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A Study on Alternative Urban Transportation Mode Choices in Ulaanbaatar City of Mongolia

by

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Abstract

Construction of railway infrastructure impacts positively on mobility and accessibility of urban residents. However, it needs a huge investment cost to plan, construct, operate and maintain; thus, generally challenges country`s capability. Government of Mongolia (GoM), with the assistance of Japan International Cooperation Agency (JICA), plans to construct a new Mass Rapid Transit (Metro) line which connects east and west points of central part of Ulaanbaatar city. Besides, Ulaanbaatar city has an existing railway corridor along with the planned Metro line. The city administration has an interest to implement proper investigation to maximize the utility of existing railway corridor as one part of the urban transportation planning.

Therefore, this paper aims to point out issues in the present system for financing railway infrastructure in Mongolia. This study also examines current condition of urban transportation infrastructure. Also, the authors examined mode preference survey results comparing existing transportation modes and non-existing transportation modes. This study contributes existing research by comparing four alternative urban transportation modes and examining mode choice characteristics in the city. The results indicate that residents tend to choose transportation modes considering total time, total fare, and headway. Also, characteristic variable affects for choosing a transportation mode.

Keywords: Mass rapid transit (MRT), Existing railway line, Railway infrastructure, RP and SP survey, Ulaanbaatar city, Multinomial logit model

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1. Introduction

Mongolia is a country which is situated in Central Asia and bordered by Russia to the north and China to the south, east and west. According to National Statistics Office of Mongolia (NSO)[1)], total population is estimated to number 3.2 million and total area is 1,565,000 square kilometers. The capital and largest city is Ulaanbaatar city and it is home of about 45% of total population.

The country has been facing lack of effective rural and regional development strategies since the transition from central planned economy system to free market economy system in 1990 (The Regional Development Concept of Mongolia[2)]). During the socialist regime before 1990, in-migration had not been allowed throughout the country. Since the amendment of new constitution in 1992, precipitous in-migration started; especially, people in rural area have been intending to move to the capital city. As a result, Ulaanbaatar city has been experiencing various issues, such as huge expansion of informal residential areas to the north, northwest and northeast, and huge traffic congestion on major arterial roads. The number of total people residing in informal area reached to 700,000 in 2015 (approximately half of total population of the city). Moreover, number of inspected vehicles are estimated to 340,000 in 2016.

Majority of in-migrated people reside in Ger area (1) due to low cost of living. These people usually prefer to live in Ger (2), which has limited access to major infrastructure facilities. **Figure 1** shows the distribution of ger area and apartment house area in Ulaanbaatar city.

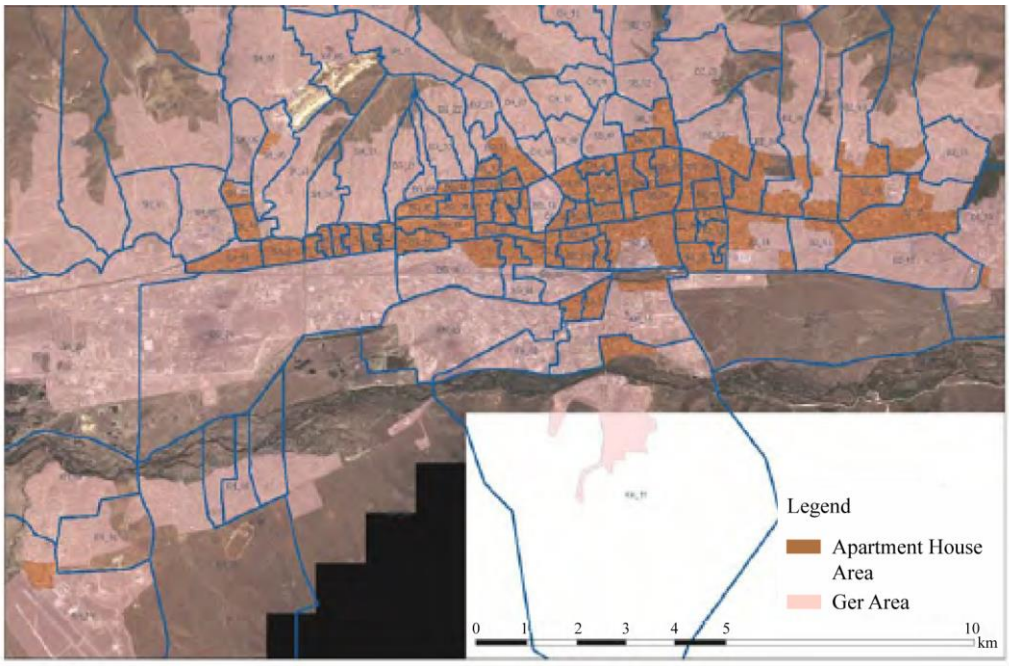

Fig. 1 Distribution of Ger Area and Apartment House Area.

2. Background and Objective

In 2009, JICA conducted a Household Interview Survey (HIS)[3)] to assess consciousness about infrastructure facilities, urban travel behavior and etc. According to HIS, total travel demand in Ulaanbaatar city is estimated 3.4 million trips/day, including walking trip. The demand is composed walking (30.6%), car (24.2%), taxi (9.2%), bus (including micro bus and trolleybus, 33.4%), and

others (2.6%). When walking is excluded, the total demand is 2.3 million trips/day, comprising car (34.8%), taxi (13.3%), bus (48.1%), and others (3.8%). In addition, it concluded that urban traffic condition worsens when taking do-nothing alternative and average travel speed in central part of the city will fall in approximately less than 10km/h in 2030.

Considering above conditions, JICA also conducted "The Study on Implementation of Ulaanbaatar City Urban Transportation Project in Mongolia[4]" (hereinafter "Metro Project") to establish new metro line connecting East-West points of the city. The projected metro line runs alongside of main arterial road Peace Avenue (hereinafter "PA"). This proposal; however, needs a huge amount of investment cost to construct, operate and maintain.

Furthermore, Municipality of Ulaanbaatar (hereinafter "MUB") requested to "Ulaanbaatar Railway [(3)]" (hereinafter "UR") to open a new service on the existing railway corridor. Consequently, UR allowed to open a new service (Railbus service) using an existing railway corridor as a new mode of urban transportation in the city from June 2014. Nowadays, the Railbus runs between two biggest cities (Ulaanbaatar city ↔ Darkhan city [(4)]) due to insufficient number of passengers to use the service. **Figure 2** shows the location of projected metro line and existing railway line. Meanwhile, MUB[5)] reported that implementation of Metro is one of the primary projects in Ulaanbaatar city; although, the city would construct this railway infrastructure after improvement and utilization of existing railway corridor as one of the main urban transit modes.

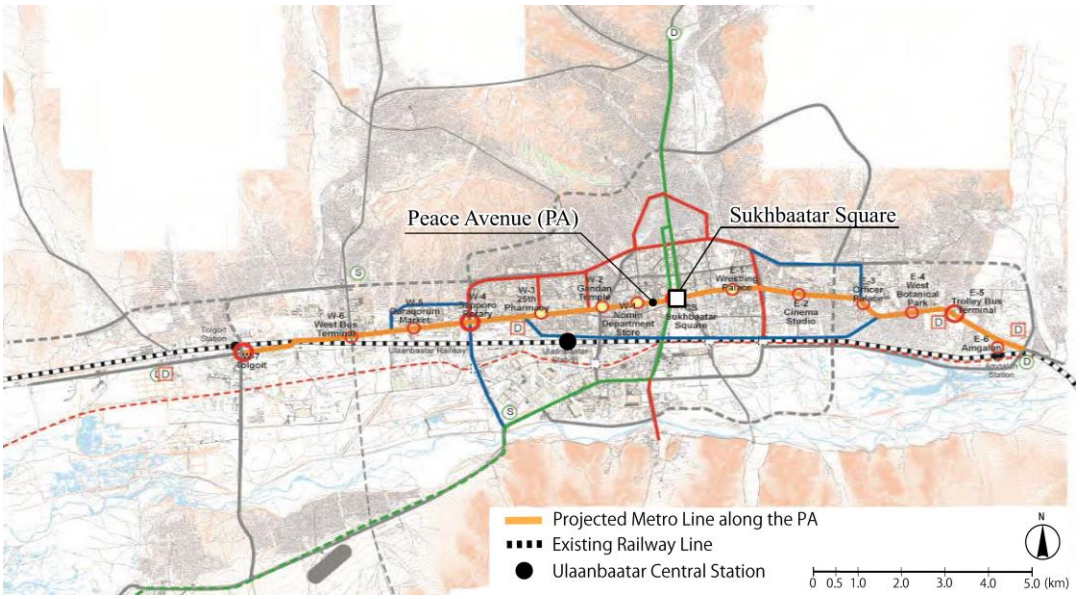

Fig. 2 Projected Metro Line and Existing Railway Line.

Considering above mentioned situations, this paper aims; (1) To assess features of urban transportation system in Ulaanbaatar city based on the economic characteristics of the country, (2) To grasp urban travel characteristics of the residents and demonstrate results of the revealed preference (RP) survey and stated preference (SP) survey which implemented in Ulaanbaatar city in 2016, (3) To develop a multinomial logit model based on the SP survey results.

3. Review of Existing Literature

There are several studies have been investigated regarding railway infrastructure in recent

years. In response to a request from the Government of Mongolia, JICA conducted "The Study on Implementation of Ulaanbaatar City Urban Transportation Project in Mongolia" and suggested to install Metro line through the PA to support long-term and continuous growth of the city. Khurelbaatar[6] investigated which urban rail transportation mode will be preferable in Ulaanbaatar city based on the change of number of average passengers per hour through the PA. Thus, metro will be preferable in 2028 due to number of average passengers reach to 200,000 per hour. Buyantsogt[7] presented current condition of public transportation service and investigated possibility to install medium-sized buses into public transportation service as one of the public transportation modes. Moreover, Fujiwara[8] empirically examined the reliability of SP data for mode choice models by using SP panel data for the new transit system and a newly planned rail station in Hiroshima city, and investigated the effectiveness of an alternative SP interviewing and model updating methods to improve the reliability.

This study contributes existing research by comparing four (two existing modes and two non-existing modes) alternative urban transportation modes and examines whether there is different consciousness about mode choice in two different residential areas, such as Ger area and Apartment house area. In addition, this study also contributes existing research by grasping primary factor of urban transportation mode choice issues in the city which has insufficient urban railway system.

4. Urban Transportation Characteristics of Ulaanbaatar city

Ulaanbaatar city is the center of economic and political power of Mongolia. Generally, 60% of total country`s GDP and 45% of total population gather in Ulaanbaatar city. Total area is 4,704 square kilometers and population density is 272 person/km^2. The total area is similar to Fukuoka Prefecture in Japan (4,971 square kilometers). Since the shift to free market economy system in 1990, mechanical growth of population has been increasing sharply. Consequently, motorization is in progress; thus, total number of registered vehicles reached to 340,000 in 2016 compared to only 14,000 in 1990. 75,000 (approximately 22%) out of 340,000 registered vehicles are hybrid vehicles.

Fig. 3 Overlapping of Main Public Transportation Routes.

For example, the number of registered hybrid vehicles are estimated to 57,000 in 2015 and it is increased by 30% in 2016.

These phenomena have brought numerous changes in the city`s traffic manner, such as time delay in daily commuting trips, huge traffic congestion on the main arterial roads. Traffic police statistics[9] report that during 1997-2007, average vehicle travel speed is declined from 40km/h to 17-25km/h, with the worst congestion during the peak hours in central part of the city.

Major urban transportation modes are car, bus (regular bus, trolleybus and microbus), and taxi. 66 (46.5%) out of 143 main bus routes are for regular bus and trolleybus. **Figure 3** shows the overlapping of main public transportation routes. According to **Fig.3**, PA has most overlapping routes.

5. Issues of Railway Infrastructure Construction in Ulaanbaatar city

Construction of railway infrastructures needs a huge investment cost. According to the World Bank report[10], annual GDP growth rate of Mongolia reached peak level of 17.3% in 2011, the fastest growth rate in the world. Since 2011, the annual GDP growth rate is decreased and reached to 7.8% in 2014. The report also predicted that annual GDP growth rate would decline to 3.9% in 2017. Large-scale projects, such as Metro project, associated with the GDP growth rate of the country. According to JICA`s study, the annual GDP growth rate is expected to keep the double-digit growth in the mid and long term.

Halcrow Group Limited[11] is warning that without proper decision of urban transit modes, in the consequences the wrong choice can be costly and long lasting. In case of Ulaanbaatar city, it is essential to consider about all possible alternatives; such as, possibility to increase level of service of existing railway line etc.

Therefore, it is important to examine about possibility to utilize an existing railway corridor and compare it to the projected metro project based on the awareness of the residents. Sections 5.1 and 5.2 will briefly grasp characteristics of the metro project and existing railway corridor.

5.1 Metro Project

According to JICA`s study, the network length of projected metro line is 17.6 km and consists of 14 stations. The line connects east and west points of the city. The stations consist of elevated, at grade and underground structures and average interval between stations is 1,356m. The total construction cost is roughly estimated US$1.539 billion including US$1.3 billion of construction cost for a tunnel, elevated bridge, stations and related facilities and US$200 million of procurement cost for rolling stock and opening expenses.

The project cost has been estimated based on the full adoption of Japanese companies that can enter into main constructions and procurements (Japanese core case). In this scheme, GoM is responsible for US$700 million, and remaining US$800 million would come from Japanese Official Development Assistance (ODA) fund, which is a long-term loan with a low interest rate and bilateral technical assistance from Japan. Also, it is important that the project must be approved by GoM as a national strategic project to have priority consideration. Thus, it will be challenging to implement this kind of large-scale project; since GoM and JICA are utilizing annual GDP growth rate as an evaluation criterion of public investment.

5.2 Existing Railway Corridor

The history of Mongolian railway development started in 1940’s, where the construction of Trans-Mongolian corridor began in 1947, reaching Ulaanbaatar city from the north in 1950 and the

Chinese border in 1955. The railway plays a strategic role for development of country's economy and Mongolia owns 51% of total railway assets (remaining 49% belongs to Russian Government). The total length of railway network between three countries is 1,140km. Russia and Mongolia use 1,520mm broad gauge. It is a single line railway corridor and approximately 18km of the total network crosses the central part of the Ulaanbaatar city. Many facilities, such as depots, maintenance facilities and freight and passenger terminals locate near Ulaanbaatar city. Ulaanbaatar central station is the main hub station of the whole network and plays an important role for passenger movements.

On October 2012, the Minister of Ministry of Road and Transportation (MRT) and the MUB concluded a memorandum of their cooperation during 2012-2016. Under the Memorandum, the railway related items are to construct the basic structure of Bogdkhan Railway (170km) to increase the speed of the railway; shorten the time which trains run through Mongolia, and secure better living and working conditions and to develop a second East-West public transport corridor by developing LRT on the railway track running through Ulaanbaatar city. Moreover, relocate railway depots for locomotives, and passengers and freight trains from within Ulaanbaatar city area and to develop overpasses and underpasses at railway crossings for a better traffic flow. **Figure 4** shows the outline of Bogdkhan Railway project.

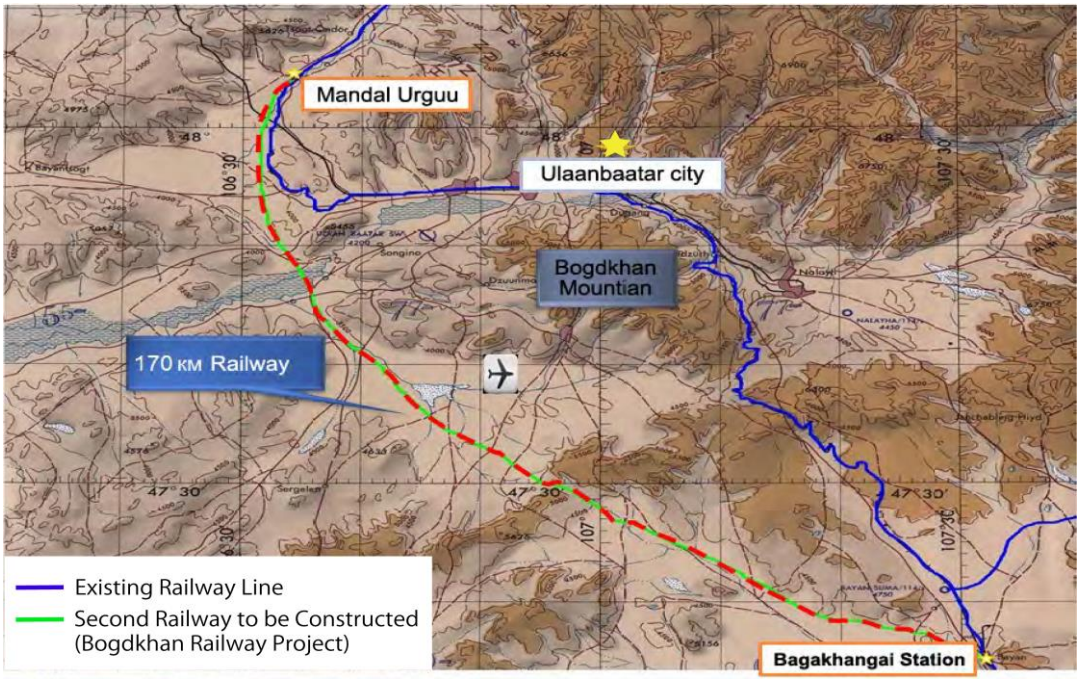

Fig. 4 Bogdkhan Railway Project.

As a first stage of Memorandum, MUB requested to UR to use existing railway line as an alternative urban transit mode for urban transportation in the city in 2013. Further, UR decided to use existing line as an additional mode connecting east and west points of the city during off-peak hours of main railway operation time. The

Fig. 5 Railbus Chassis. (Photo taken by author)

rolling-stock, Railbus [5] was brought from Russian manufacturer "Metrovagonmash" with estimated cost of US$3.85 million. The Railbus can carry 400-500 passengers for one-way trip with 136 available seats **(Fig.5)**. The main concept of using existing railway line is derived from current geographical condition of the city where the existing line is located along the main arterial road PA.

6. Travel Behavior Analysis

6.1 Outline of Mode Preference Survey

Currently, a railway service does not exist in Ulaanbaatar city. As residential area of the city is divided into two areas (Ger and Apartment house areas), the Ger area has been expanding enormously to the north, northwest and northeast directions.

The objective to conduct a travel behavior analysis is to compare consciousness of the residents when non-existing transportation modes are added into the public transportation system. Based on this, the authors carried out mode preference survey to grasp the mode choice behavior of two residential areas.

The mode preference survey consists of three parts; (1) Personal information (filled out by head of household), (2) Commuting trips information (RP survey), and (3) Consciousness about future comprehensive transportation system (SP survey). The target area is selected based on the distance from central part (Sukhbaatar Square) of the city and surrounding areas where metro stations to be allocated. In total five areas (one short distance (Vokzal), two middle distance (Kharkhorin and Botanik) and two long distance (Tolgoit and Amgalan)) are selected as a target area (**Fig.6**).

Since existing railway line is located along the metro line; thus, the authors select the middle point of the projected metro line and existing railway line as a survey point. Then, survey participants were chosen in a radius of less than ~400 meters, between 401~800 meters and between 801~1200 meters starting from the survey point. **Table 1** represents details of the target area and distance from central part of the city.

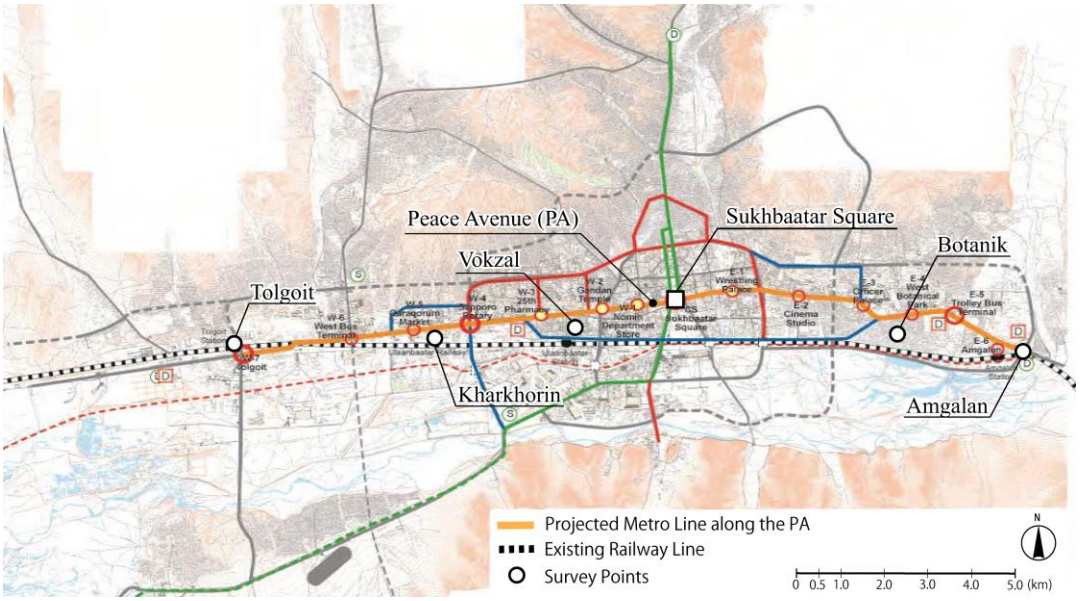

Fig. 6 Mode Preference Survey Points.

Table 1 Target Area and Distance from Central Part of the City.

Target area	Distance from central part of the city (km)	Residential area		
		~400m	401~800m	801~1200m
Amgalan	7.8km	Ger area	Ger area	Ger area
Botanik	5.3km	Ger area	Ger area	Ger area
Vokzal	2km	Apartment area	Apartment area	Apartment area
Kharkhorin	5.6km	Apartment area	Apartment area	Ger area
Tolgoit	9.6km	Ger area	Ger area	Ger area

Two questionnaire sheets are distributed for each household. The sampling method of target area is based on the existence of two different residential areas, distance from/to planned metro line and existing railway line. **Table 2** shows detailed outline of the mode preference survey.

The return rate of the mode preference survey is shown in **Table 3**. 750 (83%) out of 900 distributed sheets were collected. The valid return rate is 509 (57%).

Table 2 Outline of the Mode Preference Survey.

Item	Contents
Target area	More than 16 years old residents in Ger and Apartment house areas who makes commuting trips
Survey method	Distributed questionnaire sheet and collected next day
Survey duration	From 5th September 2016 to 9th September 2016
Surveyor	10 students from Mongolian University of Science and Technology
Items of the survey	1. Personal information (age, sex, employment condition, driving license, income, car possession) 2. Commuting trips information (RP survey) 3. Consciousness about future comprehensive transportation modes (SP survey)
Total distributed sheets	400m: 30 households * 2 persons (head of HH + 1 person) 401-800m: 30 households * 2 persons (head of HH + 1 person) 801-1200m: 30 households * 2 persons (head of HH + 1 person) Total: 90 households * 2 persons * 5 areas = 900 persons

Table 3 Valid return rate (number of persons).

Target area	Residential area	~400m	401-800m	801-1200m	Total
Amgalan	Ger	45	37	35	117
	Apartment	0	2	9	11
Botanik	Ger	38	12	1	51
	Apartment	0	0	0	0
Vokzal	Ger	0	0	0	0
	Apartment	33	1	48	82
Kharkhorin	Ger	12	15	26	53
	Apartment	22	14	14	50
Tolgoit	Ger	27	48	45	120
	Apartment	8	11	6	25
Total		185	140	184	509

6.2 Descriptive Statistics

6.2.1 Personal Information

This section analyzes personal information of the residents based on the information provided by head of household. First, age and sex structure are analyzed based on the distance from center of the survey point in the radius of less than ~400m, between 401~800m, and between 801~1200m.

Figure 7 and **Figure 8** show the age structure and sex ratio. The age structure shows that approximately half of the survey participants were below 35 years old. The sex ratio has mostly same ratio in three residential areas. The ratio is approximately 55:45 for male and female. **Figure 9** shows the number of driving license holders. The number of driving license holders in area less than ~400m is approximately 71%. The remaining two areas have similar ratio. The car possession ratio is shown in **Fig.10**. The car possession ratio in area less than ~400m (75%) is greater than remaining two areas.

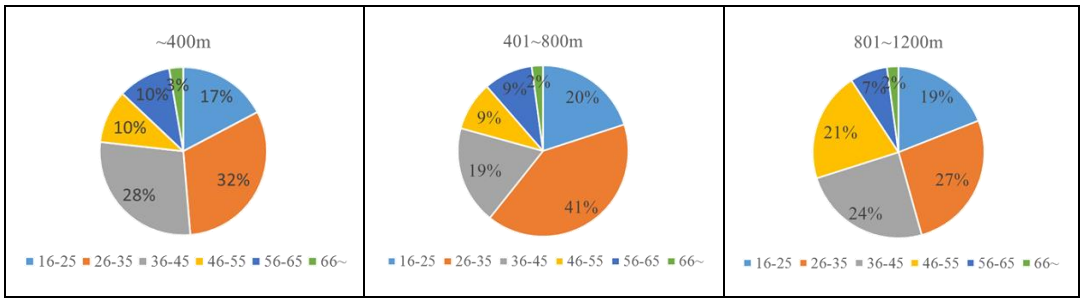

Fig. 7 Age Structure.

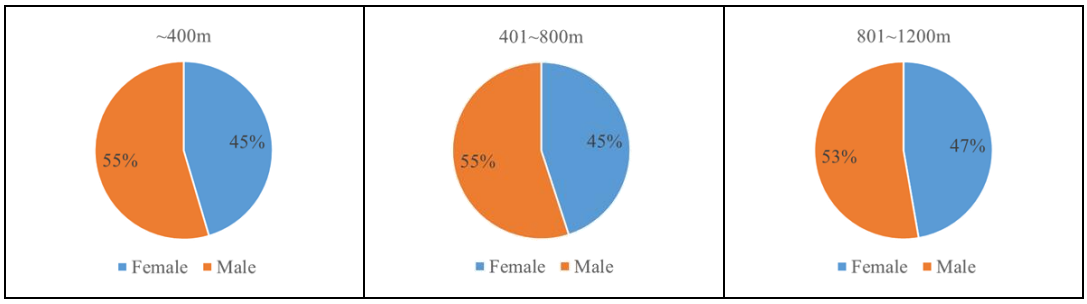

Fig. 8 Sex Ratio.

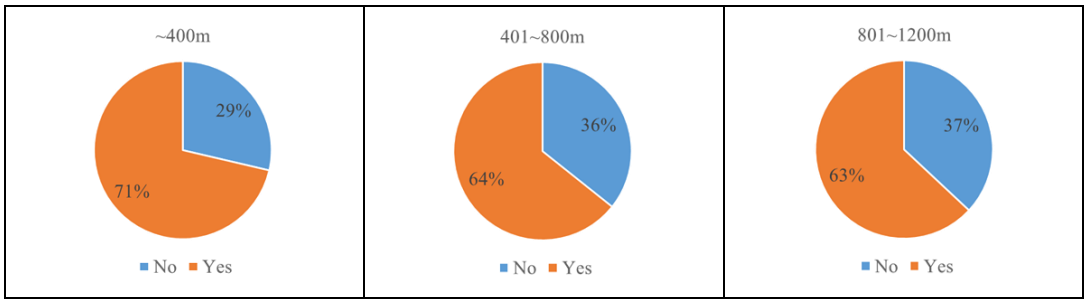

Fig. 9 Driving License Holders.

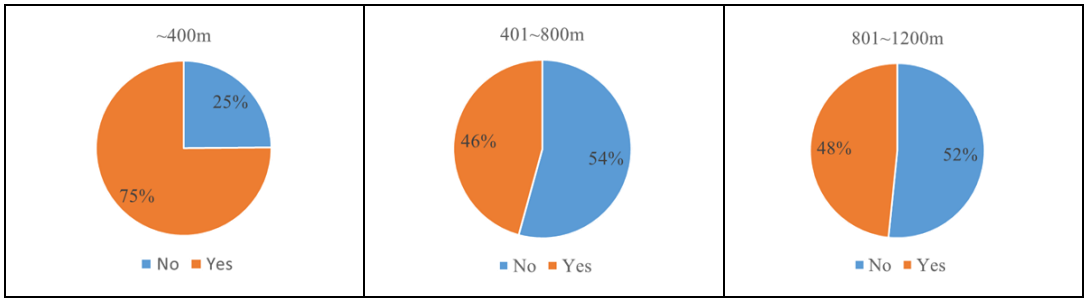

Fig. 10 Car Possession Ratio.

6.2.2 Commuting Trips Information

This section analyzes commuting trip (RP) survey results subjectively. According to RP survey results, 302 out of 509 survey respondents choose car as their commuting transportation mode. 207 survey respondents choose public transportation mode (regular bus, micro bus, and trolley bus). In Ger area, 145 (approximately 43%) out of 341 respondents choose public transportation; on the other hand, 62 (approximately 37%) out of 168 respondents choose public transportation in Apartment house area. **Table 4** shows mode choice results in two residential areas.

Table 4 Mode Choice in Residential Areas.

Area / Mode	Apartment house area	Ger area	Total
Car	106	196	302
Public transportation	62	145	207
Total	168	341	509

As a result, more than 50% of survey respondents choose car than public transportation in both areas. For this reason, mode choice results have been analyzed in different distances from the mode preference survey points (~400m, 401~800m and 801~1200m). **Table 5** shows mode choice results in different distances from survey points. The result shows that the choice of car relatively higher than public transportation in all areas.

Table 5 Mode Choice in Residential Areas in Different Distances.

	Apartment house area			Ger area			Total
	~400m	401~800m	801~1200m	~400m	401~800m	801~1200m	
Car	37 (59%)	19 (68%)	50 (65%)	79 (65%)	59 (53%)	58 (54%)	302
Public transportation	26 (41%)	9 (32%)	27 (35%)	43 (35%)	53 (47%)	49 (46%)	207
Total	63 (100%)	28 (100%)	77 (100%)	122 (100%)	112 (100%)	107 (100%)	509

Next, mode choice results aggregated by its age category. The result shows that more than 68% of people in age category 26~35 and 36~45 are choosing car than public transportation. On the other hand, approximately 66% of age category 16~25 choose public transportation for commuting trips.

Table 6 Mode Choice by Age Category.

Age	Car	Public transportation	Total
16~25	32	63	95
26~35	113	51	164
36~45	92	31	123
46~55	38	32	70
56~65	22	23	45
66~	5	7	12
Total	302	207	509

6.2.3 Stated Preference (SP) Survey

(1) Outline of SP Survey

The SP survey is implemented together with commuting trips survey. The authors assumed that two additional public transportation modes will be available in Ulaanbaatar city in the future. These public transportation modes are "New Train" which utilizes existing railway infrastructure and projected "Metro". The former is assumed to have same level of service with metro, such as number of stations, travel time and cost. The latter will have a level of service same as in its feasibility study.

Therefore, in total four modes (car, bus, new train and metro) are included in SP survey to investigate consciousness of the residents. Since SP survey is not actual mode choice survey, the authors used full experimental design framework to prevent possible bias occurrences.

(2) Level of Service

To compare existing modes (car and bus) with non-existing modes (new train and metro), the authors implemented following field survey. For car and bus, two surveyors rode a car and bus and counted in-vehicle time from survey points to central part of the city during the peak hour. Second, to set up level of service of new train and metro, the level of service of metro is used as a base.

(a) Car and Bus

Table 7 represents the results of the field survey of car and bus. To set up a SP survey values, the authors assumed that traffic congestion will decrease in the future in result of infrastructure development. Thus, the value which decreases by 10% of field survey were used to design a SP survey sheet. About waiting time of bus, current timetable is used to determine survey value. Then, 500 MNT [(6)] adopted as a bus fare. The egless time has same value for car and bus. Moreover, an access time to bus station is 5 minutes for the area less than ~400m, 8 minutes for 401~800m, and 11 minutes for 801~1200m. The authors assumed that headway (number of tracks per hour) of bus will decrease due to opening of new train and metro and decided to adopt 10 track/hour as a headway for bus.

Table 7 In-Vehicle Time of the Modes.

Survey points	Distance to central part of the city (km)	In-vehicle time of car (minute)	In-vehicle time of bus (minute)
Amgalan	7.0	55	33
Botanik	5.9	46	29
Vokzal	3.2	25	15
Kharkhorin	5.9	40	28
Tolgoit	9.8	61	46

(b) New Train and Metro

To compare an awareness of residents, the authors decided to adopt a level of service of metro as a base value. Travel fare of the new train and metro adopts a bus fare as a base value and has three levels. The travel fare will be changed within survey points due to its distance from central part of the city. **Table 8** shows three level of travel fares of two modes.

In-vehicle time of two modes have different values due to its location of the lines. For new train line, three travel speed cases are considered and converted into in-vehicle time. The three cases are 20km/h, 25km/h, and 30km/h. **Table 9** shows converted in-vehicle time of new train.

Table 8 Travel fare of new train line and metro line (Tugrug).

	Amgalan			Botanik			Vokzal			Kharkhorin			Tolgoit		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
New train	400	500	600	350	450	550	300	400	500	350	450	550	400	500	600
Metro	600	700	800	550	650	750	500	600	700	550	650	750	600	700	800

※Level 1 refers to ~400m, Level 2 refers to 401~800m, and Level 3 refers to 801~1200m

Table 9 In-Vehicle Time of New Train (Minutes).

Survey point	Distance to central part of the city (km)	20km/h	25km/h	30km/h
Amgalan	7km	21	16	14
Botanik	5.9km	17	14	11
Vokzal	3.2km	9	7	6
Kharkhorin	5.9km	17	14	11
Tolgoit	9.83km	29	23	19

In case of metro, the travel speed is considered faster than new train line. The three cases are 25km/h, 30km/h, and 35km/h. **Table 10** shows converted in-vehicle time of metro.

Table 10 In-Vehicle Time of Metro (Minutes).

Survey point	Distance to central part of the city (km)	25km/h	30km/h	35km/h
Amgalan	8.0km	18	15	12
Botanik	6.5km	15	12	10
Vokzal	2.6km	8	6	5
Kharkhorin	6.1km	15	12	10
Tolgoit	10.0km	25	21	17

An access time, waiting time and headway have the same value. The access time for the area less than ~400m is 5 minutes, 8 minutes for 401~800m, and 12 minutes for 801~1200m. Also, waiting time is 3, 4, and 5 minutes. Besides, an egless time is 7 minutes for new train and 5 minutes for metro line. This is because stations of the new train locate far from central part of the city.

(3) Setting up an Explanatory Variable

There are two types of variables which will be used in the analysis. The former will be changed through the experimental design and the latter will have a fixed value. The authors used a data analysis software MINITAB to complete an experimental design. Also, Taguchi's $L_{27}3^{13}$ orthogonal array used for experiment. The following **Table 11** shows outline of explanatory variables.

In total 9 variables are used for experimental design. These variables are parking cost for car, fare, waiting time, in-vehicle time, and headway for new train and metro.

Table 12 shows result of first nine rows out of 27 rows of Taguchi's $L_{27}3^{13}$ orthogonal array table. These nine rows apply to the first day of survey in Amgalan area. About distribution of survey sheets, rows 1, 4, 7 are distributed in the area less than ~400m, rows 2, 5, 8 are distributed in the area between 401~800m, and rows 3, 6, 9 are distributed in the area between 801~1200m. In total three different mode choice sheets are distributed for each survey participant. Totally, 1527

Table 11 Outline of Explanatory Variables.

Variable	Unit	Car	Bus	New train	Metro
Fare	MNT	-	△	○	○
Access time	Minute	-	△	△	△
Waiting time	Minute	-	△	○	○
In-vehicle time	Minute	△	△	○	○
Egless time	Minute	△	△	△	△
Headway	Track / Hour	-	△	○	○
Gasoline cost	MNT	△	-	-	-
Parking cost	MNT / Month	○	-	-	-

○Variables used for experimental design △Variables with fixed value

samples (509 survey participants * 3 mode choice survey sheets) are collected. All survey participants are asked to choose most preferable mode in their order. All survey participants received universal set of choice which contains four alternative modes.

Table 12 Result of $L_{27}3^{13}$ Orthogonal Array.

Row	Survey period	Target area	Iteration number	CP	TC	TW	TI	TH	MC	MW	MI	MH
1	Day 1	Amgalan (~400m)	1	0	400	3	14	6	600	3	12	6
2	Day 1	Amgalan (401~800m)	1	500	500	4	16	8	700	4	15	8
3	Day 1	Amgalan (801~1200m)	1	1000	600	5	21	10	800	5	18	10
4	Day 1	Amgalan (~400m)	2	0	400	3	16	8	700	5	18	10
5	Day 1	Amgalan (401~800m)	2	500	500	4	21	10	800	3	12	6
6	Day 1	Amgalan (801~1200m)	2	1000	600	5	14	6	600	4	15	8
7	Day 1	Amgalan (~400m)	3	0	400	3	21	10	800	4	15	8
8	Day 1	Amgalan (401~800m)	3	500	500	4	14	6	600	5	18	10
9	Day 1	Amgalan (801~1200m)	3	1000	600	5	16	8	700	3	12	6

※ `CP` - Parking cost, `TC` - New train cost, `TW` - New train waiting time, `TI` - In-vehicle time of new train, `TH` - Headway of new train, `MC` - Metro cost, `MW` - Waiting time of metro, `MI` - In-vehicle time of metro, `MH` - Headway of metro

6.3 Application of Statistical Model

6.3.1 Aggregation of SP Survey

In this section, simple statistical analysis of data will be shown. **Table 13** represents the aggregation of first choice of first survey sheet. The most chosen mode is metro, car, bus and new train. Next, the first choice of mode is categorized by its residential area. The following **Table 14** shows the first choice of mode categorized by residential area. For the model accuracy, the authors decided to create a model only for first choice of the first survey sheet.

Table 13 First Choice of Mode.

	~400m	401~800m	801~1200m	Total
Car	55	37	39	131
Bus	41	32	38	111
New Train	40	31	32	103
Metro	49	40	75	164
Total	185	140	184	509

Table 14 First Choice of Mode by Residential Area.

	~400m		401~800m		801~1200m		Total
	Ger	Apartment	Ger	Apartment	Ger	Apartment	
Car	29	26	23	14	19	20	131
Bus	26	15	28	5	24	14	111
New Train	28	12	26	5	18	14	103
Metro	39	10	35	5	46	29	164
Total	122	63	112	28	107	77	509

According to **Table 14**, ratio of choosing metro is higher in Ger area. On the other hand, people in Apartment house area mostly choose car in the area less than ~400m and 401~800m.

6.3.2 Application of Multinomial Logit Model

As mentioned in the Section 6.2.2, there are two existing transportation modes in Ulaanbaatar city. These modes are car and bus. In SP survey, two non-existing transportation modes are added and created universal set of choice consisting four transportation modes. This means, all survey participants received universal set of choice to compare four different modes. Based on this condition, a multinomial logit model has been applied in order to estimate parameter values of the resident choices. Here, "JICA STRADA 3.5" is used for parameter estimation.

The mode choice result was set up as a dependent variable. Moreover, as an independent variable (explanatory variable), all variables were set up as an explanatory variable and applied multinomial logit model. These variables are, 1) In-vehicle time, egless time, gasoline cost and parking cost for car, 2) Access time, waiting time, in-vehicle time, egless time, headway and fare for bus, new train and metro. In this case, a parameter estimation result was quite less statistically significant where hit-ratio of model is less than 10%.

Next, the model was built up based on the combination of explanatory variables. The combination is sum of access and waiting time of bus, new train and metro and all other variables remained same as in the previous model. The result is same with previous model. Moreover, the authors combined all time related variables of the modes and applied a multinomial logit model (Model 1). In total three explanatory variables were included in the model. The parameter estimation result is shown in **Table 15**. The result shows not high hit-ratio (31.6%) but all t-values of explanatory variables are statistically significant.

Table 15 Parameter Estimation Result of Model 1.

Explanatory variable	Parameter value	t-value
Constant 1-1 (Car)	-0.891*	-1.885
Constant 1-2 (Bus)	0.539*	1.810
Constant 1-3 (New train)	0.172	1.137
Total time (minute)	-0.042**	-2.961
Total fare (MNT)	0.001***	3.171
Headway (track / hour)	-0.090**	-1.966
Roh	0.0209	
Roh_bar	0.0171	
Chi-square	29.5	
Hit-ratio	31.6%	

Note: * ,**, ***, indicates significance at the 10, 5, 1 percent level

Based on Model 1 result, combination of characteristic variables is considered. These variables are sex, age, holding a driving license and private use car, and living place (Ger area = 1, Apartment house area = 0). In this case, hit-ratio of model and t-value of parameters decreased enormously. Thus, only living place included as a car`s characteristic variable and created Model 2. **Table 16** and **Table 17** show setting of explanatory variable and characteristic variable.

Table 16 Setting Explanatory Variable.

	Car	Bus	New train	Metro
Explanatory variable - 1	Total time - 1	Total time - 2	Total time - 3	Total time - 4
Explanatory variable - 2		Total fare - 2	Total fare - 3	Total fare - 4
Explanatory variable - 3		Headway - 2	Headway - 3	Headway - 4

Table 17 Setting Characteristic Variable.

	Car	Bus	New train	Metro
Characteristic variable - 1	Ger	-	-	-

The parameter estimation result is shown in **Table 18**. The result shows hit-ratio (34.6%) of the model is higher than Model 1 and t-value of the parameters are statistically significant. First, parameters of total time and total fare have negative sign as expected. This means, if total time and total fare decrease, the residents tend to choose public transportation modes. On the other hand, headway has positive sign. It means if number of tracks per hour increase, people tend to choose public transportation modes.

Table 18 The Parameter Estimation Result of Model 2.

Explanatory variable	Parameter value	t-value
Constant 1-1 (Car)	-1.933**	-2.323
Constant 1-2 (Bus)	-2.200***	-2.791
Constant 1-3 (New train)	-1.795***	-2.745
Total time (minute)	-0.034*	-1.775
Total fare (MNT)	-0.008**	-2.497
Headway (track / hour)	0.397**	2.311
Ger	-0.745***	-3.092
Roh	0.0245	
Roh_bar	0.0200	
Chi-square	34.63	
Hit-ratio	34.6%	

Note: *, **, ***, indicates significance at the 10, 5, 1 percent level

Using the result of Model 2, it can be written the utility functions of all transportation modes. **Table 19** shows the utility functions of the transportation modes.

The hit-ratio of multinomial logit model were relatively low. Low statistical significance can occur when SP survey sheet is distributed, and survey participants face to choose among non-existing transportation modes. This is due to low perception of people about non-existing transportation modes. Thus, survey participant’s awareness is important factor to increase accuracy of the model. To solve this problem; on the one hand, RP and SP combined statistical model can be

considered. On the other hand, face-to-face interview survey will be the solution for increasing of accuracy of multinomial logit model.

Table 19 Utility Function of Modes.

Mode	Utility function
Car	V_1 = -1.933 - 0.034 * (Total time) - 0.745 * (Ger)
Bus	V_2 = -2.200 - 0.034 * (Total time) - 0.008 * (Total fare) + 0.397 (Headway)
New train	V_3 = -1.795 - 0.034 * (Total time) - 0.008 * (Total fare) + 0.397 (Headway)
Metro	V_4 = - 0.034 * (Total time) - 0.008 * (Total fare) + 0.397 (Headway)

Conclusion

This paper has investigated features of urban transportation condition in Ulaanbaatar city. The purpose of this paper was to grasp urban travel characteristics of the residents, demonstrate results of the RP and SP surveys, and build up a multinomial logit model based on the SP survey results.

This study grasped urban travel characteristics of Ulaanbaatar city based on the existing literature and data. Then, current transportation mode choice condition was examined subjectively based on the RP survey results. Moreover, based on the SP survey results multinomial logit model was applied. As result of the parameter estimation, residents tend to choose transportation mode considering total time, total fare, and headway. Also, characteristic variable affects for transportation mode choice.

Finally, it is recommended to build-up RP and SP combined statistical model using RP and SP survey results. Moreover, face-to-face interview SP survey can be the solution to increase accuracy of the model.

Note

(1) Ger area is the informal residential area where people live in traditional tent house “Ger” or detached house. Generally, the Ger area has limited connection to the basic infrastructure networks.
(2) Ger is a traditional round tent and portable house. It spent almost 3000 years to reach to the current format. Ger has a circular framework and supported by two pillars in the center.
(3) Ulaanbaatar Railway (UR) is a national operator of Mongolian Railway.
(4) Darkhan city is the third largest city in Mongolia and the capital of Darkhan-Uul Province. It is situated approximately 250km Northwest of Ulaanbaatar city.
(5) Railbus is a lightweight type of passenger rail vehicle. It is commonly used in Germany, Italy, France, United Kingdom and Russia.
(6) MNT is a Mongolian National Currency and referred as Mongolian Tugrug. As of 31 July 2018, 1 MNT equals to USD0.00049.

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