Study the impact of railway crossing severity on the traffic characteristics

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Abstract: The surfaces of the road must not be contain undesired condition such as loose aggregates, potholes, cracking, rutting, bad railway crossing which the quality of road service and indeed the quantity of traffic provided would be reduced significantly. The main purpose and objectives of the present study are to measure traffic volume and speed under control condition and then evaluating them under adverse condition of railway crossing with different severity: low, medium, and high. In the present study, traffic and speed were recorded. Greenshields model is adopted to find the relationship between the traffic characteristics. The results show that the traffic characteristics of the control section were 86.86 (Km/h) and 1592 (vph) for speed and traffic flow, respectively. The impact of the railway crossing on the traffic can be summarized, where the speed reduced to 28.8%, 46.27%, and 70.57% for low, medium, and high railway crossing severity, respectively. Finally, the models for traffic capacity; speed with pavement condition index PCI have been found. The predicted models have a good correlation between traffic capacity; speed with PCI where the correlation coefficient ($R^2$) was greater than 0.9.

Keywords: Traffic Characteristics; Pavement Condition; Railway crossing; Greenshields Model

1. Introduction
Adverse conditions such as traffic congestion, inclement weather [1][2] and pavement distress among others have significant impacts on vehicle speed and traffic flow. With respect to motorist, they limit visibility [3], vehicle control, surfacing grip, driving comfort and also increase vehicle operating costs [4][5][6]. In addition, they are source of extra maintenance and safety costs to road providers [7][8]. Three primary measures namely flow, speed and density characterize the operational state of any given traffic stream. For the purpose of measuring quantity, the parameters, density and flow are important, whereas speed and flow are often relied on for measuring quality of road service [9]. Flow ($q$) can be determined by:

$$q = \frac{n \times 3600}{T} \text{ (vph)}$$  

(1)

Where:
$n = \text{Number of vehicles crossing a point in T sec. and,}$
$q = \text{Equivalent hourly flow.}$

The general equation regarding traffic flow, density, and space can be used:

$$\text{Flow} = \text{density} \times \text{speed} \quad (q = k \times \bar{v})$$  

(2)

Each of the variables in Eq. (2) also depends on several other factors including the characteristics of the roadway, characteristics of the vehicle, characteristics of the driver, and environmental factors such as the weather (e.g. rainfall, wind).
Regarding traffic flow relationships, it can be mathematically grouped into two general classifications; macroscopic and microscopic counting on the style used in the evolution of these relationships [10]. The two main familiar used models in term the macroscopic relationship are the Greenberg models and Greenshields. Pavement distress measurements are usually taken in literatures as percentage of affected area relative to road section with particular attention on sizes, numbers and depth of the distress. Studying the effect of distress on the traffic characterize are limited, especially the effect of railway crossing defects. For example, Ben-Edige (2010) [11] studied the effect of adverse pavement condition on traffic characteristics. The author found out the rutting distress on the traffic flow and the speed. The results stated that a significant reduction in speed and traffic flow up to 50% and up to 20% resulted from adverse road surface condition, respectively. Wang et al. (2014) [12] investigated the effect of improvements in pavement roughness on driving performance regarding speed. The results stated that the pavement roughness has a slightly effect on free-flow speed. A change in international roughness index (IRI) of 1 m/km led in a reduction in average free-flow speed of about 25%. Al-Obaedi, (2019) [13] investigated the impact of speed hump on the U-turn traffic. He showed that the time spent of the merging traffic is clearly decreased when building speed humps. The literatures show a gap in knowledge in terms the impact of the railway crossing on the traffic flow and speed.

2. Objectives of the Research
Railway crossing defects considered as a distress effects on the traffic flow characteristics and may increase the accidents. The objective of the present study is to determine the effects of the railway crossing and its severity on the speed and traffic flow.

3. Methodology
3.1 Study Area
The study area is located near the International Iraqi Railway Station. 14th Tamuze Street that joins Aden intersection and Al Alawi Terminal station has a several railway crossings, which considered as adverse pavement condition. Such condition can effect on the traffic serviced in the above street. In addition to the adverse pavement condition, normal pavement condition without distresses was selected. The locations of the selected railways crossing (RC) and the normal section are shown in Figure 1.

![Figure 1 Study Area and Location of the Selected Railway Crossing](image)

14th Tamuze Street has four lanes with width of 3.5m. The distances between the railways crossing were manually measured. The distances are RC1 to RC2 =683m, RC2 to RC3=465m, and RC3 to Normal section =695. The reason of measuring the distances between railway crossings is to evaluate the mutual impact of each one on the other if found. At the same time, the observed average free flow speed of 90 km/h (design speed at normal section) was adopted in the study. Then, the acceleration and deceleration sight distances of motorists were estimated using Eq. (3) and Eq. (4), respectively. The results show that the distance for acceleration and deceleration are 223m and 110 m, respectively. The
total distance to reach 90 km/h and then dropped to zero is (333m). The distances between railway crossings are greater than the minimum required distance. Thus, there is no mutual impact.

\[
S = 0.385 \times a_1 \times V \\
B = 0.278V + 0.01V/a_2
\]

Where:
- \(S\) = Acceleration distance;
- \(B\) = Stopping sight distance, (m) and,
- \(V\) = Design speed, (km/h);
- \(a_1\) = Driver acceleration, 1.4 (m/s^2) and,
- \(t\) = Brake reaction time, 2.5s and,
- \(a_2\) = Driver deceleration, 3.4 (m/s^2).

### 3.2 Railway Crossing Severity and PCI

The type and railway severity level were determined using ASTM D6433 [14]. The inspector should drive at the normal operating speed and standard car. The severity can be determined according to speed reduction at railway crossing, where for low severity there is noteworthy, but no decrease in speed is necessary for safety or comfort. For medium severity, vibrations of the vehicle are considerable and some decrease in speed is necessary for safety and comfort. On the other hand, vehicle vibrations are too much that speed must be decreased considerably for safety and comfort, where it can be considered as high severity railway crossing. For calculating the pavement condition index (PCI), prepared charts [14] can be used. The charts depend on the railway crossing severity by which the PCI is found.

### 3.3 Flow and Speed Recording

Video recordings style was adopted to collect the data needed for estimating traffic flow (see Figure 2). Speed radar “Bushnell Speedster III” was used (Figure 2) which is better than using video recording for estimating speed. The use of such device in estimating of speeds provides more reliable results than the estimating of speeds from video recordings. The used speed gun device provides speed measurements with an accuracy of ±1 mi/hr for collecting the desired speed data [15]. In addition to the standard speed radar that mentioned above, smart phone technique to estimate the low speed was adopted in the present study. This technique can be used to measure the speed depending on the vertical distance between the moving bodies (e.g. car) and the observer (Figure 3).

![Figure 2 Video Recording and Speed Spot Recorder](image1)

![Figure 3 Smart Phone Technique for Measuring Speed](image2)
Before starting measuring the speed in the field, calibration between standard speed gun (radar), smartphone and real speed of the car (specified car) were achieved. The results show that the smartphone technique could be used especially with speed less than 20 Km/h (e.g. at railway with high severity).

4. Results and Discussions

4.1. Effect of railway crossing on PCI

Ride quality was evaluated in order to establish a severity level for the selected railway crossing (RC). The results show that the selected RCs have a different severity. In addition, the pavement condition index (PCI) was calculated (Section 3.2) for each railway and the control section according to ASTM D6433 [14] as shown in Table 1.

| Location    | Ride quality (Severity) | PCI |
|-------------|--------------------------|-----|
| Control section | NO                       | 100 |
| RC1         | High                     | 20  |
| RC2         | Low                      | 80  |
| RC3         | Medium                   | 50  |

4.2. Impact the Railway Crossing Severity

The data of traffic volume and spot speed were collected for all four locations; control section, RC1, RC2, and RC3. The observed and Greenshields models for speed-density relationship, speed-traffic flow were drawn. Figures (4) show the results of the above models for the control section. The models for railway crossing (RC2); low severity level are shown in the Figures (5). At RC2, the results indicate that the speed reduced from 86.86 (Km/h) (speed at control section) to 61.86 (Km/h) which is equal to a reduction in speed around 28%. In addition, the traffic flow were 1592 (vph) and 1134 (vph) for control section and RC2, respectively.

![Figure 4](image1.png)  
**Figure 4.** The Observed and Fitted (Greenshields Model) Relationship; (A) Speed-Density, (B) Traffic Flow-Speed Relationships for Control Section.

![Figure 5](image2.png)  
**Figure 5.** The Observed and Fitted (Greenshields Model) Relationship; (A) Speed-Density, (B) Traffic Flow-Speed Relationships for RC2 (PCI 80).
Figures (6) show the effect of railway crossing of medium severity on the traffic, speed and density. These figures show that the free flow speed reduced to 46.67 (Km/h) and flow rate also reduced to 878 (veh./h).

At the railway crossing with high severity, the pattern of the traffic speed relationship is changed. Due to the impact of this type of crossing, the traffic flow tends to increase with increasing speed until reach capacity. Figures (7) show the effect of high severity railway crossing on the traffic characteristics. They show that the maximum speed can be reached to 25.56 (km/h) with corresponding traffic flow of 432 (veh./h).

![Figure 6. The Observed and Fitted (Greenshields Model) Relationship; (A) Speed-Density, (B) Traffic Flow-Speed Relationships for RC3 (PCI 50).](image)

![Figure 7. The Observed and Fitted (Greenshields Model) Relationship; (A) Speed-Density, (B) Traffic Flow-Speed Relationships for RC1 (PCI 20).](image)

4.3. Modeling the Traffic Flow and Speed with PCI

The relationship between the predicted traffic capacity; speed verses pavement condition index (PCI) were determined using Excel software (Figure 8). Figure (8) shows a high correlation coefficient $R^2$ values (0.97) specify that there is a good agreement between traffic capacity and pavement condition index. Analysis of Variance (ANOVA) is usually used as a primary estimation tool to evaluate the degree of influence of the studied parameters on the test (Table 2).

In Table (2), p-values are 0.015 and 0.014 which indicate that the parameter and model are significant (model and term p-value < 0.05 indicate the model and the term are significant for 95% confidence intervals) for evaluating the value of responses.
Figure 8. Traffic Capacity and Speed Verses PCI

Table 2. Analysis of Variance for Traffic Capacity and Speed with PCI

| Source          | DF | SS    | MS   | F    | P   | Source          | DF | SS    | MS   | F    | P   |
|-----------------|----|-------|------|------|-----|-----------------|----|-------|------|------|-----|
| Speed Versus PCI|    |       |      |      |     | Volume Versus PCI|    |       |      |      |     |
| Regression      | 1  | 1940.02 | 1940.02 | 66.92 | 0.015 | Regression      | 1  | 1685998.685998 | 69.98 | 0.014 |
| Error           | 2  | 57.98  | 28.99 |      |     | Error           | 2  | 19606 | 9803  |      |     |
| Total           | 3  | 1998.00 |      |      |     | Total           | 3  | 3705604 |      |      |     |

5. Conclusions
In the present study, efforts were made to evaluate of railway effects on the traffic characteristics, where three types of crossing severity were selected in addition to control section. The following conclusions were drawn:

The traffic characteristics of the control section were 86.86 (Km/h) and 1592 (vph) for speed and traffic capacity, respectively. For low severity railway crossing, the speed reduced to be 61.86 (Km/h) and with maximum traffic capacity of 1134(vph). Furthermore, same trend has been occurred at railway crossing of medium severity, where the speed was 46.67 (Km/h) and traffic capacity 878 (veh./h). Dramatically dropped in speed and traffic capacity were found at the railway crossing with high severity, the pattern of the traffic speed relation-ship was changed. The maximum speed can be reached to 25.56 (km/h) with corresponding traffic capacity of 432 (veh./h). Finally, predicted model for traffic capacity and speed show a significant correlation with PCI where the correlation coefficient $R^2$ was greater than 0.9.

6. Acknowledgment
The authors would like to thank the Mustansiriyah University, College of Engineering, Highway and Transportation Department for their support and help to accomplish this modest work contained in this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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