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ICOSTA 2020 **Journal of Physics: Conference Series** 1811 (2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 1 Improving vehicle routing decision for subsidized rice distribution using linear programming considering stochastic travel times Filscha Nurprihatin<sup>1</sup>, Yuri Delano Regent Montororing<sup>2</sup> 1 **Department of Industrial Engineering, Faculty of Technology and Design, Universitas Bunda Mulia, Jakarta, Indonesia** 2Department **of Industrial Engineering, Faculty of Engineering, Universitas Bhayangkara Jakarta Raya, Bekasi, Indonesia** fnurprihatin@bundamulia.ac.id Abstract.

As the highest regency with the absolute poverty rate in Indonesia, Bogor Regency must be able to handle the poverty program appropriately and ensure its effectiveness and efficiency. Subsidized rice is **one of the government** programs for poor households. This program is important because rice is a food commodity with the largest contribution **to the food poverty** line.

The effectiveness of the distribution is very dependent on the accuracy of the target number of beneficiaries and the accuracy of the amount of rice received at the consumption points. Meanwhile, the distribution efficiency is measured from the distribution route **by taking into account the** travel time that is directly related to transportation costs. This study discusses the distribution from only 1 (one) warehouse to 57 destinations.

This study contributes to the enrichment of a cluster first route second approach to solve the routing problem. It applies WDMETD and K-Means sequentially which generates 4 (four) clusters. Linear programming under **the Capacitated Vehicle Routing Problem model** is utilized to generate the routing decisions. Clusters 1 and 3 must take 1 and 2 trips, respectively.

Meanwhile, clusters 2 and 4 each take 3 trips. As a result, the proposed method ensures all trips consume the shortest time. 1. Introduction The poverty line is an indicator to declare the poor population where people below this line are declared poor. The poverty line is stated in two components, namely the food poverty line and the non-food poverty line. The food poverty line has a greater role than the other.

The food commodity that contributes the most to the food poverty line is rice, which is 21.81 percent. The government runs the program to sell low-priced or subsidized rice. This program aims to reduce the burden of poor household expenditure by meeting some of the basic food needs and preventing the reduction in energy and protein consumption.

The effectiveness of its goods distribution is very dependent on the accuracy of the consumption points and the amount of rice. Meanwhile, the distribution efficiency is measured by distribution routes that are directly related to transportation costs. Stakeholders must always be aware of things that can disrupt the smooth running of business processes [1]. In this context, it is necessary to exceed customers' expectations to be classified as excellent [2].

ICOSTA 2020 Journal of Physics: Conference Series 1811 (2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 2 Poverty is not merely a lack of income to meet basic living needs or decent living standards, but it involves the probability of poor people to carry out and develop their businesses and living standards.

The absolute poverty rate in Bogor Regency occupies the highest number among all cities/regencies in Indonesia, which is almost 400 thousand individuals. Therefore, this research is conducted in the coverage area of the warehouse which is located in Bogor City. This warehouse not only serves Bogor City but also Bogor Regency and Depok City as Figure 1 shows.

This paper assumes the consumption point is at the district level in the 3 (three) cities/regencies. Thus, there are 57 consumption points in total [3]. This study focuses on solutions to the distribution effectiveness problems which is closely related to distribution efficiency by considering stochastic travel times. Figure 1. The warehouse coverage area 2.

Problem formulation The distribution problem with travel time from one point to another requires different travel times even with the same distance. Travel time is dynamic [4] and varies due to traffic congestion or weather conditions that affect the efficiency and feasibility of shipping routes [5-6]. By minimizing the travel time of the

distribution route, operational costs are assumed to be minimal as well to achieve the effectiveness and efficiency of distribution.

Any waste should be minimized if not eliminated [7]. A study was carried out related to the effectiveness of the distribution of goods without regard to the distribution efficiency factor. A location-allocation problem with dwell time was discussed to support the decision-making process[8].

A previous study discussed the transportation mode allocation by considering demand uncertainty using the hill-climbing approach[9]. Previous studies discussed the efficiency of the distribution of goods that had been carried out using exploratory survey methods and the system dynamics approach. The exploration survey method was used to reduce exhaust emissions in the transportation industry in Sweden[10].

Other studies used the system dynamics approach to estimate and minimize costs caused by transportation[11] by considering environmental impacts[12]. These studies did not point out the effectiveness of distribution. Other studies discussed the effectiveness and efficiency of distribution by various methods, including analytical descriptive methods, simulations, Genetic Algorithms (GA), Fuzzy Genetic Algorithms (FGA), and simulated annealing.

A previous study was conducted to measure the effectiveness and efficiency of distribution routes using descriptive-analytical methods [13]. Simulation models were applied to improve the sustainability of the distribution network performance in British logistics companies by taking into account exhaust emissions[14-15]. Research using GA, FGA, and simulated annealing aims to optimize costs on the distribution of fresh food products[16].

Respectfully, the above research did not use the Capacitated Vehicle Routing Problem (CVRP) as used in this study. ICOSTA 2020 Journal of Physics: Conference Series 1811 (2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 3 A Mixed Integer Non-Linear Programming (MINLP) was developed model for planning the movement and storage of food grain from surplus states to deficit states considering the seasonal procurement, silo capacity, demand satisfaction, and vehicle capacity constraints[17].

CVRP model can be used as the powerful model to solve the routing problems considering many characteristics [18]. A previous study performed a CVRP model considering the stochastic travel times to minimize the transportation cost [19]. In performing CVRP, it is necessary to identify 2 (two) types of locations namely source point and consumption points. The source point is defined as a single warehouse.

There are 1,550 storage warehouses throughout the country responsible to ensure the distribution of subsidized rice is successfully done. One of them is an important part of this research because it is the only warehouse that serves Bogor Regency. The distribution activities are carried out at an agreed distribution point such as sub-district offices or places that are closer to the community.

The distribution route is partial shipping from the warehouse to each destination. This study aims to determine and minimize travel time for distribution routes in a particular area. The intended distribution route is taken from a warehouse to 57 districts in Bogor City, Bogor Regency, and Depok City.

By minimizing the length of the distribution route, operational costs are assumed to be minimal and in turn, it can achieve the effectiveness and efficiency of distribution. 3. Methodology This paper aims to determine the distribution route started with clustering analysis and followed by the CVRP model as shown in Figure 2. The scope of this study is the distribution route Bogor City, Bogor Regency, and Depok City.

A collection of materials, data, and information is derived from books, field studies, and relevant scientific articles to strengthen the understanding of the distribution route. At the same time, some data are collected such as travel time between distribution points, the average consumption of rice per person in a certain time along with the type, and capacity of transportation modes. After the data is collected, the analysis is carried out and then formulate the recommendations.

A previous study used K-Means to determine the location of distribution centers as the representative of each region [20]. This paper uses the same logical proportion of demand [20] since the data is obtained at the regency/city level. The travel time data acts as an input for clustering analysis and CVRP model respectively.

The transportation cost is approximated by the travel time between the distribution points. Travel time should follow the normal distribution, so the average value is taken as transportation cost. To obtain the travel time between distribution points, the coordinates of each destination are needed.

After obtaining the coordinates, the travel time can be found using the Google Maps application by repeating at least 30 (thirty) times in working time and workdays. Working time is defined as the active time during the hours of 8:00 to 16:00, while workdays are defined as Monday to Friday. The warehouse capacity is assumed to be able to meet the demand. ICOSTA 2020 Journal of Physics: Conference Series 1811

(2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 4 Figure 2.  
Research methodology 4.

Results and discussion The data on the poorhouseholds were obtained only at the city/regency level, so this paper performs a proportional calculation of the poorhouseholds to the total population at the district level. Each person is assumed to consume 114.6 kg per year [21] or 0.3140 kg per day. This assumption also indicates that the distribution is carried out every day to the consumption point.

Meanwhile, the transportation mode is assumed to have a capacity of 25,000 kg or 25 tons. The consumption point with the lowest and highest demand is in the Limo District coded DE7 (784 kg) and Gunung Putri District coded KA18 (10.392 kg) respectively. 4.1. Clustering analysis Because CVRP is Non-Polynomial hard (NP-hard), clustering analysis is performed beforehand so that the computing time would not be too long.

In the clustering analysis stage, we conduct two stages, namely hierarchical clustering analysis using Ward's method and non-hierarchical using K-Means. 4.1.1. Ward's method. The results of Ward's method are shown in Table 1. This table explains the number of clusters formed as seen from the percentage increase in the coefficient value after a merger between the two clusters.

Coefficient values describe the distance that occurs between clusters formed at a particular stage. The greater the increase in the coefficient value between one stage with another stage indicates that the two clusters are increasingly heterogeneous. For example, at stage 2 there is a merger between points 4 and 7 with a coefficient of 0,000 while at stage 3 there is a merger between points 51 and 57 with coefficients 0.001. The increase in the coefficient value for both stages is equal to 1.056893. Eventually, each point will merge into one large cluster.

The average increase in the value of the coefficient for each stage is 0.183805 or 18.2805%. The value of the increase in the coefficient that is greater than the average value is a candidate for the number of clusters to be formed. The biggest increase occurred during stage 2, which amounted to 1.056893, but this value could not be taken because the number of clusters was too large, namely 56 clusters.

The second-largest increasing coefficient occurs at stage 54 and indicates 4 (four) clusters are formed, with a value of 0.613912. Figure 3 also states the same thing, namely an increase in the coefficient seen from the elbow graphic ICOSTA 2020 Journal of Physics: Conference Series 1811 (2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 5 shape that increases significantly at the 54th

stage.

The value of 4 (four) clusters will be input (k value) on K-Means. Table 1. Agglomeration schedule Stage Coefficients Number of Cluster After Combining Proportionate Increase in Heterogeneity to Next Stage

1	.000	57	2	.000	56	1.056893	3	.001	55	0.542532	...	...	...	...														
51	.306	7	0.178231	52	.360	6	0.196578	53	.431	5	0.231449	54	.530	4	0.613912	55	.856	3	0.515521	56	1.297	2	0.431887	57	1.858	1	Average	0.183805

Figure 3. Agglomerative schedule coefficients (elbow) 4.1.2. K-Means. K-Means clustering results in a significant membership of each cluster based on the ANOVA value.

Cluster members can be seen in Figure 4 where clusters 1, 2, 3, and 4 have 10, 19, 7, and 21 members respectively. Cluster 1, 2, 3, and 4 are shown in red, yellow, blue, and green icons respectively. Each cluster proceeds to the CVRP calculation stage separately. ICOSTA 2020 [Journal of Physics: Conference Series](#) 1811 (2021) 012007 IOP Publishing doi:10.1088/1742-6596/1811/1/012007 6 Figure 4. Proposed routes 4.2.

Capacitated vehicle routing problem (CVRP) computation To calculate CVRP, it takes travel time between points in each cluster. It requires different computational time to reach the optimal global solution for each cluster due to the different number of points. In clusters 1 and 3, the computation time is very short (finished instantaneously), while in cluster 2 it must spend 7 hours 13 minutes and 50 seconds.

The longer time needed by cluster 4 which is 8 hours 43 minutes 17 seconds to solve 22 points. Table 2 explains the proposed route to be taken by each cluster. Clusters 1 and 3 must travel 1 trip and 2 trips, respectively. Meanwhile, clusters 2 and 4 each took 3 trips. The time required for all trips is the shortest and longest taken by cluster 3 (447.4 minutes) and cluster 4 (646.8 minutes) respectively.

Furthermore, the extension analysis may include uncertainty demand [22]. The commodity can be transported using heterogeneous fleet [23]. When it comes to fleet management, both corrective and preventive maintenance policies need to be taken into account for every transportation mode [24]. Future research may also consider the performance [25] with their performances [26]. The performance measure can consider the last mile distribution until the small- medium enterprise stage [27]. Table 2.

Proposed routes in each cluster

Cluster	Membership	Proposed Route	Traveled Time (minutes)
Cluster 1	WH – KA8 – KA24 – KA25 – KA27 – KA33 – KA10 – KA20 – KA39 – KA30 – KA32 – WH	516.6	
Cluster 2	WH KO1 KA17 WH	579.8	
Cluster 3	WH KO6 KO3 KA1 KO5 KO4 KO2 KA13 WH WH KA5 KA28 KA40 KA37 KA11 KA9 KA3 KA6	447.4	
Cluster 4	ICOSTA 2020 <a href="#">Journal of Physics: Conference Series</a> 1811 (2021) 012007 IOP Publishing	646.8	

doi:10.1088/1742-6596/1811/1/012007 7 KA26 – KA14 – WH Cluster 3 WH KA18 WH 447.4 WH KA23 KA12 KA21 KA4 KA38 KA34 WH Cluster 4 WH KA7 KA2- KA35 WH 646.8

WH KA31 KA15 KA22 KA29 KA19 DE2 DE9 DE7 DE5 DE1 DE8 DE6 KA36 WH WH DE3 DE11 DE10 DE4 KA16 WH Total Time Travel 2,190.6 5. Conclusion The second-largest increasing coefficient occurs at stage 54 and indicates 4 (four) clusters are formed, with a value of 0.613912. The increase in the coefficient can also be seen from the shape of the elbow graphic which increased significantly at the 54th stage.

The value of 4 (four) clusters denotes the number of clusters to be formed. Clusters 1, 2, 3, and 4 have 10, 19, 7, and 21 members respectively. Clusters 1 and 3 must travel 1 trip and 2 trips, respectively. Meanwhile, clusters 2 and 4 each took 3 trips. The time required for all trips is the shortest and longest taken by cluster 3 (447.4 minutes) and cluster 4 (646.8 minutes) respectively.

This study does not take into account the time needed for loading/unloading so that this assumption can be considered in future research. This study also uses one vehicle in each cluster, so the intuitive total travel time can be shortened by increasing the number of transportation modes. References [1] Andry J F, Tannady H and Nurprihatin F 2020 Eliciting requirements of order fulfilment in a company IOP Conference Series: Materials Science and Engineering vol 771 pp 1 6 [2] Tannady H, Nurprihatin F and Hartono H 2018 Service quality analysis of two of the largest retail chains with minimart concept in Indonesia Bus.

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