CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter will review the methodology and the research process, the outcomes, some suggestions for future improvements, and the concluding section. A macro or "big picture" perspective will be provided so that the purpose of the research is revealed along with a better understanding of the work that has been conducted to achieve the research results. Specific chapters contain details for those who have an interest in a certain niche area and would like to obtain a wider scope of analysis and understanding.

6.2 Overview of the Research

This research is a collaboration of spatial techniques and the vehicle routing problem (VRP) engine in the transportation problem field. Unlike other VRP research which focuses on the advancing algorithm and methodology used, this research is focused on the use of spatial techniques for providing good inputs for VRP engines, choosing the most acceptable output, and then analyzing the results. This collaboration is used for finding the optimal route of school buses. The school bus in this research is a free school bus whose daily operations are managed by the government to ease the burden of transportation costs for needy students.

The purpose of this research, which can be reviewed in chapter 1, is to help city government analyze the transportation costs and benefits associated with using a school bus for supporting their needy students. The study area is in Surabaya, Indonesia, and an introduction to Indonesia as well as Surabaya itself can be reviewed in this chapter. Because of the time constraints, the study area focuses on the northen area of Surabaya

which has been chosen because the concentration of needy students in this area. The rationale and background of this research is because the number of children who cannot go to school because of their inability to cover school costs in this area. Even though the city government has abolished the tuition fee and granted some money for buying school supplies, a lot of needy children still remain unschooled. This research is focused on developing a methodology and model in order to aid the government in its decision to implement school buses which will in turn assist the needy by easing their transportation costs.

Before this research commences, there are intensive explorations in several research areas which are related with the research. This exploration is required prior to setting up the methodology and working with any data or tools in this research. All the results of these initial processes are documented in chapter 2. In this chapter, readers will be introduced to several different areas of knowledge related in this research. Starting with a thorough understanding of school buses and types, followed by an introduction of the specific type of school bus used in this research, we continue with a discussion of the characteristics of the needy student. A needy student is a child of school age that lives within a needy family. The characteristics of a needy family have been determined by city government who collect the information to create a needy family database. This chapter then continues with literature studies, which explore previous routing area research, and provides more detail regarding previous School Bus Routing researches. This literature is used to compare the work and the position of this research. Literature studies regarding accessibility research are also examined in order to find the useful and appropriate analyst that can be used after working through the routing process. This chapter ends with a discussion to educate readers about ArcGis Network Analyst Function which will be used for the VRP process.

After providing a solid base of understanding regarding previous research, the work continues to conceptualize the processes that needed in this particular research. Chapter 3 explains the route finding method and route analyzing process as concepts that will be used in this research. In the conceptual framework of route finding, readers will figure out how the VRP process and the VRP output assessment will be done manually. The explanation is illustrated with the use of simple figures to provide a better understanding. The key of the routing process is that the route must be covered as much as possible by needy student areas. In other words, the route must be a visited area that has a high concentration of needy students. The analyst process is the same; the process of load analyst and accessibility is presented step by step with simple examples.

Variable and notations also explained in this chapter before moving to make the concept more technically in methodology schema. Methodology schema contains the methodology that is used in order to achieve the goals of this research. In this scheme, there is a conceptual flow which shows the processing of data stage. The methodology is built in 3 stages: data preparation, VRP and assessment process, and finally the analyst stage. The next part of this chapter is about the geospatial technology that will be used in the whole process. There is an explanation about the ArcGis Model which all processes in this research were built upon. In the developed models, there are several geospatial functions that are used to manipulate the data. These include: select function, calculate function, buffer function, clip function, identify function, dissolve function, update function, union function, intersect function, join function, and feature to point function. The last section in this chapter provides an explanation of the ArcGis ArcScene that will be used for representing the analyst result in 3D.

After the concept has been figured out, and the technology relevant to the research has been explored, the next step is to develop the data and GIS model. Chapter

4 is starting with an explanation of the study area and the underlying characteristics of the city region school bus routes. There are explanations about the Surabaya region and how to present the needy database in this region. This chapter also explains the most important data of the routing process which is the street network. The street network for the routing process is different than the usual street map used in common GIS applications. It has to follow a special format before transforming to a Network dataset that can be used in ArcGis Network analyst. The street data is the most time-consuming object in the survey and in the preparation process. This chapter also shows where the schools and bus depots are located. In order to see the effect of a school bus in the transportation system, data about existing transportation system characteristics also need to be collected. After explaining the data, this chapter continues explaining the process in stages listed in the methodology. In the preparation stage, there are several important processes. The first process involves refining the needy area. This process needs to be conducted with the assumption that the needy students surrounding a school can be forced to go to that particular school and not necessarily take a school bus. This will change the school capacity, because some seats are already filled by surrounding needy students. It also changes the shape of potential passenger areas. The next important process is generating a visiting point. Visiting point is the location that has to be visited by the school bus. This location is generated in the area with a high concentration of needy. Next, the street load must be calculated. The result of this calculation will be used in the VRP process in order to check that the total number of passengers in the route does not exceed the total capacity of schools on that route. In the routing stage, there are explanations related to how the street data is used to generate a network dataset, and how this dataset and other data will be used to fulfill the requirement data in the VRP Class. After setting the VRP class, the process will continue to reveal how many routes are needed to cover all schools with an appropriate

coverage of needy students. It is then discovered that the number of routes is 4 which represents four different destinations; west, east, north, south. After the number of the routes is found, the next step is discovering how to assess the routes so that every different setting generates different outputs which can then be appraised. The values of each result will then be compared to determine the optimal one.

There are several aspects to be assessed. These include the balance of the load of passengers along the route in relation to the capacity of schools on that route, how the total needy can be covered, the consumed time in the journey of the bus, and how many needy live in the shared area. Each of those aspects, except the consumed time, is needed in a series of processes. Chapter 4 also explains the detailed process of how to calculate those aspects. After an explanation is given with regard to choosing the optimal route, this chapter moves to a discussion of how to analyze the chosen route. There are two analyst processes; the first is the load analyst. This analyst will make a prediction of passenger flow time by determining time in each route destination. The section for this analyst is provided with the algorithm in finding this flow. A little programming script needs to be done because there is no ArcGis function that can be used to automate this process. This analyst will show the flow of passengers in 3D perspective. Output of this analyst is a number of buses that need to be provided in order to cover the passengers in each route. This number of buses is then used for completing the existing transports system media. The effect of adding new school buses into existing transport will be analyzed in accessibility analyst. This will compare the accessibility levels before and after the school buses have been added.

The research steps then move into the repetitive work which is the implementation of methodology. Chapter 5 records this implementation process. This chapter lists all results of VRP process and its assessment values. There are 3 different listings. The first listing is the VRP without directing the group of schools. In this

setting, the VRP will freely choose what school to join in what destination route. All the results of this setting point to a failure in the route balance aspect. In order to comprise this, a direction for the routing area is need to conduct . It has already been determined which schools are in the west, east, north and south routes. There are 2 different grouping areas so it will use 2 different listings. The most optimal route is the one that lies in the last listing. It has appropriate load balance, provides ample coverage for the needy, and a reliable amount of time consumed. After the optimal route is chosen, this chapter then details the route before continuing with the implementation of the analyst process. Each route destination is then processed in the secondary application which is developed using Visual Basic 6 and Esri MapObjects library. This application will calculate and fill the fields in the database. The Field that indicates the value of the passenger flow is presented as Z value in the ArcScene.Route segment, with a higher load viewed as a higher wall and segments with a lower load seen as a lower wall. When using the calculated passenger flow in this load analysis, the number of buses has to be provided in each route is discovered. This number was then used in another analyst which is the accessibility analyst. The particular analyst is conducted to discover the effects of the new bus route, with numbers of provided school buses, in the accessibility of the transportation media. This analyst reports an output as a comparison map which compares accessibility level before and after the school buses system is adapted.

After the implementation, all the steps will then be reviewed, the findings unveiled while working through the research will be explained, and the results of the research will be concluded. This chapter, Chapter 6, is the concluding chapter in our research. We have reviewed all the information put forth in the previous chapters in this section. The next section will go on to explain the finding and outcomes of the research, and finally continue with proposing a positive initiative related to the research findings.

6.3 Research Findings

There are several major findings which need to be considered. When exploring previous school bus research, it is found that all the previous research uses the exact address or exact point position of the student. The data for this research is not as detailed so there had to be an adjustment in the method used to determine the exact position of the house. In other words, this data needed to be represented in another form. It is then determined that a polygon area map can be utilized by filling up the number of students in each polygon. The more detail the polygon area, the better it can reflect the student house positions. The polygon needs to be more detailed than the official sub-district area, so a field survey and a mapping of the block data have to be conducted. Even though this mapping consumes 1 month of work, it is still far less time than the time required to make a map of all student houses.

It is also found that the city has a lack of existing transportation system data. For this reason, another field survey needs to be conducted in the collecting process of the existing transportation system. There is no map of existing transportation route and there is also no official information regarding the number of vehicles passing the route in a particular time frame.

In exploring accessibility subject, it is discovered that the distance is the most important parameter. The distance represents the acceptable walking length for people to obtain transportation services. The distance used in the previous researches varies from 400 to 600. This research follows previous works that used the distance parameter as the significant parameter. However, because the object in this research is children at secondary school ages, some factor need to be taken into consideration because they will decrease the distance parameter. For example, environmental factors such as humidity present a challenge, as do the street facilities in Surabaya area which may not

be as comfortable as those presented in the previous research's area. The number that will be used in all distance parameters in this research is set at 300 meters.

While exploring the appropriate technology, especially the network analyst technology, it is discovered that the street data is very important and the quality has to be seriously considered. In order to make a good output of the analyst, the network dataset must be perfect. The street data, which will be generated into network dataset, is the key of the network analyst process. It must have perfect vertex to vertex joins and must have perfect attributes that represent the real condition and characteristics of the streets. The special format of the street data needs to be digitized carefully and tested intensively.

After exploring the technology and then making the conceptual framework, it is noted that there is no function to overcome it, in the methodology step, so this calculation is done in a different application. The application for doing this calculation is built in its own programming script that works with MapObject library, a GIS engine that was also built by Esri. Another process that cannot be done easily with the functions in Esri ArcGIS 9.0 is the reducing redundant area process in refining the needy area step. But, unlike the calculation of the passenger flow, the methods for this process cannot easily be implemented in its own programming script. It is then decided that the process for reducing the redundant area must be done manually. Still, with the ArcGIS technology, it is found that Esri have developed a very useful environment approach in mapping process and map and data manipulation. That is the ArcGIS Model. When developing this research in a Model based environment, it saves a lot of time which could otherwise be wasted in repetitive work.

By doing vehicle routing process many times, it is found that the VRP engine performs very well with respect to optimizing the route. However, it is not yet equipped with a function that focuses on route balancing. In this research, the balancing of the

route is achieved by directing the route to cover just its particular area. Route directions are forced to discover the optimal routing to visit schools in their own direction. This is achieved by using grouping parameters that lie in the Orders dataset.

From the load analyst process, it is discovered that the passenger load along the route is often in maldistribution. In some route paths, the passenger numbers are excessive, while other routes experience a shortage. However this research does not cover this problem. Instead, this research uses the maximum number of the passenger load in each route for calculating the amount of the buses which needs to be provided.

This research has some differences among school bus researches. The main aspect is in all those researches, the number of bus or bus capacity is determined, while in this research the number of bus is being objective. Other differences are shown in table 6.1 below.

Table 6.1. The School bus routing problem research

Reference	Problem type	Objective	Constraint
(Bennett & Gazis, 1972)	Single school	Minimize total student travel time	Bus capacity
(Dulac et al 1980)	Single school	Min (total distance x number of routes)	1. Bus capacity 2. The number of stops 3. The length of a route
(Chen & Kallsen 1990)	Single school	1. Minimize the number of buses required 2. Minimize fleet travel time 3. Balance the bus loads	1. Bus capacity 2. Student riding time 3. School time window
(Bowerman et al 1995)	Single school	1.Minimise the number of routes (buses) 2. Minimize total bus route length 3. Balance bus loads and route lengths 4. Minimize student walking distance	1. Bus capacity 2. Travel time on each route 3. The total travel time
(Nayati, 2008)	Single school	1.Minimise the number of routes (buses) 2. Minimize student walking distance	Bus stop location
(Bodin & Bermen ,1979)	Multi-school	12 Minimize total bus travel time	1. Bus capacity 2. Allowable student travel time
(Braca et al,1994)	Multi-school	Minimize the number of buses needed	1. Upper and lower bounds on bus capacity 2. Student riding distance 3. School time window 4. Earliest pick-up time
This Research	Multi-school	1. Minimize the number of routes needed 2. Balance of passenger and school capacity 3. Calculate the number of buses	1. School time window 2. Depot locations 3. School groups

6.4 Outcome of the Research

The optimal route found in this research has been verified and evaluated. For verification processes, a field simulation has been conducted. With the same starting time and using a normal speed, a car has been used to travel along the route to represent of a school bus. This process is used for checking whether the time windows of each route segment are reliable. The result of this ground checking is that the car has gained more free time than indicated on the schedule. Therefore, the schedule and the route are acceptable.

For the evaluation process, this research has been shown to the Head of Empowering Department of Surabaya whose job is to support needy families and reduce their numbers in the city. He has provided a positive response and commends the research and methodology used. The methodology is acceptable for finding the best route and describing the flow of passengers. However, it cannot be implemented immediately because it requires significant financial support and intensive coordination with other departments such as the Department of Culture and Education, the Department of Transportation, the Financial Department, as well as the school authorities, and the city council. He also suggests and supports the use of this research for the whole Surabaya city data, considering that this research is limited to the North Surabaya data.

In working on this project, several outcomes have been brought forward. A map of sub-sub district or block area, a map of needy student areas, a map of streets equipped with bus speeds in each street segment in the network analyst ready format, and also a map of the existing transportation system has been created and is now ready to be reuse in another research. Characteristics of the existing transportation system were introduced. Methods for preparing the appropriate data for VRP engine have been conducted. The new VRP analyst function, introduced in ArcGIS 9.3 in 2009, has been

explored and is now ready to be referenced by other vehicle routing problem or network analyst researchers. Methods in spatial techniques for choosing the output of this VRP engine have been introduced. A method in spatial techniques for detailing and analyzing the output of this VRP engine has been conducted. A method for calculating the load of passengers has been scripted. Methods for comparing the before and after accessibility of the transportation system have also been built. Because all processes in this research have been built in the ArcGis model, several ArcGis models for different purposes have now been developed and are ready to be re-used or implemented with other data. The methodology that replaces the need for having to know the exact position of passenger house locations with the weighted areas is a new approach in the bus routing research. With this approach, this model will also be applicable to other areas of the world that have insufficient map data, such as many cities in the developing world.

6.5 Suggestions for Future Research

There have been a lot of important tasks accomplished in this project, and these research results provide a solid groundwork for future exploration in the area of optimal school bus routing. For the government of the city of Surabaya, this research cannot immediately be implemented because findings are limited to the north area of Surabaya only. This research omitted data outside the north area. A broader understanding and application of the research across the whole city can now be completed and referenced at a future time by government officials. This outcome from this project has helped to build a solid foundation and rationale for further investigation and discussion regarding the school bus transportation for the needy.

There are more aspects of this research which can continue to be built upon going forward. This research has assumed that all parts of the street can be used for picking up passengers which can be problematic. This assumption could lead to a

dangerous situation if crowded traffic areas or other hazardous road conditions are not taken into consideration. More research in this area may tackle this assumption by providing specific areas that can be used for bus stops, and then introducing some methods that optimize bus stop placements.

In the chapter 4, there is a manual trial and error step. This is the step for inspecting how many routes can cover all orders. Fortunately, this research does not take a long time to discover the number of routes. However, in different research areas, it may not be the same case as in this research. So, there exists an opportunity to make a method for calculating how many routes must be provided to covers all orders.

In the load analysis, there are some areas of street segments that have been calculated twice or more, and this makes the total area of each part of the street more than the covered area of the route. In this research, this covered area of each part must then be adjusted with a simple method. For a better result, more sophisticated methods to calculate the sharing area should be applied so that this adjustment is not required.

However in the load analyst, it is discovered that, as a result, the routes often have a maldistribution of passengers. This is an open opportunity for conducting research that eliminates this flaw. With this research, not just the balance of passengers between one route and another is guaranteed, but also the balance of the passenger load along the route destination. The impact of this research will result in the elimination of the number of needed buses and make more efficient and greater use of buses.

For a GIS programmer, a set of processes from the raw data until the analyzed output can be bundled in one single specialty application. A user can just browse and select the input data, the street, the schools, the depot, and the needy area. Next, with one click on a run button, the best routes can be shown, equipped with the details and all the analyzed output.

6.5 Conclusion

This research aims to provide the city government with a tool for analyzing the possibilities of the use of the school buses in supporting needy students in their transportation costs. After exploring the existing work in the school bus field areas and collecting the city data, it is then noted that the city has a lack of data for doing the analysis. Field surveys have been conducted in order to meet the needs of the research. However, given the time limitations in this research, the work has had to take a different direction and approach than previous school bus research. This research has had to discover methodology that meet the timeframe and deliver acceptable results.

The methodology in this research has made light of the needed data by using a block map and number of customers, the needy student in this case study, instead of knowing every house location of the customer. Even so, with assessment process proposed in this research, the pattern and correlation between the needy and the schools can be discovered, and the optimal solution can be chosen. The use of geospatial technology makes the limitation of raw data work well in the VRP engine. This methodology can also be used by other cities which lack important map data.

The result of this research has been accepted and has received positive response from the government. The results are compelling and provide a springboard for further discussion around system requirements, the services that can be delivered, and the effect of introducing changes to the existing transportation system. Importantly, this research is developed based on a reusable Model. Therefore, although the study area is limited to a portion of the city area, it is not necessary to re-build or "reinvent the wheel" by having to do the work again from scratch. The foundation is well set for those considering further studies which apply to the whole city.