CHAPTER 4

DATA DEVELOPMENT AND GIS MODEL DEVELOPMENT

4.1 Introduction

This chapter will explain about the initial data will be used in this study. This data will be processed in all steps that have been explained in the methodology chapter. Some steps have a process that built into sub models.

4.2 Surabaya City Region Characteristics Underlying School Bus Route

As explained in the first chapter, this project is using the map and data of Surabaya city, limited to the north area of school division district. This chapter will explain the characteristics of Surabaya City Region.

4.2.1 Surabaya City Region

Surabaya is the second largest city in Indonesia with a land area equal to 33,306 KM^2. Approximately, 3 million people are spread over 31 districts and 163 sub districts. The government of Surabaya has grouped the public school in several areas: center, north, south, west, and east. Students with elementary school in one area are encouraged to continue to secondary school in the same area. They can still move to another area but numbers are limited. This policy is applied equally to secondary school and to high school. The purpose of this division is to achieve smooth distribution for the school intake with hopes that they there will be a proper distribution of output, and also reduce the traffic that crosses the city.

This research covers 6 districts in the north area. Each district has several sub districts. Sub-district regions are not divided by the large area of their regions, but by the number of people who inhabit them. This is why the northern area has a larger sub-district. The northern area is abutted with the sea and a wide range of areas are used for industry and are container ports.

The smallest area of the sub district is about 500.000 m^2. Imagine it resembles a rectangle area with 1 KM width and 0.5 km^2 height. This area is not detailed enough for mapping the needy students, therefore a decision was made to divide the sub-district into sub-sub-district. The government of Surabaya city simply has a map with sub-district area in detail. For this reason, a sub-sub-district survey for mapping the sub-sub-district boundary must be conducted. With two surveyors in one month, we have done the survey and built a map of sub-sub-district. This map can be seen in the Figure 4.1 below. This figure shows some areas which are still large and not divided into smaller parts. It is because those areas are not administrated by the government of Surabaya but are in the control of the military department since the area is intended for military use. The total number of sub-sub-district in this study area is 274 regions. Next, in the following sections, this sub-sub-district map will also be called a block map.

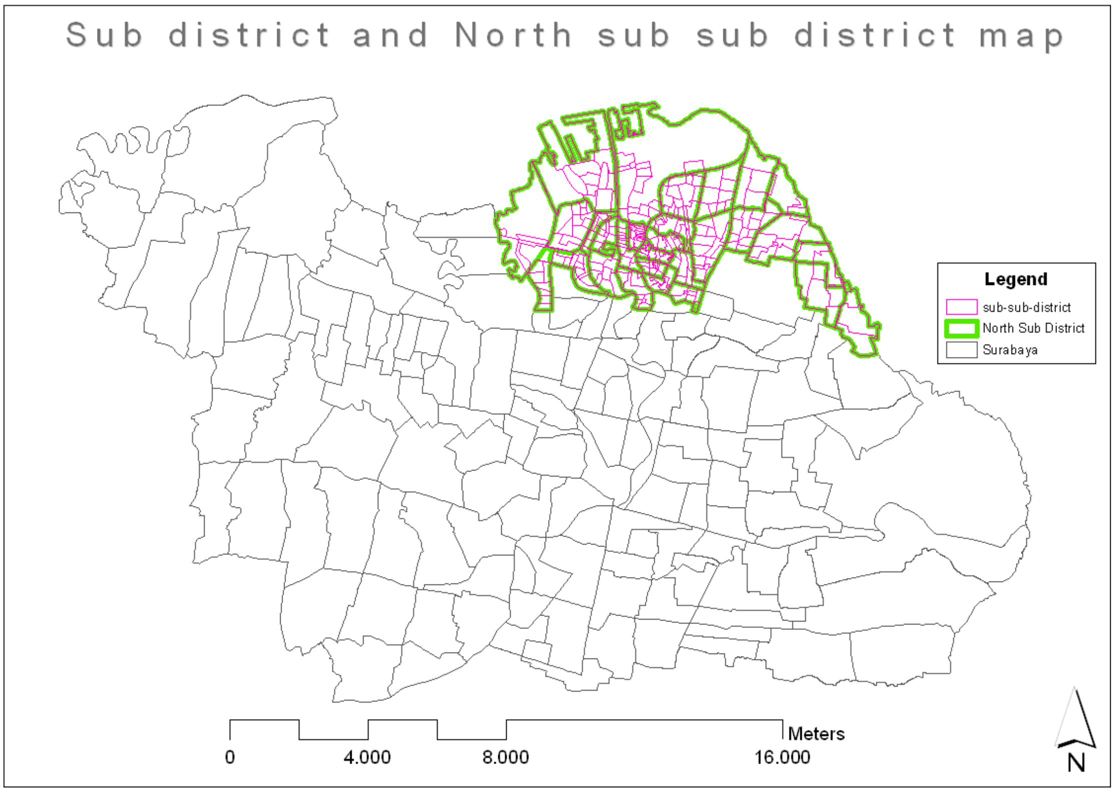

Figure 4.1. Map of The North Sub Districts, and the sub-sub district.

4.2.2 Identifying the Needy School Children

As introduced in section 2.3, the Surabaya city government has implemented the formula from the Centre of Statistical Bureau (BPS) regarding how to classify the needy citizen. The formula has been used by city government officials to determine their needy family population. In 2007, it was determined that there were 550.783 people in the 119.219 families detected who live below the poverty line. This needy people data already include needy name, birthplace and birthday, address, sex, and occupation information. This data was then extracted for finding the total needy student for each sub-sub-district. As explained in chapter 1, this project uses the secondary school level. So the data should be queried with respect to the 13-15 year old age category. The database is in the Microsoft Access format. The following is the query for extracting data with regard to the needy secondary student for each sub-sub district.

```
SELECT district,sub_district, sub_sub_district, count(people_id) AS total
FROM needy
WHERE age Between 13 And 15
GROUP BY district,sub_district, sub_sub_district.
```

This query succeeded in extracting 1233 records for all Surabaya city regions. This data was then converted in the DBF format for loading in the ArcMap and joining with tabular data of the sub-sub-district map. Constraining this record for only the select the north sub district is not necessary since it will automatically be relevant by joining the data with sub-sub-district map. Records that have no sub-sub-district to be joined with will be eliminated. After this joined process, the amount of needy students was written in the needy population field of the block map in the previous section. The total number of needy students spread in this sub-sub-district map is 8579 students. Since the needy population field type is a number field, it can be used to produce a quantity-based map. For example, a dotted density map can be produced for easily viewing the distribution of the needy students in each sub-sub-district. This dot density needy map is shown in Figure 4.2.

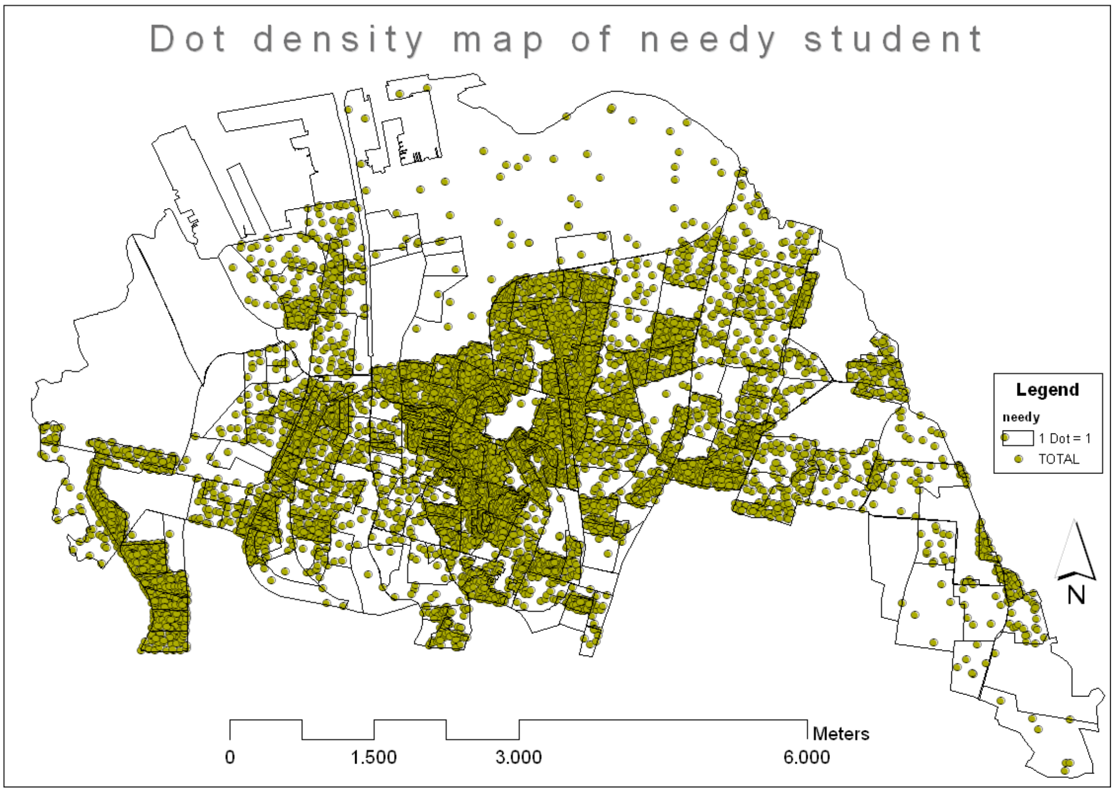

Figure 4.2. Dot density map of needy student

Figure 4.2 shows that the needy are centralized in the center of the study area. There is also a small needy cluster in the west area. Besides illustrating the amount of needy students, we also need a field for saving the needy density. The density field will be helpful for recounting the total number of needy when there is a change related to a particular region or when there are modifications in their shape and/or size. For example, a clipping operation could be taken into account or analyzed using a density field. This needy density, like another density, needs a certain area for its reference. In this project, the area size is 1 ha (hectare) area. For example, if the needy density number is 4, it means that in a distance of 100 Meters X 100 Meters in this area can be the location of 4 needy students.

Since the map unit is in Meters, and the area of a region in the map in M2 the map needs to divide the area with 10.000 to get hectare unit before it can be used to divide the number of needy students. Little script is needed in calculating this density field. Below is vbscript used in the calculation:

```
Dim dblArea as double
Dim pArea as IArea
Set pArea = [shape]
dblArea = pArea.area
density=[needy_count]/ ( dblarea/10000)
```

Because it is a numeric field, the needy density field can also render like a quantity base map. In Figure 4.3, this needy density field is represented in the gradation color and shows where there are places with high or low needy density.

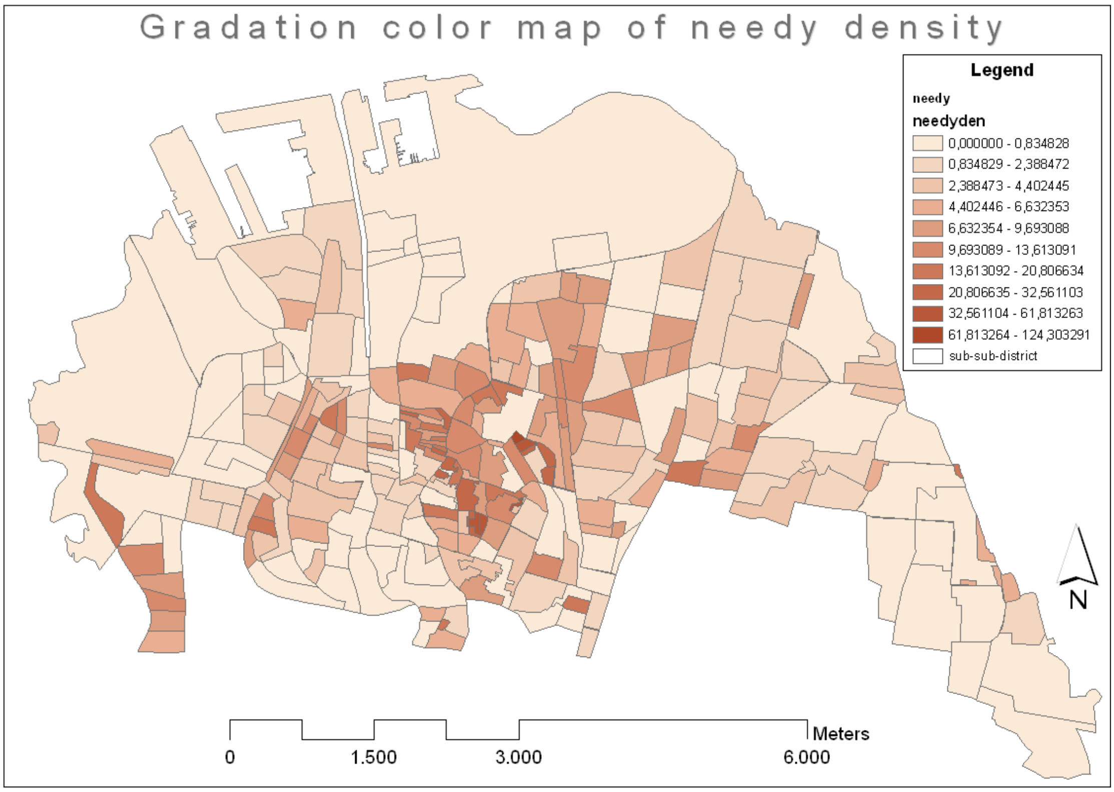

Figure 4.3. Gradation color Map of Needy Density students

4.2.3 The Street Network in Northern Surabaya

Street network is the primary element in the VRP and other network analysis. The street characteristic is closely related to the vehicle in terms of network access. This section will begin with the street characteristic and then continue with the street network that will be used in this research.

The street map is needed for generating the routes where the school bus will pick up students and then deliver them to schools. The government of Surabaya city has already mapped their streets. However, it cannot directly use these maps for generating the bus route. Firstly, a problem exists because not every street can be passed by the bus. The following regulation will explain this.

Public roads in Indonesia, by function, are classified as arterial roads, collector roads local roads, or environmental roads. An arterial road functions to serve the primary transportation system which has a long distance, a high speed, and a confined access. The collector road functions as a collector and divider for transportation which has a medium distance, a medium speed, and a confined access. The local road is servicing local transportation which has a short distance, a low speed, and access into it which is not confined. Finally, the environmental road is servicing neighborhood transportation which has a short distance and a low speed. The arterial road, collector road, and the local road are divided into primary and secondary types.

Primary arterial road and secondary arterial road are artery roads whose characteristics are shown in Table 4.1. The characteristics of primary and secondary collector roads are shown in Table 4.2, and the characteristics of primary and secondary local roads are shown in Table 4.3.

Table 4.1. Characteristic of Primary and Secondary Arterial Road

Characteristic	Primary Arterial Road	Secondary Arterial Road
Connecting of	the national hub and other national hubs. Continuously connecting the national hub, the regional hub, the local hub, and the environmental hub.	the primary area with the first secondary area, the first secondary area with the second secondary area, and the arterial road or the primary collector with the first secondary area
Minimum speed	60 km/h	30 km/h
Minimum wide	11 meters	11 meters
Capacity	equal or more than the average traffic volume	equal or more than the average traffic volume
Entrance	is confined efficiently and the minimum distance between entrances is 500 meters.	Direct access is confined with interval not less than 250 meters
Junction	is managed with a certain method based on the traffic volume	is managed with a certain method based on the traffic volume
Facility	Have an adequate road equipped with traffic lamps, traffic signs, road markers and road lighting.	Have an adequate road equipped with traffic lamps, traffic signs, road markers and road lighting.
Bicycle and motorcycle	Provide with special lane	Provide with special lane
Heavy freight vehicle	All allowed to pass	Light freight vehicle and bus for city services can pass
Parking	highly confined	On-street stopping location and parking location and in the rush hour is highly confined
Traffic	The average daily traffic generally is higher than the other primary system.	The average daily traffic generally is higher than the others secondary system.
Additional characteristic		Distance interval with a similar road class is greater than the distance interval with a lower-class road.

Table 4.2. Characteristic of Primary and Secondary Collector Road

Characteristic	Primary Collector Road	Secondary Collector Road
Connecting of	Connecting cities between the regional hub and the local hub and/or the small-scale area and/ or the regional and the local feeder port	Connecting between the second secondary areas and the second secondary area and third secondary area
Minimum speed	40 km/h	20 km/h
Minimum wide	7 meters	7 meters
Capacity	Have a capacity in equal or more than the average traffic volume	Not defined
Entrance	Direct access is confined with interval not less than 400 meters	Not defined
Junction	The junction is managed with a certain method based on the traffic volume.	Not defined
Facility	Have an adequate road facility which includes traffic lamps, traffic signs, road markers and road lighting	Have an adequate road facility which includes traffic lamps, traffic signs, road markers and road lighting
Bicycle and motorcycle	Have a special lane for bicycle and motorcycle	Have no a special lane for bicycle and motorcycle
Heavy freight vehicle	Heavy freight vehicle and bus is allowed to pass through	In the residential area, a heavy freight vehicle is not allowed to pass through
Parking	On-street stopping location and parking location in the rush hour in highly confined	Parking area on-street is confined
Traffic	The average daily traffic generally is lower than the primary arterial road	The average daily traffic generally is lower than the primary and secondary arterial road
Additional characteristic	A primary collector city road is a continuation of a primary collector country road. A primary collector is passing through or going to a primary area or primary arterial road.	-

Table 4.3. Characteristic of Primary and Secondary Local Road

Characteristic	Primary Collector Road	Secondary Collector Road
Connecting of	Connecting the national hub with the environment hub, regional hub with environment hub, between the local hubs or the local hub with the environment hub, and between the environment hubs.	Connecting the first secondary area with the residential area, second secondary area with the residential area, third secondary area with residential area.
Minimum speed	20 km/h	10 km/h
Minimum wide	6 meters	5 meters
Capacity	Not defined	Not defined
Entrance	Not defined	Not defined
Junction	Not defined	Not defined
Facility	Not defined	Not defined
Bicycle and motorcycle	Not defined	Not defined
Heavy freight vehicle	A Freight vehicle and a bus may be allowed to pass through	In the residential area, a heavy freight vehicle is not allowed to pass through
Parking	Not defined	Not defined
Traffic	The average daily traffic generally is the lowest than the others primary system	The average daily traffic generally is the lowest than all others system
Additional characteristic	A primary local city road is a continuation of a primary local country road	

By this regulation an elimination process must be conducted in order to make sure all streets can be passed by a bus. A map of the street that can be passed by bus is shown in Figure 4.4 below.

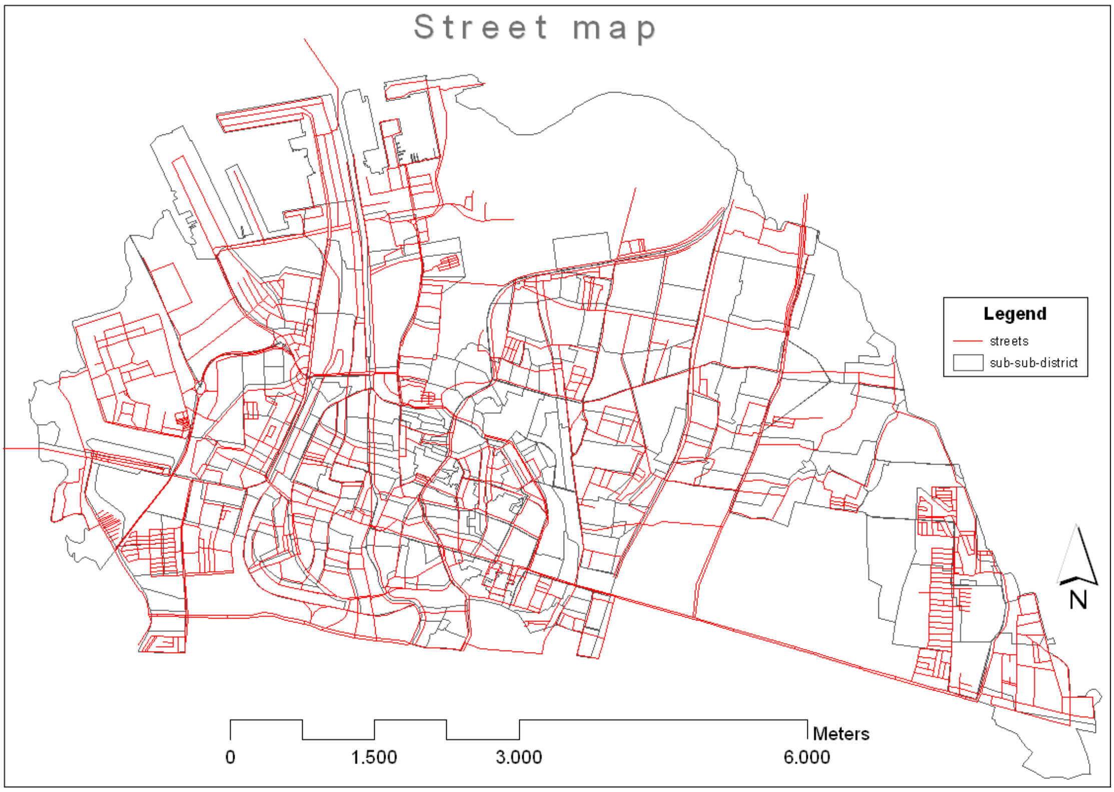

Figure 4.4. Streets that can be passed by bus

Street data processing

Street maps used in ArcGIS Network analyst need a special format. This special requirement demands extra attention and can be time-consuming to create. It must carefully reshape each street object by focusing in each junction. Every junction determines whether vehicles are capable or incapable of turning to particular streets. The common street map is not concerned with separating each edge in every junction. Street maps from the government need to be cut in almost every junction. Junctions which are not being cut can be visualized in such a way that the streets across it are not in the same elevation. One street object is lying under or above another. The highway and the flyover road across it as shown in Figure 4.5 are an example of crossed streets that are not a junction.

After separating street objects in its all junctions, a checking process is needs to be conducted to guarantee that all vertices correspond to these junctions and are perfectly patched. If they are not perfectly patched, problems can arise. For example, when used in the vehicle routing problem after it builds the network dataset, the bus will not be able to pass through that junction. For this purpose, a snapping function became an important function to include in the map editor.

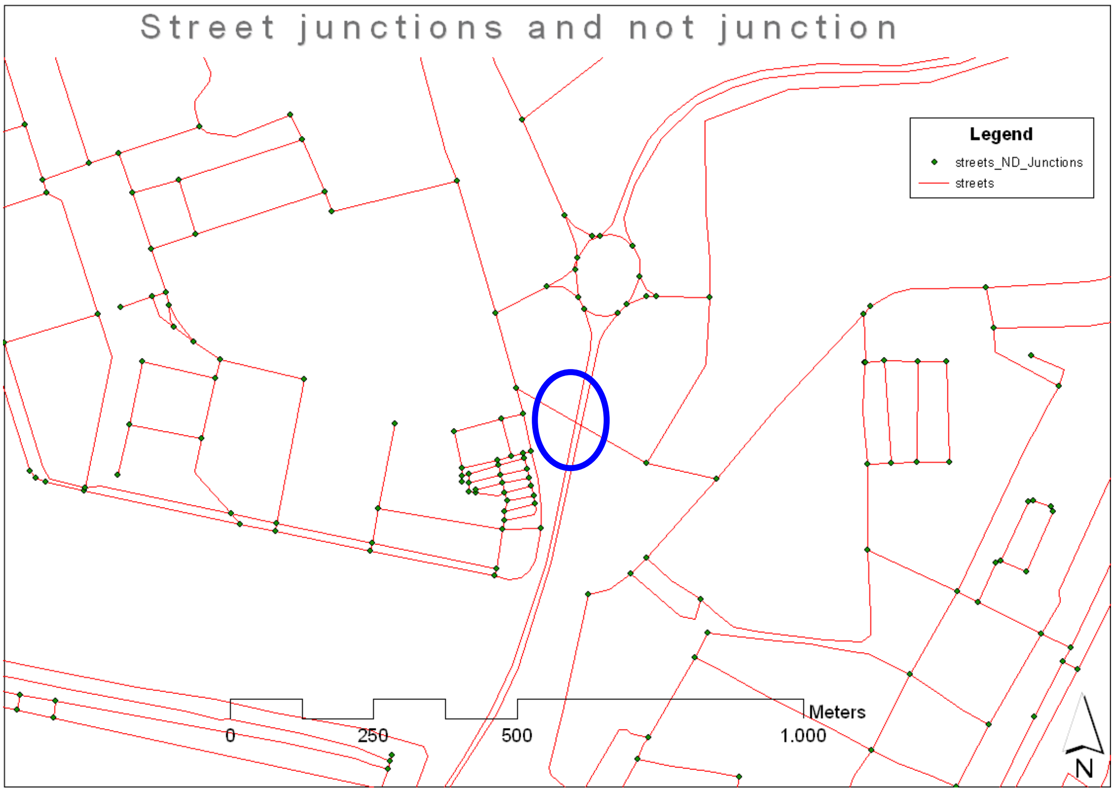

Figure 4.5. Street junction and example of not junction in the highway (blue circle)

Some streets can show passing in two ways or just one. It also needs to take into consideration the one-way streets. This one-way rule depends on the two things. First, how the sequence of the vertices are arranged in the digitizing process, and second the value of the 'ONEWAY' field. The value of one-way field is 'FT', 'TF', or 'None'. 'None' means the street is not one way. FT stands for From-To, and TF stands for To-From. If the value is FT, it means that the street is a one way street with the direction taken from the earlier digitized vertices to the latest digitized vertices. In contrast, if the value is ‘FT’ for example, someone wanting to make a one-way street from West to East can utilize one of these two methods. Firstly, he can digitize the street along from West to East and fill the one-way field with ‘FT’, and secondly he can digitize from East to West and fill the one-way field with ‘TF’. North Surabaya city streets do not have many one way streets. Most of the one way streets are as part of the double way streets. The one way streets situated in the west, east, and center areas can be seen in Figure 4.6 below.

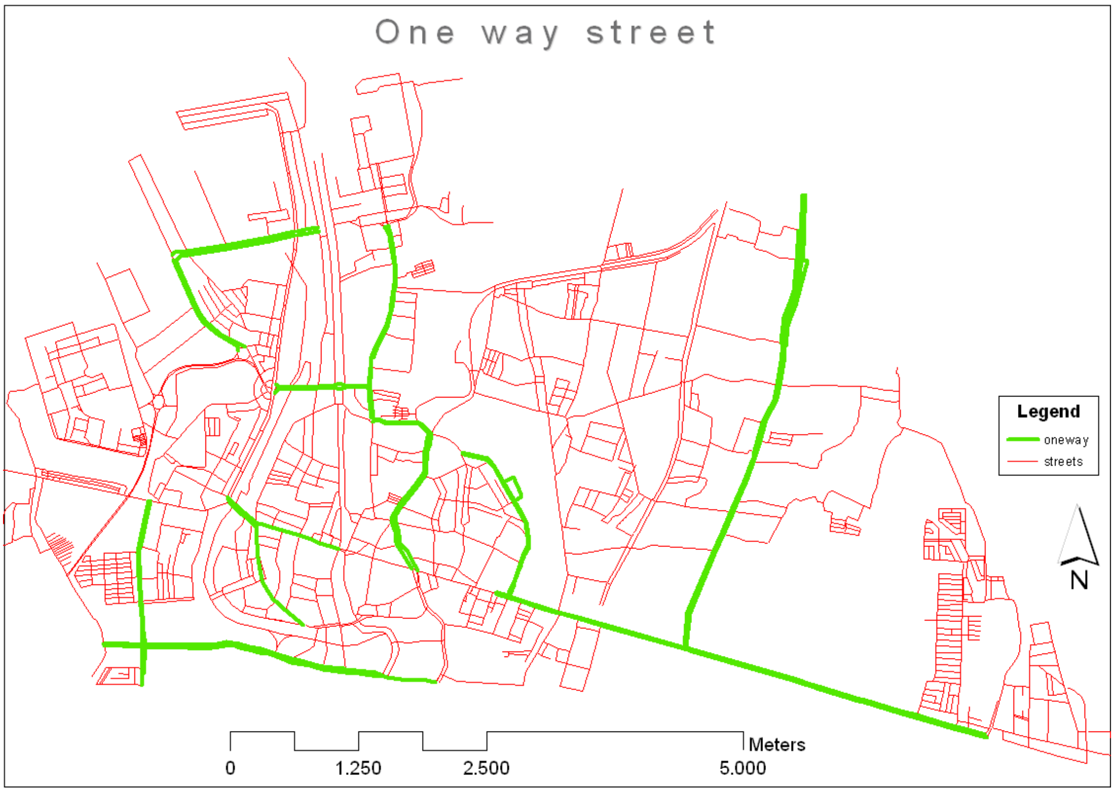

Figure 4.6 The one way streets

Vehicle routing process will find the most optimal route. For the routing process, the street data must have a field that saves a value which relates to how much time is needed for passing each street. The standard field name for this purpose is ‘FT_MINUTES’ and ‘TF_MINUTES’, which are used for reducing the time needed to pass the street in the same direction as the digitizing sequence, and reserve the digitizing sequence respectively. In order to accurately fill these two fields, and for making the result closer to the real world, a physical survey must be conducted.

Four surveyors are assigned to monitor the estimated time for passing the street. The survey is conducted in the most crowded traffic time which is 6:30 am-7:00 am during school days and work days. Every street is surveyed in two or three spots depending on the street length. In these spots, the average bus speed is calculated. If the street is not used by bus, the speed is taken from the speed of a medium truck. If there is neither bus nor truck, the speed is taken from the speed of a family car. The survey took two months to complete. Figure 4.7 shows the street map in the form of its average speed of bus that is passing it.

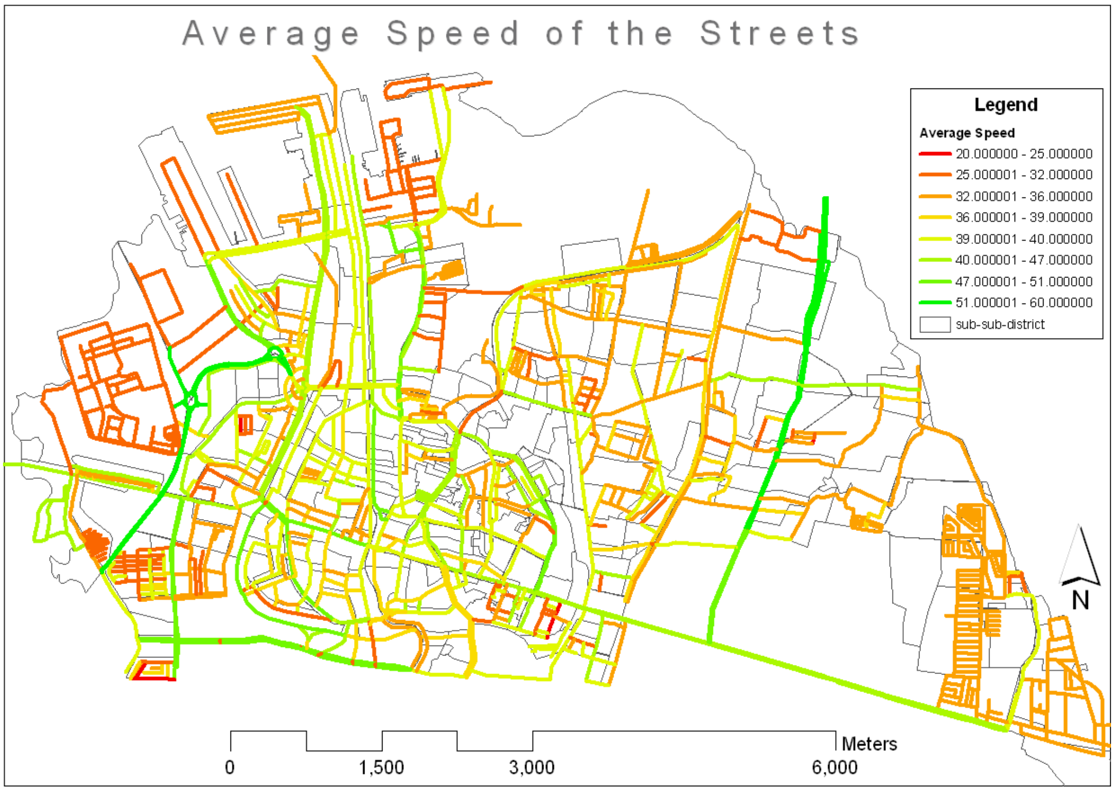

Figure 4.7 The average speed of the streets

Figure 3.7 above shows that the average speed varies from 20 Km/h to 60 km/h. The speed is presented in the gradation color in the natural breaks from red to yellow to green for the slowest to the fastest. This speed data is then used to divide the street length to get the drive time value. The street's length is in kilometers and street's speed is in Km/hour. After this dividing process, the drive time value needs to be converted from hours to minutes. This drive time value is then used to fill the ‘FT_MINUTES’ and ‘TF_MINUTES’ field. The figure 4.8 shows the variation of drive time value of the streets in gradation color in the natural breaks. This figure suggests that most of the street can be passed in over 1 minute. This is because the each road has been segmented in the preparation of the network dataset and most of the streets can consist of two or more segments. Therefore, the drive time values, which refer to this segment, mostly have a lower numeric measurement.

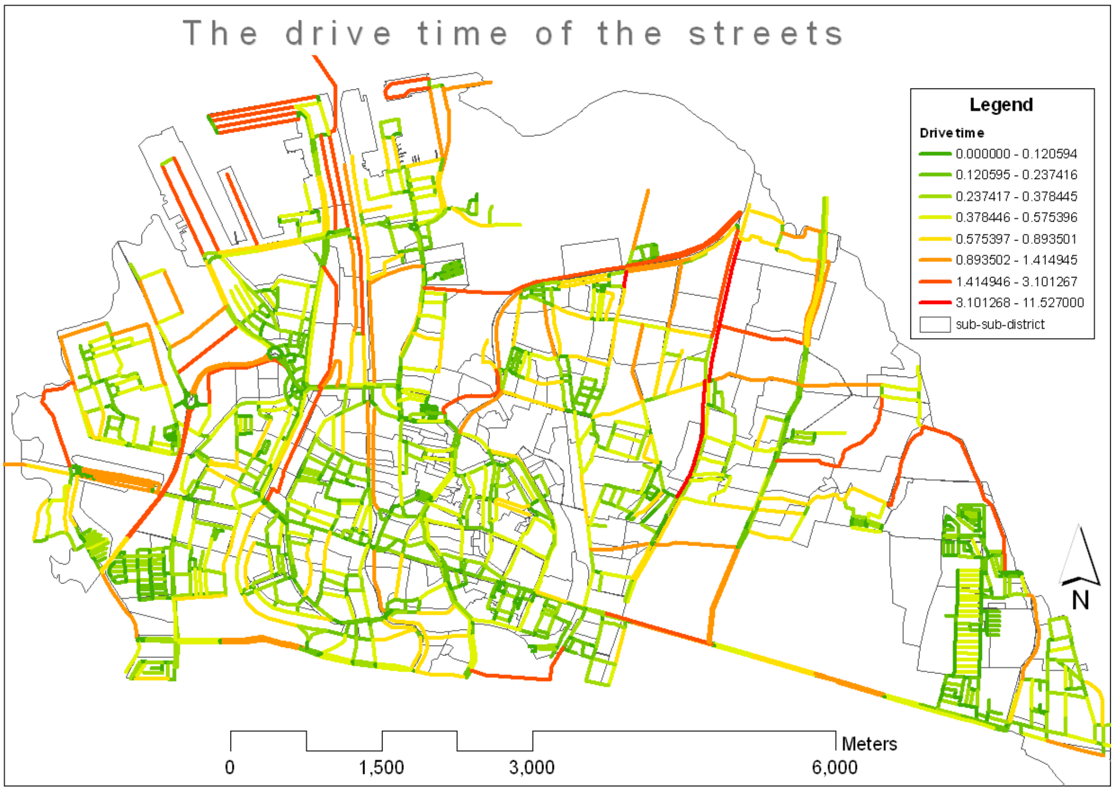

Figure 4.8. The drive time of the streets

4.2.4 Location of School in Northern Surabaya

School buses will traverse the street and stop near the schools. Therefore, the next data which needs to be collected is the location of schools. This map has already been created by local government. There are 57 schools consisting of 8 public schools and 49 private schools. The public school is a school owned by the government, and they will receive attention not only as places for delivering/picking students, but also for the bus depots. It is because the public schools commonly have a greater student capacity than private schools. They also have more extensive buildings in their surrounding areas. And, most importantly, the government has a right to manage these areas. The locations of the 57 schools with 8 public schools can be seen in Figure 4.9 below.

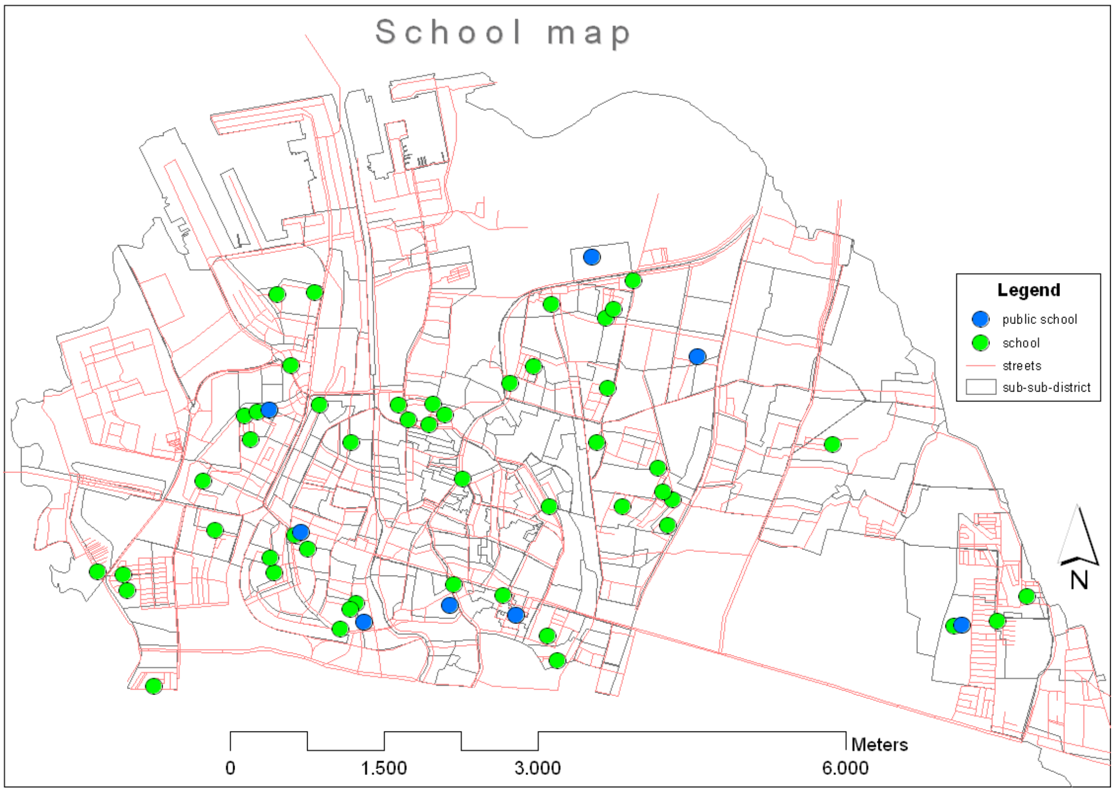

Figure 4.9. School and the public school map (blue dotted)

Chapter II noted that the number of schools is 57, while the number of needy students is 8579. In average, each school can be set to provide 155 seats for needy students. This number of seats will be used for the capacity measurement in the CVRP term. Therefore, this number we will call Needy Capacity in the subsequent chapters.

4.2.5 Identifying the Depot

School buses will travel from one school to another. However, before traveling in the first school in the sequence, the buses need a starting point. After visiting the last school in the sequence, the buses need to end their travel at a stopping point too. This start and stop point is called depot. Surabaya city has several bus depot locations spread throughout the city area, and they are already mapped by the government just like other public facilities. At the north area, there are two bus depot locations; one is located in the center and the other is in the west. For the next discussion, it will be called center depot and west depot respectively. We can see these two depot locations in the map in Figure 4.10

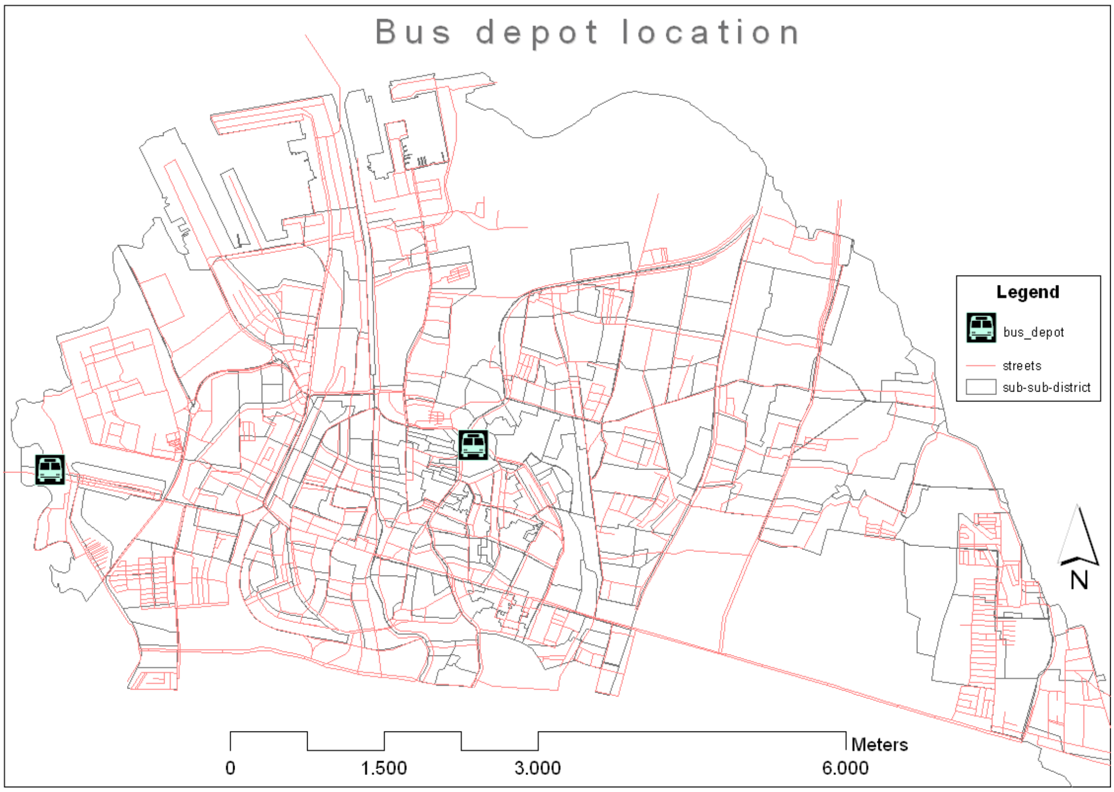

Figure 4.10. Location of the bus depots

4.2.6 The Existing Transportation System in North Surabaya

In Surabaya, there are several transport media can be used to deliver people from one place to another. They include taxi, becak, lyn, and bus. Taxis are a sedan type car with four seats and resemble other usual forms of taxis typically found in towns around the world. Becak is a traditional vehicle. It has no engine and is powered by man paddle like a bicycle. It has two wheels in front and one in the back. There are two seats in the front side for passengers and the driver resides behind it. Becak is used for short distance traveling. Taxi and becak have no route. Their route is random and depends on the passenger need, and its cost is relatively high for needy people. Lyn is a modified station wagon car. It removes usual seats in the second and third row and replaces them with long seats patched at the left and right sides. Similar to a taxi, a bus in Surabaya is like a common bus found in any city. It can hold about 50 passengers. The lyn capacity is about 10 passengers.

There are plenty of routes covering Surabaya city, but for the north region, there are just 13 lyns and 2 buses passing through the streets. There is no official document showing how many fleets exist or any transporation data related to how long the fleets are on the street each day for each region. To remedy this situation, a survey needs to be conducted. It is a time-consuming process, and approximately three week days are required to record the information. Each lyn and bus route has been monitored at the time, showing when students go to school and return home. The result of the survey is shown in Table 4.4 below.

Table 4.4 Route of Bus and Lyn

Route Name	Capacity	Number of Vehicle passed	
		05:00 - 07:00	12:00 - 15:00
Bus Damri JMP	50	18	56
Bus Damri Perak	50	27	26
Lyn C	10	18	60
Lyn D	10	25	76
Lyn DA	10	3	49
Lyn DP	10	23	48
Lyn IM	10	3	11
Lyn JMK	10	11	33
Lyn K	10	97	167
Lyn LMJ	10	32	41
Lyn M	10	10	50
Lyn O	10	34	78
Lyn Q	10	37	77
Lyn USP	10	51	106
Lyn WB	10	6	45

Table 4.4 shows that there are more vehicles available for return trips rather than for beginning the journey to school. What can be covered by the transportation in the morning will automatically be covered by the evening ones, but not in the other direction. Therefore, this project just uses the amount of morning vehicle data for calculating and in relation to the building of existing transportation accessibility in next

chapters. Those entire routes have been digitized for making the spatial data. The map of the route is shown in Figure 4.11.

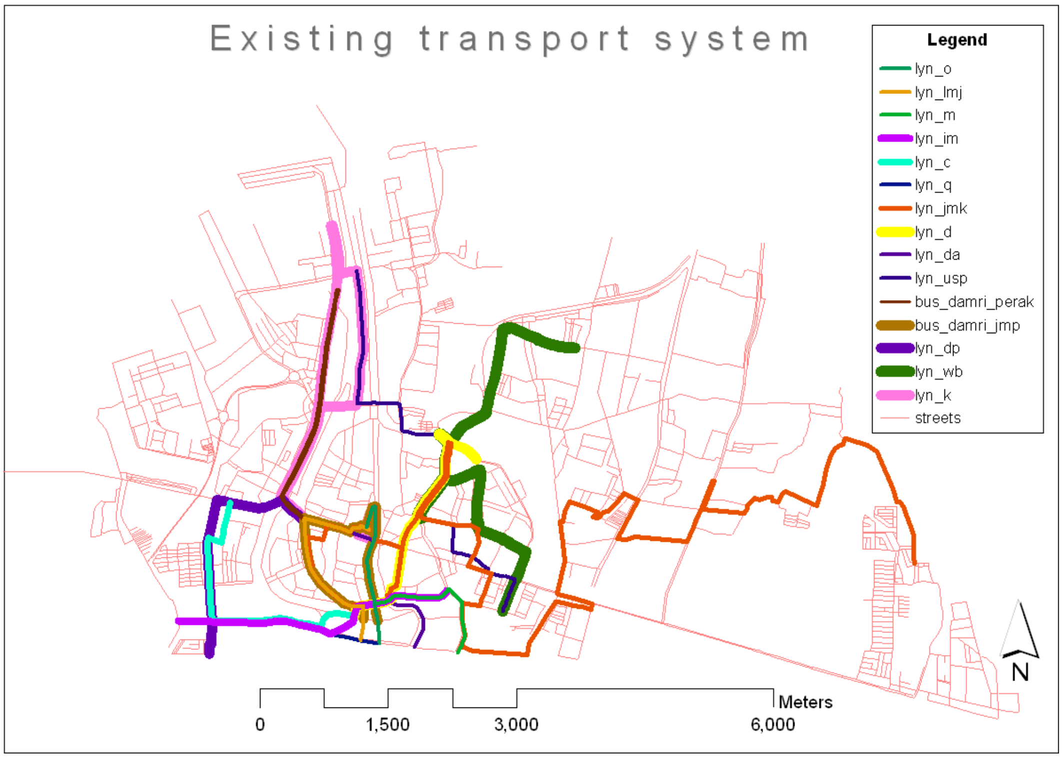

Figure 4.11 Route of Bus and Lyn

Those are the initial data need to provide before any process. Those data will be refined, in order to get more realistic data. The next chapter will explain about this refining process.

4.3 Refining Needy Area

Chapter 2 noted that the number of schools is 57, while the number of needy students is 8579. For covering all of the needy student population, each school can be set to provide 155 seats. Next, this seat number will call needy capacity. However, there is a concern which needs to be addressed; not all students will need to ride the bus. Government can eliminate the number of needy passengers by implementing a rule that forces the needy to choose a school near their home. With this rule, the needy capacity in each school will be reduced by the number of needy surround them. Some schools may consider eliminating the bus route if all the needy capacity is fulfilled especially if they are located in a poor neighborhood. This section will show what is involved with respect to refining the raw needy area to uncover the priority needy area that really needs to be covered by bus routes. Figure 4.12 show the genuine needy area and schools map.

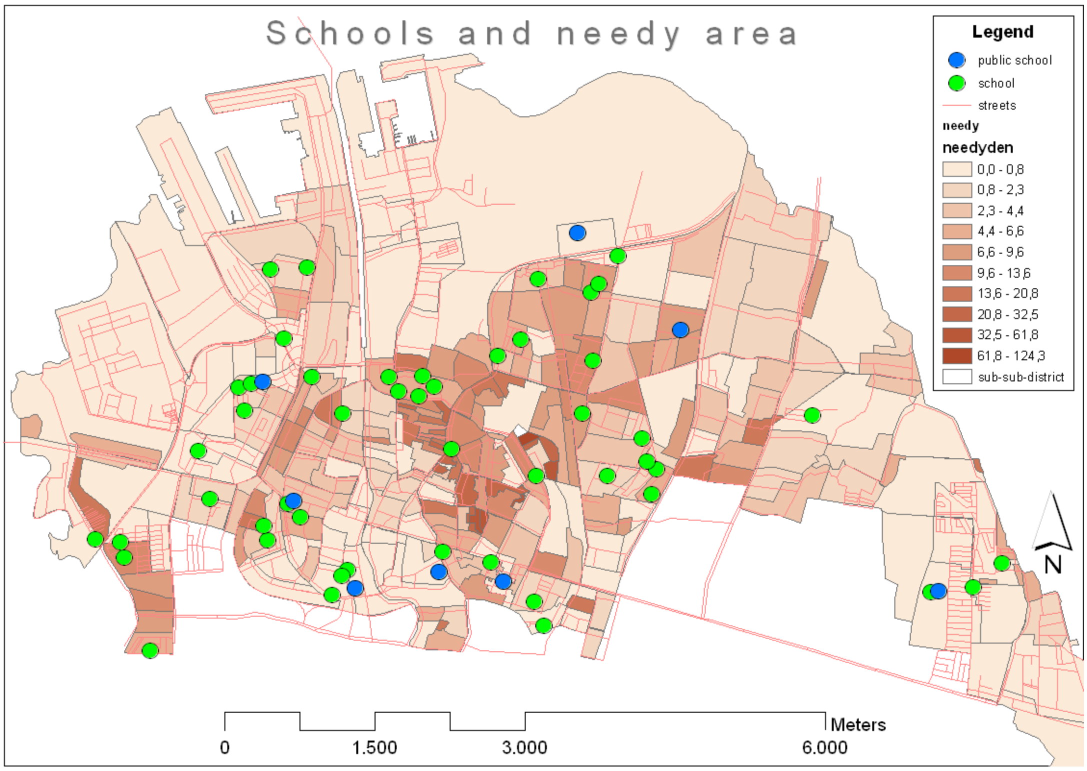

Figure 4.12 Schools location and needy student area

The big process for this refinement is as follows: First, we make a neighborhood area for each school and calculate how many needy reside in those areas. Second, this neighborhood needy number can then be compared with the needy capacity in each school. This calculation will determine how many needy capacities are left in each school after some seats are fulfilled by needy in the surrounding area. Also there will be recalculation of new needy student area, with the purpose of uncovering who the needy student actually is and who really needs to ride the bus. The first step to calculate the neighborhood area is modeled in Figure **4.13** below.

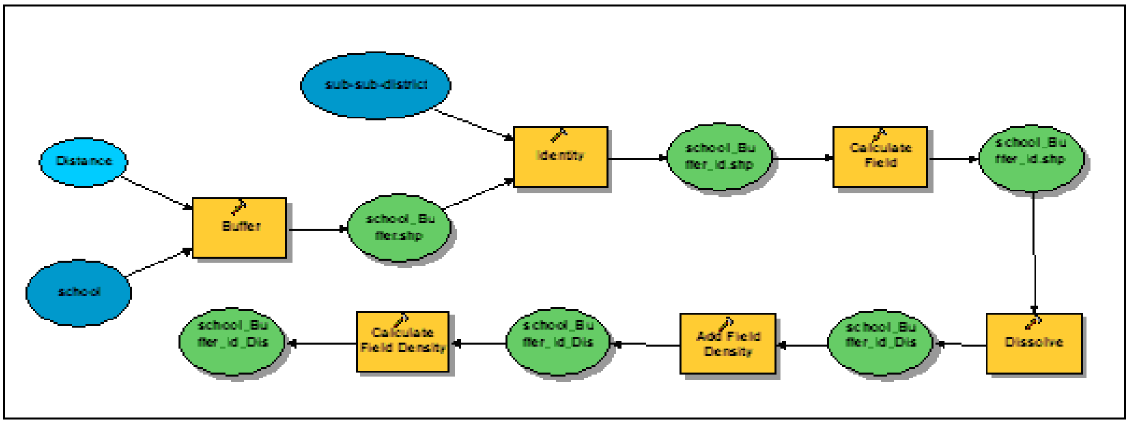

Figure 4.13. Model for make neighborhood needy for each school

The main input is school map and parameterized with a distance variable. This model and a lot of models in this project use the walking distance 300 meters. The number is chosen based on the former study that showed the acceptable walking distance to bus stop or other transportation transit point to be 400 to 500 meters (see chapter 2). Since the neighborhood environment in Surabaya is not as comfortable as cities in which those studies resided, and the walking objects in this study are not at adult ages, this study decreases that number to 300 meters.

Above distance number is used for buffering school in order to determine the area around the school. After the buffering process, which makes a circle area around each school, the process continues with Identity process. Identity process will make these circles have some parts formed by regions in the sub-sub district map. Output of this step can be seen in Figure 4.14 below.

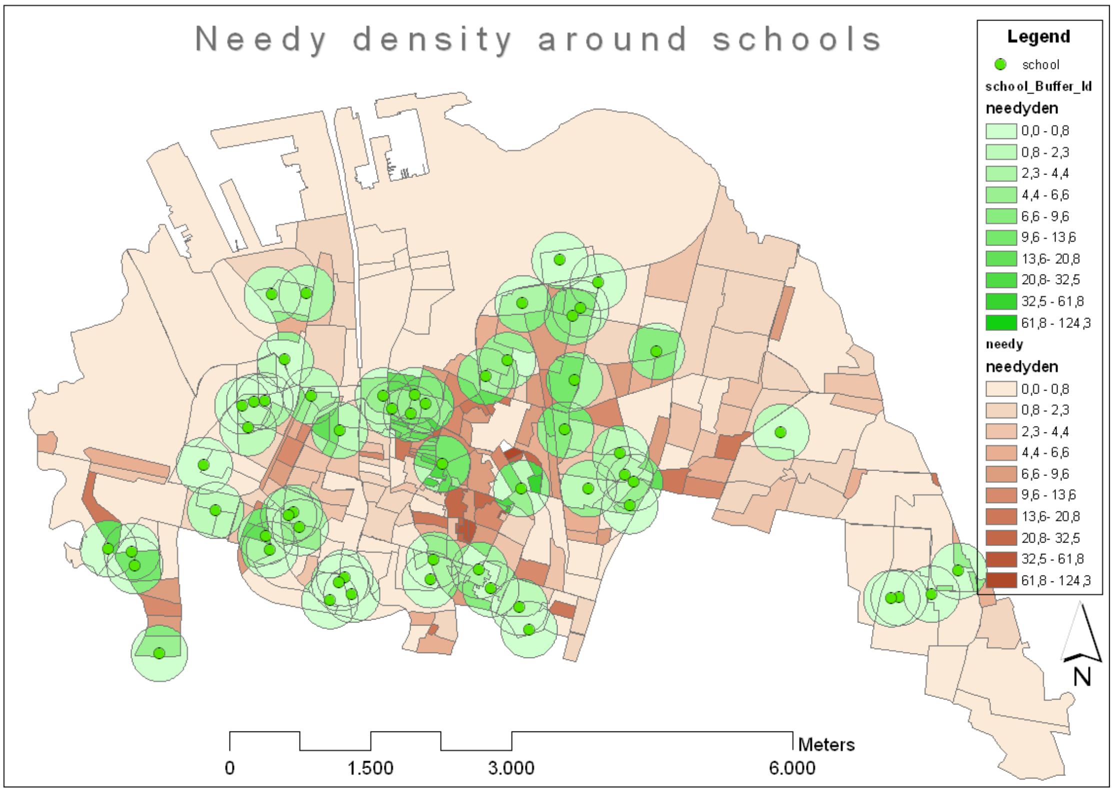

Figure 4.14 Identify output of buffer of school and sub-sub district map.

Not only is this procedure used for cutting circles with sub-sub-district shapes, the Identify process also makes field data from the sub-sub-district map added in every part in each circle, including the needy density field. This relevant and important data will be needed in next steps. Next in the methodology is the calculate process. In this process, the needy density field is used to calculate the total needy number by multiplying the area of each part. This calculation makes all circles have a number of needy in each part. Then the next step, the dissolve process, makes these parts conjoin again in its origin circle, where the total needy number will be summed. At this point, there is a full circle established with a total needy number in its covered area. The next step is to make a new needy density field in order to prepare a recalculation of needy number if there are any changes in the shape of circle area. This is accomplished using the Add field density process and Calculate field density process.

The steps above are for making a surrounding area for each school and finalizing the totals for the number of needy students in the area. This total number of students is the number of students who can reach the school by walking and do not need to ride a bus. It may sound as if the conclusion can be applied directly for reducing the school capacity and the sub-sub district needy number, but unfortunately it is not the case. These circle areas have an obstacle that requires us to do some additional steps before the reducing process. Essentially, the problem is that some circles have a sharing area with others because the position of those schools is less than 300 meters. It makes the total number of needy students which surround it no longer valid. This problem is exemplified in the simple example in Figure 4.15 below.

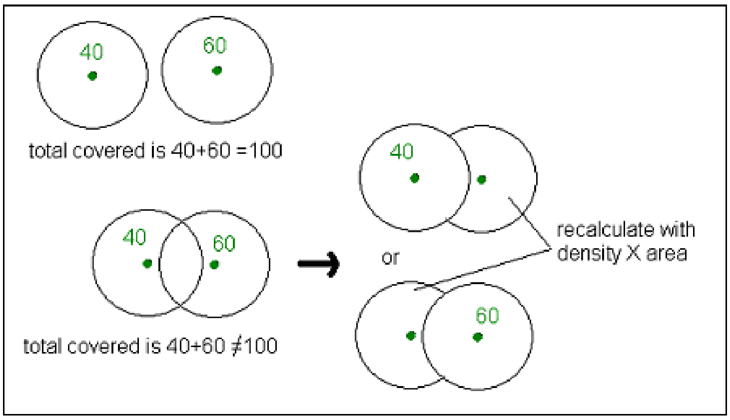

Figure 4.15 Sharing area makes total number of needy surrounding the school invalid

To make sure these surrounding needy numbers are valid involves checking the process for every circle. If one circle area has a shared area with another, it has to be subtracted by the other one or vice versa. The shapes of subtracted areas will not be a circle anymore, and will require a recalculation of the needy number by multiplying needy density with the new shape area. After this minimization of the circles' shared area, data is ready for next process.

The next step in our methodology is to calculate the impact of needy that are covered in circles around schools. The number of needy that do not need to use school buses will affect the number of needy capacity in each school, and needy number and needy density in sub-sub-district layer. The first step requires adding a new field which will be called 'Reduce' field. This field is used to save or exempt a number of students who can go to school by walking. If the number is more than the original capacity, 155 needy for example, the reduced number is cut into this number, and the number of the residual value saves into 'Residue' field. If there are values in the 'Residue' field, it means that there is still a needy student necessity to ride the bus in the surrounding school area, even though they can go to school by walking. This is due to the fact that the school capacity is not broad enough to accommodate them. It also adds new 'capacity' field for saving the new number of students who can still be accommodated by each school. The process model for these steps is shown in Figure 4.16. This model also shows the step for recalculation in the sub-sub-district layer and shows the updating of the school layer.

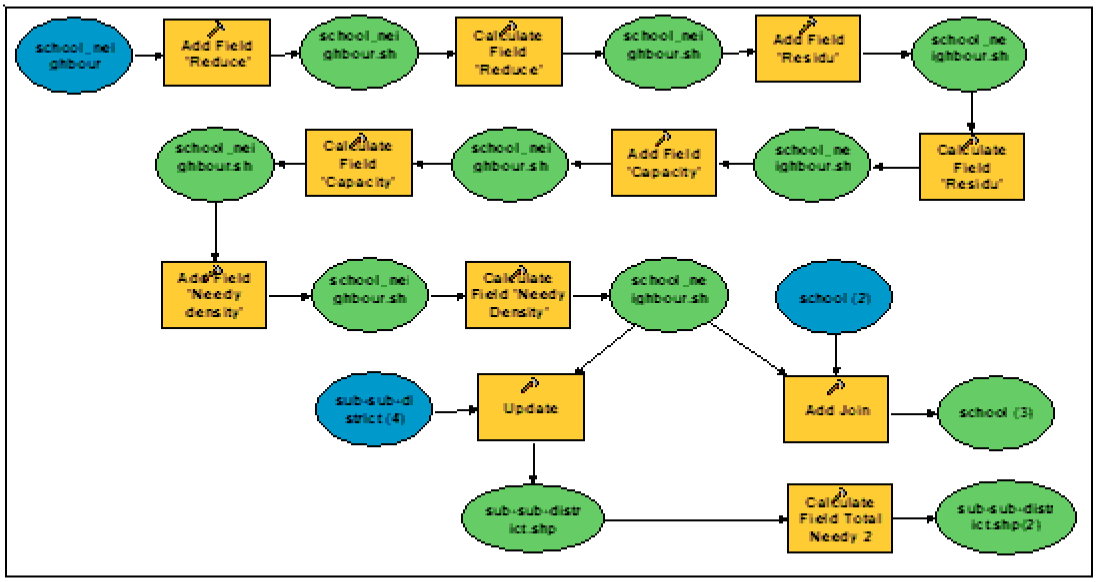

Figure 4.16. Process model for calculating new school capacity and needy area

Still in above model, surround school areas that still have not accommodated students will act like sub-sub district areas. These areas will be blended into the sub-sub-district map as a new needy region. For this reason, it has to include the needy density field in this surrounding school area. This needy density value is taken from the Residue field value divided by 10000, similar to the needy density formula in the sub-sub district layer in previous section. After this needy density calculation, this surrounding area mixed with sub-sub district area can be further refined with 'Update' function. Update function makes a shape of each object in sub-sub-district map updated with each shape of object in the surrounding school map. Please review figure 3.15 to see the example process of update function. Because there are modifications of shape in the sub-sub district map, it needs to recalculate the needy number again. After this recalculation, the total number of needy students is 5265. The results are noteworthy; compared with the total of 8579 needy students, it eliminates the need to transport 39% of passengers who do not require bus passenger service.

The previous process has eliminated the excess passengers for bus routing which, in other words, means that it has successfully reduced the number of buses required to operate. In addition, the process continues to eliminate the stop location of bus routing with the positive result of reducing the traveling time. This reduction is achieved by eliminating schools that have no more capacity for the needy student. For this process to be complete, it needs to join the surrounding school area map with school map, with the Add Join function. The output of add join function is a school map that has been added with three calculation fields as shown in the Table 4.1 below. In this table, one can view the results of the field and the calculation process which was discussed earlier. Virtually speaking, the school table now has 3 new fields. By querying which school that has 'New Capacity' field equal to zero, and continuing with deleting the selected field, a school that has no more place for the needy student can be removed. There are 9 schools that will not be visited by school bus. Table 4.5 marks these schools with a red background. These removed schools can also be seen in Figure 4.17, which shows the new sub-sub district map as a new needy area. All processes in the next chapters will use this new list of schools and this new needy area map.

Table 4.5. The school list with its new capacity

CODE	NAME	ORIG. CAPACITY	REDUCE	RESIDU	NEW CAPACITY
SMP0002	SMP Negeri 8	155	19	0	136
SMP0003	SMP Negeri 2	155	1	0	154
SMP0004	SMP Negeri 5	155	87	0	68
SMP0005	SMP Negeri 7	155	6	0	149
SMP0021	SMP Negeri 18	155	1	0	154
SMP0050	SMP YPPI 1	155	8	0	147
SMP0055	SMP Al-Ikhlash	155	6	0	149
SMP0073	SMP AL GHOZALI	155	30	0	125
SMP0085	SMP Muhammadiyah 1	155	36	0	119
SMP0086	SMP YP 17 SURABAYA	155	62	0	93
SMP0088	SMP PGRI VI SBY	155	45	0	110
SMP0089	SMP ISLAM AL AMAL	155	116	0	39
SMP0090	SMP Islam	155	83	0	72
SMP0093	SMP Mujahidin	155	46	0	109
SMP0096	SMP PGRI 7 Pabean cantian	155	155	1	0
SMP0098	SMP PGRI 36	155	34	0	121
SMP0102	SMP PGRI 5 Surabaya	155	9	0	146
SMP0103	SMP Ta'miriyah	155	1	0	154
SMP0104	SMP Katolik Angelus Custos	155	1	0	154
SMP0105	SMP GATOTAN 1 SURABAYA	155	5	0	150
SMP0106	SMP Bina Karya	155	79	0	76
SMP0107	SMP TUNAS BUANA	155	155	29	0
SMP0125	SMP Ganesya I Surabaya	155	80	0	75
SMP0134	SMP Kemala Bayangkari 6	155	43	0	112
SMP0140	SMP Muhamadiyah XI	155	60	0	95
SMP0141	SMP Kawung 1 Surabaya	155	104	0	51
SMP0142	SMP UNESA 1 SURABAYA	155	30	0	125
SMP0145	SMP Hang Tuah-4 Surabaya	155	25	0	130
SMP0149	SMP ALKHAIRIYAH	155	55	0	100
SMP0150	SMP ATTARBIYAH	155	155	22	0
SMP0151	SMP AL IRSYAD SURABAYA	155	40	0	115
SMP0152	SMP KEMALA BHAYANGKARI 08	155	155	82	0
SMP0153	SMP NASIONAL	155	155	41	0
SMP0154	SMP MUHAMMADIYAH 16	155	125	0	30
SMP0155	SMP ISLAM LIL WATHON	155	114	0	41
SMP0157	SMP AL HUDA	155	155	30	0
SMP0164	SMP Gatra	155	64	0	91
SMP0165	SMP Barunawati	155	28	0	127
SMP0180	SMP PGRI XI	155	5	0	150
SMP0307	SMP Negeri 41	155	81	0	74
SMP0308	SMP Triyasa	155	7	0	148
SMP0321	SMP Terbuka 5	155	6	0	149
SMP0323	SMP Bina Bangsa	155	21	0	134
SMP0324	SMP K St. Mikael	155	30	0	125
SMP0326	SMP Negeri 27	155	8	0	147
SMP0327	SMP Terbuka 11	155	155	96	0
SMP0331	MTs Nurul Salam	155	142	0	13
SMP0333	MTs Taswirul Afkar	155	155	205	0
SMP0396	SMP Negeri 31	155	155	10	0
SMP0397	SMP Muhammadiyah 15	155	23	0	132
SMP0398	SMPK. Pecinta Damai	155	7	0	148
SMP0399	SMP Cahaya	155	21	0	134
SMP0400	SMP Tri Tunggal VII	155	58	0	97
SMP0401	SMP Taruna Jaya I	155	12	0	143
SMP0402	SMP Wachid Hasyim I	155	56	0	99
SMP0438	SMP Terbuka 18	155	3	0	152
SMP0440	SMP Romly Tamim	155	37	0	118

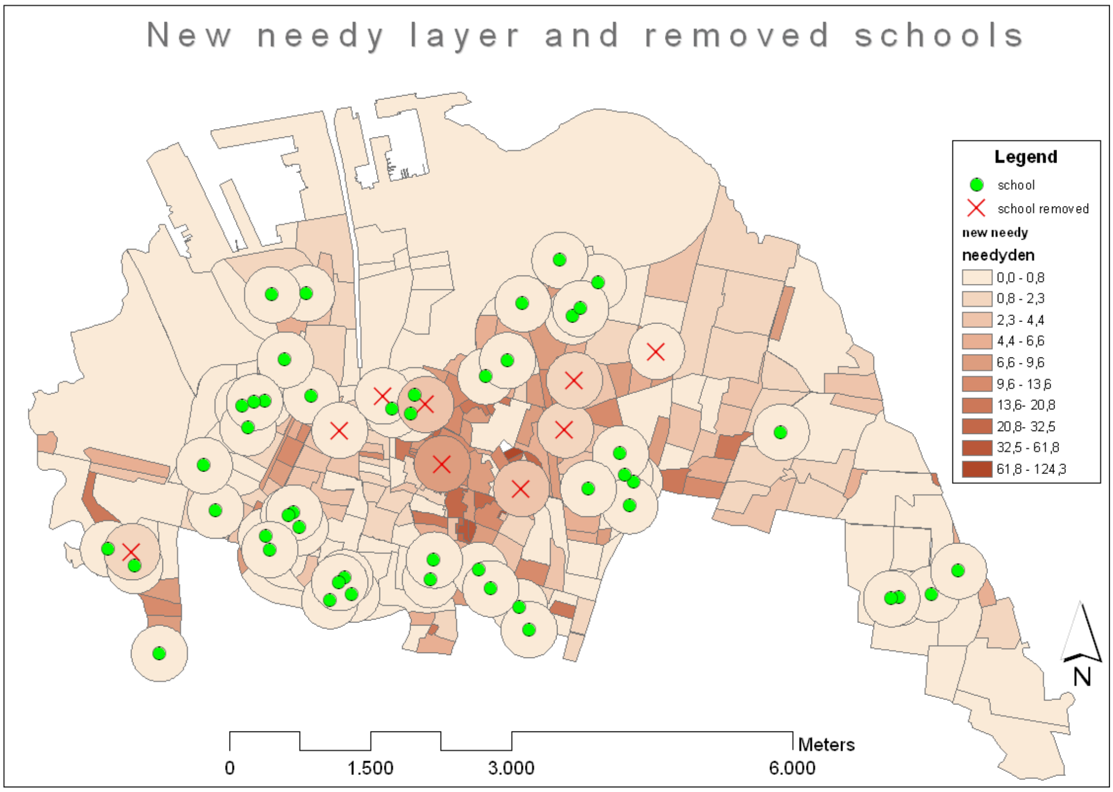

Figure 4.17. The new needy area and schools that will be eliminated

4.4 Generating Visiting Point Layer

Considering the needy map in the previous section, the bus is expected to visit all schools and this involves overstepping the sub-sub-district area with a lot of the needy. In the vehicle routing function, the route can be directed to visit any number of places. The problem is however, is that it has to use point type layer as a source for importing into 'Orders' layer. School location is already in point type, so it can be used directly. Since needy map is in polygon type, it cannot be used like the school map. Instead, it needs to generate a point layer from the needy map. Figure 4.18 is a model for this generation process.

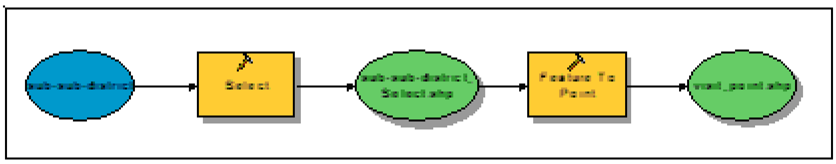

Figure 4.18. Model for generate Visiting point

From now on, let's refer to the generated point layer as visiting point, since they are places that need to be visited in the new bus routing. The first step is to select the areas that have a plentiful number of needy which must be transported. Here, the process forces the bus to visit half of all the needy and lets the remaining half be visited optionally by the routing process in order to make the routing process operate with the aim of achieving a deliberate and optimum solution. Half the number of needy is receiving bus service. From the greatest number to the least, the process continues with taking one by one row from the most until the total number of selected rows is half of all needy numbers. Alternatively, it can make selection criteria that will approximate results using a manual method. It found that the selection criteria are: [Total]>40. That means that in cases where the needy area exceeds 40 that will be selected. In addition, the total number from those areas is a half of all needy numbers. After the selection process, it continues with the most important process which is the making of point layer. This step can be done by using 'Feature to Point' function. This function will make a point in the center of each polygon equipped with all it attributes. Figure 4.19 shows the point layer generated by this function. This visiting point function is used to make the bus travel at the potential area. If there are any of these points which are not visited by the VRP function, the proposed route is still valid and can be accepted.

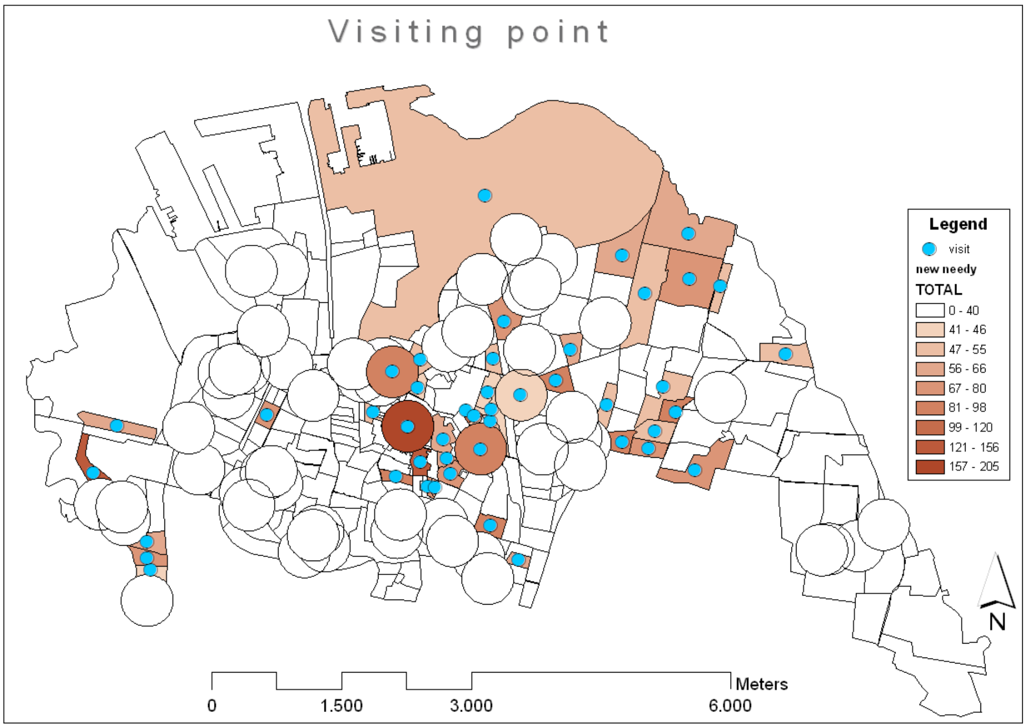

Figure 4.19. The selected needy area and the generated point layer

4.5 Calculating Street Load

In next chapters pertaining to vehicle routing, some of the process needs to accumulate a load of passengers while traveling. The load value is calculated from the computation of the number of the needy surrounding each road which is traveled. For this calculation, it needs to prepare a field, which can represent the load value. A process for this preparation has been modeled in figure 4.20 below.

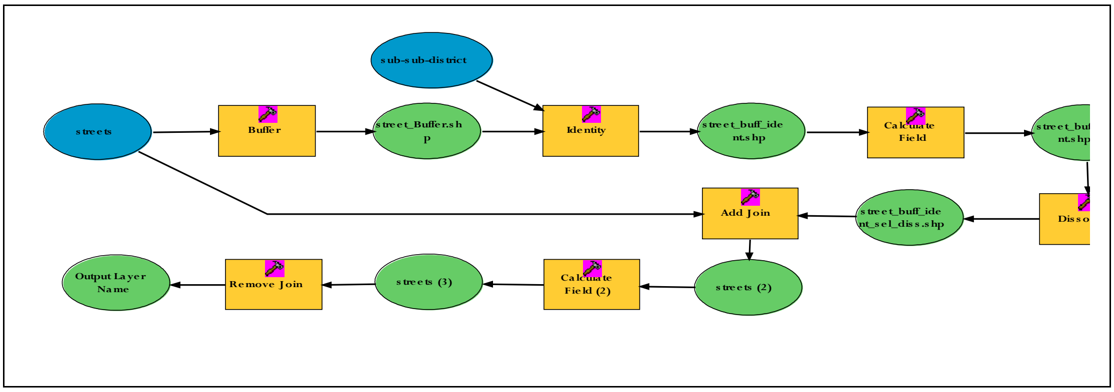

Figure 4.20. Process model for generating street load

The process is a little bit similar to the process of calculating needy surrounding schools. But this time, the school points have been changed with the road part referred to as polyline. First, there is a buffering process to make an area around the street parts. Next, with Identity process, the buffer is separated with sub-sub-district shapes and injected with the needy density value. This needy density is then recalculated to obtain the accurate number of needy in each separated part. Separated parts from the same buffer then re-unite again with the Dissolve process, and the value of needy of each part will be summed. This summed value is then copied to the Cost field in the street layer. This copying process started with the Join process, continued with Calculate process, and finally continued with removal of the Join. The output of these steps is shown in Figure 4.21. It presents the value of Cost field in gradation color.

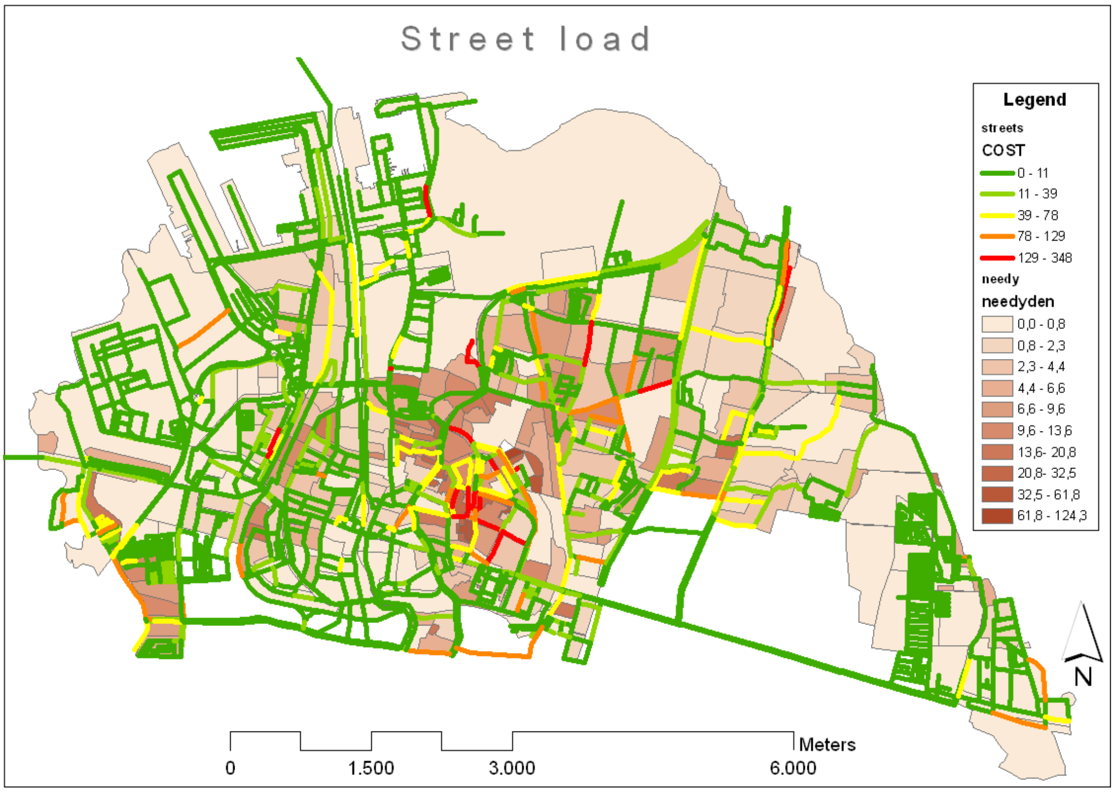

Figure 4.21 Street load presented in graduate color

This chapter has shown how make new layers and steps involved with preparing layers for the next process; the VRP process. After this chapter, all things that are necessary requirements in the VRP process will be met.

4.6 Network Dataset

Network analyst in the ArcGIS 9.3, as also seen in the previous versions, works with a special data called Network dataset. This special data needs a one way process. It is called one way because it builds it and then uses it. When there is any error detected, usually the road layer has a difficult or cumbersome shape or design at the street junctions. It cannot just fix and continue the analyst process. It has to rebuild the network dataset. And because all data generated in the analysis uses this network dataset, it is not impossible that someone has to repeat all the process which has been done. This project also got to experience this multi-faceted re-generate process. While the analysis process is held in ArcMap, the network dataset building process is conducted in ArcCatalog.

The main resource to build Network dataset is the street map. A street map that can be used is not a common street map, but a street map that has a special characteristic listed in chapter III. Since it has used the standard field name like ONEWAY, FT_MINUTES, and TF_MINUTES, the process will automatically detect and use the data to generate a network dataset. In addition to the above, there is another field use in this process.

Another setting which needs to be considered in this project is the turning setting. There are two types of turning used in the network analyst. The first type is using the turn feature and the second is using the Global turn. While using turn feature, The network dataset has to be managed their every turning rule in every junction. It has to set the turn right or left, and implement a u-turn rule, and determine how much time each turn consumes. In contrast, while using general turn, it is assumed that all junctions have the same turning rule and time values.. Since almost all junctions in this study area have a similar characteristic, this project uses the global turn for managing the turn rule. This turn will add some extra time when a bus is passed through. In this project, a little modification from the default value needs to be allowed. Specifically, the time needed for reserve direction must be adjusted. This value set tripled because the large size of the bus makes it more difficult to turn back compared with the turn capabilities of a usual car. Figure 4.22 is the setting form for this global turn delay.

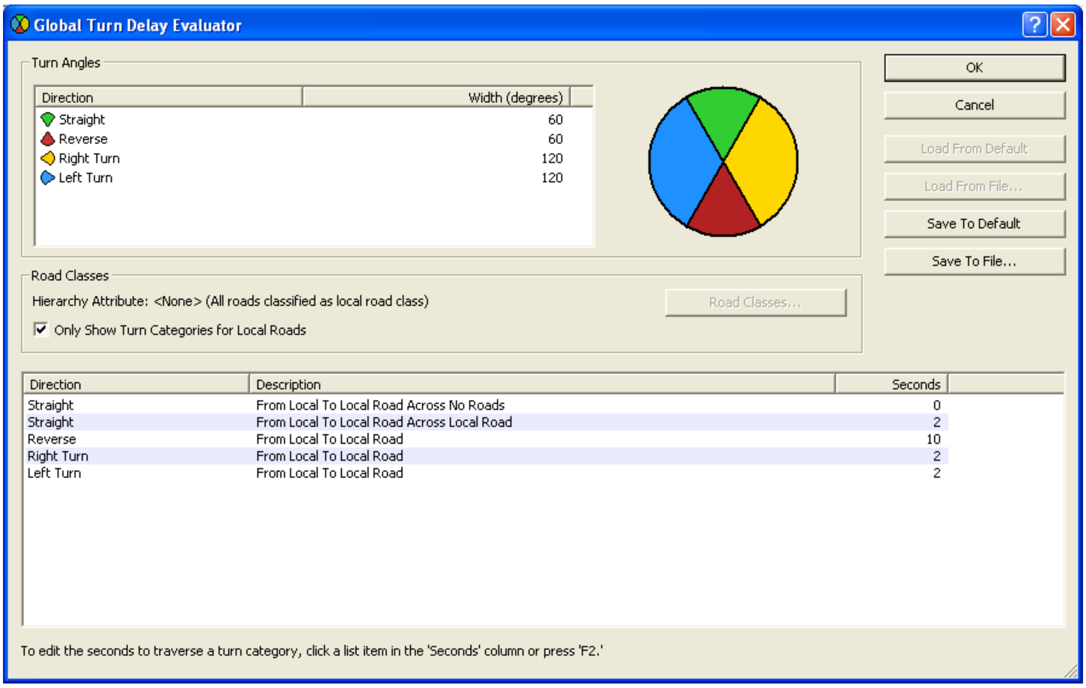

Figure 4.22 . Form for setting the Turning cost

4.7 Vehicle Routing Problem Class

After generating the network dataset in ArcCatalog, the rest of the process will be conducted in ArcMAP. Before the network analyst can be used for finding solutions, it has to define a collection of settings that is called Vehicle Routing Problem Class. This class will be shown in the map as a vehicle routing problem analysis layer. Acting like a common layer, it can set the display property of the object when shown in the map. The minimum setting for VRP class is a defined 3 subclass; they are Orders, Depots, and Routes. The optional setting sub-class which will also be set is the Breaks sub-class.

4.7.1 Orders

The first step is defining Orders. Orders are places that have to be visited by the vehicle. It could be a place for delivering something, picking up something, or just a place to inspect. After the preprocessing in previous section, the total number of needy students is 5265 students for 48 schools. We import all the school data which will become Orders items. We also add Visiting point layer generated in previous chapter.

The important parameter in the Orders layer is Service Time and Time Window. Service time is time needed for all people or goods to bring into or load from the vehicle in that place. In this case, this is the time needed for the school bus to travel, from stopping in a school area, discharging a passenger, picking up another passenger, and heading to another location. In this project, this parameter is set with 2 minutes when importing the School layer as orders items. On the other hand, while importing the visiting point layer, it is set with zero because that point is not specified for picking and loading, but just for a helper in finding the route in the optimum needy area. Visiting point adds 39 points to this sub-class and makes this sub-class have 87 items. All these items can be seen in Figure 4.23 below.

Figure 4.23. Orders items, consist of: School (green) and Visiting point (blue)

Another important parameter for Orders sub-class is time windows. Time window is separated into 2 parameters, 'time window start' and 'time window end' which defines the starting time a vehicle can do its service when it becomes unavailable. School starts at 7:00 AM, but at 6:00 AM the door is already open for students. Therefore, for orders imported from school layer, it must set 6:00 AM as the value for the time window start parameter, and 7:00 AM as the value for time window end. The bus can pick up students earlier than that time. Students already wake up and prepare at home by 5:30 AM, therefore while importing the visiting point layer, the 'time window start' parameter is set with 5:30 AM, and 'time window end' parameter with 7:00 AM. The longer the duration, the more places that can be visited and the longer the route will travel. However, it also means the less fleet which can be set up. For example, if a route starts from 5:50 AM and ends at 7:00 AM, we have 20 minutes for loading another fleet. If time between each fleet is 5 minutes, we can have 4 more fleet to load and still be in the acceptable time window.

4.7.2. Depots

Next is Depots. Depots define where the bus starts and ends its journey. In the school bus routing, the bus starts from bus depot, travels and visit schools, and ends in another depot. It may be come back to rest in the starting depot, or stay in that end depots until the end of the schooling time, and then go backward reversing the route above. In previous section, it noted that there are 2 bus terminals, which can be used as depots. We load those as items in this Depots sub-class.

This project also adds more available depot locations; in order to make buses that can stay and wait in some places. It is more efficient than going back to the terminal, and before school time is ended the bus must travel to the last school visited in 'go to school picking', and then start the 'go home picking' by reserving the route. For these waiting places, it can use the area of the public schools, because the government is the owner of those locations and has the authority to use them. Therefore, for this sub-class, we import two maps, the bus depot layer and selected school layer. School layer is select by query to get only the public school. The location of the Depots layer is shown in Figure 4.24 below.

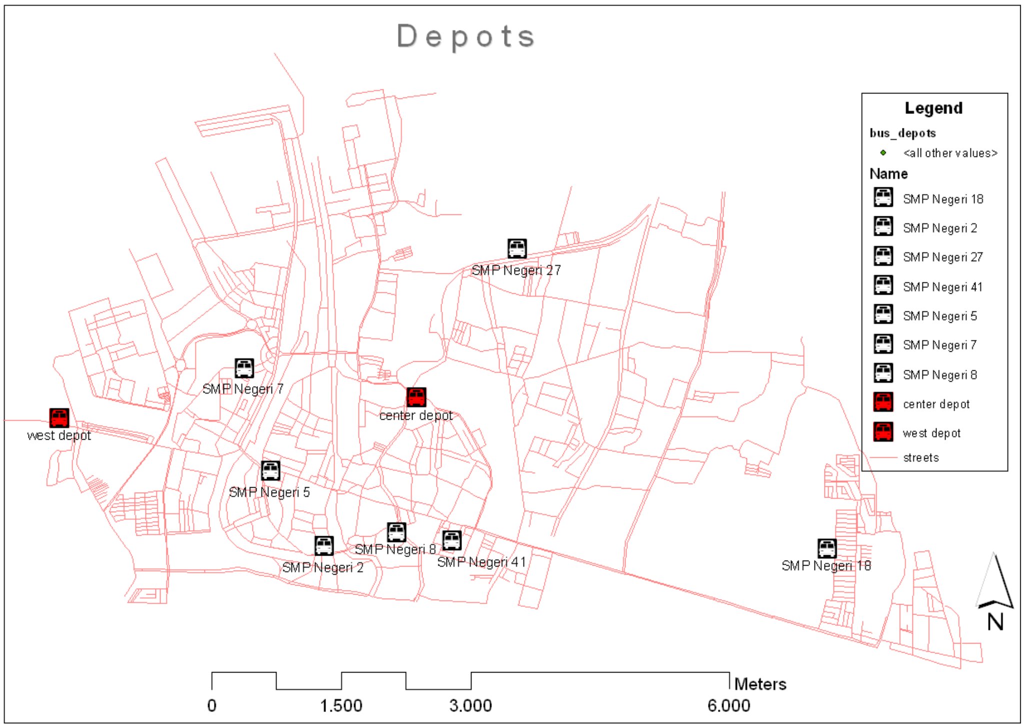

Figure 4.24. Depots, consist of bus depots (red) and public school (white)

Depot also has a service time and time window parameter. Service time is set to 2 minutes, and the service time is set to 5:30AM to 7:00:00 AM. This means the depot can start loading the bus at 5:30:00 AM and has 30 minutes to travel and get passengers before visiting the first school at 6:00:00 AM. The bus does not have to start traveling 30 minutes before visiting the first school; it's just the maximum time that can be used. The real start time will be generated by the analysis process.

4.7.3. Barriers

Sometime a school bus needs a route to pass on a certain street, and sometimes a route needs to be omitted. In order to omit a street from the traveling route, VRP Dataset uses Barriers. Some streets in the street map lie on the outside of the study area. The study area is North Surabaya, and some streets lie in the east and center regions. Because those streets are outside the study area, it should be noted that this project doesn't concern itself with the needy student population in those areas and so the bus cannot pick any needy from those locations. Considering these areas outside our study will render unproductive results and be unnecessarily time-consuming. In short, some barriers need to be in place. This project did not have any barriers layer set. It needs to make a new layer and digitize some points on the street outside the study area and then this layer can then be imported as Barriers sub-class. The locations of barriers can be seen in Figure 4.25 below.

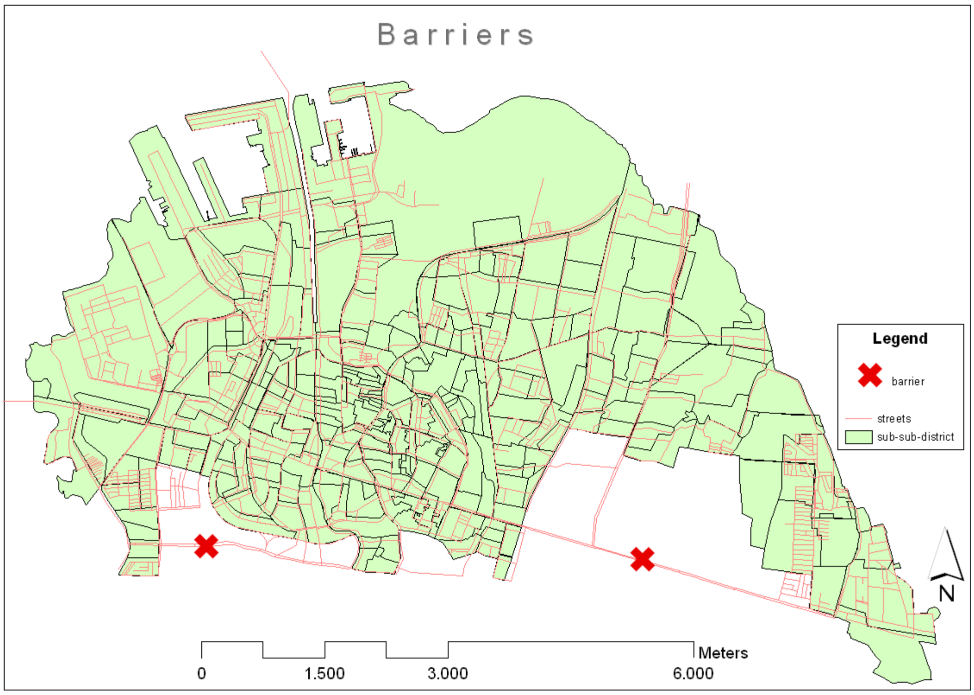

Figure 4.25. Locations of barriers (x sign)

The 3 sub-classes have been defined as where the bus will start, where the bus will travel and not travel, and where the bus will stop. Next, it will need the Routes which are the last sub-class. Unlike the previous 3 sub-class that were not altered, the last sub-class will be altered in order to get the best proposed routes. For this reason, the sub-class added the new section as follows.

4.8 Inspecting the Needed Number of Routes

Now it is ready to define the route with some specific rule we want applied. To be considered and analyzed first is whether less routes result in more school choices for students. For example, if all the schools in the study area can be visited in one route, then whatever school a student wants to attend, the route will be available thus providing the student with choice. If there are two routes, then the school will divide into two paths and the student can only choose from half of the total number of schools. Therefore, the algorithm, firstly, tries to define one route and then begins incrementing that number if it cannot cover all the school locations.

There are some parameters which need to be considered in defining Routes sub-class. First, it has the StartDepotName and the EndDepotName parameter. For the Start depot, this project will always use the center depots, since they lie at the center of the town and would contain the biggest depots that can be used by government to place a "sleeping bus".

4.8.1 One Route

This first design attempts to reach all schools and ends the bus in another bus depot in the west. It is expected that the bus will visit the schools in the east first and then return back to the west. The design of start and stop depot in this first trial can be seen in Figure 4.26 below.

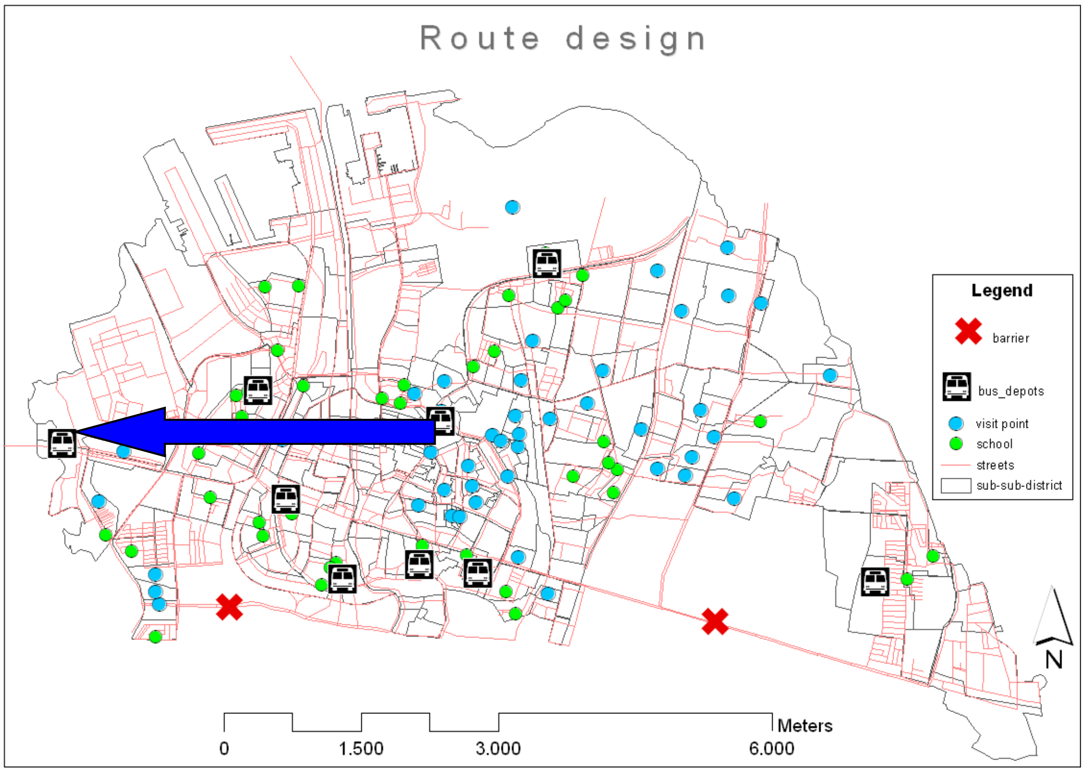

Figure 4.26. Design of start and stop depot for 1 route

While setting the route, there is another important parameter after start depot and stop depot, and these are EarliestStartTime, LatestStartTime, and MaxOrderCount. EarliestStartTime and LatestStartTime parameter makes the vehicle have time range to begin its traveling. The routing engine will choose a time in that range for optimal routing. For example, the first order to visit is at time 5:30AM, and then it set the earliest to 5:00AM and the latest as 5:30AM. This engine process may take 5:25AM for bus to load from start depot, have 5 minutes time to travel, and at 5:30AM come to the first depot. MaxOrderCount parameter is used for limiting the route to visit orders in a set maximum number. If this number is reached before travel time is ended, the bus will not take another order. Maybe it passes through the order, but does not take action. This number is set with the count of all orders.

After we set those parameters the VRP process is ready to run. The process will need a couple of attempts depending on the complexity of the route and our settings. In this first trial, we get a route like that shown in Figure 4.27 below.

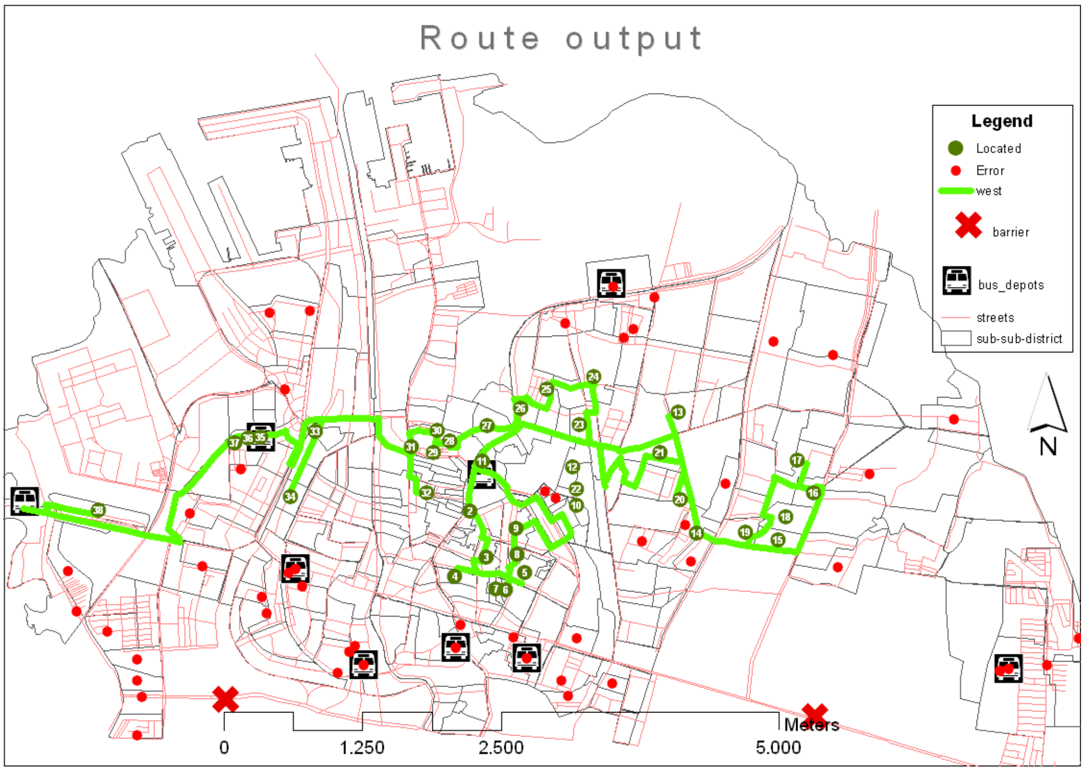

Figure 4.27 Output of VRP Analyst for 1 route design

In the above figure, it can be clearly seen that 1 route just covers a little part of orders. There are a lot of points of error orders (red dotted). The bus travels to the east, but not too far, and then goes back to the west and eventually reaches the west depot. The time limit of the school that opens from 6:00 AM to 07:00 AM limits the operational time of the bus. Any route designed in another direction will definitely function like this design. Therefore, one route will be added in the next section.

4.8.2 Two Routes

The second design is using two destinations. If the first is to the west, the second one is set to east. It is expected that one route will take the north area first, and the other will take the south area first before continuing to each destination. The new route can be made by adding a new route item in the Routes sub-class complementing the west one that has been there previously. Figure 4.28 shows this 2 routes design and Figure 4.29 shows the output.

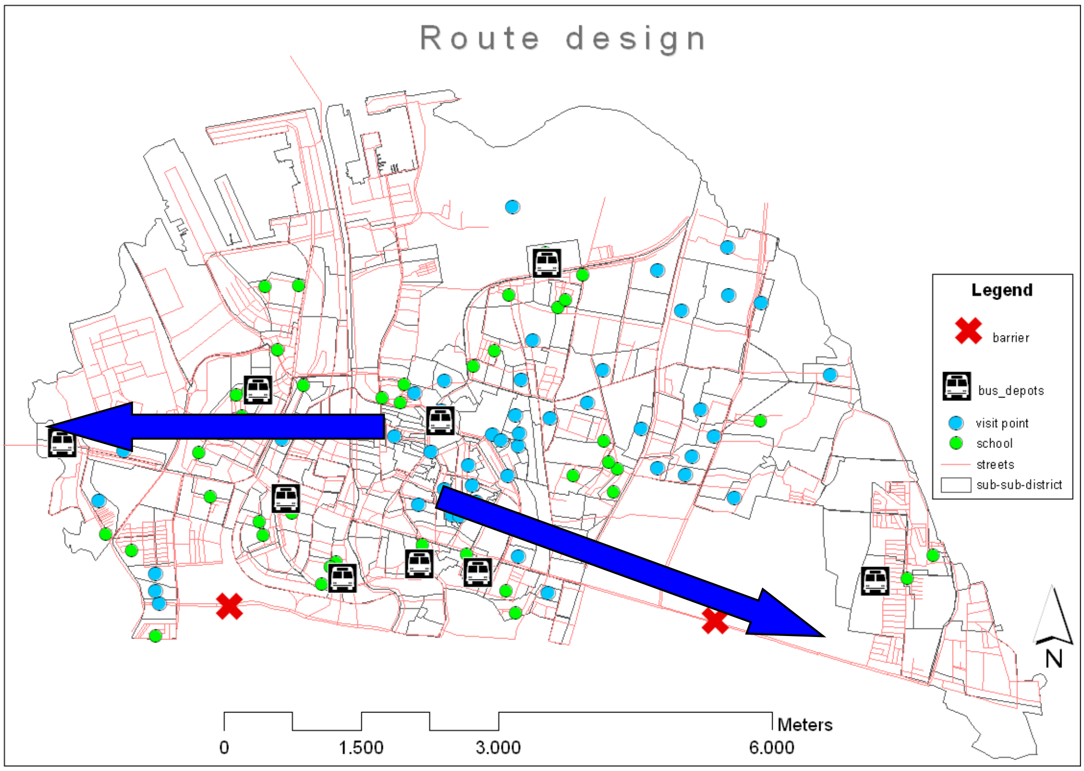

Figure 4.28. Design of start and stop depot for 2 routes

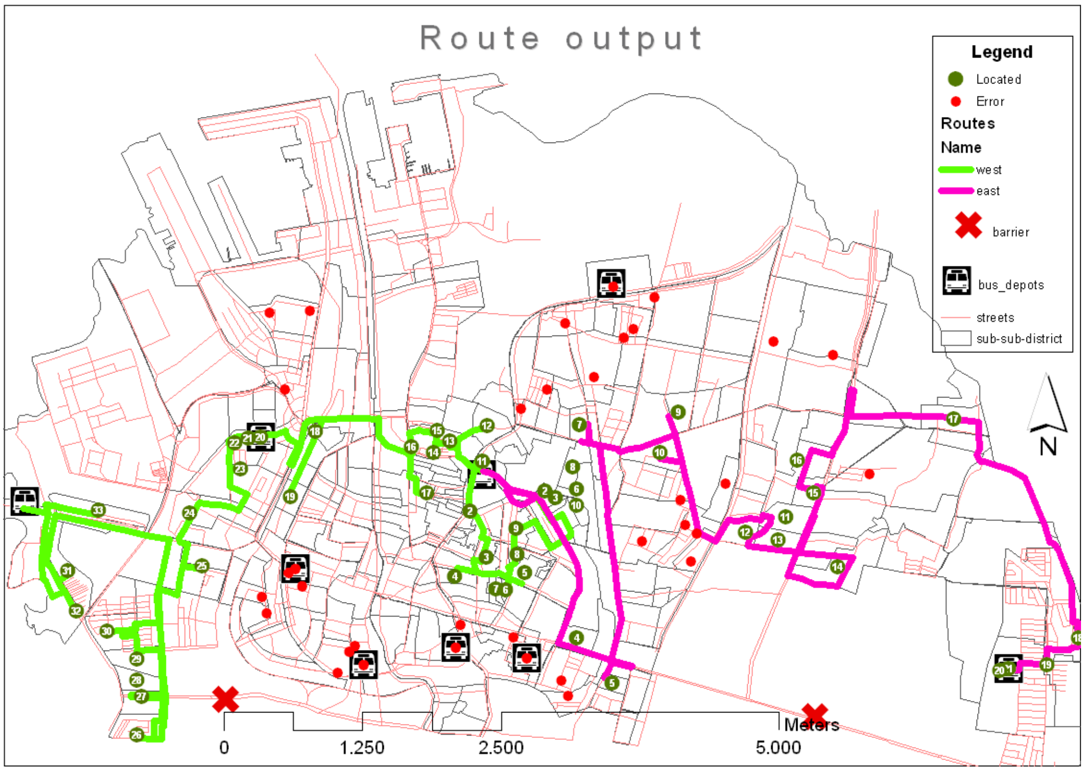

Figure 4.29. Output of VRP Analyst for 2 routes design

The Output of the 2 routes design exhibits actions similar to those we have expected or predicted; one route goes to the north first, and the other goes to the south before traveling to their destination. But, these 2 routes still cannot cover all orders locations. The number of visited orders is about 60% of all orders items. There is no other way except adding new route items.

4.8.3 Three Routes

It continues now with adding new routes to the north. Expecting this new direction will cover the north area, while the previous two directions cover their own direction and the south area. Although from the statistical analysis in the previous section, this adding of 1 route sounds as if it cannot answer the demand, but we must give it a try. The design of the new route can be seen in Figure 4.30, while the results can be viewed in Figure 4.31.

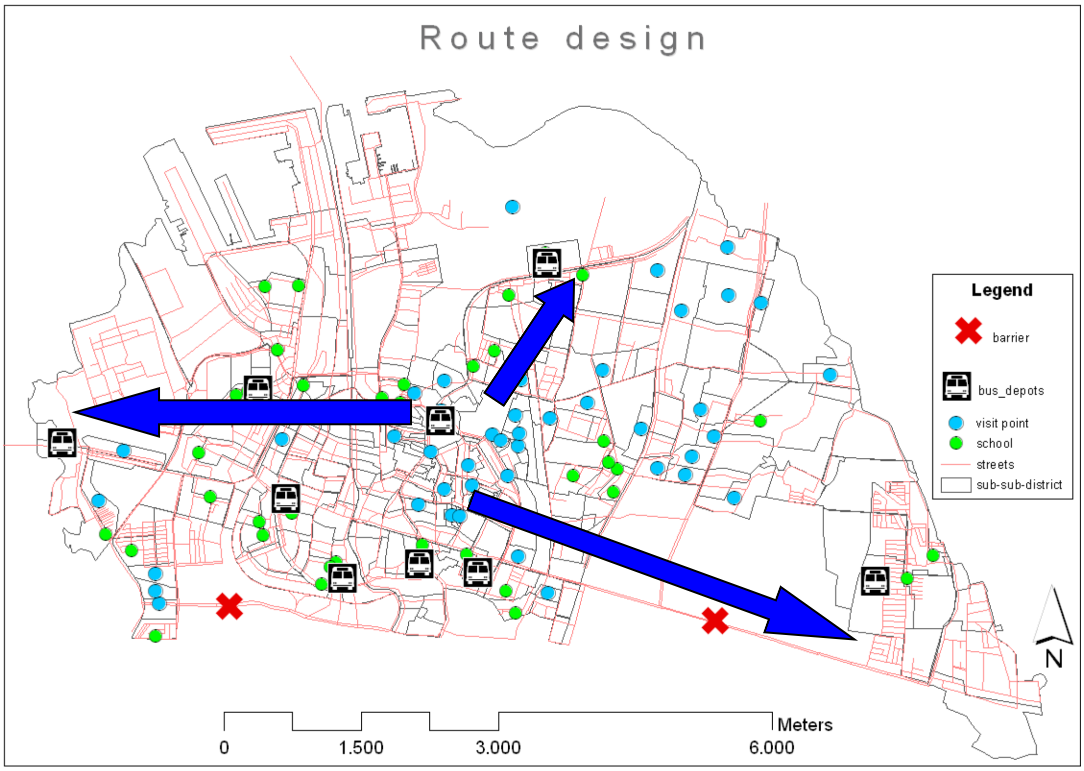

Figure 4.30. Design of start and stop depot for 3 routes

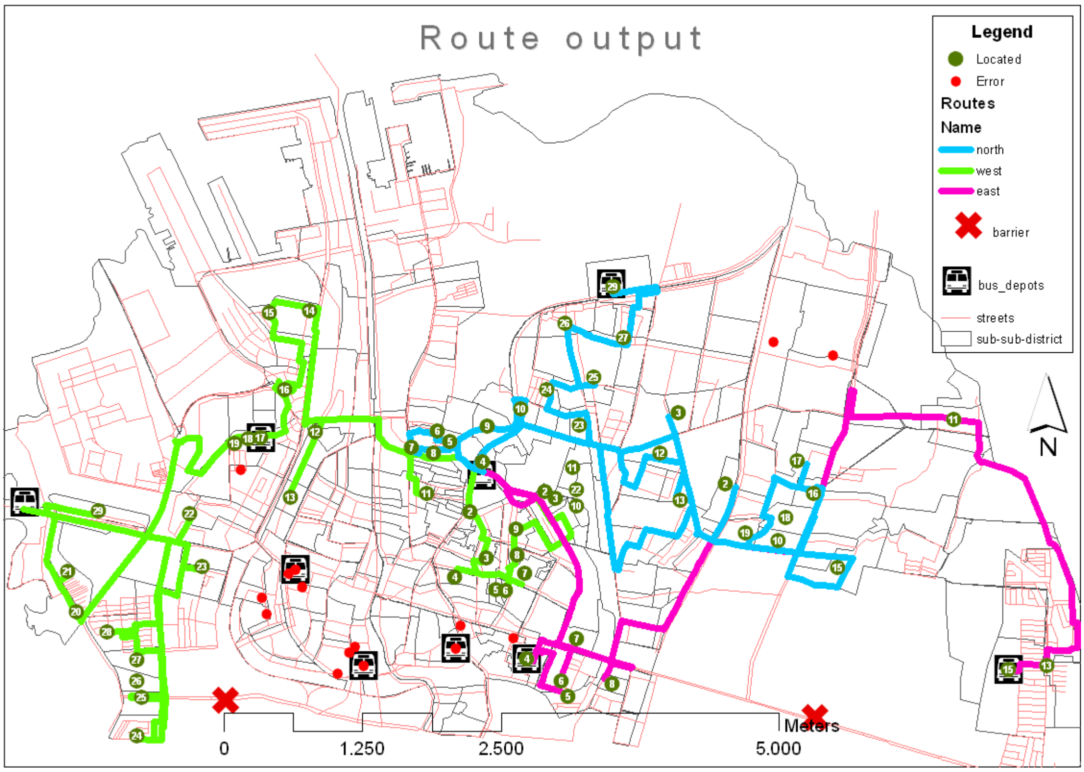

Figure 4.31. Output of VRP Analyst for 3 routes design

The west route takes the west area. The north route takes the center and north, and the east route takes the south and east area. However, again, the time limit still cannot be beaten by these 3 route items. There are 18 uncovered orders and, continuing from the previous action, one more route will be added in the design and then a re-run of the VRP analyst will be performed.

4.8.4 Four Routes

The added route is directed to the south area. The fourth route is added with the same setting like the other existing route directions. This four directions route design can be seen in Figure 4.32 and the output in Figure 4.33.

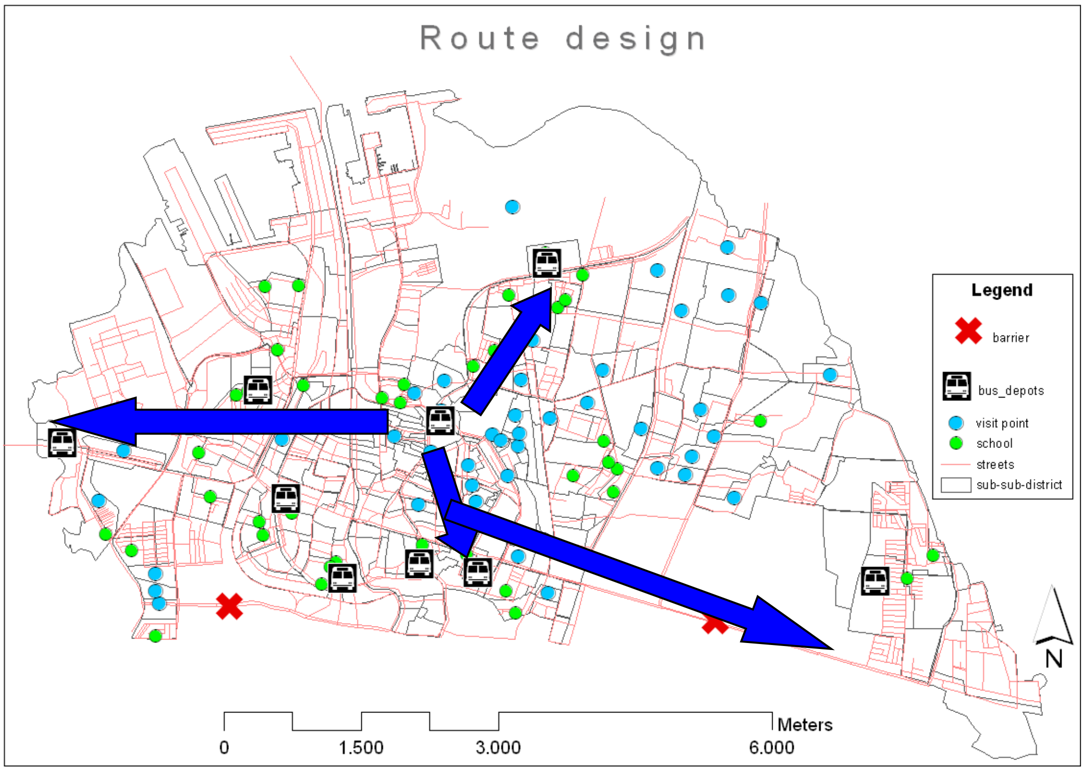

Figure 4.32. Design of start and stop depot for 4 routes

Figure 4.24 shows that almost all orders are covered by these 4 routes. There are 2 red dots indicating that there are orders that are not covered, but with a simple observation of the information presented in those dots, it is discovered that 2 dots are not school but just visiting points. As noted in the previous section, these stop can be omitted. Because whole school area is already covered, it will not add another new route for covering them. East route covers the east area, west route covers a portion of south area and west area, south route covers center and a portion of north area, and north route covers a portion of the west area, south area, and north area. This first 4 destination route designs have been inspected for how many route directions are needed to cover all schools. In the next chapter, the design of the route will use 4 destination routes with a variation of the depots that are used for the destination.

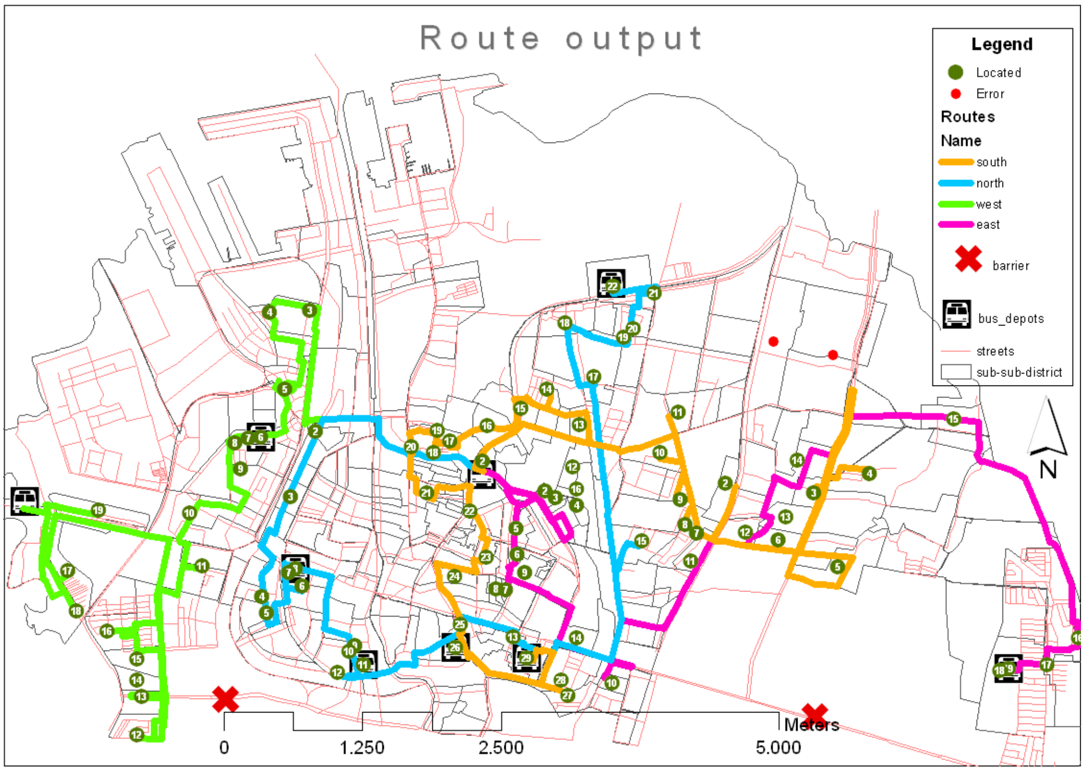

Figure 4.33. Output of VRP Analyst for 4 routes design

4.9 How good is the Route?

The VRP process will be done several times with variations in the Routes class and Orders class. In Routes class, the stopping depots are amended several times---as many as the possible variations. In Orders class, the variation is the distribution of the orders. Each variation has to run and generate an output. The output is a route of the school bus. An assessment process will then applied for each route. Aspects to be considered to adjust how good the route is include:

a) Balance of the school capacity and the covered area of the route

To calculate this balance, each route must be separated from the others and their loads calculated individually. This number is then compared with the total school capacity in this route.

b) The number of covered needy

The more the needy can served, the better the route. In order to find how many needy can be serviced a covered area analysis must be performed. As mentioned earlier, the Analyst uses a buffer with a reference distance of 300 m. This buffer clips the sub-sub-district areas to make sub-sub-district areas that are near the route. After continuing with recalculating the total number based on the needy density field, the total needy that live near the route can be found.

c) Travel time

The less travel time consumed the better the route. After the VRP process is done, the travel time of each route can be easily read.

d) How many needy in the shared area

The shared area is an area that lies near two or more routes. The greater the number of needy covered in a shared area, the better the route. To find this area, each route destination must be calculated independently. After finding the covered area of each destination, this step continues with combining two different routes and calculating their intersections. All intersection areas will then be joined with Union process. This process will produce an area with two or more routes around it.

The above criteria are in sequence. It means the load balance is the primary criteria, followed by coverage of the needy, travel time, and the sharing area. The travel time is placed in the third criteria after the number of covered needy because the object of this research is a free bus school. For another object, this criterion may appear in a different sequence.

The next sections will show what steps have to do with discovering those points. The steps will be bound in an Arcgis model, because it will be used continually in every route design.

4.9.1 Finding Covered Area

After we have an optimum solution to reach all schools and a heavy needy area, the first thing that can be discovered is how well this solution can be applied in terms of covering the needy students. This calculation is built in an ArcGIS model, so if there are any changes in the generated route--new schools or an updated needy area that requires VRP analyst to be re-run--it can be re-used without having to run step by step again with the different data.

This analyst will be used with respect to the distance number, 300 m, presented in chapter II. But first however, the routes have to convert to Line feature, then all streets in the routes will be buffered at this distance and make a 'close to the route' area. It is important to continue extracting the number of the needy in this area. The next step for calculating this needy number can be performed using the Clip process, and continue with Calculate field process. In the Clip process, the input layer is sub-sub-district area equipped with needy density, and the clip layer is the 'close to the route' area. This Clipping function makes a 'close to the route with needy density' area, while the Calculate process makes a 'close to the route with needy number' area. These steps are modeled in Figure 4.34 below.

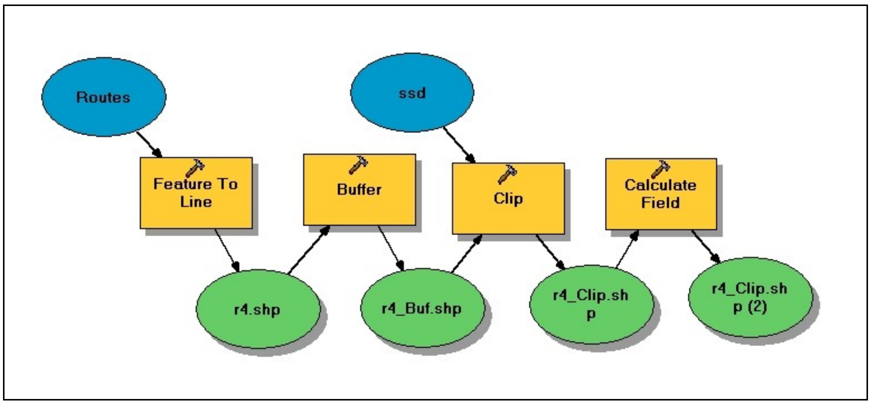

Figure 4.34. Model for finding covered area of the routes

4.9.2 Finding Shared Area

As shown in the example generated output, each route has a redundant area and has some sharing streets. This is not a flaw however; moreover, it is an advantage to have many intersections from the routes. Because of these intersections, the needy from some areas who need to go to 'far' schools can still reach those schools by traveling two or three times on a bus ride. This changing of the bus is happening at the intersections. The more number of intersections, the more flexible the routes. Let's call the needy area that lays in this intersection a lucky area, because the needy in this location get 2 or more bus routes. To discover where the lucky areas are, we build a model like that shown in Figure 4.35.

The process is as follows: first do a Select function to separate the route by its direction. Each direction is then buffered with a distance of 300 meters, like in the model used in finding the covered area. After buffering, there is a special step required prior to clipping and calculating. This special step is the core step that represents the best way to find the lucky area. This is a step for finding the area that has two or more sharing routes. This task involves pairing west and east, west and north, west and south, east and north, east and south, and north and south. It will produce 6 separate layers that have access to two routes. These 6 separated layers then have to be united. With Union process, all of these layers are written as one layer. This layer is then processed like the steps in finding the covered area as detailed in the previous section.

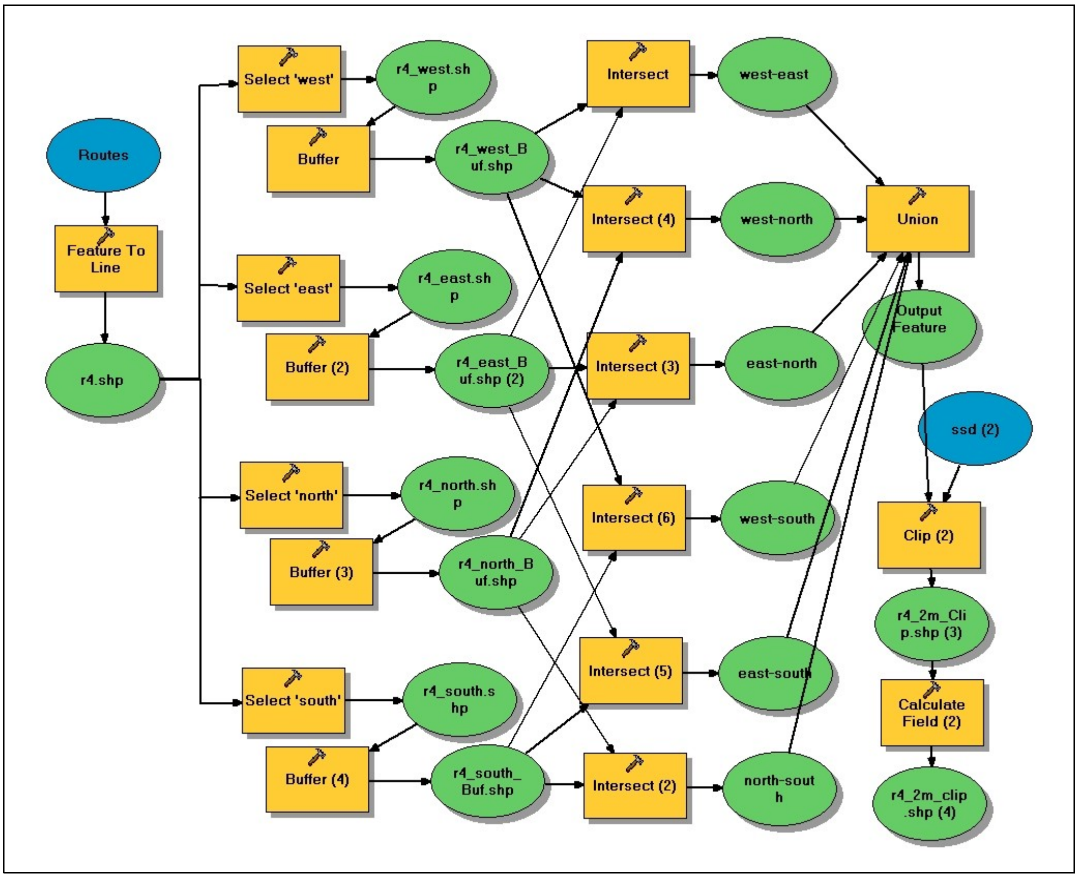

Figure 4.35. Model for generate area with 2 or more access routes

In a similar way, an area that has access to 3 or more bus routes will be discovered. The difference from the previous lucky area is in the special steps. In this very lucky area, the step will set different combinations than the lucky one. Here we have to combine 3 different routes: west – east – north, west-east-south, west-north-south, and east-north-south. Each route is intersected in those three combinations, then every intersection output will unite with the Union process. The area will be smaller than the previous one. Figure 4.36 is the model which exemplifies this very lucky area.

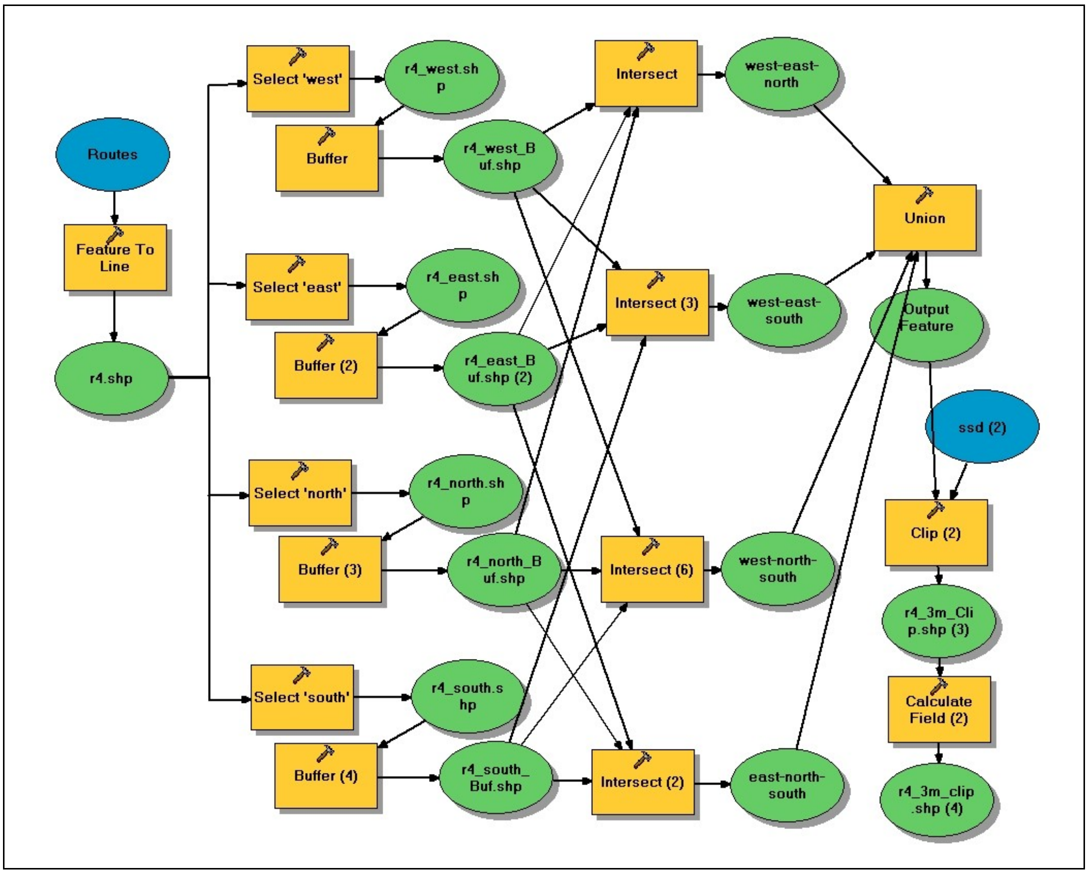

Figure 4.36. Model for generate area with 3 or more access routes

At last, there is also location that can access 4 routes. Let's call it a very, very lucky area. The different between the previous one is that in this model there is no Union function needed because after intersecting all different routes, it just has 1 output. This last model is shown in Figure 4.37 below.

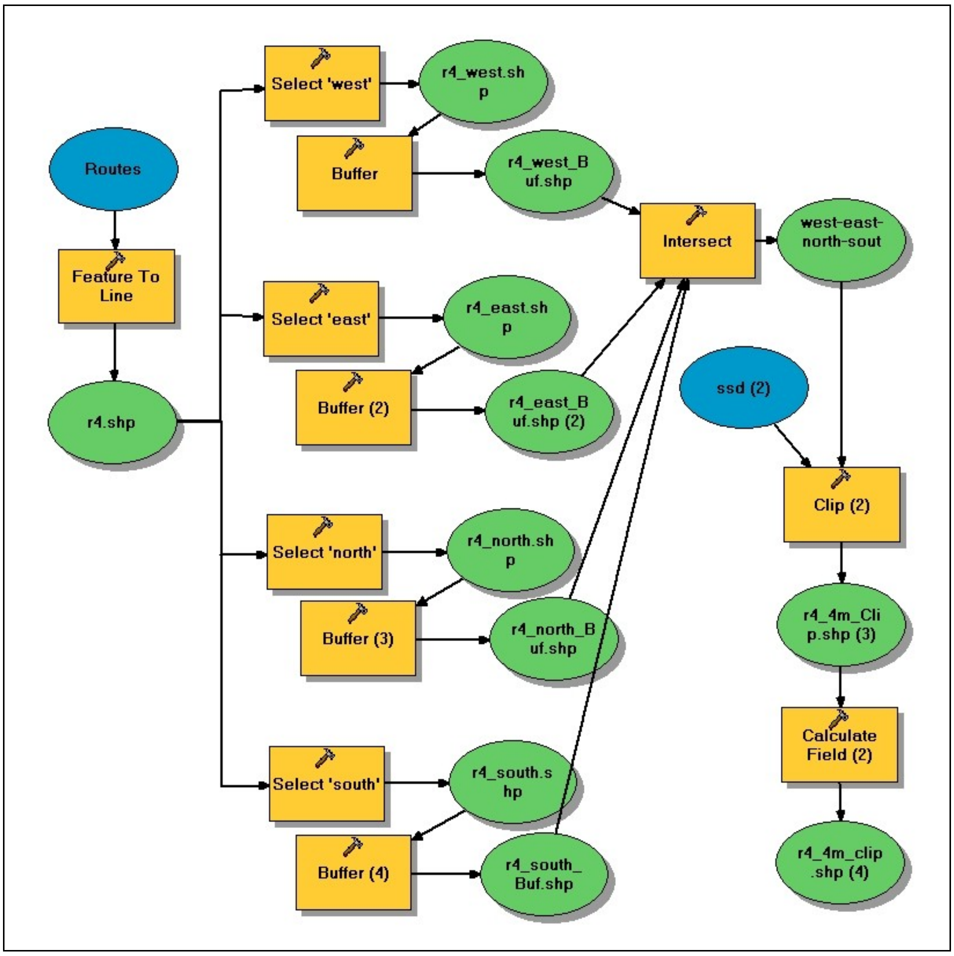

Figure 4.37. Model for generating area with 4 access routes

4.9.3 Finding Route Balance

Routes must have a balance between the school capacity and the needy that will use that route. To determine this, each route direction needs to be calculated in terms of its covered area and its school's capacity. The best proposed routes are those that have each direction in a covered area equal to approximately the capacity of their specific school. Therefore, there are two processes here that are noteworthy; the first is to find each route direction covered area, and the second is to find which schools are traveled by each route. Figure 4.38 is a model for separating each covered route direction, and Figure 4.39 shows the separation of the school layer into each route direction.

Initial steps for calculating each route covered area in the Figure 4.38 is similar to the finding lucky area process. The difference is that there is no process implemented by two or more routes. Each route is processed by itself. After begin separated and buffered, each route area continues to be used for clipping the sub-sub-district area. Then, with each calculated process, each route will have a number of needy in each area.

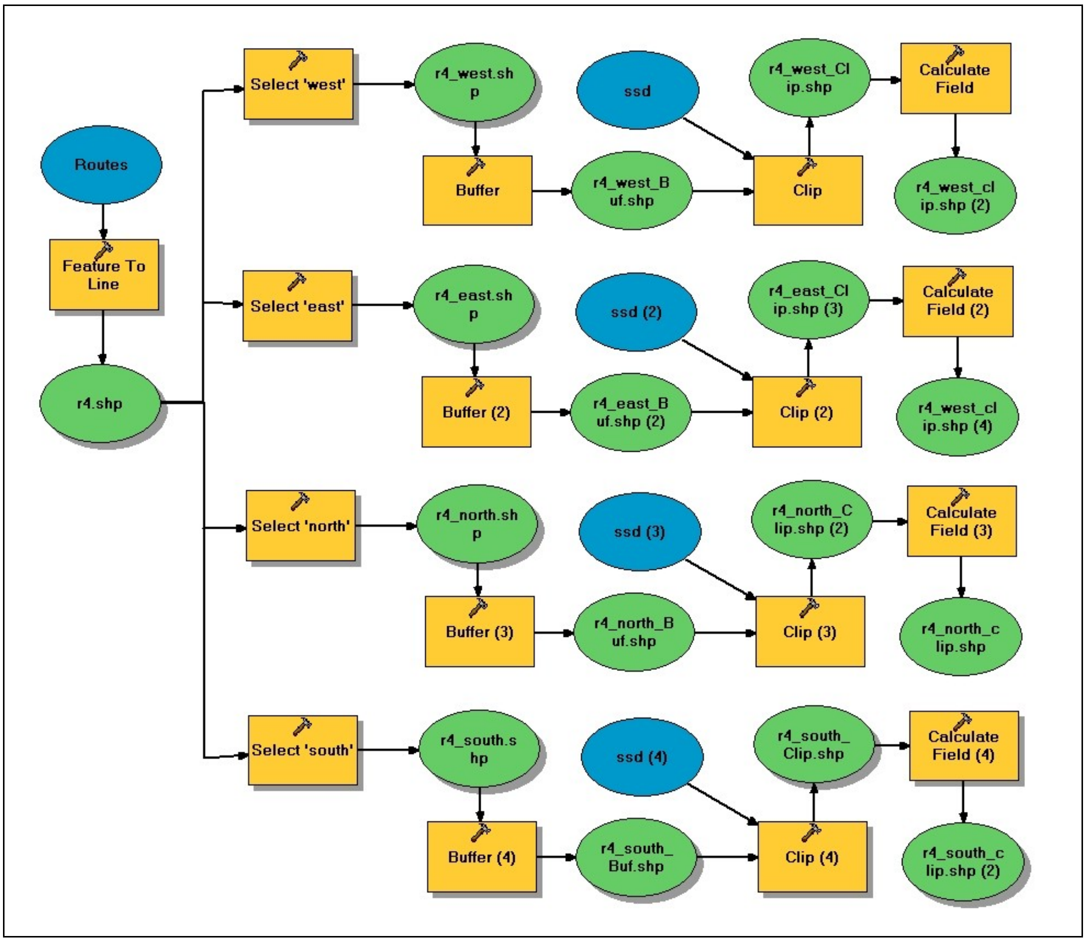

Figure 4.38. Model for separating each route and discovering each covering area

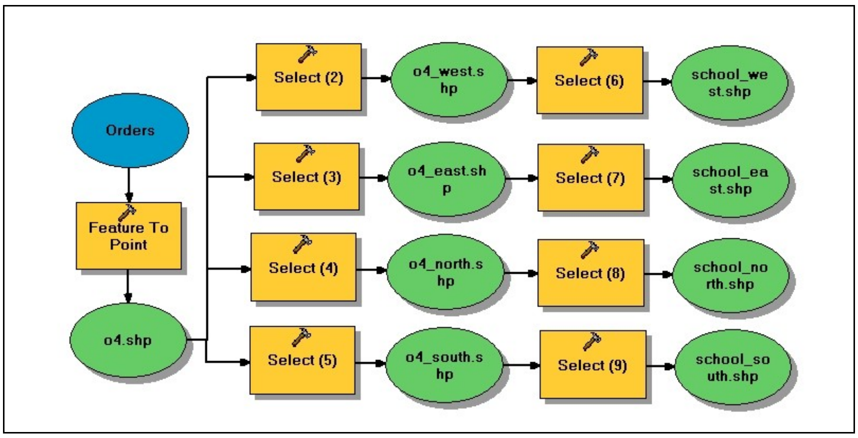

Figure 4.39. Model for separating schools by its route.

In processing the schools, the first step is separating each school in each route. The process entails using the Orders sub-class function. After VRP process, the Orders have a field ‘Routename’ that indicates what route they are assigned to. This sub-class is first exported as point Feature, and then continues with select for each route name. After this step, there are 4 different layers---orders for each direction. Orders have two different types of points which are schools and visiting points. Therefore, each layer can then be filtered again with select function to eliminate the visiting point and just leave the school point intact.

4.10 Analysis Process

After the VRP process has been done and the output is assessed, the most optimal route is chosen. Until that phase, the geospatial technology has been used for preparing the appropriate input for the VRP engine and doing assessment of the VRP output. The ability of others functions in geospatial technology will be used to enhance the existing result. The route will be analyzed to predict the load of passengers that changed from time by time in each route. The number of passengers can be used to calculate the number of required bus fleets. The addition of a number of bus fleets will make changes in the accessibility of the transportation system. Therefore the next process is to view the differences between accessibility levels of the transportation system before and after the school bus addition.

4.10.1 Load Analysis Process

In general, there are 3 big processes in load analysis. These include dividing each route into a small part, calculating the dynamical of the number of passengers in it, and then effectively and accurately presenting this change The number of passengers is affected by the needy that get into the bus while passing the needy settlement, and the needy that are neglected or left behind when the bus arrives at a school. A 3D model will be used to present this changing condition so it will be accessible and easy to understand.

The first step entails dividing the route into small parts. This part will have a sequential id number that is incremental from starting depot to end depot. For accomplishing this, manual steps have to be completed. First, each route has to be edited. In the edit mode, with a Divide function, the route will change into parts. This function needs a parameter that sets how many parts are to be made or how long each part is to be cut. This project uses the parts length as a parameter and again sets it with a value of 300 meters.

Next, every part needs to be calculated in terms of how many needy surround them. A series of buffer, identify, select, and dissolve processes need to be conducted. The number of surrounded needy are then copied in the Load field of the parts. The process is similar with the process presented in previous chapter which outlines the method of calculating street load. The difference this time however, is that the calculation is not in each street but in street parts.

If this needy covered value of each part is summed up, it will produce a total number that is greater than the total number of the east route covered area. It is because there are some parts which have a sharing area that are counted twice. Therefore, it is advisable and rationale to proceed with making another field called AdjLoad from the term adjusted load, since this field is filled in with a number of loads that have been adjusted. This way, the total number of all parts will be the same number as the total number of the route covered needy area. This calculation formula is AdjLoad equal to value of Load field, multiplied by covered needy of the route that has been divided with the total covered Needy of each street part.

The above process will produce a map like that shown in Figure 4.40 below. The picture illustrates the parts of East route. Each part is colored with different colors to clearly show the parts. It also shows that in each part there is a buffer area. Some buffers could not be seen because they were covered by other buffers from other parts.

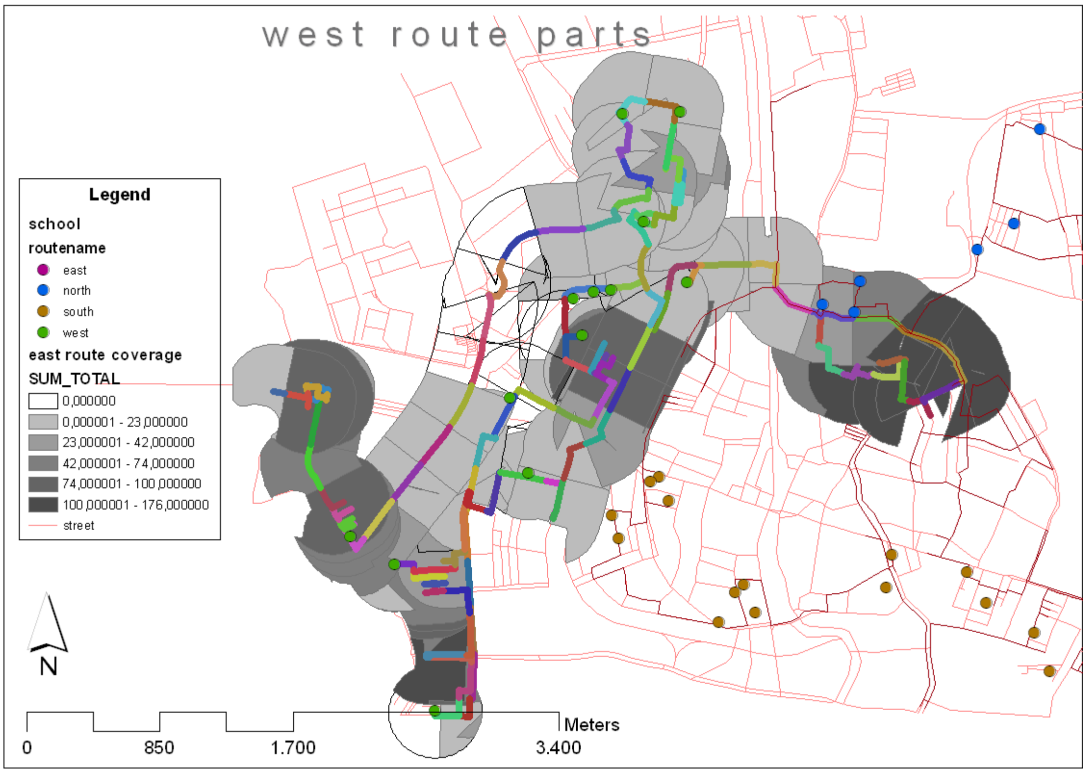

Figure 4.40. example of dividing route into parts for load analyst.

The next process is determining the details of the capacity, and for this we must make use of the Capacity field. This field is manually filled in by looking for the parts which have schools nearby. This involves looking at the capacity of the school and then this value is written into the Capacity field. The next process involves calculation. For this process, the fields which need to be added are TempLoad, Loss, GoTake, GoLoad, BackTake, and BackLoad. TempLoad is for counting the load for the first step. Loss is for saving the number of potential losses in terms of school capacity. This can happen when the number of bus passengers is less than the school capacity which then creates an imbalance.GoTake field is used for saving the number of needy that take the bus in each part when traveling from the center depot in destination, while GoLoad is the sum total of GoTake while going along the route. BackTake and BackLoad is similar, but for the contra route. These fields fill in with a little visual basic program using an algorithm such as that presented in Figure 4.41 below.

Step 1

Calculate increment of passenger part by part from center depot to destination. Also calculate losses that happen when they meet a school and the number of passengers is less than school capacity.

```
 for i = 1 to N
   for j = 1 To i
             residue = total_load + adj_load(j) – school_capacity(j)
              If residue < 0 Then
                 loss = 0 - residue
                 residue = 0
                 total_load = 0
              Else
                 loss = 0
              End If
           total_load = residue
      next j
     Update field TotalLoad of record i
     Update field Loss of record i
   Next i
   last_residue=totalload
```

if step 1 have a residue in the last part (totalload of part N > 0) continue with step 2 and 3

Step 2

This step will calculate passengers that take part by part, but from destination to center depot. The school capacity is changed with the number of Loss field in that record. Continue with Calculation of accumulation of passenger part by part from destination to center depot with value of load in each parts taken from this field BackTake

```
 for i = N  To 1
          total_backload = total_ backload + passenger_load(i)
           If total_backload < last_residue Then
                Update field BackTake of record i with passenger_load(i)
           End If
    Next
 for i = 1 to N
    For j = 1 To i
             residue = back_load + Field BackTake(i) – (field Loss(i))
              If residue < 0 Then
                 residue = 0
                 back_load = 0
              End If
           back_load = residue
      next j
     Update field BackLoad of record i
   Next i
```

Step 3

Re-calculate the load from center depot to destination with new passenger_load, the new value after the original passenger_load substracted with back_take in step 2. save in field Go_take

```
For i=1 to N
    Field Go_take = Passenger_load(i) - field back_take
Next
for i = 1 to N
    For j = 1 To i
             residue = total_load + Field GoTake(i) – (School_Capacity(j)-field loss(i))
              If residue < 0 Then
                 loss = 0 - residue
                 residue = 0
                 total_load = 0
              Else
                 loss = 0
              End If
           total_load = residue
      next j
     Update field GoLoad of record i
   Next i
```

Figure 4.41 Algorithm for filling the load analyst fields

For illustrating the above algorithm, let's create a simple example. In this example, there are 10 street parts and order are in place already at its sequence. For making light of the calculation, all records are set to 10 in the AdjLoad field. It means in all parts there are 10 passengers. The schools are in the fourth, sixth and eight parts, with capacity 30, 30 and 40 respectively. Figure 4.42 illustrates this example. This example will then be calculated by the above algorithm. Table 4.6 will show the value of calculation field per row in this example.

The first step runs from first part to end part. It will sum the total capacity from parts it has traveled. In the second part, the TotalLoad is 20, because it has 10 passengers from the first part and 10 passengers from the second part. It shows the same condition in the third part. In the fourth part the capacity is 30. Here the TotalLoad value is 40, but because there are schools here with capacity 30, the passengers will fill in the school capacity and the rest of the passengers are 10. In the fifth part, it collects more than 10 passengers so the total passengers are 20. There is a school in the sixth part with capacity 30. With an added 10 passengers, all passengers can then get out of the bus and fill in the school capacity. The load is now 0. Continue the traveling, and in the seventh part collect 10 passengers. While it has more 10 passengers in the eighth part, making the total 20, all passengers then leave the bus and fill in the school capacity with value 40. Because there are 20 passengers for 40 capacities, there are 20 seats that cannot be filled. This value writes in the Loss field. With 0 passengers, it moves to the ninth part and collects 10 passengers and also continues in the last part. While stopping in the last part, it still has 20 passengers who cannot fill in any school because the journey has ended. Because of this dilemma, there is more step to solve this problem. The 20 passenger is saved in to last residue variable.

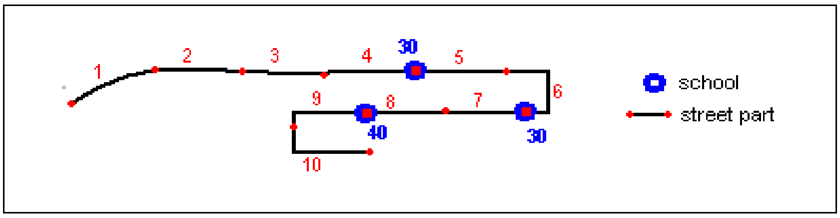

Figure 4.42. Illustration of the example case

Table 4.6 Example process for illustrating the algorithm

Part Seq.	Adj Load	Capa city	Step 1		Step 2		Step 3	
			Total Load	Loss	BackTake	BackLoad	GoTake	GoLoad
1	10	0	10	0	total backload already same with last residue	0	10	10
2	10	0	20	0		0	10	20
3	10	0	30	0		0	10	30
4	10	**30**	10	0		0	10	10
5	10	0	20	0		0	10	20
6	10	**30**	0	0		0	10	0
7	10	0	10	0		0	10	10
8	10	**40**	0	20		0	10	0
9	10	0	10	0	10	20	0	0
10	10	0	20	0	10	10	0	0

→last residue =20

The second step runs from end part to the first part. The step also collects and sums the part AdjLoad field. However, it just runs until the total summed is no more than the last residue variable. In the tenth part and also in the ninth, it collects 10 passengers. It has 20 passengers and can then stop the calculation because it is already comparable with the last_residue variable. The collected passengers save into BackTake field and the sum is saved into BackLoad field.

The BackLoad field indicates that this route will need a bus that travels contra the destination. It needs to travel reversing the route because there is some needy student who needs to travel into the center depot, because the school is not in the destination but in the way to the starting depot.

The third step is for correcting the first step. It includes the needy that need to be covered by the route and are not yet covered by the Inverse route. The number of needy that not be taken by the inverse route will be saved in the GoTake field. Then, with the

GoTake field replacing the AdjLoad field, a calculation similar to the first step needs to be conducted. At the end of the journey, the bus in the direction will not have any unschooled needy. The rest have already been taken by the bus in the inverse route. The maximum number of passengers in the direction route is 30, while the inverse route maximum is 20. If a minibus with a capacity of 10 passengers is being utilized for this transport job, the direction route needs 3 buses while the inverse route needs 2 buses. Figure 4.43 Illustrate this needed fleet.

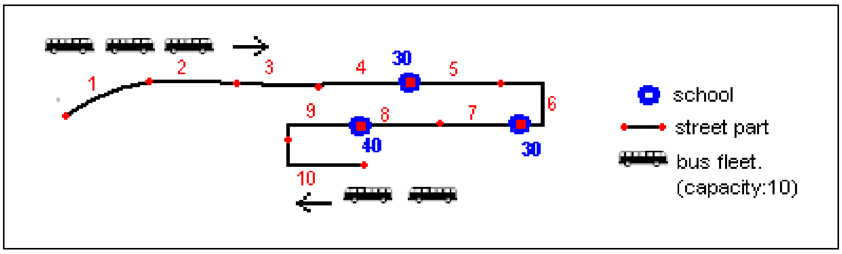

Figure 4.43. Illustration of bus fleet needed

4.10.2 Accessibility Analyst Process

This section will explain the affect of the new school buses, if they are to be provided, with respect to accessibility of transportation media for the secondary school student. This analyst will produce two accessibility maps. One will be for the existing transportation system, and the other will be for the new transportation system after added school buses.

The process is referenced by the existing transportation system in section 3.7 and the number of bus fleets taken from the load analyst output. All transportation media have a number of fleets, a capacity, and a number of secondary school students who use the media. This process is for presenting what the characteristics of the existing transportation system are. The output is an accessibility area map that can be used to discover where areas are adequate and where they are not. It uses a buffering process with 300 meter distance set from each route.

In order to get better representation, we will not just generate from the one flat area in the existing transportation system, but also provide an accessibility grade. This grade is calculated by summing up all opportunity value in using the transportation system in all study areas. The opportunity value is the capacity of the vehicle multiplied by the number of fleet in its route. The process to make this accessibility map requires several steps including repetition process with different data. Therefore, again, an Arcgis model needs to be built.. The distance to the route will be set as a parameter, so it can be changed easily when used by another application with a different distance value. Each lyn and bus route becomes the input. Each of those will be used in the buffering process. The buffer output is equipped with the accessibility value. It can be seen in the Figure 4.44 below.

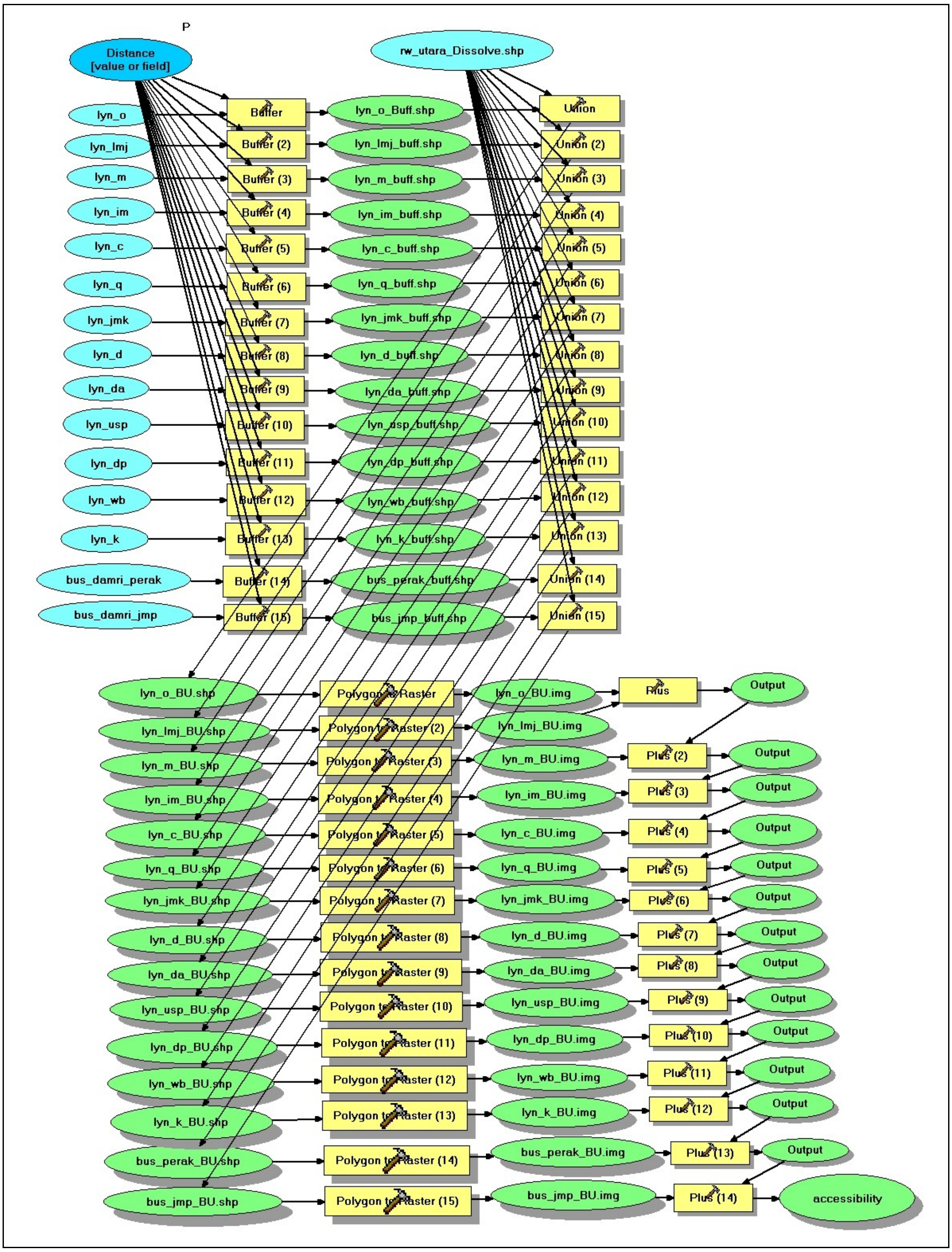

Figure 4.44 Model Diagram for generating accessibility map

The accessibility value of each medium needs to be summed up. The summing up process will be easier to complete in the raster type map. Therefore, after the buffering process, all output is converted to raster. But before this can happen, each layer must be made fully covering all study areas, as leaving out the 'blank' value can adversely affect the results. The process involves Union-ing the buffer result with the study area polygon that is created by dissolving the sub-sub-district map. After the union process, it continues with converting polygon to raster process as it becomes ready for summing up with Arithmetic Plus function. After using plus operator, some areas will have a high level number if there are a lot of seats summed up from many different routes. On the other hand, another area with fewer routes and fewer seats around it will have a low accessibility level.

Uncovered Needy

After finding a number of people that can access the transportation system before and after the addition of a school bus (as noted in the previous section), we will now calculate the opposite side---that is the number of needy that cannot access the transportation system. The model for doing this is like that show in figure 4.45 below.

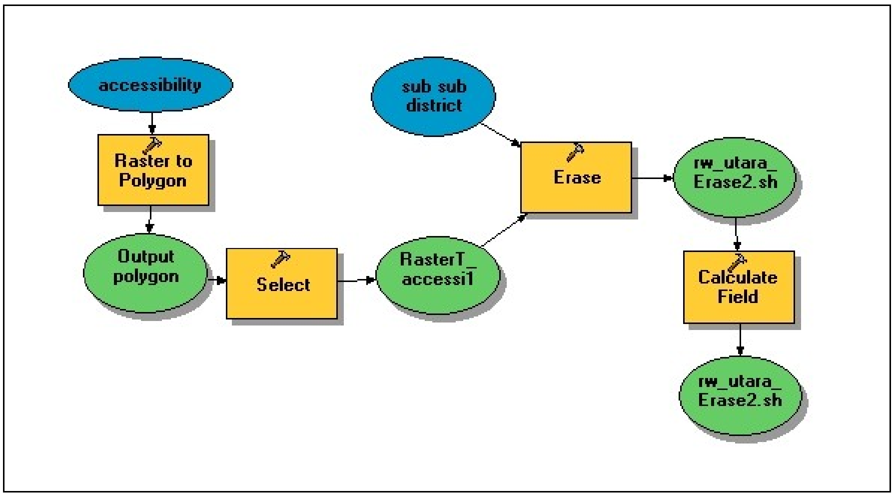

Figure 4.45. Model for generate uncovered need map

Figure 4.45 shows that the accessibility map in the previous section, which is a raster file converted into polygon (vector). This conversion is needed to conduct the next steps since it will be collaborative with the sub-sub-district map or block map which is in vector type. The block map will be cut with the area in the accessibility map. Before the cutting process however, the accessibility map has to make a selection to get the only area that has an accessibility level. In other words, selecting those which have accessibility level >0. The cutting process will be done with the Erase function which will erase area in the accessibility map in the block map. Consequently, the block map then has to recalculate the total needy in it because there are changes in its shape.

4.11. Summary

This chapter further exemplifies and seeks to explain the data development and GIS development. By finishing this chapter, the reader has learned and visualized how the conceptual framework in chapter 3 is being implemented, how data collection in being processed, and how the uses of several geospatial functions have been applied. This chapter first introduces the initial data need to be provided in this research. The then will used in a several processes. The first process had to be detailed with respect to how to refine the needy area. This process needed to be conducted because the needy surrounding the school is forced to go to that school and it is not necessary to take a bus. The next process introduced is how to create a visiting point. Visiting points need to be generated in order to make sure the school bus will visit regions with plenty of needy. Next, in order to count the total passengers in the school bus journey, a process which calculates street load needs to be conducted. After all these preprocessing steps, this chapter continues with an explanation of the VRP stage. Starting with the building of special formatted data called network dataset, the chapter continues with the VRP classes and a discussion relating to the setting up of data for research in this class. One of the components in the VRP classes is Routes. The explanation continues with an inspection process that needed to be conducted for the purpose of discovering how many routes are needed to cover all schools appropriately. It is discovered that the number of routes is 4. In each route, the start and the end depot have to be determined. All variations of this start and end depot will be conducted in next chapter. Each result of VRP process in different settings needs to be assessed. This chapter continues to explain the process in this assessment. There are explanations about how to calculate covered area, shared area, and route balance. By comparing the assessment value of each output, the most optimal route will be chosen. The chosen solution will then progress to the analysis process. This chapter ends with an explanation of load analyst process and accessibility analyst process. All processes are built based on an ArcGis Model, therefore all steps in this methodology can be performed repetitively with different variables or parameters. The result of this data development will be clearly explained in the next chapter.