BUS ROUTE NETWORK ANALYSIS FOR HIGH SCHOOL TRIPS IN URBAN PERIPHERY OF SAPPORO CITY

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ABSTRACT: *In Sapporo city, since the high school students are not eligible for driving licence, they are not using passenger car for their school trips. Rather, they are dependent on public transportation like bus and subway. Since the existing public bus route does not give a special consideration for high school locations in the urban periphery, the connection between the high schools and the subway (which serves mainly the centre of the city) is weak. Therefore, a reasonable number of students make undesirable connections to reach to their destination (especially for school based trips). To create a strong link between the high schools located in the periphery area with the nearest subway stations, the bus route networks in the periphery area (taking Kiyota ward as a case neighbourhood) is analyzed. For this GIS based analysis is implemented with Graph interface network analysis. The result of the analysis shows that new shortest bus routes that facilitate high school trips can be introduced.*

Key words: *Public bus, Network, High school, GIS, Graph Interface*

INTRODUCTION

Urban transportation policies tend to favour public transportation than passenger cars because of many reasons like environmental, congestion, economical etc. In Sapporo city the major public transportation (especially bus) users are high school students and elderly people. Therefore, special technical and managerial considerations are essential to facilitate bus travel for the mentioned groups. In optimizing the public transport services one of the elements that should be modelled is the network. Many researchers apply different models in analysing the route network. In this paper the combined application of the classical Graph theory and Geographical Information System (GIS) for bus route network analysis is presented. This research aims:

- To analyze the effectiveness of the existing public bus network in providing service to high school students trip and identify related problems
- To examine the demand and the supply of bus routes services
- To find out the optimal bus route that facilitates the high school bus trip to and from urban peripheries with better transit.

The case study area is the neighbourhood located at the south eastern part of Sapporo city, which is called Kiyota-ku or Kiyota ward. It is the neighbourhood located at the periphery of the city and exhibits an increasing population growth (9.5% population change between 1995 and 2000; source: demographia)

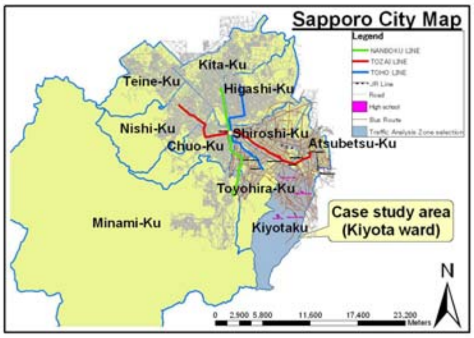

Figure 1- *Case study area*

METHODLOGY

For spatial network analysis Geographical Information System (GIS), Arcview 8.2 and Graph Interface (GRIN) software are employed. The non-geographical representation of GRIN is converted and encoded to the exact geographical location using GIS. The 'All-Shortest-path' algorithm (Dijkstra's algorithm) is the main idea in the Graph Interface to analyse the bus route network and introducing optimal routes that connect high schools with the subway stations. The 1994 Sapporo city trip survey is analysed to assess the demand of bus service by high school students.

DEMAND INDICATORS

According to the 1994 trip survey, the dominant bus users are in the age group of 16-24 ages who are potentially high school and university students. Schooling as a trip purpose is ranked third with other personal trips. Out of high school age respondents only 15% have other trip purposes than from/to school. According to the OD matrix, the high school students' movement is taking place from/to Kiyota neighbourhood. A significant number of students are coming from the adjacent neighbourhoods like Toyohira ward. Concerning the modal connection made by the high schoolers, 68% have a '**Bus-to-Subway**' connection followed by a '**Bus-to-Bus**' and '**Bus-to-Others**' connection both accounts 15%. Only 1% has a '**Bus-to-JR**' connection. The typical mode of transportation is **walk-subway-bus-walk and/or walk-bus-subway-walk.** All analytical figures show that there must be a strong link among different modes to facilitate high school bus trips.

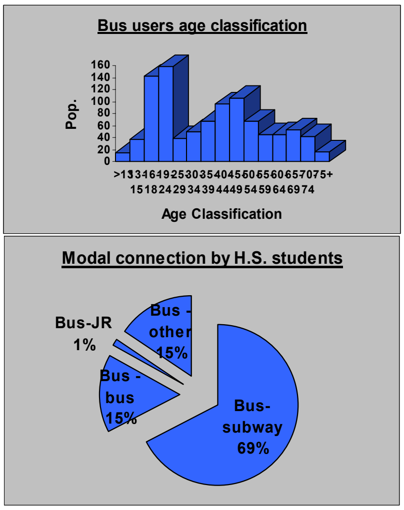

Fig. 2 Demand indicators

SPATIAL NETWORK ANALYSIS

All human beings have a natural tendency of choosing the shortest path to go from place to place. Transit operators as well as passengers both prefer short and faster

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routes to reduce operating cost and the in-vehicle time respectively. Although route selection varies by mode, the underlying principles remain similar; in its most simple form, a route selection process (**R**) tries to respect these general constraints:

$$[\mathbf{R} = f(\min C : \max E)] \qquad (1)$$

Such constraints can be modelled using mathematical method like graph theory. In graph theory there are many analysis solutions for network optimization. The most common and classical is shortest path algorithm (Dijkstra's Algorithm). In this study the other version of Dijkstra's Algorithm, which is called "all-shortest-path algorithm" is used.

Shortest path:- in the network for two given nodes n_1 and n_2 (from n_1 to n_2) is the path P such that $\Sigma\, e\varepsilon P\; w(e)$ is minimum.

Given a weighted graph (G, w) and a node n_1, ***a shortest path tree (all-shortest-path)*** rooted at n_1 is a tree T such that, for any other node $n_2 \varepsilon G$, the path between n_1 and n_2 in T is a shortest path between nodes.

In this study, the nodes are considered as the *intersection in the network and/or the bus stops* where as the links are the *bus ways between the intersections and the bus stops.* The bus stops considered as nodes are stops near to the schools and they serve as a root node to perform the All-shortest-path algorithm.

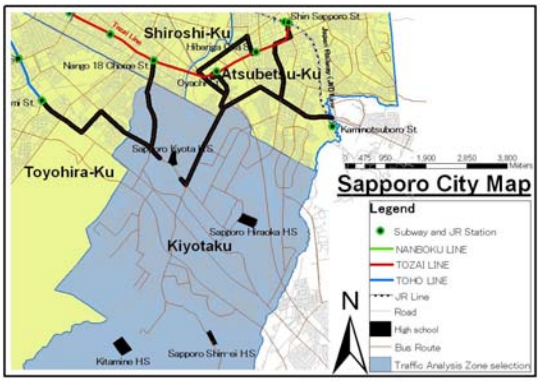

Fig. 3 Shortest route from Kyota High school

DIAGNOSIS PROCEDURE AND RESULT

For the analysis, the bus stops near to high schools are considered as a *source* node and the subway stations around the study area are considered as *sink (target)* nodes. The analysis criterion is the *length* of the bus route which is given as a weight for the link. After digitizing public bus networks, the shortest path from the source nodes to the sink nodes is found out. Using the output result and the existing bus route network, the *diagnosis analysis* has been made with the predefined parameters such as:

- **WELL CONNECTED (W):** When there is one direct short bus line that matches with the output shortest line
- **CONNECTED (C):** When there is one direct short bus line that matches with the out put, bus still has some walking distance. (When the bus stop to catch the bus is not the identified bus stop which is near to the school)
- **LESS CONNECTED (L) :** When the shortest path can be covered with one bus transit (two bus links)
- **NOT CONNECTED (N) :** When there are more than one transits (more than two bus links)

The analysis result is summarized in table 1:

Table 1 Diagnosis result

		Kyota H. S.	Hiraoka H. S.	Kitamine H. S.	Shin-ei H..S.
Toho Line	Fukuzumi Station	W	W	W	W
Tozai Line	Nango 18 Chome Station	C	L	L	L
	Oyachi Station	L	W	N	N
	Hibariga Oka Station	N	N	N	N
	Shin Sapporo Station	N	L	N	N
	Kaminotsuboro Station	N	N	N	N

DISCUSSION

Since most of the bus lines that connect the high school to the subway/JR stations are not one direct line, the students are forced to pay double or triple price while there is a possibility of introducing one direct and economical line. The cost for the connected trip ($\mathbf{C_c}$) and the direct trip ($\mathbf{C_d}$) can be calculated using the following two formulas respectively.

$$\mathbf{C_c = \Sigma\,(i_{xy})} \qquad (2)$$

$$\mathbf{C_d = i + a} \qquad (3)$$

Where, 'i' is the initial cost of each bus lines for the connected trip, 'x' and 'y' are the initial and the point of change bus stops respectively, 'a' is the increment of the fare with the increment of the length

Therefore, the new routes reduce the user cost by more than half price. In addition it reduces the waiting times created at bus stops because of the connected trips using buses for trips between subway stations and schools (25 min. for two connected trips and 45 min. for more than 2 connected trips are observed). Therefore, the proposed route at large reduces the total time incurred by the students from their origin to their destination

CONCLUSION

This paper introduces the application of combined models for bus route optimization in urban periphery areas. Since the subway is the rapid transit service in the city and with the fact that the catchment is only the centre of the city, the connection of schools with the subway stations using public bus is the foreseeable strategic measure. The validity of the model used in this research is tested using the existing temporal bus network of one high school (provided by bus companies). The out put result matches with the existing one so that other schools with no school bus can implement the model for their school bus plans.

Reference

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