A Study of Pedestrian Traffic Safety at Three-leg Unsignalized Intersections

Asst. Prof. Dr Sahar S. Neham  
Al-Furat Al-Awsat Technical University, Kerbalaa Technical Institute  
Naham_1969@yahoo.com  +964(0)7802143934

Abstract. The damage caused by vehicle-pedestrian traffic accidents is no less than that caused by vehicle-vehicle traffic accidents in terms of the health, economic, psychological, and social effects on both individuals and the community, especially in urban areas. However, poor reporting of pedestrian crashes causing injury and fatality to traffic officials has created a loss of authenticity in the data on pedestrian traffic accidents, thus necessitating study of the causes of these incidents to help inform developments in pedestrian traffic safety. This research uses a sustainable strategy to examine traffic conflicts or "near-crash" scenarios to study pedestrian traffic safety rather than waiting for traffic accidents to happen. Data on six types of pedestrian traffic conflict were collected at selected sites in Baghdad, Karbala, and Babylon based on a case study of three-legs unsignalized intersections. The results showed that the third type of pedestrian traffic conflict (PC3) was the most dangerous in terms of the value of Severity Rate, particularly in approach No.16 in the city of Karbala. The developed models also showed that exponential relationships offer explanations of the relationships between hourly pedestrian traffic conflict/approaches and pedestrian delays or conflict, with the coefficient of determination for these ranging between 0.7133 and 0.8966.

Keywords: pedestrian traffic safety, Sustainable Strategy, Pedestrian Rick Index (PRI), Traffic Conflict and Severity Rate (SRPC).

1. Introduction

In 1968, the concept of traffic technology was introduced for the first time in the International Co-operation on Theories and Concepts in Traffic Safety (ICTCT) meeting in Oslo. [1] concluded that traffic safety at four leg-signalized intersections could be efficiently evaluated by using traffic conflict techniques, and [2] confirmed the possibility of evaluating pedestrian traffic safety by relying on short periods of collection for pedestrian conflict traffic data; based on such investigations by previous researchers, for every 3000 conflicts there is at least one pedestrian traffic accident. From 2007 to 2013, 26% of pedestrians involved in incidents were injured and 13% were killed at unsignalized intersections [3], [4] thus studied 775 pedestrian behaviours at signalized intersections and noted that many factors affect pedestrian safety, including gender, speed, vehicle type, and suitable gap; a suitable model was thus developed for the relationship between pedestrian delay and traffic conditions. The probability and sequences of pedestrian accidents were estimated by [5], and a Pedestrian Risk Index developed to improve pedestrian safety, while [6] presented a methodology to evaluate pedestrian safety levels on crossings using a composite index. Pedestrian fatalities and total number of fatalities were reduced by 36% and 41% respectively from 2007 to 2016 in the European Union (excluding Lithuania and Slovakia) due to improvements in road and pedestrian traffic safety [7], though pedestrian collision data shows that they are still in more danger from turning vehicles than straight traffic [8]. [9] further explored factors influencing pedestrian traffic safety, including drivers, pedestrians, the environmental conditions, and traffic features, while [10]
developed a Linear Model relating traffic and pedestrian volumes and pedestrian accidents to develop an estimated Relative Risk Index for pedestrians.

2. Research objectives
The main objectives of this study are to
1. Evaluate pedestrian traffic safety using a sustainable strategy, the pedestrian-vehicle traffic conflict technique at three-leg unsignalized intersections;
2. Develop a model that relates pedestrian traffic conflict and the time taken to cross the approach (Pedestrian Delay) for three-leg unsignalized intersections;
3. Develop a model that relates pedestrian traffic conflict and pedestrian traffic volume at three-leg unsignalized intersections;
4. Determine the Severity Rate for Pedestrian Conflicts (SRPC); and
5. Estimate the value of Pedestrian Risk Index (PRI) for three-leg unsignalized intersections as an indicator for those interested in pedestrian traffic safety in terms of the future planning and design of traffic intersections.

3. Data Collection and Strategy
Baghdad, Karbala and Babylon were selected for this case study (see Figure 1 (a-c)) examining pedestrian traffic safety using the pedestrian-vehicle traffic conflict technique in order to estimate their respective Pedestrian Risk Index (PRI) values.
Filming took place from Sunday to Thursday during the morning peak period from 9 to 11 am and from 1 to 3 pm; the number of pedestrian conflicts, pedestrian conflict types, pedestrian volume, traffic volume, traffic distribution, and pedestrian delay (from the moment a pedestrian is ready to cross the intersection to the moment they can move without encountering vehicles) were recorded.
Table (1) describes the hourly pedestrian and traffic volume sequentially, while Figure (2) explains the pedestrian conflict types studied. Table (2), Table (3), and Table (4) show summaries of traffic distribution, hourly pedestrian conflict types, and pedestrian delays as recorded at all selected intersections.

Figure 1a. Studied Intersections in Baghdad.
Figure 1.b. Studied Intersections in Babylon.

Figure 1.c. Studied Intersections in Karbala.

Table 1. Hourly pedestrian and traffic volume for studied intersections.

| City     | In. No.* | App. No.** | HPV*** | HTV**** |
|----------|----------|------------|--------|---------|
| Baghdad  | 1        | 1          | 256    | 1995    |
|          | 2        | 2          | 301    | 2154    |
|          | 3        | 3          | 366    | 1856    |
|          | 4        | 4          | 132    | 1273    |
|          | 5        | 5          | 283    | 1956    |
|          | 6        | 6          | 301    | 2104    |
|          | 7        | 7          | 322    | 2480    |
|          | 8        | 8          | 322    | 1676    |
|          | 9        | 9          | 270    | 1789    |
|          | 10       | 10         | 218    | 1590    |
|          | 11       | 11         | 376    | 1973    |
|          | 12       | 12         | 226    | 1575    |
| Karbala  | 13       | 13         | 116    | 1356    |
|          | 14       | 14         | 311    | 2184    |
|          | 15       | 15         | 202    | 1498    |
|          | 16       | 16         | 351    | 2403    |
|          | 17       | 17         | 344    | 2373    |
|          | 18       | 18         | 66     | 965     |
| Babylon  | 19       | 19         | 162    | 1657    |
|          | 20       | 20         | 338    | 2089    |
|          | 21       | 21         | 110    | 1230    |
|          | 22       | 22         | 158    | 1465    |
|          | 23       | 23         | 186    | 1356    |
|          | 24       | 24         | 137    | 1269    |

*Intersection Number; **: Approach Number; ***: Hourly Pedestrian Volume and ****: Hourly Traffic Volume
Figure 2 Pedestrian Conflict Types.
### Table 2. Hourly Traffic distribution.

| City  | In. NO.* | Hourly Traffic distribution ** | In. NO.** |
|-------|----------|-------------------------------|-----------|
|       |          | PC  | B   | T   | MC | OT |
| 1     | 1        | 1400| 290 | 198 | 97 | 10 |
| 2     | 2        | 1498| 324 | 195 | 85 | 52 |
| 3     | 3        | 1288| 281 | 164 | 74 | 49 |
| 4     | 4        | 866 | 211 | 117 | 56 | 23 |
| 5     | 5        | 1424| 265 | 179 | 75 | 13 |
| 6     | 6        | 1488| 273 | 184 | 85 | 74 |
| 7     | 7        | 1598| 298 | 289 | 92 | 203|
| 8     | 8        | 1088| 240 | 150 | 84 | 114|
| 9     | 9        | 1134| 276 | 163 | 73 | 143|
| 10    | 10       | 1075| 232 | 144 | 78 | 61 |
| 11    | 11       | 1296| 289 | 179 | 71 | 138|
| 12    | 12       | 997 | 253 | 137 | 68 | 120|
| 13    | 13       | 595 | 125 | 57  | 445| 134|
| 14    | 14       | 994 | 178 | 68  | 658| 286|
| 15    | 15       | 767 | 136 | 43  | 454| 98 |
| 16    | 16       | 1271| 257 | 49  | 712| 114|
| 17    | 17       | 1164| 185 | 56  | 701| 267|
| 18    | 18       | 1001| 170 | 49  | 609| 260|
| 19    | 19       | 1198| 189 | 45  | 153| 72 |
| 20    | 20       | 670 | 106 | 50  | 104| 35 |
| 21    | 21       | 895 | 119 | 25  | 118| 73 |
| 22    | 22       | 999 | 142 | 55  | 127| 142|
| 23    | 23       | 864 | 185 | 54  | 126| 127|
| 24    | 24       | 871 | 144 | 38  | 115| 101|

### Table 3. Hourly pedestrian conflict.

| City  | In. NO.* | Hourly Pedestrian Conflict Types Studied*** | App. NO.** |  
|-------|----------|--------------------------------------------|------------|
|       |          | PC1 | PC2 | PC3 | PC4 | PC5 | PC6 | PC7 |
| 1     | 1        | 11  | 8   | 20  | 7   | 5   | 3   | 54  |
| 2     | 2        | 16  | 12  | 28  | 9   | 8   | 5   | 78  |
| 3     | 3        | 16  | 12  | 27  | 10  | 8   | 6   | 79  |
| 4     | 4        | 6   | 4   | 13  | 3   | 2   | 3   | 31  |
| 5     | 5        | 9   | 9   | 20  | 8   | 6   | 5   | 57  |
| 6     | 6        | 12  | 11  | 20  | 8   | 6   | 5   | 62  |
| 7     | 7        | 16  | 13  | 28  | 10  | 9   | 5   | 81  |
| 8     | 8        | 14  | 10  | 24  | 8   | 7   | 5   | 68  |
| 9     | 9        | 10  | 8   | 22  | 5   | 5   | 4   | 54  |
| 10    | 10       | 7   | 7   | 19  | 4   | 5   | 3   | 48  |
| 11    | 11       | 20  | 11  | 27  | 10  | 7   | 6   | 81  |
| 12    | 12       | 9   | 7   | 18  | 4   | 5   | 3   | 46  |
| 13    | 13       | 6   | 5   | 16  | 2   | 1   | 2   | 32  |
| 14    | 14       | 9   | 9   | 26  | 6   | 6   | 6   | 62  |
| 15    | 15       | 9   | 7   | 14  | 7   | 5   | 3   | 45  |
| 16    | 16       | 25  | 15  | 31  | 11  | 11  | 11  | 104 |
| 17    | 17       | 14  | 11  | 18  | 10  | 8   | 11  | 72  |
| 18    | 18       | 3   | 5   | 5   | 2   | 3   | 2   | 20  |
| 19    | 19       | 8   | 5   | 17  | 4   | 4   | 6   | 44  |
| 20    | 20       | 11  | 13  | 24  | 11  | 8   | 9   | 76  |
| 21    | 21       | 4   | 4   | 7   | 2   | 1   | 2   | 20  |
| 22    | 22       | 10  | 6   | 15  | 5   | 3   | 2   | 41  |
| 23    | 23       | 5   | 5   | 14  | 4   | 3   | 3   | 34  |
| 24    | 24       | 5   | 5   | 11  | 4   | 2   | 3   | 30  |

---

* Intersection Number, **: Approach Number; PC: Passenger Car; B: Bus; T: Truck; MC: Motorcycle and OT: Other

---

* Intersection Number; **: Approach Number; ***: pedestrian conflict types explained in Figure (1).
Table 4. Average Pedestrian delay (s) / Conflicts types

| City      | In. No.* | App. No.** | AP(D/C1) | AP(D/C2) | AP(D/C3) | AP(D/C4) | AP(D/C5) | AP(D/C6) | AP(D/CT) |
|-----------|----------|------------|----------|----------|----------|----------|----------|----------|----------|
| Baghdad   | 1        | 1          | 88       | 70       | 119      | 79       | 54       | 54       | 464      |
|           | 2        | 102        | 72       | 123      | 90       | 66       | 57       | 510      |
|           | 3        | 111        | 88       | 104      | 97       | 72       | 60       | 532      |
|           | 4        | 72         | 53       | 102      | 60       | 47       | 39       | 373      |
|           | 5        | 93         | 74       | 115      | 77       | 60       | 54       | 473      |
|           | 6        | 102        | 76       | 119      | 85       | 66       | 54       | 502      |
|           | 7        | 111        | 80       | 122      | 97       | 73       | 73       | 556      |
|           | 8        | 102        | 78       | 117      | 83       | 66       | 54       | 500      |
|           | 9        | 88         | 72       | 123      | 72       | 54       | 53       | 462      |
|           | 10       | 97         | 60       | 121      | 77       | 60       | 47       | 462      |
|           | 11       | 115        | 85       | 121      | 93       | 77       | 60       | 551      |
|           | 12       | 77         | 56       | 111      | 70       | 54       | 47       | 415      |
|           | 13       | 66         | 39       | 111      | 47       | 30       | 35       | 328      |
|           | 14       | 88         | 72       | 120      | 77       | 68       | 60       | 485      |
|           | 15       | 77         | 66       | 104      | 76       | 54       | 46       | 423      |
|           | 16       | 102        | 86       | 125      | 97       | 72       | 54       | 536      |
|           | 17       | 111        | 83       | 112      | 88       | 72       | 75       | 541      |
|           | 18       | 54         | 47       | 83       | 47       | 50       | 40       | 321      |
| Karbala   | 19       | 83         | 66       | 109      | 68       | 54       | 58       | 438      |
|           | 20       | 119        | 77       | 118      | 95       | 66       | 68       | 543      |
|           | 21       | 60         | 39       | 96       | 54       | 30       | 33       | 312      |
|           | 22       | 77         | 54       | 109      | 60       | 54       | 39       | 393      |
|           | 23       | 75         | 52       | 88       | 68       | 47       | 47       | 377      |
| Babylon   | 24       | 54         | 47       | 103      | 60       | 39       | 37       | 340      |

*: Intersection Number, **: Approach Number, ***:AP(D/C): Average Pedestrian (Delay / Conflicts types) (s)

4. Traffic Distribution
Figures (3-a) to (3-c) show the distribution percentages of observed traffic for the three-leg unsignalized intersections categorised by the five types of transport most frequently used (passenger cars, buses, trucks, motorcycles, and other) in the studied cities. The highest ratios of passenger cars, buses, trucks, motorcycles and others at Babylon, Baghdad, Baghdad, Karbala, and Karbala respectively.

5. Relationships between Hourly Pedestrian Conflict and independent variables
With coefficients of determination ranging between 0.7133 and 0.8966, Figure (4) illustrates the exponential model relating each type of hourly pedestrian conflict observed to average pedestrian delay, while Figure (5) and Figure (6) describe the exponential relationships between hourly pedestrian conflict and hourly pedestrian and traffic volume, with coefficients of determination of 0.9097 and 0.8215, respectively. Table (5) shows the parameters of the statistical model developed by ANOVA analysis using IBM SPSS software version 24.
Figure 3. Traffic distribution for the studied intersections

Figure 3.a. Traffic Distribution for Baghdad Intersection

Figure 3.b. Traffic Distribution for Karbala Intersection

Figure 3.c. Traffic Distribution for Babylon Intersection
Figure 4 Relationships between different types of Pedestrian Conflict and Average Pedestrian Delay

PC1 = 1.2091e^{0.0234(APD - PC1)}
R² = 0.7677

PC2 = 1.5242e^{0.0246(APD - PC2)}
R² = 0.8221

PC3 = 0.4454e^{0.0331x}
R² = 0.7156

PC4 = 0.432e^{0.0339(APD - PC4)}
R² = 0.8974

PC5 = 0.2963e^{0.0473(APD - PC5)}
R² = 0.8966

PC6 = 0.5691e^{0.0383(APD - PC6)}
R² = 0.7133
6. Pedestrian Risk Index and Severity Rate for Pedestrian Traffic Conflicts (SRPC)

Equations 1 and 2 are used to calculate the values for the Pedestrian Risk Index (PRI) and Severity Rate for Pedestrian Traffic Conflicts (SRPC) as explained in Table (7). Figure (7) explains the average value of PRI for each studied city.
\[ PRI = \frac{HTPC}{HPV} \]  
\[ SRPC_i = \frac{HPC_i}{HPV} \]

where

- PRI: Pedestrian Risk Index;
- HTPC: Hourly Total Pedestrian Conflict / Approach;
- HPV: Hourly Pedestrian Volume / Approach;
- SRPC\(_i\): Severity Rate for Pedestrian Traffic Conflicts of type \(i\); and
- HPC\(_i\): Hourly Pedestrian Conflict of type \(i\)/ Approach.

### Table 6. Pedestrian Risk Index and Severity rate of Pedestrian Conflicts

| City     | In. No.* | App. NO.** | PRI/APP *** | Severity rate for Pedestrian Conflicts | SRPC\(_1\) | SRPC\(_2\) | SRPC\(_3\) | SRPC\(_4\) | SRPC\(_5\) | SRPC\(_6\) | MSRPC/CT | MPRI/APP  |
|----------|----------|------------|-------------|----------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Baghdad  | 1        | 1          | 0.211       | 0.204 0.148 0.370 0.130 0.093 0.056 0.370 | 0.247     | 0.136     | 0.333     | 0.123     | 0.086     | 0.074     | 0.333     | 0.303     |
|          |          | 2          | 0.259       | 0.205 0.154 0.359 0.115 0.103 0.064 0.359 | 0.250     | 0.156     | 0.311     | 0.111     | 0.062     | 0.346     | 0.391     | 0.247     |
|          |          | 3          | 0.216       | 0.203 0.152 0.342 0.127 0.101 0.076 0.342 |           |           |           |           |           |           |           |           |
|          | 2        | 4          | 0.235       | 0.194 0.129 0.419 0.097 0.065 0.097 0.419 |           |           |           |           |           |           |           |           |
|          |          | 5          | 0.201       | 0.158 0.158 0.351 0.140 0.105 0.088 0.351 |           |           |           |           |           |           |           |           |
|          |          | 6          | 0.206       | 0.194 0.177 0.323 0.129 0.097 0.081 0.323 |           |           |           |           |           |           |           |           |
|          | 3        | 7          | 0.252       | 0.198 0.160 0.346 0.123 0.111 0.062 0.346 |           |           |           |           |           |           |           |           |
|          |          | 8          | 0.211       | 0.206 0.147 0.353 0.118 0.103 0.074 0.353 |           |           |           |           |           |           |           |           |
|          |          | 9          | 0.200       | 0.185 0.148 0.407 0.093 0.093 0.074 0.407 |           |           |           |           |           |           |           |           |
|          | 4        | 10         | 0.220       | 0.208 0.146 0.396 0.083 0.104 0.063 0.396 |           |           |           |           |           |           |           |           |
|          |          | 11         | 0.215       | 0.247 0.136 0.333 0.123 0.086 0.074 0.333 |           |           |           |           |           |           |           |           |
|          |          | 12         | 0.204       | 0.196 0.152 0.391 0.087 0.109 0.065 0.391 |           |           |           |           |           |           |           |           |
| Karbala  | 5        | 13         | 0.276       | 0.188 0.156 0.500 0.063 0.031 0.063 0.500 |           |           |           |           |           |           |           |           |
|          |          | 14         | 0.199       | 0.145 0.145 0.419 0.097 0.097 0.097 0.419 |           |           |           |           |           |           |           |           |
|          |          | 15         | 0.223       | 0.200 0.156 0.311 0.156 0.111 0.067 0.311 |           |           |           |           |           |           |           |           |
|          | 6        | 16         | 0.296       | 0.240 0.144 0.298 0.106 0.106 0.106 0.298 |           |           |           |           |           |           |           |           |
|          |          | 17         | 0.209       | 0.194 0.153 0.250 0.139 0.111 0.153 0.250 |           |           |           |           |           |           |           |           |
|          |          | 18         | 0.303       | 0.150 0.250 0.250 0.100 0.150 0.100 0.250 |           |           |           |           |           |           |           |           |
| Babylon  | 7        | 19         | 0.272       | 0.182 0.114 0.386 0.091 0.091 0.136 0.386 |           |           |           |           |           |           |           |           |
|          |          | 20         | 0.225       | 0.145 0.171 0.316 0.145 0.145 0.105 0.118 0.316 |           |           |           |           |           |           |           |           |
|          |          | 21         | 0.182       | 0.200 0.200 0.350 0.100 0.050 0.100 0.350 |           |           |           |           |           |           |           |           |
|          | 8        | 22         | 0.259       | 0.244 0.146 0.366 0.122 0.073 0.049 0.366 |           |           |           |           |           |           |           |           |
|          |          | 23         | 0.183       | 0.147 0.147 0.412 0.118 0.088 0.088 0.412 |           |           |           |           |           |           |           |           |
|          |          | 24         | 0.219       | 0.167 0.167 0.367 0.133 0.067 0.100 0.367 |           |           |           |           |           |           |           |           |
|          |          | MSRPC/CT   | 0.247 0.250 0.500 0.156 0.150 0.153 |           |           |           |           |           |           |           |           |           |
|          |          | MPRI/APP   | 0.303       |           |           |           |           |           |           |           |           |           |           |           |

* Intersection Number, **: Approach Number; PRI/APP: Pedestrian Risk Index / Approach; MSRPC/CT: Maximum Severity rate for Total Pedestrian Conflict / Approach and MSR/CT: Maximum Severity rate for Pedestrian / Conflict Type.
7. Conclusions

1. Pedestrian conflicts have serious socioeconomic, psychological, and health costs, and the recorded number of pedestrian injuries and fatalities according to official statistics is lower than the actual numbers; pedestrian traffic safety must thus be assessed using an alternate sustainable strategy (pedestrian traffic conflict strategy).

2. A statistical exponential model with coefficient of variation ranging between 0.7133 and 0.8966 relating six types of hourly pedestrian traffic conflict with average pedestrian delay was thus developed.

3. A statistical exponential model with a coefficient of variation of 0.9097 relating hourly pedestrian traffic conflict and hourly pedestrian volume was also developed.

4. A statistical exponential model with a coefficient of variation of 0.8215 relating hourly pedestrian traffic conflict and hourly traffic volume was also developed.

5. Northbound-Back Pedestrian & Northbound-Right Vehicle (PC3) types demonstrate the maximum severity rate for pedestrian conflicts among all six type of pedestrian conflicts studied. This may be attributed to the fact that the vehicle cannot be easily seen by the pedestrian, being located behind them, making it difficult to predict for the pedestrian to assess and predict the passage of the vehicle.

6. The city of Karbala has the highest average Pedestrian Risk Index (PRI) for its intersections among the studied cities, suggesting that it has the most hazardous intersections. This could be due to more modern modes of transport that have entered the Karbala highways that conflict with less modern traffic forms such as tuk-tuks.

7. Pedestrian traffic safety is a present and mostly unexplored problem in Iraq in terms of procedures and solutions. In order to improve pedestrian traffic safety, it is thus necessary to focus on both the infrastructure and behaviour of road users to identify the risks to pedestrians and address them appropriately.

Figure 7 Average Pedestrian Risk Index
8. References

[1] Ewadh, A.H. and Neham, S.S. 2011, Proceeding of the Institution of Civil Engineers ICE "Conflict to Study Safety at Four Leg-signalised Intersection.", Transport Vol. 164 Issues TR4.

[2] Laureshyn A, Svensson A, Hydén C., 2010, Accident analysis and prevention, "Evaluation of traffic safety, based on micro-level behavioural data: theoretical framework and first implementation", vol. 42, pages 1637-1646.

[3] Olszewski, P., Szagata, P., Wolanski, M., Zielinska, A., 2015, Accident Analysis & Prevention, "Pedestrian fatality risk in accidents at unsignalized zebra crosswalks in Poland" Vol.84, pages 83-91.

[4] Marisamy N. and Vedagiri P., 2014, Journal of Traffic and Transportation Engineering (English Edition), "Study on pedestrian crossing behavior at signalized intersections", Vol. 1, Issue (2) , pages 103-110.

[5] Cafiso S., Garcia A. G., Cavarra R., Rojas M. R., 2011, Proceedings of the 3rd International Conference on Road Safety and Simulation "Crosswalk safety evaluation using a pedestrian risk index as traffic conflict measure".

[6] Olga B., Luca P., Davide S. and Usami T., 2010, "A methodology to assess pedestrian crossing safety", Res. Vol. 2: pages 129–137.

[7] Safety Net Accident Causation Database 2005 to 2008 / EC Date of query: 2010.

[8] Ma L. and Wang Z. F., 2010, Traffic Standardization, "Intersection crossing safety analysis based on traffic conflict", vol. 47, no. 11, pp. 94–97, 2011.

[9] Lee C. and Abdel-Aty M., 2005, Accident Analysis and Prevention, "Comprehensive analysis of vehicle–pedestrian crashes at intersections in Florida", pages 775-786.

[10] Bushra B. O. and Imad A. Al-Hashimi, 2015, Conference Paper Proceedings of the 10th International Space Syntax Symposium, "Pedestrian Risk Index for Irbid city, Jordan", SSS10.