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# Impact of pedestrians crossing road width on vehicles traffic flow at IJP road

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*Abstract-* **In the developing countries, mostly pedestrians are involved in traffic accidents. These accidents occur due to the non-abidance of rules by both pedestrians and drivers. To quantify pedestrians crossing a road width impact on vehicular flow, a case study has been conducted at Inter Junction Principal road in Rawalpindi, Pakistan. Pedestrian crossing road width impact (of single, two, three and four pedestrians) has been calculated on vehicular flow, speed and density. For this purpose, roadside traffic video was recorded three times a day from a pedestrian bridge for eight consecutive days. For traffic flow analysis, Camlytics (commercial traffic analysis software) has been employed. Pedestrian's road width crossing time, speed and impact on different types of vehicles have been analyzed according to pedestrian's age and gender. Furthermore, road crossing impacts on vehicular flow, speed and density are analyzed by pedestrian's age and gender. Relationships are developed between speed and flow, speed and density, and flow and density by the disturbances caused by pedestrian road crossing. It was observed that old female pedestrians cause the most vehicular flow disturbances. Furthermore, the speed distribution does not follow the Greenshield speed distribution characterization. The traffic speed does not reduce to zero even when there is maximum traffic density present on the road.**

*Index Terms*: **Pedestrians, road width crossing, Vehicular flow, Greenshield speed distribution**

## I. INTRODUCTION

In developing countries, traffic flow is of heterogeneous nature which gives rise to different challenges. These challenges range from traffic congestions, road accidents, greenhouse gas emissions to name a few [1], [2]. With an increasing number of vehicles plying road these challenges will compound even further. For example, the registered vehicles in Pakistan have increased to 17,317,600 in 2016 [3]. At present approximately 1.35 million road fatalities are reported worldwide, costing about 3% of GDP or respective countries [1]. About 93% of these fatalities are reported in developing countries though their share of registered vehicles stand at 60% [1].

These traffic related challenges are further compounded in the developing countries at locations where pedestrians crossing a road facility is not present. This is an illegal act of pedestrians crossing a road width. This not only endangers a pedestrian life but also stacks the driver and vehicle occupant lives. Need to study the impact of illegal pedestrian road walking on vehicular flow, speed and density is imperative. This study is significant as half of 1.35 million road fatalities worldwide involve pedestrians, motorcyclists and cyclists.

### A. RESEARCH CONTEXT

Many factors such as individual error, environmental and vehicular condition can be attributed to road traffic accidents (RTA). However, a major factor is human errors which causes 64-95% of RTA [4]. Every year, more than 270,000 pedestrians lose their lives in road accidents [5]. Pedestrians are involved in 22% of the road accidents worldwide. Out of these 22%, 80% involve a pedestrian and vehicle.

According to traffic police department statistics, 91% of RTA are caused by pedestrians in Karachi, Pakistan [3]. Only 20% of pedestrian crossings are undertaken on designated crosswalks as compared to 48% and 89% in Bangkok and UK respectively. Furthermore, only 1% of Karachi's drivers were observed to come to a complete stop when encountering pedestrians on the road [3].

There are various factors which govern the road crossing decisions of pedestrians. These factors range from age, gender, signals, crosswalk distance, environmental and vehicular speed and density. Environmental factors (such as rain, fog, winter) play in an oversized role in pedestrian crossing decisions and increased instances of jaywalking [7]. In [6], it was reported that pedestrians are more absent minded while crossing the road while they are busy eating or have headphones on.

In [8], it was reported that male pedestrian road crossing behavior is more hazardous as compared to female pedestrians. Female pedestrian's waiting tendencies are higher. In two studies conducted on pedestrian crossing behavior in Israel, it was concluded that pedestrian walking tendency was higher in male pedestrians as compared to female pedestrians when crosswalk light is red [10]. Miscalculations of safe gaps between vehicles in child pedestrians are higher than adult pedestrians [10].

In existing literature, it was concluded that crosswalk width, crosswalk signal timings, and pedestrian's speed and direction and traffic volume and flow affect pedestrians crossing decisions [8], [10], [11], [13]. In [8], models were developed to propose road crossing widths by considering pedestrians crossing speed and time [8]. Effect of vehicular speed and other pedestrian behavior on pedestrian's crossing was studied [10].

Different studies were undertaken and it was concluded that pedestrian crossing behavior can be classified as single-stage, two-stage and rolling [12], [13]. It was observed on on-way roads, the number of pedestrians were greater for two-stage gaps. Whereas single-stage crossings were prevalent on two-way roads. In [16], it was concluded that pedestrian speed and crossing width was a deciding factor in a pedestrians embrace or refusal of gaps. There is a 2 s difference between lap and gap. Where Gap acceptance is actually the clear path available for the pedestrian to cross the road without any risk [12]. In [12], [13], models were developed to study the size of traffic gaps accepted according to pedestrian's demographic characteristics.

### B. SCOPE AND OVERVIEW

In this paper, pedestrian crossing behavior is analyzed on IJP (Inter Junctional Principle) main thoroughfare in Rawalpindi, Pakistan. This location is chosen because of the metro bus station, which is an attraction point for high pedestrian traffic. Though a pedestrian bridge is available, jaywalking is prevalent. The road width is 30 m, with video recorded from the top of the pedestrian bridge located on the road. The videos were recorded for three times a day over a period of 8 consecutive days and analyzed using Camlytics software. The objective of the study are following,

1. Pedestrians road crossing impact on vehicular flow, speed, density, traveling time and time headway in relation to number of pedestrians,
2. Pedestrians road crossing time and speed distribution according to pedestrian's age and gender,
3. Relationships between vehicular speed and density, speed and flow, vehicular flow and density were developed with and without pedestrian crossings.

The rest of this paper is organized as Section 2 presents research methodology. Results and discussions are detailed in Section 3, while conclusions are presented in Section 4.

## II. RESEARCH METHODOLOGY

For pedestrian crossing behavior analysis, IJP (Inter Junction Principle) road Rawalpindi, Pakistan is chosen. This road is chosen because it is a main thoroughfare running through Rawalpindi. The specific location for analysis is chosen because of Faizabad metro station, which results in high pedestrian traffic volume. Though a pedestrian bridge is present, a large number of pedestrians cross the 30 m wide road illegally. Roadside videos were recorded for 8 consecutive days from November 1st to 8th, 2020. Videos were recorded three times a day at 8 AM, 2 PM and 4 PM as the traffic volume is large. Each time a video of 1200 s was recorded. For pedestrian behavior analysis, a commercial traffic analysis software 'Camlytics' has been employed.

Camlytics software was used to detect vehicles and pedestrians crossing in the given section as can be seen in Figure 1. Travel time of both pedestrians and vehicles were calculated in this section. After knowing the time taken to cover the given distance then vehicular speed, density and flow were determined. The maximum speed was recorded as 45 km/h and the minimum speed was 3.94 km/h.

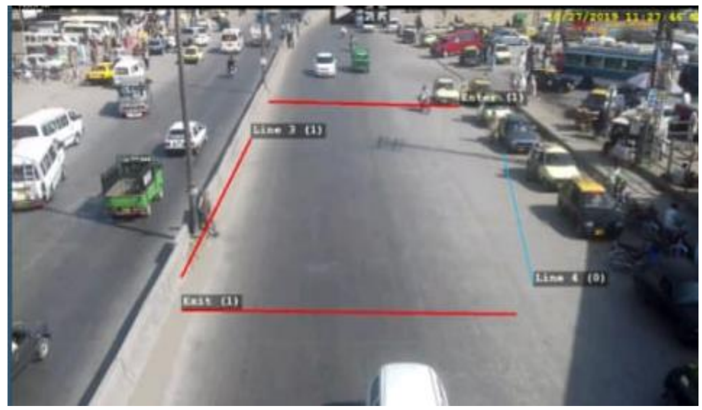


FIGURE 1: View of under observation IJP road in Camlytics Software.

Summary of all parameters considered for this case study have been summarized in Table 1.

TABLE 1: SUMMARY OF ALL PARAMETERS FOR THIS CASE STUDY.

| S. No | Parameter | Description |
|---|---|---|
| 1 | Data Collection Site | IJP Road Rawalpindi |
| 2 | Video recording interval | 1200 s |
| 3 | Section of the road considered | 30 m |
| 4 | Software used for data analysis | Camlytics, Excel |
| 5 | Maximum speed recorded | 45 km / h |
| 6 | Minimum speed recorded | 3.94 km / h |

## III. RESULTS & DISCUSSION

The elements that influence the pedestrians crossing are the age, gender, individual or group of pedestrians.

### 3.1 PEDESTRIAN ROAD WIDTH CROSSING TIME

Pedestrian crossing times are heavily influenced by pedestrian's age and gender as can be seen in Figure 2. On the under observation road, male child pedestrians on average take 4.2 s to cross the 30 m wide road as compared to female child pedestrian's mean time of 4.9 s. Thus female child pedestrian time to cross the under observed road is 16.6% higher that male child pedestrian.

For adult male pedestrians, the mean time for road crossing is 3.5 s, while for female pedestrians it is 4.1 s. Thus female pedestrians on average take 17% more time to cross the road. For male and female pedestrians above 50 years of age, respectively mean crossing time observed was 5.6 s and 6.1 s. Thus female pedestrians over 50 years take 9% more time on average than male pedestrians over 50 years.

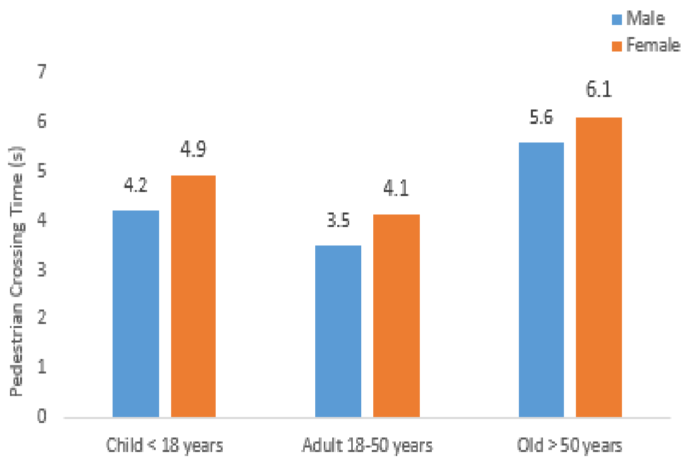


FIGURE 2: Different age of pedestrians traveling time over a 7.5 m wide road section at I.J.P road Faizabad

3.2 PEDESTRIAN CROSSING ROAD WIDTH SPEED

Speed is highly dependent on pedestrian's age and gender. As can be seen in Figure 3, the mean speed of male pedestrian's road crossing is highest with 2.2 m/s. The lowest mean speed 1.3 m/s is recorded for female pedestrians with age of above 50 years.

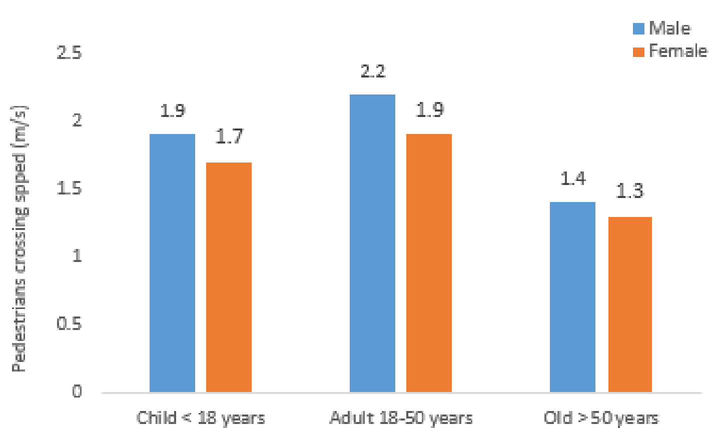


FIGURE 3: Pedestrians crossing speed over a 7.5 m wide road section at I.J.P road Faizabad.

The maximum speed for a male child pedestrian crossing the road is 1.9 m/s, while for females it was recorded at 1.7 m/s. For adult male, it is 2.2 m/s and 1.9 m/s for adult female pedestrians. While for male and female pedestrians over 50 years, it was recorded at 1.4 and 1.3 m/s respectively. The speed of the adult male pedestrian road crossing was 57% higher than old male pedestrian while the adult female pedestrian road crossing speed was 46% higher than old female pedestrian.

3.3 PEDESTRIAN CROSSING IMPACT ON DIFFERENT TYPES OF VEHICLES

Impact of jaywalking on vehicle speed varies depending upon vehicle types. Heavy vehicles are affected more as compared to the light vehicles. Figure 4 shows that the speed of two-wheelers in absence of pedestrians observed was 30.2 Km/h. This mean speed was reduced to 28.9 Km/h when pedestrians were crossing the road. While on the other hand, mean speed of heavy traffic (trucks, buses) was observed at 21.9 Km/h and 18.5 Km/h with and without pedestrian crossings respectively.

The mean speed drop with and without pedestrian crossings for two-wheelers, cars and heavy traffic were observed at 1.3 Km/h, 2.1 Km/h and 3.4 Km/h respectively. This represents an average speed drop of 7% and 8% for two-wheelers and cars, respectively. Thus substantiating that lighter traffic is more agile to adjusting with jaywalking and more prone to accidents.

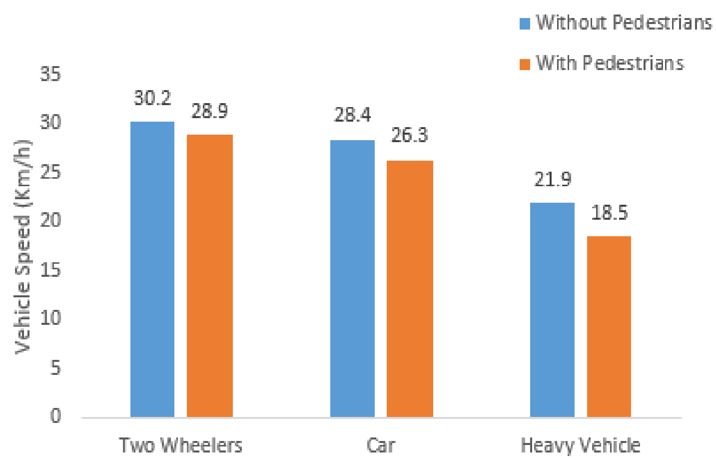


FIGURE 4: Effect of pedestrians on different types of vehicles at I.J.P road Faizabad

3.4 PEDESTRIAN CROSSING IMPACT ON VEHICULAR SPEED AND DENSITY

Impact of pedestrian crossings on vehicular speed and density can be observed in Figure 5. It is evident from observed data that with increase in number of pedestrians, vehicular speeds drop while vehicular density increases. When there are no pedestrians, traffic density is recorded at 50.6 veh/km with a mean speed of 17.6 km/h. For one pedestrian, the mean vehicular density and speed are observed at 51.2 veh/km and 16.91 Km/h respectively. In case of four pedestrians, the mean traffic density increased to 53.3 veh/km with mean speed of 14.6 Km/h.

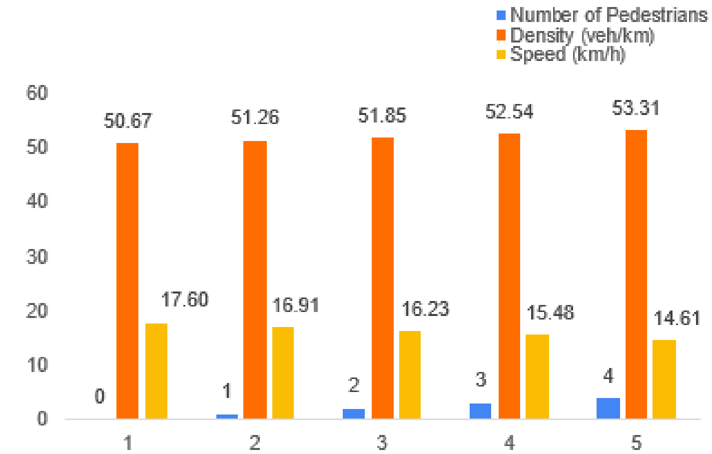


FIGURE 5: Effect of pedestrians on speed and density of the vehicles

3.5 PEDESTRIAN CROSSING IMPACT ON VEHICULAR SPEED AND FLOW

Impact of pedestrian crossings on vehicular speed and flow can be observed in Figure 6. As evident from Figure 6, in absence of pedestrian crossings the mean speed and flow is recorded at 15.72 km/h and 444 veh/h respectively. While when 1 pedestrian is crossing the road the mean average speed and flow are reduced to 15.17 km/h and 443.78 veh/h respectively. Thus an overall reduction of 3.5% is noted for vehicular speed as compared to the speed in the absence of the pedestrians.

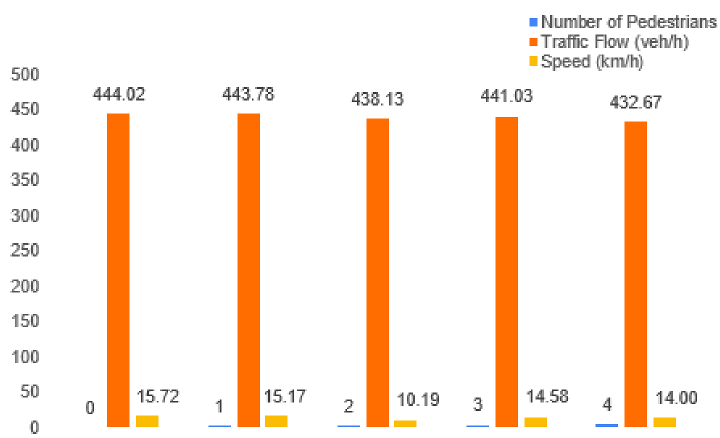


FIGURE 6: Effect of pedestrian on speed and Traffic flow

When two pedestrians are attempting to cross the road, average speed and flow are observed at 10.19 km/h and 438 veh/h respectively. This is a further reduction of 32.8% in speed when compared to when one pedestrian was crossing the road. For three pedestrians crossing the road average speed is 14.58 km/h and the flow is 441 veh/h. For four pedestrians in the section the mean speed is 14 Km/h while the mean flow is 432 veh/h. A decrease of 4 % as compared to when three pedestrians were crossing the road.

3.6 PEDESTRIAN CROSSING IMPACT ON VEHICULAR DENSITY AND FLOW

Linear relationship has been observed between the number of pedestrians while crossing and vehicular density and flow. As can be seen in Figure 7, in absence of pedestrian crossing mean vehicular density and flow are recorded at 78 veh/km and 628 veh/h respectively. Both mean vehicular density and flow increased to 83 veh/km and 632 veh/h respectively when four pedestrians were crossing the road.


FIGURE 7: Effect of pedestrian on density and flow

3.7 PEDESTRIAN CROSSING IMPACT ON VEHICLE'S TRAVELING TIME

Impact of pedestrian crossing on time a vehicle takes to cross under observation road section can be seen in Figure 8. Pedestrians have a direct effect on the travelling time of the vehicles. In the absence of pedestrians, the vehicles take a small time to cover the section, while in the presence of pedestrian the time taken by the vehicles to travel the section is increased.

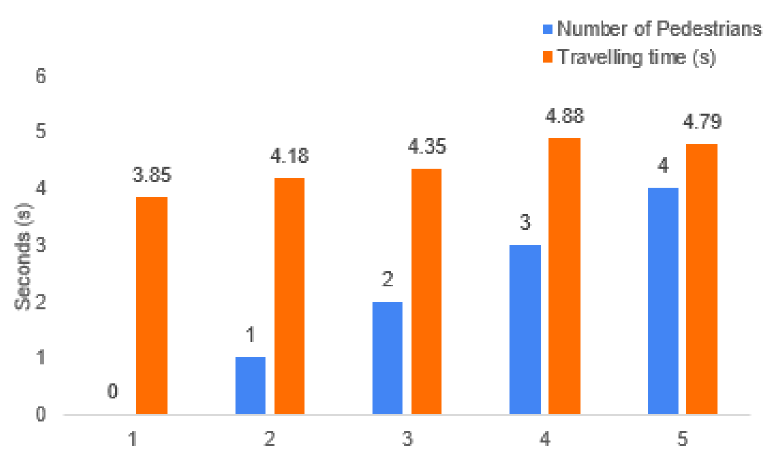


FIGURE 8: Effect of pedestrian on travelling time of vehicles

When there is no pedestrian crossing, the average vehicle takes about 3.8s to cross the under observation road section. For one, two, three and four pedestrians crossing the under observation road section, the average time a vehicle takes to cross the road are 4.17, 4.34, 4.88 and 4.78 s respectively. The percentage time increase calculated 9.7%, 4% and 12.4% with every single increase in pedestrian number respectively. The time headway has a quadratic relation with the speed. Time headway at 2 m/s is 291 % larger than time headway at 40 m/s.

3.8 PEDESTRIAN CROSSING IMPACT ON VEHICULAR FLOW

In order to analyze pedestrian crossing impact on vehicular flow characteristics different parameters were measured. These parameters range from individual vehicle type and speed, and overall vehicular flow, speed and density. Relationships between vehicular speed and density, speed and flow, vehicular flow and density were developed with and without pedestrian crossings as can be seen in Figure 9, 10 and 11 respectively. These calculations produced a straight-line relationship between traffic speed and density. While a quadratic relationship between traffic speed and flow, and traffic density and flow. It can be deduced that whenever there is a drastic change in traffic flow characteristics, it implies that drivers are giving more space to jaywalking pedestrians.

As is evident from Figure 9, there is a linear relationship between vehicular speed and density. Vehicular speed is maximum when density is almost zero, meaning there is no disturbance. On the other hand vehicular speed approaches zero at a jam density as can be seen in Figure 9.

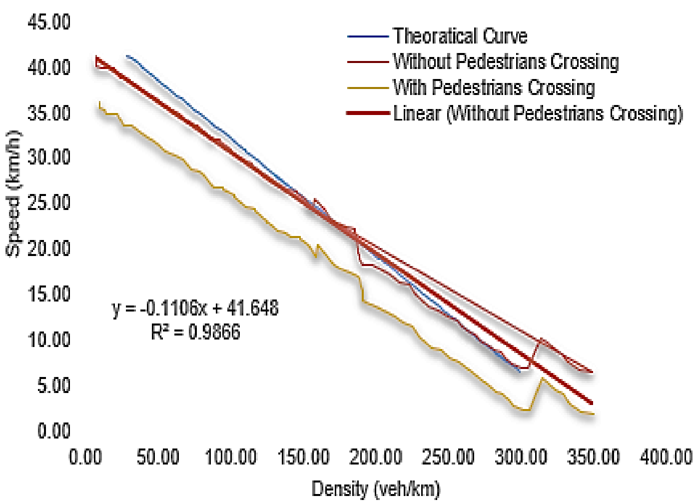


FIGURE 9: Speed and density relationship theoretical, with and without pedestrians

Figure 9 shows that the vehicle's speed with no pedestrian is approximately the same as the theoretical speed (Greenshield) [14]. There is a small difference in speed at 50 veh/km, which reduces to zero at 200 veh/km. However with pedestrians crossing the road width, approximately a uniform difference of 5 km/h has been observed between theoretical and observed speed distributions. When there are no pedestrians present on the road, maximum speed is 41.28 km/h which occurs at 7.60 veh/km as shown in Figure 9. When traffic density increases to 350 veh/km, speed reduces to 5.52 km/h. With pedestrian crossing the road width, maximum and minimum speed of 36.18 and 2.5 km/h are observed at 2.59 and 348.71 veh/km, respectively.

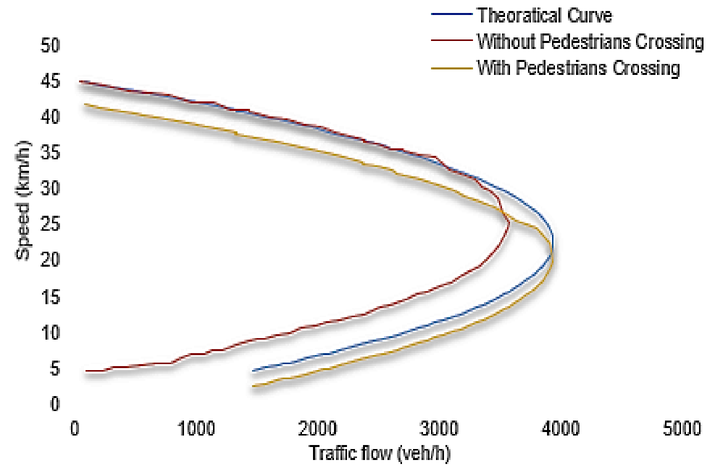


FIGURE 10: Flow vs speed relationship theoretical, with and without pedestrians

Vehicles traffic flow is 45.8 veh/h at 44.7 Km/h when there are no pedestrians present on the road width. The maximum flow is 3535 veh/h at 23.4 km/h, which is a critical flow. As the speed decreases from 23.4 km/h to 4.96 km/h, the flow is reduced to 93.3 veh/km. The critical flow is 3931 veh/km at 21.78 km/h with Greenshield relation (theoretical). When there are no pedestrians on the road width, flow is 82 veh/h at a faster speed of 44.7 km/h. When pedestrians are crossing the road wdth, the flow is 79 veh/h at 41.66 km/h. The maximum flow is 3931 veh/h at 19.68 Km/h. A larger critical density occurs with pedestrians present on the road section and is the same with theoretical critical density. However, when pedestrians are not present on the road width, the critical density is smaller.

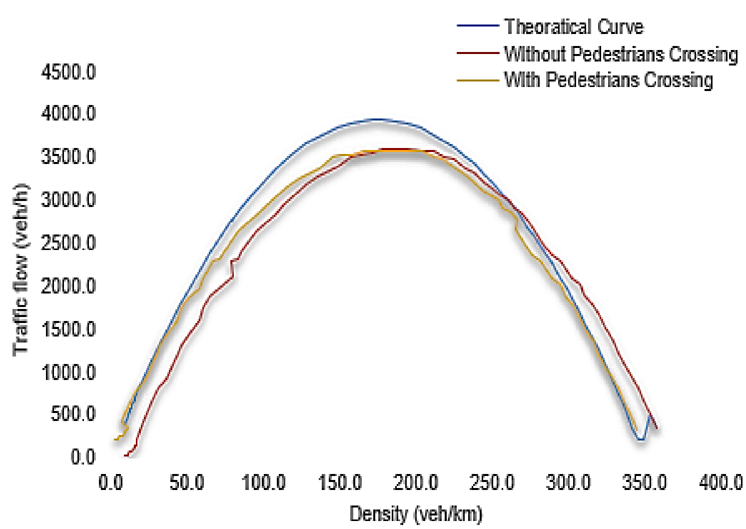


FIGURE 11: Flow vs density curve theoretical, with and without pedestrians

Fundamental flow-density relation is shown in Figure 11. Without the presence of pedestrians on the road, flow is 22.7 veh /h at 9.13 veh/km. Critical flow is 3575 veh/h at critical density of 211 veh/km. After critical density (211 veh/km), flow from critical flow reduces to 670 veh/h at 350 veh/km. For the theoretical Greenshield relation, the flow at 9.1 veh/km is 400 veh/h. The maximum flow is 3920 veh/h at 186 veh/km. For the pedestrians crossing the road width, the flow is 320 veh/h at 10 veh/km. The maximum is 3580 veh/h at 187 veh/km.

### 3.9 TIME HEADWAY AND VEHICULAR SPEED

Relationship between time headway and vehicular speed can be observed in Figure 12. At recorded vehicular speed of 1.06 m/s, maximum time headway was noted at 6.34 s. However as mean vehicular speed increases to 39.6 m/s, a drastic reduction in time headway is observed at 1.1 s.

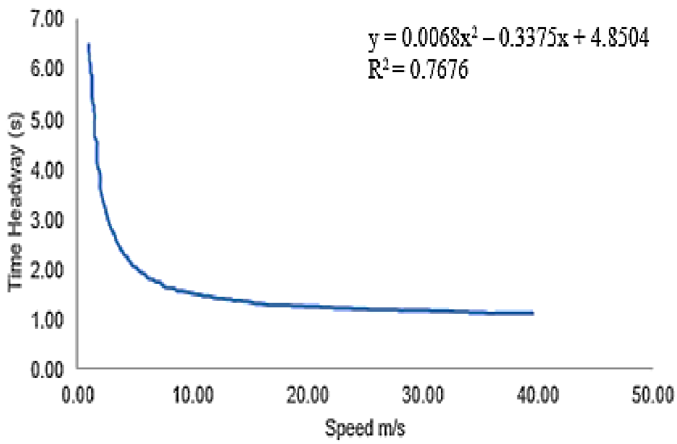


FIGURE 12: Time Headway and the corresponding traffic speed relation over a 7.5 m wide I.J.P road Faizabad

## IV. CONCLUSION

In this work, a case study has been conducted to quantify the impact of pedestrian's crossings on vehicular flow, speed and density. In this context a main arterial thoroughfare, IJP road Rawalpindi, Pakistan was chosen. Roadside videos were recorded three times a day for eight consecutive days. Each time, the duration of recorded roadside video was 1200 s. For traffic analysis, a commercial traffic analysis software 'Camlytics' was employed. Using Camlytics, pedestrian's road width crossing time and speed, and their impact on different types (two-wheelers, cars and heavy vehicles) of vehicles was analyzed according to the pedestrian's age and gender. Furthermore, pedestrian's crossing impact on vehicular flow, speed, density and 30 m road section crossing time were analyzed. Relationships between pedestrian's crossings and vehicular flow, speed and density were developed.

In the undertaken study, relationship between road crossing parameters (such as time and speed) and pedestrian's age and gender (such as male/female child, male/female adult, male/female old pedestrian) were developed. The least road crossing time and speed was recorded for female old pedestrian at 6.1 s at 1.9m/s. Pedestrian's crossings impact on different types of vehicles (such as motorcycles, cars and heave vehicles) were quantified. Least affected were motorcycles, whose average speed with and without pedestrians were recorded at 28.9 and 30.2 km/h respectively. Impact of number (one, two, three and four) pedestrians on traffic flow and density were observed. Traffic speed and flow observed in presence of no (15.72 km/h, 444 veh/h) one (15.17 km/h, 443 veh/h), two (10.19 km/h, 438 veh/h), three (14.58 km/h, 441 veh/h) and four (14 km/h, 432 veh/h) pedestrians respectively. It is concluded that reduction in flow, speed and increase in vehicular density is not significant as the vehicles do not come to a complete axle zero stop. This is because most of drivers ignore pedestrian presence thus increasing the probability of traffic accidents. The speed distribution in the presence of pedestrians follows an inverse linear relationship with the density. However, vehicular speed observed in the presence of pedestrians is smaller when compared with Greenshield speed distribution characterization. While with no pedestrians present, the speed distribution is identical to Greenshield distribution. However, there is an increase in speed when the flow is congested, and speed is not zero. Furthermore, recorded time headway at 2 m/s is 291% higher than time headway at 40 m/s thus giving quadratic relationship between time headway and vehicular speed. While distance headway with 360% higher at 7m/s as compared at 31 m/s, generate a linear relation between distance headway and vehicular speed.

For future, we plan to study pedestrian crossings on multiple road sections to further validate results of this study.


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