Determination of passenger car equivalent for Bus in urban roads using AIMSUN (Case study: Emam reza avenue, amol city)

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Abstract - *Passenger Car Equivalent (PCE) is applied to capacity analysis and demonstrate how many Passenger car, replacing to, maintain the effect of considered vehicle on traffic flow, without any change in road situation or traffic flow. Parameters and traffic systems are different from a country than other country, thus it is necessary to calibrate such parameters. One of these parameters is bus equivalent in urban roads. in, our country, because of shortage or lack of modern-based mass public transportation system including metro light rail way and high volume of urban travelling, urban public transportation system, has caused to highlight the role of bus usage as a public transportation vehicle with more occupancy rate, and take over the major rate of passengers relocation. Regarding of increasing the presence of such vehicle in traffic flow that is considered as a main policy to decrease demand, need to investigate the impact of this vehicle on roads capacity is increasing. This research aims at estimate the actual rate of bus PCE in urban roads. For this reason, the information of traffic and bus movement behavior has been collected by field study of two Line Street in Amol and simulated in three different scenario including mixed flow, free-bus flow and base flow using software AIMSUN. Through frequent analyzing data and compare road performance indicators such as density, headway and speed, the PCE was equivalent to 4.58 for bus.*

Key Words: **Passenger Car Equivalent, urban roads, Bus, simulation, AIMSUN**

1. INTRODUCTION

Characteristic of ways transportation system, patterns and traffic index is different from a country to others. It's reason is due to topography condition, geometrical design, vehicle performance (specially speed), drivers behavioral suitable distance headway, facilities and development rate in transportation section. Thus, It is possible that standard relations and factors used in a country may not be suitable to other countries. One of these parameters is "bus vehicle equivalent" in urban roads. PCE is used for capacity analysis, and capacity is an important parameter in planning thus it is so necessary the consideration of this issue in studies concerning capacity analysis.

PEC is a coefficient that show how many passenger car will be replaced by traffic flow, without any change in road condition or traffic flow. It is often calculated based on ratio of a certain parameter while there is considered flowing vehicle (mixed flow) and in the case that all vehicle are passenger car (basic flow). The more accurate calculations of equivalents result in more accuracy of capacity analysis.

Because of rapid growth in urban traffics, it is evident the need to improve transportation systems conditions. For this reason, modern urban transportation strategies emphasize on qualitative and quantitative development of public transportation. Because of shortage or lack of modern-based mass public transportation system such as Bus Rapid Transit (BRT) and … particularly in middle and small cities and very high of urban trips result in highlight the role of using public transportation systems that have high occupancy coefficient, as a primary policy of decreased demand in urban roads, and take over the considerable fraction of passengers relocation.

For three reasons, the effect of bus on traffic is more than passenger car. First, they are larger than passenger car. Second they are weaker than passenger car at any stop and movement start, in term of performance capabilities particularly acceleration, break and ability to keep speed. Third, these vehicles show more special movement and lane changing while passengers ride off and on than passengers car. As a result, buses imposed abundant delays on other vehicles because of frequent stops and special movement behavior on lanes. However, they cause to disorder in traffic flow and occurring sever changes in capacity and service level of roads, Increasing presence these vehicles in traffic flow, the need to investigate impact of these vehicles on roads capacity enhance.

The main issue in this study is calculating PCE and the impact of bus on major arterial urban and to determine the factors affect PCE for bus.

Research method used in this study is based on data collected from field work (including detect volume, average service time, and distribution of bus stops) along with traffic simulation of traffic flow using AIMSUN software and it considerably focused on special behavior of this vehicle, due to deceleration, frequent stops and maneuvering across the road. The aims of this project are identifying frequent stops as an effective parameters in road capacity, in addition to estimate bus passenger car equivalent across urban roads.

2. REVIEW PRIOR STUDIES

By 1965, Highway Capacity Manual (HCM), for the first time has provided the concept of Level Of Service (LOS) and a definition of passenger car equivalent, in it's second edition [1]. In this manual, PCE was defined as number of passenger car replaced through a traffic flow with the same condition by a bus or a truck [2]. Since after, researchers innovated various methods to estimate this parameter and most of them based on whole comparison of one parameter dependent on level of service (such as flow volume, middle speed, average headway, density, delay …) in the mode of base and mixed flow to find PCE and estimate PCE with establishing a ratio between them [3].

Among studies conducted on this field, it can be pointed to Waker study. He used "overtaking" concept to determine passenger car equivalent of heavy vehicles. In this method, passenger car equivalent is obtained by number ratio of passenger car overtake from a truck to average overtake numbers from a passenger car across one km road (in a certain time extent) [4]. This method have been the basis of determining passenger car equivalent in writing HCM by 1965. Webster (1958), drawn average output heavy vehicle per cycle as a function of average output light vehicle per cycle by dividing vehicle to both heavy and light groups. He considered fitness line gradient reverse given to mentioned points as passenger car equivalent and calculated this parameter in the mode of saturated direct flow as 1.75 for heavy trucks and 2.25 for buses [5].

In 1968, Ashtoon conducted a study to determine passenger car equivalent. He used a combination of mathematical modelling and experimental methods (Queue theory) [6].

One common method of calculating passenger car equivalent is "ratio of time distance-head" method established by 1974, for the first time [7]. This method was considered as base of determining equivalent in rewriting HCM at 1985. According to results of studies, amount of this coefficient assumed as 1.5 that increased in rewriting HCM of 1994, 1997 and 2000 by factor of 2 [8].

In 1976, some studies conducted by John et.al on traffic flow in upstream roads aiming at determine toll of slow vehicle available on traffic flow compared with traffic flow in different ratio of heavy vehicles using software TWOWAF [9].

Habber (1982), calculated passenger car equivalent (PCE) based on finding different traffic rate with the same traffic characteristic, so that to determine PCE of a typical vehicle, a base traffic rate and a mixed traffic rate are selected such that they have the same performance in traffic flow [10].

At 1984, Van Andre and Yagar detected a method to calculate PCE based on relative rate of deceleration [11].

Demarchi (2003) used an intermediate coefficient to calculate PCE. Demarchi's model was provided by studying Haber and Samner method and analyzing interactions of heavy vehicles on each other [12].

In recent decade, computer methods and simulations have been heavily considered to calculate this coefficient. In manual "Highway capacity", written in 2000 and 2010, software TWOPAS and been used to determine PCE [13].

In Iran, there is no significant studies on this field and limited conducted studies can't meet available requirements. While, at present, result of studying on other countries, in traffic analysis, is regarded to a base to calculate PCE, whereas discrepancy in efficiency of vehicles and drivers behavior in Iran with developed notions and also this point that Iran is a developing country, and that using regulations patterns of advanced countries to developing countries is accompanied by a reviewing and calibrating, requires conducting studies on estimate PCE in the country. Here we don't retention effort conducted across the country due to similarity of them and just investigate on given new methods.

Nasiri and Tabatabai conducted a study to estimate amount of PCE in Iran's signalized cross-sections with predetermined schedule and in a pre-saturation situation based on delay parameter using "Traffic-Netsim" software. Results show that from made model for a general intersection, number 1.9 estimated as PCE for "near to saturation" condition [14].

Afandizadeh et.al suggested a method based on using simultaneously speed and density as a performance criteria in the case of base and mixed flow to determine PCE in suburban roads. According to methods suggested in the study, amount of heavy vehicle equivalent in understudied road obtained as 4.1 passenger car that is 2 time of it's suggested amount at HCM regulation [15].

Behzadi and Hashemian, also investigated on Taxi equivalent on urban streets using simulation method with AIMSUN software. They obtained these coefficients between 2.4 to 2.7 in term of density and headway using field data and simulation and comparing traffic variable in different scenario, and assessed the results in the case of increasing percentage rate of taxi presence in traffic flow [16].

3. RESERCH METHODOLOGY

3.1 Introduce studying zone and streets

In this research, Amol's main second-order arterial streets have been studied to conduct field work in order to simulation. Amol city is placed on the center of Mazandaran province that is limited from north to Mahmood Abad, from east to Babol town, from west to Noor and from south to Tehran. Amol's roads structure, in term of classifying has radial-cricoid system of street network.

Study on traffic statistic obtained from available streets on the city level showed that in addition to being long, Imam-Reza Blud is known as the most main street of accessibility from east to city center, thus regard to high volume of demand to handle passengers, it is the only across which urban buses with certain stations, relocate passenger to meet this requirement. Picture 1 shows the selected street to study and in table 1, some of it's features are provided.

Fig -1: image of understudied street

Table -1: physical and performance features of understudied street

Street Name	Lane Width (M)	Length of street (KM)	Understudied length (KM)	Functional classification
Imam Reza	3.7	3.6	2.4	Main second-order arterial

The selected road with two lanes in each direction has been investigated on a work day, during two consecutive weeks at the same period and with the same climate condition. Also, behaviors of bus vehicle in traffic flow, Number and distribution of stops through the way are investigated.

Bus service time is the other parameters that should be considered in the field study. Service time of passengers includes the time required to ride off and on passengers from a vehicle that is defined according to second (s) per passenger. On the other hand, this time, in fact is lane occupancy time by a vehicle as bus result in imposing delay on other vehicles across traffic flow and play an important role to determine bus equivalent.

It is necessary to note that passengers start to ride off getting up their chairs with different local position just after stopping bus at per road stations, that result in a queue of passengers to exit vehicle, consequently it is impossible the note of service time for per chair. Thus this problem to be overcome, the consecutive notes of maximum and minimum duration of vehicle stop to ride off and on should be registered to obtain an average service time with standard deviation based on table 2.

Table -2: bus service time obtained from field study

Parameter kind	Minimum ride off and on time (s)	Maximum ride off and on time (s)	Average bus service time (s)
Standard deviation	12	60	36
	3.2	15.1	9.2

3.2 Simulation process

To determine bus equivalent, data obtained from field noting that express traffic kind and volume, stops number, average flow speed, average service time and how stops are distributed across the rout are included in AIMSUN software and simulation process is conducted by establishing target traffic network and calibrating software. (At any scenario, Traffic variables value result from software output is registered).

The first mode of simulation is really the same mode simulated of current traffic situation conjugate with bus stop at different level of service and this mixed flow (base mode) is defined as scenario 1. At second scenario, the bus stop is deleted in simulator software to investigate the effect of stop role rate on any described variable over base mode. The second scenario, in fact is a model with base flow and is a situation in which bus is deleted from flow and passenger cars is replaced it in required number, to result in the same effect of bus stop on understudied variables at mixed flow (base mode) and traffic variables (headway, density, speed, …) in this scenario being equaled with base mode. As a result, the equivalent of this vehicle is obtained by ratio of replaced passenger car with bus.

4. ANALYZE SIMULATION TO DETERMINE BUS EQUIVALENT

Conducting simulation process, number value obtained from output diagram of software is recorded at scenario 1 (base mode) for density variable. Density is an important traffic parameter that describe traffic performance and reflect the freedom amount of vehicle. In second scenario, changes due to effect bus stop on flow density compared with scenario 1, with detecting bus stop from traffic flow in simulation model, and consequently, in order to determine bus equivalent, it should be gradually added the replaced passenger car to available flowing vehicles volume as required, in order to average density concentration with increasing volume reach to real mode of flow (base mode). Deleting 19 buses from the first scenario and adding 84 passenger cars to flow, average value of density parameters in third scenario is the same as base mode (scenario 1). In fact, with adding 84 passenger car/hour, it can be compensated the traffic decline creating by pass and stop of 19 vehicle (bus) in average, per hour in the studied street. On the other hand, this number of replaced vehicles supply the same density that in average, per hour result in 19 buses with stop across the road. Thus regard to added passenger car volume ratio to available bus volume, equivalent in two-lane roads for bus, in term of density is 4.42. Diagrams 1 and 2 show the road density for different scenario.

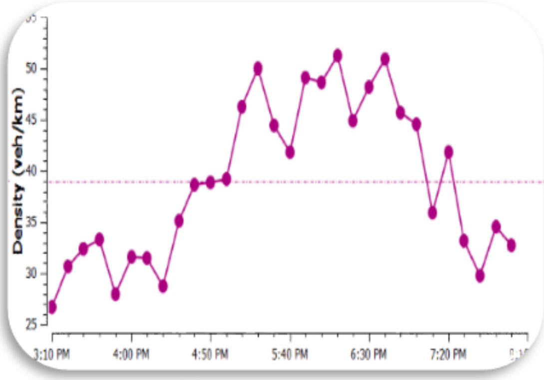

Diagram -1: Road density in base mode

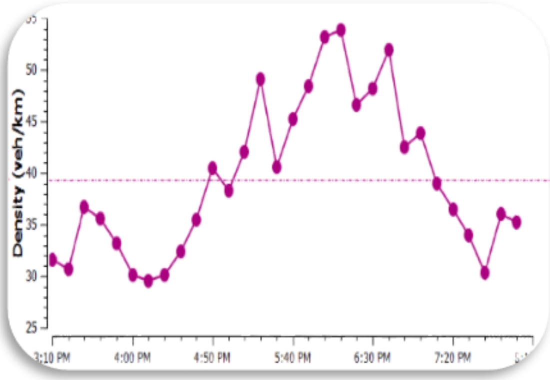

Diagram -2: Road density in passenger car replaced by bus

Among other understudied variables expressing the effect of bus stops on vehicles available around and also on traffic, is "headway" parameter. Across the traffic, in addition to total number of vehicle passing target point during a time distance, duration between continuous vehicles are regarded too. This parameter is evaluated using comparison between three mentioned scenarios. The average value of vehicles headway will be reached to base mode through removing buses from traffic flow and adding 90 passenger cars. Thus the ratio of replaced passenger cars instead deleted bus is 4.47 that this value express bus equivalent, in term of headway of both vehicles.

The last variable in which three mentioned scenario have been analyzed is speed parameter. Regard to results of simulation, the difference of average vehicle speed at second scenario is less than 2% than value obtained from scenario 1, that it can be considered as software error. In describing reasons of this problem, it can be said that to establish a network and calibrating it in "AIMSUN" software, the average speed should be defined to road and this limitation allow to there is no distinction between any vehicles available in urban highways in term of speed and no tangible changes occur in case of average speed. As a result, it can be said that speed parameter, in this simulation method with AIMSUN software is not suitable option to calculate PCE, thus it is ignored. Table 3 shows the change of average amount of understudied variables in three scenario and obtained results of bus equivalent.

Table -3: change of understudied variables and obtained results for bus equivalent

	Scenario 1	Scenario 2	Scenario 3	PCE
	Base mode	The mode without bus stop	Replaced passenger car required to reach to base (veh/hr)	Ratio of added passenger car to bus
density (veh/hr)	39	35.8	84	4.42
Headway (s)	2.88	3.05	90	4.74
speed (km/hr)	30.94	31.22	-	-

5. CONCLUSIONS

This study conducted in order to estimate bus vehicle equivalent across urban streets based on total comparison of variables analyzing traffic flow in the case of base flow and case of without stopping target vehicles and consequently passenger cars replaced by these vehicles in AIMSUN simulator software and estimate these vehicles equivalent through determining ratio between them. Regard to results of this study, bus equivalent based on density variable is 4.42 and based on headway is 4.47 that finally, for understudied street, value 4.58 can be considered as passenger car equivalent across urban streets.

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