheduling also used on integrate production scheduling and distribution routing problems to minimize the total cost of the supply chain under uncertain environments [15]. Therefore it is necessary to considered more variable that also influence the determination of the shortest route. An

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optimization on determine a Route was not only influenced by the distance, but also by traffic density and road condition [16], because that variable could not measured in precise.

Model determination made to determine optimization of the distribution route in the distribution process, so that the products will be shipped from the manufacturer to the consumer timely and the product is still in a fresh condition. The specific objectives. This research are to analyze horticultural logistics costs and designing horticultural logistics distribution model based on fuzzy approach.

I. METHODOLOGY

Subject Research

Respondents were taken in this study consists of various horticultural companies such as PT. Saung Mirwan, PT. Parung Farm, PT. Masada Indonesia. Purposive sampling is the sampling method chosen. Information was obtained from interviewed people which was selected by the author according to the role of respondent on company operation management. This research was performed through several stages as shown on Fig 1.

Cost Analysis

Based on information gathered we performed cost analysis using Activity Based Costing (ABC) method. This method was a calculation method to determine the cost of the product or service based on actual activity which add costs [17]. Once identified and then the data were analyzed using the methods Relief with the following formula [18]:

$$w_i = \frac{\sum_{t=1}^{(n-1)} \sum_{j=t+1}^{n} diff(x_t, y_j)}{(n-1)} \quad (1)$$

The difference between the two examples feature values xi and yi (hi or mi) defined by following the function diff [19]:

$$diff(x_t, y_j) = \begin{cases} +\left(\dfrac{|x_t - y_j|}{max_i - min_i}\right) & \text{(if } x_t \text{ and } y_j \text{ are different class)} \\ -\left(\dfrac{|x_t - y_j|}{max_i - min_i}\right) & \text{(if } x_t \text{ and } y_j \text{ are the same)} \end{cases} \quad (2)$$

Where:

w_i = Weight of attributes-i
x_t = instance of attribute-t (t= 1,2,3…n)
y_j = neighbor of attribute-j (j=2,3,4…n)
max_i = maximum value of attribute-i
min_i = minimum value of attribute-i

Fuzzy Model Design

Model was design using several steps involved in working fuzzy inferens system [11]. The first step was selection of input and output variable. Traffic and road conditions cause difficulties in the calculation of exact travel times [20]. Thus, the input variables as follows:

- Traffic Density
  Traffic density is a traffic situation in which the amount of vehicle on the road.
- Road Condition
  This variable using road condition index as an indicator of the level of comfort of a road section which can be estimated from the other functional performance parameters such as the road surface by visual observation or using a standard data Road Condition Index (RCI).

Defuzzyfication stage was performed by convert the aggregated fuzzy set output of the inference engine in to a single real number. Thus variable output determined as follows:

- Speed
  This variable is the output value of the speed of vehicles traveling on a particular route that influenced traffic density and road condition.

Set of variables divided into several linguistic scale [3], [10], [11], [13] using Fuzzy triangle as a function of the set membership (Fig 1). For example linguistic scale velocity as follows:

- Low
- Medium
- High

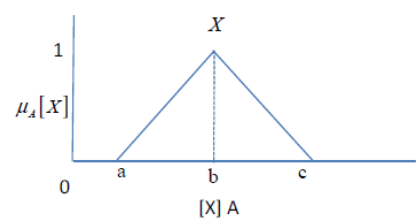

Fig 1. Membership function Fuzzy triangle set X with variable A

Membership value is calculated as follows:

$$\mu_A[X] = \begin{cases} 0 & ; x \le a \text{ or } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(b-c); & b \le x \le c \end{cases} \quad (3)$$

Where:

$\mu_A[X]$ = Membership function of an item value x on Fuzzy set X at variable A
a, b, c = a, b, c are parameters of membership function curve and b is midpoint.

Travel time variable was the final decision. This variable was obtained from the relationship between the distance and speed as follows:

$$\text{Time} = \frac{\text{Distance}}{\text{Speed}} \quad (4)$$

Distance data obtained in this research is by using google maps, and speed data obtained in that the data output variables. The fastest route was compute using Kruskal algorithm. This method is a minimum spanning tree search algorithm commonly used.

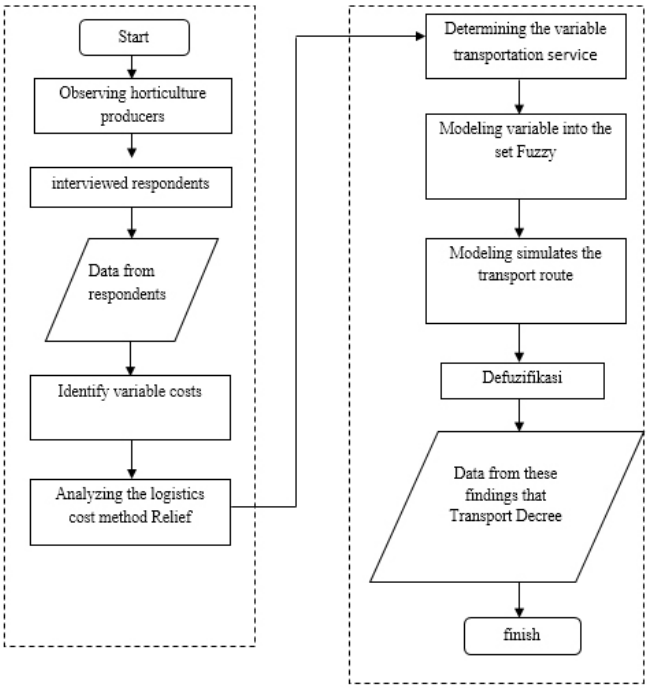

Fig. 1. Research framework.

RESULT AND DISCUSSION

Observtation

Logistics activities that have identified in the horticulture company visit, including:

Purchase of horticultural commodities

Horticultural commodities largely purchased from farmer partners. Farmers grow crops in accordance with the commodities needed by the company. The farmers supported the farmers by supply the seed and financing for purchase the fertilizers, then the company will purchase the crops.

Sorting and Packaging

The company perform sortation process by separate a good product and less good. Then packaged into the packaging material and loaded into the truck for shipment.

Transportation

Transport was performed by using the company's vehicles. Products will be delivered to customers with a variety of points of each consumer. Decision variable on the actual transport activity influenced by short term decision such as trip mode and trip route [21].

Cost Analysis

Activity-based costing (ABC) system could help to increase the competitiveness of a company. In order to make an effective decision costing method have to determined realistically [17]. These systems were used as effort to obtain more reliable product costs. Cost was analyzed by examine all activities that were relevant to the production process of horticulture commodities. Each activity in logistic activites consume resources such as labor, logistic material, fuel for transportation etc. Hence, cost analysis was performed with identified and determine exactly what portion of each resource have been consumed. Cost was identified and selected into several group activity costs based on the number of units produced, equipment hours, kilowatt hour, and the number of purchases of materials. An activity that has the same resources at the same level are grouped into a group activity cost. There were 4 levels of hierarchy On the ABC, such as:

a. Facility sustaining activity cost

The cost of activities supporting facilities such as vehicle tax. This costs was adding annually for supporting facilities, because transport facilities were used for shipping the product to the various areas destination.

b. Product sustaining activity cost

Horticultural commodities was a product that handle on this research study. Thus, this cost was include purchase costs. Purchasing activities add a portion of cost because the product was supplied from farm partners / farmers surrounding of the company.

c. Batch activity cost

Costs that associated with the number of batches manufactured products such as overhead transport costs. The cost including electricity, water, transportation costs on the shipping process such as meal cost for driver and conductor, parking fees, tax road, fuel costs etc.

d. Unit level activity cost

This cost was associated with the size of units product that produced such as: Such as direct labor costs and the cost of packaging material. Direct labor costs refer to the cost for pay wages workers who directly participate in shipping the final product. The cost was added on packaging activities to fulfilling high customer demand. Besides that packaging material costs was also added for the purchase of packaging materials. Based on the cost hierarchy, the details cost of the logistics activities that have identified in each company shown in Table 1. The activity start from packaging until shipping in case of shipment to several city for instance Tanggerang, Bekasi and Kuningan.

TABLE I: COST OF HORTICULTURAL COMMODITIES

Cost Classification	PT.Saung Mirwan (IDR)	PT.Parung Farm (IDR)	PT. Masada Indonesia (IDR)
Labor	60.000.000	40.500.000	55.000.000
Overhead	300.000.000	12.500.000	1.700.000
Commodity Purchase	600.000	1.200.000.000	380.000.000
Packaging material	30.000.000	70.000.000	40.000.000
Transportation	60.000.000	1.800.000	31.000.000
Tax	4.500.000	5.833.333	716.667
Destination	Tanggerang	Bekasi	Kuningan

Costs that identified on logistics activity were analyzed using Relief alghorithm to select the influenced/important cost attribute which was could control to optimized the cost [9]. The computation result using Equation (1) was shown at average value weighted, as showed in Table 2.

TABLE II: DATA ANALYSIS RESULTS WITH METHOD RELIEF

Types of cost	Average Value Weighted		
	PT. Masada Indonesia	PT. Saung Mirwan	PT. Parung Farm
Labor	0,42	0,32	0,03
Commodity purchase	-0,17	0,03	1,04
Packaging material	-0,30	0,62	0,53
Transportation	0,23	0,08	0,06

Transportation costs were include of three highest average value weighted which need to be considered for optimization. Tax costs were not calculated because the cost was fixed in each time period. Thus horticultural logistics distribution model with the fastest route have to designed to optimize routes and minimize transportation costs. The Optimization could achieve if a company could shipping the products in short travel time in order to bring the fresh product timely and avoid losing of fresh produce logistics with transportation distance [4].

Transportation route planning considering several dynamic environment condition that has to measured although of rapid changes and high levels of uncertainty [10]. The conditions of traffic density is always changing with time and its value could not be precised. Fuzzy method was used to assist decision-making by creating a model of decision support system, one example of which is to determine the fastest route based on travel time. Fuzzy model consisted of two input variables such as the set of road conditions (R_c) and traffic density (T_f). Then, output variable was Speed (S_p).

Fuzzy Model Design

Road Condition Variable (R_c)

Road conditions could affect the actual speed of a vehicle. Value road conditions were standardized with namely international standards Road Condition Index (RCI) [22]. This standard could used as indicator that could estimated functional performance parameters such as the condition of road surface. Index road conditions can also be determined by direct visual observation in the field by some of the experts. Classification of RCI parameter shown in Table 3 [22].

TABEL III: CONDITION OF THE ROAD SURFACE IN VISUAL AND RCI VALUE

RCI	Road surface conditions visually
6 - 10	Flat, regular
4 - 6	Average, Few or sometimes there is a hole, but the road surface is uneven
2 - 4	Damaged, bumpy, many holes the whole area of pavement crushed

The state of the road conditions greatly affect the speed of vehicle. Modeling the speed of vehicles that influenced by road conditions were based on assumptions:

a. The great of road surface condition, cause the higher vehicle speed and the shorter travel time, and otherwise.
b. The maximum vehicle speed was 50 km / hour on good road conditions (RCI score> 6) and a speed of 10 km / hour on bad road surface (RCI> 2).

Fuzzy membership function for Road Condition (Rc) was shown in Fig 2.

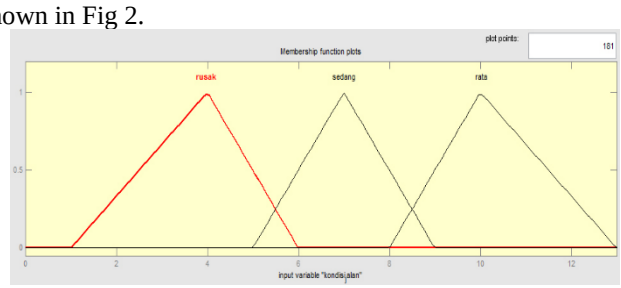

Fig 2. The membership function of fuzzy sets road conditions.

Fig 2 shows the variable road conditions (R_c) has 3 linguistic scale which the value of the fuzzy sets were:

- Good = 2
- Medium = 4
- Bad = 6

Membership function for each sets compute using Equation (3) as follows:

$$\mu Good[x] = \begin{cases} 0 & x \le 0 \; atau \; \ge 4 \\ \frac{x-0}{2} & 0 \le x \le 2 \\ \frac{4-2}{2} & 2 \le x \le 4 \\ 1 & \end{cases}$$

$$\mu Medium[x] = \begin{cases} 0 & x \le 2 \; atau \; \ge 6 \\ \frac{x-4}{2} & 2 \le x \le 4 \\ \frac{6-x}{2} & 4 \le x \le 6 \\ 1 & \end{cases}$$

$$\mu Bad[x] = \begin{cases} 0 & x \le 4 \; atau \; \ge 10 \\ \frac{x-4}{2} & 4 \le x \le 6 \\ \frac{10-x}{4} & 6 \le x \le 10 \\ 1 & \end{cases}$$

Trafic Density Variable (T_f)

The traffic density influence the speed of vehicle, therefore the fuzzy set and linguistic scale of this variable determine as follows:

TABLE IV: THE LEVEL OF TRAFFIC DENSITY [16]

Value	The level of traffic density
≥ 1000	High
500 - 1000	Normal
100 - 500	Low

The membership value fuzzy sets of traffic density shown in Fig 3.

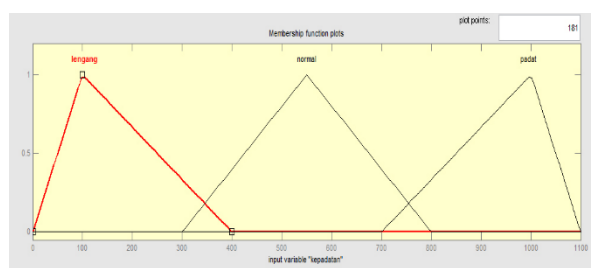

Fig 3. The membership function of the fuzzy set traffic density.

Fig 3 shows the variable traffic density (T_f) has 3 fuzzy linguistic scale each set having membership functions which the value of the fuzzy sets were:

- Low = 100
- Normal = 500
- High = 1000

Speed Variable (S_p).

The linguistic scale for output of fuzzy model was speed obtained from the assumptions as shown in Table 5 and membership value fuzzy sets of traffic density shown in Fig 4.

TABLE V: THE SPEED VARIABLE

Value (Km/Hr)	Speed Level Traffic
≥ 50	High
30 - 50	Normal
10 - 30	Low

Fuzzy set output speed is variable implications of the outcome variable road conditions and density described in the form of curves as in Figure 6.

The value of linguistic scale for Speed (S_p) set as follow:

- High = 50
- Normal = 30
- Low = 10

Fuzzy set for speed has a minimum value of 10 km / h and a maximum value in units of 50 km / h. This value is based on the value of the speed that is likely used on the streets of urban.

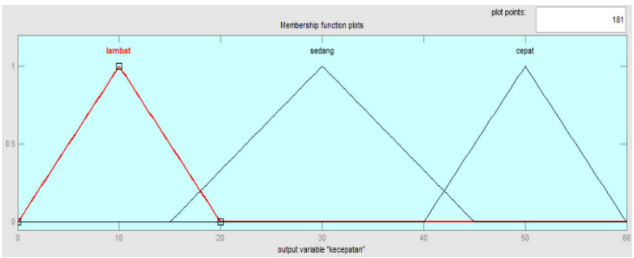

Fig 4. The membership function the fuzzy set speed.

Determining Fuzzy Rule

The value of the variables that have been determined in this study then conducted to the linguistic fuzzy rule. Fuzzy method require several function of the implications based on Mamdani method. There was 9 rules, as shown on Table 6

TABLE VI: FUZZY MODEL RULE

Traffic Density (*Kp*)	Road Conditions (*Kj*)	Velocity (*Vc*)
Low	bad	Low
Low	Medium	Normal
Low	Good	High
Normal	Bad	High
Normal	Medium	Normal
Normal	Good	High
High	Bad	Low
High	Medium	Low
High	Good	Low

Case study

The case studies were performed for PT. Parung Farm. The company assumed perform a shipping activities of vegetables to the city of Bekasi. Graphs of origin and destination was depict on Fig 5.

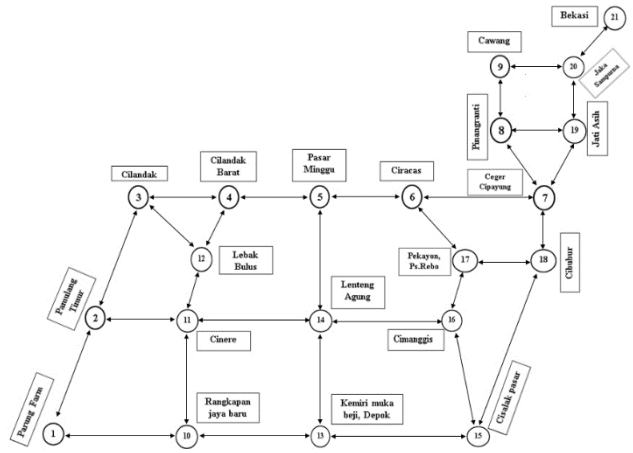

Fig 5. Graph of routes from Parung to the city of Bekasi.

The vehicle should pass several node that connect the origin area to destination area based on the possible alternative route that obtain from the real condition on map. Route determination conducted using Kruskal algorithm which could select the optimal route from the possible route. The value of each variables that have measured such as road conditions (Rc), traffic density (Tc), speed (Sp), distance and time travel (Tv) on each point of origin and destination shown in Table 7.

TABLE VII: WEIGHTS WITHIN EACH SEGMENT

From	To	Distance (KM)	Kj	Kp	Kc (Km/Hour)	WT (Hour)
1	2	13,7	3	579	10	1,37
2	3	11,3	7	119	30	0,38
3	4	2,9	6	715	28,2	0,10
4	5	5,8	9	514	50	0,12
5	6	2,8	9	526	50	0,06
6	7	2,4	8	662	30	0,08
7	8	4,7	3	732	10	0,47
8	9	5,2	10	285	50	0,10
9	20	9,6	9	110	50	0,19
20	21	7,2	4	949	10	0,72
1	10	12	6	221	30	0,40
10	11	8,3	5	870	10	0,83
2	11	4	2	684	10	0,40
11	12	4,1	2	540	10	0,41
3	12	1,7	3	344	10	0,17
4	12	2,5	3	148	10	0,25
10	13	11,2	6	290	30	0,37
13	14	2,6	2	384	10	0,26
11	14	12,1	2	688	10	1,21
5	14	7,2	4	901	10	0,72
13	15	4	4	264	10	0,40
14	16	2,9	9	987	10	0,29

Based on mathematical relationship between distance, speed and time on Equation (4) the value of travel time variable could obtained. The Kruskal alghoritm compute the value of Travel time which could result the shortest travel time as shown in Table 8. The results of the analysis obtained from the alternative area for transportation planning. The alternative route chosen based on the National, Provincial and District streets. This assumption was used because transport route has to meet the criteria for a traffic distribution of horticultural logistics. The fastest route by using the Kruskal algorithm shown in Fig 6.

TABLE VIII: COMPUTATION RESULT FOR THE SHORTEST ROUTE

Origin	Destination	Tv (Hour)
1	10	0,40
10	13	0,37
13	14	0,26
14	16	0,29
16	17	0,19
17	18	0,06
18	7	0,50
7	8	0,47
8	9	0,10
9	20	0,19
20	21	0,72

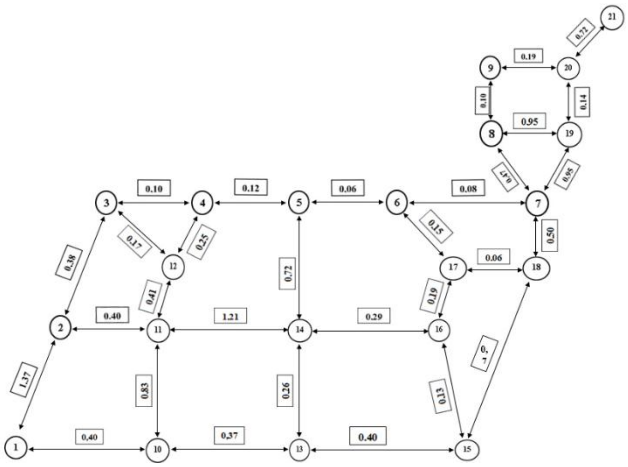

Fig 6. Decision routes based on the shortest travel time (Tv).

The shortest route from Table 8 was obtained with total travel time 213.4 minutes or 3.55 hour. The route as shown in Fig 6 was a route that recommended for transportation planning of logistic vehicle. This analysis could support the decision making for delivering the horticultural product timely to costumer destination and could minimize the transportation cost. This models could use to another purpose in order to support decision making for transport a product or material.

CONCLUSION

The results of analysis of the horticultural commodity costs that were calculated using Relief shows that three great of weighted value variables that influence the costs include the purchase of horticultural commodities, packaging materials, and transport. This study succeeded in modeling the distribution route determination using fuzzy method, which connects more than 20 distribution nodes by considering input variable such as road conditions (Rc), traffic density (Tc), distance and speed of the vehicle as output variable (Sc) then the decision variables was based on travel time (Tv).

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