

MODELING THE RELATIONSHIP BETWEEN SEASONAL CONSTRAINTS AND MODAL CHOICE CHARACTERISTICS OF HIGH SCHOOL STUDENTS IN SNOWY REGIONS

MINTESNOT Gebeyehu
Ph.D. student
Graduate School of Engineering
Hokkaido University
North 13, West 8, Kita-Ku, Sapporo,
060-8628, Japan
Fax: +81-11-706-6206
E mail: minte@eng.hokudai.ac.jp

Shin- ei TAKANO
Associate Professor
Graduate School of Engineering
Hokkaido University
North 13, West 8, Kita-Ku, Sapporo,
060-8628, Japan
Fax: +81-11-706-6205
E mail: shey@eng.hokudai.ac.jp

Abstract: In snowy regions, there is always transportation challenges associated with seasonal changes. Until now there is no study conducted on modeling the modal choice variation of different seasons for snowy regions. Therefore this study aims to build high school students mode-choice behavior model to predict the probability of students modal choice under seasonal constraints. From the analysis result, it is observed that there occurs a modal shift from bicycle in the summer to walk (for their short distances trips), bus and passenger car in the winter. Therefore, this study tries to form the relative importance of attributes that affect the high school students mode-shift from bicycle in the summer to other modes in the winter. The result is used to suggest policy and strategic options to facilitate high school students trips.

Key words: Modal choice, Snowy regions, High school students, Logit model

1. INTRODUCTION

In snowy regions, there is always transportation challenges associated with seasonal changes. Climate and weather affect the planning, design, construction, maintenance and performance of transportation facilities. The northern part of Japan is one of the areas characterized by such phenomena. In such areas, there exists inevitable modal shift from one mode in summer to another in the winter. There have been many models developed to present the mode and route choice behavior of the travelers (V. Thamizh Arasan et al 1996, Ahmed Hamdy Ghareib1996, Toshiyuki Yamamoto et al 2000). However, there is no study conducted until now on modeling the modal shift behavior of travelers with seasonal changes in snowy regions. Therefore, this study would highly be significant to draw policy and strategic measures especially for bus and other public transportation planning in such regions.

In this study, the factors determining high school students modal shift from one season to the other were studied. The modal-choice behavior of travelers is generally explained by three basic factors: characteristics of the journey to be made (e.g., length, time of day of journey, and purpose), the socio-economic characteristics of the person making the journey, and the characteristics of the transport system (V. Thamizh Arasan et al 1996). To model such challenges, one case study city, called Asahikawa, was chosen. Asahikawa is located at the center of Hokkaido prefecture, northern part of Japan. It is the second biggest city in the prefecture with the population of 360,000. The city is characterized by intense snow so that using bicycle as a mode of transportation in winter is impractical.

The data sets used in this study are Asahikawa city person trip (PT) surveys (summer and winter) and other data collected on the trip characteristics of high school students. The data on high school students comprises the trip characteristics of high school students in the summer and in the winter. The analysis result of this data shows that there occurs a modal shift from bicycle in the summer to bus, passenger car and walk in the winter. It is found out that in the winter students use bus and passenger car for their long trips while walk for the short trips (when their school location is the same as or closer to their residence location). Concerning gender issue, in summer more male students use bicycle than female students do while more female students use bus and passenger car in the winter than male students. In the winter, more male students walk than female students.

The slight modal shift to the school bus is also observed. Even though there are no separate school buses running for high school students in the city, bus companies provide a special morning and afternoon school hour services by rearranging their schedule in winter. Therefore, some students shift their trips from bicycle in the summer to school bus in the winter. Other mode of transportation like taxi and train has no significant influence on the modal shift of high school students.

Therefore, this research has an objective of building high school students mode-choice behavior model and predicting the probability of their choice under seasonal constraints. It analyses the relationship among attributes associated with the choice and the choice makers i.e. high school students.

This paper is organized in 7 sections. The second section explains the data source and the methodology. Section 3 describes the analysis results from 2002 Asahikawa city high school students trip characteristics survey and section 4 presents the model structure used in this study and the generation of dependent and independent variables. Section 5 explains the modeling results and the section 6 discuss the results and give policy recommendations. The final section describes the conclusion.

2. DATA SOURCE AND METHODOLOGY

In this research, three data sets are used. i.e., the 2002 Asahikawa city person trip (PT) survey (summer data), The 2003 Asahikawa city person trip (PT) survey (winter data) and the 2002 data on high school students seasonal variation in modal usage. Those data are used to find out the attributes of the choice and the characteristics of the choice makers (high school students). Another data on high school students is used to analyze and explain the existing modal variation in different seasons since the survey concern is on the existing modal shift. It is not used for the modeling as it contains limited variables.

Table 1- The data source

	2002 PT* Summer	2003 PT* Winter	2002 High school students survey
Number of records (total Number of trips)	62203	25072	3813
Number of respondents	26515	9318	3813****
Average Number of trips per individual	2.34	2.69	
Number of high school age out of the total trips	1991	560***	
Number of high school respondents	886	225	
Average Number of trips per individual (H.S.**)	2.24	2.48	
*Personal trip survey *** The same respondents are sorted out for summer and winter analysis ** High school ****Sample of 2 nd grade high school students from 16 schools in the city			

According to the above table, number of high school respondents for winter are 225 (with 560 individual trips) so that the same respondents are sorted out from the summer data to analyze the characteristics of a specific individual in both seasons. The logit model is developed to predict the probability of modal shift by the high school students from summer to winter.

3. DATA ANALYSIS

3.1. Modal choice seasonal variation

High school students using bus are 5.52% in summer for the trips to school and increased to 43.93% in the winter (Refer figure 1). It shows that a reasonable number of students shift to public bus in the winter from other modes. For the trip from school the figure is from 6.11% to 51.56%. It is observed from this analysis that the students are more dependent on bus for their trips from school than their trip to school.

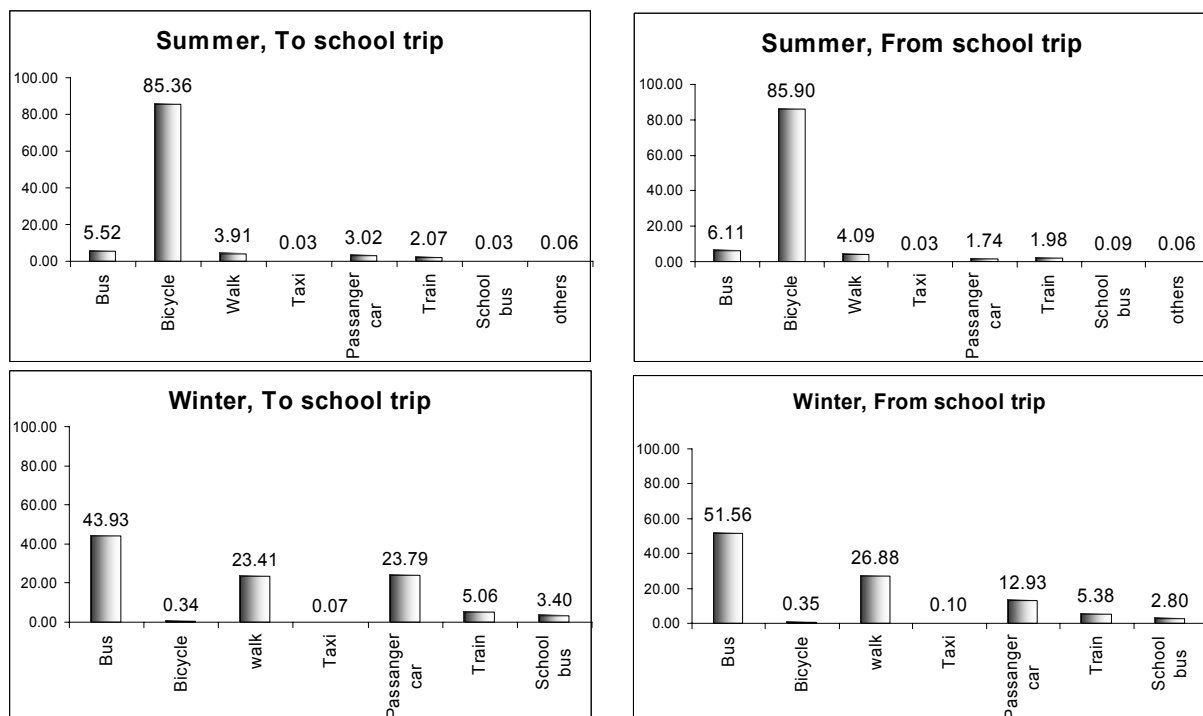


Figure 1- Modal choice seasonal variations

In the summer, it is obvious that almost all students use bicycle. Only 0.34% use bicycle in the winter for their trip to school where as 85.36% use in the summer. For their trip from school only 0.35% use bicycle in winter and 85.90% in the summer. It is because of the intensive snow in the winter so that it is inconvenience to use bicycle. Walk as a means of transportation is favoured in the winter than in the summer. For the trip to school 23.41% use walk in the winter where as it is 3.91% in the summer. For the trip from school, it is 26.88% in the winter and 4.09% in the summer. Students are using walk in the winter for the short distances when they cannot use bus because of unmanageable distance to use bus and not using bicycle because of the snow. They are not using taxi in the winter. The students are shifting their mode not only to public buses but also passenger cars of their families. For trips to school 3.02% in the summer and 23.79% in the winter and for trips from school 1.74% in the summer and 12.93% in the winter use passenger(family) car. More families drive their sons/daughters in the morning than in the afternoon because morning is more time sensitive for going to school than the afternoon. Not many students are use train. For trips to school

2.07% in summer and 5.06% in the winter and for trips from school 1.98% in the summer and 5.38% in the winter. Therefore, train is also one of the options of mode shift from summer to winter even if it is not significant. There is some provision of school buses and it is observed that the service is flexible. In the summer almost no students are using school bus where as in the winter a small amount of students use school buses.

3.2. Seasonal modal shift

According to the 2002 data on high school students, most of the students use public bus in the winter and reasonable number of students use passenger car and walk. Though high school students are not eligible to get driving license, their families drive them to the school. When the summer mode is concerned, the majorities of the students are using bicycle and some students are still using public bus and car as well as walk. Generally, there observed a modal shift from bicycle in the summer to public bus, passenger car and walk in the winter.

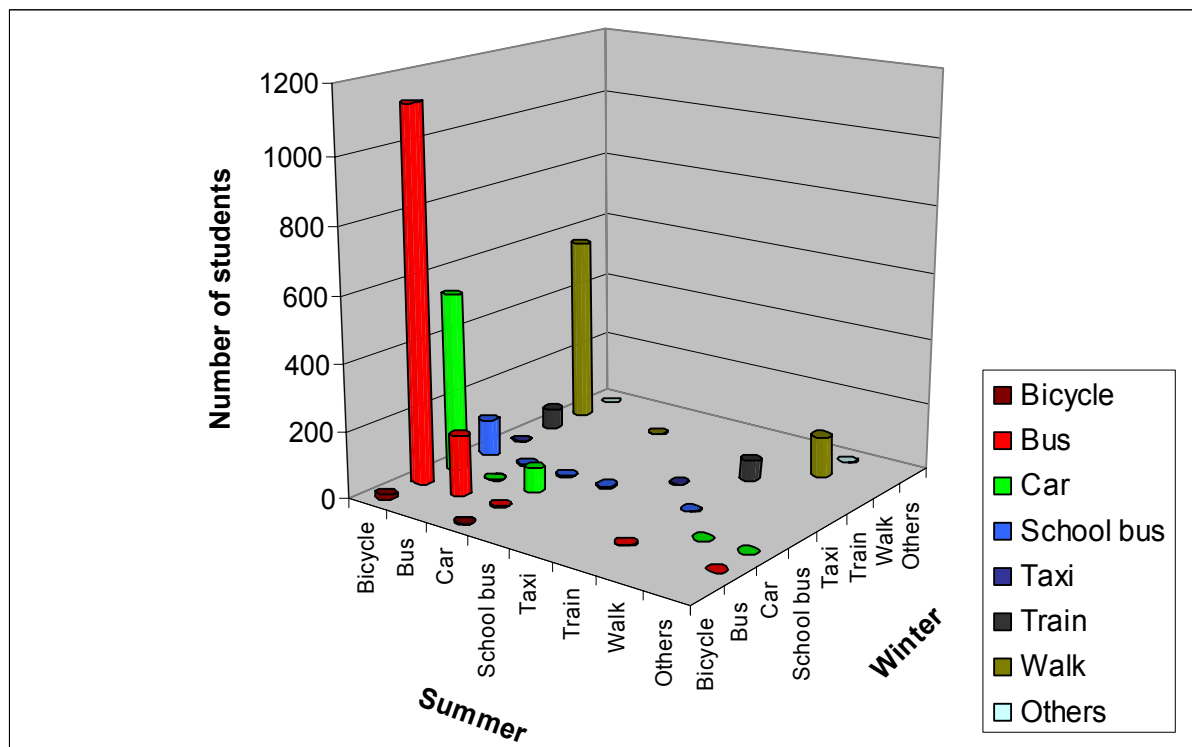


Figure 2- Summer-winter modal shift

Figure 3 and 4 below shows the percentage change of the modal shift from summer to winter. It is observed that there is a significant shift from bicycle in summer to other modes in the winter. It is because of the impossibility of using bicycle in the winter due to intense snow. The percentage shift of bus is high (38.42% for trips to school and 45.45% for trips from school). The second largest mode shift is walk which is 19.5% for trips to school and 22.79% for trips from school. It is observed that students are using bus and walk in the winter for their trip from school because it is not time sensitive where as they are using passenger car more for their trip to school than trip from school (20.76% and 11.20% respectively)

Other modes of transportation like train and taxi are insignificant but there is a slight modal shift is observed to the school bus from summer to the winter. The city's bus company has a flexible bus service running in the winter with a school hour schedule and an existing route considering school locations.

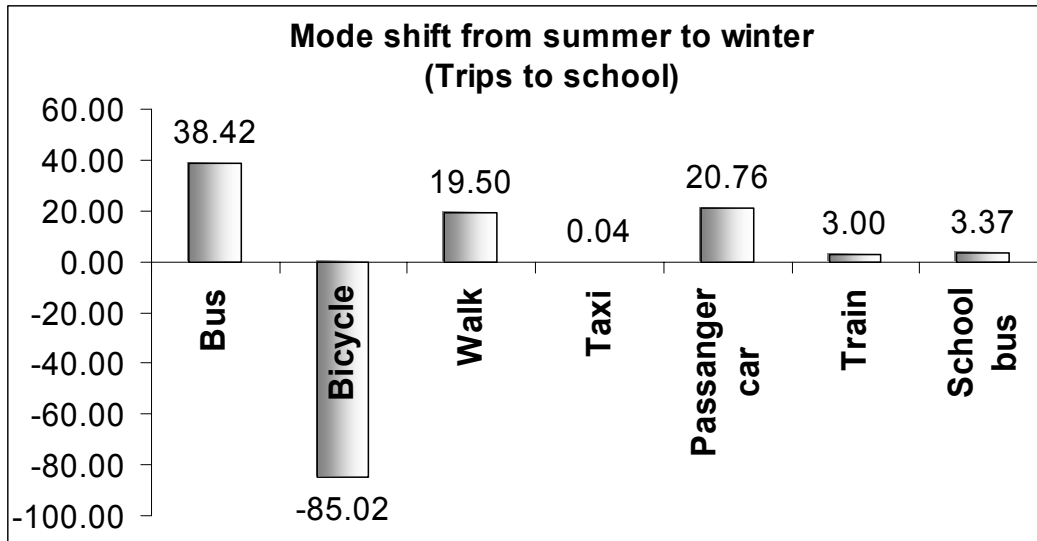


Figure 3- Modal shifts from summer to winter for trips to school

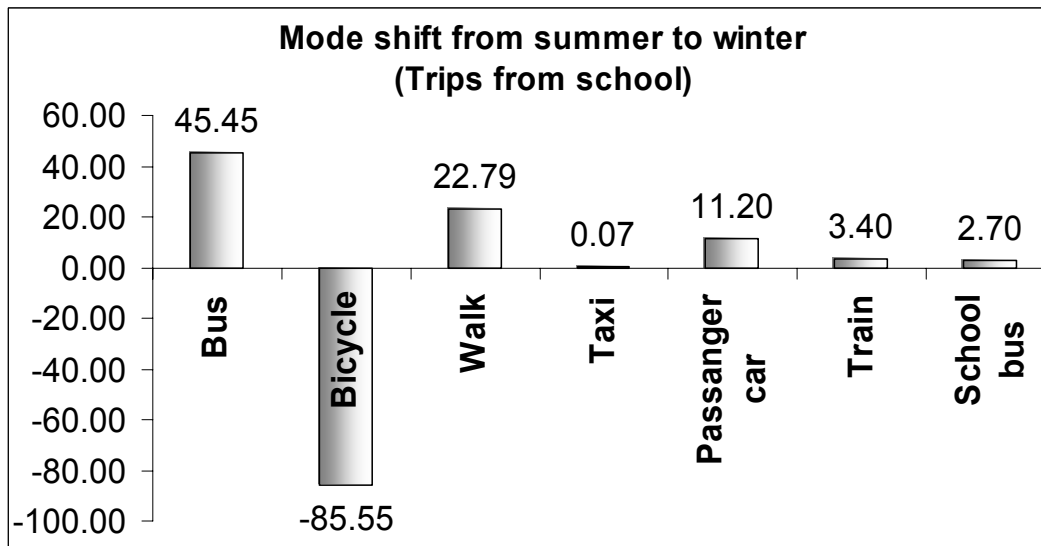


Figure 4- Modal shifts from summer to winter for trips from school

3.3. Influence of sex on modal choice

When the gender issue is concerned, both female and male students use bicycle in the summer but still there is a little variation that more male students use bicycle than female students. Among those who are using bus, the majorities are female students and among those who are using walk, the majorities are male students. In the winter, both male and female students use bus. However, a significant number of male students walk than female students. Among those using passenger cars, the majority are female students. This data set shows that sex has an influence on the modal choice of high school students.

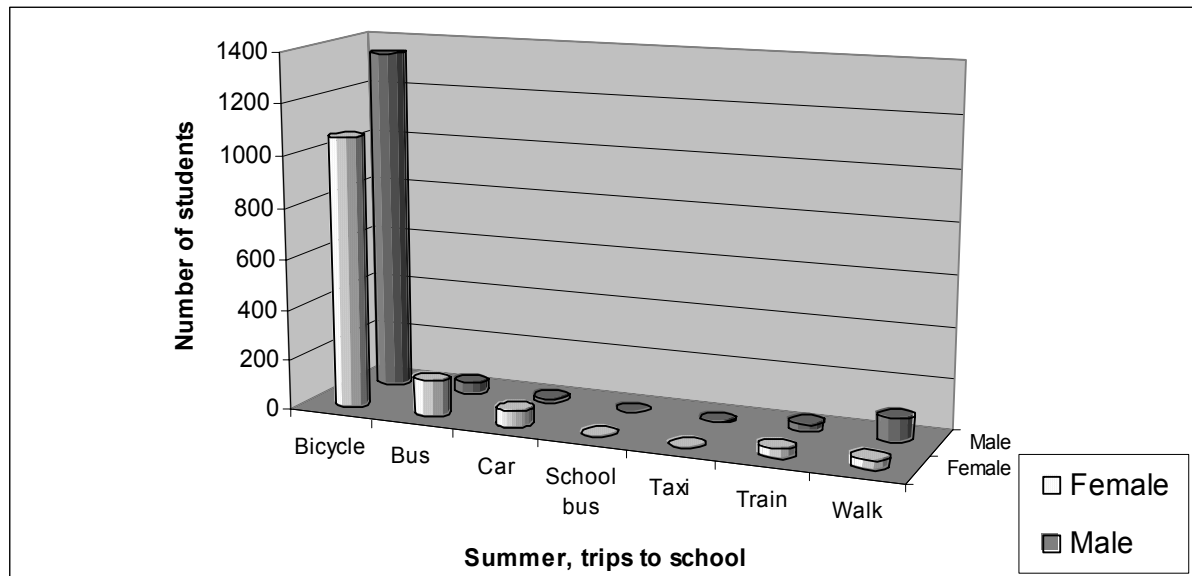


Figure 5- Influence of sex on the modal choice (summer)

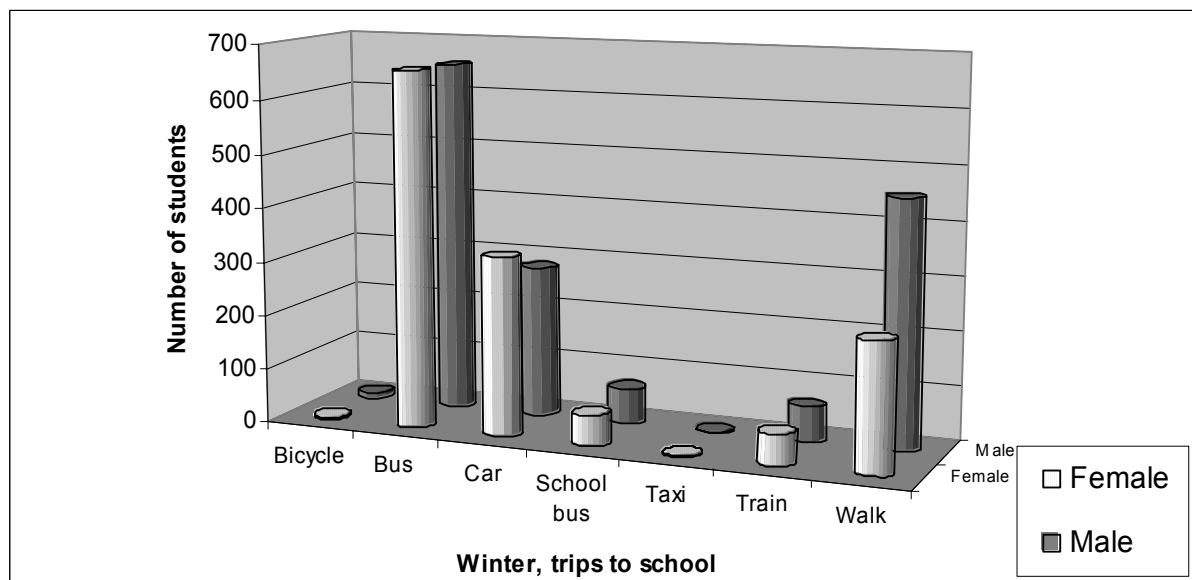


Figure 6- Influence of sex on the modal choice (winter)

3.4. Modal choice Vs school locations

To see the influence of school location and residence location on the modal choice by high school students, GIS based analysis was made taking one case high school (Daikou high school) in the city (Figures 7 to 14). The figures explain the number of trip attraction to the mentioned school from different part of the city using different mode of transportation. There are 16 high schools and 25 traffic analysis zones identified in the city. The summery of the school location Vs mode-choice presented in table 2 is drawn by analyzing each school's location and its trip production zones.

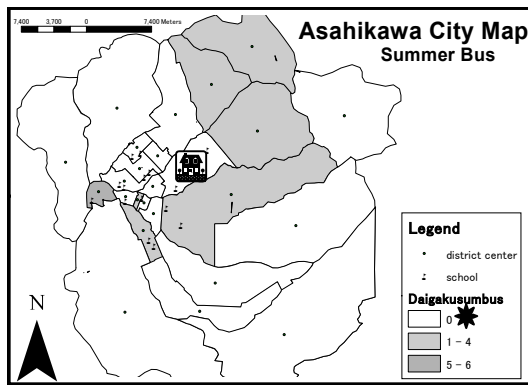


Figure 7- Summer Bus, to Daikou School trip

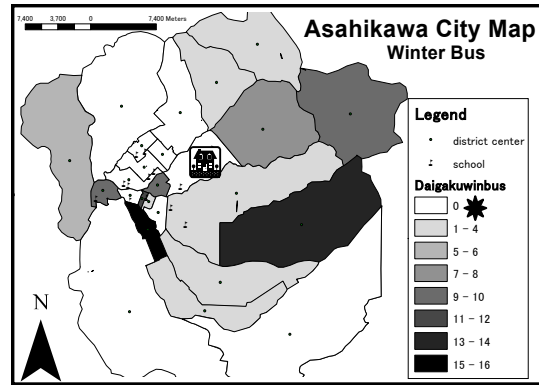


Figure 8- Winter Bus, to Daikou School trip

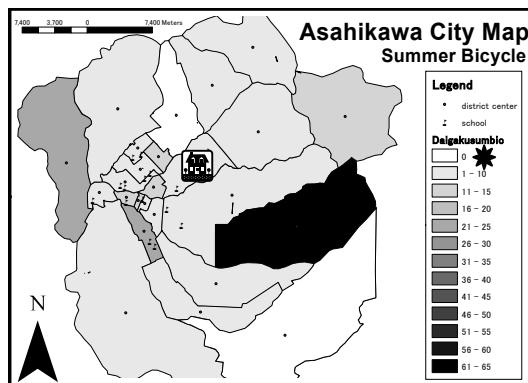


Figure 9- Summer Bicycle, to Daikou School trip

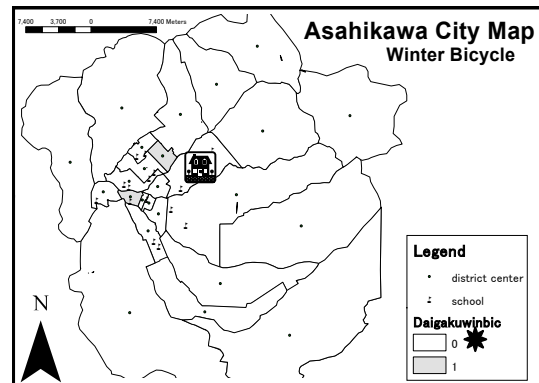


Figure 10- Winter Bicycle, to Daikou School trip

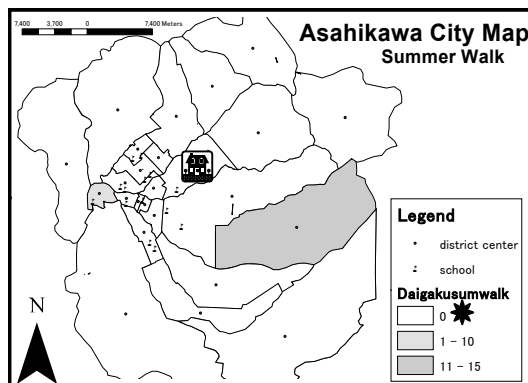


Figure 11- Summer Walk, to Daikou School trip

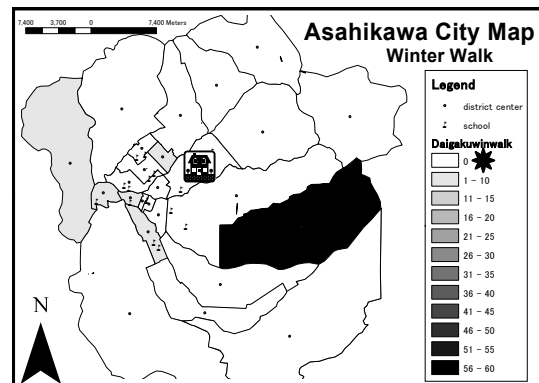


Figure 12- Winter Walk, to Daikou School trip

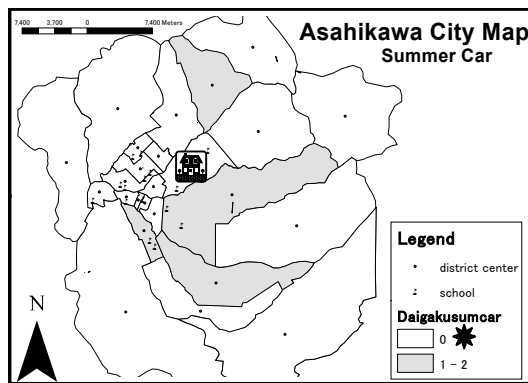


Figure 13- Summer Car, to Daikou School trip

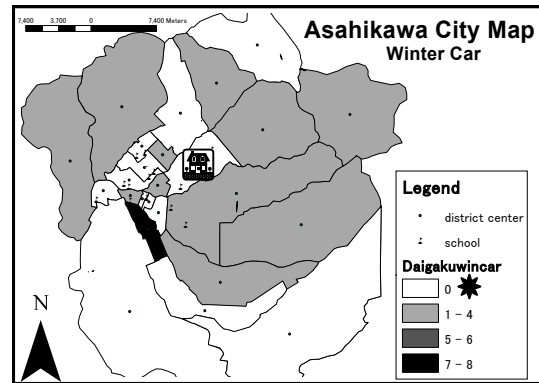


Figure 14 - Winter Car, to Daikou School trip

 The location of Daikou High school
 Number of students

Table 2- Summary of modal choice Vs school locations (the summary analysis of 16 high schools)

Mode of transportation	Modal choice Vs school location
Bus	In winter students coming from far zones as well as those who are living in the same zone of the school location use bus where as in the summer only students coming from far zones use bus for their school trip.
Bicycle	In winter students who are using bicycle are insignificant where as in the summer students coming from every zones of the city to Daikou high school use bicycle irrespective of the distance between the school location and their residence
Walk	In winter, students living in and around the school location are using walk as a mode of transportation. In the summer also students living in and around the school zone walk even if their number is insignificant
Passenger car	In winter, students from almost every zones of the city are using their family car where as in the summer only students living far from the school location area are using passenger car to come to school.
School bus	In winter, only students from adjacent zones are using school bus where as in summer some students from far zones are also using school bus. This shows that students living even in far zones still prefer bicycle.

4. MODEL STRUCTURE FOR SUMMER-WINTER MODE-SHIFT

Choice models are widely used in economic, marketing, transportation and other fields to represent the choice of one among a set of mutually exclusive alternatives. Many models have been developed to analyze the choice behavior and it is the key aspect of the demand analysis. A number of papers also devoted in modeling route and modal choice behavior in transportation field. However, there is no research that has been made on modeling the summer-winter modal shift behavior of travelers. This research aims to model the mode-choice behavior of high school students under seasonal constraints using binomial logit model. When the high school students are faced with two dominant alternatives of mode-shift, the situation will be termed as a binary choice case. The derivation of any binary choice model is conceptually straightforward that the probability of alternative i to be chosen can be easily solved. Consequently, the probability that j is chosen is equal to $[1-P(i)]$.

The general form of the binomial logit model is

$$\text{Prob}[y_i=1] = \frac{e^{\beta x}}{1 + e^{\beta x}} \quad , \quad (1)$$

The model application is based on the utility theory, which assumes that the decision maker's preference for an alternative is captured by a value called utility (U). The decision maker selects the alternative in the choice set with the highest utility: $U(\text{alternative } 1) = \beta_1 x_1$, where β_1 is the coefficient associated with the alternative and x_1 is the variables value.

Logit model is developed in this study to analyze the mode-shift choice behavior of high school students from summer to winter. In the summer, Most of the students use bicycle whereas in snowy winter the modal shift occurs to public bus, passenger car, walk and other mode of transportation so that the attributes for the modal shifts are modeled.

Dependent and independent variables design

The dependent variable is the mode of transportation chosen by the high school students. In summer, the dominate mode of transportation is bicycle. However, there exist walk, bus and passenger car trips as well. For the summer bicycle, trip two mode shift categories in the winter are developed for binomial logit model. Since other modes are few and are not dominant modes, they are excluded. Therefore, public bus and passenger car are the modes chosen by high school students in winter from summer bicycle trips. For summer public bus trips, since the modal shift is observed to public bus itself and passenger car the mode category is designed likewise. In this study, only the summer-winter mode-shift is analyzed. The mode-choice characteristic of the students in the summer is not included in the modeling because of the dominancy of one mode of transportation, i.e. bicycle. The high school students' survey is not used for the modeling as it is in short of comprising attributes.

Concerning the independent variables, Table 3 is generated from the 2002 and 2003 person trip (PT) surveys of Asahikawa city in summer and winter respectively. There are categorical data like sex as well as continuous variables. Some continuous variables are taken directly from the PT data but some are generated from the same data source. Bus waiting time is generated by adding the waiting times of buses of different trips. The minimum 0 and maximum 46 minutes bus waiting time is observed and the average is 7 minutes. The average bus waiting time is distributed to other mode users. Bus travel time is generated as a sum of travel times of different trips for the respective modes where as bus travel time is the sum of the travel times of the mode bus and the average is distributed for other mode users. The minimum of 14 minutes and the maximum 90 minutes travel time is observes and the average bus travel time (in-bus time) is 41 minutes. The zone-to-zone distance is measured from the Asahikawa city zonal map using GIS. The remaining data is directly taken from the PT data or generated as an interaction of two variables.

Table 3- Independent variable

	Explanatory variable	Label	Measurement
<i>a</i>	<i>Alternative specific constant</i>	ONE	
<i>b</i>	<i>Sex</i> 1, if male; 0, if female	SEX	
<i>c</i>	<i>Number of family members</i> Continuous variable for the number of family members	FAMILY	
<i>d</i>	<i>Number of cars</i> Continuous variable for the number of car in the family	NOOFCARS	
<i>e</i>	<i>Travel time</i> The sum of travel time per trip an individual made per day	TRAVELTIME	Minute
<i>f</i>	<i>Bus waiting time</i> Generated from the PT data, adding the waiting times of buses at modal change points	WAITINGTIME	Minute
<i>g</i>	<i>Travel distance</i> The distance from the departure point to the arrival point	TRAVELDIS	Kilometer
<i>h</i>	<i>Zone to zone distance</i> The distance form the center of one zone to the other	ZTZDISTANCE	Kilometer
<i>i</i>	<i>Bus travel time</i> The in-bus time	BUSTRAVEL	Minute
<i>j</i>	<i>Total bus time</i> (Bus travel time plus waiting time), $f+i$	BUSTRAPLWAI	Minute
<i>i</i>	<i>Car share,</i> d/c , Car per family member ratio	CARPERFAMILY	

5. MODELING RESULTS

To explain the heterogeneity of preferences among decision makers, a disaggregate model must include choice makers characteristics such as the socio-economic variables. In this study sex, family members and number of cars in the family are chosen as a socio-economic variables. The alternatives are two dominant mode of transportation of which the students use in the snowy winter.

- ◆ Bicycle in the summer to passenger car and public bus in the winter and
- ◆ Public bus in the summer to passenger car and public bus itself in the winter.

For simplicity purpose and for considering the modal shift clearly, those who are using bicycle and public bus in the summer are sorted out for the modeling and their modal shift in the winter is analyzed.

After running a program several times with combination of independent variables, the results with the $t > |1.64|$ with the 0.05 significant level are presented in the tables below.

Table 4- Logit result, from bicycle in summer to passenger car and public bus in winter

	β	t-value
Constant	-32.1077	-4.09729
Bus travel time	0.603888	4.26036
Bus waiting time	0.404514	4.38556
Number of cars	-0.887593	-2.08663
Dependent variable	MODE	
Number of observations	205	
Log likelihood function	-54.73926	
Restricted log likelihood	-141.9756	
Chi-squared	214.4727	
Significance level	95%	
Likelihood ratio	0.61	
Predicted outcomes	95.6%	

Table 5- Logit result, from public bus in summer to passenger car and public bus in winter

	β	t-value
Constant	-7.07021	-2.82452
Car per family member ratio	1.89929	1.65224
Total bus time (bus travel plus waiting time)	0.0889252	2.53254
Dependent variable	MODE	
Number of observations	57	
Log likelihood function	-30.31028	
Restricted log likelihood	-37.51227	
Chi-squared	14.40397	
Significance level	95%	
Likelihood ratio	0.19	
Predicted outcomes	77.1%	

6. DISCUSSION AND POLICY RECOMMENDATIONS

The model is best fit as the likelihood ratio is in acceptable range and all the attributes with $t > |1.64|$ with 0.05 significant level are taken as a determining parameters. For the modal shift from bicycle in the summer, the attributes associated with the public bus affects the mode-choice of the students. As the bus travel time increases, the probability of choosing passenger car is increasing and that of public bus is decreasing. This implies that long in-bus time discouraged students from using public buses so that they prefer to get a ride from their families. The same is true for the in-bus time plus bus waiting time. When the bus waiting time and travel time is increasing, the students tend to shift to passenger car than using public buses.

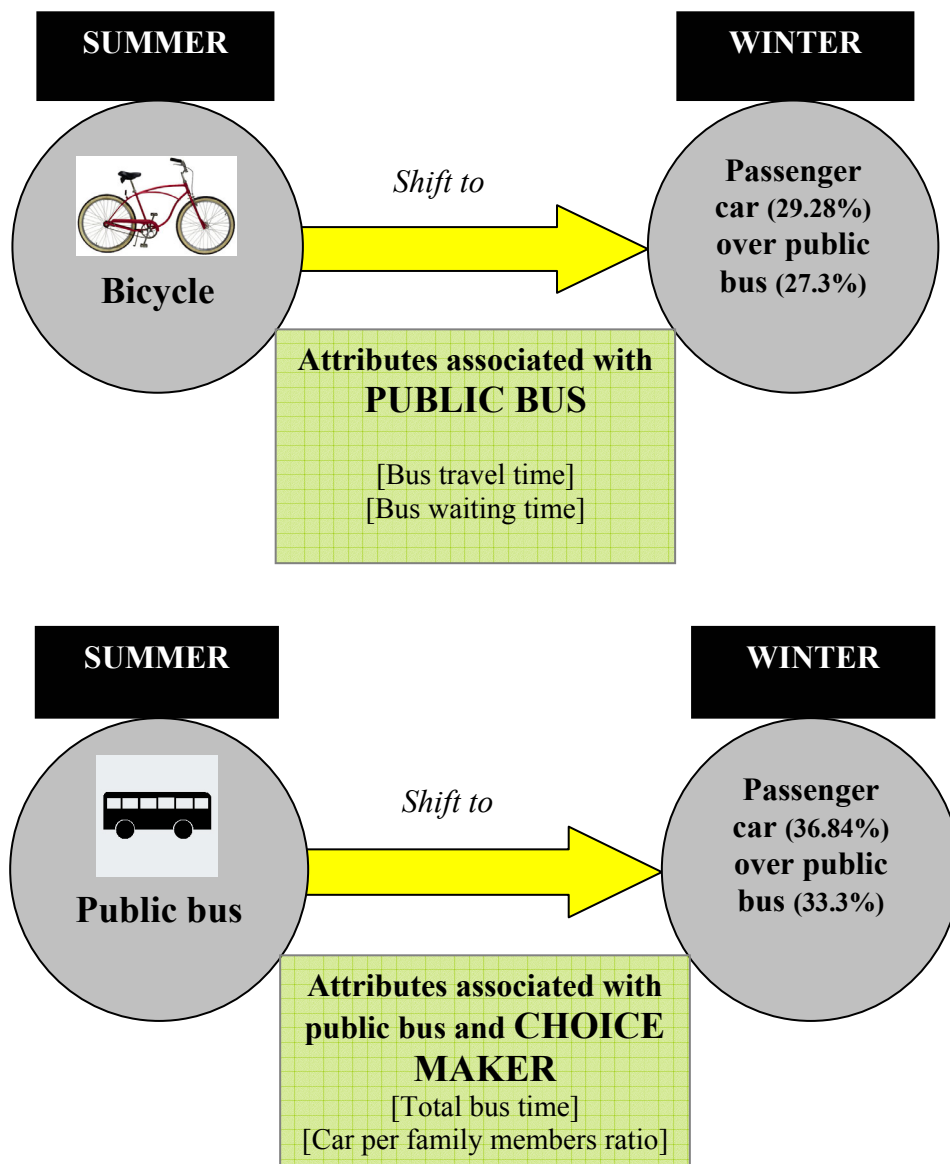


Figure 15- Factors affecting the modal shift from winter to summer

For the modal shift from public bus in the summer to other modes in the winter, the socio-economic attributes as well as the attributes associated with the public bus affects the modal shift of high school students. The car share per family member has a positive impact on

shifting to passenger car in the winter. The higher the car per family share, the lower the probability of choosing public bus. The total bus travel time (including waiting) also affects the probability that the longer that travel time, the less probability of using public buses.

According to figure 16 on the sensitivity analysis of the effect of waiting time and travel time for the mode-shift from bicycle, there is high influence of the change of the waiting time in the probabilities. For the less (5 minutes) bus waiting time the probability of using passenger car is small for long bus travel times (in-bus time). However, for long (20 minutes) bus waiting time the probability of using passenger car is high for long in-bus times i.e., the probability of choosing public buses is low.

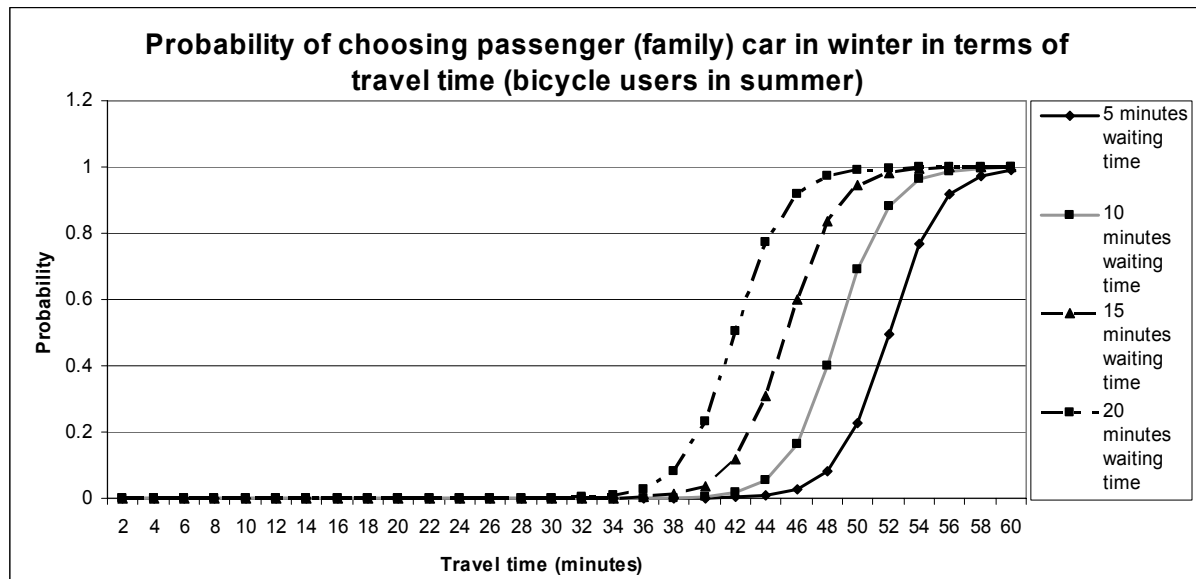


Figure 16- Sensitivity analysis

Therefore, applying the policy recommendations below and improving the bus level of services, the probability of using public bus will be increased. The public bus level of service is the main factor determining the probability of high school students modal choice in the winter. Waiting time and in-bus times are the main factors that the choice is depend on. Bearing this in mind this study come up with the following policy guidelines to improve the high school students trip.

1. *Improving the bus level of services*: This will be improved by dealing with bus frequencies to reduce waiting time. The condition of bus stops like heating in the winter and bus shades have to be improved. The networking solutions and optimal bus linkage plays an important role in improving the bus level of service. Improving the public bus level of services will ultimately reduce the usage of family cars by high school students so that the environmental and congestion problems will be tackled.
2. *Improving school buses*: In Asahikawa city there is no a separate school bus running even though there are some endeavors by bus companies to give a school time services for high school students specially in the winter. Therefore, introducing or improving the school bus option will improve the usage of public buses over passenger cars.

3. *Introducing flexible bus services*: Flexible bus schedule and routes at school times should be improved in the city.
4. *Introducing a shared taxi services*: In the city, the shared taxi service is not common practice. If it is introduced, it will be the affordable means of transportation and it will facilitate high school students' trip. It will contribute in the reduction of passenger car usage and enhancing students' social interaction.
5. *Seasonal tickets*: To encourage students to use public buses in the winter, introducing a seasonal discount or all year round ticket for high school students would be beneficial.
6. *Creating awareness*: Schools should give a an awareness teaching to their students in encouraging students in using public buses using *travel feed back* measures

7. CONCLUSION

According to the 2002 survey on high school students trip characteristics in summer and winter, there occurs a modal shift from bicycle in the summer to bus, passenger car and walk in the winter. In snowy winter, students use bus and passenger car for their long trips while walk for the short trips. In summer, even though there is high dominancy of bicycle usage by both sexes, more male students use bicycle than female students while more female students use bus and passenger car in the winter than male students. In the winter, more male students walk than female students. The influence of sex in the modal choice is not significantly shown in the modeling, as the data set used for the modeling is different (the person trip data). The modal shift to the school bus is also observed even if it is not significant. There are no separate school buses running for high school students in the city. However, bus companies provide a special morning and afternoon services for high school students by rearranging their schedules in winter. Therefore, some students shift their trips from bicycle in the summer to school bus in the winter. Other mode of transportation like taxi and train has no significant influence on the modal shift of high school students.

A number of models on the mode-choice have been developed in transportation behavior analysis. However, the seasonal constraints on the modal choice in snowy regions have not yet addressed. It is obvious that using some mode of transportation like bicycle is impractical in winter seasons and there are anticipated modal shifts. Besides, the impact of seasonal changes on the mode-choice is one of the key issues to be considered in transportation planning in such regions. In this research, the summer-winter modal shift behavior of high school students has been studied. The result of this study shows that there are attributes that affects the summer-winter modal shift. Factors associated with bus like waiting time and in-bus time and other socioeconomic attributes like car ownership and family size have an effect on the modal shift of high school students from summer to snowy winter. Depending on the interaction and sensitivity of one factor over the other, some policy guidelines were drawn. As the seasonal modal variation model is not yet developed, this study would be significant for transportation planning in snowy regions.

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