Study the Effect of Guide Sign Position on Traffic Behavior at Exit Freeway Weaving Areas by Developing Computer Simulation Program (FWASIM)

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الخلاصة

توفر اجهزة السيطرة المرورية التنظيم لمستخدمي الطرق والتحذيرات والارشاد المطلوب للامان والترتيب وتشغيل كفوء لكل عناصر الزخم المروري. اجهزة السيطرة المرورية اصبحت جزء من نظام الطريق. البحوث قيمت مختلف مجالات التصميم والتشغيل واماكن وضعها وطرق صيانتها. ان الغرض من هذا البحث هو تطوير برنامج محاكاة لتقييم تاثير موقع العلامات المرورية المثبتة عاليا على اداء منطقة التداخل المروري للطرق السريعة عند منطقة الخروج من الطريق. لانجاز ذلك تم اضافة موديل على برنامج FWASIM لحساب موقع العلامة ومقارنته مع مسافة الرؤيا للسائق. تم اختبار مثال مقترح بمختلف تكوينات الزخم المروري لمنطقة تداخل مروري في منطقة خروج لطريق سريع. النتائج بينت ان معدل السرعة للطريق السريع ينخفض عندما لا توضع العلامات المرورية بينما لا يوجد تاثير واضح في حال تغيير موقع العلامات ضمن مسافة الرؤية للسائق. كاستنتاج فان العلامات المرورية عامل مهم لكفاءة الطرق السريعة ويجب ان يؤخذ بنظر الاعتبار في عملية دراسة مشاريع الطرق.

Abstract

Traffic control devices notify road users of regulations and provide warning and guidance needed for safe, uniform, and efficient operation of all elements of the traffic stream. Traffic control devices have been a part of the roadway system. Researches have evaluated various aspects of the design, operation, placement, and maintenance of traffic control devices.

The purpose of this research is to develop a simulation model in order to evaluate the effect of overhead sign position on the traffic performance at exit of freeway weaving area. To achieve that subroutine was developed and added to FWASIM program to compute the sign position and compare it with the driver sight distance. Following that a proposed example represents an exit weaving area was examined with different traffic flow configuration (different percentages of link flow and on-ramp flow) with respect to no sign installed and other three sign positions. Results indicate that the average traffic speed is underestimated when there is no sign installed, while no significant effect is shown when the sign position is changed within the driver sight distance.

In conclusion Guide signing is a critical element in the effective, efficient and safe operation of motorways and expressways. Signing issues must, therefore, be fully considered at the feasibility stage of any project.

Keywords: control device, weaving, traffic signs, simulation.

1.Introduction

Traffic control devices provide one of the primary means of communicating vital information to road users. Traffic control devices notify road users of regulations and provide warning and guidance needed for the safe, uniform, and efficient operation of all elements of the traffic stream. There are three basic types of traffic control devices: signs, markings, and signals. These devices promote highway safety and efficiency by providing for orderly movement on streets and highways (1).

Traffic control devices have been a part of the roadway system almost since the beginning of automobile travel. Throughout that time, research has evaluated various aspects of the design, operation, placement, and maintenance of traffic control devices.

Freeways are fundamental elements in highway system network. The efficiency of traffic operation in freeway weaving sections is a key factor to the capacity of the whole freeway system, hence planners, designers and engineers are concerned mostly with the design, analysis and operation management of these sections. Weaving area always occurs when two or more vehicle streams, driving in the same direction, cross each other. Therefore, different drivers employ different techniques to travel through such sections while interacting with other drivers.

Near on and off ramps or weaving sections, drivers often change to the lanes that are connected to their destinations. These areas are potential locations for bottleneck formation when high proportion of drivers attempt to change lanes.

Guide signs provide motorists with information on direction and distance to destinations on their selected route of travel. The design and layout of guide signs should be directed at the motorist who is unfamiliar with the area and consequently requires clear, concise and consistent sign messaging so they are able to navigate to their destination in an orderly manner (2).

Guide signing is a critical element in the effective, efficient and safe operation of motorways and expressways. Meanwhile excessive or inconsistent signing should be avoided since it tends to confuse road users and diminish the effectiveness of freeway guide signs. Signing issues must, therefore, be fully considered at the feasibility stage of any project (3).

Research in Intelligent Transportation Systems (ITS) is being performed to develop traffic management and operation strategies to deal with problems associated with congestion. The number of strategies needed to be tested for a transportation system may be large and field testing would be prohibitively expensive. For this purpose, microscopic traffic simulation is a suitable tool.

Research Objectives

The objectives of this research may be summerized by the followings:

1- Development the (FWASIM) which is a computer simulation program for studying traffic behavior at freeway weaving areas, to be able to study the effect of the exisitance of overhead guide signs near the off-ramps.

2- Study the effect of guide signing on the traffic behavior and the efficiency of freeway weaving areas at exit off ramps, which is the critical section in the freeway that may cause the traffic disturbance and congestion.

Related Literature Issues

Freeway weaving areas

Weaving area is always formed when two or more vehicle streams, driving in the same direction, cross each other. Weaving area is the critical section in the freeway that may cause the traffic disturbance and congestion. It is a key factor to the capacity of the whole freeway system, hence planners, designers and engineers are concerned mostly with the design, analysis and operation management of these sections.

According to Highway Capacity Manual (HCM, 2000) weaving area is defined as the crossing of two or more traffic streams raveling in the same general direction along a significant length of highway without the aid of traffic control devices (with the exception of guide signs). Weaving segments are formed when a merge area is closely followed by a diverge area, or when an on-ramp is closely followed by an off-ramp and the two are joined by an auxiliary lane (4).

Weaving segments require intense lane-changing maneuvers as drivers must access lanes appropriate to their desired exit points. Thus, traffic in a weaving segment is subject to turbulence in excess of that normally present on basic freeway segments.

The most critical aspect of operations within a weaving segment is lane changing. Weaving vehicles, which must cross a roadway to enter on the right and leave on the left, or vice versa, accomplish these maneuvers by making the appropriate lane changes. The configuration of the weaving segment (i.e., the relative placement of entry and exit lanes) has a major effect on the number of lane changes required of weaving vehicles to successfully complete their maneuver.

In transportation analysis for highways, the main issues to be disscused deeply is the capacity and level of service of weaving sections. Therefore, an analysis of traffic behavior is essential within these areas. This requires the development of traffic theories to explain driver behavior at the microscopic level.

Near on and off ramps or weaving sections, drivers often change to the lanes that are connected to their destinations. These areas are potential locations for bottleneck formation when high proportion of drivers attempt to change lanes. Lane changing operations are critical in selecting geometric configuration of such areas (5). This is because drivers' lane changing behavior has direct influence on the capacity and safety of such areas.

Signing

Informational signing and lane choice play a critical role to drivers. Reviewing the placement of signing and delineation may provide operational improvement of this section. It is the opinion of the authors of this report that signing and delineation is not provided at the most beneficial decision points for the freeway and pass through traffic, contributing to the congestion in the right lane of the freeway (6).

Guide signing is a critical element in the effective, efficient and safe operation of motorways and expressways. Signing issues must, therefore, be fully considered at the feasibility stage of any project. It is not possible however, to sign every destination to which road users may want to travel. The basic assumptions made for guiding travellers through any roading system are that they will (3):

1- Do some preparation to determine the route to be followed before commencing a journey, and

2- Use a road map while travelling.

Motorwaya and expressway sings are primarily for the benefit and direction of drivers who are not familiar with the route or area. Therefore, they must:

1-command attention.

2-Have a consistent appearance.

3-Be located in positions that give adequate times for drivers to respond safely to their messages, particularly where unusual manoeuvres are required.

4-Contain clear and simple messages in the same terms as information available from other sources, and

5-Achieve continuity throughout a route.

However, road signs have little effect on the driving behavior of motorists. There are several reasons for this:

(1) road signs may be poorly placed,

(2) information provided on the sign may not agree with motorists' perception of the situation, and

(3) motorists’ visual ability may be limited.

Guide signs on freeways and expressways should serve distinct functions as follows (7):

A. Give directions to destinations, or to streets or highway routes, at intersections or interchanges;

B. Furnish advance notice of the approach to intersections or interchanges;

C. Direct road users into appropriate lanes in advance of diverging or merging movements;

D. Identify routes and directions on those routes;

E. Show distances to destinations;

F. Indicate access to general motorist services, rest, scenic, and recreational areas; and

G. Provide other information of value to the road user.

Sight distances

The ability to see ahead is of the utmost importance in the safe and efficient operation of a vehicle on a highway (5). Sight distance may be defined as the length of roadway ahead visible to the driver. Stopping sight distance is the sum of two distances: the distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the breaks are applied and the distance required to stop the vehicle from the instant brake application begins. These are referred to as brake reaction time.

For design values, the sum of the distance traversed during the break reaction time and the distance to a stop the vehicle in the minimum stopping sight distance. The following formula represents this design value for the minimum stopping sight distance (5):

$$d = 0.278tV + V^2 / 254(f+g)$$

where:

t = break reaction time, generally assumed to be 2.5 sec.

V = initial speed, km/h, and

f = coefficient of friction between tyres and roadway.

g = is the gradient of the roadway.

Simulation

The computer simulation can play a major role in the analysis and assessment of the highway transportation system and its components (8). Often they incorporate the other analytical techniques, such as demand-supply analysis, capacity analysis, traffic flow models, car-following theory, shock wave analysis, and queuing analysis, into a framework for simulating complex components or systems of interactive components. These components may be individual signalized or non-signalized, residential or central business district dense networks, linear or network signal systems, linear or corridor freeway systems, or rural two-lane or multilane highways systems.

Microscopic simulation of traffic is based on each vehicle's kinematics. Each vehicle is individual and each vehicle's properties and operations are modeled individually. As the microscopic simulation method is based on the vehicle - vehicle and vehicle - infrastructure interactions it makes much versatile analysis possible.

Simulation models are designed to emulate the behavior of traffic in a transportation network over time and space to predict system performance (9). Simulation models include the mathematical and logical abstractions of real-world systems implemented in computer software. Simulation model runs can be viewed as experiments performed in the laboratory rather than in the field.

Traffic simulation models describe the changes in the system state through discrete intervals in time (6). There are generally two types of models, depending on whether the update time intervals are fixed or variab**le**:

1- Discrete Time (Time-Scan) Models

2- Discrete Event (Event-Scan) Models

Simulation models are typically classified according to the level of detail at which they represent the traffic stream. These include:

1- Microscopic Models
2- Mesoscopic Models
3- Macroscopic Models

Discription of freeway weaving area simulation model (FWASIM)

The simulation model named FWASIM (Freeway Weaving Area SImulation Model) is written in visual basic programming language (10). The model is of periodically scanning type and simulates the traffic behavior at weaving area for highways at Baghdad city.

The model permits measurement of a full range of traffic characteristics and is allowing many alternative designs to be tested. This type of modeling of traffic is classified as microscopic because of its nature of handling the movements of vehicles and resolution.

The simulation model FWASIM in general has three components;

1. The highway segment geometry consisting of the on-ramp, freeway link, off-ramp, and the freeway link lane numbers, which consists of up to six lanes.
2. traffic data that related to vehicles and flow characteristics, and
3. the driver attributes.

The following are the vehicle and driver characteristics that are modeled in the developed simulation model;

1. Time of arrival (vehicle generation).
2. Vehicle type (traffic composition).
3. Type of vehicle movement (weaving or non-weaving).
4. Desired speed of each vehicle.
5. Acceleration and deceleration rate.
6. Space gap.
7. Driver break reaction time.
8. Entry lane number and label for each vehicle.
9. Driver preferred headway.
10. Vehicle spacing.
11. Vehicle desired spacing.

The simulation model results are, the average flow space mean speed, and traffic density. They are also represented graphically in the model output.

FWASIM development

This model is of microscopic type, therefore, it permits measurement of a full range of traffic characteristics and allowing many alternative designs to be tested. The simulation program was designed in modular manner and a great deal of care was made to make allowances for future developments.

The main objective of this research is to study the effect of the overhead guide sign positions on the traffic behavior in the freeway weaving area. This is achieved within two steps.

The first step is development **FWASIM** programe to be able to simulate the effect of sign position on other traffic flow fundemantals in the weaving area. The old version of this program locate how to measure the sign position with respect to other geometric design of the selected area. Figure (1) below show this location.

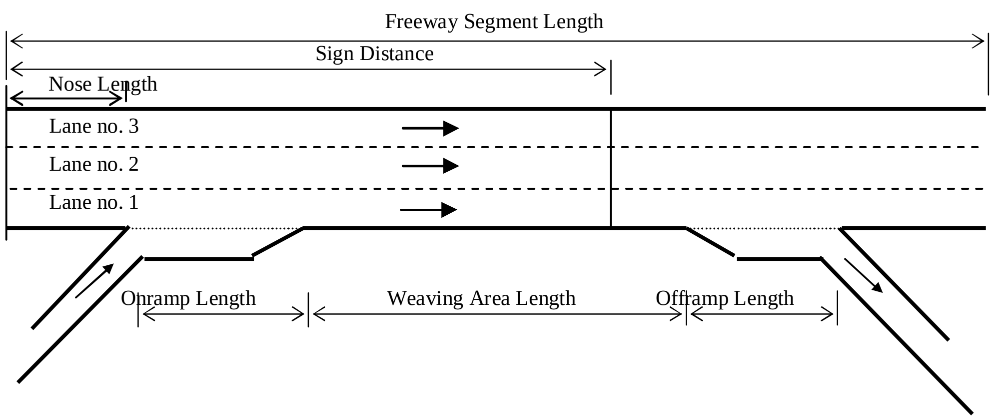

Figure 1-: Typical cross section illustrating the modeled geometric

The concept of sign position simulation is based on driver sight distance and the type of simulated vehicle (weaving type or non weaving type). The exit sign is considerd to be detected and identified by the driver if its position is became within the driver sight distance and the simulated vehicle is of weaving type.As discribed in the literature here in above, the following sight distance equation is adopted in the simulation model development stage.

$d = 0.278tV + V^2 / 254f$

Where;

(V) is the vehicle speed, in the model each vehicle assigned an individual desired speed drawn from a normal distribution with mean, standard deviation, maximum, and minimum values specified during the input stage.

(t) is the break reaction time which represents one of the driver attributes that generated also in the simulation model.

no gradient in the simulated freeway section is considerd , therefore the its effect is neglected in the equation and the friction is also considered to be 0.3. the formula simulated in the simulation model as follows.

Link(Lane, 1).SightDist = 0.278 * Sg * Brt + ((Sg ^ 2) / (254 * 0.3))

Where, speed was modelled as (Sg) in km/h, (Brt) is the break reaction time in seconds and (0.3) value represents the friction between tyres and road surface.Vehicle flows from highway link and on-ramp segment are divided into two types. These two types are weaving and non-weaving vehicles. The decision that a vehicle is considered as weaving or non-weaving is based on comparison with a random number. This number is drawn from a uniform distribution in the interval (0, 1).This flow origin destination configuration below divide the flow to weaving and non weaving types. The subject vehicles that their drivers are interesting with the exit sign existance are those of weaving type which generating from the freeway link and the non weaving type that generating from the on ramp.

Figure (2) below represents the macroscopic flow configuration diagram as specified by the Highway Capacity Manual (HCM, 2000). This diagram represents origin-destination of vehicles entering the weaving area.

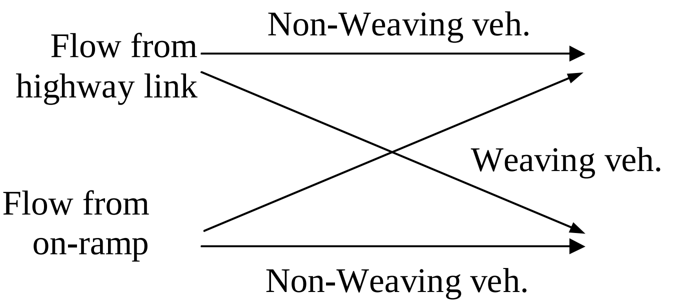

Figure 2-: Flow configuration diagram

Subroutine was added to the main listing of the simulation model inside the subroutine resposible for the lane change maneuver decision. The purpose is to let the model be able for achieving the research objective. The main and final statements which are necessary to study the effect of sign position on traffic behavior for the vehicle that want to exit the freeway weaving area from the offramp are as follows;

```
For j = 1 To Link_Occupancy(4) - 1
    If Link(4, j).Position >= (FWLink.SignPosition - Link(4, j).SightDist) _
    And Link(4, j).Weaving = 2 And _
    Link(4, j).Speed < Link(4, j).DSpeed Then
    Call Check_Link(4, 3, j)
    End If
  Next j
End If
```

This subroutine was added as statements to all five lane change cases adopted in the simulation model taking into consideration the vehicle features.

It is considered that each vehicle which its sight distance equal or greater than the distance of the overhead sign, and the vehicle type is weaving, then the sign is detected and the driver make the needed response to change its lane if it isnot on the first lane to be ready to exit from the offramp without disturbing other traffic.

The second step to achieve the research objective is to execute the model with different sign positions to study their effects on traffic behavior, while other factors related to the driver and vehicle features remain constant.

To achieve this purpose, typical proposed highway section was examined by simulating of vehicle parameters under various flow conditions. Driver behavior and vehicle movement are simulated on the basis of the following assumptions;

1. A range of percentage on ramp flow from the total flow of (20%,-60%) in 20% increase for each traffic flow condition.

2. percentage of nonweaving vehicles for freeway link flow was assumed to be 67%, and for on ramp flow was 33%.

3. the value of driver and vehicle attribute parameters were proposed as shown in Table (1) below.

Table (1):- Proposed traffic attribute parameters

Attribute	Mean	Std	Min	Max
Gap	6.00	1.00	3.00	10.0
Brt	1.00	0.26	0.30	2.00
Pref. headway	1.40	0.40	0.36	2.70
Speed	90.0	22.0	40.0	140
Acceleration	3.0	0.62	1.0	5.0
Deceleration	3.0	0.62	1.0	5.0

4. traffic condition was assumed to be, 95% passenger cars, 5% trucks.
5. vehicle arrivals was assumed to follow the negative exponential distribution.
6. the sign position (distance from the generation point to the erected sign position) was assumed (100m, 200m, 300m). and no sign existence was also assumed.

The geometric layout used in this simulation experiment is shown in Figure (3). Typical obtained results are presented in Table (2). The obtained values of average vehicle speed are presented in Figures (4 to 6).

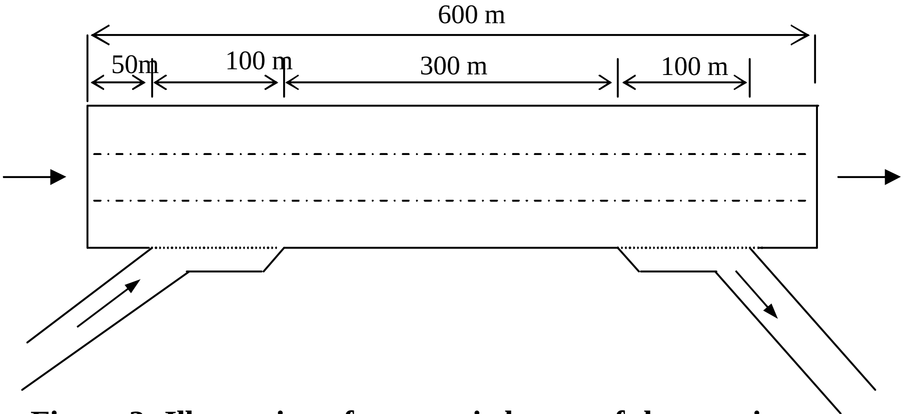

Figure 3: Illustration of geometric layout of the weaving segment

Table 2:- Obtained simulated data for the weaving segment

Flow, Pcu/hr	Sign position (no sign exist)			Sign position (100m)			Sign position (200m)			Sign position (300m)		
	Proportion of on ramp flow %			Proportion of on ramp flow %			Proportion of on ramp flow %			Proportion of on ramp flow %		
	20	**40**	**60**	**20**	**40**	**60**	**20**	**40**	**60**	**20**	**40**	**60**
	Speed, km/hr			Speed, km/hr			Speed, km/hr			Speed, km/hr		
500	86.9	85.5	84.5	88.0	87.2	86.3	87.7	87.0	85.0	87.5	86.6	86.7
1000	85.2	83.9	82.8	87.7	86.1	83.4	86.3	85.2	83.8	87.1	85.0	83.5
1500	84.8	82.0	80.6	86.4	84.7	81.3	86.4	84.7	82.0	85.9	84.2	81.3
2000	83.4	81.2	78.7	85.7	83.6	81.0	86.2	83.0	80.4	85.0	83.0	80.2
2500	82.1	79.6	77.4	85.3	82.5	79.4	84.6	82.7	79.1	84.6	81.2	78.8
3000	81.2	78.5	75.9	84.6	81.2	77.7	84.4	80.8	77.4	84.1	80.9	77.8
3500	80.5	77.4	74.4	84.1	80.4	76.6	83.3	79.9	77.1	82.8	80.1	76.3
4000	79.4	76.7	73.2	82.2	79.3	75.4	82.8	79.1	75.4	82.6	78.9	75.3
4500	79.0	75.7	72.2	81.8	77.7	74.1	81.9	78.3	73.7	81.7	77.8	74.1
5000	78.2	74.6		80.6	77.3		81.0	76.9		81.0	76.8	
5500	77.4	73.5		80.0	75.8		79.8	75.8		80.1	75.8	

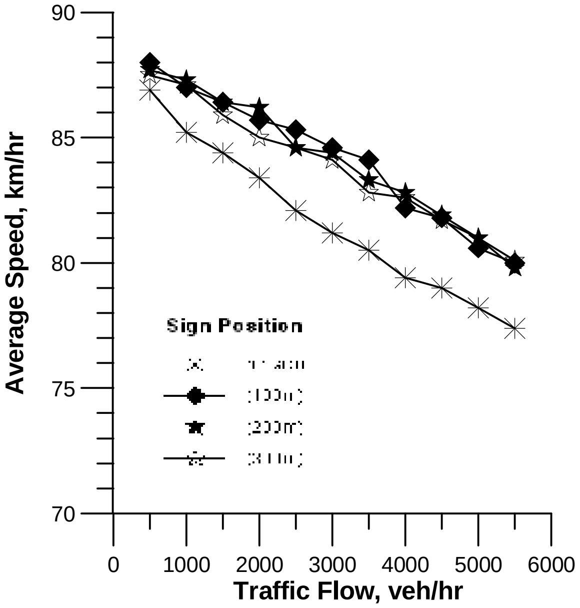

Fig. (4):-Speed-Flow relationship for 20% on-ramp flow

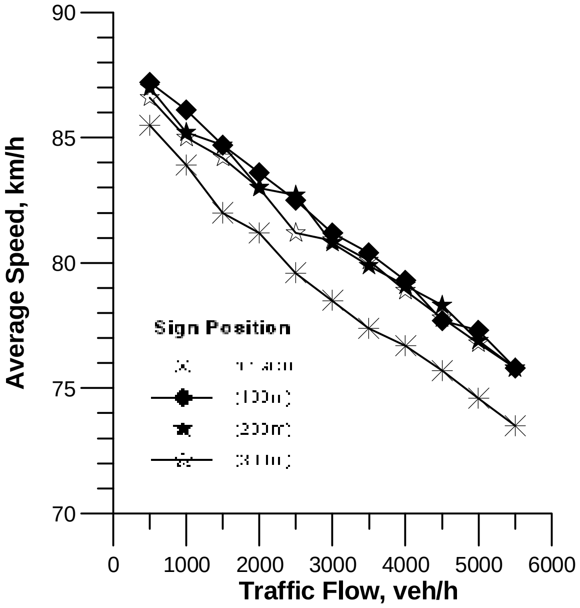

Fig. (5):-Speed-Flow relationship for 40% on-ramp flow

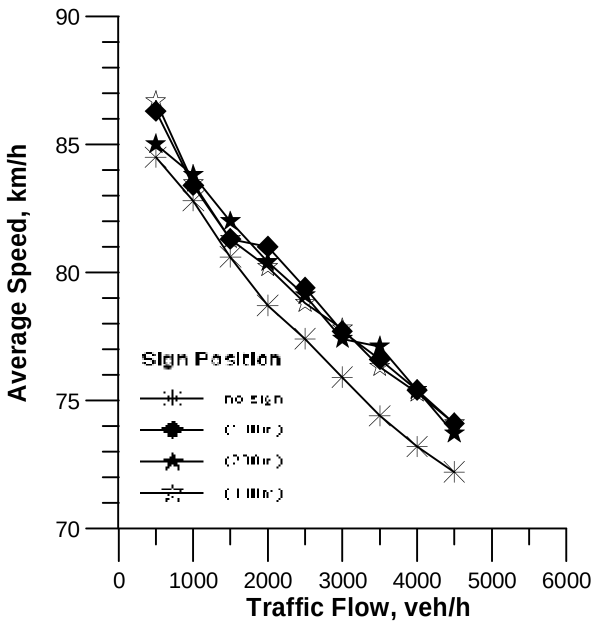

Fig. (6):-Speed-Flow relationship for 60% on-ramp flow

Conclusions

From the above, the following conclusions can be drawn:

1-With all on-ramp flow percentages, when there is no guide sign installed within the driver sight distance, the average freeway weaving speed is tend to be less than the all average speeds when there is sign installed on the exit freeway weaving area. This is attributed to the fact that when the driver detect an exit sign he can manage his direction and choose his preferred lane to make smooth lane changes without traffic disturbance made to others, this will not lead to decrease in the stream average speed.

2-The change in sign positions within the driver sight distance are slightly effect the average speed as shown in the figures (4, 5, and 6). This is attributed mainly to the existence of these positions within the driver sight distance, therefore driver can detect them despite of their positions. The other reason is that most of the drivers are familiers with these areas and recoginize their destinations without detecting the signs early.

3-From table (2), it is clearly shown that the average speed decrease with the increase of the on-ramp traffic flow percentage for different sign positions, this is attributed to the increase in the weaving process occur in the weaving section and also to the fact that the average speed for the flow coming from the on-ramp is less than the average freeway link speed.

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