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INVESTIGATE THE HIGHWAY TRAFFIC BY USING THE EFFECT OF PLACE-TIME HEADWAYS ON PERFORMANCE OF DRIVERS

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ABSTRACT

Traffic flow characteristics depend on driver behaviors, vehicles characteristics, physical properties of the way, and interaction of these factors. In such a way that even if the vehicles crossing and geometrical characteristics of the paths are same, traffic flow characteristics will not be same due to the difference of passing drivers. Although various models have been proposed to forecast the traffic flow characteristics from 1934 until now, the most appropriate model representing the relationship between parameters of traffic is still controversial. This is mainly due to the difference in behavior of vehicle drivers according to conditions on the paths.

This article analyzes the behavior of traffic flow based on native data of the flow with an emphasis on Khi 2 (two) model for Khorram-Khayyam highway in Isfahan. To this end, the place and time headwayswere examined at different hours after collecting the data related to vehicles and classified by the EXCEL software, and generalized with SPSS software. Then, the obtained data was analyzed by using the MATLAB software, and the effect of headways on traffic flow was investigated through obtained results and its comparison with the Highway Capacity Manual (HCM) [1].

Keywords: Highway, Place headway, Performance of drivers, Time headway

INTRODUCTION

Highways are considered among the most important communication ways and urban transport. Due to the dramatic increase in car ownership and the increasing demand for

trips within the city and suburban, highways daily experience a lot of congestions around the world. Congestions that are constantly developing in terms of size and time and reduce the capacity of existing infrastructures especially in peak hours of traffic and times which require the full utilization of capacity of the passages more than any other time and are associated with major problems such as increasing the travel time, reducing the safety level, increasing the fuel consumption and environmental pollution.

One of the ways to confront with this congestions and problems caused by them is building the new infrastructures to increase the capacity of passages which is not considered an appropriate solution due to the high economic and environmental costs, and lack of space in urban areas. Another way to deal with the traffic is encouraging the use of public transportation vehicles such as bus, subway, and ... by giving the priority of passing to them and enhancing the cost of using the private cars through price of fuel and tax related to occupy the streets. But the third strategy is the use of communication and computer control system to more exploitation of the existing infrastructures and paths which is called dynamic traffic management.

The other strategies can be tested and exploited via this infrastructure. For example, due to the volume and density of available traffic in Isfahan highways and online management by tips for driving cameras and signs, the service level of traffic can be controlled by the software.

Variable speed limited is one of the most efficient dynamic traffic management techniques. Its impact in determining the place and time head ways is remarkable. Variable speed limited is a special control device to manage the collective behavior of drivers (collective speed of vehicles) on highways which tries to manage the current traffic conditions of main flow through determining the exposure limits of speed on highways given the changing conditions of traffic situation, weather, accidents and safety issues, air pollution and also showing these limits on the variable message signs in various intersection of highways [2].

History of these investigations and management of traffic parameters such as speed of place and time headways date back to countries such as Finland, China, America, Germany, and so on. In China, the speed limit is also 120 km per hour for highways that the place and time headways of vehicles are easily determined by using it.

These limits reduce the accident rates, improve the service levels, etc. It should be mentioned that the speed control and headway are simultaneous and are applicable with imposing the restrictions on driving. As well as, micro and macro parameters like these two have the direct relationship with each other. So considering the importance of issue, determining the speed and then determining the place and time headways of vehicles to more precisely control have been examined in this article to use its influence in improving the speed and safety and also the service level of highway. In this study, data was extracted by using the new computerized strategies and flow online simulation which was conducted by the Isfahan municipality.

Definition of general concepts

The purpose of transportation is a desirable and acceptable moving of people and goods from one point to another, or production of transportation services or coordinated, comprehensive, integrated, safe, abundant, regular, fast, convenient, and cheap demanding for the movement of people and goods.

According to statistics of Research Center in Islamic Consultative Assembly and toll and road transportation organization, there are about 17000000 million cars in Iran roads that the role of ways in human and goods movements is quite evident and specifically the highways have an important role in easy and safe transportation. But nowadays, traffic control and management is very important due to the number of them, because the service level of highway is different from the ordinary road, and this particular parameter distinguishes these two from each other. In order to better management, it is necessary that all contributing factors in traffic to be examined.

Review and analysis conducted for many years in Iran and other countries show that two types of analysis are involved in road and urban traffic.1- Micro-analysis of traffic, 2- Macro-analysis of traffic. In macro-analysis, speed, density, and volume are examined that it is not always indicative of the actual analysis of urban traffic due to its generality. Therefore, it is better that we enter into the micro-analysis of traffic and examine parameters such as place and time headways. Of course, the average speed has a direct effect on these parameters [3].

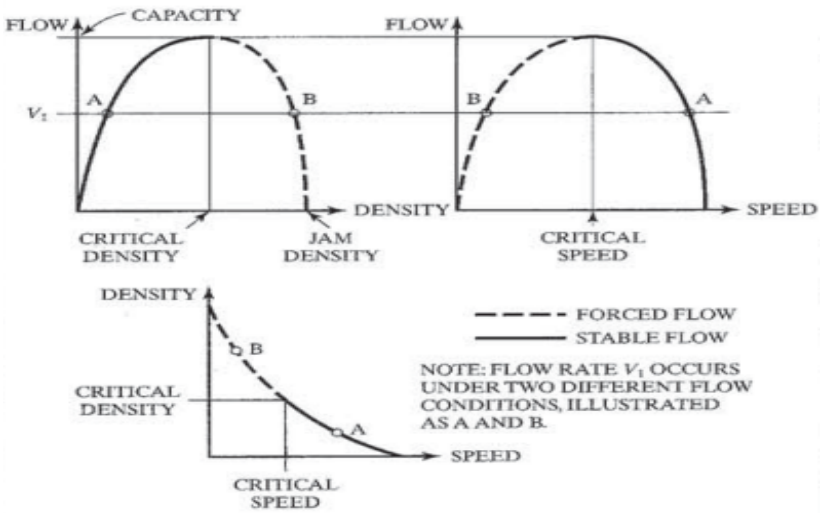

Figure 1: Diagram of Speed - Flow – Density

The main equation of a macro traffic is equivalence of the flow with the multiplying the density and speed [4].

(1) $$V = S \times D$$

V: (F) Flow rate: veh/hr

S: Speed flow: km/hr

D: Density flow: veh/km/ln

In the micro analysis, models such as Green Shields models, chi square, logarithmic models, etc. are used to the simulation and statistical analysis of data. Relationships in all of them were used in a way that the more statistical items can be deduced from them and tried all those parameters to be used for improving the quality of service. It is worth mentioning that the valid inference of the data obtained has a great importance. For detailed analysis, it is attempted to be considered the ideal conditions on the Khorram, Khayyam highway and then achieved the level of traffic performance according to it and after that compared to the international authoritative references.

Place and time headwaysand drivers behavior

Time headway is one of the fundamental parameters in study of traffic flows which enjoys the great importance and application in surveying the capacity of research in highways and freewaysand also in simulation studies, and modeling of traffic.

To properly plan in different situations, traffic managers and design engineers should have a precise understanding of driver's behaviors in choosing the place and time headways. Because how the distribution of place and time headways is effective on various parameters of flow such as capacity, service and safety levels. Detailed analysis of headway also makes it possible for planners

to reduce the delay of travel time and increase the capacity of ways facilities through the production of micro models in simulation. As well as, distributed information of headway has a great application to the implementation of digital simulation in modeling process of highway traffic. In addition, understanding the causes of accidents and ways to increase the safety of roads can be obtained by analyzing the headways.

It should be noted that issues related to safety of vehicles headways will not be considered in most modeling of roads capacity and this increases the safety and reduces the likelihood of accidents and will lead to the more satisfaction of traveling. An example of the place and time headways of vehicles has been provided in terms of their speed in the following.

Table 1: Safe distances of vehicles follows at different speeds - Country of America

Safe distances	2 seconds rule	The half-speedometer rule
Both vehicles move at the speed of 30 kph	17 m	15 m
Both vehicles move at the speed of 50 kph	28 m	25 m
Both vehicles move at the speed of 70 kph	39 m	35 m
Both vehicles move at the speed of 90 kph	50 m	45 m
Both vehicles move at the speed of 110 kph	61 m	55 m
Both vehicles move at the speed of 130 kph	72 m	65 m

In some European countries such as Germany, the half-speedometer rule determines the safe distance of vehicles from each other; this means that the length of safe distance (in meter) is equal to half of the speed number in follower vehicle (in kph) and in other words, the follower vehicle is required to keep a safe distance equal to 1.8 seconds from the leading vehicle [5], [8] and [9].

Check the geometric traffic conditions of Khorram-Khayyam highway

The elected section is lengths of 200 m in Khorram-Khayyam highway of Isfahan. Distance of inventory section from the upstream ramp exit is 650 m and distance from the downstream entrance ramp is 500 m. The selected site includes 3 lines to cross the vehicles under the uninterrupted flow. The line width is 3.3 m and side distance from the right of road is 1.4 m.

The longitudinal slope of section is less than 2%. The quality of furnishing the selected section is satisfactory and its elevation figure is approximately 5 meters below the slow roads surface of surrounding. Both sides of the traffic route have been separated by the middle refuge at width of 80 cm.

Inventory

As mentioned above, the geometric conditions of highway were considered ideal, but traffic flow was examined in the saturation hours and in the separation of lines. Considering the installation of traffic cameras and speed control on the highway by the municipality and police, statistics related to the number of vehicles and speed and determining the headway of the existing images was taken. Time of inventory is for the last 3 months of 2014 and the first quarter of 2015, which has been taken in the peak traffic time within the intervals of 15 minutes.

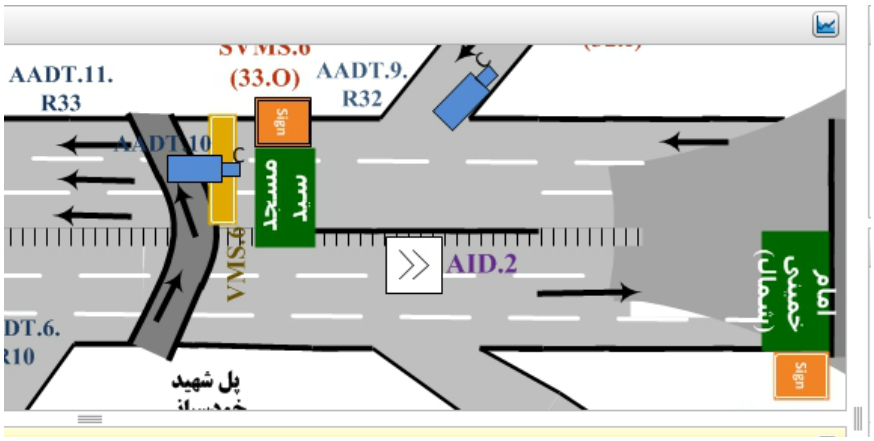

Figure 2: Locating the control traffic camera

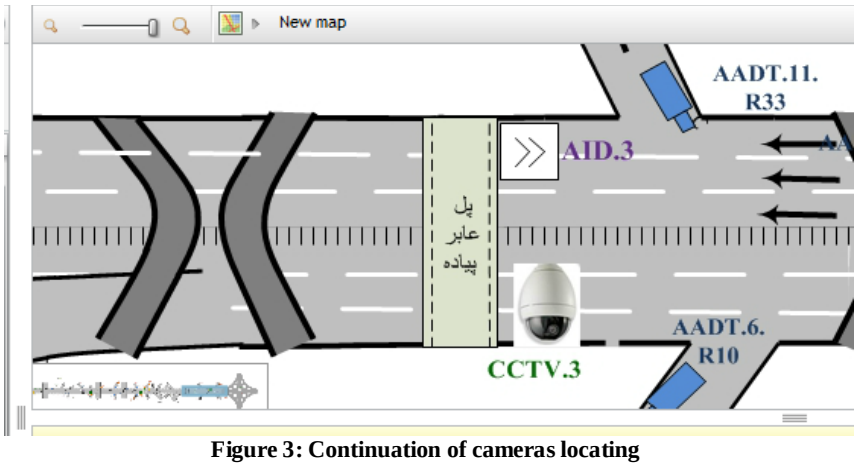

Figure 3: Continuation of cameras locating

Then, the data was set and categorized by the required software like EXCEL 2007. After that, the statistical data was analyzed by SPSS-V13 software, and data such as average, maximum, and minimum of speed, variance, the total number of vehicles passing on a single line which is approximately 2000 vehicles, place and time headwayswas obtained based on traffic information and formulas and was prepared to enter the information fit by statistical model.

Statistical model

One of the best models, chi square, was selected among the various statistical models with significance level of 5% and then, the information was fitted by this statistical model. The reason for choosing this statistical model was the possibility of fitting the discrete data by chi-square formula based on a variable. Due to the direct relationship of place and time headways and instantaneous speed, data fitting was conducted based on instantaneous speed and the number of vehicles. Of course, I noted that these statistics should be generalized to the entire of highway after examining and analyzed the probability of rejecting the Khi 2 (two) hypothesis.

Khi 2 (two) formula [3]

(2)

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

Data entry to MATLAB software

At first, the goodness of entered statistics to MATLAB was fitted. Then, the data was analyzed by using the normal logarithm model which the appropriate flow rate of vehicles and the average place and time headways were obtained from it. These statistics were distributed by using the normal logarithm on the highway; and the statistics after distribution and analysis of statistics were compared to the actual collected statistics of prior to performing the distribution.

The average of free speed in HCM methodology

To compare the data derived from MATLAB software, it is needed the average of free speed to be extracted from HCM tables. There are two methods to determine the free-flow speed. 1- Direct method 2- Indirect method.After referring to formulas and methods available, the range of average speed was determined 80 kph. The average value of each parameter can be achieved by the HCM methodology through using the speed obtained and with the place and time headways formulas that these data are useful for comparing the obtained headway from the MATLAB.

After careful comparison and implementation of statistics on the chart, it was observed that 70% of drivers (according to the nominal headway in America) did not adhere the 2 seconds rule in average for all existing lines and their time headway has been less than 2 seconds to the vehicle in front.Also, 30% of the vehicles had headway about 1 second. After examining the HCM tables, the service level of current highway was determined in C category.

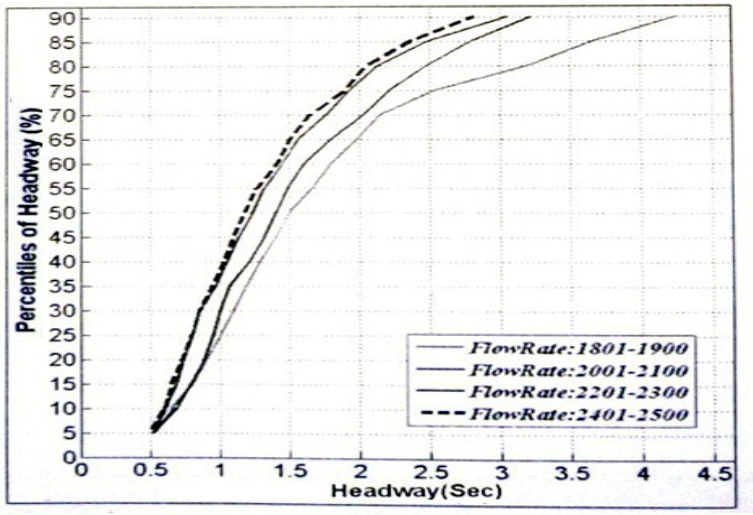

Figure 4: Time headway based on percentage of headway - line number 3

Investigate the safety based on headway

Given the all points mentioned in the previous sections, it can be deduced that a very high percentage of drivers in following situations does not observe the safe headway to follow. This increases the risk appetite of drivers, reduces the safety in driving, and ultimately increases the risk of accidents. There are different opinions about the origin and main cause to the high risk appetite of most drivers. Some believe that failure to observe the safe headway of follower vehicle stems from the fact that the reaction time of some Iranian drivers community is very low and the amount of these driver's awareness is the extent that they are still able to control the vehicle and continue the process of following without feeling the danger, despite the high speed and short headway.

In contrast, some believe that the reaction time of Iranian drivers' community is in normal range of the other countries and drivers tend to continue for following with short headways despite the feel threatened by accident.

No matter which of the above assumptions is the main origin of selecting the unsafe headways by Iranian drivers, this point can be examined that the risky behavior of drivers is to what extent effective in increasing the risk of an accident.As seen in this table, approximately 80% of the accidents on Khorram-Khayyam highway is among the category of "front to back" accidents.

This category of accidents mainly results from the risky behavior of drivers in following with very short headway and its selection. It should be mentioned that the

average speed of most drivers was 90 kph before the accident and their average of time interval based on speed has been calculated less than 1 second. With a little reflection in reaction time, one can understand that the time required to complete stop without collision is about 3 seconds. The formula to calculate the distance of a complete stop has been mentioned in following part [3].

(3)

$$D = 0.278 \times V_0 t + \frac{V_0^2 - V_1^2}{254(F \pm G)}$$

D: Distance of braking m

V_0: Initial velocity km/hr

V_1: Terminal velocity km/hr

F: Friction coefficient

G: Gradient coefficient of road

In Table 4, the main causes of accidents on the Khorram-Khayyam highway have been identified by sorting the type of accident. It can be seen that the cause of about 30% accidents on the Khorram-Khayyam highway was "tailgating".

As well as, about 30% of accidents has been caused by "lack of attention to front". As a result, about 60% of accidents on the Khorram-Khayyam highway has been due to two factors: lack of tailgating and lack of attention to front (statistics presented in Table 2, 3 and 4 have been reported by the traffic police of Isfahan).

Table 2: Accidents statistics in breakdown of the last quarter of 2014

Way of accident	Type of accident			Total of accidents	Percentage
	Damaging	Wounded	Deceased		
Front to back	83	36	1	120	52.6%
Front to side	41	1	0	42	18.4%
Side to side	23	4	0	27	11.9%
Other states	38	1	0	39	17.1%
Total	185	42	1	228	100.0%

Table 3: Accidents statistics in breakdown of the first quarter of 2015

Way of accident	Type of accident			Total of accidents	Percentage
	Damaging	Wounded	Deceased		
Front to back	28	0	0	28	80%
Front to side	2	0	0	2	5.7%
Side to side	3	0	0	3	8.6%
Other states	2	0	0	2	5.7%
Total	35	0	0	35	100.0%

Table 4: Cause of accidents divided separately in 2014 and 2015

Cause of accident due to disrespect of the following cases	Type of accident			Total of accidents	Percentage
	Damaging	Wounded	Deceased		
Unknown	18	0	6	24	9.13%
Observe the longitudinal distance (Tailgating)	53	24	1	78	29.66
Observe the lateral distance	6	4	0	10	3.80%
Yield sign	9	3	0	12	4.56%

Attention to front	57	16	0	73	27.76%
Driving skill	8	2	0	10	3.80%
Control of vehicle	13	1	0	14	5.33%
Safe speed	2	1	0	3	1.14%
Fixed rate	14	3	0	17	6.46%
Deviation to the left	7	5	0	12	4.56%
Deviation to the right	4	1	0	5	1.90%
Turn the wrong way	5	0	0	5	1.90%
Move in opposite direction	0	0	0	0	0%

RESULTS

The aim of this study is to examine and evaluate the macro and micro variables of traffic flow and driver behavior in base sections of the intra city highways. The case study is Khorram-Khayyam highway in Isfahan that plays an arterial role with the first grade in the functional classification of pathways as part of the third ring of the Isfahan. In this research, some traffic flow parameters were examined by using the data related to the highway via separating the lines at different hours of day, and drivers' behavior in base sections of the highway was analyzed in both macro and micro scales.

The results of this study are divided in two sections: results of analyzing the place and time headways, and analysis results of speed.

In section related to analyzing the time headway, results indicate that a high percentage of drivers do not observe the safe headway in process of following. Failure to observe a safe headway in following increases the risk appetite of drivers, decreases the immunity in driving, and ultimately increases the risk of accidents; so that, more than 60% of accidents on the Khorram-Khayyam highway is caused by the lack of tailgating and lack of attention to front.

Also, with distribution modeling of time headways in vehicles was identified that the suitable model for distribution of headways in midline and passing line are different under the heavy traffic conditions. Of course, strategies such as a notification to drivers in online form were suggested to the traffic control center for reducing the volume of traffic by the news boards which caused to the smooth flow of traffic with secondary inventory. Other methods such as signage and long-time stop were proposed at the entrances of the highway, etc; but its impact was not specified due to restrictions on the implementation.

CONCLUSION AND SUMMATION

The base section capacity of highway was estimated by using the microscopic and macroscopic methods. Microscopic analysis of capacity was performed by using the time

headways of vehicles in different conditions (day and night - passing and midlines). For this purpose, the methodology was presented by three different methods of calculating the capacity. These methods have been developed based on reasonable headways of drivers in the process of following. As well as, the amount of capacity was calculated by using the three microscopic models. The used models include linear model of Green Shields, exponential model of Underwood and logarithmic model of Greenberg. These models have been developed based on the relationship between average speed and density [5] and [6] and [7].

The results of microscopic analysis of capacity showed that the average of time headways for vehicles in passing line during daylight hours is equal to 1.42 seconds which will be correspond to capacity of 2527 veh/hr/1n. This value has a little difference with the capacity value of linear macroscopic model of Green Shields 2556 veh/hr/1n [5].

The average of mean headways during daylight hours in midline was obtained equal to 1.69 seconds with the analysis of headways that will be correspond to capacity of 2083 veh/hr/1n. According to macroscopic models, the highest estimated values of capacity are related to the linear model of Green Shields and the lowest values are related to the exponential model of Underwood.

The results of both models indicate that the obtained capacity of all methods in both passing line and midlines during daylight hours is more than the capacity provided by Highway Capacity Manual (HCM) equal to 2000 veh/hr/1n. Also, the higher average of headways in the evening hours compared to day indicates that the capacity of highway lines in the evening hours reduces compared to daytime hours. This capacity reduction is from 2 to 7 percent in microscopic models and from 4 to 12 percent in macroscopic models.

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