

**FREE SCHOOL BUS SERVICE FOR NEEDY
CHILDREN IN SURABAYA: FINDING THE
OPTIMAL ROUTE USING GEOGRAPHIC
INFORMATION SYSTEM**

DANIEL HARY PRASETYO

**DISSERTATION SUBMITTED IN FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE**

**DEPARTMENT OF GEOGRAPHY
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR**

2012

ABSTRACT

Surabaya city, Indonesia, has a considerable number of unschooled children. Even though the Government has eliminated the tuition fee, the number of needy school aged children remains high because of additional schooling costs beyond the tuition fee. The Government tries to support the needy student population by donating money for books, uniforms, shoes, and other school supplies, and would also like to offer help by easing transportation costs. The distribution of upper school make the traveling length and traveling costs excessive, compared with lower level schools. This goal of this research is to provide a clear framework of methodology and analysis which will serve to assist the government in analyzing the probability of the use of school buses in supporting the needy with their transportation.

The work begins with an exploration of the research area and the related technology. This research is in the vehicle routing problem area, with a special emphasis on the school bus. The environment is an urban area, with uniform fleet, across multiple schools. Within this concept, that data that will be required is defined. This research requires a needy area map, street map, school map, depot map, and existing transportation map. The concept then details in a methodology. From the methodology it is noted that there are several types of work which must be completed over 3 broad stages: preprocessing, routing and analyzing. In the preprocessing stage, the needy area must be refined, the network dataset needs to be built, and the visiting places and the number of passengers in the street segments need to be generated. In the routing stage, some experimentation is required and is useful with respect to looking at the street network in different settings, discovering how many routes need to be provided to cover all needy areas and school locations. There are two analyst processes in the analyzing stage; load analyst and accessibility analyst. The load analyst will show the passenger flow characteristic and the accessibility analyst will show the effect of the school buses in the existing transportation system.

Several models have been developed for different functionalities. The routing model is used repetitively and each output is assessed and compared. This assessment is based on load balancing, number of covered needy, time consumed, and shared area. The best route is then discovered and analyzed. Finally, the route is evaluated with ground checking. The positive results of the research and its methodology are twofold: the methodology provides a framework for analysis that can be easily and effectively used by government to make decisions regarding the creation of practical and acceptable bus routes to help needy families. Secondly, the methodology also provides a useful new starting point in those cities across the world that lack sufficient spatial data in conducting VRP research.

ABSTRAK

Bandar Surabaya, Indonesia mempunyai ramai kanak-kanak yang tidak bersekolah. Walaupun kerajaan telah menghapuskan yuran pengajian, tetapi bilangan kanak-kanak miskin yang tidak bersekolah masih lagi tinggi kerana terdapat kos tambahan sampingan selain yuran pengajian. Kerajaan berusaha untuk populasi kanak-kanak miskin dengan menyumbang wang untuk membeli buku, pakaian seragam, kasut dan barangan keperluan persekolahan yang lain, selain itu kerajaan juga ingin membantu mengurangkan kos pengangkutan mereka. Lokasi sekolah menengah adalah lebih jauh dari rumah dan memerlukan kos pengangkutan yang lebih tinggi berbanding dengan kos perjalanan ke sekolah rendah. Matlamat utama kajian ini adalah untuk menyediakan satu kerangka kerja dan kaedah analisis yang jelas yang dapat membantu kerajaan mengkaji kemungkinan penyediaan bas sekolah percuma yang dapat membantu perjalanan kanak-kanak miskin.

Kajian ini dimulakan dengan melakukan explorasi bidang kajian dan teknologi yang berkaitan. Kajian ini meliputi bidang *vehicle routing problem* dengan fokus kepada bas sekolah. Kajian ini dilakukan di kawasan bandar dengan *uniform fleet* dan *multiple school*. Di dalam konsep ini, data yang diperlukan telah dikenalpasti. Kajian ini memerlukan peta kawasan populasi miskin, peta jalan raya, peta lokasi sekolah, peta stesen bas dan peta sistem pengangkutan sedia ada. Konsep ini kemudiannya dijelaskan di dalam metodologi kajian. Di dalam metodologi kajian, terdapat beberapa jenis gerak kerja yang terbahagi kepada tiga peringkat iaitu *preprocessing*, *routing* dan *analyzing*. Pada peringkat *preprocessing*, kawasan miskin dikenal pasti, *network dataset* perlu dibangunkan, tempat yang dikunjungi dan jumlah penumpang pada bahagian-bahagian jalan haruslah dijana. Pada peringkat *routing*, beberapa percubaan perlu dilakukan untuk melihat seluruh rangkaian jalan raya dalam pembolehubah berbeza yang merangkumi berapa jumlah laluan yang diperlukan untuk melingkupi seluruh kawasan miskin dan lokasi sekolah. Terdapat dua proses analisis di peringkat menganalisis iaitu *load analyst* dan *accessibility analyst*. *Load analyst* akan menunjukkan ciri-ciri dari aliran penumpang manakala *accessibility analyst* akan menunjukkan pengaruh daripada bas sekolah pada sistem pengangkutan sedia ada.

Beberapa model telah dibangunkan untuk pelbagai tujuan. Model *routing* digunakan secara berterusan dan hasil model dinilai dan dibandingkan. Penilaian berdasarkan kepada *load balancing*, jumlah dari *covered needy*, masa yang diperlukan dan *shared area*. Laluan yang terbaik kemudiannya dipilih dan dikenalpasti. Akhir sekali, laluan akan dinilai dengan semakan di lapangan. Hasil kajian dan kaedah yang positif dapat digambarkan: kaedah kajian menyediakan kerangka kerja analisis yang berguna kepada kerajaan untuk membuat keputusan berhubung dengan penghasilan laluan bas yang praktikal dan diterima oleh keluarga miskin. Kedua, kaedah kajian juga menyediakan titik permulaan yang baru dan berguna untuk bandar-bandar lain di dunia yang mempunyai data ruangan yang tidak mencukupi untuk memulakan kajian VRP.

ACKNOWLEDGEMENTS

Alhamdulillah hirabbil'amin, thanks God I can finish my master thesis on time. It would not have been possible to complete this thesis without the help and support of the kind people around me, only some of whom it is possible to give particular mention here.

Above all, I would like to give my heartfelt thanks to my beloved wife Lulu for her personal support and great patience at all times. Also, to my wonderful children Atha, Shifa, Aira, thank you for all the joy and happiness you bring me each day. Finally, to my parents for their prayers and to my father and mother in law who have been looking after our baby and home, I gratefully acknowledge your commitment and faith during this time.

Also, I'd like to acknowledge the assistance, support and understanding of my principal supervisor, Prof. Jamilah Muhamad, whose advice and unsurpassed knowledge of social transportation inspires me. The good advice, support and friendship provided by my second supervisor, Dr. Rosmadi Fauzi, the most famous GIS expert in Malaysia, also deserves worthy mention.

Finally, I would like to acknowledge the financial, academic and technical support of the University of Surabaya, my lecturer friends and all staff, especially Mrs. Lisana and Mr Bambang, the head of department. Also, thank you to Codaventura crews who covered my my responsibilities while I moved to KL. I am most grateful to Sharif and Wan Arif who make KL and UM a very welcoming place for me.

TABLE OF CONTENTS

Abstract	ii
Abstrak	iii
Acknowledgements	iv
Table of Contents	v
List of Figures	ix
List of Tables	xiii
CHAPTER 1 – INTRODUCTION	1
1.1 Background	1
1.2 Statement of Problem	7
1.3 Goal and Objectives of Study	11
1.4 Research Methodology	12
1.5 Scope of Study	13
1.6 Organization of Study	14
CHAPTER 2 - STUDIES IN SCHOOL BUS ROUTING AND NETWORK ANALYSIS	
2.1 Introduction	16
2.2 School Bus Transport	16
2.3 Definition of Needy Children	19
2.4 Finding Optimal Route	20
2.4.1 VRP Types	24
2.5 School Bus Routing	29
2.6 Problem Solution Definition	35
2.7 Accessibility Concept	36
2.8 Network Analyst Technology	39
2.8.1 Network Dataset	40
2.8.2 Functions in Network Analyst	43

2.8.3 algorithm used by Network Analyst	51
2.9 Summary	55
CHAPTER 3 – RESEARCH METHODOLOGY	
3.1 Introduction	57
3.2 Conceptual Framework of School Bus Route Finding and Route Analysis	57
3.3 Variables and notations	68
3.4 Methodology Schema	72
3.5 The Geospatial Technology Used	75
3.5 Summary	83
CHAPTER 4 – DATA DEVELOPMENT AND GIS MODEL DEVELOPMENT	
4.1 Introduction	84
4.2 Surabaya City Region Characteristics Underlying School Bus Route	84
4.2.1 Surabaya City Region	84
4.2.2 Identifying the Needy School Children	86
4.2.3 The Street Network in Northern Surabaya	88
4.2.4 Location of School in Northern Surabaya	97
4.2.5 Identifying the Depot	98
4.2.6 The Existing Transportation System in North Surabaya	99
4.3 Refining Needy Area	101
4.4 Generating Visiting Point Layer	109
4.5 Calculating Street Load	111
4.6 Network Dataset	112
4.7 Vehicle Routing Problem Class	114
4.7.1 Orders	114
4.7.2. Depots	116
4.7.3. Barriers	117
4.8 Inspecting the Needed Number of Routes	118
4.8.1 One Route	119

4.8.2 Two Routes	121
4.8.3 Three Routes	122
4.8.4 Four Routes	124
4.9 How good is the Route?	125
4.9.1 Finding Covered Area	127
4.9.2 Finding Shared Area	128
4.9.3 Finding Route Balance	131
4.10 Analysis Process	133
4.10.1 Load Analysis Process	133
4.10.2 Accessibility Analyst Process	139
4.11 Summary	143

CHAPTER 5 - ASSESSING RESULT AND ANALYZING THE CHOSEN ROUTE

5.1 Introduction	145
5.2 Route Assessment	145
5.3 Undirected Orders Routes Design	155
5.4 Directed Orders Routes Design	159
5.5 The Chosen Route	167
5.6 Load Analyst Result	174
5.7 Accessibility Analyst Result	180
5.8 Summary	186

CHAPTER 6 - CONCLUSION AND RECOMMENDATIONS

6.1 Introduction	187
6.2 Overview of the Research	187
6.3 Research Findings	193
6.4 Outcome of the Research	197
6.5 Suggestions for Future Research	198
6.5 Conclusion	200

Bibliography	201
--------------	-----

LIST OF FIGURES

Figure 1.1. Map of Indonesia	2
Figure 1.2. Map of East Java	6
Figure 1.3. Grouping of secondary school area	8
Figure 1.4. Distribution of needy students at the third level of school.	9
Figure 1.5. Schema of the research methodology in this research	13
Figure 2.1. The city bus and the Lyn	17
Figure 2.2. Four different types of school bus	17
Figure 2.3. A.VRP Input: Depot and location ; B. VRP Output : Vehicle route	21
Figure 2.4. Representing route in graph	22
Figure 2.5. Concept of LAR Strategy	32
Figure 2.6. Concept of ALR Strategy	32
Figure 2.7. Example of the accessibility visualization	38
Figure 2.8. Example of a simple transportation network	41
Figure 2.9. Combination of Turn	43
Figure 2.10. Two different base attribute routing: a. time based, b. distance based	45
Figure 2.11. Examples output of Closest facility solver	46
Figure 2.12. Example output of Service Area Solver	47
Figure 2.13. Example of OD Cost matrix using	48
Figure 2.14. Example of storage data in OD Cost matrix	49
Figure 2.15. Example output of Vehicle Routing Problem solver	51
Figure 3.1. Conceptual framework diagram	58
Figure 3.2. Needy area layer (example).	59
Figure 3.3. Street, School, and Depot layer (example)	60
Figure 3.4. School layer and the reshaped needy area	60
Figure 3.5. Street, School, and Depot layer overlay on the new needy layer	61
Figure 3.6. Two different output of routing process (example)	62
Figure 3.7. Two different coverage needy layer (example)	63

Figure 3.8. The entry and exit number in each segment (example)	64
Figure 3.9. The calculation of passenger load (example)	65
Figure 3.10. Initial entry and exit value for reserve road (example)	66
Figure 3.11. The calculation of passenger load in reserve route (example)	67
Figure 3.12. The existing transport system and it's accessibility layer (example)	67
Figure 3.13. Accessibility after buses added (example)	68
Figure 3.14. Methodology schema	74
Figure 4.1. Map of The North Sub Districts, and the sub-sub district.	85
Figure 4.2. Dot density map of needy student	87
Figure 4.3. Gradation color Map of Needy Density students	88
Figure 4.4. Streets that can be passed by bus	93
Figure 4.5. Street junction and example of not junction in the highway	94
Figure 4.6. The one way streets	95
Figure 4.7. The average speed of the streets	96
Figure 4.8. The drive time of the streets	97
Figure 4.9. School and the public school map (blue dotted)	98
Figure 4.10. Location of the bus depots	99
Figure 4.11. Route of Bus and Lyn	101
Figure 4.12. Schools location and needy student area	102
Figure 4.13. Model for make neighborhood needy for each school	103
Figure 4.14. Identify output of buffer of school and sub-sub district map.	104
Figure 4.15. Sharing area makes total number of needy surrounding the school invalid	105
Figure 4.16. Process model for calculating new school capacity and needy area	106
Figure 4.17. The new needy area and schools that will be eliminated	109
Figure 4.18. Model for generate Visiting point	109
Figure 4.19. The selected needy area and the generated point layer	110
Figure 4.20. Process model for generating street load	111
Figure 4.21. Street load presented in graduate color	112
Figure 4.22. Form for setting the Turning cost	114
Figure 4.23. Orders items, consist of: School and Visiting point	115

Figure 4.24. Depots, consist of bus depots and public school	117
Figure 4.25. Locations of barriers	118
Figure 4.26. Design of start and stop depot for 1 route	119
Figure 4.27. Output of VRP Analyst for 1 route design	120
Figure 4.28. Design of start and stop depot for 2 routes	121
Figure 4.29. Output of VRP Analyst for 2 routes design	122
Figure 4.30. Design of start and stop depot for 3 routes	123
Figure 4.31. Output of VRP Analyst for 3 routes design	123
Figure 4.32. Design of start and stop depot for 4 routes	124
Figure 4.33. Output of VRP Analyst for 4 routes design	125
Figure 4.34. Model for finding covered area of the routes	127
Figure 4.35. Model for generate area with 2 or more access routes	129
Figure 4.36. Model for generate area with 3 or more access routes	130
Figure 4.37. Model for generating area with 4 access routes	131
Figure 4.38. Model for separating each route and discovering each covering area	132
Figure 4.39. Model for separating schools by its route.	132
Figure 4.40. example of dividing route into parts for load analyst.	135
Figure 4.41. Algorithm for filling the load analyst fields	136
Figure 4.42. Illustration of the example case	138
Figure 4.43. Illustration of bus fleet needed	139
Figure 4.44. Model Diagram for generating accessibility map	141
Figure 4.45. Model for generate uncovered need map	142
Figure 5.1. The routes setting (example)	146
Figure 5.2. The output (example)	147
Figure 5.3. Covered Area of the example routes	148
Figure 5.4. Shared areas of example output which have access to 2 or more route directions	149
Figure 5.5. Shared areas of example output which have access to 3 or more route directions.	150
Figure 5.6. Shared areas of example output which have access to 4 route directions	150
Figure 5.7. The 4 route directions including their covered areas and schools	151
Figure 5.8. Illustration of the first design of school distribution	160

Figure 5.9. Illustration of second design of school distribution	163
Figure 5.10. The chosen routes	167
Figure 5.11. Result Table of the Orders class	168
Figure 5.12. The west route	170
Figure 5.13. The east route	171
Figure 5.14. The north route	172
Figure 5.15. The south route	173
Figure 5.16. Table of the Load analyst	174
Figure 5.17. The 3D representation of the passenger load in the west route	176
Figure 5.18. The 3D representation of the passenger load in the east route	176
Figure 5.19. The 3D representation of the passenger load in the north route; the main direction	178
Figure 5.20. The 3D representation of the passenger load in the north route; the inverse direction	178
Figure 5.21. the 3D representation of the passenger load in the south route	179
Figure 5.22. The existing transportation system map	180
Figure 5.23. Accessibility map before school bus was added	182
Figure 5.24. Accessibility map after school bus was added	183
Figure 5.25. Uncovered needy in existing transport system	184
Figure 5.26. Uncovered needy in new transport system	183

LIST OF TABLES

Table 1.1. Indonesia Primary commodities	3
Table 2.1. Needy family criteria	20
Table 3.1. Color and meaning of the Tool	76
Table 3.2. Color and meaning of the Variable	76
Table 3.3. Example of geospatial functions	82
Table 4.1. Characteristic of Primary and Secondary Arterial Road	90
Table 4.2. Characteristic of Primary and Secondary Collector Road	91
Table 4.3. Characteristic of Primary and Secondary Local Road	92
Table 4.4. Route of Bus and Lyn	100
Table 4.5. The school list with its new capacity	108
Table 4.6. Example process for illustrating the algorithm	138
Table 5.1. Schools separated by routes and capacity	153
Table 5.2. Route design and output analyze of Unsupervised Orders type	156
Table 5.3. End depot design, output, and the assessment result of Distribution 1	161
Table 5.4. End depot design, output, and the assessment result of Distribution 2	164
Table 5.5. Schools visited sequence and time	168
Table 5.7. Existing Transport System statistic plus new school bus routes	181
Table 6.1. The School bus routing problem research	196