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TRANSPORTATION POLICY FOR KABUL CITY

SHORT-TERM AND LONG-TERM

Elyasuddin Jalal[1], Prof. Shoshi Mizokami[2]
Civil and Environmental Engineering
Kumamoto University
Japan
[1]elyas_jalal@yahoo.com , [2]smizo@gpo.kumamoto-u.ac.jp

Abstract— **Kabul city (capital of Afghanistan) is one of the fastest growing cities in the world. This city is suffering from a highly congested traffic, caused by a dramatic increase of its population and a growing flow of economy during the last decade.**

This research is a very important and initial step towards transportation planning of Kabul city. In this research, the travel demand of Kabul city has been analyzed and forecasted for the current year of 2015 and mid-term future year of 2025. Traffic assignment analysis and a simulation were performed to comprehend the main causation of congestion.

The results signify that the private transportation demand is less than the physical capacity of road network in Kabul city. Thus, in the short term there is no need to introduce any new link to the road network of Kabul city and the actual capacity of the road network should be raised to reach its physical capacity by developing the road infrastructure and improving the traffic management.

On the other hand, the traffic assignment results pinpoint that the main factor in creating congestion in Kabul city is the large proportion of public transportation demand. Therefore, it is recommended that high capacity public transportation facilities should be introduced to the highly required links as shown in the study.

The simulation results indicate that in the long-term the travel time will dramatically increase by the growth of population. Hence, in the mid-term future (2025) the capacity of highly congested links should be improved by introduction of new links.

The data for analyzing transportation of Kabul city is not fully sufficient, yet this study can quantify the large scale transportation problems. At the end of the study, the required transportation data is quoted, which is to be gathered for more precise results.

Index Terms— **Transportation; Planning; Policy; Kabul; Afghanistan.**

I. INTRODUCTION

Kabul is the capital of the Islamic Republic of Afghanistan. Kabul city is the largest city of Afghanistan. It is located in the eastern section of Afghanistan. Kabul city is 3500 years old and Kabul city‘s main importance is in its strategic location in Asia, connecting east to the west and north to the south of Asia. The population of Kabul city was around 3.28 million in 2012. Kabul city is in the 5th position between the fastest growing countries. [1]

Kabul became the capital of Afghanistan in 1773 under the reign of Timur Shah, who move the capital from Kandahar province to Kabul. Kabul city showed its first urban movements in 1950’s, during which Jadayi Maywand Road was constructed together with the Kabul University and Maiwand Hospital. Kabul city’s first master plan was prepared in 1962 for the 800,000 population and then revised in 1978 for a population of 2 million. By 1967, the city had ninety-seven secondary, technical and vocational schools and a university. [2]

Invasion of Afghanistan by soviet troops opened the ugliest pages of this country in 1979 which continued through 1989. Kabul city's population increased from around 500,000 in 1978 to 2 million in 1988 as the result of being the safest place in the country. Civil war started right after 1989 till the Taliban regime got the opportunity to completely destroy this city in 1996. Finally after September 11th, US air strikes hit the targets and the Taliban were forced out of Kabul in October 2001.

U.S. government, ISAF and the international community helped Afghans to re-establish their government and now Kabul city is full of opportunities and the most attracted place of the country.

The population of Kabul city was 2,268,300 in 2005 as estimated by Central Statistics Office (CSO) for the older city area consisting of 14 districts. The jurisdiction of the Kabul Municipality area was expanded in January 2005 to 22 districts and the population increased to 2.4 million. The population of Kabul city was estimated 4.22 million in 2008 by Japan International Cooperation Agency (JICA) study team and the municipality area was expanded to 1022.7 km2. In the latest Kabul metropolitan area urban development master plan 26 zones is considered for Kabul city, zone “23, 24, 25 and 26” as new Dehsabz city and zone 1,2,3,4 and 10 as central parts of Kabul city. (Shown in Fig. 1) This great city is now

suffering from its rapid population growth and needs an adequate urban management to guide it towards sustainability. [3]

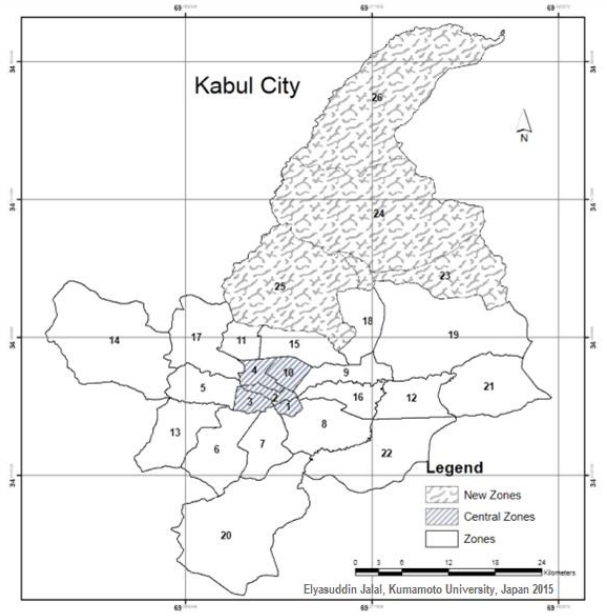

Fig. 1. ***Kabul city zones (1-26)***

Kabul city is surrounded by mountains. The mountains have limited the number of roadways leading into and out of the city. Furthermore, these mountains have limited the downtown of Kabul city to the center of the city. Kabul River flows from the south to the east of Kabul city crossing the downtown of Kabul city. The mountainous topography of Kabul city is one of the challenges for transportation planners.

The most attractive places in Kabul city are shown in the Fig. 2. The central business district (CBD) of Kabul city is located mainly in zone 1 and part of it in zone 2. The CBD has so many parts which are divided by roads and Kabul River. The CBD mainly includes the biggest food market, biggest trading market and shopping malls. The CBD is a part of what is called the old city. The Old City is amaze of narrow alleys, houses, and shrines. Deafghanan Business District (DBD) is located in zone 2, DBD is surrounded by shopping malls, governmental administrations and highly congested bus stop. Sharenaw Business District (SBD) is called by the name of Sharenaw which means the new city, where most of the modern shopping malls, restaurants, banks and international community offices are located.

Kabul Market (KM) is located in zone 4. KM is the biggest food supplier after CBD; KM is made of a group of one or maximum two floor buildings. The other attractive places of Kabul city include Kabul University (KU) in zone 3. KU is indeed the biggest university of Afghanistan and has around 25000 students. Kabul Polytechnic University (KPU) and Kabul Education University (KEU) are located near each other in zone 5. KPU and KEU are the second and third largest universities of Afghanistan respectively.

Maryam Business District (MBD) is the third most attractive place located in the 11th zone in Kabul city. However MBD is far from the city center but MBD is covered with high residential areas. Kabul Airport (KA) is very near to the city center in zone 15 and located only 5 kilometers far from the city center. Macrorayan Business District (MBD) is located in a highly dense high rise residential area of Macrorayan. Wazir Akbar Khan neighborhood is located in zone 10 where many government organizations, non-government organizations, embassies, banks and restaurants are located. Finally Karte Naw Business District and Kotesangi Business District (KBD) are also among the attractive places of Kabul city.

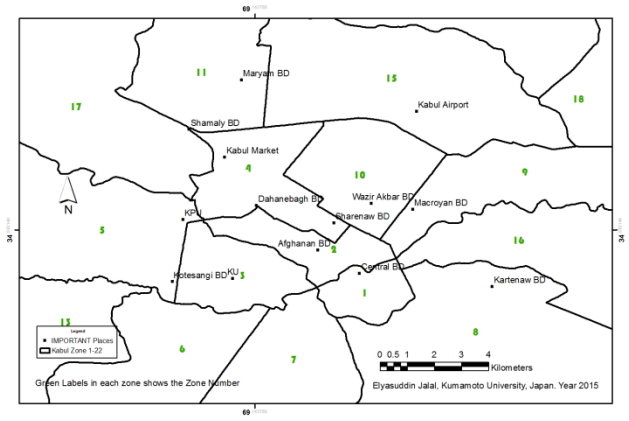

Fig. 2. ***Important places in Kabul city***

II. TRAVEL DEMAND MODEL ESTIMATION AND FORECASTING OF KABUL CITY

A. Existing Travel Demand of Kabul city

Characteristics of road traffic in Kabul were examined based on the results of person trip(PT) survey conducted by Japan International Cooperation Agency (JICA 2008). In this study, by using PT survey data of JICA the existing travel demand of Kabul city in 2008 is estimated. Which indicates the travel behavior of Kabul city in 2008.

1) Main mode of transport

It can be clearly seen in Table I that public transport contributes nearly half of the total trips. The private transportation shares only 12% of the trips.

TABLE I TOTAL TRIPS IN KABUL CITY BY MAIN PURPOSE

No	Mode	Trips	Share
1	*Walk*	950,088	39%
2	*Public Transport*	1,206,217	49%
3	*Private Transport*	288,468	12%
Total		2,444,773	

2) Trip Purpose

Nearly half of the total trips are home based with respected percentage of 49%. School, Work and personal purpose based trips have the highest proportion with 22, 19, and 7 percentages respectively. The Personal purpose trips are included the business and shopping based trips. (As shown in Table II)

TABLE II TOTAL TRIPS IN KABUL CITY BY PURPOSE

No	Purpose	Trips	Share
1	*To Work*	467,883	19%
2	*To School*	539,229	22%
3	*Personal (Business + shopping)*	176,717	7%
4	*Home*	1,189,919	49%
5	*Others*	71,025	3%
Total		2,444,773	

3) Trip Mode

In Kabul city, the public transportation mode of travel includes the large bus, minibus, microbus, and taxi. As the economy of Kabul citizens are not high in general, most of the citizens can't afford the car. Walking shares 39% of total trips which is the highest modal trip. Among the public transportation the microbus mode of travel contributes the highest share of 18%. Large bus and taxi includes the second and third highest trips with 14% and 11% respectively. (As shown in Table III)

At the other hand the large bus is not enough for the large demand of public transportation. The microbus which can be also considered as share car is very active in Kabul city. Majority of Kabul citizens prefer to use microbus because of its high frequency and quality of service. Microbuses are owned by ordinary people privately. There is not any specific governmental organization to manage, control and regulate the microbus transportation system. At the same time, microbus has high fare and Kabul citizens can't afford it. However, large bus compared to microbus has cheaper fare but people can't use it frequently due to its poor service and low frequency.

TABLE III TOTAL TRIPS IN KABUL CITY BY MODE

No	Mode	Trips	Share
1	*Walk*	950,008	39%
2	*Bike*	185,905	8%
3	*Microbus*	427,997	18%
4	*Minibus*	158,764	6%
5	*Large bus*	342,213	14%
6	*Taxi*	277,243	11%
7	*Car*	66,406	3%
8	*Truck & Others*	36,157	1%
Total	*All Mode*	2,444,773	100%

1) Gender and Age

A huge difference can be seen in the travel behavior of male and female. Male dominates the 72% of total trips while female only 28%. The reason behind it is the Afghanistan culture. In Afghanistan most of the women don't work and stay at home. (As shown in Table IV)

Life expectancy in Afghanistan is 60. As it can be seen in the (Table V), majority of the trips, around 80% are done by the people aged between 5-40 years.

TABLE IV TOTAL TRIPS IN KABUL CITY BY GENDER

No	Category	Trips	Share
1	*Male*	1,765,795	72%
2	*Female*	678,978	28%

TABLE V TOTAL TRIPS IN KABUL CITY BY AGE

No	Category	Trips	Share
1	*Age (5-18)*	937,911	40%
2	*Age (18-40)*	983,467	42%
3	*Age (>40)*	406,644	18%

B. Future Travel Demand Forecasting of Kabul city

1) Trip Generation and Attraction Model

Trip generation is the first step in the conventional four-step transportation forecasting process (followed by trip distribution, mode choice, and route assignment), widely used for forecasting travel demands. It predicts the number of trips originating in or destined for a particular traffic analysis zone. [4].

The (1) and (2) were considered trip generation and attraction models in this study.

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

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

TABLE VI PARAMETERS OF TRIP GENERATION/ATTRACTION MODELS

Trip Generation Modeling (gi)		
Variable	*Parameter*	*T- Value*
Population	0.561	10.691
Employment	0.479	3.383
Constant	-9881.692	
Trip Attraction Modeling (aj)		
Variable	*Parameter*	*T- Value*
Population	0.459	6.825
Employment	0.594	3.272
Constant	4312.579	

Two variables; "Population" and "Employment" were considered for achieving trip generation and attraction models. In Kabul city the trip generation and attraction models have been achieved from the surveyed trip generation and attraction in 2008. Zone 14 and 21 was not considered for finding the trip generation/attraction modeling, because it was not surveyed.

The Table VI depicts that population and employment has a positive relationship with trip generation and attraction.

The trip generation and attraction of zone 1 to zone 22 of Kabul city was forecasted to 2015 and 2025 periods of time as shown in Table VII.

TABLE VII TRAVEL DEMAND FORECAST IN 2015 AND 2025 (UNIT: TRIPS)

Travel Demand Forecast (Trips)				
	2015		*2025*	
	Generation	*Attraction*	*Generation*	*Attraction*
1	137438	169689	137843	169963
2	112867	134520	110701	131891
3	124236	125337	123144	125860
4	251081	232519	243222	228829
5	234473	218891	236357	225480
6	150036	145078	158033	155131
7	194456	183410	201998	194619
8	220977	210643	272029	257507
9	223634	214368	276328	265827
10	264022	243916	284667	268872
11	161727	153444	153505	148746
12	127183	126001	142295	140995
13	160752	155028	167429	163570
14	137011	138702	168169	166496
15	241711	220070	239649	223325
16	112812	115809	133725	135528
17	127173	131641	148462	149954
18	76611	83168	120289	125031
19	87153	89093	240119	232742
20	47066	53603	122304	125641
21	34408	45009	118341	121425
22	20602	32630	86777	96907
Σ	3247429	3222569	3885386	3854339

1) Trip Distribution Model

Trip distribution is the second component (after trip generation, but before mode choice and route assignment) in the traditional four-step transportation forecasting model. 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 generation model) and the predicted number of trips ending in each destination zone (trip attraction model). Thus, trip distribution is a model of travel between zonal trips or links. [5]

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

T_{ij} - Trips between zones i,j

G_i - Generated trips from zone i

A_j - Attracted trips to zone j

D_{ij} - Travel time impedance from zone i to j (km)

k, α, β, γ - Parameter

The (3) is a gravity model which is used for trip distribution modeling. The gravity model is based on Newton's gravitational theory from physics, interpreted in a transportation context. The gravity model assumes that the trips produced at an origin (gi) and attracted (aj) to a destination are directly proportional to the total trip productions (tij) at the origin and the total attractions at the destination.

TABLE VIII PARAMETERS OF TRIP DISTRIBUTION MODEL

Trip Distribution Modeling		
Variable	*Parameter*	*T- Value*
Constant	0.000154	
Generation	0.833	16.753
Attraction	0.747	13.217
Impedance	-0.832	-8.673

Trips between zones i,j data, generated trips from zone i and attracted trips to zone j is calculated in trip generation and attraction modeling stage. In this study the impedance is minimum route distance which calculated using the road network of Kabul city.

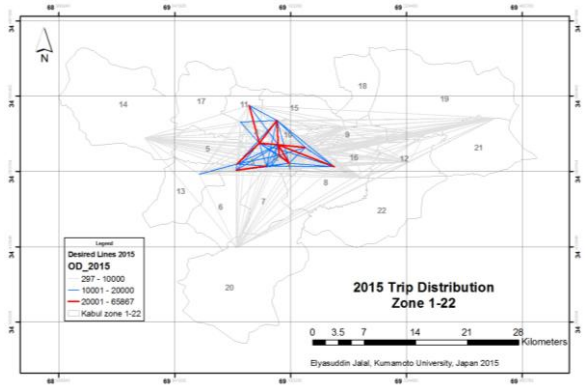

Fig. 3. *Forecasted 2015 trip distribution*

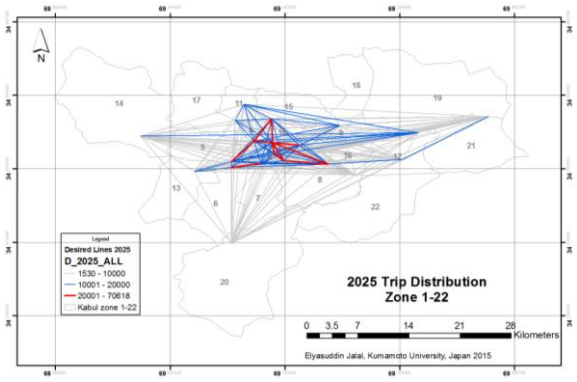

FIG. 4. *FORECASTED 2025 TRIP DISTRIBUTION*

After trip distribution model parameters are found (shown in Table VIII), trips between zone i,j is calculated for 2015 and 2025 periods of time using the trip distribution model.

It can be captured from Fig. 3 and Fig. 4 that trip distribution in 2025 is more spread then 2015 and the trips are mostly spread to the east part of the Kabul city.

1) Modal Split Model

Modal split models aim to determine the number of trips on different modes given the travel demand between different pairs of nodes (zones). These models try to mathematically describe the mode choice phase of the sequential demand analysis procedure. [6] In this study (4) is considered for modal split model.

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

P_{ij} - Modal Share

t_{ij} - Average Travel Time between zone i and j (km)

a, b - Parameter

Average travel time between zone i and j or in other words the impedance is calculated from the observed minimum path distance from one zone to another zone in kilometer.

At the first stage the total trips were divided to trips by walk and vehicles. Then at the second stage the trips using vehicles were split to trips by public transport and trips by private transport. (As shown in Fig. 5)

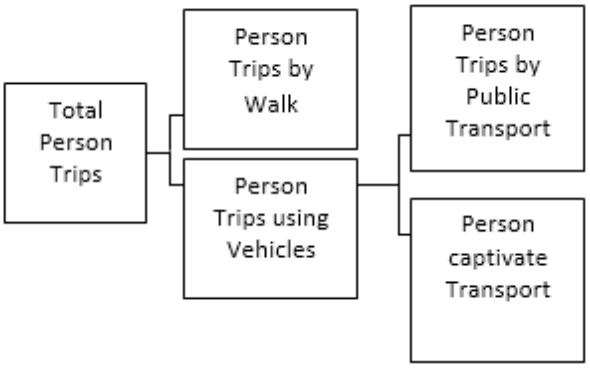

Fig. 5. *Modal split methodology A*

There is no observed and forecasted travel time data between zones in Kabul city. Therefore in this study, the average travel time (tij) for each mode has been calculated by dividing the observed minimum route distance (dij) to each mode's average speed. The average speed for walking, vehicle, public transport and private transport are considered as 4, 40, 20 and 60 (km/h) respectively. The convergent method as shown in Fig. 6 is used to forecast travel time for 2015 and 2025. The new travel time (tij) is found after the traffic assignment and it is used as future travel time to forecast the travel demand for each mode. The convergent process has been done until the new travel time (found by assignment) and the travel time used as future travel time (for forecasting) remains the same, with one decimal precision. (Shown in Fig.6)

For modal split modeling in split tree 1, the "travel time difference between walk and vehicle and in split tree 2, the travel time difference between public transport and private transport has been used as variable. The result of the modal split modeling has been given in Table IX.

Public transport mode of travel has decreased from 49% to 47% and 43% from 2008 to 2015 and 2025 respectively. Private transport has dramatically increased from 12% to 24% and 31% from 2008 to 2015 and 2025 respectively. However, walking has decreased with share of 39% in 2008 to 29% in 2015 and 26% in 2025. (As shown in Fig. 7 and Fig. 8)

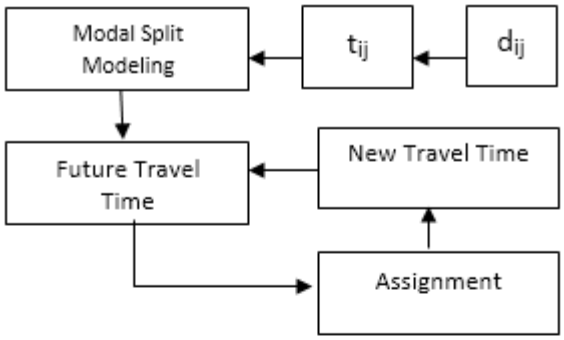

Fig. 6. Modal split methodology B

TABLE IX PARAMETERS OF MODAL SPLIT MODEL

Modal Split Tree 1		
Variable	*Parameter*	*T- Value*
Travel Time Difference (Walk-Vehicle)	-0.000963	-1.0627
Constant	2.0582122	
Modal Split Tree 2		
Variable	*Parameter*	*T- Value*
Travel Time Difference (Public – Private)	0.006162	3.480
Constant	-2.146	

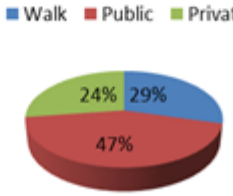

Fig. 7. Forecasted share of trips by main transport modes (2015)

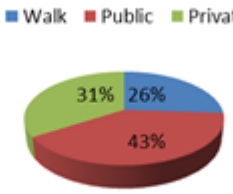

Fig. 8. Forecasted share of trips by main transport modes (2025)

III. NETWORK ASSIGNMENT AND ANALYSIS

A. *Pre assignment procedure*

Traffic assignment concerns the selection of routes (alternative called paths) between origins and destinations in transportation networks. It is the fourth step in the conventional transportation forecasting model, following Trip Generation & Attraction, Trip Distribution and Modal Split. To determine facility needs, costs and benefits, we need to know the number of travelers on each route and link of the network (a route is simply a chain of links between an origin and destination). We need to undertake traffic (or trip) assignment. [7]

1) Vehicle trip origin destination table:

In this study traffic assignment analysis has been done with the help of JICA STRADA software using the transportation demand data for 2008, 2015 and 2025. At first, the Person trip origin destination (PTOD) tables were converted to vehicle trip origin destination table (VTOD) and at the next step, the VTOD tables were converted to PCU values (given in Table X) for inputting to traffic assignment. Updated road network was created and OD tables were assigned on the created road network.

TABLE X AVERAGE NUMBER OF PASSENGERS AND PASSENGER CAR UNIT [8]

Type	Public transport	Private transport
Average number of passengers	9.4	1.9
Passenger car unit	1.2	1.0

2) Link cost function:

For each link there is a function stating the relationship between resistance and volume of traffic. The relation between the link flow and link impedance is called the link cost function and is given by the (5).

$$t = t_0\left[1+\alpha\left(\frac{x}{k}\right)^{\beta}\right] \quad (5)$$

t_0 – Free flow travel time on link per unit of time

x - Flow (or volume) of traffic on link per unit of time

k - Capacity of link per unit of time

$\propto$, β are the model parameters.

The Bureau of Public Roads (BPR) has considered the value of $\propto$ and β parameters as 0.15 and 4.0 respectively.

For this study, the default parameter values of BPR link cost function (0.15 and 4) are considered.

1) Road Network:

The private transportation road network used in this study network consists of 387 links in 22 zones of Kabul city as shown in Fig. 9. The road network was created and updated for this study from the road network designed by JICA in 2008.

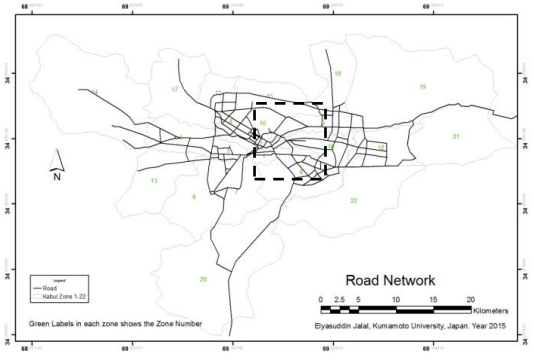

Fig. 9. *Kabul city car road network (created for this study)*

B. Traffic Assignment Results:

At the first stage the Private transportation demand was assigned on the road network. The results of the private transportation assignment in 2008, 2015 and 2025 are shown in the Fig. 10, 11 and 12 respectively. In Fig. 13, the microbus and taxi modes of travel was added with private transportation mode of travel and assigned on the same road network of Kabul city. The label on the top of the links shows the link volume in hundreds (00) and width of the links indicates their volume scale. The links were divided to four colors by their volume per capacity rate (VCR) or simply congestion rate. To better understand the road network assignment of Kabul city, the alphabets from A to L are shown in the trip assignment figures. These alphabets indicates the location of specific places in Kabul city, which are named as: A) Kabul Airport, B) Presidential Palace, C) Mandawi Central Business District, D) Sharenaw Business District, E) Kabul TV Tower, F) Kabul University, G) Kabul Polytechnic University, H) Badam Bagh Region, I) Maryam Business District, J) Kardan University, K) Kabul Stadium, and finally L) Macrorayan Business District.

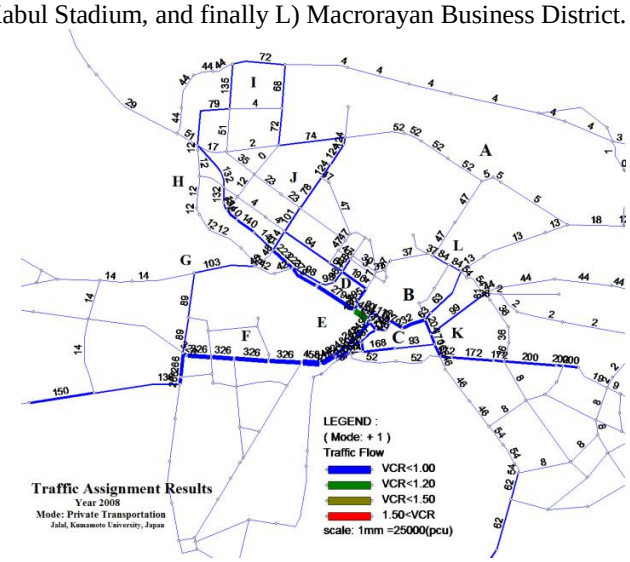

Fig. 10. Private Transportation traffic assignment (2008)

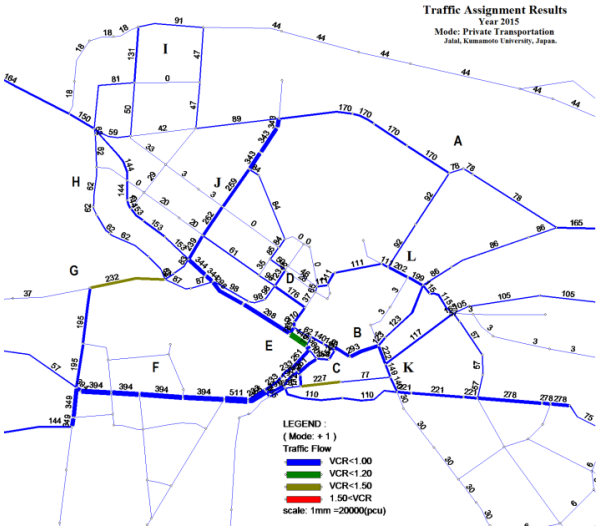

Fig. 11. Private Transportation traffic assignment (2015)

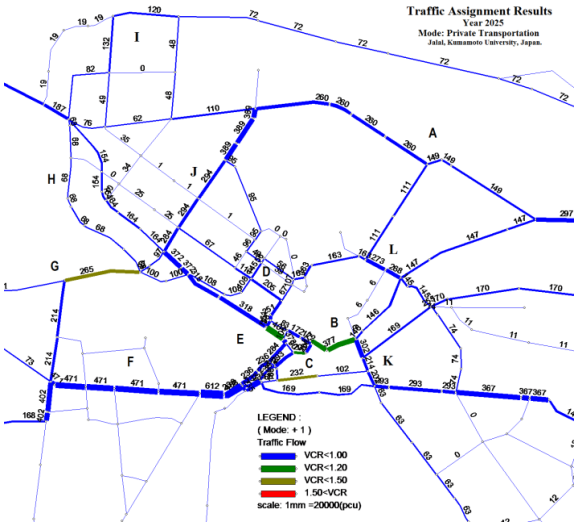

Fig. 12. Private Transportation traffic assignment (2025)

Fig. 13. Private Transportation plus microbus and taxi traffic Assignment (2015)

The main focus of the study was the private transportation analysis. The private transportation assignment results in "2008, 2015 and 2025" show that the congestion rate in most of the links were less than 1.00. (Shown in Fig. 10, 11 and 12) The private transportation demand is less than the physical capacity of existing road network of Kabul city in 2015 and 2025.The microbus and taxi modes of transportation were included in the traffic assignment and shown in Fig. 13. It shows that if the microbus and taxi is included in the traffic assignment; some links get congested. These links are given in red color which indicates the high congestion rates. Therefore, in the short term the main cause of congestion is not the private transportation demand but it's the lack of high capacity public transportation facilities such as large bus and huge amount of microbus and taxi in the shown congested links.

IV. TRANSPORTATION PLANNING POLICY

A. Land use of Kabul city:

As it is shown in Fig. 14 most of the planned business and commercial areas (shown in red and pink colors respectively) are located in the center of Kabul city (shown inside the circled area).

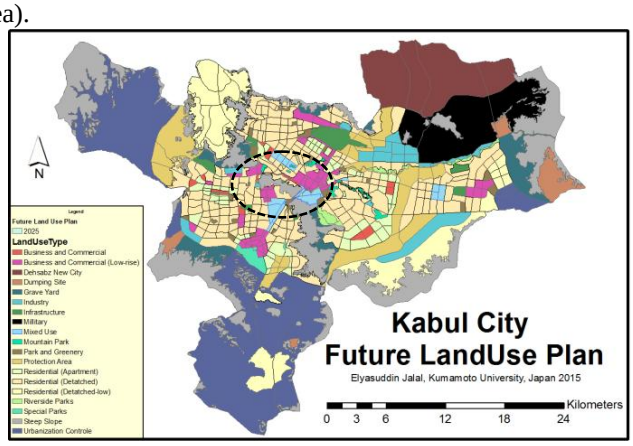

Fig. 14. Future land use plan [9]

At the other hand, Kabul city is a mountainous area (steep slopes are shown in gray color) and a series of mountains have divided the Kabul city to east and west, crossing from the city center. The high traffic demand and mountainous type of land has created some congestion around the city center area.

B. Short term planning:

From the car traffic assignment results of 2008, 2015 and 2025 (as shown in Fig. 10, 11 and 12) it can clearly depicted that in the short term the physical capacity of road network in Kabul city is capable of private transportation. Thus, there is no need to introduce any new link for private transportation in the near future.

If it is assumed that actual capacity of Kabul road network is 20% smaller than its physical capacity for private transportation, then the private transportation assignment results will change and some links shown in Fig. 15 will get congested. It is recommended that the actual capacity of the road network should be raised to physical capacity of road network with traffic management and building road infrastructures in Kabul city especially in the links with high congestion rate shown in Fig 15.

Public transportation is consist of 4 parts; taxi, microbus, minibus and large bus. In this study the microbus and taxi is included in the "2015 private transportation traffic assignment" which is given in Fig. 17 because of their size similarity and their service network similarity with the private car. Microbus and taxi don't have a specific network for service and it depends on the passenger's choice. Microbus contributes a high share of 18% from all trips in 2008 (shown in Table III). Microbus is very active in Kabul city because there is no high amount of large bus and mini bus in Kabul city. Microbus is a very good mode of travel in Kabul city but it can be also problematic in highly congested links.

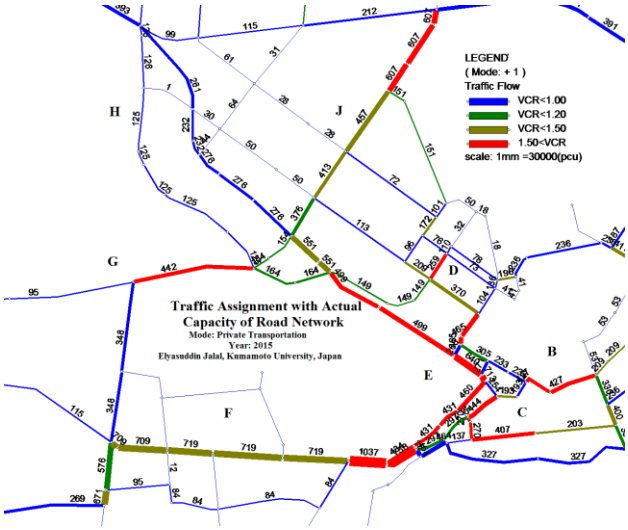

Fig. 15. Private Transportation traffic assignment (2015) with 20% capacity decrement

From the traffic assignment results of private transportation plus microbus and taxi in 2015 as shown in Fig. 13, it can be realized that public transportation demand is the main factor in creating congestion. Thus, in the short term period of time, it is recommended that public transportation facilities with higher capacities than car should be introduce to reduce the congestion in shown congested links.

C. Impact of Introducing Light Rail Transit (LRT) System

From the traffic assignment results (Shown in Fig. 11 and 12) it was found that Kabul city roads are capable of private transportation demand. On the other hand, the congestion occurs due to high amount of public transportation demand and small capacity of microbus in Kabul city.

In this study the route which is shown in Fig. 16 has been nominated as an example for introduction of high demand public transportation. As it can be seen in the Fig. 11 and 12

the width of the roads and physical capacity of these links are high enough for private transportation in 2015 and 2025, though after introduction of public transportation facility, the public transportation capacity of the road network can increase but at the same time, the private transportation capacity of these links will decrease.

In Fig. 16 the width, length, volume and congestion rate of each link is given in the proposed route for introduction of high capacity public transportation facilities. The several locations in the proposed route namely A,B,C,D,E are shown in Fig. 16 are investigated for better understanding in Table XI.

If the light rail transit (LRT) is introduced to the proposed route, it will enhance capacity of the public transportation system.

After introducing LRT due to high amount of LRT passenger capacity; the congestion problem caused by high number of micro bus and taxi will be solved. However, at the same time, LRT will shorten the right of way in these roads for private transportation. (Shown in Fig. 17 and Fig. 18)

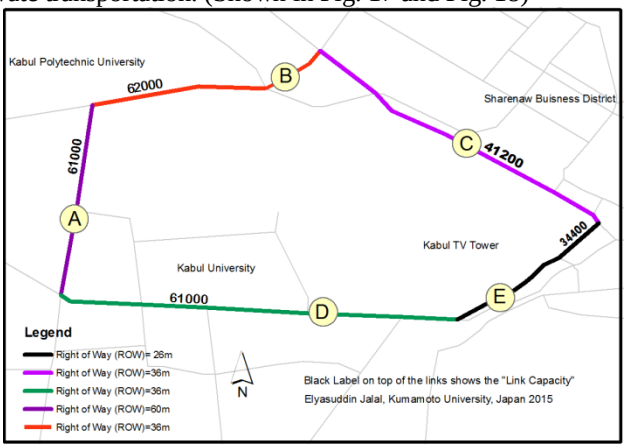

Fig. 16. Proposed high public transportation demand route

In this study, for instance the LRT is considered on the proposed route to increase the capacity of public transportation demand in these links.

It has been studied that if the LRT system with 4 meter right of way is built on the proposed route, what are its impacts on private transportation.

TABLE XI CAPACITY OF PROPOSED LINKS AFTER INTRODUCTION OF LRT

No	Capacity (pcu/day)	Right of Way (m)	LRT width (m)	Capacity Decrement (%)	Capacity Decrement (pcu/day)	New Capacity (pcu/day)
A	61000	60	4	6.67	4066.67	56933.33
B	62000	36	4	11.11	6888.89	55111.11
C	41200	36	4	11.11	4577.78	36622.22
D	61000	36	4	11.11	6777.78	54222.22
E	34400	26	4	15.38	5292.31	39692.31

The Fig. 17, Fig. 18 and Table XI indicate that in the short term after introduction of LRT, the private transportation capacity in these links will decrease to a certain level but will not make high congestion in most of the links. Though, in the near future (2025) the congestion will occur in some part of the links which should be enhanced by increasing their capacity by widening the road or introducing a new link.

A. Long Term Planning

For the long term planning a simulation has been done to find the relationship between travel time and population.

In this simulation, the total travel time on all links calculated in with the respect of increment in population. The (5) is used to find travel time from the trip assignment results for each considered population.

$$\sum_{i=1}^{n} t_i = \frac{l_i}{v_{0i}}\left[1+0.15\left(\frac{x_i}{k_i}\right)^4\right] \qquad (5)$$

l –length of each link (km)

v_0 –speed in free flow traffic in each link (km/h)

x - Flow (or volume) of traffic on link per unit of time (pcu/day)

k - Capacity of link per unit of time (pcu/day)

i - number of link

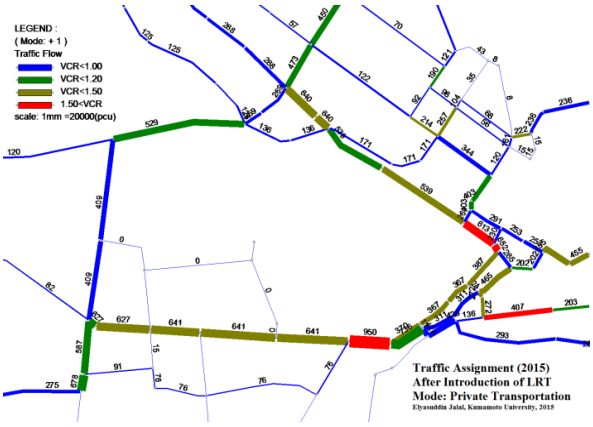

Fig. 17. After introduction of LRT (2015)

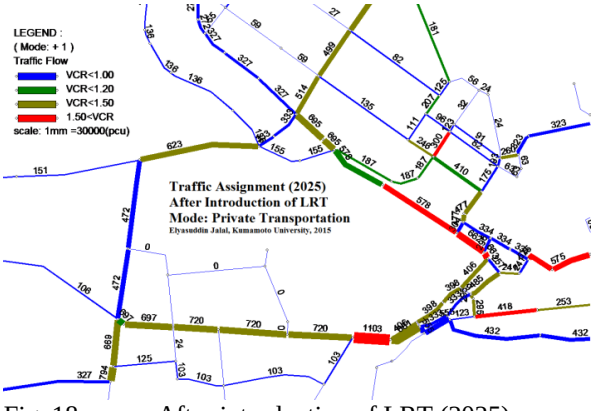

Fig. 18. After introduction of LRT (2025)

The result of this simulation (shown in Fig. 19 and Table XII) indicates that in the near future the private transportation demand will increase dramatically. Thus, for the long-term new links should be increase to reach the demand of transportation.

For the long term, it has been investigated and plotted how the travel time change in respect of population. It shows that in the long term, by increase of population the travel time of private transportation will increase dramatically and needs to be considered in future planning. It may require introducing new links in the Kabul city road network.

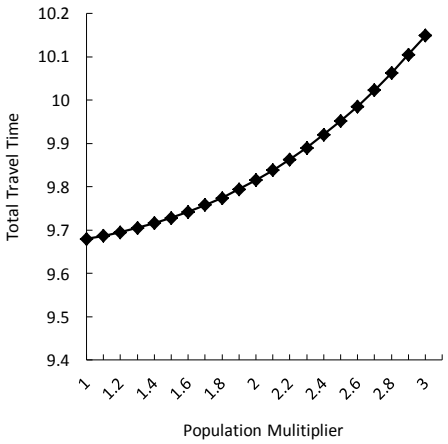

Fig. 19. Population and travel time relationship

TABLE I TOTAL TRAVEL TIME AND POPULATION

Population	Total Travel Time
1	9.68
1.1	9.687
1.2	9.695
1.3	9.705
1.4	9.716
1.5	9.728
1.6	9.742
1.7	9.758
1.8	9.774
1.9	9.794
2	9.815
2.1	9.838
2.2	9.863
2.3	9.89
2.4	9.92
2.5	9.952
2.6	9.985
2.7	10.023
2.8	10.062
2.9	10.105
3	10.149

V. FUTURE RECOMMENDATIONS:

This study has covered a broad study area of an integrated transportation planning for Kabul city in the short-term and

long-term periods of time. This study has investigated the main reason of congestion in Kabul study. Lack of data is one of the biggest problems in the planning sector of Afghanistan. In this study, some data is required in order to achieve more precise results in the future researches. These required data found by this study, which is a big achievement of this research are quoted below in each step of transportation planning.

1) Demography

Used: In this study the "zonal population and economy of Kabul city" estimated by JICA has been used. JICA has estimated the population from the combination of Central Statistics Office (CSO) and District Head estimated population. There is no specific demography data in Kabul city and the data differs in each organization. By having the demography data we can forecast different purpose trips to future, finding different varieties of traffic characteristics to enhance the trip generation and attraction modeling.

Recommended: A census is recommended for Kabul city which is the common direct method of collecting demographic data. A census is usually conducted by a national government and attempts to enumerate every person in a country. Censuses typically occur every 10 years or so. Censuses do more than just count people. They typically collect information about families or households in addition to individual characteristics such as age, sex, marital status, literacy/education, employment status, and occupation, and geographical location.

Responsible Organization: Central Statistics Office (CSO)

2) Travel Survey

Used: In this research only the person trip (PT) survey of JICA has been used. The person trip (PT) survey of JICA was done for preparing master plan of Kabul city and it was not done in zone 14 and 21 due to some security reasons in 2008.

Recommended: The survey should be conducted to all the related zones in Kabul city by the responsible organization after some period of time such as every 5 years to capture the updated transportation conditions in Kabul city.

Responsible Organization: Ministry of Transport and Civil Aviation.

3) Model

Used: In this study, the minimum route distance impedance is used for travel demand forecasting models. The best data for using as impedance is the travel time data which was not available.

Recommended: Travel time impedance is one of the most important data for forecasting the travel demand and should be measured from one zone to another zone, by each mode of travel such as car, bus and walking.

Responsible: Ministry of Transport and Civil Aviation.

4) Network

Used: In this study only the Major arterial and Arterial types of roads were considered in the road network of Kabul city. In Kabul city the roads are not categorized on the basis of international standards.

Recommended: Road network density can be increased by considering the secondary and community roads of Kabul city for achieving more precise results.

Responsible Organization: Kabul Municipality and Ministry of Public Works.

5) Calibration

Used: Calibration data is necessary in order to check how much the estimations fit the actual conditions.

Recommended: Traffic count survey should be done to find the goodness of fit for the travel demand models.

Responsible: Researcher may conduct a traffic count survey to compare with the forecasted results.

VI. CONCLUSION

This study has focused on main cause of congestion in Kabul city by studying the public and private transportation (except large bus and mini bus). This study is a very important achievement for Kabul urban studies because it identifies the short term and long term transportation needs in Kabul city. In this research, the transportation planning has been done for the short term (2015), mid-term (2025) and long term periods of time.

It was found that in the short-term the road network of Kabul city has the capacity of the private transportation flow without causing congestion. The actual capacity of the road network has been decreased from their physical capacity due to lack of traffic management and poor infrastructure. Therefore, in the short-term there is no need to introduce new links to remove congestion but to raise the actual capacity of the road networks in Kabul city.

On the other hand, it was found that in the short term there is large amount of public transportation demand in Kabul city. Furthermore, there is not enough "high capacity public transportation facilities" such as large bus, bus rapid transit (BRT) or light rail transit (LRT).

It has been found from this study that; if LRT is introduced in a proposed route to tackle congestion, it can decrease the pressure from public transportation demand. As the main focus of this study is private transportation, the existing and future impacts of LRT on the private transportation capacity in the proposed route has been studied. It was found that after introduction of LRT, in the short term there is no need to increase the capacity of the proposed route but in the future it should be increase by widening the road or introducing new links.

For the long term, it has been investigated and plotted how the travel time change in respect of population. It shows that in the long term, by increase of population the travel time of private transportation will increase dramatically and needs to be considered in future planning. It may require introducing new links in the Kabul city road network.

The required data for a detail transportation planning of Kabul city, to be gathered for more precise results in the future are quoted at the end of the research, which is a main

achievement of this thesis to solve the future problems and having a better planning in the future.

VII. ACKNOWLEDGMENT

I would like to proudly express my deepest gratitude to my respected supervisor, Professor Shoshi Mizokami, for his excellent guidance, caring, patience, and providing me with an excellent atmosphere for doing research.

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