Modelling School Bus in Favor of Needy Student: The Conceptual Framework

Daniel Hary Prasetyo, Jamilah Muhamad , and Rosmadi Fauzi

***Abstract*—Surabaya city is not yet have a school bus system. With a numerous needy student, the government is realized that free school bus can support the needy student in their transportation cost. The purpose of this research is make a model that can be used by the government to designs the most optimal route and optimal distribution of the free school bus. This paper is focusing on the conceptual framework of the processes in finding the optimal route and analyzing the chosen route. The optimal route is a route that covers the area with the most number of potential passengers, the needy student. The needy density layer is the primary data that will accompanied with street layer, school layer, and bus depot layer. Not just finding the route, the chosen route then used in an accessibility analyst in order to find its effect of the school bus in existing transportation system. The result of this research indicates that the model in this project can be used to find the best route and can support the government in making a decision in the limitation they have.**

***Index Terms*—Needy student, optimal route, coverage analyst, load analyst, school bus.**

I. Introduction

Surabaya, the second-largest city in Indonesia after Jakarta, lies at the eastern part of the island of Java. The government of Surabaya has calculated the participation rate of each education level. The participation rate is a comparison between the numbers of students in a certain education level with all citizens at the respective age level. In early 2008, in Surabaya, the elementary school participation rate was 92.92%, the secondary school participation rate was 79.85%, and in the high school participation rate was 83.53%. There are more than 19,000 citizens of elementary school age, more than 23,000 of secondary school age, and more than 17,000 of high school age who are not participating in school. The primary reason these citizens are unschooled is that they cannot pay schooling costs because they live in needy families. With the number of elementary schools, about 5 times more than the secondary schools and 7 times more than the high schools, students must travel greater distances as they advance to higher levels of education.

The city government becomes the committee for public secondary and high school student acceptance. They have grouped the public school to several areas: center, north, south, west, and east. Student with elementary school in one area was suggested to continue to secondary school in that area. They still can move to another area but with limitation on the number. It applied equally to secondary school to high school. The purpose of this division is to get the smooth distribution for the school input with hope that they will produce the proper distribution of output, and also for reducing the traffic that crossing the city.

This research focused on the north area of Surabaya, which has the largest number of needy students, due to the internal limitations. All the spatial and tabular data used in this project represent this area. This project also limited the scope to needy student in secondary school. However, the model developed here is not dependent on these limitations. The model can be easily used for surveys of other areas in Surabaya, for the needy in elementary or high school, and for any other places in other country.

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Daniel Hary Prasetyo , Dept. of Information Technology University of Surabaya (UBAYA) 60293 Surabaya, Indonesia (email: daniel@ubaya.ac.id)

Prof. Jamilah Muhamad , Department of Geography University of Malaya (UM) 50603 Kuala Lumpur, Malaysia (email: jamilahmd@um.edu.my)

Dr. Rosmadi Fauzi , Department of Geography University of Malaya (UM) 50603 Kuala Lumpur, Malaysia (email: rosmadifauzi@um.edu.my)

II. Literature Review

A school bus is a type of bus designed and manufactured for student transport: carrying children and teenagers to and from school and school events. School buses are distinguished from other types of buses by design characteristics standards that require school buses to be painted school bus yellow and equipped with specific warning and safety devices. The first school bus introduced in 1827 north-east of London (UK), and was designed to carry 25 children. Today, according to the modern nomenclature, there are 4 types of school bus; type A, type B, type C, and type D.

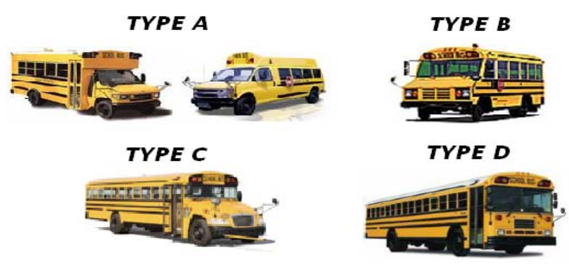

Figure 1. Four different types of school bus

Bus routing has gained the attention of many researchers in various fields. Some researchers are focusing on the making new algorithms, while others are advancing existing algorithms and applying existing algorithms to the real-world problems [1][2][3]. Robert Bowerman et al. [4] contributed to the advancement of algorithms by introducing a multi-objective approach to modeling the urban school bus routing problem. They developed a heuristic algorithm and tested it with data from a sample school board location in Wellington County, Ontario, Canada. They defined several optimization criteria to evaluate the desirability of a set of school bus routes.

Several studies have reviewed school bus routing methodologies [5][6][7]. Based on the number of schools, bus routing can be divided into the many-to-one and many-to-several methodologies [8]. An example of many-to-one can be viewed in the work of M. Fatih Demiral et al. [9] and Nayati Mohammed [10]. Both used one school location as a depot and a student home location for the customer location to generate bus routes. These authors worked with study areas in Isparta, Turkey, and Hyderabad, India, respectively. Other authors are Li and Fu [11]. Li and Fu implemented a heuristic algorithm for the existing data of a kindergarten in Hongkong, whereas Bektas et al. used integer programming for an elementary school in central Ankara, Turkey. These authors saved 29% and 26%, respectively, for their newly generated routes compared to the then current implementations. Based on the location or environment of the data, bus routing can be divided into urban [12][13] and rural areas [14]. The many-to-one method of Bektas et al. and Li and Fu can be a good example of applications for urban areas. For rural areas, Armin Fu¨genschuh [15] took five counties in Germany as the student locations. Another work focusing on rural areas is using rural school data in Savigny and Forel, Switzerland [16]. These two rural areas find buses routes for multiple schools.

Accessibility is from word accessible, which from oxford dictionary means able to reach or entered. Accessibility is concerned with the opportunity that an individual at a given location possesses to participate in a particular activity or set of activities. Basically accessibility represents the ease with which activities may be reached from a given location by means of a particular transportation system [17]. An accessibility measure is usually formulated in terms of a set of destinations representing activity sites and a set of origins representing potential users of the facilities at the activity sites. Individual destinations may be weighted by their attractiveness. For a shopping centre, its attractiveness can be measured by a combination of factors such as floor space and parking space, which might affect customer's interest in it. In the case of a school, its attractiveness may be measured in terms of the maximum number of pupils and the range and quality of school services provided.

Accessibility also has a portion in the public transport and it's stopped points. Jennifer Rogalsy has calculated the service of existing public transport for the working poor in Knoxville, Tennessee, USA [18]. Talat Munshi and Mark Brussel have discovered accessibility of public transport in the different income rate and work activity in Ahmedabad city India [19]. Sankar et al using the GIS to optimizing accessibility and placing bus stops. While accessibility can be calculated in various ways, the gravity-based measure of accessibility is the most widely used measure in planning studies [20]. Thomas J Kimpel et al using this gravity based measure for calculating overlapping service at existing bus stops [21]. Additional stops along a route usually mean greater access, because a stop is more likely to be within an acceptable walking/driving standard for a larger number of people. On the other hand, more stops and greater access slow transit travel speeds, thereby decreasing the area of service reachable given a travel time budget. More stops along a route translate to greater service interruption and longer travel times. Allan T Murray and Xiaolan Wu have make a research about accessibility to trade off these two sides [22]

This project concerns an urban area and multiple schools, and does not focus on the advancing route algorithm. Considering its illustrious effectiveness in the presentation of routing problems, this project used GIS and its applications as the primary tools. The recent Djikstra algorithm adopted in ArcGIS 9.3 is using for vehicle routing problem (VRP) analysis. This study focuses on the process of providing appropriate data and settings used for the VRP process, and it provides analysis after the generated routes. In this study, the data processing and analysis uses one essential parameter: distance. Distance, as used here, refers to the maximum acceptable distance for a needy student to traverse to arrive at the bus line from their home and or school. Because the study area is a tropical zone, and the objects are not adults but children in their early teens, this project decreased the distance from value of 400 m, as used in most research, to 300 m.

III. Conceptual Framework

The key of the process in finding a route for this free school bus is how to find one optimal route with a coverage area that have the most number of needy. Coverage area is the area surrounding the route. Needy in this area will need to calculate to get the total number of needy. It will need a needy layer, a layer that represents needy number in a specific area distribution. In order to keep the process easy to follow, this explanation uses simple example map layer. In the example needy area layer, there are 5x3 square district areas. Each district has a number of needy. The number of needy is represented in little squares in the district square. There are 3 different colors in the little squares. Let say the darkest color represents 3 needy students, lighter color represents 2 needy students, and the lighter color represents 1 needy student.

The other layer need to provide is street layer, school layer, and bus depot layer. Street layer is represented in red line. School layer is represented in green square (green point). Bus depot layer is represented in blue square (blue point). The school layer has a specific capacity of student. The street layer is segmented with the end of each segment is the junctions. Each segment has its own drive time value.

The school bus is used by the needy student to take them to the school. However, students who live around their school is not necessary to ride the bus. This situation will decrease the number of the bus to be provided. So, we need to calculate how many needy surrounding the schools and decreasing the number of needy in those areas. A specific distance is need to set and a specific percentage of needy whose school is around need to be determined. The output of this process will make two changes: the first is, the capacity of the school will be reduced because some seats have been filled in by the surrounding needy student, and the second, because the number of needy in the needy area around the schools is diminished, the needy area will be reshaped.

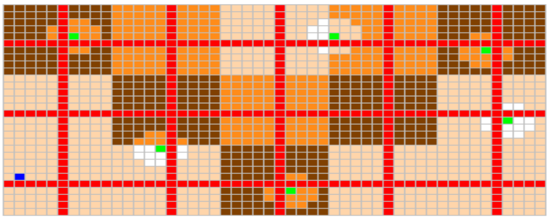

Figure 2. Needy area, street, schools, and bus depot(example)

In the route finding process, start and end place of the school bus have to be determined. In this example, the one and only bus depot which symbolized in blue point is act as start depot and also end depot. The school bus is starting the journey at start depot, visiting all school locations, and ending the journey at end depot. In this example case, the route will looks like a loop. By provided a certain algorithm, with an input are street network, school locations, and bus depot location, the process will generate an output in form of new polyline type layer. The routing process is done in several times in different setting. Along with the polyline type layer, the output also provided with drive consumed time. Consumed time is how long the bus begins until ends the journey. The value is taken from summing all the drive time in all passed road segments and adding with the visiting time of the bus in the school location and in every bus stop.

Since this research is for a free school bus, which the main objective is to service as much as needy students, the length of the route is omitted. The consumed time is also not the primary factor in choosing the route. As long as the time range is in an acceptable range, the candidate route will not be eliminated.

Next process is calculating the number of needy that covered by the route. It will need a certain distance value which represents the maximum acceptable walking distance of needy student for going from their home to the closest route. The process need to make a surrounding area along the route, which in GIS familiarly called as Buffer. After buffering process, there will be an area in the form of polygon layer type. This polygon then will be used to get the needy area in the region inside it. In GIS this called Clipping. The clip process is like cookie dough and a mold. In this case, the cookie dough is the needy area, and the mold is the polygon surrounding the route. Let's call the output as coverage needy layer. Figure 3 shows the result of the coverage needy layer of the example route.

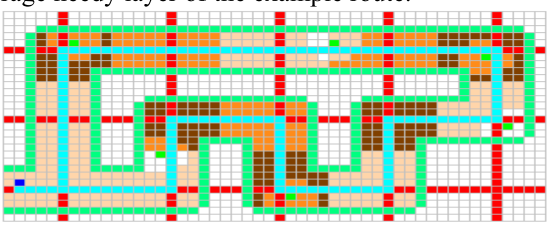

Figure 3. The result in finding coverage needy (example)

Once the optimal route was founded, this research continues to explore that route. The first exploration is to find out the characteristic of the passenger load along the journey of the bus. The coverage needy layer from the previous section is used for calculation. This layer needs to be segmented in a certain distance. In each segment will be calculated the number of potential entry and exit of the passengers. The number of entry passenger is calculated from the total number of needy in the segment. The number of exit passenger is determined with the number of student capacity in the school in the segment. If there is no school in the segment, this exit number is set to 0. In order to make simple this example calculation, all schools is set to have the same number of; 150 seats. With these entry and exit number, the load of passenger will be predicted.

The bus is doing its journey in counter clock wise, so the bus will going to the east then make two weaves, go to the north, back to the west and ending with going to the south. In every visited segment the load of passenger is counted. The load of passenger value is added with the entry number and subtracted with the exit number. If the load of passenger is less than the exit number, the load will set to 0 and the segment is marked for use in the reverse route. The entry point is rounded for simplifying.

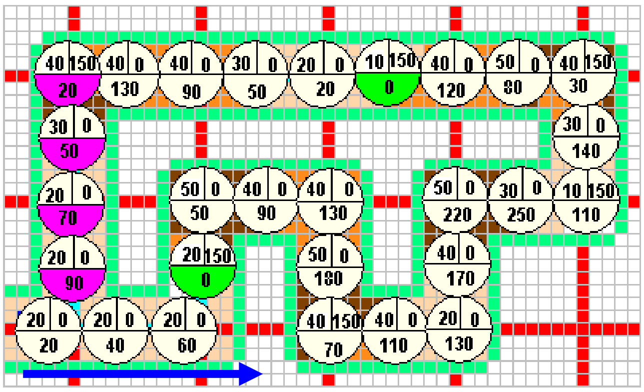

Figure 4. The calculation of passenger load in main route (example)

Figure 4 shows the calculation process. The first segment have 20 entry value and 0 exit value and also with the second and third segment. In the forth segment there is an exit value 150. The passenger load in the second and third segment is 40 and 60 respectively. In the fourth segment the total passenger load is 0 because there is a school in there. The school capacity, also known as the exit value, is 70 seats more than the passenger, therefore in this fourth segment the passenger load is set back to 0, and the segment is marked. In the above figure, this segment is marked with green color and. the unused seats value is kept for the calculation in reserve route. The calculation in the next segments is in similar way. There are no unused seats in the next four schools in the journey. In those locations the passenger load is more than the school capacity. A little unused seat is generated in the fifth school, and the segment is colored with green again. After the last school, the sixth school, the segment is colored with purple for marking that in this segment the passenger can not any school by this main route. For servicing the passenger in these segments the reserve route is needed to conduct.

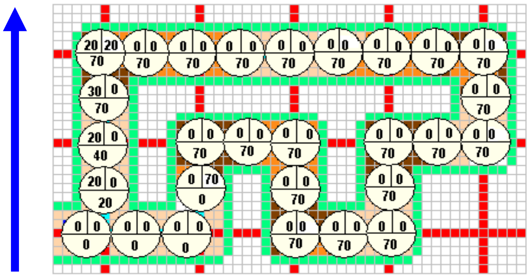

Figure 5. The calculation of passenger load in reserve route (example)

The reserve route needs an initial value of entry and exit passenger. The entry value is taken from the undelivered needy student, which in the previous figure is from the segments marked in purple color. The exit value is taken from the unused seat, which in the previous figure is from the segments marked in green color. There are 2 school locations in this reserve route with capacity 20 and 70. The reserve route is running in clock wise with the similar calculation way. So the potential passenger is located in the beginning of the journey. There are 20, 20, 20, and 30 values in the first to fourth segment respectively. In the fourth segment there is an exit value but less then the passenger load which as much as 20. The rest passenger load, as much as 70, is delivered until the last school which still has a capacity. Figure 5 shows this calculation.

The maximum number of passenger in the main route is 250, while in the reverse route is 70. These number can used for calculating how many number of buses need to be provided. If the bus capacity if 50 seats, the number of buses have to provide for the main route is 5 buses and the reverse is 2 buses. The number of busses then will be used in the second analysis, the accessibility analyst. The purpose of accessibility analyst is to discover the improvement of accessibility level in the study area after a set of new school buses was added in the existing transportation system. Therefore, this part will need an existing transport characteristic map.

The accessibility of existing transport system has to be made. The accessibility layer is made from buffer process like in the process in finding coverage area. The different is, in this surrounding area, the value of the buffer is set from the number of available seats in the transport media. In this example, the existing route in the east side has more available seats then the west one. Therefore the accessibility level of the right route is higher and represented in darker color. The transportation system then added with a set of bus schools. This additional process then followed with recalculating the accessibility level of all route. The existing accessibility layer is added with accessibility of the bus route. Since this is an adding process, a street which has many transportation routes along it, will have a high accessibility level. Figure 6 shows the example of new accessibility map. In this example map there is four different accessibility levels. The darker color raise in the area shared street of east existing route and the bus route.

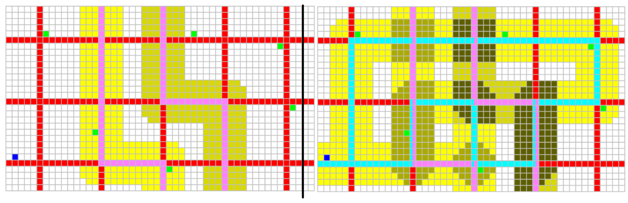

Figure 6. The accessibility level before and after buses added (example)

IV. Study Area

Several collected data use in this research. There is region map, school location, bus depot location, street map, needy citizen database, and the existing transport system map.

The Surabaya city government only has a map with sub-district detail. Consequently, a survey for mapping the sub-sub-district boundary of the project's study area had to be conducted. The total number of sub-sub-districts in this study area is 274.

There are 57 schools in this study area consist of 8 public schools and 49 private schools. Public schools are schools owned by the government. These schools serve both purposes because they commonly have appropriate buildings and surrounding areas. Most importantly, the government has a right to manage these areas. So they can act not only as places for delivering and picking up students but also as bus depots. Completing the actual two bus depot reside in the center and west area.

There are Highway Street, Primary Street, Secondary Street, and Tertiary Street in this study area. This research uses Primary and Secondary Street. Highway Street is eliminated because it cannot use for picking up passengers. Some of Tertiary Street that can be passed by bus is also included. This map also has to be equipped with "drivetime" field.

The specification of poor is different in every country. In Indonesia, needy specification is formulated by Centre of Statistical Bureau.

TABLE 1 Needy Family Criteria

NO	Variable	Indication
1	Floor area per family member	Less than 8 m2 per family member
2	Type of the floor of the house	Most of the part is sand or cement
3	Type of the wall of the house	Most of the part is bamboo or low quality plywood
4	Toilet facilities	Have no private toilet
5	Drinking water source	Not from government water supply or not a good water
6	Lighting source	Non-electric
7	Fuel used	wood or charcoal
8	Frequency of Meals in One Day	2 times or less
9	Ability to buy Meat, Chicken, Fish, Eggs, and Milk in a week	Have no ability
10	The ability get a treatment in the hospital / clinic	Have no ability
11	Education level of the householder	never schooling or not passing the elementary

12	The ability to buy new clothes for every family member	One or less per year
13	The occupation of the householder	Farmers, Fishermen, Daily Labor, or other with incomes below USD 60 /month
14	Ownership of assets or goods worth USD 50	Does not have

The Surabaya city government has collected needy citizen data. In 2007, 550,783 people of the 119,219 families registered lived below the poverty line. This needy people survey recorded name, birthplace, birthday, address, sex, and occupation.

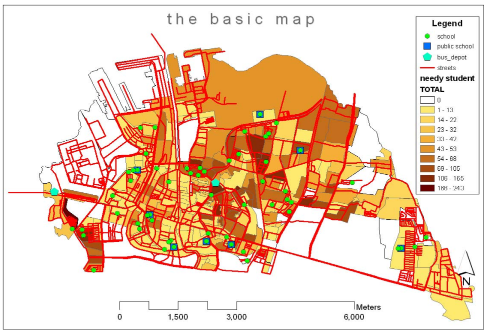

Figure 7. The basic map.

Street map and previous maps called basic map. Figure 7 shows this map. Street map is shown in red line, school map in green dot, public school in blue rectangle, and bus depot in blue dot. The needy area symbolized in the gradation color of sub-sub-district area. Area with darker color mean has more number of needy students than the lighter ones.

In Surabaya, there are several transportation systems that can be used, including taxi, lyn, and bus. Lyn is modified station wagon with long seats patched at the left and right sides. Buses in Surabaya are like typical buses in other cities, having a capacity of about 50 passengers. The lyn's capacity is about 10 passengers. There are numerous routes covering Surabaya, but in the north region, there are only 13 lyns and 2 buses. There is no documentation of how many fleets there are and when they pass through the region. A survey in a certain time window was conducted.

V. The Result

The output of this research is an optimal route and the characteristic of it. After the optimal route is chosen, the load analyst will produce the changes of passenger time to time while travel from center depot to each direction. This load will be shown in 3D in order to make it easy to understand. Figure 8 shows each passenger load in 3D visualization.

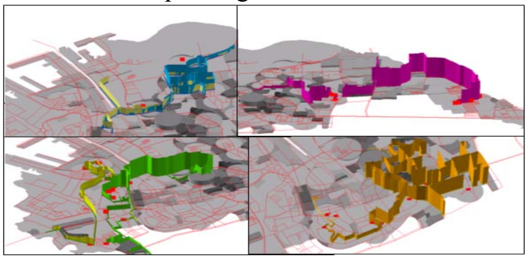

Figure 8. The 3D view of passengers load

The load analyst result can predict the passengers load in each route. With this prediction, the government can make a decision of how many buses that needs to be provided. Say, the bus can carry about 70 needy (50 sitting and 20 standing). The west route will need 9 buses in the main direction and 4 buses for the inverse. The east route needs just for main direction, 11 buses. The north route needs more inverse than the others. The main direction needs 7 buses and for the inverse needs 4 buses. The south route has to provide the most fleets in the main direction. It needs 16 fleets.

The existing accessibility level and the new one used to subtract the needy area to make an uncovered needy map. There is 4523 needy student who uncovered by the existing transportation system. After added with the bus schools, the uncovered needy decreased to 1341 needy. Figure 8 shows the accessibility level of existing transportation system and the new transportation system after the bus school was added.

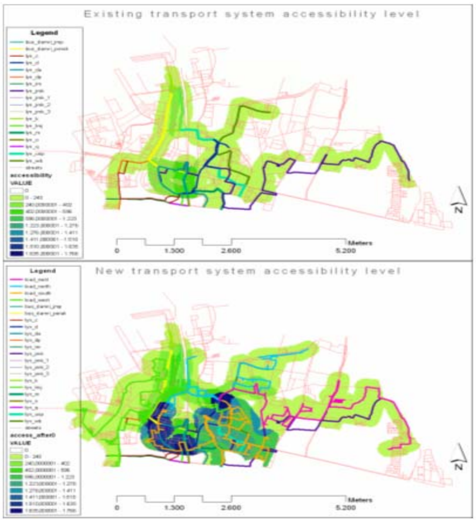

Figure 8. Accessibility map before and after added with school bus.

VI. Conclusion

With the conceptual framework in this paper, the optimal route can be chosen. This research has proposed the most minimum traveling time bus school routes, cover the most number of needy students, and divide the area in favorable distribution. With the load analyze method; this project can predict how many buses need to provide to covers all orders completely. Even, In this case study, the numbers of buses to be provided may be a great number for the government, the government still can use this calculation number for a reference to distribute their limited number of buses wisely.

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