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Application of Remote Sensing and GIS for Angkuta Stop and Route in Malang City

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Abstract**—** *Malang city has one public transportation that is Angkuta, but the current conditions are considered ineffective. Mass transportation planning requires adequate facilities such as bus stops and effective routes. This research aims to select the most optimized bus stop locations for the Malang city transportation user from Angkuta and to extend bus route based on the existing route of Angkuta with review performance assessment. This research determines the potential location for bus stops with scoring method or parameter assessment, which can find out the potential trip production and trip attraction of passengers in the block area. By manually digitizing building roofs from the satellite image, physical parameters of buildings such as building density, average building size, and building layout are calculated. The method used for route evaluation is by analyzing route performance parameters. These parameters are carried out by field surveys for six Angkuta routes. The results of this study generated potential locations for bus stop locations on the six routes. ABB route has 18 stop points, Route AG has 28 stop points, the AMG route has 33 stop points, the ADL route has 34 stop points, the LDG route has 37 stops, and the ABG route has 33 stops. The results of route performance analysis show that the ABG, ADL, and AMG routes have a fair performance. LDH routes have good route performance. Routes AG and ABB have bad route performance. This study shows that using satellite image data can be used as a recommendation to determine potential locations for bus stops. Moreover, the analysis of route performance parameters can use as a reference in route performance assessment.*

Keywords**—** *Satellite Image, Trip Production, Trip Attraction, Angkuta, Bus Stop, Route Performance.*

I. INTRODUCTION

Malang City is one of the cities in Indonesia that has developed into one of the regional education centers and tourist destinations. Malang City has one public transportation that is *Angkuta*. *Angkuta* has a capacity of 12 people, does not have a schedule, and does not have a stop so passengers can get on and off anywhere. Congestion is increasing every year in Malang, because users are not interested in using public transportation and prefer to use private vehicles. The number of private transports based on Malang City data in 2017 has reached 673,125 units of vehicles covering 556,693 units of two-wheeled vehicles and 116,432 units of four-wheeled vehicles. The urban population of Malang, which reaches 895,387 people [1]. Malang City area has an area of 145.28 km^2 has a population density of 6,175 inhabitants per km^2,

certainly has a high spatial mobility behavior, so the need for mass transportation facilities or mass transit becomes an important point in the daily lives of Malang urban people. Overcoming congestion in Malang, the government start using mass transportation such as the Trans Malang Bus to replace Angkuta. Remote sensing and Geographic Information System (GIS) can be applied to assist in data acquisition in overcoming transportation problems, especially information the basis needed to evaluate the arrangement of public transport routes, especially Trans Malang bus routes and also to determine the position of the strategic Trans Malang bus stop. Remote sensing and GIS are referred to as important tools and often used in various fields; one of them is transportation planning. Remote Sensing and GIS for transportation network is applied to planning in the area of Land Use and digitized road network [2]. In [3], determine bus routes and bus stop using 1994 SPOT image and 1999 aerial photograph of Birkenhead for mapping, then processed by using three GIS tools, which are buffering, shape arc, and identity.

The consideration of bus stops location is a place aspect for operational purposes as the strategic location of the bus stop will ensure comprehensive coverage and easy accessibility to all categories of users. The location of the candidate is a location that has a large demand value and the location meets the criteria for establishing a bus stop [4]. Estimated travel demand can use trip generation forecasts that consist of trip production and trip attraction [5]. Trip production is the number of passengers who have the possibility of moving from a zone or land use. Usually, the passenger production zone originates from land use in the form of settlements. The factors that influence passenger production are income, vehicle ownership, household structure, house size, the density of residential areas, and accessibility [6]. Passenger attraction is the number of movements attracted to land use or zone [7]. The zone consists of education, offices, trade, industry, and settlements or housing. Zones that have high demand are ranked according to the parameters of trip production and trip attraction using the index model method. Index model is used for calculating the index value for each unit area and producing a ranked map based on the index value [8]. In [9], evaluate existing land use patterns and transportation service, predicting travel demands using indexing in GIS for measuring and mapping levels. Quickbird satellite image processing is used as material for zone interpretation and analyzed using trip production parameters consisting of building density, building size, and building regularity [10]. Factors affecting trip attraction can be categorized into five regions for parameters; Office area, industrial area, education area, service area, and trade area [6].

Evaluate routes by evaluating public transport performance. Performance evaluation of public transport routes based on the identified performance indicators. Relative weights for performance indicators are identified based on field surveys on the route and given an assessment. Route survey data are analysed by formulating an index for travel costs, travel time, comfort, safety, reliability, and accessibility [11]. Evaluation analysis of urban public transport performance based on the BCC model optimization by using input indicators are the number of bus stations, the number of daily bus shifts and the main vehicle kilometres travelled, waiting time, the number of running buses and the punctuality rate [12]. Based on World Bank 1987 and the Directorate General of Land Transportation, the standard for public transport services has parameters for the performance of public transport [13]. There are nine parameters nine public transport performance parameters; travel time to go and return, vehicle frequency and frequency variation, load factor, time of progress, number of trips and distance traveled by vehicle per day, cycle time, number of passengers per vehicle per day, number of vehicles, and circulation time [14]. The parameters for each route are given a value weight. Weighting technique and give five criteria for each of the parameters is very good, good, fair, bad and very bad [14].

II. METHODOLOGY

A. Study Location

This research investigates six public transportation routes in Malang City, which are ABB, ADL, LDG, ABG, AG, and AMG as shown Figure 1. Six *Angkuta* routes are used as research locations to determine the location of bus stops and routes are evaluated to determine whether the route is suitable as a bus route.

Fig. 1. Six route are used in the study

B. Research Material

Satellite imagery of Malang City area becomes an interpretation material that is processed in GIS. Information of images is used to assess the physical variables of settlements that used as potential variables for passengers in each passenger unit. Physical variables of settlements tapped from images are settlement density, settlement size, and layout. In addition to the physical variables of the settlement, other data from remote sensing images are the attraction of passenger areas such as education, office, trade, service, and industry.

Field survey of *Angkuta* route was carried out by recording the number of passengers going up and down. During the survey also recorded the time of departure and arrival, interview surveys with *Angkuta* drivers to find out the number of trips in one day.

C. Research Methods

The method used is the index model by weighting parameters and ranking them to get optimal results. Using this method, it is used to evaluate the location of the *Angkuta* stop for the bus stop and evaluate the performance of each route.

D. Determination of Location for Bus Stop

Determination of the location of bus stops is based on potential locations, which is locations that have high demand. To determine potential locations, calculations for trip production and trip attractions are calculated. The passenger production and attraction source area are obtained from the assessment of the physical variables of settlements through the interpretation of remote sensing images. Figure 2 shows the steps to get the potential map results for the stop location. Data used from the approach of trip production and attraction from the digitization of GIS.

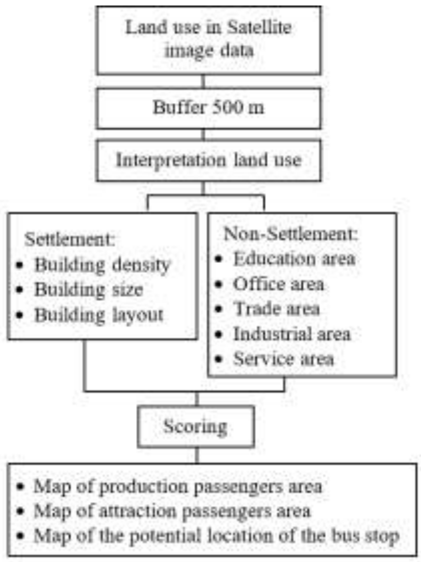

Fig. 2. Stage potential map location

Data from satellite imagery are digitized using GIS. Before digitizing, it is carried out a buffer of 500 m along the *Angkuta* route [15]. After buffering, the blocks are made in the buffer area. Divided into several sub-blocks to help find out in detail the types of land use, as shown in Figure 3. After determining the blocks in the buffer area, then digitize the roof of each building, as shown in Figure 4. Calculation of total roof area and area in the sub-block for building density parameters and building size parameters.

Mapping trip production based on an assessment of three parameters, that is the density of the building, the size of the building, and the layout of the building.

Fig. 3. Block in the buffer area

Fig. 4. Digitizing the roof of the house

The density of building is calculated through an image based on a comparison between the area of the roof and the area of the settlement. The size of the building calculated from the average roof area from digitized in GIS and the layout of the building is assessed from the interpretation of satellite images. Table I shows the parameters used and the score for each parameter.

The three parameters are summed based on the value of each parameter, and the weighting factor, the formula used is as follows [16]:

$$S\ tot = (Sp.Bp) + (Su.Bu) + (St.Bt) \quad (1)$$

Where Sp represent the value of population density, Stot represent the total value of passenger occupancy units, Bp represent the density of settlements, Su represent value of settlement size, Bu represent the size of the settlement, St represent layout value, Bt represent layout weight.

The next calculation is to get the trip production value existing settlement blocks and the weighting of the value of existing parameters [16]. From the formula below, it is classified into five classes as shown in Table II.

$$Interval = \frac{Maximum\ score - Minimum\ score}{Number\ of\ categories} \quad (2)$$

Mapping trip attractions based on area parameters that attract people to travel. The areas of the highest in order of education, offices, shops, industry and services are shown in Table III [6].

TABLE I. Classification of trip production parameters

Parameters	Classification	Percentage	Score
Building density	Dense	> 60%	3
	Rather dense	41%-60%	2
	Not dense	<40%	1
Building Size	Big	> 60% more than 100 m^2	3
	Moderate	> 60% between 51-100 m^2	2
	Small	> 60% less than 50 m^2	1
Building Layout	Regular	Regular pattern (> 50% uniform)	1
	Rather regular	Quite regular pattern (25-50% uniform)	2
	Irregular	Irregular pattern (<25% uniform)	3

TABLE II. Classification of passenger production class

Trip Production Value	Trip Production Class
0-4	Very low
5-9.	Low
10-14.	Medium
15-19	High
20-24	Very High

TABLE III. Classification of trip attraction parameters

Class	Activity Center	Value
Class I	Education area	5
Class II	Office area	4
Class III	Trade area	3
Class IV	Industrial area	2
Class V	Service area	1

Analysis of the potential location is calculated by the sum of the values obtained from the trip production parameters and the trip attraction parameters. After that it is ranked and classified for potential locations as shown in Table IV.

E. Route Evaluation

Route evaluation by analyzing six *Angkuta* routes is used for bus routes. Route analysis based on the results of the field survey using public transport performance parameters. There are seven parameters used to analyze route performance. Figure 5 shows the process flow of field data retrieval, parameters to be used and results of evaluated routes.

TABLE IV. Potential location ranking

	Very High	**High**	**Medium**	**Low**	**Very Low**
Very High	25	24	23	22	21
High	20	19	18	17	16
Medium	15	14	13	12	11
Low	10	9	8	7	6
Very Low	5	4	3	2	1

The seven parameters are calculated based on survey data fields on six routes to find out if the route is optimal. Travel time obtained from the field survey recorded travel time to leave and travel time to return. The frequency of the vehicle is obtained from the number of *Angkuta* observed passing one point in one hour.

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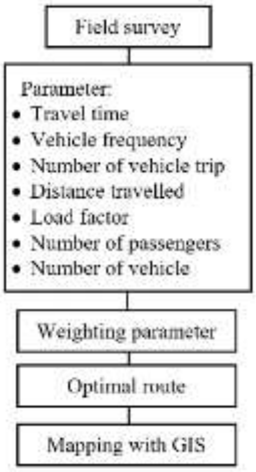

Fig. 5. Stages route evaluation

Load factor is a comparison of the number of passengers in a vehicle compared to the amount of vehicle capacity, calculated using the following equation:

$$Load\ Factor = \frac{Number\ of\ passengers}{Vehicle\ capacity}\ x\ 100\% \tag{3}$$

Time headway is the differences between time two vehicles to pass a bus stop or point. The number of vehicle trips obtained from vehicle trips can be done in one day. Distance travelled per vehicle per day is calculated by multiplying the distance travelled with number of vehicle trips. The Number of passenger per vehicle per day calculation from the average number of passengers multiplied by the number of vehicle trips.

Weights of each route, which has been analysed by the standards of public transport services. The weighting criteria for each parameter in this study defined as in Table V [14].

III. RESULT AND DISCUSSION

The results of data processing with the method that has been used. Data used to evaluate *Angkuta* stop using satellite image data while the data used to evaluate routes are field survey data.

TABLE V. Weighting Criteria for Each Parameter

No.	Parameter	Unit	Standard	Criteria				
				Very Good	Good	Fair	Bad	Very Bad
1	Travel time	Hour	1-3	1'-1.30'	1.30'-2.00'	2.00'-2.30'	2.30'-3.00'	>3.00'
2	Vehicle frequency	Veh hour	3-6	≥ 12	12-9	9-6	6-3	< 3
3	Load factor	%	≤ 100	100-90	90-80	80-70	70-50	< 50
4	Time Headway	Minute	5-20	≤ 5	5-10	10-15	15-20	> 20
5	Number of Trip	Veh./day		≥ 8	7	6	5	< 5
6	Vehicle Distance	km	230-260	≥ 260	260-230	230-200	200-170	<170
7	Number of Passenger	Person	250-300	≥ 300	249-187	186-124	123-61	<62
	Weighting routes			5	4	3	2	1

A. *Identification of Potential Bus Stop*

Determine the location of passenger stops is based on the value of production and attraction in the area. Calculations and interpretations are carried out on buildings in buffer blocks in satellite images with the help of GIS. Calculating and interpreting buildings in the buffer zone generate parameter values for trip production and trip attractions. Parameter calculation and then ranking for each trip production parameters and trip attraction parameters. The results of these calculations are combined to get a potential location for the location of the bus stop.

The optimal number of bus stops is based on location point parameters for stops. The parameters used are bus stops in zones that have high production and attraction values, distances between stops are less than 500 m, and in locations where demand for public transport is high such as offices, schools, malls, markets, etc. If the bus stops according to parameters, the bus stop is optimal [4]. In this study using six routes, the following plan location and number of stops the results of this study.

The calculation results on route AG have 28 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 6.

Fig. 6. Potential bus stop AG route

The calculation results on route ABB have 18 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 7.

Fig. 7. Potential bus stop ABB route

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The calculation results on route AMG have 33 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 8.

Fig. 8. Potential bus stop AMG route

The calculation results on route ABG have 31 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 9.

The calculation results on route ADL have 34 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 10.

Fig. 9. Potential bus stop ABG route

The calculation results on route LDG have 30 stops and a range of values 17-20 indicates the highest potential area value, as shown in Figure 11.

B. Route Performance Evaluation

Data from the field survey were used as a parameter to assess the level of route performance in this study. The following is a table of data that was processed from survey data that has been carried out. The survey was conducted on six routes by calculating and assessing seven parameters to get the performance value on each route. Survey data from six routes are used to calculate seven parameters. Table VI show the result of parameter travel time. Table VII show the result of parameter vehicle frequency, time headway, load factor, and number of passenger per day. Table VIII show the result of parameter number of vehicle trip, distance of route, and vehicle distance.

Fig. 10. Potential bus stop ADL route

Fig. 11. Potential bus stop LDG route

TABLE VI. Total travel time

Route code	Time to leave		Time to return		Total time (Hour)
	Travel time (minute)	**Waiting time (minute)**	**Travel time (minute)**	**Waiting time (minute)**	
AG	53	10	59	13	2:15
ADL	52	8	55	4	1:59
AMG	47	8	51	4	1:50
ABG	65	5	69	5	2:24
LDH	43	8	54	8	1:53
ABB	56	21	59	24	2:40

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TABLE VII. Vehicle frequency, load factor, and time headway calculation

Route Code	Vehicle frequency per hour	Time headway (minute)	Average of load factor %	Number of Passenger per Vehicle per day
AG	5	22	38.96	55
ADL	11	10	41.66	72
AMG	9	11	43.75	54
ABG	10	11	47.03	80
LDH	8	15	42.63	72
ABB	3	45	38.54	40

After analyzing performance calculations for *Angkuta* from the six *Angkuta* routes, then providing values for each parameter. A summary of the results of the analysis of the seven parameters in this study is summarized in Table IX.

TABLE VIII. Number of vehicle trip and distance calculation result

Route Code	Number of Vehicle Trip (Vehicle/day)	Distance of route	Vehicle distance
AG	5	28.8	142.5
ADL	8	29.2	233.6
AMG	7	27.2	190.4
ABG	8	38.2	305.6
LDH	8	31.6	252.8
ABB	4	27	108

TABLE IX. Summary of calculation results of parameters

No	Parameter	Unit	Standard	Route Code					
				AG	ADL	AMG	ABG	LDH	ABB
1	Travel time	Hour	1.-3	2:15	1:59	1:50	2:24	1:53	2:40
2	Vehicle frequency	Veh./hour	6.-12	5	11	9	10	8	3
3	Load factor	%		38.96	41.66	43.75	47.03	42.63	38.54
4	Headway	Min.	5. -20	0:22	0:10	0:11	0:11	0:15	0:45
5	Number of trip	trip/day		5	8	7	8	8	4
6	Vehicle travel distance	km	230-260	142.5	233.6	190.4	305.6	252.8	108
7	Number of passenger	Person	250-300	55	72	54	80	72	40

From the summary calculation of the parameters, then each calculated parameter value is given a value. Table X shows the results of weighting the *Angkuta* route performance parameters.

TABLE X. Results of weighting route performance parameters

No	Parameter	Unit	Standard	Route Code					
				AG	ADL	AMG	ABG	LDH	ABB
1	Travel time	Hour	1.-3	3	4	4	3	4	3
2	Vehicle frequency	Veh./hour	6.-12	2	4	3	4	3	2
3	Load factor	%		1	1	1	1	1	1
4	Headway	Min.	5. -20	1	4	3	3	3	1
5	Number of trip	trip/day		2	5	4	5	5	1
6	Vehicle travel distance	km	230-260	1	4	2	5	4	2
7	Number of passenger	Person	250-300	1	2	1	2	2	1
Total				**11**	**24**	**22**	**23**	**25**	**10**
Average				**2**	**3**	**3**	**3**	**4**	**2**
Criteria				**Bad**	**Fair**	**Fair**	**Fair**	**Good**	**Bad**

The results of weighting for AG and ABB routes have bad route performance, while for AMG, ADL and ABG routes have fair route performance. LDH route has a good route performance. Routes that have bad route performance will make an alternative route

Figure 12 shows the mapping of parameter weighting results on six *Angkuta* routes, on the red line map shows bad performance route; yellow lines indicate fair performance route, and green lines indicate good performance routes.

Fig. 12. Route performance

IV. Conclusion and Suggestions

The results of the calculation of production and attraction parameters in the regional blocks on the ABB, AG, AMG, ADL, LDG, and ABG routes were obtained potential locations for the bus stop location. After knowing the location of blocks that have a high potential value, a bus stop point is based on the willingness to walk using a distance of 250 to 500 m. The ABB route has stop points, Route AG has 23 stop points, the AMG route has 38 stop points, the ADL route has 39 stop points, the LDG route has 42 stops, and the ABG route has 33 stops. A bus will replace *Angkuta*, the government must plan a bus stop to be placed in a zone that has a large demand, in an area where the public area is located, and the distance between buses stops 300-500 m. From planning an *Angkuta* stop before the government only places a stop in a certain area and the distance between stops is too far away. So that users are not interested in using it.

Based on the results of the field survey for evaluating route can conclude three public transport routes in Malang have fair performance criteria, that is: route ABG, ADL, and AMG. There is one public transport route have good performance is route LDH. Route AG and ABB categories of performance criteria are bad. There are six performance parameters of routes AG that need to be improved and there are seven performance parameters of routes ABB that need to be improved Alternative routes are needed to replace the routes AB and AG so that these routes can be used optimally for buses.

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