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Empirical Study of Complex Vehicular Interactions At A Junction

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Abstract
Driver behavior is investigated at the aerial road, where two different roads meet each other at the junction. The performance measurement of congestion such as speed, time headway, and the saturated flow rate is calculated. Their influences due to change in the road's geometric properties under heterogeneous flow conditions were analyzed in this study. Vehicles are more stimulus to merging traffic and is the leading cause of congestion at junction. It is concluded that speed stimulates time headway and driver interaction at junctions, which results in a capacity drop and increases the risk of accidents. Field data is recorded at a three-leg intersection. Speed drops upstream while the vehicle downstream accelerates easily to attain the desirable speed ahead.

Keywords — *Speed, Time Headway, Driver Behaviour, Junction, Heterogeneous Flow.*

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I. INTRODUCTION

The increase in population is accelerating vehicular demand worldwide, which increases the chance of congestion and decreases traffic flow on any road. Congestion contributes to delay trip time, safety and increases pollution [1]. Intersections are essential to design elements of a road that significantly influence traffic performance [2-3]. Traffic flow becomes jam when vehicular demand goes above the capacity and produce traffic shockwaves. Congestion mostly occurs at junctions, U-turns, and ramps. Congestion is defined as the continuous decrease in vehicles' speed due to some external effects [4-6]. Headway and speed are fundamental measures in vehicular movement applications [7]. Time headway is defined as the time difference (in seconds) between two consecutive vehicles as it crosses a reference point in the road section. It is the safety factor that is applied in planning and designing [7-8]. Numerous aspects that influence speed and headway are traffic volume, vehicle size, vehicle shape, road design, the geometry of surrounding infrastructure, and environmental conditions [9-12]. Therefore, it is important to analyze the speed and time headway precisely. Headway characterizes driver performance and is used to treat road safety [13]. The driver response is more stimulus to vehicular moment. It is determined that a driver's reaction is gentle for vehicles having large headway and aggressive for little progress [14]. The field data will investigate driver behavior called car following and lane changing [15]. Capacity is the maximum number of vehicles accommodated by the road segment and is influenced by headway and vehicular interactions. Capacity increases with small headway and vice versa [16].

When the vehicle merges at the junction, it reduces the main road traffic speed and creates congestion at the upstream road segment. This Paper aims to investigate the performance of vehicular movement at a junction such as a congestion problem and propose a model that will mitigate the traffic problem and improve traffic operations. The headway is affecting the average speed of vehicles both upstream and downstream of the junction.

The rest of the paper is organized as mentioned. Section-II presents the survey technique for data collection and traffic data physical characteristics. Section-III describes the investigation, analysis, and performance evaluations, while section-IV presents some conclusions and future discussion.

II. FIELD DATA COLLECTION AND METHODOLOGY

This study was planned to evaluate the speed and time headway variation at the road intersection. The traffic information was collected at a three-legged junction located at Phase 1-Hayatabad, Peshawar. The investigating site consists of two incoming roads at a junction point and having one outflow at the downstream road see (Figure 1). Time headway and speed are two important parameters of the road to model driver response at a junction.

1) Survey of the road:

Field data were collected by installing a series of cameras at a high raised building along the road's length, shown in (Figure 2) and (Figure 4). To precisely capture driver behavior and vehicle location in the road section, time was recorded in a millisecond. Different statistical analysis was established to find time headway, vehicle classification, and speed trajectory. All the data were extracted manually using a video recorder.

2) Characteristics of road traffic:

The traffic characterization at the intersection of a road network is meant to describe the traffic flow behavior. The junction has two roads at the intersection, such as the merging road and main road. The geometric features such as speed, headway, and other parameters are listed (Table II).

A. Headway:

Headway analysis is important in numerous transportation engineering applications such as service level, the road's capacity, junction, merging problems, etc. [17]. Time headway is expressed as the reaction time among vehicle and is defined as the difference in time between two successive vehicles crossing any reference point as shown in (Figure 3) and (Figure 4), and learning example is listed in (Table I)

$$\tau_h = \tau_{n+1} - \tau_n . \qquad 01$$

Where $\tau_h$is time headway, τ_{n+1} is time exit of the leading vehicle, andτ_n is time exit of the following vehicle.

B. Saturated Flow

Saturated flow rate is an essential parameter for predicting road capacity, traffic performance, and is inversely related to time headway. The driver response and spacing between vehicles are very important [18].

$$q = \frac{1}{\tau_h} \qquad 02$$

Where $q$is traffic flow?

C. Speed

Speed is defined as the time occupied by a vehicle while covering any referenced distance. To understand the science of speed variation, calculations of a selected chain of vehicles are listed in (Table III and IV) respectively, while overall findings are written in (Table II)

$$v = \frac{s}{t} \qquad 03$$

vThe speed$s$ is the distance covered by the vehicle and $t$is the time taken by the vehicle.

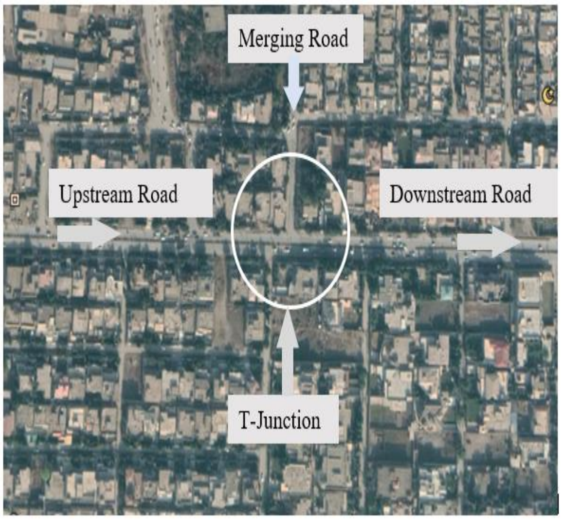

Figure 1: Image of T-junction

Figure 2: Video recording at T-junction

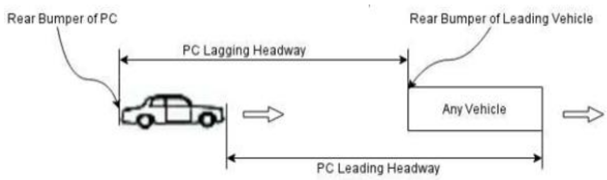

Figure 3: Estimation of headway

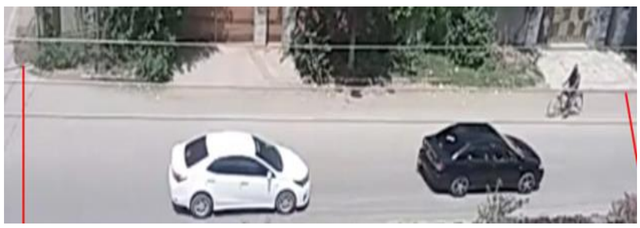

Figure 4: Vehicular moment in the road section

TABLE I
Example of headway calculation

Vehicle type	The vehicle leaves the section	Headway
	Seconds	Seconds
Car	75.92	---
Car	84.53	14.52
Car	96.28	08.61
Truck/Damper	108.17	11.74
Car	112.07	11.89
Car	124.26	03.90
Car	126.84	12.19
Car	141.92	02.57
Car	154.05	15.08
Truck/Damper	167.54	12.13
Mini Truck	172.31	13.48
Average Headway		10.60

TABLE II
Traffic parameters

Analysis parameters				
Road Parameters	**Unit**	**Merging Road**	**Upstream Road**	**Downstream Road**
Length	$\mathcal{L}$ (m)	60	120	90
Width	$\mathcal{W}$ (m)	3.3	3.3	6.6
Average speed	v (m / s)	5.6	7	11
Average time headway	$\mathcal{T}$ (s)	9.6	5.3	3.5
Number of vehicles	$\mathcal{N}$	83	155	238
Time frame	$\mathcal{T}$ (s)	900	900	900

III. RESULTS AND DISCUSSIONS

The vehicles approaching from merging road to the junction reduce the main road's vehicular speed, which influences the time headway of the upstream and downstream section of the main road. Meanwhile, some drivers reduce their speed at the upstream section while some accelerate, which produces congestion, road accident, and effects on road safety. At the downstream section of the main road, the driver only accelerates his speed due to free space availability. It was observed that the majority of vehicles had reduced their speed to avoid collisions, but after crossing the junction point, they accelerate and attain higher speed. The speed behavior of both roads is shown in (Figure 5).

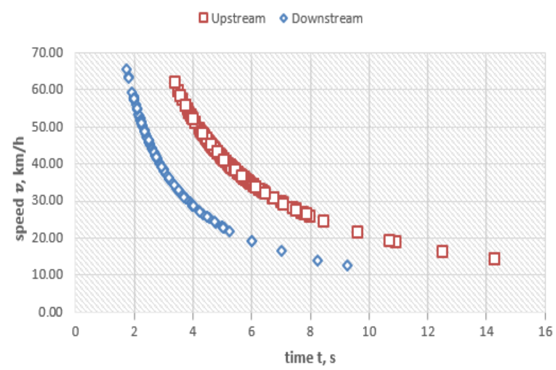

Figure 5: Speed trajectory of upstream and downstream traffic at a junction

1) *The behavior of Merging traffic*

Merging vehicles reduces their speed due to continuous inflow from upstream road see (Figure 6). Merging vehicles have to wait at the merging point, speed will be decreased, and the headway will decrease (Figure 7). In (Figure 8), we observe that the vehicle accelerates as it finds free space ahead, thus having large headway.

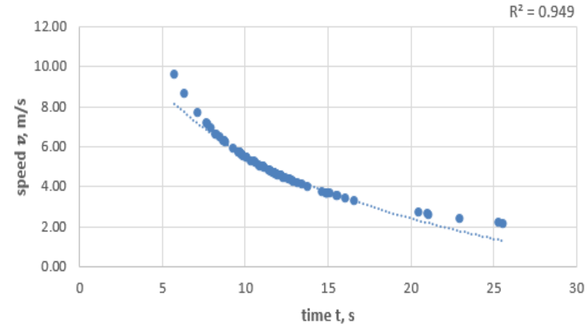

Figure 6: Continuous drop of speed at merging road section

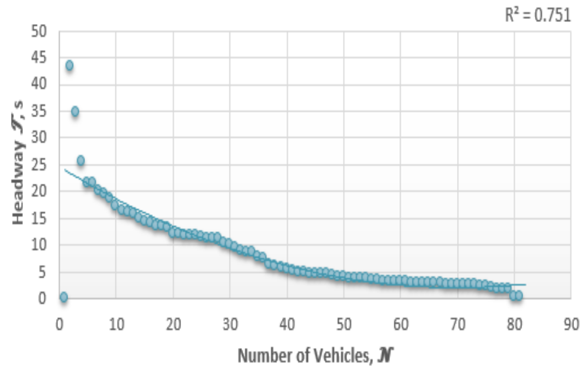

Figure 7: Headway decreases with the increase of vehicles in the merging section

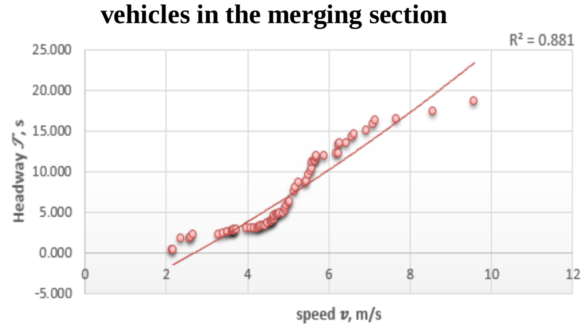

Figure 8: Speed rises as headway increases in the merging section.

2) *The behavior of Upstream Traffic*

When approaching vehicles from the upstream section of the main road reaches the junction, it gradually reduces its speed. This decrease in speed is due to the entrance of new vehicles from the merging road. This type of performance is somehow called driver psychological behavior, causes heterogeneity and tail-backing at the upstream road section. This phenomenon is mostly adopted by vehicles in an un-signalized intersection due to uncertainty among vehicles at junction. If the number of vehicles increases, the smaller be the headway, dense traffic will be floating at the upstream section. (Figure 9) explains that headway has no major difference upstream and downstream of the main road when no ingress traffic enters the section. Each vehicle has the same driving behavior at both segments, while (Figure 10) explains some dissimilarity in downstream traffic behavior due to ingress traffic.

TABLE III
Speed of vehicles at the upstream section of the main road

Vehicle Type	Time	Distance	Speed	Speed
	s	m	m/s	km/h
Car	4.94	57	11.54	41.55
Car	4.52		12.62	45.44
Car	3.48		16.36	58.90
Car	4.60		12.38	44.58
Mini Bus	4.68		12.18	43.86
Car	5.10		11.17	40.21
Mini Bus	9.59		5.95	21.41
Car	4.44		12.83	46.21
Car	5.29		10.79	38.83
Car	4.50		12.67	45.62
Average Speed			11.84	42.66

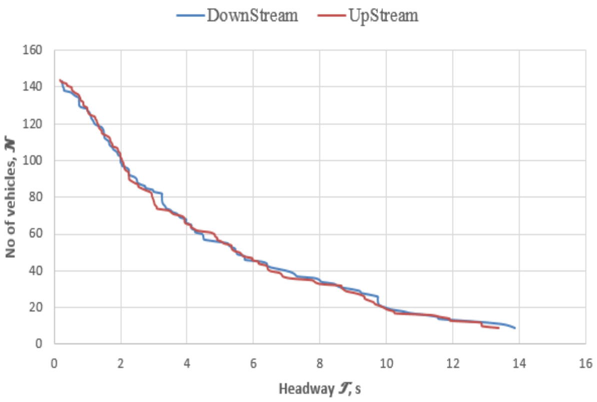

Figure 9: Headways of the main road with no ingress traffic

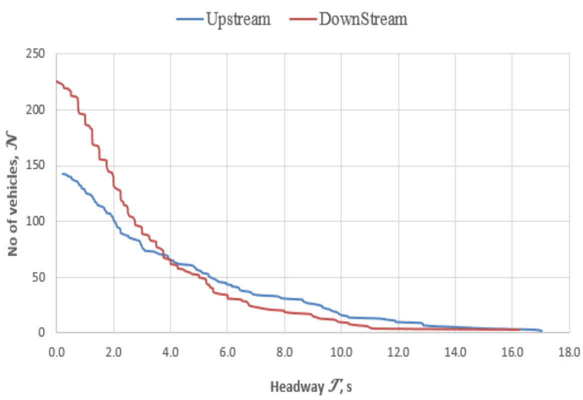

Figure 10: Headways of the main road with ingress traffic

3) *The behavior of Downstream Traffic*

When traffic injects from the merging road, it reduces the speed and headway of primary road traffic. When upstream vehicles cross the junction point and enter the downstream section, vehicles' average speed increases. For example, in (Table IV), the speed of chained or following vehicles increases from 42 km/h to 49 km/h. Each vehicle gains speed downstream, and this behavior is called driver aggressiveness due to free space ahead. The headway also reduces as speed increases downstream see (Figure 9-10). The average headway recorded downstream is 3.5 s and 5.3 s at the upstream road. At downstream, vehicles accelerate faster and follow the next vehicles.

TABLE IV
Speed of vehicles at the downstream section of the main road

Vehicle Type	Time	Distance	Speed	Speed
	s	m	m/s	km/h
Car	2.51	32	12.77	45.99
Car	2.00		16.02	57.66
Car	2.55		12.57	45.25
Car	2.20		14.52	52.27
Mini Bus	1.82		17.61	63.40
Car	2.51		12.77	45.99
Mini Bus	5.01		6.39	23.02
Car	2.00		15.99	57.57
Car	2.75		11.64	41.91
Car	2.01		15.93	57.34
Average Speed			13.62	49.04

IV. CONCLUSIONS

Driver behavior was analyzed at a three-legged intersection. The impact of ingress traffic on both upstream and downstream of traffic had been studied. At the upstream road section, the speed reduces due to the increase in the number of vehicles at a junction and creates jamming effects. When there was no new traffic coming from the merging road, traffic behavior was homogenous at both road segments (upstream and downstream). The speed and headway recorded at the main road were relatively dissimilar at upstream and downstream road segments.

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