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TRAFFIC CONGESTION COST ESTIMATION AND VALUE OF TIME: A CASE STUDY OF PASHTUNISTAN-AIRPORT ROAD IN KABUL CITY

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Abstract-Traffic congestion problems are global that are observed in large cities due to many different reasons dependent case by case. Kabul city is suffering from this problem in various areas which have to be studies and estimated quantitatively. A main road (Pashtunistan- Airport) road was chosen in this study that has significance importance as it connects the Kabul city center with Kabul international airport, therefore, it has excessive traffic congestion. The traffic data was collected using video cameras at different locations at the road to calculate the traffic volume, average speed and average delay. Additionally, the congestion costs per day was estimated in terms of opportunity and fuel consumption costs due to the massive delays by traffic congestion. A stated preference survey was conducted at different organizations, business centers and common people that is located along the road using convenience survey that was analyzed with multinomial logistics regression model to determine the value of time. The results establish the traffic time and costs for the road that needs adequate travel time saving plan which can be accomplished by congestion relive action and efficient transport planning.

Key Words: Kabul City, Traffic Congestion, Cost Estimation, Multi nominal Logit.

1. INTRODUCTION

This study focused, to study the congestion problem in one of the most congested roads in Kabul city as example for congestion problems of one of the developing countries. Kabul city is estimated as the fifth fastest growing city in the world with population count increased from 1.5 million to 6 million from 2001 to 2014.[1] However, the city seems to be incapable to keep up with this fast urbanization. Congestion is a significant problem in Kabul city that is triggered by many reasons such as the inadequate structure of urban road system, lack of public transportation, lack of road networking, high demand of private vehicles, shortage of traffic maintenance, lack of awareness about traffic rules, link of narrow roads with width road, parallel parking, political situation such as too many blocks/ check points and many other reasons.[2] There are some studies that tried to understand and study the increased congestion problem in different places in Kabul city to offer some solutions. (Safi, Z. U 2011) explored the factors that caused the excessive congestion especially the individuals and community actions that contributed to exacerbate the problem.[2] The results indicated the unawareness of traffic laws and regulations and gave recommendation mainly to the road police and ministry of urban development to regulate the traffic laws. (Noori, W. A 2010) investigated the reasons behind the congestion that causes air pollution, costly transportation, accidents and lowers the individual income to less than 100 dollars.[3] The research showed that the city unable to develop new transportation infrastructure such as mass transit, BRT, rail and tram and attempts should be run to improve the current infrastructure and public transport. Other researchers focused on specific areas for example, (Mohamed Noor Naeemi et al 2016) studies the causes and capacity of congestion at rotary intersection of Kulula Pushta square.[4]

On the other hand, a limited research was done on the economic aspect, cost benefit analysis on Kabul city inner ring road was done to propose alternatives for the road network under this study.[5] However, gathering data and making exact study is very difficult and there is shortage in data resources in Kabul city. The city is suffering from too much congestion, lack of public transit, negative effect of crowding and high cost of transportation that needs further research to study and quantify congestion besides offering some strategies to relieve the current situation of traffic congestion. The concept of Value of time (VOT) was developed and applied in many research to estimate the value of travel time especially that associated to business trips.[6-9]

This paper studies the congestion at one of the most congested roads in Kabul city (Pashtunistan- Airport) road with a conventional approach to quantify congestion in terms of costs. For this reason, traffic parameters were collected from field survey while the data for VOT through stated preference survey in a questionnaire survey.The

results can be used by policy makers to reduce congestion and time loss through efficient transport planning.

2. STUDY AREA

The study area is located in the middle of Kabul city center which is very vital area. Many vital organizations and major governmental offices are located along the road, such as, ministry of finance, presidential palace, ministry of mines and petroleum, ministry of defense, ministry of public work, ministry of urban and land use, ministry of tribes and border affaires, ministry of public health and supreme court of Afghanistan besides many embassies, public hospitals and residential places. The road is 6.1 Km which connects the Kabul city center to Hamid Karzai international airport. It comprises of six Major intersections, such as, Pashtunistan, Puli Mahmood khan, Abdul Haq, Masood, Makroroyan 4 and Airport Intersections as shown in Fig.1. The all intersections are without any traffic lights, Traffic signs and road surface marking, which sometime the traffic is managed by only traffic police. The study area is complex of residential, governmental organizations and Business place, therefore, the traffic characteristics are also heterogeneous and mix vehicles are used in the stretch, such as private cars, bus, minibus, microbus, taxi, truck and motorcycle. The passengers are frequently using private cars for commuting and small cars as a share mode for public transport. This is also one of the major reasons for the extra traffic congestion. Daily working trips for jobs purpose has also tolerance on traffic congestion in the study area as shown Table 4.1.

Fig. 2.1 The google Image of the Studied Area

3. DATA COLLECTION AND METHODOLOGY

The methodology framework is based on data collection, data analysis, congestion estimation and evaluation based on the collected data. Data for value of time was collected through a stated preference survey. This survey was conducted at various organizations along the road targeting variety of citizens who commute daily on the road. A paper based questionnaire survey was done where respondents were given multi-choice and hypothetical mode options. The survey is comprised of (32) questions to gather data like age, gender, income, travel destination, mode, expenses, people opinions towards congestion, stated preference, journey time and others. The other section of the survey was related to the stated preference data, in this section, the respondent could choose the option based on his/her current using mode, such as, in case of private car users were given the choice for a motorcycle. In case of public transport users, the choice of microbus while for the ordinary small cars which are also used for public transport was given the choice of bus. In another meaning, all respondents, were given hypothetical choices that are different than the mode they are currently using. So, for every respondent there are five modes to choose from and excluding their current mode and truck, which is the sixth mode as this study investigates six modes (Car, Taxi, Bus, Minibus, Microbus, Motorbike). In addition, hypothetical choices of the travel time and cost are well formulated depending on materialistic data such as maximum driving speed on the studies road and the vehicles kind that are the majority in this road. We put in consideration one criteria as the base condition that ensures that all modes and alternative modes choices are stochastic. Relatively, the alternative modes choices are predefined from the predicted time and cost and the values of time and cost choices change with respect to the actual values but always there is a balance in mode type and values of time and cost. For traffic volume and traffic characteristics data collection, video cameras were used for traffic volume observation at 6 different positions which are in the intersections Fig.1. The data was collected for two days, workday and holiday at each point to record the traffic volume for 14 hours and midnight time is neglected because of very few vehicele counts. Traffic data was sorted into different travel modes private cars, Taxi, Bus, Minibus, Microbus, Motorbike, and trucks. The delay time was calculated from the difference of experimental travel time and theoretically based on a reference speed. Value of time (VOT) was estimated from the survey (socio-economic survey) based on the 234 questionnaire response which provid's information such as, travel time and travel costs for each traveling mode; cars or buses. Addi-

tionally, applying this information in equation (1) and (2) as a part of multinomial logit model to estimate the value of time by maximizing log-likelihood. The average estimated coefficients for the travel time and costs by STATA software are summarized in Table 1. for the car mode, where the negative value is due to the increase in both time and cost.

$$U_i = B_0 + \beta_1 . TTi + \beta_2 . TCi \quad (1)$$

U_i = Utility of mode i
(i= {Car, Bike, Microbus, Taxi, Bus,}),
TT_i= Travel time for mode i,
TC_i= Travel cost for mode i,F
B_0= Intercept,
β_1= Coefficient of travel time [1/min]
β_2= Coefficient of travel cost [1/Afg]

$$VOT = \beta 1 / \beta 2 \quad (2)$$

Consequently, the value of time is used to measure the opportunity costs while vehicle operating costs can be deduced from fuel consumption and fuel efficiency data. Equations (3) and (4) represent the expressions for opportunity and vehicle operating costs.

$$OC = \sum^{m}_{m=1} (VOTm \times Delay_m \times V_m \times Vocc_m) \quad (3)$$

Where, OC = Opportunity Cost of traffic congestion, VOT_m = Value of time for specific mode m,
$Delay_m$ =travel delay in time units observed for mode m (estimated at some reference speed),
V_m =number of vehicles of type mode per day, $Vocc_m$ = Average vehicle occupancy for specific mode m.

$$VOC = L * \sum^{m}_{m=1} (FC_m \times Delay_m \times V_m) \quad (4)$$

Where, VOC= Vehicle operating Cost, FC_m = Fuel cost in Afg/hr. for specific mode m, and L= length of stretch in Km.

$$FC_m = \sum^{3}_{ft=1} (Fcq\ m^{Ft} \times Fp^{Ft} \times \mu^{Ft}) \quad (5)$$

Where, Fcq_m= Fuel consumption quantity in liters/km or Kg/km of specific mode m, Fp^{Ft} = fuel price of specific fuel types Ft = 1, 2 and 3 such as LPG, Gasoline and Diesel, respectively in Afg./liters or Afg/kg.
μ^{Ft}= proportion of specific mode type m using a particular fuel type for travelling on that road.

Table-3.1 Coefficient for MNL Model of Private Car Users

Coefficients	Value
Constant	-5.6995 E-08
Time Coefficient (/ min)	-0.1335
Cost Coefficient (/ AFG)	-0.042
Value of Time (AFG/h)	190.3
Value of Time (USD/h)	2.75

4. RESULTS AND DISCUSSION

The collected data was applied in the parameters as described above in equations (1) to (4). The average value of the traffic volume collected at the six different locations is shown in Table 2 for different modes of transportation. The survey was done for 14 hours of the whole day (working day), and these values are considered a value for single average day. The significant amount of private cars is mainly due to the deficiency in public transport system. The peak hours in the road was determined from 7:30- 10:30 and 15:30-17:30, which is excessively crowdy as this road contains important organizations and hospitals. Moreover, there are huge number of private taxi, are used as share modes for public transport which contributes in extra congestion and lowers the average vehicle occupancy. In addition, the average speed and average time delay were calculated for the peak hour and non-peak hour separately for all the transportation modes for accurate estimation as shown in Table 3.1 and Table 4.2. The average speed is very low for all transportation modes, indicating the bad mobility along the road due to the excessive congestion., This road is vital and should serve the increased demand but the road has deteriorated pavement structure and too much jam. Table 3 demonstrates that the travel delay is larger for bus and trucks but lower for cars and bike so, the delay is not similar for all modes along the road. The level of service of the road was also calculated to be F.

Table-4.1. Traffic Volume for Different Transportation Modes and Vehicle Occupancy

Mode	Traffic volume (Veh/day), Peak H	Traffic volume (Veh/day) Non-peak H	Vehicle Occupancy
Car	15576	11272	1.9
Taxi	4186	3102	1.9
Bus	142	102	20
Minibus	480	174	14
Microbus	2858	1034	9.4
Truck	244	81	1.2
Bike	248	92	1

Fig. 4.1 Represents the change in peak hour between the working day and non-working day. Apparently, the road is more crowdy in the working days due to the massive number of organization that is contained. On the other hand, the portion of each mode was observed and counted from the recorded video, we can see clearly that most passengers are using the private cars and Taxi. In addition, the public transport is used in a very small portion of the studied area. Figure 3 shows the percentage of the traffic modes used along the road.

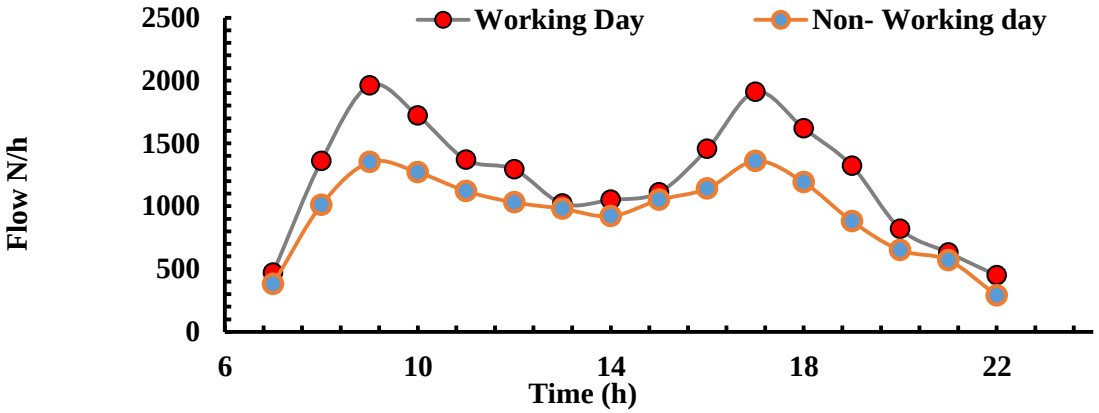

Fig. 4.1 The Traffic Volume in Pashtunistan- Airport Road in both Working and Non-Working days

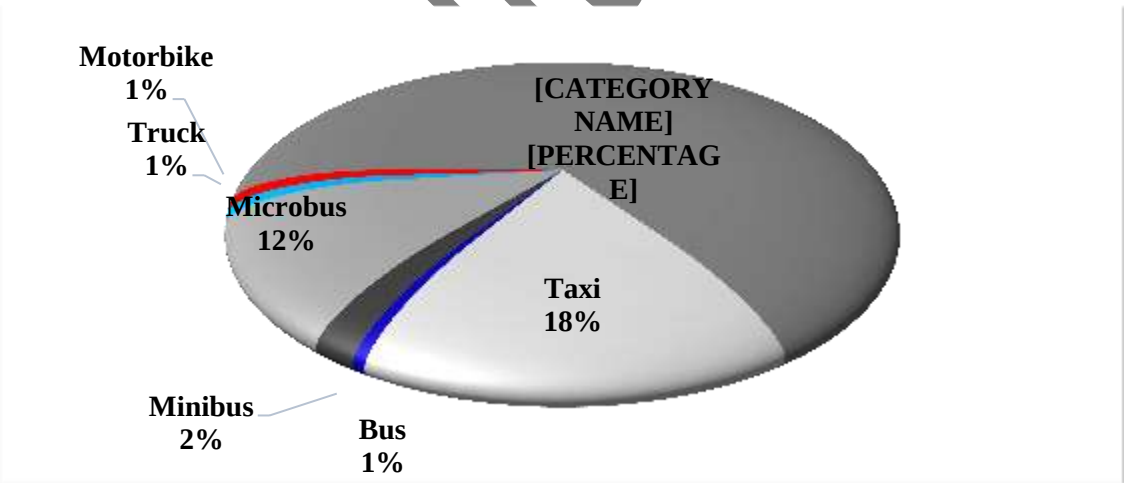

Fig. 4.1 The Mode Share in Daily Traffic Volume

Table-4.2 Average Speed and Average Travel Delay for Peak Hour

Mode	Average speed (Km/hr.)	Ave. delay (Min/ Veh) at reference aped 30 Kph	Avg. Delay (Min/ Veh) at reference aped 20 Kph
Car	14	15.1	8.5
Taxi	14	15.1	8.5
Bus	7	43.37	36.8
Mini Bus	9	30.8	24.2
Microbus	12	19.8	13.2
Truck	10	26.4	19.8
Motorbike	15	13.2	6.6

Table- 4.3 Average Speed and Average Travel Delay for Non- Peak Hour

Mode	Average speed (Km/hr.)	Ave. Delay (Min/ Veh) at reference aped 30 Kph	Avg. Delay (Min/ Veh) at reference aped 20 Kph
Car	27	1.5	-
Taxi	27	1.5	-
Bus	17	10.09	-
Mini Bus	20	6.6	-
Microbus	25	2.6	-
Truck	22	2.64	-
Motorbike	30	0	-

The value of time was also estimated (Table-4.4) as described before in the methodology with respect to the transportation mode. Fuel consumption quantities for each traffic mode and each mode ratio of using a specific fuel type (LPG, Gasoline, and Diesel) with the corresponding values of μ_1, μ_2, and $\mu 3$, respectively, are quantified according to the data collected from the ministry of transportation and civil aviation, Kabul Afghanistan[10]. Putting into consideration the vehicle kind (car, truck etc.) and fuel kind as mentioned.

Table-4.4 Value of Time for Various Transportation Modes and Fuel Consumption Quantity

Mode	VOT (Afg/hr.)	μ_1	μ_2	μ_3	Fcq LPG (Kg/100Km)	Fcq Gasline (L/100Km)	Fcq Diesel (L/100Km)
Car	30	0.11	0.89	-	8-10	10-12	-
Taxi	35	0.13	0.87	-	8-12	10-12	-
Bus	10	-	-	1	-	-	22-25
Minibus	10	-	-	1	-	-	17-19
Microbus	25	-	-	1	-	-	15-17
Truck	-	-	-	1	-	-	19-24
Bike	15	-	1	-	-	4-6	-

The results from Table 3.1,4.1, 4.2, 4.3 and 4.4 are utilized to quantify the level of congestion and traffic congestion costs by equations (3), (4) and (5). As shown in Table 3 above, the time loss for average vehicle each mode is approximately 23.4 minutes/trip using the conservative definition of delay (i.e. 30km/hr. reference speed) along with the volume of traffic which is 41,076 vehicles/day. On this bases, the total delay was found to be 961,178 minutes/day, which is nearly 667.5 days/day. The Level of Service (LOS) for this stretch was found out to be F. The free flow travel time for the stretch, was 14 minutes, but in actual circumstances, the average travel time per average vehicle at the peak hour is found to be 37.4 minutes for the complete stretch of road which is around 6.1 km. The per trip additional time as associated with the free flow speed is approximately 165 % of the free flow travel time, which provides travel time index value as 1.65. Furthermore, a very interesting fact is that the free flow speed is hardly achievable on this track at any time of the day. Table 6 shows the total traffic congestion costs as around 24,562,151 Afg per day which equals 355,973 and 10,239 USD per day for the working day and holiday respectively in the road under study. Furthermore, according to the Afghanistan Calender 249 days are working days and 116 are the holidays. It means around 10,051,377 USD / year for both working days and holidays is estimated (Table 4.6), this significant amount of money is lost due to the congestion problem and can be avoided by taking actions in the near future.

Table-4.5 Total Cost of Traffic Congestion Per Day in USD

Heads	Working day	Non-working day
Opportunity Cost (OC)	26982	7536.1
Vehicle Operating Cost (VOC)	7832	2457.4
Wear and Tear 10% VOC)	783.1	245.7
Total Cost	35,597	10,239

Table-4.6 Total Cost of Traffic Congestion Per Annum in USD in the Study Area

Heads	Working day	Holiday
Total Cost /day	35597	10239
Total Cost	8,863,653	1,187,724
Grand Total/ Annual	**10,051,377**	

We can extrapolate the congestion cost for the whole arterial roads in Kabul city by calculating the cost for one Km which is around 1,647,766 USD km/year. Then multiplying the cost of the one Km with the existing length of the congested network of Kabul city. The whole arterial network of Kabul city is 330.7 km[11], while, the total length of the most congested urban road is 104 km. In this case the approximate total congestion cost of the whole city will be equal to 171,367,664 USD /year for Kabul city, which is around 0.88 % of the entire Afghanistan GDP[12].

CONCLUSION

This paper studied the congestion problem in the vital road Pashtunistan-Airport Route in Kabul city. The survey revealed the very bad condition of the road, as well as, the extra congestion that is exacerbating with time. This research is the first to investigate the congestion cost in the targeted road which can be used to enhance other parts of Kabul city and for relieving the traffic congestion problem. A stated preference survey and statistical analysis were applied to calculate the value of time and different costs. The results demonstrated that around 10,051,377 USD /year are lost due to the traffic congestion, which needs a serious action at once. Furthermore, the calculated costs in this research are due to the loss from the traffic congestion and not included the environmental and other associated costs. Thus, the loss should be extended to the whole city for estimating the total loss. The loss of time, longer trips, paralyzed transportation, massive queues and the low level of service are all off another matter. Consequently, further research and immediate actions have to be taken by the government and decision makers to relieve this problem in the near future.

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