Estimating Traffic Density: Trends and the Impact of BRT Construction on Traffic Junctions of Karachi using Geospatial Techniques

Imran Akbar[1], Saad Malik[2], Hassan Amjad[3]

(Received June 12, 2020; Revised October 12, 2020; Accepted November 11, 2020)
Online First Publication
DOI: 10.33317/ssurj.203

***Abstract*— Everyone must commute on a daily basis to work, get educated, buy necessities, seek entertainment or visit friends and family. Thus, transport infrastructure has become an integral or probably the most important aspect of urban design. Major cities of the world have a mass transit system or even multimodal transport system to cater for the transportation needs of their citizens. Karachi a mega polis city of approximately 23 million residents lacks a properly coordinated and well scheduled transportation mechanism. Therefore, its residents primarily rely on their own means to fulfill their commuting needs resulting in heavy traffics and very significant time delays on its roads. These time delays and rush hour frustrations in turn have a negative impact on the overall productivity and psychological and social well-being of the populace. The government has in recent years taken up this matter seriously and begun construction of Bus Rapid Transit (BRT) systems along various major traffic corridors of Karachi. The purpose of this thesis was to study the change of traffic behavior in recent years, traffic density variations and the impact on transportation road might have along its corridors using geospatial techniques. The results of this study showed that daily average passenger commutes experienced an increase of approximately 58.4% from 2012 to 2017 and that major mode of transportation shifted from public transit vehicles to private ones specially motorcycles resulting in unfavorable occupancy to Passenger Car Unit (PCU) ratio. This in turn has adversely affected the traffic density of the city. This congestion can only see some relief when the BRT becomes operational.**

***Index Terms*— Estimation, Traffic Density, Bus Rapid Transit (BRT) Construction, Geospatial Techniques, Traffic Junctions.**

I. INTRODUCTION

Currently, large cities depends, in particular, on the transportation system and the congestion of traffic has bad impact on economic survival and environmental social sustainability. Over the years, the infrastructures of such busy avenues have reached a certain degree of stagnation, especially in the urbanized area of Karachi. The number of new vehicles entering the road is increasing. Each year, new cars are heavily registered but there is no culture that can discard old antique cars in Pakistan. This situation has already had many effects on the human environment, including congestion, more energy consumption, pollution, traffic accidents, loss of time, delays, decrease in productivity and social costs [1]. After determining the main traffic jams in the urban area of Karachi, these negative effects can be minimized and then corrective measures can be taken to control these factors. In the last two decades, traffic in Karachi has grown significantly, due to the large population of the city, with a large number of owners and citizens who trade from one city to another. Although many infrastructures have been established in Karachi in the past decade, such as access, broad roads, bridges and unsigned corridors, the increase in traffic and other important factors is currently rapidly reducing these facilities and affecting the overall productivity of the system. There are psychological effects of these factors on humans like fatigue. It is predicted that if there has not been long-term planning done in advance, the worst situation will occur in the future. As a result, our economy will be seriously affected. A large amount of research has been carried out to regulate the movement of vehicles through manual or automatic signal installations, which results in an orderly flow of traffic. Despite the large investments in road infrastructure, traffic congestion, accidents, air and noise pollution in major cities are increasing to serious level. One of the basic problems of the Karachi bus service is poor management, especially the failure of the management and supervision on part of enforcement agencies [2].

The rapid increase in population has become one of the main causes of traffic problems and has caused serious issues and confusion in traffic management. Ultimately, it will have a negative impact on the economic development of Karachi and Pakistan [3]. Due to the privately-owned transport of citizens, the growing volume of traffic has become a growing problem in urban areas [4]. It is necessary to identify traffic jams on the roads of the city of Karachi and use geospatial technology to find alternative routes. In the past, many researchers have worked in the same related field, but due to the rapid changes in the structure of the city of Karachi and the growth of the population, more and more space and facilities for vehicles are needed. The difficulty of managing traffic is increasing, so long-term planning is needed, to protect the problems related to the future that should be achieved today. The main factors that affect traffic congestion were chosen as variables for this

[1]Director, Government Firm, Karachi, Pakistan. imranakbar8@gmail.com
[2]Assistant Professor, Institute of Space Technology, Islamabad, Pakistan. mr.saad@gmail.com
[3]Assistant Director, Government Firm, Karachi, Pakistan. hassan004z@hotmail.com

study. The study of the choice of corridors and the application of Geographic Information System (GIS) in traffic management are also the main steps of the expected approach.

II. PROBLEM STATEMENT

Due to the random increase in traffic volume, urban traffic congestion has become a major problem in many streets of Karachi. Without considering the road infrastructure for optimal routing of transport system, the city's existing public transportation system has brought great difficulties and mental torture to the Karachi's people, as well as broader urban traffic problems such as air and noise pollution and congestion, which only compound the huge economic costs in the city. The people of Karachi have suffered a lot in the past. It also leads to deterioration in physical and mental health as well as quality of life. Therefore, the BRT was proposed to solve the problem of providing high-speed, reliable and convenient services to high-quality public transport systems. The idea behind BRT is to perceive it like Metro Train system as available in most of developed countries: it works in a unique way, at high speed and precision travel time and high capacity. However, this particular study will focus on identifying traffic congestions on the BRT route in the center of Karachi using geospatial technology.

III. STUDY AREA

The road network of Karachi was digitized using freely available satellite data in 'ArcGIS' software specifically highlighting the Green Line Bus Rapid Transit and its adjoining areas. The digitized road network with town boundaries is shown in Fig. 1.

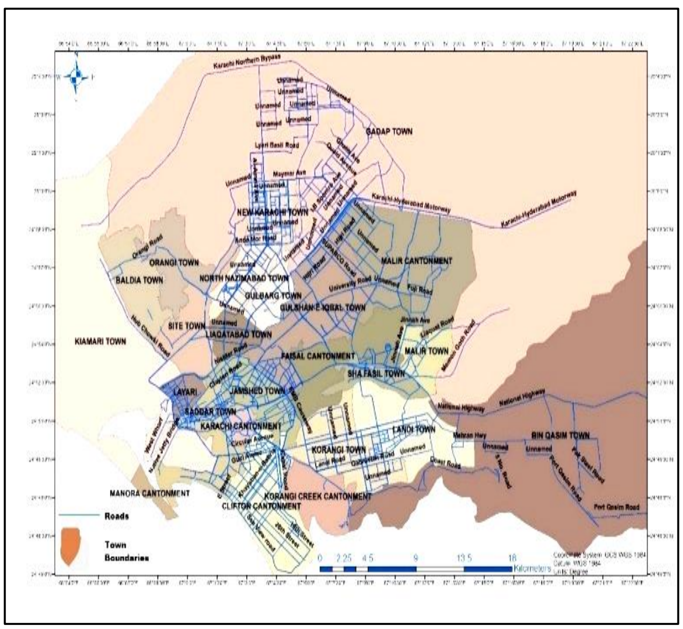

Fig. 1: Road Network of Karachi

IV. METHODOLOGY

The methodology adopted for the study is:

i. Identification of parameters which affect traffic congestion.
ii. Selection of study corridor.
iii. Collection of data for existing road and passenger throughput.
iv. Prediction of passenger throughput considering BRT in operation
v. Analysis of traffic density using GIS to predict combined effect of passenger throughput in conjunction with BRT.

We will see for last 6 year i.e., till 2016/2017 to determine the changes in traffic density as density is a function that is directly proportional to number of vehicles plying on road over a certain period of time and is inversely proportional to the throughput of road. Throughput includes number of traffic stoppages and width of road. More the width less is traffic density as there is more space for vehicles to ply. Narrower the width, keeping traffic constant, density will increase.

Using the above-mentioned flow of methodology, it is intended to check passenger occupancy, road width, peak timings and number of vehicles per unit hour (influx and out flux). Also, it is intended to check number of people travelling in a vehicle for example in a car. If a car is only taking one or two passengers occupying one Passenger Car Unit (PCU) then obviously one bus occupying 3 or 4 PCUs is far better because it may accommodate around 50 passengers. It will result in 12 to 13 passengers per PCU which is much better than a car occupancy of 3 to 4 passenger for one PCU.

The methodology followed in thesis comprises of 3 major phases, i.e., the data collection, the processing phase and the compilation of results. Two sets of data were required to analyze the change in volume and behavior of road traffic on and around the Green Line BRT route before and after its construction respectively. The methodological flowchart is shown in Fig. 2.

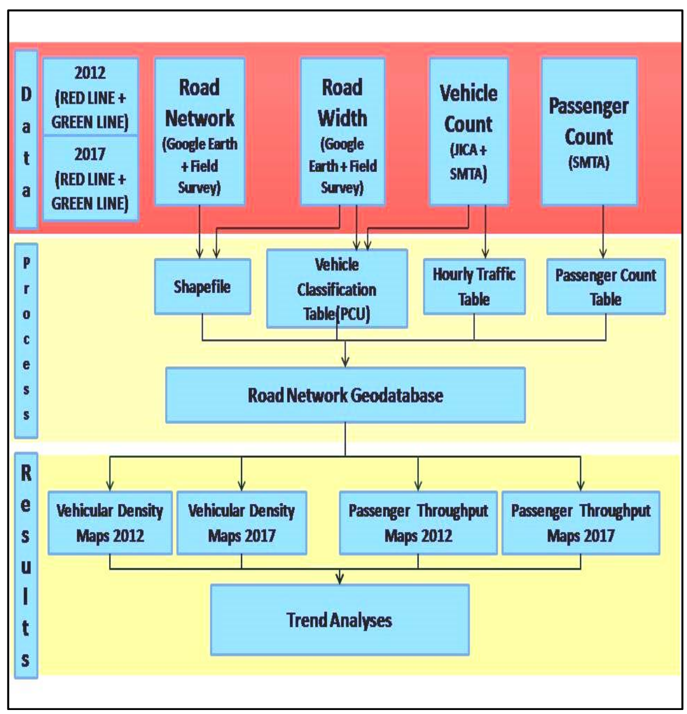

Fig. 2: Methodological Flowchart

In order to accurately assess traffic density or traffic flow, it is necessary to have fair estimates of the number and types of different vehicles plying on the roads and also show the road width or number of lanes available to them during various segments of their commute.

V. DATA COLLECTION

An extensive field survey was carried out to measure the road width of Karachi in 2018. The road width was measured using a Laser Range-finder manufactured by 'SNDWay' which has a measuring accuracy of plus minus 2 mm. The equipment did not require calibration. Fig. 3 and Fig. 4 show pictures of the Laser Range-finder and the field survey respectively.

Fig. 3: SNDWay Laser Range-finder

Fig. 4: Field Survey

The measurements taken thereof were also cross-checked using the satellite images of 2018 using Google Earth measuring tool. Since there was no field survey conducted in 2012 with respect to the width of the roads it was necessary to ensure that the measurements taken from the satellite imagery exhibited high accuracy when compared to the in-situ measurements. As the results were found to be fairly accurate, the road widths for 2012 were measured from Google Earth.

A. Vehicle Count

The 2012 vehicular count data was obtained from a survey conducted by Japan International Cooperation Agency (JICA), whereas the 2017 data for vehicular count was obtained from Sindh Mass Transit Authority (SMTA).

In the 2012 survey, various types of vehicles were counted at a 15-minute interval for 16 hours at all major intersections along the then nonexistent BRT on a typical day. For ease of use this data was consolidated for a one-hour interval. Six major categories of vehicles were identified based on their sizes or uses, i.e. cars, rickshaws, motorcycles, pick-up lorries, mini-buses, buses and trucks and the total number of vehicles of each category travelling through an intersection every hour was recorded.

In 2017 however the survey data for only 3 hours was available. Moreover, only a couple of road segments were the same as that of the survey conducted in 2012. This was due to the fact that SMTA had conducted this survey for the construction of the Red Line BRT and only some of the corridors were common with the Green Line BRT. Therefore, the change of vehicle counts for each category of vehicle from 2012 to 2017 was calculated, averaged for 3 hours and then extrapolated to create a 16-hour dataset similar to that of 2012.

B. Traffic Density

The traffic densities for both the years under discussion were calculated in the following manner. Each class of vehicle was assigned a Passenger Car Unit or PCU weight-age. This weight-age was assigned based on the size of the vehicle in question and the space it would occupy on the road. Table I shows the PCUs assigned to every category.

Table I: Passenger Car Units for Each Category

S.No	Description	PCU
1	Passenger Cars [Including. Jeeps & Station Wagons]	1
2	Taxies [Yellow & Black Cabs, Yellow Cabs & Radio Cabs]	1
3	Auto Rickshaws (Old Style & CNG 4-Stroke]	0.7
4	Motorcycles & Scooters	0.5
5	Contract Carriages including Suzuki	1
6	Large Public Busses [Intercity, UTS, KPTS etc.]	4
7	School Busses	3
8	Mini Busses	3
9	Coaches	3
10	Light Freight Vehicles [Pickups, Shehzore, etc.]	2
11	Single Unit Trucks [2 & 3 Axle]	4
12	Trailers	4

The traffic density was then calculated using the formula shown in Eq. (1)

$$Traffic\ Density = \{\sum_{i=1}^{n} P_n * C_n\} / RW/10 \quad (1)$$

Where:
n = Number of categories,
P = PCU value,
C = Count,
RW = Road Width in feet

Simply put, for every given segment of time, the numbers of vehicles counted in each category were multiplied with their respective PCUs. The results of all the categories were then summed up to arrive at the total volume of traffic for that time segment. This volume of traffic was then divided among the total number of lanes available on that road to calculate the total traffic density. For the purpose of this thesis it was assumed that each lane must be 10 feet wide. The resultant densities were then classified into categories ranging from 1 to 10 where 1 means very sparse traffic, 2 means light traffic, 3 means moderate traffic, 4 means dense traffic and 5 to 10 mean various stages of heavy congestion.
This calculation was repeated for 16 hours for both 2012 and 2017 data in order to generate thematic maps of traffic density along the BRT.

VI. RESULTS AND DISCUSSION

A. Road Width

A total of 238 road segments including U-turns were measured around 12 intersections along the Green Line BRT using a Laser Range-finder and free satellite imagery for 2012 and 2017. It was noted that a fairly large portion of the width of the roads have decreased along the Green Line BRT route since 2012.
Out of a total of 238 roads of the intersections along the BRT, 147 roads have shrunk in width, 74 have increased while 17 roads have remained the same. The average reduction in width is 6.28 feet and a maximum reduction of 20 feet was observed on some roads near Liaquatabad area. A reduction in road width due to the construction of BRT means that there are fewer lanes available for the traffic to commute on. Moreover, it was also observed that encroachments like permanent presence of pushcarts, rickshaw stands, etc., rendered the serviceability of the roads compromised.

B. Vehicle Count and Occupancy

The vehicular count for 6 different categories of vehicles was extracted from JICA and SMTA reports and then combined with the digitized shape files using the ‘Join’ functions in ArcGIS software to generate a geo-database for 16 hours of data. The combining factor of ‘matching IDs’ was utilized for this purpose. The same activity was repeated for 2012 and 2017. A sample segment of the resultant tables in geo-database is shown in Table II.

Table II: Sample Table of Vehicle Counts on Various Intersections

Road ID	Car 11-12	Rickshaw 11-12	Motorcycle 11-12	Pickup 11-12	Mini- Bus 11-12	Bus 11-12	Truck 11-12
494	107	16	98	6	0	0	0
342	67	13	87	4	2	1	1
765	114	25	66	6	0	0	0
456	145	33	99	3	1	2	0
345	123	24	95	7	0	3	1
917	145	23	82	8	2	1	0
867	123	33	76	10	5	0	2
563	99	23	60	4	0	2	0
143	113	25	90	5	1	5	3
7g2	146	12	79	2	0	0	0
895	119	15	94	0	0	1	1

The observed number of occupants in different types of vehicles was categorized in 6 vehicle classes from the 2012 data and average occupancy per class of vehicle was computed. Under the assumption that occupancy remains the same over time, the average occupancy per class was multiplied with the count data of 2017 to compute occupancies for that year, as shown in Table III and Table IV.

Table III: Average Occupancy in Different Classes of Passenger Carrying Vehicles

S.No	Vehicle Type	Average Occupancy
1	Motorcycle	1.2989
2	Auto Rickshaw	2.0959
3	Car & Taxi	2.3021
4	Pickups	6.9691
5	Mini-Buses	26.9843
6	Buses	44.0622

C. Traffic Density

Traffic density has an inverse relationship with the number of lanes provided that number of vehicle-PCU remains constant in a given time frame. Given this context, certain assumptions were made in the computation of traffic density for 16 hours along the traffic intersections along the Green Line BRT:

- Traffic is considered absolutely free flowing if the vehicles can maintain a constant speed of 30 km/h or 30000 m/h or 8.333 m/s.
- The intersections are the only hindrances in a free-flowing traffic.
- The average length of the intersections was found to be 100 meters.

Based on these assumptions a vehicle travelling at 8.333 m/s needs 12 seconds to freely pass the intersection:

100m/8.333 m/s = 12 seconds

Given that the data is hourly based, the following maximum number of cars that can freely commute on the roads was calculated:

1 hour = 3600 seconds

So 3600 seconds/12 seconds = 300 vehicles/lane/hr

Passenger Car Unit (PCU) equivalent values of major roads of Karachi were used from thesis submitted by Dr. Rizwan Ali Memon in 2001. The analysis of PCU values were carried out by comparing the average passenger car headway with the average headway of other vehicle types.
Therefore, it was considered that every additional 300 vehicles per lane would render the class of traffic density change for that segment of the road. The traffic density maps were developed based on this reason with 10 classifications of equal interval of 300 as shown in Table V.

Table IV: Sample Table of Passenger Occupancy in Various Vehicle Classes for One Hour

S. No	Road Name	ID	OCP_CAR	OCP_RICK	OCP_MC	OCP_PU	OCP_Mini	Ocp_bus	Total OCP
1	FROM GURU MANDIR TO NISHTER PARK	4946	7917	2728	3306	997	0	262	15209
2	FROM GURU MANDIR TO TARIQ ROAD	7392	12114	4530	6525	3045	769	682	27665
3	FROM GURU MANDIR TO TOWER	7382	126569	41479	103842	11353	19681	71468	374391
4	FROM GURU MANDIR 1	7459	146601	48737	113672	15395	20450	72411	417266
5	FROM LINES AREA TO NUMAISH	7485	6995	8333	12242	1540	156	0	29267
6	FROM LINES AREA TO TOWER	7486	1739	671	731	91	36	157	3425
7	FROM LINES AREA 1	7447	8734	9005	12973	1631	192	157	32692
8	FROM NISHTER PARK TO GURU MANDIR	7487	4302	1587	1349	836	0	52	8127
9	FROM NISHTER PARK TO TARIQ ROAD	7483	16998	3681	4085	2690	96	157	27707
10	FROM NISHTER PARK TO TOWER	7489	4995	2352	2533	453	72	210	10614
11	FROM NISHTER PARK 1	7488	26295	7620	7967	3979	168	419	46448
12	FROM NUMAISH CHOWRANGI TO LINES AREA	6883	1255	1545	2800	606	36	0	6242
13	FROM TARIQ ROAD TO GURU MANDIR	7454	12768	5592	7199	2816	468	682	29524
14	FROM TARIQ ROAD TO NISHTER PARK	7384	10578	2930	3829	1680	156	0	19172
15	FROM TARIQ ROAD TO TOWER	7445	48418	10066	14958	5143	7325	734	86644
16	FROM TARIQ ROAD 1	4932	71764	18587	25985	9638	7949	1416	135339
17	FROM TOWER TO GURU MANDIR	7458	94921	37047	56098	15771	24352	88194	316387
18	FROM TOWER TO NISHTER PARK (LEFT)	7490	7976	1808	4312	495	36	105	14732
19	FROM TOWER TO TARIQ ROAD (RIGHT)	4945	67907	6685	8623	4265	6833	524	94837
20	FROM TOWER TO TOWER	7446	3190	1615	3036	878	12	52	8784
21	FROM TOWER	992	173994	47155	72069	21409	31233	88876	434735
22	TOWARDS GURUMANDIR 1	588	111990	44225	64645	19423	24821	88928	354032
23	TOWARDS NISHTER PARK	4979	26471	7465	11447	3171	192	367	49113
24	TOWARDS TARIQ ROAD	4930	97019	14897	19233	10001	7697	1363	150210
25	TOWARDS TOWER	7446	184912	56183	125099	17918	27126	72621	483859
26	FROM GURU MANDIR TO NUMAISH	7460	80283	49366	77618	12740	18120	64494	302620
27	FROM GURU MANDIR TO PEOPLES CHOWRANGI	554	8329	2479	3001	2692	372	1258	18401
28	FROM GURU MANDIR2	985	88612	51845	80619	15701	18492	65752	321021
29	FROM JAHANGIR ROAD TO M.A JINNAH ROAD	7465	67894	26615	45125	4844	3698	3723	151899
30	FROM JAMSHED ROAD TO JAHANGIR ROAD	2213	81747	38380	41246	15611	4059	6449	187492

Table V: PCU Table of Karachi [5]

S.No	Vehicle Type	PCU Values
1	Car /Taxi/Jeep	1.0
2	Auto Rickshaw	0.40
3	Motorcycle	0.33
4	Mini-Bus	1.53
5	Pickups	2.0
6	Bus	2.90
7	Truck/Trailer	2.90

VII. PASSENGER THROUGHPUT

All vehicles observed during the survey were categorized on the basis of passenger occupancy. For cars, motorcycles and rickshaws, the categories were based on absolute numbers.

However larger vehicles were categorized as "only driver", "half seats occupied", "full seats occupied", "half passengers standing", "full passengers standing" and "passengers hanging".

These vague categorizations were given actual numbers based on average public transport vehicle sizes shown in Table VI.

Table VI: Vehicle Category Converted to Number of Passengers

Vehicle	Half Seats	Full Seats	Half Stand	Full Stand	Hang
Pickups	5	12	15	18	20
Mini-buses	13	25	30	33	35
Buses	18	40	48	54	60

The calculations based on the numbers above show that in 2012 approximately 19.5 million passengers travel along the intersections and the corridors alongside the Green Line BRT on a daily basis. This high number is probably due to multiple rides by the same commuters during the span of a day, when they go to and come back from work, schools, colleges, shopping, etc. In 2017, the number of commuter drastically increases to 30.9 million commuters.

In 2012, motorcycles riders constituted the majority of the passengers with 23% of the share followed by cars with 20.4%. In 2017 however, 36.4% of the passenger load was being borne by cars, followed by motorcycles with 24.5% as shown in figure i.e., Fig. 5.

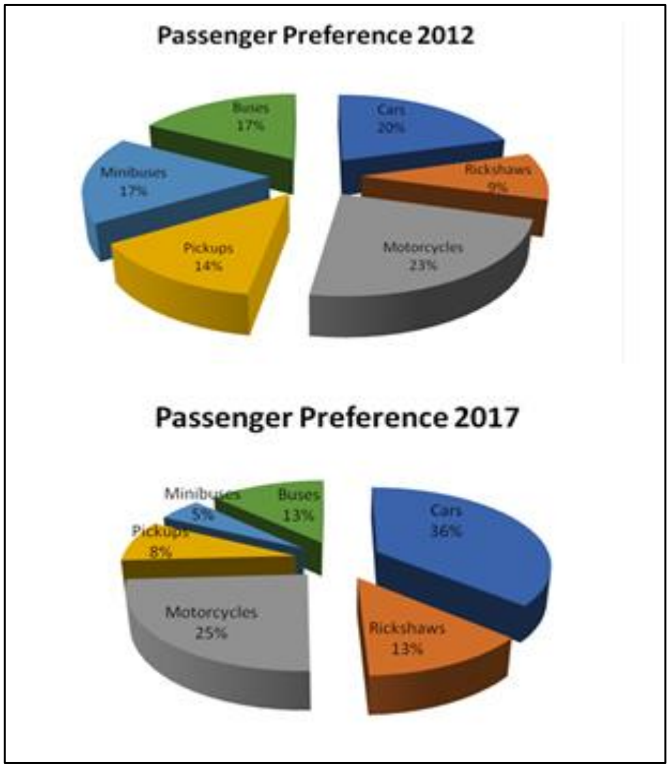

Fig. 5: Percentage of Passengers Travelling in Each Category of Vehicle

It may be worth mentioning here that cars have the worst average occupancy to PCU ratio, yet majority of the commuters prefer to travel in this mode of transportation. This may be due to a lack of other mass transit alternatives. It may also be noted that the passenger share of buses and mini-buses have also shrunk over the years probably due to their shabby conditions. The total number of passengers plying on different segments of the roads along the Green Line BRT daily, in different categories of vehicles, is shown above for ease of understanding.

VIII. CONCLUSION

Due to lack of a mass transit system, the people of Karachi have shifted over to their own means of transportation in the form of cars and bikes. Since the concept of a car pool system is lacking in our society, cars are usually travelling at much less than their optimal capacity resulting in very low average occupancy. Even with full occupancy the unfavorable occupancy to PCU ratio of cars, in turn has adversely affected the traffic density of the city. This congestion can only see some relief when, the BRT becomes operational and complies with comfort and proper scheduling standards, the other buses, mini-buses and pickups are removed from the roads and people start preferring using the BRT system.

REFERENCES

[1] Muhammad Tahir Masood, Azhar Khan, Hasnain A. Naqvi, (2011) .Transportation Problems in Developing Countries Pakistan: A Case-in-Point. *International Journal of Business and Management (6)*11. 256 – 266 . (www.ccsenet.org/ijbm)

[2] Rao, K., & Grenoble, W. L. (1991). Modelling the effects of traffic congestion on JIT. *International Journal of Physical Distribution & Logistics Management. (21)*2, pp.3-9, https://doi.org/10.1108/09600039110005178; http://www.emeraldinsight.com/doi/pdfplus/10.1108/09600039110005178

[3] Golob, T. F., & Regan, A. C. (2003). Traffic congestion and trucking managers' use of automated routing and scheduling. *Transportation Research Part E: Logistics and Transportation Review, 39*(1), 61-78.

[4] Weisbrod, G., Vary, D., & Treyz, G. (2003). Measuring economic costs of urban traffic congestion to business. *Transportation research record", 1839*(1), 98-106.

[5] Memon, R. A. (2001). Estimation of Saturation flow at signal controlled junctions. A thesis submitted for the degree of M.E department of Civil Engineering Mehran University of Engineering and Tech. Jamshoro