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The Prediction of Optimal Route of City Transportation Based on Passenger Occupancy using Genetic Algorithm: A Case Study in the City of Bandung

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Abstract

Currently, the existence of city transport is increasingly eliminated by private vehicles such as cars and motorcycles. This situation is further exacerbated by the behavior of city transport drivers who are less discipline in driving, or in picking up and dropping off their passengers. The bad behavior is partly caused by the low level of passenger occupancy. The drivers try to search for passengers as much as possible but often ignore the traffic rules. To overcome this problem, an optimal transport route with high passenger potential is required. Therefore, this study investigated the optimal route of city transport based on the passenger occupancy rate in the city of Bandung as the case study. The method employed for determining the optimal route is Genetic algorithm combined with Ordinary Kriging method used for the process of passenger prediction and fitness calculation. The optimal routes are those with higher occupancy rate. The analysis results showed that the use of the Genetic algorithm with a low number of generations succeed in creating new optimal routes even though the increase is not too high the maximum only reaches 4%.This result is certainly important enough to be used in making better public transport routes.

Keywords*: optimal route, genetic algorithm, occupancy, kriging*

1. Introduction

The continuous increase in vehicles produced by automotive companies, which are not offset by the improvement in the capacity and quality of roads, can lead to congestion. In Indonesia, besides being triggered by the increase in vehicles, congestion is also caused by the economic growth of the people, thus encouraging them to use various vehicles to fulfill their needs. They use either private vehicles or public transportation to support their dynamic mobilization. Public transportation operating in Indonesia is quite a lot such as buses, city transport, rickshaws, and trains. However, the one which causes traffic jam lately is city transport (angkot). It is because it has typical characteristics such as having various shape and size, low passenger capacity, passing through a route which depends on the coverage area so that each route has different mileage, a different number of modes in each route, and inexpensive fare. In addition, there are also some other factors affecting the traffic jam due to city transport including passengers dropping off anywhere (not at the terminals) and drivers picking up passengers at will.

The low number of passengers of the city transport is one of the causes of undisciplined drivers. This condition is not in accordance with the government regulation that one of the provisions in the procurement of modes of transportation is the potential number of passengers per vehicle (i.e. 250 passengers per day) [1]. The drivers try to make every effort to get his daily income target fulfilled. At the beginning of the launch of city transport, it was believed to be one solution to reduce congestion, but its existence currently contributes to congestion. Therefore, the problem of city transport especially the one related to the determination of optimal city transport routes is interesting to study. The improvement of quality standard and public transportation service is one of the solutions and attractions of increasing public awareness to use public transportation. Some solutions which are believed to increase people’s desire to use public transport include: public transportation routes should be able to reach all urban areas,

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construction of shelters should be done at crowded points, public transport may only pick up or drop off their passengers at shelters, and vehicles should be upgraded periodically.

One of the ways to overcome the congestion caused by public transportation especially in Bandung City is by obtaining the optimal variable values from the problem formulation. This study offers a solution by optimizing the urban transport routes by which the existing routes are considered not complying with such requirements stipulated in the government regulation. One of the methods of route optimization commonly done by many researchers is to use an algorithm with a supporting variable, i.e. distance [2]. The determination of optimal route based on the distance has a weakness, i.e. unable to consider the potential income of the city transport drivers appropriately. In other areas such as in the determination of tourism scenic routes, the determination of an optimal tourist route is designed by considering the constraints of slope and roughness[3]. Meanwhile in Express Delivery Routing optimization, the value of the transportation costs is a measure for optimal route determination[4]. The transportation costs should still be able to ensure the quality of delivery service and customers' satisfaction remains good.

All research on the determination of optimal route for public transportation above, no one has paid attention to passenger occupancy factor. Whereas the occupancy of passengers is a very decisive thing for the sustainability of the availability of public transportation that is currently its existence is still held by the private sector. Passenger occupancy should be a key consideration in determining the optimal routes of public transportation. The problem of determining the efficient transportation cost for the determination of the optimal urban transport route becomes a consideration in this research. Passengers certainly want the smallest possible cost, while the provider of urban transport vehicles wants a high tariff to get more income.

The income of drivers can increase if urban transport has routes with high potential passengers. To overcome this, this study proposes the determination of optimal route based on the passenger occupancy rate. This is in line with the results of data analysis of city transport routes that the average passenger occupancy on the existing routes is still relatively low. This study used a genetic algorithm with the fitness function defined as urban transport occupancy at a location. the genetic algorithm is chosen based on the consideration that the algorithm is quite effective in the case of route determination, as did Changqing et al in the determination of Route Optimization of Stacker [5].This passenger occupancy value is obtained from the results of prediction using the Kriging method. It is expected that this study can recommend more optimal city transport routes in Bandung so that the transport becomes more directed at the crowded points and is able to generate a higher level of passenger occupancy.

2. Related Work

In the field of transportation, one of the generally-addressed issues is route optimization. Each researcher has a different definition in determining the optimal route, depending on the problems to be solved. Generally, a transportation route as the focus of research is the bus route. Today, the determination of the optimal bus route also considers the arrival and departure of other modes of transportation such as trains. Determining the optimal public transportation route (e.g. bus route) separately without being connected to the schedule of other modes of transportation is classified as a less complex issue and able to be solved using a simple algorithm such as Dijkstra. Nevertheless, the determination of the optimal transportation routes which are associated with other modes of transportation (e.g. train schedules) is a complex optimization issue which requires long computation time. Such a model is called the time-dependent model. One of the most effective approaches to solving such a route optimization problem is by employing the concept of transfer patterns. Some researchers have made route optimization in association with the concept.

Shrivastava and Mahony combine genetic algorithm and the specialized heuristic algorithm to determine optimal routes [6]. They develop feeder routes by using a genetic algorithm and then use a specialized heuristic algorithm to satisfy the demand of all the nodes. In relation to the computation of route optimization with respect to the concept of transfer patterns, [7]-[8] also develop special heuristics algorithm to obtain a feasible pre-computation time. This is because the use of an algorithm such as Dijkstra is time-consuming.

. In a similar study, Chien et al. used the minimal value of total system cost, including operator and user costs as a measure for determining an optimal bus route [9]. They developed method which applicable to irregular grid networks. They also show that the optimal route is sensitive to demand distribution over the service area. The determination of the cost-based optimal route is also done by Sadrsadat et al. who apply the bus route users' profit subtracted by the cost of network operator as an optimal route indicator. The most optimal route is the one which has the maximum profit value [10].

Another issue which arises in the field of transportation is the determination of transit route networks. Chakroborty and Dwivedi propose an optimal route based on the link travel times and transit demand [11]. On the other hand, in determining the optimal route on the pickup service of travel car passengers, [2] employ the minimum distance weight to determine the optimal pickup route.

The method or algorithm used to solve transportation problems also varies. One method the researchers often use is the genetic algorithm. It has long been used by researchers to solve many complex problems. A genetic algorithm can be used to solve complex optimization and is suitable to solve the problems of transportation route optimization [11], [12]. In addition, Sadrsadat et al. [2012] employ a genetic algorithm by which the fitness function is defined as the bus route users' profit subtracted by the cost of the network operator. This fitness function will maximize the distribution of bus routes in the observed area. Another method to determine an optimal route is a combination of genetic algorithm and specialized heuristic algorithm [6]. In another case, the Ant Colony System can also be a suitable method to determine optimal routes [2]. In the latter case, the optimal routes are those with the shortest distance.

3. Data Processing and Methods

3.1. Data

Data processed in this study included the occupancy of city transport passengers in Bandung area as recorded in 2016. As many as 6 routes of city transport were observed from which the data on each route where passenger occupancy was grouped into two categories, i.e. weekday and weekend.

3.2 The making of shapefile

Shapefile or commonly known as SHP is a geospatial data format generally used for the geographic system software with an extension of .shp. A shapefile is depicted in the forms of lines, extents, and dot geometry which form the mapping of territories, rivers, roads, seas, and so on. In this study, the shapefile functioned to create a map of Bandung City along with the streets. The shapefile was created using the QGIS Desktop 2.18.3 application and was displayed using the ArcMap 10.5 application. The unit of the shapefile was then converted to UTM, so it turned into meter. Subsequently, the occupancy data on the shapefile was input into ArcMap. The labels displayed on the shapefile included street names at the crowded points. The shapefile along with the streets are displayed in Figure 1.

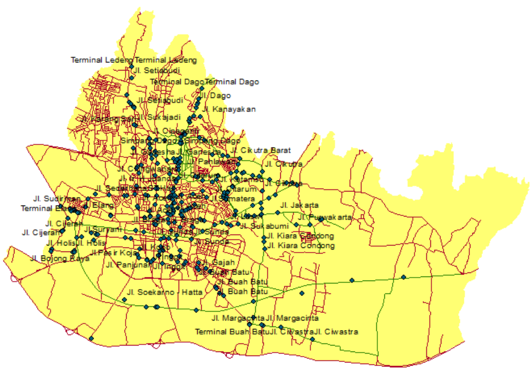

Figure 1. Bandung City Shapefile and the Crowded Points

3.3 Processing of location data

This process is the combination between of a shapefile map created in ArcGIS and passenger occupancy data as the observation results. The labels or attributes displayed in the shapefile were the occupancy value in crowded points and street names in Bandung City. The shapefile read the occupancy which were displayed based on the coordinate points (x,y) - latitude (x) and longitude (y) at all routes. Table 1 shows the observation of occupancy on one of the routes in Bandung.

Table 1. The Observation of Occupancy in Abdul Muis - Cicaheum (Via Aceh) Route

Nbr	Street	Location of the crowd	latitude(X)	longitude(Y)	Occupancy
1	Terminal Kebon Kalapa	Terminal Kebon Kalapa	787978.00	9233470.00	1.03
2	Jl. Dewi Sartika	SMP 10 Bandung	787933.00	9233298.00	1.34
		SMP 3 Bandung	787918.00	9233312.00	1.84
3	Jl. Kautamaan Istri	SMP 43 Bandung	788020.00	9233674.00	1.77
4	Jl. Balong Gede	SMK Pasundan 1 Bandung	788061.00	9233556.00	2.07
5	Jl. Pungkur	Pasar ancol	788448.00	9233263.00	3.00
6	Jl. Karapitan	Universitas Langlangbuana	789045.00	9233059.00	1.75
7	Jl. Sunda	Gedung Lippo	789251.30	9233964.66	1.94
		Toserba Yogya	789318.00	9234452.00	1.47
8	Jl. Lombok	Stadiun Siliwangi	789398.81	9235378.02	1.59
9	Jl. Taman Pramuka	Baltos	788353.83	9236649.25	3.14
		SMPN 14 Bandung	790683.00	9235603.00	2.35
		SMPN 22 Bandung	791067.00	9235138.00	2.58
		Ganesha Bimbingan Belajar	790741.56	9235936.56	1.79
11	Jl. Jend. Katamso	Plaza Fleksi	790739.00	9235882.00	2.05
		PUSSENIF	790950.00	9236136.00	2.26
		Griya Pahlawan	791109.00	9236474.00	3.23
12	Jl. Pahlawan	ITENAS	791100.00	9236763.00	3.05
		Taman Makam Pahlawan	791239.89	9237289.08	3.41
13	Jl. Cikutra	Universitas Widyatama	792178.44	9236751.83	2.40
14	Jl. Hasan Mustofa	Terminal Cicaheum	793600.34	9236200.40	1.77

3.4 Prediction of kriging value

This process is the prediction of occupancy value at other locations in Bandung city map, outside the observation data. The result showed that all of the location points on the streets which were potential to be new alternative routes would have the occupancy data (prediction) to be the reference in determining alternative routes. The prediction process employed ArcGIS 10.5 tool while the Kriging method used was the Ordinary Kriging. This Ordinary Kriging method was chosen with the consideration that the passenger occupancy value tended to be stationary, or had no up or down trends. The prediction result of Kriging value and its location information were then stored in an adjacency matrix. The location points were subsequently codified in the forms of location numbers to simplify the writing.

3.5. Searching for new route solutions using genetic algorithm

The next process was to search for solutions using genetic algorithm. The solution offered was an alternative route which had the following conditions:

1) Passing through certain location points
2) Having a higher predicted value of passenger occupancy than the original route

Stages of genetic algorithm conducted in this study included:

a. Initialization of N Random Population
b. Reproduction Process
c. Selection Process
d. Cross-over Process
e. Mutation Process
f. Evaluation and Termination of Regeneration

a. Initialization of random population

This process is a process for generating individuals in a population size of N. Each individual is expressed as a chromosome that has the first cell containing the mode starting point and the last cell in the forms of the mode destination point. The searched individuals were those who had a high fitness value. This initialization process was only done once. The formula of fitness function can be seen in equation (1).

$$fitness = average\_occupancy on\ a\ route \tag{1}$$

b. Reproduction process

The reproduction process means a process for generating new offspring by passing on the same traits of the parent chromosome. This process aims to keep the good parents from disappearing. The process also contains the elitism, i.e. a process of maintaining the best individuals.

c. Selection process

In the selection process, there are two steps to be done, i.e. calculating Linear Fitness Ranking (LFR) and making the selection using the Roulette Wheel method. After all individuals were arranged in order by the LFR value, the next process was to select individuals based on the LFR value using the Roulette Wheel method. Individuals who had a larger LFR value would have a higher chance of being selected. The LFR formula can be seen in equation 2[13].

$$f_{LR} = f_{max}\left(f_{max} - f_{min}\right)\left(\frac{R(i)-1}{N-1}\right) \tag{2}$$

where

f_{max}: maximum fitness

f_{max}: minimum fitness

R(i) :the i-th individual rank

N : Number of chromosome in population

d. Crossover process

The crossover process means a process of producing a new chromosome as a result of the combination of two parents who have been selected at random. The result indicated new individuals implying a new route. The ultimate goal was to bring out individuals with better fitness. The crossover rate used was 0.8. The *crossover mechanism* used the PPX (Precedence Preservative Crossover).

e. Mutation Process

The process of mutation in the formation of routes here was done by replacing or switching genes or points of intersection with each other in the hope of making the fitness value better than before. The mutation probability used in this study was 0.1. The mutation probability value was chosen not too high in order that the chromosome of the new offspring did not change in the extreme. The optimal value of mutation probability is actually different for each case handled. In some cases of non-transportation fields, the optimal value of mutation probability is obtained from a higher value [14-15]. While in the field of transportation research, the used mutation probability value is relatively low [6], [10-11] .

f. Evaluation and Criteria for Termination of Regeneration

This stage includes terminating the generation or epoch according to the desired conditions. The terminating conditions may be based on either the number of epochs or on the fitness value (when the new route fitness>the old route fitness). Once the conditions have been as expected then the process of solution search will stop and will not return to the reproduction process. Subsequently, the system will provide optimal solution in the forms of more optimal new routes.

4. Experiment Results and Analysis

Based on the observation data on 6 city transport routes in Bandung, the experiment was done with the parameter configuration as follows: population size=30, crossover probability=0.8, and mutation probability=0.1. The number of tested generations included 50, 200, 500, 1000 and 2000. The detailed search results of the optimal routes for weekend and weekday periods can be seen in Table 2 and Table 3.

Table 2: Optimal Route Acceleration Prediction using Genetic Algorithm (Weekend)

No.	Route	Number of Generation 50	200	500	1000	2000	Real Occupancy	Increase
1	Abdul Muis-Cicaheum	3.25	3.25	3.25	3.25	3.25	3.12	4%
2	Cicaheum-Abdul Muis	3.15	3.15	3.16	3.16	3.16	3.12	1%
3	Abdul Muis-Dago	3.28	3.35	3.35	3.36	3.36	3.17	6%
4	Dago-Abdul Muis	3.38	3.37	3.38	3.39	3.39	3.29	3%
5	St.Hall-Dago	3.53	3.53	3.53	3.53	3.53	3.49	1%
6	Dago-St.Hall	3.50	3.50	3.50	3.50	3.50	3.45	1%

Table 3. Optimal Route Acceleration Prediction using Genetic Algorithm (Weekday)

No.	Route	Number of Generation 50	200	500	1000	2000	Real Occupancy	Increase
1	Abdul Muis-Cicaheum	3.94	3.95	3.95	3.95	3.95	3.80	4%
2	Cicaheum-Abdul Muis	3.85	3.85	3.85	3.86	3.86	3.81	1%
3	Abdul Muis-Dago	3.81	3.88	3.88	3.86	3.88	3.73	4%
4	Dago-Abdul Muis	3.88	3.90	3.93	3.93	3.93	3.83	3%
5	St.Hall-Dago	3.95	3.95	3.95	3.95	3.95	3.84	3%
6	Dago-St.Hall	3.94	3.94	3.94	3.94	3.94	3.80	4%

Table 2 and Table 3 show that the passenger occupancy rate on city transport on weekdays is higher than that on weekends. This implies that urban communities in Bandung use more city transport services for daily work activities. The use of genetic algorithm to search for new, more optimal routes is successful with the highest increase reaching 6% for the weekend and 4% for the weekday. In this study, the determination of optimal route can be commonly achieved in the 50th generation although in some cases, the new optimal route is obtained in the 500th and 1000th generations.

5. Conclusion

This study discusses the determination of optimal route of city transport based on the passenger occupancy rate in Bandung City. The method used is genetic algorithm combined with Ordinary Kriging method for the passenger prediction process and fitness calculation. The determination of route optimality according to the passenger occupancy rate is based on the data that the city transport operators' income is decreasing due to the decreasing rate of passenger occupancy.

The analysis results show that the use of genetic algorithm with a low number of generations succeeds in producing new, more optimal routes even though the increase is not that high. Factors affecting the passenger occupancy rate such as schools, markets, supermarkets, and others may be considered for inclusion in the prediction of passenger occupancy rate to produce a better predictive occupancy model.

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