GIS and Remote Sensing in urban transportation planning: A case study of Birkenhead, Auckland

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ABSTRACT

In this research the use of geographic information systems (GIS) and remote sensing in two specific aspects of transportation planning in Birkenhead Region, Auckland, New Zealand is discussed. These two aspects are bus routes and bus stops facilities. A 1994 SPOT image and a 1999 aerial photograph of Birkenhead were utilised for mapping land-use types of the region. The study contains two assumptions related to the adequacy of the above-mentioned facilities. The assumptions state that the adequacy of bus routes/bus stops can be achieved if 80 percent or more of the residential area as well as the commercial area in the region are located within a buffer zone of 300 metres from all routes/bus stops. The assumptions were examined by using three GIS tools namely buffering, shapearc, and identity. These tools proved to be very useful. It is concluded that GIS and remote sensing can be effectively used in urban roads mapping and in urban transportation planning.

1. INTRODUCTION

1.1 Research Problem and the Population of Birkenhead

Geographic information systems and remote sensing are considered to be powerful tools for monitoring urban facilities. A fast growing environment such as the area covering suburbs located in the North Shore City of Greater Auckland Auckland (namely Birkenhead, Chatswood, Birkdale, and Beach Haven) requires special attention for its development planning (Fig. 1). Since these four suburbs appear on one remote sensing image, they are jointly known as Birkenhead Region.

In this research bus routes and bus stops in Birkenhead region were studied. A 1994 spot image as well as a 1999 aerial photograph of the study area were used to extract the main land-use types in the region. Detailed maps for Birkenhead were used as ancillary data to study the properties of existing bus routes. Buffer zones around bus routes and bus stops and querying the database in Birkenhead were used as methods for accepting or rejecting the assumptions of the research.

Birkenhead was an important place for new migrants coming from abroad. European pioneers started to arrive at Birkenhead in 1840. Only few families were reported there by 1870. (Mc Clure, 1987, pp. 15, 23). The Birkenhead Wharf was built in 1882 to facilitate ferry transport to Auckland City. By 1956 the population of Birkenhead reached 500 people. The area was famous for its fine strawberry gardens. The sea going traffic and the strawberry gardens vanished as crowds of motor vehicles crossed the Harbour Bridge to new homes. Meanwhile, the Birkenhead Transport Company prepared for the changeover to road transport via Onewa Road and the Bridge.

The convenience of bus and car travel to Auckland radically altered the land-use of the Birkdale suburb located to the northwest of Birkenhead. In 1961, within only few years of the opening of the Harbour Bridge, Birkdale and Birkenhead's population doubled. The population of Birkenhead increased from 6,000 in 1961 to 13,000 in 1967 and to 20,000 in 1978. This growth in population gave it a greater importance (Mc Clure, 1987, pp. 183, 197). In 1981, the population of Birkenhead exceeded 31,000 while in 1991 it reached more than 34,000. Currently, the number is estimated to have exceeded 37,500 putting Birkenhead's population among the top suburbs in the North Shore City (Table 1).

Table 1: Total Population of Selected North Shore Suburbs
(1981-2000)

Suburb	1981	1991	2000	% of Increase
Albany	5,085	8,703	14,900	71.2
Birkenhead	31,338	34,293	37517	9.4
Davenport	15,450	16,314	17,228	5.6
Glenfield	23,946	25536	27,221	6.6
Takapuna	30,981	34,095	37,537	10.1

Source: NZ Department of Statistics
Percentages and estimates for 2000 were calculated by the author.

The early roads in the study area were so bad that owners of cars were forced to use chains on their wheels in winter. After it had been raining, buses and carts often sank up to their axles in soggy clay. Mr. Charles Verran started a carrying business down near Birkenhead Wharf as early as 1904. In later years he opened a big stable for his horses at the highest point in Birkenhead. The site soon became known as Verran's Corner. In later years the corner carried on the tradition of being the centre of transport, and Birkenhead Transport Limited later taking on the site (Haddon, 1993, pp. 34-36).

Birkenhead Transport Limited is currently the major private operator of scheduled bus services on the North Shore. The realm of this company cover much more area than the four suburbs mentioned above. The scope of this research, however, is determined by the available remote sensing data. Bus transportation in Birkenhead is considered to be one of the most important services in the region. The adequacy of bus routes and bus stops is a vital aspect not only to the population of the area but also to the planners in North Shore City. Therefore, by integrating the capabilities of geographic information systems and remote sensing, bus routes and bus stops in Birkenhead Region are studied as a problem in urban transportation planning.

1.2 Research Objectives

This research has the following three main objectives:

(1) To draw accurate maps showing existing bus routes and bus stops in the study area.
(2) To evaluate the adequacy of Birkenhead bus routes and bus stops for the residents of the region. This is determined by generating buffer zones around the sides of the roads in the case of the bus routes and around given points in the case of bus stops.
(3) To recommend modification schemes to certain routes or stops depending on the level of adequacy in both facilities. It is aimed that the percentage of a land-use cover inside certain buffer zones in the region can help in determining the acceptance or the rejection of two assumptions related to such an adequacy.

1.3 Assumptions of the Research:

This research has the following assumptions:

(1) It is assumed that bus routes in the Birkenhead region are adequate if 80 percent or more of the residential or the commercial land-use are located inside a buffer zone of 300 meters from all routes.
(2) It is assumed that bus stops in the Birkenhead region are adequate if 80 percent or more of the residential land-use or the commercial are located within a buffer zone of 300 meters from all bus stops.

These two assumptions are based on the author's judgment which will allow a normal person to walk about eight minutes to catch a bus provided he can walk 40 metres per minute.

1.4 Significance of the Study:

The significance of the study is demonstrated in the following:

(1) The practical nature of the study because it deals with a vital aspect of an important region in the North Shore city.
(2) The fact that, to the best knowledge of the writer, there is no previous study that tried to examine the adequacy of bus routes and bus stops in the Birkenhead region.
(3) It is based on recent remote sensing data as well as current information about bus services in the study region.
(4) It uses the GIS capabilities of Arcinfo and Arcview in analysing and preparing final maps.

1.5 The Data

The test site is a region in the North Shore City composed of four suburbs, namely Birkenhead, Chatswood, Birkdale, and Beach Haven. These four suburbs are called collectively Birkenhead Region because they all appear on one 1994 SPOT image and on one 1999 colour aerial phtograph, both available in the database of the Department of Geography, University of Auckland under the name Birkenhead (Plate 1).

The SPOT image was a colour composite of three multispectral bands acquired on 28 November 1994. Both SPOT image and the aerial photograph were geometrically rectified to the New Zealand Map Grid Coordinate System. This means that land cover maps generated from them could be directly overlaid with road data from other sources.

Some maps of the study area were also available. These include a map by Jason Publishing Co. Ltd., 1997 and other maps in a road atlas called "Auckland Street Directory", New Zealand Minimaps Group, 1997.

The author also used Birkenhead Transport Limited Timetable, effective 21 June 1999, as a guidance while mapping the bus routes and bus stops in the study area. However, field surveys for locating bus stops were necessary. Arcview and Arcinfo were used for data analysis and mapping. They proved to be very useful in implementing most of the research.

2. EXISTING BUS SERVICE IN THE STUDY AREA

Bus services cover most residential, commercial, industrial, and educational locations in the study area. These services include trips from Birkdale, Beach Haven, Highbury, Island Bay, Chatswood, Verbena Rd, and Maritime Tce to Auckland City and Takapuna and vice versa. The main bus routes are: (1) Beach Haven – Rangatira – Highbury shops – Auckland; (2) Beach Haven – Birkdale Rd – Highbury shops – Auckland; (3) Beach haven – Highbury shops – Takapuna; and (4) Beach Haven – Glenfield- Link Drive. In addition to these main routes, there are two peak period extras. Peak period A serves residents who are living in Chatswood, Hinemoa St., Island Bay Rd, and Aeroview drive. Peak B serves residents who are living in Verbena Rd, Lauderdale rd, and Eskdale Rd . In addition to this, a request bus service for people living in certain streets exists (Fig. 2). These routes are discussed in the order shown below.

1. Beach Haven / Auckland.
2. Beach haven / Takapuna.
3. Beach Haven / Highbury.
4. Beach Haven / Wairau Park.
5. Maritime Tce.
6. Verbena Rd / Island bay / Chatswood.
7. Berkenhead request bus.

With the exception of Beach Haven / wairau Park service which is provided by Ritches Transport Ltd, all services are provided by Birkenhead transport Ltd.

2.1 Beach Haven / Auckland:

There are forty-seven bus trips that leave Beach Haven for Auckland on Mondays – Fridays. Among these trips twenty-three trips run in the mornings whereas twenty-four trips run in the afternoons (Tables 2a & 2b). All these trips are performed by the 973 and 974 buses that start from Verrans Corner where they usually stay overnight. The 973 bus going to Auckland leaves Beach Haven and travels via Birkdale Rd back to verrans Corner. Then it departs Verrans Corner to Highbury shops and continue to Auckland City where it terminates in front of the Sky Tower on Victoria Street. Similarly, the 974 bus leaves Verrans Corner via Birkdale Rd to Beach Haven and departs Beach Haven via Rangatira Rd to Verrans Corner. From there buses continue to Highbury shops and then to Auckland City.

Table 2 a: Bus service from Beach Haven to Auckland City via
Highbury shops (Monday – Friday mornings)

Bus #	Verrans corner	Via	Depart Beach-Haven	Via	Depart Verrans Corner	Depart Highbury	Arrive Auckland City
974	5:45	B	5:50	R	5:55	6:00	6:15
974	6:00	B	6:10	R	6:15	6:25	6:40
973	6:25	R	6:35 W	B	6:45	6:50	7:10
974	6:50	B	7:00	RZ	7:10	7:15 O	7:30
973	7:00	RA	7:10	BZ	7:20	7:25 O	7:45
974	-		7:25	RZ	7:30	7:35 O	8:00
973	-		7:25	B	7:35	7:40	8:00
973	-		7:40 W	BZ	7:50	7:55 O	8;20
974	7:30	B	7:40	RZ	7:50	7:55 O	8:20
973	-		7:50	B	8:00	8:05	8:25
974	8:00	B	8:05	AR	8:20	8:25	8:50
973	8:00	R	8:10	BZ	8:20	8:25 O	8:50
973	8:05	R	8:20	B	8:30	8:40	9:00

974	8:30	B	8:40	R	8:50	9:00	9:20
973	8:50	R	9:00	B	9:10	9:20	9:40
974	9:10	B	9:20	R	9:30	9:40	10:00
973	9:30	R	9:40	B	9:50	10:00	10:20
973	9:50	R	10:00	B	10:10	10:20	10:40
974	10:10	B	10:20	R	10:30	10:40	11:00
973	10:30	R	10:40	B	10:50	11:00	11:20
973	10:50	R	11:00	B	11:10	11:20	11:40
974	11:10	B	11:20	R	11:30	11:40	12:00
973	11:30	R	11:40	B	11:50	12:00	12:20

R = Rangatira Rd
B = Birkdale Rd
A = Aeroview Rd
W = Departs Beach Haven Wharf. All other beach Haven departures are from Rangatira Rd near Sunnyhaven Rd (Beach Haven shops)
O = Departs top of Onewa Rd. All other Highbury departures are from Birkenhead Ave near Hammond Place
Z = Via Bypass.

Table 2 b: Bus service from Beach Haven to Auckland City via Highbury shops (Monday – Friday afternoons)

Bus #	Verrans Corner	Via	Depart Beach Haven	Via	Depart Verrans Corner	Depart Highbury	Arrives Auckland City
973	11:50	R	12:00	B	12:10	12:20	12:40
974	12:10	B	12:20W	R	12:30	12:40	1:00
973	12:30	R	12:40	B	12:50	1:00	1:20
973	12:50	R	1:00	B	1:10	1:20	1:40
974	1:10	B	1:20W	R	1:30	1:40	2:00
973	1:30	R	1:40	B	1:50	2:00	2:20
973	1:50	R	2:00	B	2:10	2:20	2:40
974	2:10	B	2:20W	R	2:30	2:40	3:00
973	2:30	R	2:40	B	2:50	3:00	3:20
973	2:50	R	3:00	B	3:10	3:20	3:40
974	3:10	B	3:20W	R	3:30	3:40	4:00
973	3:30	R	3:40	B	3:50	4:00	4:20
973	3:50	R	4:00	B	4:10	4:20	4:40
974	4:10	B	4:20W	R	4:30	4:35	4:50
973	4:00	R	4:40	B	4:50	4:55	5:20
974	5:00	B	5:15W	R	5:20	5:30	5:50
974	5:40	B	5:50	R	5:55	6:00	6:20
974	6:10	B	6:20	R	6:25	6:30	6:50
973	6:40	R	6:50	B	6:55	7:00	7:20
974	7:10	B	7:20	R	7:25	7:30	7:50
973	7:50	R	8:00	B	8:05	8:10	8:30
973	8:50	R	9:00	B	9:05	9:10	9:30
973	9:50	R	10:00	B	10:05	10:10	10:30
973	10:50	R	11:00	B	11:05	11:10	11:30

An individual trip from its origin at Verrans Corner to its destination at Victoria Street takes 40 – 50 minutes including waiting at certain bus stops . These 40 – 50 are distributed as follows:

- 10 minutes from Verrans Corner to Beach Haven;
- 5 – 10 minutes from Beach Haven to Verrans Corner;
- 5 – 10 minutes from Verans Corner to Highbury shops; and
- 20 minutes from Highbury shops to Victoria Street.

Out of the above-mentioned forty-seven trips, there are eleven trips depart from Beach Haven Wharf. All other Beach Haven departures are from Rangatira Rd near Sunnyhaven Rd (Beach Haven shops). There are six trips that travel through Highbury Bypass and then depart at top of Onewa Rd. All other Highbury departures are from Birkenhead Avenue near Hammond Place (Highbury shops). The 1st trip arrives to Auckland City at 6:15 in the morning, while the last trip arrives to Auckland City at 11:30 in the evening.

There are thirty-eight bus trips from Beach Haven to Auckland City via Highbury shops in the weekends and in the public holidays; 23 trips on Saturdays and 15 trips on Sundays and public holidays (Table3). The 973 and 974 buses are also the ones that run this service. The 1st trip arrives to Auckland at 6:30 in the morning on Saturdays and at 8:30 in the morning on Sundays and public holidays. The last trip arrives to Auckland at 11:30 in the evening on Saturdays and at 10:30 in the evening on Sundays and public holidays.

Table 3: Bus service from Beach Haven to Auckland City via Highbury shops in the weekend and public holidays

Days	Number Of Trips	Bus #	Verrans Corner	Via	Beach Haven	Via	Verrans Corner	Highbury	Auckland City	
Saturday	23									
Ist trip		974	5:55	B	6:05	R	6:10	6:15	6:35	am
last trip		973	10:55	R	11:05	B	11:05	11:10	11:30	pm
Sundays & public holidays	15									
1st trip		973	7:50	R	8:00	B	8:05	8:13	8:30	am
last trip		973	9:50	R	10:00	B	10:05	10:13	10:30	pm

Another 48 trips on Mondays – Fridays and another 38 trips on Saturdays, Sundays, and public holidays operate as a return bus service from Auckland City to Beach Haven via Highbury shops (Table 4). The final destination for all these trips is Verrans Corner. It is worthy of mentioning that the 1st trip arrives to Verrans corner at 6:55 in the morning on Mondays – Fridays, at 7:05 am on Satudays, and at 9:05 am on Sundays and public holidays. As for the last trip, buses arrive to Verrans Corner (where they stay overnight) at 12: 05 in the evening on Mondays – Fridays and Saturdays. They arrive to Verrans Corner at 11:05 pm on Sundays and public holidays.

Table 4: Summary of return bus service from Auckland
To Beach Haven via Highbury shops

Days	Number Of Trips	Bus #	Auckland	Highbury	Verrans Corner	Via	Beach Haven	Via	Verrans Corner	
Monday – Friday	48									
1^{st} trip		973	6:15	6:30	6:40	R	6:50	B	6:55	am
last trip		973	11:30	11:45	11:50	R	12:00	B	12:05	pm
Saturday	23									
1^{st} trip		974	6:35	6:50	6:55	B	7:00	R	7:05	am
last trip		974	11:30	11:45	11:50	B	12:00	R	12:05	pm
Sunday & Public Holidays	15									
1^{st} trip		973	8:30	8:45	8:50	R	9:00	B	9:05	am
last trip		974	10:30	10:45	10:50	B	11:00	R	11:05	pm

2.2 Beach Haven / Takapuna:

Takapuna is considered to be the most important commercial suburb in the North Shore City. Therefore, the 975 and 976 buses travel to and from Takapuna early in the morning until late at night. There are twenty-five trips between Beach Haven and Takapuna Monday – Friday (Table 5). The 1^{st} trip leaves Verrans Corner at 6:25 am and arrives Beach Haven via Rangatira Rd at 6:25 am. It arrives Verrans Corner via Birkdale Rd at 6:30 am, arrives Highbury shops at 6:35 am and Takapuna at 6:50 am. The last trip in the Monday – Friday schedule leaves Verrans Corner at 8:30 pm and travels via rangatira Rd to Beach Haven. It leaves Beach haven at 8:40 pm and travels via Birkdale Rd back to Verrans Corner. It departs Verans Corner at 8:45 pm to Highbury shops. It departs Highbury shops at 8:50 pm and arrives Takapuna at 9:10 pm.

Table 5: Summary of bus service from Beach Haven to
Takapuna via Highbury shops

Days	Number Of Trips	Bus #	Verrans Corner	Via	Beach Haven	Via	Verrans Corner	Highbury shops	Takapuna	
Mon. – Fri.	25									
1^{st} trip		975	6:20	R	6:25	B	6:30	6:35	6:50	am
last trip		975	8:30	R	8:40	B	8:45	8:50	9:10	pm
Sat.	15									
1^{st} trip		976	7:50	B	8:00	R	8:10	8:20	8:40	am
last trip		975	5:50	R	6:00	B	6:10	6:20	6:40	pm

Sun. & holidays	9									
Ist trip		976	9:20	B	9:30	R	9:35	9:43	10:00	am
Last trip		976	5:20	B	5:30	R	5:35	5:43	6:00	pm

From Beach Haven to Takapuna, there are fifteen trips on Saturdays and nine trips on Sundays and public holidays. Bus stops in the weekend and public holidays are the same as Monday – Friday. Departure and arrival time, however, is different. The 1st trip starts at 7:50 am on Saturdays and at 9:20 am onSundays and public holidays. The last trip leaves at 5:50 pm on Saturdays and at 5:20 pm on Sundays and public holidays.

Similar number of bus trips exists in the reverse service from Takapuna to Beach haven via Highbury shops i.e. 25 trips Mondays – Fridays; 15 trips on Saturdays, and 9 trips on Sundays and public holidays (Table 6).

Table 6: Summary of reverse bus service from Takapuna
To Beach Haven via Highbury shops

Days	Number Of Trips	Bus #	Takapuna	Highbury shops	Verrans Corner	Via	Beach Haven	Via	Verrans Corner	
Monday – Friday	25									
1st trip		975	7:05	7:20	7:25	R	7:35	B	7:40	am
last trip		975	9:10	9:25	9:30	R	9:40	B	9:45	pm
Saturday	15									
1st trip		976	8:40	9:00	9:10	B	9:20	R	9:30	am
last trip		976	6:40	7:00	7:05	B	7:10w	R	7:20	pm
Sunday & Public Holidays	9									
1st trip		976	10:00	10:15	10:20	B	10:30	R	10:35	am
last trip		976	6:00	6:15	6:20	B	6:30	R	6:35	pm

2.3 Beach Haven / Highbury:

Birkenhead Transport Ltd. provides 116 trips from Beach Haven to Highbury as part of bus service travelling either to Auckland City or Takapuna. Among these trips, 54 trips are in the weekdays and 62 trips are on Saturdays, Sundays and public holidays (Table 7). More trips are provided between Highbury shops and Beach Haven than any other service in the study area. Buses that run this service are numbered: 973, 974, 975, and 976.

Table 7: Number of trips for bus service from Beach Haven to Highbury

shops and vice versa (Bus # 973, 974, 975, and 976)

Days	Destination On bus	Beach Haven to Highbury shops (total)	Highbury shops to Beach Haven (total)
Mon. – Fri.		54	61
	City	39	
	Takapuna	15	
Saturday		38	38
	City	23	
	Takapuna	15	
Sunday & holidays		24	23
	City	15	
	Takapuna	9	
Grand total		116	122

2.4 Beach Haven / Wairau Park:

There are four trips operating between beach haven and wairau Park (Link Drive) via Beach Haven shops and Glenfiels shops. The 1st trip leaves corner of Beach haven Rd and Birkdale Rd at 9:15 am, Beach Haven shops at 9:23 am, Glenfield shops at 9:35 am and arrives to Wairau Park at 9:45 am. The 2 nd trip departs corner of Beach Haven Rd and Birkdale rd 10:15 am, the 3rd trip at 1:15 pm, and the 4th trip at 2:15 pm. Each of these four trips takes thirty minutes to travel between departure and destination stations (Table 8).

The reverse service has also four trips; each takes twenty-three minutes of travelling between Wairau Park and Beach Haven shops. The 1st reverse trip departs Wairau Park at 10:00 am, the 2nd at 11:00 am, the 3rd at 2:00pm, and the 4th trip departs at 3:00 pm. All these services are operated by 978 bus and are provided by Ritchies Transport Ltd.

Table 8: Bus service from Beach Haven to Wairau Park and vice versa

Beach Haven / Wairau Park						Wairau Park / Beach Haven				
Bus #	Cnr Beach Haven & Birkdale Rd	Beach Haven shops	Glenfield shops	Wairau Park		Bus #	Wairau Park	Glenfield shops	Beach Haven shops	
978	9:15	9:23	9:35	9:45	am	978	10:00	10:10	10:23	am
978	10:15	10:23	10:35	10:45	am	978	11:00	11:10	11:23	am
978	1:15	1:23	1:35	1:45	pm	978	2:00	2:10	2:23	pm
978	2:15	2:23	2:35	2:45	pm	978	3:00	3:10	3:23	pm

2.5 Maritime Tce:

Bus service operates between Maritime Tce and Auckland City via Highbury. There are five trips that operate in the morning and two trips in the afternoon. The morning trips depart at 6:20, 6:50, 7:05, 7:45, and 8:20 am. The afternoon service leaves Maritime Tce at 4:45 and 5:50 pm. Concerning the reverse service from Auckland City to Maritime Tce, there are five trips scheduled to depart Auckland at 4:20, 5:10, 5:30, 5:50, and 6:20 pm (Table 9). Passengers who go to Beach Haven, Island Bay, or Verrans Corner can catch these buses at Auckland and transfer to their destinations.

Table 9: Bus service from maritime Tce to
Auckland City and vice versa

Maritime Tce / Auckland City				Auckland City / Maritime Tce				
Maritime Tce	Highbury	Auckland		Auckland	notes	Highbury	Maritime Tce	
6:20	6:25	6:40	am	4:20	V	4:35	4:45	pm
6:50	6:55	7:15		5:10	I	5:25	5:40	
7:05	7:15	7:30		5:30	B	5:45	5:50	
7:45	7:50	8:15		5:50	B	6:05	6:10	
8:20	8:25	8:55		6:20	B	6:35	6:40	
4:45	4:50	-	pm					
5:50	5:55	-						

B= catch Beach Haven bus at Auckland I= catch Island Bay bus at Auckland V= catch Verrans Corner bus at Auckland

2.6 Verbena Rd / Island Bay / Chatswood:

Eight morning trips operate from Verbena Road, Island Bay, and Chatswood to Auckland City by using 971 and 972 buses Monday – Friday. Buses take between thirty and forty-five minutes to complete a trip from these areas to Auckland City depending on whether there are travelling in the rush hours or not.

Passengers from Verbena Road can travel either via lauderdale Rd, Birkdale Rd, and Verrans Corner or via lauderdale Rd, Levesque St., Birkdale Rd, and Eskdale Rd. They also can transfer to Auckland bus from Greenhite at the top of Onewa Rd. Passengers from Island Bay can either transfer to Auckland bus from Beach Haven at Verrans Corner or from Greenhite at top of Onewa Rd. (Table 10). There are four reverse trips from Auckland City to these areas at 4:20, 4:35, 5:10, and 5:20 in the afternoon.

Table 10: Bus service from Verbena Rd/ Island Bay/ Chatswood to
Auckland City via Onewa Rd (Mon. – Fri.)*

Bus #	Verbena Rd	Island Bay	Chatsood Balmain Rd	Notes	Verrans R	Highbury	Auckland	
972	6:30	-	-	L	-	6:45	7:10	am
971	-	7:00	-	T	7:10	-	7:30	
971	-	-	7:00	-	-	-	7:35	
972	6:55	-	-	L	-	7:10	7:35	
972	7:25	-	-	E	-	-	8:05	
971	-	7:30	-	T1	-	-	8:10	
971	-	-	8:05	-	-	-	8:50	
972	9:00	-	-	T	-	-	9:40	

L = via lauderdale Rd, Birkdale Rd, Verrans Corner
T = transfer to Auckland bus from Beach haven at Verrans Corner
E = via Lauderdale Rd, Levesque St, Birkale Rd, Eskdale Rd
T1 = transfer to Auckland bus from Greenhite at top of Onewa Rd.

- There are four reverse trips from Auckland City to Verbena Rd, Island bay, and Chatswod at 4:20, 4:35, 5:10, and 5:20 pm.

2.7 Birkenhead Request Bus:

This service operates between 9:00 am and 3:00 pm Monday – Friday for residents of the areas marked on the map (Fig. 3). In case residents are coming from home, they can phone Birkenhead Transport Ltd at least two hours before they want to travel. Residents need to tell the booking officer where they want to catch the bus and when they want to arrive. They will be told what time the bus will pick them up.

In addition to this, residents who live in Chatswood, Verbena Rd, Eskdale Rd, and Rosberry Ave, can use the bus to travel to Highbury. They will be picked up on time by 30 minutes past each hour. In the returning journey, the bus departs Highbury each hour, on the hour, from 10:00 am to 3:00 pm inclusive Monday to Friday.

It can be seen from the above-mentioned discussion of the existing bus service in Birkenhead that it is an extensive service that was planned and implemented efficiently. The present study, however, aims to evaluate the adequacy of this service by using some of the capabilities of GIS and remote sensing. But before starting such an evaluation a review of the literature on urban transportation planning seems to be necessary.

2. GIS AND REMOTE SENSING IN URBAN TRANSPORTA-TION PLANNING

Planning could be defined as a systematic approach used to analyse and answer social, physical, and economic problems of certain areas. In other words, it is a problem-solving field that deals with factors influencing the quality of life at scales ranging from small localities to large regions. Therefore, planning agencies usually employ several professionally trained planners specialised in different fields including land use, hydrology, housing, economic development, transportation, geographic information system (GIS), and remote sensing. These planners attempt to apply methods of data analysis to explore solutions for community problems and urban issues.

In fact, urban planning is one of the main applications of GIS. Urban planners use GIS both as a spatial database and as an analysis and modelling tool. The applications of GIS vary according to different stages, levels, sectors, and functions of urban planning. According to Yeh (1999), the increase in user-friendliness and functions of GIS software and marked decrease in the prices of GIS hardware resulted in GIS becoming an operational and affordable information system for planning. Yeh adds that the main constraints in the use of GIS in urban planning today are not technical issues, but the availability of data, organisational change, and staffing.

In an earlier work for him, Yeh (1991) mentioned that GIS is increasingly accessible to planners and is now an important tool for urban planning in developed and developing countries alike. Han (1991)agrees that GIS is one of the formalised computer – based information systems capable of integrating data from various sources to provide the information necessary for effective decision – making in urban planning. As a toolbox, GIS allows planners to perform spatial analysis using geoprocessing functions such as map overlay, connectivity measurement, and buffering (Berry 1987).

Urban planners use GIS for general administration, development (building0 control, and plan making. The first two of these tasks can be regarded as routine operations usually undertaken on a daily basis. Plan making, on the other and, is undertaken less frequently and is regarded as a strategic planning tool. It requires new local and regional plans to be advised (Longley et al. 1999).

Mapping provides the most powerful visualisation tools in GIS. It can be used to explore the distribution of socioeconomic and environmental data, and display the results of spatial analysis and modelling exercises. Spatial analysis and modelling are useful for spatial statistical analysis, site selection, land suitability analysis, and land use transport analysis.

According to Yeh (1999), the scale of the planning area covered can range from a whole city, to a sub-region of a city, a district, or a street block. The most frequently involved sectors of urban planning includes:

- management of land records;
- thematic mapping;
- land use management;
- land availability and development monitoring;
- industrial, commercial, and retail floor space recording;
- recreation and countryside facility planning;
- environmental impact assessment;
- public facilities and shops catchment area and accessibility analysis;
- land-use / transport strategic planning.

This part is concerned with studies that used GIS and remote sensing for transportation planning purposes. Several researches can be cited in this context. Only recent studies, however, will be reviewed.

Mintzer (1983) showed that engineers often use remote sensing data to:

(1) update transportation network maps;
(2) evaluate roads, railroad, and airport runway and tarmac condition;
(3) study urban traffic patterns at choke points such as tunnels, bridges, shopping malls, and airports; and
(4) conduct parking studies (see also Haack et al. 1997).

Harper and Manhein (1990) emphasised that the possibilities for GIS in transportation planing seem endless. Geocomputing concepts have developed out of parcel-based or polygon-based disciplines such as land-use planing and environmental management. Transportation networks have been used primarily as references for other features in these parcel – based systems. They added that transportation planners are applying the concepts of spatial analysis to networks. Geocomputing software, land-use modeling software, and transportation modeling are evolving towards an ideal geocomputing software solution for transportation planning that integrates all the capabilities.

Foresman and Millete (1997) explained the use of Landsat TM in conjunction with GIS to obtain land use and other spatial data for regional planning of 25 towns in Vermont, USA. Image processing techniques and manual interpretation were used to achieve their objective. They implied the notion that transportation planners can utilise satellite images for land-use identification purposes.

Couloigner et al. (1998) explained how both the future SPOT-5 and a sensor fusion method can contribute to urban roads mapping in the district of the Old Harbour of the city of Merceille, France. They concluded that such a mapping is richer and more accurate when the results are obtained from the simulated SPOT-5 data than when they come from the simulated SPOT- 1-3 data. According to the researchers, the improvement of the spatial resolution between the two sets of images allows the detection of more urban roads and are closer to the reference map of the test site. They added that sensor fusion allows the improvement of spatial resolution of the multi-band images. Consequently, it improves the results of the urban road mapping with a richer and more accurate cartography.

Spear and Lakshmanan (1998) discussed how organisations involved in transportation planning utilise computerised transportation models to forecast the impact of development patterns, transportation systems, and demographics upon regional travel demand. According to Spear and Lakshmanan these models are complex, data –intensive formulations of assumptions that are founded on the spatial organisation of residences, places of employment, and locations of commercial activity. Results from these models enable transportation planners to predict the level of usage at activity centres as a function of location, distance to urban population centres, and socio-economic composition of the surrounding community.

Coulter et al. (1999) explained how transportation planners and metropolitan organisations require up-to-date land-use information to allocate transportation resources and to forecast the location and type of growth within metropolitan areas and associated increases in transportation volumes. For areas where land-use changes are common, existing geographic databases may not provide current information. Remotely sensed imagery and existing geographic databases can be utilised to provide a wealth of information regarding current land-use and can be used to update land-use layers.

Two case studies were presented by Coulter et al. (1999) to demonstrate the utility of remotely sensed data and GIS data sources for detecting change areas and determining new land-use classes in the context of updating land-use for input into transportation models. Results from the first case study suggest that automated approaches do not provide sufficiently accurate boundary delineation and that manual interpretation and delineation of land-use change polygones is likely to be required.

Results from the second case study indicate that information derived from GIS databases can add substantial information to the land-use identification process. In this case study, the authors presented several techniques for integrating remotely sensed and GIS data that allow extraction and incorporation of information from both of these data sources were presented. Of these techniques, the most promising are likely to be the interactive GIS querying and expert systems approaches.

Jensen and Cowen (1999) presented temporal and spatial resolution requirements for extracting urban/suburban infrastructure and socio-economic attributes from remote sensor data. They explained how several remote sensing systems can provide some of the desired information when the required spatial resolution is coarser than 4 by 4 metres and the temporal resolution is between 1 and 55 days. Current high spatial resolution sensor systems, however, may provide additional capability. They suggested that resolutions of 5 to 20 metres are adequate for level II classification and that resolutions of 1 to 5 metres enable sufficient identification of many level III classes.

Waters (1999) in his chapter on Transportation GIS gave a brief introduction to the main characteristics of the Geographical Information Systems in Transportation (GIS-T) field. He elaborated on the historical antecedents which led to the rise of GIS-T. He then described the main components of a GIS-T, as well as the various types of operations and procedures that are usually available in GIS-T packages. This was followed by an overview discussion of the use of GIS-T in government departments of transportation at the municipal, regional, and national levels.

An interesting part of Waters' chapter "Transportation GIS: GIS-T" (1999) is his elaboration on the four – step urban transportation model system that includes: (1) trip generation and trip attraction (how many trips?); (2) trip distribution (where do they go?); (3) modal split (by what travel mode do they move?); and (4) traffic or network assignment (which route do they take?). The aim of trip generation models is to predict the number of trips produced by each origin zone or region. This task can be handled in a variety of different ways. Some of the more important choices include: modelling methods; the unit of analysis; the trip purpose; and the choice of explanatory variables. Trip distribution models are used to predict the flow values in the transportation zone. This can be achieved either by scaling a production – attraction matrix of existing flow or through the use of modern derivations of the gravity model which employ entropy maximising procedures.

According to Waters (1999), modal split analysis can be determined either at the zonal (aggregate) level or at the individual (disaggregate) level. Estimation procedures may involve either revealed or stated preferences and these can be modelled using any of the regression, cross classification, or discrete choice procedures. Finally, a sophisticated GIS-T should allow for a variety of traffic assignment ranging from simple tractable techniques to the more complex which are computationally intensive, especially for large municipal networks (for more on the urban transportation model system, see also Nyerges 1995; Pas 1995; Wilson 1974; and Louviere 1988).
Other useful studies that utilised GIS and remote sensing capabilities in transportation planning include articles written by Heikkila et al. (1990), Gallimore et al. (1993), Stopher et al. (1996), and Haack et al. (1997).

From the above-mentioned studies it can be concluded that:
(1) There is a sufficient use of GIS and remote sensing in urban transportation planning.
(2) Urban transportation planners and government agencies continue to need up-to-date land-use information in order to predict the location and type of growth within metropolitan areas.
(3) Most planning organisations tend to include in their activities several urban issues; the issue of transportation is considered an important one.
(4) Urban roads mapping by means of GIS and satellite images is a promising direction in the future.

It should be noted, however, that transportation geographers and planners, who use GIS and remote sensing techniques in their studies have not explored the adequacy of transportation services inside a given place. The present study, therefore, tries to address this issue of adequacy with an example of bus routes and bus stops in North Shore suburbs, Auckland, New Zealand.

3. RESEARCH METHODOLOGY

The key point in this research is to find the percentage of residential land-use that lies inside a certain buffer zone from a given distance to bus routes or bus stops in Birkenhead Region. The following steps and approaches were needed to achieve this goal:

(1) Copying a 1994 SPOT image and a 1999 colour aerial photograph of the Birkenhead Region to a selected file in Arcview from the database of the Department of Geography, University of Auckland.

(2) Screen digitisation of data from the SPOT image and the air photo to create a land-use map of three categories (fig. 4):
   - residential land-use;
   - commercial, industrial and educational (collectively known as commercial); and
   - forest and recreational land-use (collectively known as others).

   This classification is justified by the fact that buses in the study area run only in the residential and commercial areas. Therefore, methods of analysis used in this study will be limited to these two categories.

(3) With the help of Arcinfo, certain coverages showing North Shore roads were copied from the database of the Department of Geography, University of Auckland. These coverages, mainly the “northshore road outline” and the “northshore main roads”, were necessary to have a base map of the roads in the study area. A coastline coverage was imported from one of the labs of a GIS paper taught in the Department.

(4) With the help of a current timetable published by Birkenhead Transport Ltd., a map for Birkenhead bus routes was digitised. The resulted map differentiated between normal bus routes and peak hours routes.

(5) Buffer zones of different distances from bus routes were produced to find which distance can help in accepting or rejecting the 1st assumption mentioned earlier. Buffer zones were generated in Arcview. They also
can be produced in Arcinfo.

(6) Overlay the residential coverage with the buffered layer using the following commands for Shapearc and Identity in Arcinfo:

a. Shapearc
Definition: writes shapefile spatial and attribute information to an Arcinfo coverage.
Usage: SHAPEARC <in_shape_file> <out_cover> (out_subclass)

b. Identity
Definition: computes the geometric intersection of two coverages. All Features of the input coverage, as well as those features of the Identity coverage that overlap the input coverage, are preserved in Input coverage.
Usage: IDENTITY <in_cover> <identity_cover> <out_cover> (Poly I Line I Point)

- Querying the database for the amount of residential land-use within a buffer zone and outside a buffer zone. The sum figures were converted to percentages and compared with the assumptions of the research.

(7) Repeat steps 5-7 for the bus stops.

4. DISCUSSION OF BUS ROUTES AND BUS STOPS IN BIRKENHEAD

4.1 Discussion of bus routes:

Prior to the openning of the Harbour Bridge in 1952, people travelling from Birkenhead to the city of Auckland had to arrive at the Birkenhead Wharf and take the ferry to the city. The roads in the region were of poor quality and Birkenhead was a difficult place to run a bus service because of the hilly nature of its topography.

After 1952, buses from Birkenhead Region gathered passengers from Beach Haven, Birkdale, Chatswood, and Birkenhead and then cross the Harbour Bridge to Auckland City. These buses are owned by Birkenhead Transport Limited. Bus services are divided into normal routes and peak hours routes. Normal bus service passes through Beach Haven Road, Rangatira Road, Birkdale Road, Verbana Road, Mokoia Road, Eskdale Road, Lauderdale Road, and Birkenhead Avenue. This service starts from 5.50 a.m. until 11.00 p.m. Peak hour service operates in the morning and afternoon rush hours and cover certain areas in Beach Haven, Birkdale and Chatswood (Fig. 2).

A buffer zone was drawn around the existing bus routes, both normal and peak, with distance specified as 200 metres. This zone was overlaid with the different types of land-use using the Arcinfo Shapearc and the Identity commands. Below is an illustration of the use of these commands for the residential land-use and the given buffer zone.

The shapearc sequence was as follows:

```
Arc: SHAPEARC RESIDENT.SHP RESIDENT ID
Arc: ITEMS   RESIDENT.AAT
Arc: ITEMS   RESIDENT.PATID
Arc: CLEAN  RESIDENT
Arc: info
     ENTER  USERNAME > ARC
     ENTER COMMAND > SEL RESIDENT 1.PAT
```

ENTER COMMAND > LIST
MORE? NO
ENTER COMMAND > Q STOP

The identity sequence was as follows:
Arc: IDENTITY RESIDENT1 BUFFER1 RESDENT2 POLY
Producing identity of RESIDENT1 with BUFFER1 to create RESIDENT2
Sorting…
Intersecting…
Assembling Polygones…
Creating new lables
Creating RESIDENT2.PAT
Arc: CLEAN RESIDENT2
Cleaning R:\ PLANNING\ RESIDENT2
Sorting…
Intersecting…
Assembling polygons.

Calculating and Query builder procedures were implemented with buffer distance of 200 metres inside and 0 metres outside the buffer zone. With a residential area of 7.952 sq. km the percentage of inside buffer was 48.9 percent while that of the outside buffer was 51.03 percent. The commercial area was 0.679 sq. km with 59.20 percent inside the buffer zone and 40.80 percent outside. Buffering, shapearc, and identity for other land-use type (i.e. forest) were not needed because buses do not provide services to these areas. The area for the "others" land-use type is calculated as 5.772 sq. km. This resulted in a grand total area of 14.403 sq. km for the whole study area of Birkenhead region (Table 11 and Fig. 5).

Table 11: Identity values of land-use types with existing bus routes
(200m buffer zone)

Types of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	3.894	48.97	4.058	51.03	7.952	100.00
Commercial	0.402	59.20	0.277	40.80	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

The result for a buffer zone of 200 meters from normal and peak bus routes seems far less than the accepted level for the 1st assumption. In other words, bus services along these roads are not adequate. Therefore, another buffer zone with a buffer distance of 300 meters was produced. The same commands and sequences were adopted. Although there was an improvement in the sum of inside and outside buffer, the percentage of the inside buffer was still not acceptable i.e. less than the assumed 80 percent. The percentage of the inside residential zone was 63.89 and the percentage of the inside commercial was 70.65 (Table 12 and Fig. 6).

Table 12: Identity values of land-use types with existing bus routes

(300m buffer zone)

Types of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	5.081	63.89	2.872	36.11	7.952	100.00
Commercial	0.479	70.65	0.199	29.35	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

To improve the percentage of the inside buffer within both the residential and the commercial areas in Birkenhead region, three new bus routes were suggested. These bus routes are selected in heavy crowded residential areas having no bus services. The selected roads for the suggested bus routes are Fairclough Road in Beach Haven, Verran Road in Birkdale, and Roseberry Avenue in Birkenhead (Fig. 2). A third buffer zone with a buffer distance of 200
metres for all routes (normal, peak, and suggested) showed a better result than the earlier two ones. Values of identity of residential area with all routes having a buffer zone of 200 metres showed that the inside buffer was 73.75 percent leaving 26.25 percent for the outside buffer. As for the commercial area, the
inside buffer zone was 70.77 percent and the outside buffer was 29.23 percent (Table 13 and Fig. 7).

Table 13: Identity values of land-use types with all bus routes
(200m buffer zone)

Types of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	5.862	73.75	2.090	26.25	7.952	100.00
Commercial	0.480	70.77	0.199	29.23	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

The buffer zone of 200 metres around all routes and identity of residential land-use with all routes showed that buses did still not serve large area in the residential category. This fact was also the case of the commercial area. This means that with 200 metres buffer zone for all routes, bus services are still inadequate. Therefore, the researcher did a final test on all routes with a buffer distance of 300 metres. The result was that the inside buffer zone was 87.47 percent leaving only 12.53 percent for the outside buffer in the case of the residential land-use. The final test for the commercial category resulted in almost 80 percent inside the buffer zone and 20 percent outside (Table 14 and Fig. 8).

Table 14: Identity values of land-use types with all bus routes
(300m buffer zone)

Types of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	6.956	87.47	0.996	12.53	7.952	100.00
Commercial	0.539	79.47	0.140	20.53	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

This 300 metres buffer zone gives most of the residential and commercial areas bus services. In addition to this, it implies that the three suggested routes are necessary and may be incorporated by Birkenhead Transport Ltd. in their bus schedule. Therefore, assumption 1 which states that the bus routes in Birkenhead region are adequate if 80 percent or more of the residential and the commercial areas are located inside a buffer zone of 300 metres from all routes can be accepted. This indicates that the researcher was successful in adding the above-mentioned three routes in his study.

4.2 Discussion of Bus stops

The researcher conducted a field survey in Birkenhead Region to locate the existing bus stops on his base map. He was able to locate 65 bus stops on the existing bus routes (normal routes and peak hours routes). A buffer zone with a buffer distance of 200 metres was drawn around the existing bus stops using the buffering steps mentioned earlier.

The resulted buffer zone was overlaid on both the residential coverage and the commercial coverage to determine the percentage of areas located inside or outside the buffer zone in order to relate the result to the bus stops' assumption. The Arcinfo commands and sequences for both shapearc and identity in the case of bus stops were exactly similar to those of the bus routes mentioned earlier. The calculations and the querying procedures resulted in that 53.19 percent of the residential area (7.952 km2) were inside the buffer zone of the bus stops whereas 46.81 percent were outside. At the same time 56.39 percent of the commercial area were inside the buffer zone of 200 metres from the existing bus stops and 43.61 percent were outside. The grand total area of Birkenhead region is still 14.403 sq. km distributed as follows: 7.952 sq. km residential, 0.679 sq. km commercial, and 5.772 sq. km others (Table 15 and Fig. 9).

Table 15: Identity values of land-use types with existing bus stops
(200m buffer zone)

Type of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	4.230	53.19	3.725	46.81	7.952	100.00
Commercial	0.383	56.39	0.296	43.61	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

It is clear that the above-mentioned result is far below the level of adequacy for bus stops. In order to improve this result, the researcher thought of increasing the bus stops where needed. Therefore, he conducted another field survey and added ten necessary bus stops (later called suggested stops) on certain routes having less bus stops than what was needed or was not having bus stops at all. Three stops were suggested on Roseberry Avenue, three stops on Fairclough Road, two on Verran Road, one on Eskdale Road, and one on Lauderdale Road (Fig. 2).

A second buffering zone was implemented with a buffer distance of 200 metres for all the seventy-five bus stops (65 existing and 10 suggested). The result of the overlay was much better than the first one but still far beyond the desired level. The result showed that 61.86 percent of the residential area in Birkenhead region were inside the buffer zone of all bus stops while 38.14 percent were located outside. In the case of the commercial area, 59.58 percent were inside and 40.42 percent were outside the buffer zone (Table 16 and Fig. 10).

Table 16: Identity values of land-use types with all bus stops
(200m buffer zone)

Type of land use	Area		Subtotal
	Inside	Outside	

	Sq. km	%	Sq. km	%	Sq. km	%
Residential	4.920	61.86	3.032	38.14	7.952	100.00
Commercial	0.405	59.58	0.274	40.42	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

The 200 metres buffer distance not only did not satisfy the desired adequacy level of all bus stops but also left a large area of the residential land not covered by bus stops service. Therefore, a final testing was necessary to improve the buffering and overlaying outcomes of all bus stops. This testing is based on a buffer distance of 300 metres. Database querying showed a result of 81.26 percent of the residential area of the Birkenhead region located within the buffer zone of all the bus stops and leaving only 18.74 percent for areas located outside. Concerning the commercial area, 75.58 percent were located within the buffer zone of 300 metres from all bus stops whereas 24.42 percent were located outside that buffer zone (Table 17 and Fig. 11).

Table 17: Identity values of land-use types with all bus stops
(300m buffer zone)

Type of land use	Area				Subtotal	
	Inside		Outside			
	Sq. km	%	Sq. km	%	Sq. km	%
Residential	6.462	81.26	1.490	18.74	7.952	100.00
Commercial	0.509	75.58	0.170	24.42	0.679	100.00
Others					5.772	100.00
Grand total					14.403	100.00

The 300 buffer zone for all bus stops suggest that:

(a) The suggested ten stops were necessary to improve the level of adequacy of bus stops in the study area.

(b) The second assumption of this research which states that bus stops are adequate if 80 percent or more of the residential and the commercial areas are located within a buffer zone of 300 metres for all bus stops may be accepted. This is in spite of the relatively lower percentage of the commercial area located inside the 300 buffer zone. This, however, suggests that few more bus stops can be added in the commercial areas in Birkenhead.

(c) The suggested ten stops are necessary and may be added to the scheduled stops by Birkenhead Transport Ltd.

5. CONCLUSIONS AND FUTURE RESEARCH

5.1 Conclusions:

The use of GIS in the developed countries started in the late 1960s and early 1970s. Very few departments, however, installed them because of the prohibitive cost of the hardware and the limited capabilities of the software. Since the early 1980s, a marked increase in the installation of GIS is noticed not only in the developed countries but also in the developing countries as well; it is becoming an important component of planning support systems.

GIS and remote sensing applications in urban transportation planning have become increasingly popular in recent years. Among the many benefits in using GIS and remote sensing in this field are: improved mapping, greater efficiency in retrieval of information, faster and more extensive access to the types of geographical information important to planning, improved analysis, better communication to the public, and speeder access to information for planning application processes.

Transportation planners have used GIS and remote sensing in several aspects that include forecasting the location and type of growth within metropolitan areas as well as urban roads mapping. However, bus facilities including bus routes and bus stops seem to have received little attention. Therefore, the adequacy of these two facilities was chosen by the present author. These facilities constitute the major concern of this research.

It is assumed that the service of bus routes and bus stops is adequate if 80 percent or more of the residential and the commercial areas in Birkenhead are located inside a buffer zone of 300 metres. Although selection of 300 metres as an acceptable criterion was a personal judgment it proved to be practical. This generalisation is based on the assumption that a normal person can walk 40 meters in one minute. In other words, such a person can walk about seven and a half minutes to catch a bus, and this does not seem to be beyond the control of most people.

Digitising the main land-use patterns from the available remote sensing data as well as producing the bus routes from the recent timetables should increase the accuracy of the resulted maps due to the zoom-in capability of the Arcview software. Arcinfo also proved to be very useful in this research for intersecting the residential land-use with the buffer zones of bus routes and bus stops. Once the commands were implemented correctly, querying the database gave quick and easy calculations. Several field surveys were essential to determine the exact location of bus stops. It is recommended that decision makers at Auckland Regional Council take the findings of this research into their account when preparing future transport plans not only in Birkenhead but rather in the whole city of Auckland. It is emphasised that if more new bus routes and bus stops are added then adequacy percentages higher than 90 percent can be achieved.

One limiting factor was the absence of an official map for bus stops produced by Birkenhead Transport Ltd. to verify the location and the number of bus stops in the study area. Another limiting factor was the fact that this research was confined to the study of bus service in a specific area appeared on a 1994 SPOT image as well as a 1999 aerial photo. It is noteworthy that Birkenhead buses cover an area that extends far beyond Birkenhead suburb and the other three adjacent suburbs namely Chatswood, Birkendale, and Beach Haven. These limiting factors, however, should not reduce greatly the significance of the study.

5.2 Future Research:

As mentioned earlier, this research focused on a specific region in the North Shore City. It is recommended that other research be conducted on other suburbs in the North Shore for comparison purposes and verification of the findings of this study. Other research can deal with the number of people using a certain bus route or a certain bus stop. The conclusions of this research and the inferences drawn from them, therefore, are only tentative. More accurate conclusions may be obtained if suggested future research can be taken into consideration.

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