The Decision Support System by Optimization and Dynamic Analysis for Transportation Routing

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Abstract —The objective of this research is developing the decision support system by optimization and dynamic analysis (DSS_ODA) algorithm. Many techniques are used in this algorithm such as K-means algorithm, Hierarchical Clustering, Partition clustering, Lagrange multiplier method and the second condition. The checking rout paths procedure, the checking capacity procedure and optimization and dynamic analysis procedure are main elements. This research develops an application for testing efficiency that the DSS_ODA algorithm is the important algorithm of this application. The DSS_ODA algorithm is tested by 50 customers from a shipping company at Bangkok in Thailand. The results showed that, the DSS_ODA algorithm offers shipping cars for customers, reduces time and errors in finding the transportation routing from staff. Furthermore, the DSS_ODA algorithm decreases the time of transaction documents and reduces the time to decide from customer. Staffs have not over skill but they can use this program. This research surveys satisfaction of 50 customers. This survey finds the average of satisfaction is score 4.52 from score 5. In addition, the number of customers increases by 22.63 percent.

Index Terms—Optimization, dynamic algorithm, K-means algorithm, Lagrange multiplier method

I. Introduction

Transportation is an important activity in the business today. There are various forms of transport such as road transport, water transport, rail transport and air transport. The type of transport with the highest proportion is road transport, which is equal to 82.47 percent. Although, the road transport is more expensive than other forms but other forms of transport cannot manage to meet the needs of service users. Transport by truck to respond to users thus it has a better advantage and a higher proportion of transport other modes of transport. The road transport by truck can be divided according to the ownership of two categories: 1) the manufacturer of the product has to transport its own and 2) hiring transportation operators. The company produces a large volume of product is very popular, the company employed entrepreneurs, cargo agents, freight themselves. Because of it can ease the process, reduce costs and improve performance better than the action itself. In addition, the transport of goods by truck can also be divided into two categories: operation characteristics. Full transport vehicles and transport vehicles are not full. The style transport vehicle that would normally be full freight from origin to destination without the acquisition of goods and there is no pick up or delivery routes.

The economics and the social of Thailand are growing up now then consumer goods are required from population. The most population of goods transportation is the land transport because the land transport is least cost when this transport compares with other transport such as the air transport. In addition, the land transport is most satisfied from customers. There are an increasing number of shipping companies in the present. So, customers have many choices to select shipping companies when they want to send goods. Some shipping companies give good promotions such as discount for shipping and extending for the time to pay.

Shipping companies attempt to save the expenditures such as transport planning, using the car to suite the number of goods, and inspection route. However, many companies realize in these problems and they attempt to solve these problems too. The one result of these problems is the planning to reroute cargo efficiency. However, shipping companies consider about the limit of capacity of logistic cars and the limit of time for product delivery. If companies can plan and manage these limits then these companies can increase profit and can impress for customers too.

The staff of companies has routing experience only. Sometime, they plan delivery errors that errors are less experienced, criteria for planning different and taking a lot of planning. From these problems, this research focus on the efficient transport that this transportation can save cost and can increase impression of customers.

The objective of this research is the development of the decision support system by optimization and dynamic analysis for consumer goods transportation routing. This system can calculate and analysis transport routes for customers. Transport routes and vehicles appropriate are introduced for customers before they will determine by this system. In addition, they can know the timing of to deliver goods or products. Furthermore, they can know the delivery costs too. Many algorithms are used to create the decision support system by optimization and dynamic analysis for consumer goods transportation routing such as hierarchical clustering, optimal solution, Lagrange multiplier method, the second condition, clark and wright saving, k-mean, deterministic scheduling.

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From this point, this paper is divided into four main sections which one as follows. Theories and related researches are shown in first section. Secondly, the decision support system by optimization and dynamic analysis (DSS_ODA) algorithm is descripted and then the results of the DSS_ODA algorithm are presented. Lastly, the conclusion of this research is shown.

II. Theories and Related Researches

The economics and the social of Thailand are growing up now then consumer goods are required

Theories and related researches are presented in this section. The principle of DSS_ODA algorithm is an algorithm of the decision to choose transportation routing therefore related researches are presented only. However, some techniques or some algorithms can give higher popularity because these algorithms are easy to manage but these algorithms are not quickly process data.

A. The Problems of Freight Routes

The concept of the problems of freight routes is the optimization of the freight route planning which knows the expenditure of freight route, the capacity of vehicle, and the routes to send goods of customer. The limits of freight route planning are all products of a customer to use one vehicle and the quantity not exceed the capacity of the vehicle [1].

The problems of freight routes can explain by graph theory. Let nc is the number of all customers who are received goods per one vehicle. Each customer is received by quantity of goods that is q and qi is 1, 2, 3, …, n. The qi is the customer order. So, the problems of freight routes are route designs which are under the limit of the volume of cargo.

Let each node (p) is the point of delivery and p = (p0, p1, p2, …, pn) is the warehouse and pn is the point of customer. L is various routes of transportation. Each path is included nodes (p) so L is equal (pi, pj) $\in$ p, i $\neq$ j. Each node is related the quantity of goods. The goal of freight route design is decreased cost of freight route.

B. K-Means Algorithm

There are two procedures of K-mean algorithm [2]. The first procedure chooses the position of centroid from all k numbers by random sampling method. The last procedure calculates distance values by Euclidean distance technique. After that, all data is included one centroid that all data must are near with the centroid. Next step, this algorithm recalculates the position of centroid again by the average of early formed cluster technique. It repeats and stops procedure when this algorithm gives least criterion function. The popular of criterion function of K-mean Clustering is Sum of the Squared Error (SSE) equation which is present in (1).

$$E = \sum_{i=1}^{k} \sum_{x \in C_i} | x - x_i |^2 \quad (1)$$

Let E is Sum of the Squared Error (SSE) of all data set and the criterion function calculates by Euclidean distance.

To find the distance is calculated by Euclidean distance equation which finds the distance of one data. Euclidean distance equation uses the vector characteristic. Let $x = (x_1, x_2, ..., x_n)$ and other data in the data set is $y = (y_1, y_2, ..., y_n)$. To find the distance by Euclidean distance equation is shown in (2).

$$d(x_i, y_i) = [\sum_{i=1}^{n} (x_i - y_i)^2]^{\frac{1}{2}} \quad (2)$$

This research considers the efficiency of K-mean algorithm by Sum of the Squared Error (SSE) [3]. It sums of all distances of each group. If the sum of all distances is least then it is reasonable quality [4].

C. Cluster Analysis

Cluster analysis is an unsupervised learning technique. The goal of this technique is data classification. Each group is called cluster. The data classification technique is two types that are non-hierarchical algorithm and hierarchical algorithm [5], [6].

The data classification analysis is unsupervised classification. This classification uses featured data in each data (Cluster) or similar data within data set. All data classification does not define groups for data set. Generally, data clustering is used in the first of data mining [7].

The clustering analysis can solve by many techniques but this research use the hierarchical clustering technique and partition clustering technique.

- Hierarchical Clustering

The correlation coefficient is used to calculate for hierarchical clustering [8]. There are four main procedures of hierarchical clustering. First procedure, to calculate the distance or similarities between data set and other data set. To calculate the distance can use the Euclidean distance equation [9], [10]. It is presented in (3).

$$d(P,Q) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + ... + (x_p - y_p)^2} \quad (3)$$

The second procedure finds the most similar and combined together within single cluster. After that, this algorithm considers distances of all pairs. The third procedure recalculates the distances that it selects least data to new cluster. The repeat at the second procedure and the third procedure are the last procedure. It stops procedure when all data set are put to clusters which are N sets.

However, the factors of clustering analysis are to select the distance technique or the similarity technique and the new value to the agent of cluster. There are three data clustering techniques which are popular techniques.

The single linkage technique considers from nearest distance between a cluster and a cluster (Shortest distance

method). The complete linkage selects from farthest cluster or longest distance method. It finds the members in two clusters that these members are longest distance. If the cluster is longest distance then this technique includes all members and makes the new cluster. The average linkage use average value of between the distance cluster and the distance cluster.

- Partition clustering

The partition clustering is a technique for dividing of sub partition. The advantage of this technique is quickly for processing data set. K-mean algorithm is popular for the partition clustering and this research uses K-mean algorithm for clustering data set too.

D. Lagrangee Multiplier Method

Lagrange method uses for changing the optimization when the objective function has the limit [11]. Suppose that, there are two independent variables within an objective function and we want to find the maximum value of the function. Suppose that, this function is $F = f(x, y)$ and the limit of this function is $g(x, y) = c$. This situation, we can modify this function by increasing of limit at this function. The new function is called Lagrangian function which is shown in (4).

$$z = f(x, y) + \lambda[c - g(x, y)] \tag{4}$$

E. The Second Condition

To find the second derivative depends on x and y values so dy value depends on x and y values. We are received the new function that is

$$dy = -\frac{g_x}{g_y}dx \tag{5}$$

We can calculate the derivative values by functions below.

$$d^2z = d(dz) = \frac{\partial}{\partial_x}(dz)dx + \frac{\partial}{\partial y}(dz)dy$$

$$d^2z = \frac{\partial}{\partial x}(f_x dx + f_y dy)dx + \frac{\partial}{\partial_y}(f_x dx + f_y dy)dy \tag{6}$$

$$d^2z = [f_{xx}dx + (f_{xy}dy + f_y\frac{\partial}{\partial_x}(dy)]dx + [f_{yx}dx + (f_{yy}dy + f_y\frac{\partial}{\partial_y}(dy)]dy$$

$$d^2z = f_{xx}dx^2 + f_{xy}dydx + f_y\frac{\partial}{\partial_x}(dy)dx + f_{yx}dxdy + f_{yy}dy^2 + f_y\frac{\partial}{\partial_y}(dy)dy$$

But the third and sixth terms can together so this equation is shown in (7).

$$f_y[\frac{\partial}{\partial_x}(dy)dx + \frac{\partial}{\partial_y}(dy)dy] = f_y d(dy) = f_y d^2y \tag{7}$$

Then, the new equation can rewrite and is presented in (8).

$$d^2z = f_{xx}dx^2 + 2f_{xy}dxdy + f_{yy}dy^2 + f_y d^2y \tag{8}$$

F. Related Researches

The problems of routing transportation are solved as bi-objective problems, integer programming and heuristic methods [12]-[16]. The most multi-objective approach to the problem is based on the weighted sum method. All criterion functions (those related to cost and risk) are multiplied by the appropriate weight coefficient and summed in an aggregated objective function. The multi-objective problem of route selection is decreased to a single-objective, which can be solved by some of the shortest path algorithms. Then, [17] introduced the risk assessment model, by means of which this research determined the total cost attribute for each link of the urban network. After to select routes for hazmat transport using the Dijkstra algorithm, this research considered to objectives to be: travel cost, exposure of the population, environment risk and security concerns. In addition, Sever et al. provide hybrid algorithms that use different levels of both the time-dependent and the time-invariant probability distribution information. However, this research considers dynamic shortest path problems with both congestion types [18]. Na, Shi, Liu Xumin, and Guan Yong in 2010 [2] uses clustering analysis method for the main analytical methods in data mining. This paper presents an improved k-means algorithm in order to solve this question, requiring a simple data structure to store some information in every iteration, which is to be used in the next interaction. The experimental results show that this method can improve the speed of clustering and accuracy. The paper of Li, Kai, Lan Wang, and Lifeng Hao in 2009 [8] presents a new hierarchical clustering algorithm. The experimental results are compared with those of some single runs of well-known clustering algorithms. The research of Lee, Sanghwan, Zhi-Li Zhang, S. Sahu, and D. Saha in 2010 [10] shows the accuracy of the proposed embedding technique is as good as, if not better, than that of a 7-dimensional Euclidean embedding. This research can increase the dimension embedding does not reduce the embedding errors.

On the other hand, the question of the stability of traffic networks under adaptive route choice, in which users update their decision at any node of the network, has given much less attention. Concerns about the time variability of traffic under adaptive routing policies motivated [19], which analyses a dynamical evolution of traffic when users take into account real time information about the local congestion of roads only. In this article this research studies the stability of network equilibria under a realistic a realistic adaptive routing model [20].

III. Task Allocation Algorithmr Design

The objective of this research creates the decision support system by optimization and dynamic analysis (DSS_ODA) algorithm for decreased cost of transportation goods and presents freight cars for customer. This section presents two main parts as follows: The architecture of DSS_ODA technique and DSS_ODA algorithm.

A. The Architecture of DSS_ODA Technique

The architecture of DSS_ODA technique is shown at Fig. 1.

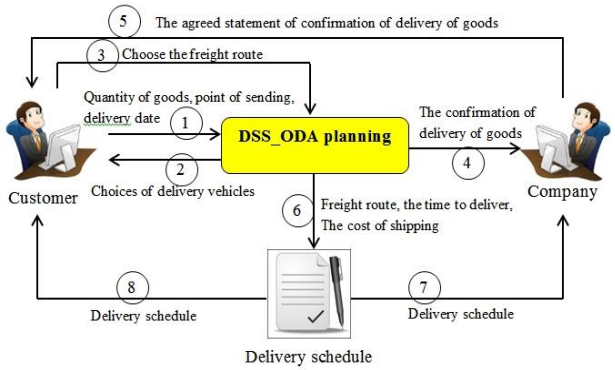

Fig. 1. The architecture of DSS_ODA technique.

From Fig. 1 presents the architecture of DSS_ODA technique. There are eight steps in this technique. First step, if the customer inputs the quantity of goods (wide long x high cubic meter per piece), point of sending and delivery date to DSS_ODA system then the system finds choices of delivery vehicles for selecting vehicle of customer. DSS_ODA planning calculates by many algorithms for solving transportation routing problem. The step two, DSS_ODA planning finds choices of delivery vehicles by optimization and dynamic analysis techniques. The step three, the customer selects the freight route to DSS_ODA planning system. The step four, the confirmation of delivery of goods is sent to company. After that or the step five, if company agrees then the agree statement of confirmation of delivery of goods will send to customer. The step six, the freight route, the time to deliver and the cost of shipping are listed in delivery schedule form. After that, the delivery schedule is sent to customer and company in the step seven and step eight respectively.

B. DSS_ODA Procedures

This section presents procedures of DSS_ODA planning system. Many algorithms are used to calculate and plan freight routes that the procedures are shown at Fig. 2.

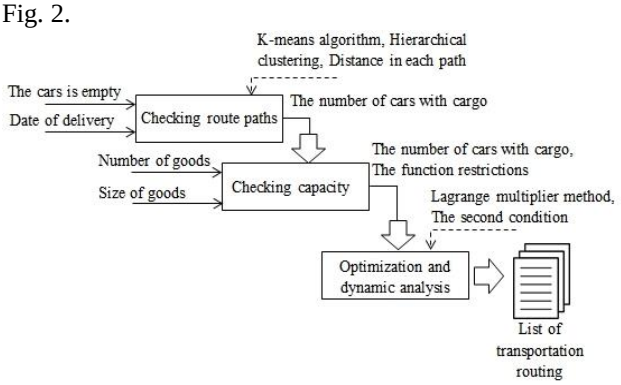

Fig. 2. DSS_ODA procedure.

From Fig. 2, there are three procedures in the DSS_ODA algorithm.

- Checking rout paths: the car is empty and date of delivery is filled from user and many algorithms such as K-means, Hierarchical clustering and distance in each path are loaded in checking rout paths procedure that these algorithm are shown in (1)-(3).

This research uses 15 cars for testing DSS_ODA algorithm. They have different space area and different space area empty too. K-mean algorithm is used to find the data clustering of transaction routing. For example, if a car send goods from Bangkok to Nakornsawan province then the customer wants to send goods to a province. This province is near Nakornsawan province so K-means algorithm can calculate the distance by the average linkage technique for decision making about transportation routing.

- Checking capacity: after pass checking rout paths, we can know number of transportation routing, which are empty. There are two data for input in this section that are number of goods and size of good. The size of goods is wide x long x high cubic centimeter piece. The objective function is created and is send to the optimization and dynamic analysis. However, if the system detects that some trucks have enough space. And during that period, no vehicle is available then the DSS_ODA technique. This situation is alternative or back-up if it is really necessary. Typically, the first vehicles freight trucks only one customer.
- Optimization and dynamic analysis: the objective function is calculated by Lagrange multiplier method and the second condition in each the size of the freight car. This research uses (4)-(8) for applying to adapt the equation. The objective function in this research is shown at (9), the limitation of the objective function is present at (10) and the Lagrangian function is shown in (11).

Let U is the objective function. $a, b, ..., q$ are volumes of goods. $x_1, x_2, ..., x_n$ are sizes of in each goods. k_i is the space of cargo and i is the cargo at 1 to maximum of the number of all cargos, which are empty.

$$U = ax_1 + bx_2 + ... + qx_n \quad (9)$$

$$ax_1 + bx_2 + ... + qx_n \le k_i \quad (10)$$

$$Z = ax_1 + bx_2 + ... + qx_n + \lambda(k_i - ax_1 - bx_2 - ... - qx_n) \quad (11)$$

After all cargos are calculated from (9) to (11) then this algorithm to five minimum of all cargos by (12).

$$DM = W_i * \max Z + W_j * \mathrm{Cost}_k \quad (12)$$

where DM is decision minimum, W_i and W_j are the weight of priorities, which plus it's currently equal 1, maxZ is the optimization of the objective function in each cargo. Cost_k is the cost of transaction route in each cargo.

All cargos are calculated by (12) and this algorithm selects the top five minimally and presents to the list of transportation routing for customer and company.

IV. The Results of DSS_ODA Algorithm

This algorithm is tested from a trucking company in Thailand. There are 15 cars for this testing and company delivery goods from Bangkok to central region.

Suppose that, there are list of transportation routes, which are shown in Table I.

Table I: The List of Transportation Routes

No. car	Places of delivery	All space area (w*l*h)	Space area empty	Date start	Date stop
1	1, 3, 5 ,7	3*5*2	3*2*2	2016-09-20	2016-09-24
2	1, 6, 9, 4	3*5*2	3*3*2	2016-09-19	2016-09-22
3	1, 7, 8,	3*5*2	3*3*2	2016-09-19	2016-09-21
4	1, 2, 3, 4, 5	3*5*2	3*3*2	2016-09-20	2016-09-23
5	1, 4, 6, 3	3*5*2	3*3*2	2016-09-18	2016-09-24
6	1, 5, 6, 9	3*5*2	3*4*2	2016-09-16	2016-09-19
7	1,6, 7, 8	3*5*2	3*4*2	2016-09-17	2016-09-20
8	1, 2, 3, 5	3*5*2	3*4*2	2016-09-16	2016-09-21
9	1, 5, 7, 8, 4	3*5*2	3*4*2	2016-09-18	2016-09-22
10	1, 3, 5, 6	3*5*2	3*4*2	2016-09-20	2016-09-24
11	1, 4, 5, 2	3*10*3	3*2*2	2016-09-18	2016-09-21
12	1, 5, 6	3*10*3	3*5*3	2016-09-19	2016-09-22
13	1, 4, 5	3*10*3	3*2*2	2016-09-18	2016-09-20
14	1, 2, 4, 5	3*10*3	3*5*3	2016-09-20	2016-09-23
15	1, 3, 5, 7	3*10*3	3*5*3	2016-09-17	2016-09-20

From Table I, places of delivery are points that shipping cars send goods. Whenever, customers request to send their goods then DSS_ODA algorithm checks date status, space area empty of all shipping cars. If some shipping cars ready then the new place of delivery and transportation routings of all shipping cars are calculate by *K*-means.

Suppose that, customer would like to send goods on 2016-09-20, all size of goods are 3*2*2 cubic meters and sending at point 10. So, the trucks are used to send goods as follow: no. 1, no. 4, no. 6, no. 10, no. 14. After that, these shipping cars are calculated distance of transportation routing by K-means algorithm. For example is shown in Fig. 3.

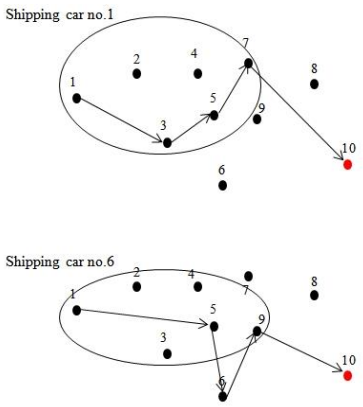

Fig. 3. To compare K-means algorithm between shipping car no. 1 and shipping car no. 6.

From Fig. 3, *K*-means algorithm selects shipping cars, which are top ten minimum. After that, DSS_ODA algorithm calculates to find the top five minimum by optimization objective function (11)-(14) in each shipping car of top ten minimum that are calculated by *K*-means algorithm. However, W_i and W_j values are both 0.5 values and the results is shown in Table II.

Table II: The List of Transportation Routes That Is Removed

No. car	Places of delivery	All space area (w*l*h)	Space area empty	Date start	Date stop	Status
1	1, 3, 5 ,7	3*5*2	3*2*2	2016-09-20	2016-09-24	Pass
4	, 2, 3, 4, 5	3*5*2	3*3*2	2016-09-20	2016-09-23	Pass
6	1, 5, 6, 9	3*5*2	3*4*2	2016-09-16	2016-09-19	Pass
10	1, 3, 5, 6	3*5*2	3*4*2	2016-09-20	2016-09-24	Pass
14	1, 2, 4, 5	3*10*3	3*5*3	2016-09-20	2016-09-23	Fail

From Table II, shipping car number 14 is fail because DW value is higher than DW value of other shipping cars.

This research develops an application, which uses DSS_ODA algorithm. After that, this application is used by 50 customers. The satisfaction survey of 50 customers is prepared in this research. The tool of satisfaction survey is questionnaire. However, features of the respondents are shown in Table III and Table IV presents the average customer satisfaction.

Table IV presents the average satisfaction of 50 customers. The highest satisfaction rating is at 5 points and the average satisfaction for this survey is 4.52 points. Then the satisfaction rating is at the highest level. In addition, the topic gives the highest level is the design of the import data is not consistent behavior change that is equal 4.73. However, the assessment of design input is high level while the results of the evaluation process in the system and the assessment of design results are highest levels.

Table III: Features of the 50 Respondents

Title		Number
Sex		
	Male	23
	Female	27
Education		
	High school	10
	Bachelor	23
	Ascended Master	17
The duration of customer (year)		
	1-3	7
	4-6	15
	7-10	22
	More than 10 years	6

Table IV: The Average Customer Satisfaction

Title	Average
1. The assessment of design input	
1.1 Design of data import is easier to use, not complicated	4.55
1.2 The design of the data import is accurate.	4.37
1.3 The design of the import data is not consistent behavior change.	4.73
1.4 The form of letters, and characters that is easy to read.	4.23
The total average	**4.47**

2. The results of the evaluation process in the system	
2.1 In the process, the system has a process to follow the correct order.	4.53
2.2 Speed data access is on the appropriate level.	4.28
2.3 This system designed to reduce duplication of data import.	4.81
2.4 Each page of this application can present quickly.	4.56
2.5 The system is designed with redundancy process to work less.	4.51
The total average	**4.54**
3. The assessment of design results	
3.1The application has to format the partition of the screen to the right.	4.66
3.2 The information is accurate, clear, easy to understand.	4.85
3.3 The application option is the use of color. And letters to be displayed properly.	4.37
3.4 The application contains information to educate and interest.	4.42
3.5 The application offers a convenient and fast.	4.42
The total average	**4.54**
The total average net	**4.52**

V. Conclusions

The objective of this research is developing the DSS_ODA algorithm by using many techniques for helping to decide of customers. There are three procedures in the DSS_ODA algorithm as follow: 1) checking rout paths procedure, 2) checking capacity procedure and 3) optimization and dynamic analysis procedure.

The advantages of DSS_ODA algorithm are offering shipping cars for customer, reducing time and errors in calculating the routs from staff. In addition, this algorithm decreases the time of travel documents and reduces the time to decide from customer. This research surveys satisfaction of 50 customers and the average of satisfaction is score 4.52 from score 5.

The DSS_ODA algorithm is created for helping customers, who decide to select shipping car for transportation goods. In addition, the customers can know expenditure and the time before decision. However, the DSS_ODA algorithm can work great with a small number of shipping cars because K-means algorithm uses a lot of time for calculating in each cluster and distances of shipping routes.

In addition, this research compares the number of customers who can deliver the goods that this research compares between using the application and the staff. This research is collected 10 times (one time per month). Form the data, the conclusion is that the application can add more customers equal 22.63 percent.

The future works is display vehicles used to transport a real time. But, some area cannot support the high speed internet then the next work wants to find a way to estimate the distance of transport routing by a new algorithm.

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