International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:10, No:7, 2016

Bus Transit Demand Modeling and Fare Structure Analysis of Kabul City

Ramin Mirzada, Takuya Maruyama

***Abstract*—**Kabul is the heart of political, commercial, cultural, educational and social life in Afghanistan and the fifth fastest growing city in the world. Minimum income inclined most of Kabul residents to use public transport, especially buses, although there is no proper bus system, beside that there is no proper fare exist in Kabul city Due to wars. From 1992 to 2001 during civil wars, Kabul suffered damage and destruction of its transportation facilities including pavements, sidewalks, traffic circles, drainage systems, traffic signs and signals, trolleybuses and almost all of the public transport system (e.g. Millie bus). This research is mainly focused on Kabul city's transportation system. In this research, the data used have been gathered by Japan International Cooperation Agency (JICA) in 2008 and this data will be used to find demand and fare structure, additionally a survey was done in 2016 to find satisfaction level of Kabul residents for fare structure. Aim of this research is to observe the demand for Large Buses, compare to the actual supply from the government, analyze the current fare structure and compare it with the proposed fare (distance based fare) structure which has already been analyzed. Outcome of this research shows that the demand of Kabul city residents for the public transport (Large Buses) exceeds from the current supply, so that current public transportation (Large Buses) is not sufficient to serve public transport in Kabul city, worth to be mentioned, that in order to overcome this problem, there is no need to build new roads or exclusive way for buses. This research proposes government to change the fare from fixed fare to distance based fare, invest on public transportation and increase the number of large buses so that the current demand for public transport is met.

***Keywords*—**Transportation, planning, public transport, large buses, fixed fare, distance based fare, Kabul, Afghanistan.

I. Introduction

TRANSPORTATION helps to systematize health care system, economic prospects and quality of life in a society, and we cannot figure out a city without using its public transportation system. Besides providing mobility for people and goods, transportation system has also its effects on economic growth. Transportation plays a key role to make relationship among economy, environment, land use safety, health, mobility, accessibility, communication and neighborhoods. Transportation system is accomplished in three ways which are air, sea and land. Nowadays all forms of transportation system are arranged with modern technology [1].

Ramin Mirzada is with the Department of Civil Engineering, Kumamoto University, Japan (e-mail: raminmirzada@yahoo.com).

Takuya Maruyama, Ph.D., Associate Professor, is with the Center for Policy Studies, Department of Civil and Environmental, Graduate school of Science and Technology, Kumamoto University, Kumamoto, Japan (e-mail: takumaru@kumamoto-u.ac.jp).

Recent decade's world has a rapid growth in every arena including transportation. Developed countries provide all kind of transport facilities for their residence. In Asia, some large cities have its own unique transport problem such as traffic congestion, air pollution (which is a serious problem for all countries but mostly in Asian countries which is growing yearly), accident and less access of public to the transport services. The main reason of all these aspects are recklessness of government, poor economy, lack of experts and lack of investments on transportation system. Among new developing countries which have poor transportation system, Afghanistan is in higher rank. It is worth to be mentioned that this study considers only on land transport system.

A. Afghanistan

Afghanistan is a landlocked country located in Southern Asia. The geography of Afghanistan is arid and mountainous.

Afghanistan is a country who has witnessed several years' war for almost three decades including civil wars due to political conflicts and external war with Russia and Pakistan. These bloody wars especially civil war (1989-2001) not only interrupted the development progress but it destroyed almost all infrastructure system including transportation system.

After 2001 by cooperation of world rich countries especially United States of America start its construction and reconstruction again.

B. Kabul City

Kabul is the capital of Afghanistan, it is located in heart hearth of Asia and it is fifth fastest growing city in the world. As estimation of Central Statistical Office (CSO), population of Kabul city was 2.27 million on 2005 on that time Kabul city was limited in to 22 zones, where zones 1, 2, 3, 4 and 10 are center part of the city. According to estimation of CSO [2] and Japan International Corporation Agency (JICA) [3], population of Kabul was estimated 4.2 million in 2008, but it does not have capacity for this much residence; therefore, by cooperation of JICA, Kabul government decided to expand Kabul City from 275 km^2 to 1022.7 km^2 (form 22 zones to 26 zones). Zones 1-22 is considered as old Kabul and zones 23-26 is considered as new Kabul city. It is worth to mention that new Kabul city is designed for more than 3 million people and the authority which is responsible for construction of Kabul new city is called Capital Region Independent City Development Authority (CRIDA) [4].

Kabul has 3500 years of history, and it became the capital of Afghanistan on 1773 under the kingdom of Timor shah (king of Afghanistan). Kabul was designed for two million on 1978 until 2000 but being the safest city during the war in the

country most of public emigrated from other cities to Kabul and in 1988 population became almost 2 million [5].

After 1989, Kabul experienced many civil wars and went through damages and destruction of all infrastructure including transportation system like transit buses, trolley buses, paved roads, sidewalks, traffic signals, traffic signs and drainage system [5].

From 2001, after establishment of new government in Afghanistan, Kabul residence faced with lots of problems including transportation problems, the reason for these problems was rapid increase in population.

C. Problem Statement

The main problem of Kabul public transport is their dependency on only one mode which is large buses and Kabul residents call it Millie bus (national bus). Besides being the only one mode (bus system), poor performance of Mille bus (national bus) authority results in the rise of large number of private cars who work as public transport such as micro bus and taxi. These private cars do not obey the public transport schedule, map, and routes. From one hand, they did not follow public transport regulation, on the other hand, this large number of private cars (micro bus and taxi) causes' congestion, traffic volumes, noises, and air pollution in the city.

D. Research Objective

The main objectives of this research are:

- To develop a travel demand model for future bus system in Kabul city.
- To compare the current supply of large size bus with the demand which is found in every individual bus route.
- To evaluate the current fare (fixed price) of large bus in Kabul city.
- To evaluate a distance based fare for large size bus in Kabul city.
- To find and analyze satisfaction level for two fare system.

E. Structure of This Study

The structure of this research is as follows: Section I gives the introduction including the background of transportation planning, Afghanistan, Kabul city, problem statement of public transport in Kabul city, objective of the research, and structure of this study. Section II gives the over view of transportation system in Kabul city including transport administration in Kabul city, condition of different type of roads in Kabul city and information about public transportation system in Kabul city. Section III includes travel demand forecast modeling for Kabul city large bus, finding required number of bus and shows comparison of the demand with current supply in Kabul city as a result. Section IV gives fare structure analysis including analysis of current (fixed fare) and proposed fare structure (distance based fare). Section V gives satisfaction level of fare structure. Section VI gives the conclusion.

II. Overview of Transportation System in Kabul city

Since 2002 with the establishment of new government after black regime of Taliban, most countries of the world tend to take part in reconstruction of new Afghanistan, by their help now Afghans is relatively secure country and it is possible to work on construction of their country.

A. Transport Administration in Kabul city

In Kabul city the following authority and ministries are responsible for transportation system:

- Kabul municipality is responsible for planning, design, implementation and maintenance of urban transport facilities including streets, bus terminal, bus stations, railways and airports in Kabul city.
- Ministry of Transport is responsible for making transport policies and administrating public transport services in Kabul city and entire country.
- Millie Bus (national Bus) enterprises is responsible for operating fleet buses, in the city and districts of Kabul city [6].

B. Roads in Kabul City

The roads in Kabul city are consisted of national road network and urban road network and classified as:

- *Main artery road* consists of three regional highways and one national highways radiating from the city center from the main frame of the city road system as well. The carriageways of two lanes and paved with asphalt.
- *Artery roads* are supplement of three regional highway and one national high way to inter-connect districts in city. The carriageways are no less than two lanes and paved with asphalt.
- *Secondary roads* connect artery road to community roads, carriage ways no less than two lanes and most of them are paved.
- *Community roads*: This type of roads having no less than two lanes form town block, many of them are not paved and without side drain.
- *Other roads*: Most of them are narrow and unpaved roads with only one lane [6].

C. Road lanes

In Kabul, no road markings are provided to indicate the lane separation. Thus, the number of lanes in each road is estimated from the road width.

Table I shows road lengths by number of lanes of major arterial and arterial road network.

TABLE I
Road Lengths by Number of Lanes of Major Arterial and Arterial Network [4]

	1 lane	2 lane	3 lane	4 lane	6 lane	Total (km)
Major Arterial	-	87.0	4.2	33.8	12.4	137.4
Arterial	7.6	143.3	1.9	34.6	5.9	193.3
Total	7.6	230.3	6.1	68.4	19.3	330.7

D. Public Transport in Kabul City

Kabul city has access to only one mode of public transport mode which is large size bus and it was operated by government. The responsible authority for operating of these buses is Mille Bus (national bus) Authority.

Mille bus (national bus) authority was established in 1979; on that time, it had 1500 buses in whole country and 467 of them were only for Kabul city and districts. The purpose of establishment of national bus authority was helping poor people. The existing government of that time was rich and they used to give subsidy to national buses every year there for the fare of Mille bus (national bus) was very less. By starting of external and internal war in Afghanistan, Afghan government stopped giving subsidy to Mille bus and Mille bus limited its operation in few routes. The reason was less bus fare and no subsidy from government, operation of bus system become limited and most of buses was knocked out [7].

By the establishment of new government in Afghanistan in 2001, national bus authority started their work again, but due to less number of buses in Mille bus authority, only few routes were active.

After 2005, some countries mainly India and Japan aided buses to Mille Bus Authority and once again it could restart their operation with less fare and government subsidy.

JICA did a research about present bus service in Kabul on 2008; Kabul city bus service is content of 54 routes based on 10 terminals through the city, and the total length of this service is 473 km, making average route length of 8.8 km (Table II shows the present bus service in existing Kabul city). Furthermore, JICA proposed new bus services by Route hierarchy which is illustrated in Table III [6].

After 2010, government stopped its subsidy to Mille bus authority, because of less income of bus users Millie bus authority cannot increase the fare and day by day the operation of national bus once again became less and instead some private company took over with high fare.

TABLE II
PRESENT BUS SERVICE IN EXISTING KABUL CITY [6]

Routes (n)	Total length (km)	Avg. trip (km/route)	Terminal (n)	Routes from 1 terminal (n)
54	473	8.8	10	5.4

TABLE III
PROPOSED ROUTE SERVICE BY ROUTE HIERARCHY [6]

Required routes (n)	Total length (km)	Avg. trip (km/route)	Desired bus stop (n)
54	473	8.8	10

III. TRAVEL DEMAND FORECASTING MODEL ESTIMATION OF KABUL CITY LARGE BUS

A. Travel Behavior

JICA did a household survey of 5000 Kabul residents which was 1% of whole population of Kabul city on 2008. This survey was done in 20 zones of Kabul city except zones 14 and 21 due to security conditions. [6]

In this study, the only way to find the origin destination table of whole population is multiplying the created origin destination table of person trip survey in to expansion rate which were obtained from Table IV.

a) Total Trip

For analysis purpose, travel modes are divided in to three main modes in Kabul city which are shown in Table V. Table IV shows that most trips are done by main mode of public transport and the share of public transport is 49%, it almost half of all trips.

TABLE IV
EXPANSION RATE [6]

District	Population	Household	Expansion rate
1	72100	105	68.64
2	88400	112	84.45
3	16200	174	101.15
4	450000	307	153.7
5	375000	244	165.45
6	200000	323	67.32
7	300000	343	103.7
8	236676	364	71.06
9	237774	277	93.49
10	380288	461	97.35
11	280000	424	66.31
12	156000	197	87
13	230000	277	91.01
14	130000	-	-
15	383826	277	148.6
16	110000	255	48.01
17	71400	52	159.16
18	13500	63	22.11
19	45000	31	128.21
20	61867	36	181.38
21	3300	-	-
22	20000	45	44.71
Total	4,007,131	4,367	

TABLE V
QUALIFICATION OF TRAVEL MODE [6]

Mode	Main modes
Walk	Walk
Bike	Private Transport
Car	
Truck, Others	
Large bus	Public transport
Minibus	
Microbus	
Taxi	

TABLE VI
TOTAL TRIPS IN KABUL CITY BY MAIN PURPOSES

No.	Mode	Trips	Share
1	Walk	950088	39%
2	Public Transport	1206217	49%
3	Private Transport	288468	12%
Total		2444773	100%

b) Trip Mode

Kabul city public transport is consisting of micro bus, minibus and large bus, nowadays most of the Kabul residence uses micro bus as public transport. Fig 1 shows that among all trips after walk, public transport has high share, it means that Kabul residence tend to use public transport.

c) Share of Transportation Mode by Trip Distance

Fig. 2 shows share of modes based on distance, and it illustrates that among all other trips after walk, the highest share is from micro bus and large bus.

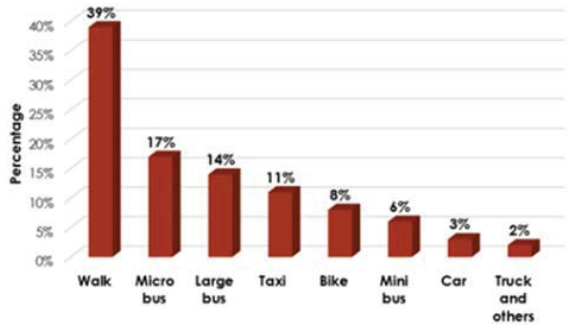


Fig. 1 Share of trip by all mode

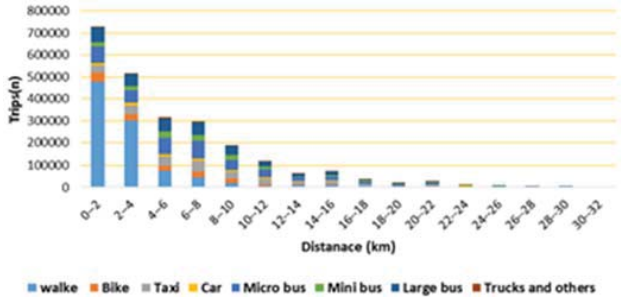


Fig. 2 Share of all mode trip based of distance

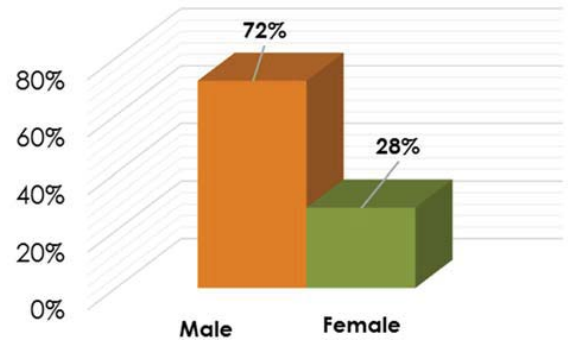


Fig. 3 Share of trips by gender

d) Share of Trip by Gender

There is a huge difference between male and female trip share in Kabul city, the only reason for this difference is Afghanistan culture. Fig. 3 shows average number of trips by gender.

e) Trip Purpose

The purpose of trips by inhabitants of Kabul city are classified in to five parts which are to work, to school, personal (shopping + business), to home and others. Most of the trips are home based trips which are almost half of all trips. Table VII shows number of trips by purpose with their shares.

TABLE VII
TOTAL TRIPS IN KABUL CITY BY PURPOSES

No.	Purpose	Trips	Share
1	To work	467,883	19%
2	To school	539,230	22%
3	Personal (shopping and business)	176,715	7%
4	To home	1,189923	49%
5	Others	71,0232	3%
Total		244771	100%

B. Travel Demand Forecasting Model in Kabul City

There are several approaches for estimation of travel demand. Among the other methods, urban transport modeling system (UTMS) is more famous. This system is also known as four step modeling. These four stages are trip generation attraction, trip distribution, model split and trip assignment.

1) Trip Generation and Attraction Model

The first step of traditional or classical four stage modeling is trip generation and attraction modeling and it is used for forecasting travel demand. The purpose of trip generation and attraction is to predict the number of trips which are originating in and destined for a particular traffic zone [8].

In 22 zones of Kabul city zone, 4, 5, 10, 11 and 15 have high shares of generation trips compared with the other zones. Especially zone 15 has almost twice generation of trips than other zones. Besides that, zones 1, 2, 3, 4, 10, 11 are the most attracted zones. On the other hand, zones 14, 17, 18, 19, 20, 21, and 22 have the smallest number of generation and attraction.

In this study, the following equations are considered as trip generation and attraction model and it is called simple linear regression model.

$$g_i = \beta_0 + \beta_1 pop_i + \beta_2 pop_i \quad (1)$$

$$a_j = \beta_0 + \beta_1 pop_j + \beta_2 pop_j \quad (2)$$

In (1) and (2), population and employment were considered as two variables. Trip generation and attraction model results are shown in Tables VIII and IX.

TABLE VIII
PARAMETERS OF TRIP GENERATION

Variable	Parameter	T-value
Population	0.6	9.03
Employment	0.44	2.4
Constant	-9047.2	-0.65

TABLE IX
PARAMETERS OF TRIP ATTRACTION

Variable	Parameter	T-value
Population	0.836	6.6
Employment	0.6	3.0
Constant	5958.1	0.24

Tables VIII and IX illustrate that the two variables have a positive relationship with trip generation and attraction.

Zones 14 and 21 were not surveyed due to security conditions; therefore, these two zones were not considered for

finding trip generation and attraction modeling. The forecasted trip generation and attraction from zone 1 to 22 of Kabul city for 2015 is shown in Table X.

TABLE X
TRAVEL DEMAND FORECAST (TRIPS) 2015

Zone. No.	Generation	Attraction
1	132,599	175,035
2	111,816	139,789
3	130,968	132,455
4	266,118	245,331
5	248,270	230,930
6	159,228	153,502
7	206,257	193,770
8	232,708	221,850
9	234,985	225,590
10	279,732	257,276
11	172,251	162,500
12	134,791	133,381
13	170,310	163,868
14	143,616	146,211
15	257,830	232,785
16	118,749	122,405
17	132,665	138,619
18	809,47	882,85
19	932,95	948,96
20	511,89	577,22
21	369,16	484,10
22	224,74	354,62
Total	341,771,4	340,007,2

2) Trip Distribution Model

The second component of traditional or classical four-stage modeling is trip distribution modeling. Trip distribution is a model of the number of trips that occur between each origin zone and each destination zone. It uses the predicted number of trips originating in each origin zone (trip production model) and the predicted number of trips ending in each destination zone (trip attraction model).

There are a number of methods to distribute trips among destinations, gravity model is the popular model among others. The gravity model is much like Newton's theory of gravity. The gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination [8], [9].

In this study, the following equations are considered as trip distribution model and called gravity model.

$$T_{ij} = k\frac{G_i^{\alpha} \times A_j^{\beta}}{D_{ij}^{\gamma}} \quad (3)$$

T_{ij}: Trip produced at i and attracted at j; G_i: Generated trips from zone j; A_j: Attracted trips from zone j; D_{ij}: Travel time impedance from zone i to zone j (km); k, α, β, γ are parameters.

For calculation of trip distribution, there is matrix which relates the number of trips generating in each zone to the number of trips ending in each zone, and trips between zone *i* and *j* are calculated in trip generation and attraction modeling stage. Table XI shows trip distribution parameter model.

TABLE XI
PARAMETER OF TRIP DISTRIBUTION

Variable	Parameter	T-value
Generation	0.836	16.9
Attraction	0.71	12.5
Min.route distance	-0.84	-8.64
Constant	0.00021	-5.97

In this study, the impedance is minimum route distance between zone centroids of each zone.

3) Model Split Model

The 3rd component of four step modeling is model split, a term that describes how many people use alternative forms of transportation. It is used to determine the number of trips on different modes given the travel demand between different zones. Mode split involves separating (splitting) the predicted trips from each origin zone to each destination zone into distinct travel modes such as walking, bicycle, car, train, bus [10], [11]. Fig. 4 shows model split model tree.

In this study, (4) is considered as model split model, and it is called growth curve function:

$$P_{ij} = \frac{1}{1+e^{(at_{ij}+b)}} \quad (4)$$

Pij: Model share; tij: Average travel time between zone i and j (km); a and b are parameters.

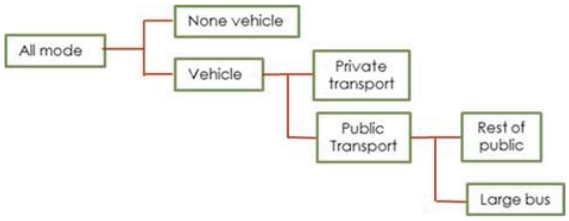


Fig. 4 Model split tree and methodology

TABLE XII
MODEL SPLIT PARAMETERS

Model split tree 1		
Variable	Parameter	T-value
Travel time difference between (none vehicle-vehicle)	- 0.00936	0.6
Constant	- 1.992	
Model split tree 2		
Variable	Parameter	T-value
Travel time difference between (Public transport-Private transport)	- 0.00596	3.48
Constant	2.017	
Model split tree 3		
Variable	Parameter	T-value
Travel time difference between (Rest of public-Large bus)	- 0.0099	1.42
Constant	- 2.136	

In this study, at the first stage, trips by all modes were divided into trips by vehicle and none-vehicle. In 2nd stage,

trips by vehicle were divided in to trips by public transport and trips by private transport. In 3rd stage, trips by public transport were divided in to trips by large bus and trips by rest of public. The result of split model is shown in Table XII. In Table XII, for model split three 1, travel time difference is used between none vehicle and vehicle. For model split tree 2, travel time difference is used between public transport and private transport. For model split tree 3, travel time difference is used between rest of public transport mode and large bus.

In Kabul city, there is no travel time data between each zones, there is just minimum route distance between zones. Therefore, in this study we use conversion method. The average travel time (t_{ij}) for each mode has been calculated by dividing observed minimum route distance (d_{ij}) to each modes average speed. In this conversion, the average speed for none vehicle, vehicle, public transport, private transport, rest of public and large bus are considered 5, 40, 20, 60, 15 and 25 (km/h) respectively.

i. Network Assignment

The 4th component and the last stage of traditional or classical four-stage modeling is trip assignment modeling. The major aims of traffic assignment are to identify congested links, to estimate traffic volume, to estimate traffic flow and to analyze travel pattern of each pair from origin to destination.

Traffic assignment concerns the selection of routes (alternative called paths) between origins and destinations in transportation networks. JICA STRADA has different types of traffic assignment such as user equilibrium assignment, incremental assignment, system optimal assignment, time of day, UE assignment and transit assignment, in this study incremental assignment is used for large bus assignment [12], [13].

Incremental assignment is a process in which fractions of traffic volumes are assigned in steps. In each step, affixed proportion of total demand is assigned, based on all-or-nothing assignment. After each step, link travel times are recalculated based on link volumes, with the incremental assignment program, you can choose from the alternatives of assignment, such as the All-or-nothing method. For getting traffic assignment result the following steps should be done [13]:

The first step in traffic assignment is converting the person trip origin destination tables (PTOD) to vehicle trip origin destination tables (VTOD). This conversion is done by help of JICA STRADA software using transportation demand data for 2015.

TABLE XIII
AVERAGE NUMBER OF PASSENGER AND PCU

Type	Large bus	Public transport	Private transport
Average number of passenger	-	9.4	1.9
PCU	3	2	1

In the second step, VTOD tables are converted in to passenger car unit (PCU), the average number of passenger for large bus, public transport and private transport are 35 [7], 9.4 and 1.9 respectively and PCU for large bus, public transport and private transport are 3, 2 and 1 respectively. Table XIII shows average number of passenger and PCU.

The average number of passenger which is used in this calculation is given from Millie bus authority.

ii. Link Cost Function

Another component for doing assignment is the relation between the link flow and link impedance called the link cost function and is given by:

$$t = t_0[1 + \alpha(\frac{x}{k})^{\beta}]$$

t = travel time on link per unit of time; x = flow of traffic; t_0 = free flow travel time; k = practical capacity or capacity of link; α and β = model parameters.

The value of α=0.15 and the value of β=4 are typically used. In this study, the BPR function of link cost function is considered.

iii. Road Network

The network which is used in this study is updated from public transport road network which was made by JICA in Kabul city. Fig. 5 shows bus road network in Kabul city.

iv. Assignment Result

As the main purpose of this study is to find the public transport large bus demand; therefore, only large bus demand was assigned on bus road network. The result of public transport large bus assignment shown in Fig. 6.

By doing large bus assignment number of bus can easily find from the PCU which is obtained from assignment.

v. Finding Required Number of Bus in Each Route

To find the required number of buses in Kabul city, JICA has mentioned some parameters in sector report 8. Peak hour ratio is estimated 7%, share of trips by large bus is assumed 40% during peak hour and the capacity of each bus is assumed 65 passengers [6]. On the other hand, the peak hour time is 60 min with different route length, and the peak hour velocity is assumed 15 (km/h).

The formula which is used for calculation of required number of bus are as [14]:

$$Number\ of \frac{trip}{day} = Avg.num.of\ \frac{PCU}{day} \times \frac{Avg.num\ of\ passenger}{large\ bus\ PCU}$$

$$Peak\ hour\ trips = number\ of \frac{trip}{day} \times (peak\ hour\ ratio)$$

$$L.bus\ trip\ share = P.hour\ trips \times (share\ of\ trip\ by\ P.hour\ )$$

$$Required\ frequency\ during\ peak\ hour = \frac{L.bus\ trip\ share}{capacity}$$

$$The\ time\ which\ bus\ is\ in\ motion = T = \frac{d}{v} \times \left(\frac{60min}{hour}\right)$$

$$Bus\ trips\ in\ peak\ hour = \frac{peak\ hour\ time}{in\ motion\ bus\ time}$$

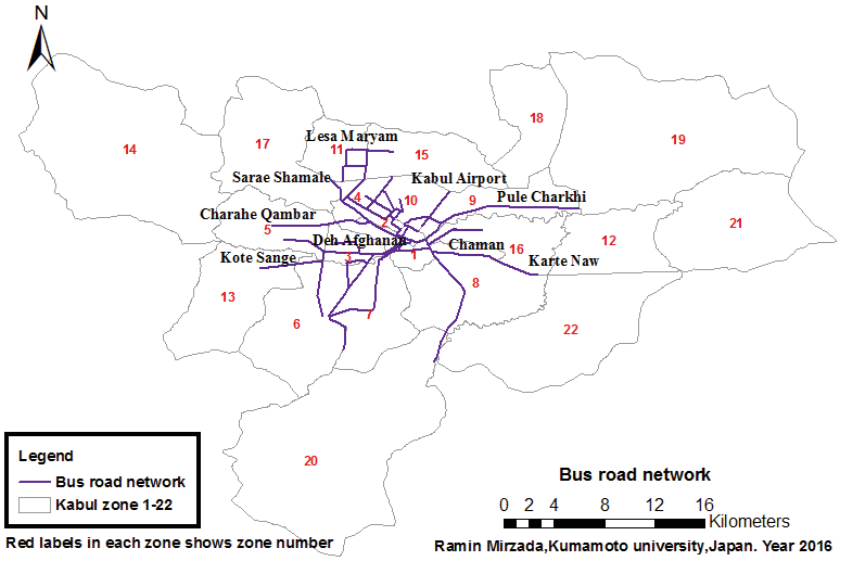


Fig. 5 Bus road network in Kabul city [6]

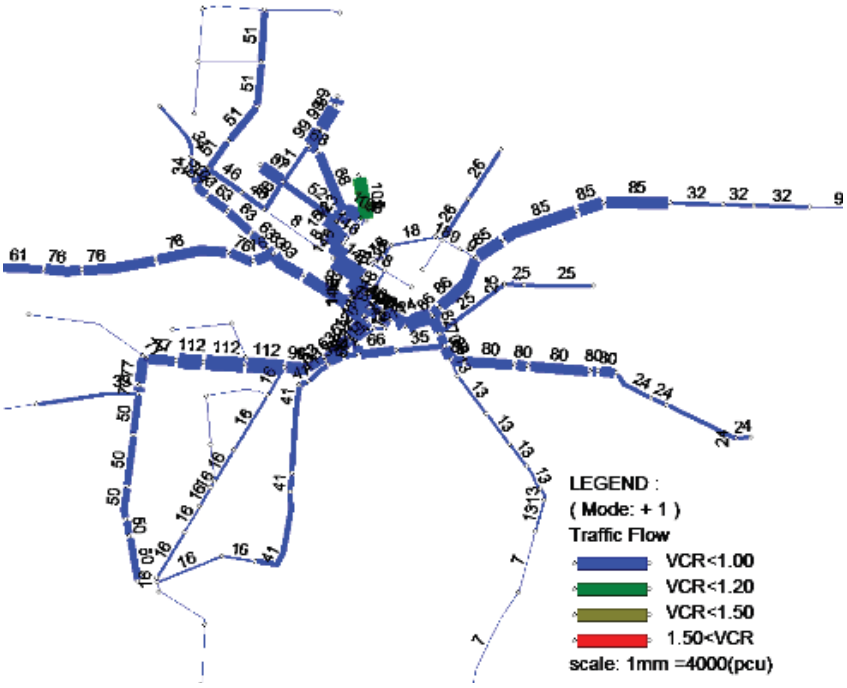


Fig. 6 Large bus assignment for 2015

$$Requird\ number\ of\ bus = \frac{bus\ frequency}{bus\ trip\ in\ peak\ hour}$$

L.bus = large bus, P.hour =peak hour

To know better about how to find required number of bus for a route, refer to Appendix A.

vi. Comparison of Found Number of Bus with Current Supply as Conclusion

After finding the required number of bus from PCU which is obtained from traffic assignment, Table XIV shows comparison of required number of large bus and current supply of Millie bus authority.

IV. Fare Structure Analysis

One of the main purpose of this research is fare structure analysis.

The only aim for establishment Mille bus was assisting of poor people; therefore, Mille bus fare was very less and annually Kabul government gave subside for Mille bus authority for its operation and office expenses. Due to civil

war in Kabul city, Afghan government did not have ability to give subside for Mille bus authority; therefore, Mille bus authority limited its operation in Kabul city. After establishment of new government in 2001, most countries of the world helped Afghanistan. Among donors, some countries assisted Mille bus to cover all routes with less fare. This situation continued up to 2010. After that, they stopped their assist and Kabul government did not had ability to give subside for Mille bus authority; therefore, Mille bus authority limited its operation. Currently, only three main routes are covered by large buses in Kabul city [7].

The aim of this research was to find the way to support Mille bus by its own income to start their activity in all routes. In this study, fixed fare structure and distance based fare structure of bus will be analyzed. For calculation of revenue and expenditure of bus, Deh-Afghanan Lesa Maryam route is selected and both calculations are done on same route.

A. Fixed Fare (Current Fare) Analysis

The first stage for calculation of fare is fixed fare structure analysis. In this calculation, all estimations are based on transportation engineering standards.

TABLE XIV
COMPARISON OF REQUIRED NUMBER OF BUS WITH CURRENT SUPPLY

No.	Route name	Required bus (n)	Current bus supply (n)	Needed bus (n)
1	Deh Afghanan-Sarae Shamali	28		28
2	Sarae Shamale-Sar, Kotal Khair khana	9		9
3	Deh Afghanan-Lesa Maryam	28	6	22
4	Deh Afgahnan-500 family	32		32
5	Charahi Ansare-Qalafatullah	52		52
6	Charahi Malik Asghar-Taimani	28		28
7	Charahi Malik Asghar-Kolola Pushta	24		24
8	Charahi Malik Asghar-Wazir Akbar Khan	9		9
9	Charahi Welayat-Charahi Qamber	32		32
10	Senama Pamir-kote Sange	16	10	6
11	Senama Pamir-Darul Aman	23		23
12	Senama Pamir-Karta Naw	21	12	9
13	Senama Pamir- Bene Hesar	25		25
14	Shah 2 Shamshera-Chil Seton	26		26
15	Murad Khane-Kabul Airport	18		18
16	Murad Khani-Pul Charkhe	45		45
17	Murad Khani-Qala, Zaman Khan	15		15
18	Kote Sange-Dasht Barche	17		17
19	Kote Sange-Darul Aman	13		13
Total		461	28	433

In fare analysis, the most import component is estimation of expenditure. And, revenue calculation is done based on fare of person in each bus.

Bus expenditure cost consists of two type of cost, variable cost and fixed cost. Variable cost and fixed cost are shown in Table XV.

One of most the important component for expenditure is fuel consumption cost which is almost half of all expenditure costs in a bus. Based on this reason, we have to estimate it very carefully. In this study, fuel consumption estimation is done based on transportation standards. Fig. 7 shows fuel consumption calculation method [15].

TABLE XV
BUS EXPENDITURE COSTS

Variable cost	Fixed cost
Fuel consumption	Office administration expenses
Tire	Driver salary
Body Maintenance	Conductor salary
Machine Lubricants	

Table XVI shows variable costs which are calculated based on standard bus operating cost and converted to Afghanistan currency for more accurate calculation in fare structure calculation. Indian standards are observed because currency of both countries are almost the same [16].

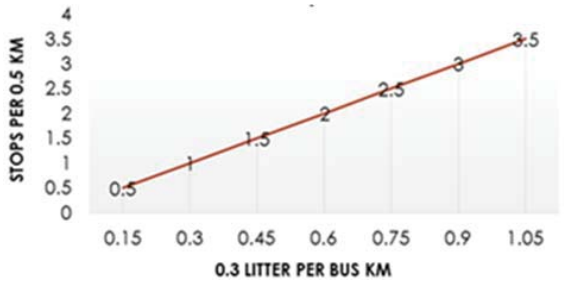


Fig.7 Fuel consumption calculation [15]

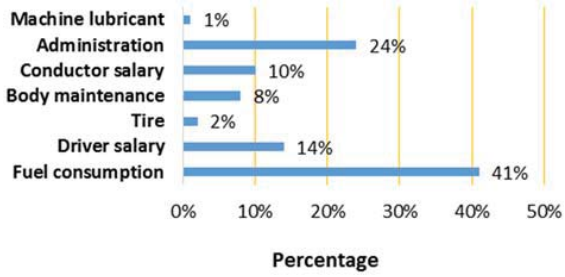


Fig. 8 Share of expenditure for one bus per month

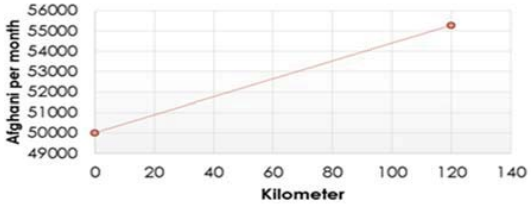


Fig. 9 Bus supply cost per month

TABLE XVI
ESTIMATING STANDARD BUS OPERATING COST

Items	Cost per Km
Fuel	15
Tire	0.7
Body Maintenance	3
Machine Lubricants	0.5

All unit costs are in Afghanistan currency.

TABLE XVII
FIXED COST PER MONTH IN AFGHANISTAN CURRENCY

Office administration expenses	25000
Driver salary	15000
Conductor salary	10000
Total	50000

All unit costs are in Afghanistan currency.

TABLE XVIII
ROUTE DESCRIPTION FOR FARE CALCULATION

Length (km)	10	A
Stops (n)	20	B
Distance between stops (km)	0.5	C
Bus Frequency	6	D
One way trip	12	E
Length per day	120	F
F = A*E		Formula

TABLE XIX
FUEL PARAMETER FOR FARE CALCULATION

Fuel consumption per km in (litter)	0.3	A
Fuel Rs.	50	B
Fuel type	Diesel	C
Fuel cost	15	D
Length per day	120	E
One way trip	12	F
Work days per month	24	G
Total fuel cost per day	1800	H
Total fuel cost per month	43200	I
D =A*B		Formula
H =D*E		Formula
I =G*H		Formula

All unit cost are in Afghanistan currency

TABLE XX
BUS EXPENDITURE PER MONTH PER ONE BUS

Items	Cos per bus per month in Afghani
Fuel consumption	43200
Tire	2016
Body maintenance	8640
Machine lubricant	1440
Administration expenses	25000
Driver salary	15000
Conductor salary	10000
Total cost	105290

TABLE XXI
BUS REVENUE PER MONTH FOR ONE BUS

Items	Quantity	
Number of bus seat	42	A
Bus capacity	65	B
Fare per person	5	C
Work days per month	24	D
One way trip	12	E
Daily frequency	6	F
Income per day	3900	G
Total income per month	93600	H
G =B*C*E		Formula
H =D*G		Formula

All unit costs are in Afghanistan currency.

Table XVII shows fixed cost parameter which are calculated per month. Parameters shown in Tables XVIII and XIX should be concerned in calculation of expenditure. Table XX shows all expenses which a bus has during its operation in one month and Fig. 8 shows share of expenditure per month for one bus. Fig. 9 shows bus supply cost of one bus per month which is consist of variable cost and fixed cost.

After finding of bus expenditure, the next step is calculation of bus revenue per month for one bus, the simplest way for calculation of bus revenue is shown in Table XXI.

In Table XXI, all characteristic of expenditure and revenue are calculated. For better understanding, Fig. 10 shows the difference between revenue and expenditure of one bus per month in Kabul with fixed price of 5 Afghani. Fig. 10 shows that there is a visible negative difference between revenue and expenditure. It shows that revenue is less than expenditure and the difference is almost 12000 Afghani in one bus per month. If this amount is calculated for all buses which are active in Kabul city, then it will be a very huge amount of difference in revenue and expenditure and the Mille bus authority will not be able to cover few routes of Kabul city bus system. Based on findings form these calculations without Kabul government subside, covering of bus routes with 5 Afghan fare is impossible.

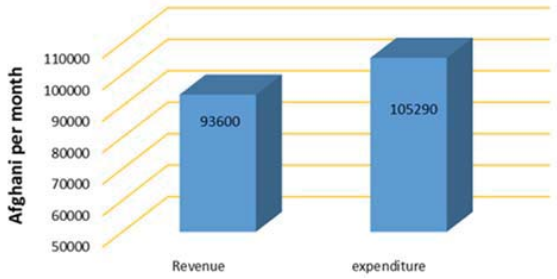


Fig. 10 Difference between Revenue and Expenditure in fixed fare structure

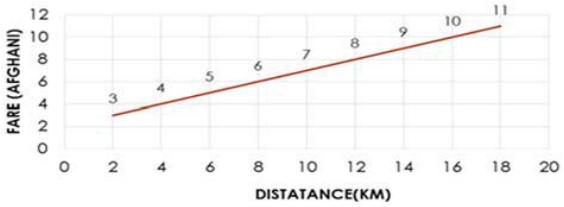


Fig. 11 Hypothetical fare model

B. Distance Based Fare Analysis

The second stage for calculation of fare structure analysis is distance base fare analysis. Findings in fixed fare analysis show that 5 Afghan fare is not enough for Mille bus expenses and without subside they cannot solve financial problems. Kabul government does not have the ability to give subside for Mille bus authority and from other hand, due to less income of bus users, Mille bus authority cannot increase the amount of fare.

One of the main aims for changing of fixed fare to distance based fare is, if Mille bus authority increases the amount of fare, the advantage will be for the authority and for those who

travel to far distance but for those who travel short distance it will be not satisfactory. Due to this reason and above problems, distance base fare will be a good alternative for Mille bus authority.

The data which are used for calculation of distance based fare structure is person trip (PT) survey which was conducted by JICA on 2008.

As it is mentioned before, both fare structures are calculated in same route with same operation time (24 days per month and 12 one way trips per day); therefore, expenditure calculation for both fare structures are the same, only the revenue calculation will change.

For calculation of revenue, the first step is using a hypothetical model based on bus user's income in Kabul city. Fig. 11 and Table XXII show hypothetical model of distance based fare structure.

The second step for fare structure analysis is calculation of bus user trips form JICA person trip survey for the same route (the route which is calculated for fixed fare) and by using hypothetical fare model, this calculation will become complete. Table XXIII shows number of trip which is done based on fare model and Table XXIV shows calculation of distance based fare revenue based on fare model. To know better about how to find revenue for each fare, refer to Appendix B.

After calculation of distance based fare, the result shows that applying distance based fare in Kabul city bus system is good alternative for fixed fare in Kabul city bus users and Mille bus authority.

With distance based fare structure, Mille bus authority will become self-supported and there will be no need for government subside. Besides, there will be no problem for bus users also.

TABLE XXII
HYPOTHETICAL FARE MODEL PARAMETERS

Variable	Parameter
Distance	0.5
Constant	2

TABLE XXIII
NUMBER OF TRIPS DONE BASED ON FARE MODEL

Distance	Fare	Trips
2	3	1063
4	4	2100
6	5	2997
8	6	3112
10	7	1890

TABLE XXIV
DISTANCE BASED FARE REVENUE PER MONTH FOR ONE BUS

Total trips	Trip for one bus	Fare	Revenue per bus per day
1063	87	3	261
2100	175	4	700
2997	250	5	1250
3112	259	6	1554
1890	157	7	1099
Total of all fare revenue per day		4864	
Total of all fare revenue per month		116736	

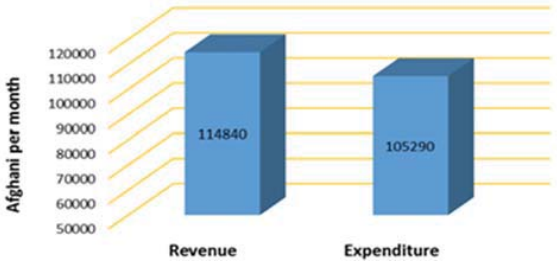


Fig. 12 Difference between Revenue and Expenditure in distance based fare structure

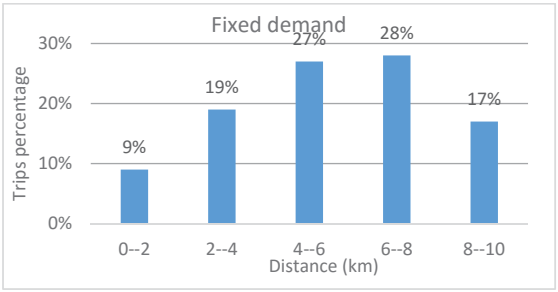


Fig. 13 Share of trips by bus based on distance

Nowadays, due to less operation of bus system, most of Kabul city residents use taxi as a share car which the price of share car is 20 Afghani per person, they use share car because there is no alternative, if bus system apply distance based fare it will be good alternative of share car for bus users and Mille bus authority.

Fig. 12 shows difference between revenue and expenditure in distance based fare, and it is visible that the difference is positive. From Fig. 13, it is clear that most trips (44%) happen on the area more than 5 Afghani fare, less trips (22%) happen on the area less than 5 Afghani fare and 24% trips happen in 5 Afghani fare. Thus, this increasing in share of trips is one of the reason for positive revenue.

a) Demand Change Analysis in Distance Based Fare

The analysis which was done for distance based fare structure was for fixed demand, the following formula is used for conversion of fixed demand to elastic demand.

$$D = D_0 \times [\varepsilon \times \left(1 - \frac{C_*}{C_0}\right)]$$

D=Elastic demand; D_0=Fixed demand; C_0= Fixed fare; C_*=Distance based fare; ε=Elasticity.

TABLE XXV
DEMAND CHANGE RESULT FROM FIXED DEMAND TO ELASTIC DEMAND IN DISTANCE BASED FARE

No.	D_0	C_0	C_*	ε	D
1	1063	5	3	1	1488
2	2100	5	4	1	2520
3	2997	5	5	0.8	2997
4	3112	5	6	0.7	2676
5	1890	5	7	0.7	1361

The result of above demand change result by using above formula is shown in Table XXV. For better understanding, Fig. 14 shows demand change difference between fixed demand and elastic demand in distance based fare.

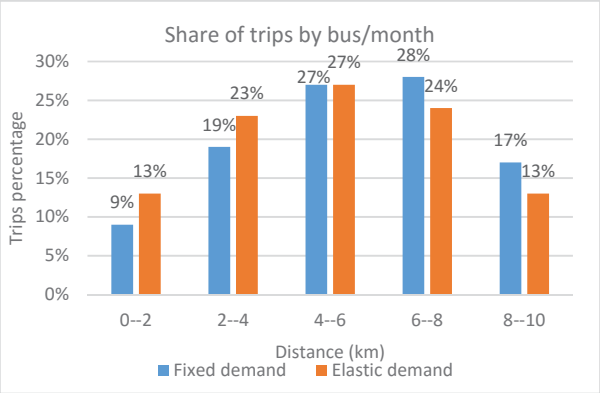


Fig. 14 Demand change difference between fixed demand and elastic demand in distance based fare

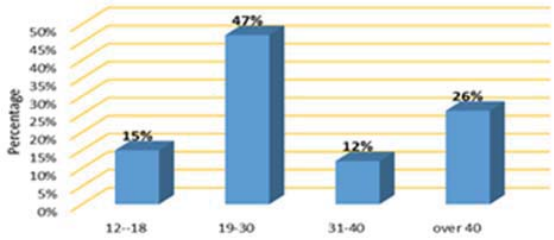


Fig. 15 Share of age group from Kabul residence bus users

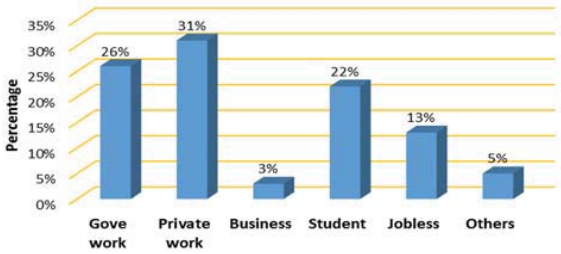


Fig. 16 Share of occupation from Kabul residence bus users

V. Satisfaction Level of Fare Structures

A. Survey

For changing fare structure, the main important component is satisfaction level of bus users. To find satisfaction level of Kabul city bus users for fare structure, a survey was done on February 2016. The sample size of this survey is 346 people, 250 are male and 96 are female. This survey was conducted by four people in eight days in six major terminals which tree of these main terminals are located inside of CBD and three of them are outside of CBD.

Terminals which are located inside of CBD are Deh Afghanan, Senema Pamir and Shah do Shamshira and the terminals locate outside of CBD were Sarae e Shamale, Kote Sange and Karte Naw terminals. Besides conducting survey in mentioned terminals, survey was also conducted from those bus users which they are inside bus during their trip. This survey was only conducted from the residents which use large buses daily. The main purpose of the survey is to know satisfaction level of bus users for fare structure. For more information, survey sheet of the mentioned survey is in Appendix C (Fig. 23).

B. Data Analysis

a) Travel Behavior Characteristics

The first step for analysis of this survey is to find travel behavior of bus users which is shown in Figs. 15-17.

Share of gender for both survey (JICA survey on 2008 and 2016 survey) are the same; therefore, there is no need to show it once again.

Fig. 15 illustrates that most tips are done in age of 19-30 which most of them are school and university student. Fig. 16 illustrates that the most user of bus are government worker, private worker and students the main reason for that is less income.

Fig. 17 illustrates that most trips are home based trips and to work trips which are 30% and 31% respectively. Shopping trips, school trips and 'others' are 15%, 13% and 11% respectively. The next step for the survey data is calculation trip share based on distance, Fig. 17 shows share of bus user's trip.

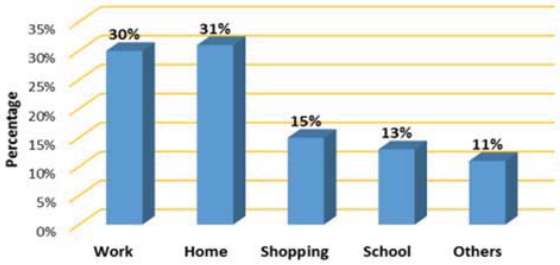


Fig. 17 Share of trip purpose from Kabul residence bus users

Fig. 18 illustrates that most of the trips are done between 4-8 km distance, the reason for that can be mostly work and university because most of government and private company offices are inside of CBD and the residential areas are out of CBD. Fig. 18 shows share of all trips based on distance, for better understanding of male and female trips based on distance see Figs. 19 and 20.

Fig. 19 illustrates that most trips are done in 4-6 km and 6-8 km; the reason for this are mostly work and universities area are located inside of CBD and residential area are out of CBD.

Fig. 20 illustrates that most trips are done in distance between 0-2 km and in short distance, the only reason for this is, in Kabul city mostly, women are school teachers and all schools are located inside residential areas; therefore, most female trips are in short distance. Beside trips in short distance, Fig. 20 illustrates that 24% and 16% of trips are done in almost fare distance the reason for that, as mentioned before are work and university which are located inside of CBD.

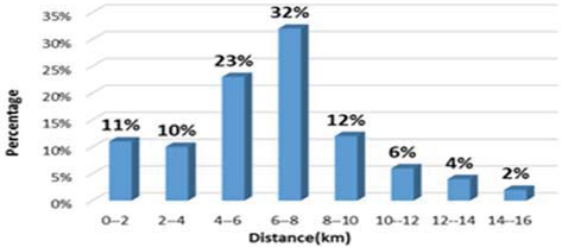


Fig. 18 Share of bus user's trip based on distance

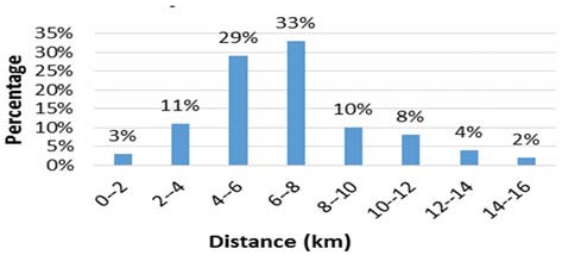


Fig. 19 Male trips based on distance

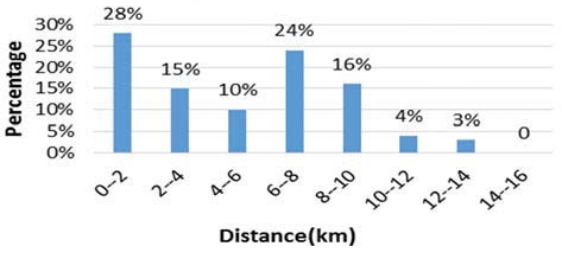


Fig. 20 Female trips based on distance

C. Result

After calculation and analysis regarding satisfaction level of both fare structures (fixed fare structure and distance based fare structure), it shows that most Kabul residence bus users are satisfied with distance based fare.

Fig. 21 shows satisfaction level for fixed fare and Fig. 22 shows satisfaction level for distance based fare.

Fig. 21 illustrates that, generally, 42% of bus users disagree with fixed fare. The reason is clear. Those who travel short distance disagree especially students and females. For those who travel long distance, fixed fare is fair; but, for Millie bus authority it is not fair. The alternative for those who travel long distance is sharing cars which the fare is more than 20 Afghani; therefore, most of them are agree with distance based fare structure.

In distance based fare structure, 'others' has the high agreement with 61%. The reason can be traveling short distance and also no other cheap fare alternative.

Fig. 22 shows that 52% of Kabul city bus users agree with distance based fare and only 19% do not agree. One of the reasons for agreement of Kabul city bus users can be that, for those who travel in short distance without any reason, this structure is satisfactory for them. That is why most of Kabul city bus users agree with distance based fare.

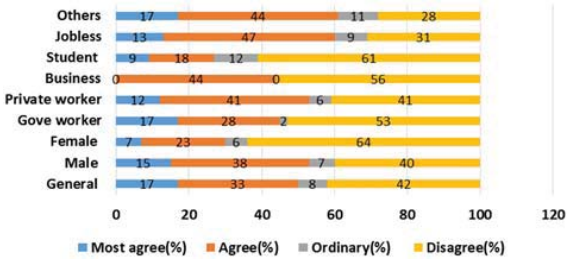


Fig. 21 Fixed fare satisfaction level

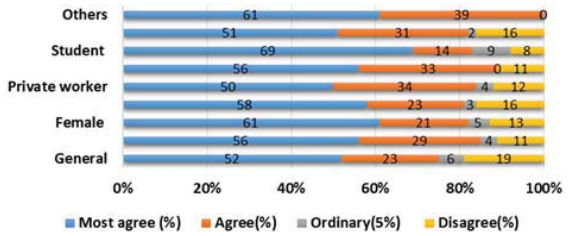


Fig. 22 Distance based fare satisfaction level

Distance based fare structure is the best option for Mille bus authority to become self-support and be able to cover all route with best operation system.

D. Chi Square Test for Satisfaction Level

Chi square test for fixed fare satisfaction level shows that the significance level is significant and shows that there is almost less similarity between samples (the difference between samples are more). For more detail see Table XXVI.

TABLE XXVI
CHI SQUARE TEST RESULT FOR FIXED FARE SATISFACTION LEVEL

Degree of freedom	3
Chi square	12.04
P-value	0.0072
P-value limit	0.01-0.05
Significance level	Significant

TABLE XXVII
CHI SQUARE TEST RESULT FOR DISTANCE BASED FARE SATISFACTION LEVEL

Degree of freedom	3
Chi square	1.66
P-value	0.64
	0.01-0.05
Significance level	Not significant

Chi square test for distance based fare satisfaction level shows that the significance level is not significant and show that these samples are almost the same and there is no much difference between samples. For more detail see Table XXVI I.

At the end of this research, it is better to mention about relationship between objectives of this research. Relation between first objective (Bus transit demand modeling) and second objective (Fare structure analysis) is very clear which is cost variable.

For splitting modes in model split model, it is possible to use different variables like travel time, cost etc. In this

research, travel time is used as variable. Here, instead of travel time fare also can used as variable; thus, these two objectives have clear relation between each other.

On the other side, satisfaction level is searched to know agreement and disagreement of Kabul residence bus users regarding fare structures and it is a part of fare structures.

VI. Conclusion

This study is mainly focused on demand and fare of public transportation system (large bus) in Kabul city. This study is very important for Mille bus authority and it is a huge achievement for public transportation of Kabul city. This research has done for 2015 and current state of bus system.

After calculation and analysis, it is found that due to less income of Kabul residents the demand for large size public transport is high but the number of buses is very less and it is needed to increase the number of buses and active all 54 routes in Kabul city. It was found that that in order to overcome this problem, there is no need to build new roads or exclusive ways for buses. Invest on public transportation and increase the number of large buses so that the current demand for public transport is met.

It was found that distance based fare is more effective for large bus in Kabul city, and this research proposes government to change the fare from fixed fare to distance based fare to solve the current problem of Mille bus authority without giving subsidy.

VII. Appendix

Appendix A

Here is an example from this calculation for one route.

- Route name: Kote Sange
- Round trip length: 5.5 km
- PCU/day: 5000
- Aveg.number of passenger: 35
- Large bus PCU: 3
- Bus capacity: 65
- Share of trip by bus during peak hour: 40%
- Peak hour ratio: 7%
- Assumed speed: 15km/hour

$$Number\ of \frac{trip}{day} = 5000 \times \left(\frac{35}{3}\right) = 58333 \frac{trip}{day}$$

$$Peak\ hour\ trips = 58333 \times \left(\frac{7}{100}\right) = 4083 \frac{trip}{peak\ hour}$$

$$Share\ of\ trip\ by\ large\ bus = 4083 \times \left(\frac{40}{100}\right) = 1633 \frac{trips}{peak\ hour}$$

$$Required\ frequency\ during\ peak\ hour = \frac{1633}{65} = 26$$

This route has 4 cross section and has 11 bus stop.

Parameters needed for finding of required bus number are as:

- Time which bus is in motion: 44 min
- Bus stop number: 11
- Bus stop time: 15 sec (0.25 min)
- Bus terminal time: 2.5 min
- Traffic signal time: 1.5 min
- Number of cross sections: 4
- Peak hour time in Kabul city: 60 min
- Total travel time = 22 min + 11 (0.25 min) + 2 min + 2.5 min + 4(1.5 min) = 35.25 min

$$Bus\ trips\ in\ peak\ hour = \frac{60min}{35.25min} = 1.7$$

$$Requird\ number\ of\ bus = \frac{26}{1.7} = 16$$

After above calculation we found that the number of required bus for the Kota Sange road is 16 large bus.

Appendix B

$Routh\ name = Deh\ Afghanan - Lesa\ mryam$

$Total\ trips = 1063$

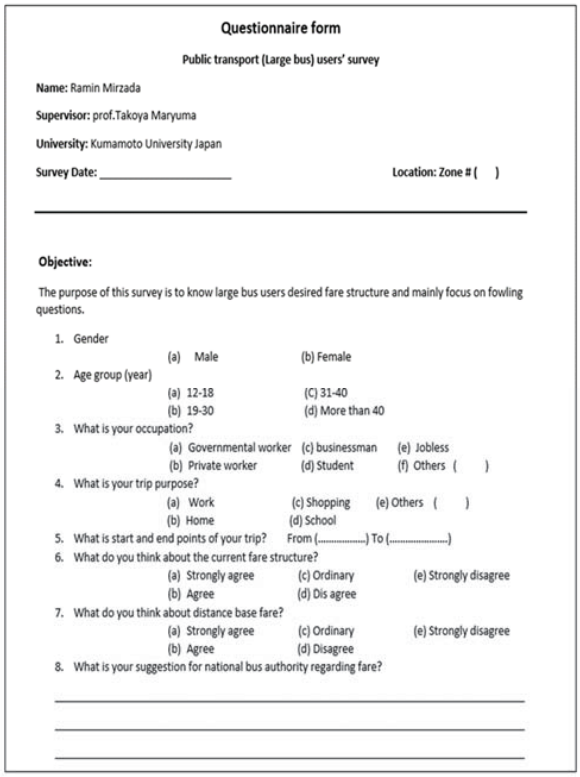
$Fare = 3\ Afghani$

$Number\ of\ one\ way\ trip\ for\ each\ bus = 12$

$$One\ way\ trips\ for\ bus = \frac{Total\ trips}{One\ way\ trip\ for\ each\ bus} = \frac{1063}{12} = 88.6 trip$$

$Revenue\ for\ bus\ per\ day = 88.6 * 3 = 266\ Afghani$

Appendix C



Questionnaire form

Public transport (Large bus) users' survey

Name: Ramin Mirzada

Supervisor: prof.Takoya Maryuma

University: Kumamoto University Japan

Survey Date: _____ **Location: Zone # ( )**

Objective:

The purpose of this survey is to know large bus users desired fare structure and mainly focus on fowling questions.

1. Gender
   (a) Male (b) Female
2. Age group (year)
   (a) 12-18 (C) 31-40
   (b) 19-30 (d) More than 40
3. What is your occupation?
   (a) Governmental worker (c) businessman (e) Jobless
   (b) Private worker (d) Student (f) Others ( )
4. What is your trip purpose?
   (a) Work (c) Shopping (e) Others ( )
   (b) Home (d) School
5. What is start and end points of your trip? From (.....) To (.....)
6. What do you think about the current fare structure?
   (a) Strongly agree (c) Ordinary (e) Strongly disagree
   (b) Agree (d) Dis agree
7. What do you think about distance base fare?
   (a) Strongly agree (c) Ordinary (e) Strongly disagree
   (b) Agree (d) Disagree
8. What is your suggestion for national bus authority regarding fare?

Fig. 23 Survey sheet for satisfaction level of bus users

REFERENCES

[1] Federal highway administration, Federal transit administration, The transportation planning process key issues, a brief book for transportation decision makers, A publication of the transportation planning Capacity building, 2015 update (Book style).
[2] Central statistical office (CSO), Islamic republic of Afghanistan (report style) http://www.cso.gov.af/. Access date 6/7/2016.
[3] Demography and social Development. Final report sector 1, Japan International Cooperation Agency (JICA), September 2009. (Report style)
[4] Kabul city master plan, sub project for revise the Kabul city master plan, Japan International Cooperation Agency (JICA), June 2011. (Master plan).
[5] Overview of Transportation in Kabul City, Afghanistan, A.J. Habibzai, S. Habibzai and C.Sun. (Report style).
[6] The study for the development of the master plan for the Kabul metropolitan area in the Islamic republic of Afghanistan, Transportation sector, Japan International Cooperation Agency (JICA), September 2009. (Report style)
[7] Ministry of transportation, Millie bus (national bus) authority, Department of planning, Mille bus history report (Report style)
[8] Barnes, G. and Davis, Understanding Urban Travel Demand: Problems, Solutions, and the Role of Forecasting, University of Minnesota Center for Transportation Studies: Transportation and Regional Growth Study, G. 2000. (Book style)
[9] Travel demand forcsting "theory and concept" the gravity model (Repot style) http://www.princeton.edu , Access date 2/6/2016.
[10] Tom V. Mathew. K V Krishna Rao "Introduction to transportation Engineering" Chapter 9 Model split, NPTEL may 2007. (Report style)
[11] Edward A. Beimborn Center for transportation studies "Transpiration Modeling Primer" University of Wisconsin-Milwaukee, Update June 2006. (Book style).
[12] Tom V. Mathew "Transportation Network Design" October 2006. (Book style).
[13] Tom V. Mathew. K V Krishna Rao "Introduction to transportation Engineering" Chapter 10 Traffic Assignment, NPTEL May 2007. (Report style)
[14] Baryalai Yusufy "Analyzing Public Transport for the Kabul City by development of bus transport mode" Kumamoto University Japan July 2014. (Report style).
[15] C.S. Papacostas, P.D Prevedouros "Hand book of transportation engineering and planning. Third edition (Book style).
[16] Godrej and Boyce Premises Gasworks Land, "Bus Karo Guide book on bus planning and operation" Indian government. (Book style).