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Improving the Capacity of the Carriageway of the City Streets of Karbala

Hayder S. Khudhair[a], **Hamid A.E. Al-Jameel**[b], **Vladimir N. Konoplev**[a]✉, **Artur R. Asoyan**[a]

[a] RUDN University, *Moscow, Russia*
[b] University of Kufa, *Kufa, Iraq*
✉ konoplev-vn@rudn.ru

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The authors declare that there is no conflict of interest.

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Undivided co-authorship.

Abstract. The religious and economic importance of the city of Karbala led to an increase in the number of daily trips and an increase in the flow of traffic, therefore it was necessary to know the city's road network. This study deals with the evaluation of the traffic performance of urban streets of the study area. The survey was conducted for several days, in the morning and the evening. The data obtained for the selected roads at a distance of 200 m are engineering data, traffic data, and side friction data. The results showed that the values of side friction occurred during the morning and evening rush hours, which affect the decrease in the average speed by 51% because of the side friction was very high.

Keywords: average speed, level of Service, highway capacity

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Повышение пропускной способности проезжей части городских улиц Кербелы

Х.С. Худхаир[a], Х.А.Э. Аль-Джамиль[b], В.Н. Коноплев[a]✉, А.Р. Асоян[a]

[a]Российский университет дружбы народов, *Москва, Россия*
[b]Университет Куфы, *Куфа, Ирак*
✉ konoplev-vn@rudn.ru

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Аннотация. Изменение экономических и социальных факторов в городе Кербела привело к увеличению количества ежедневных поездок и увеличению интенсивности транспортного потока, что потребовало в целях обеспечения безопасности дорожного движения проведения исследований загруженности городских улиц. Регистрация дорожной обстановки (пропускная способность на участках длиной 200 м) осуществлялась с помощью камер видеонаблюдения утром и вечером. Данная информация накапливалась и обрабатывалась с использованием статистических методов обработки информации (статистические оценки и графическая аппроксимация). Результаты анализа показали, что сужение проезжей части дорог в утренние и вечерние часы пик за счет интенсивного использования правой полосы, прилегающей к тротуарам с обеих сторон проезжей части, для остановки и стоянки автотранспортных средств повлекло снижение средней скорости на 51 %.

Ключевые слова: средняя скорость, уровень обслуживания, пропускная способность шоссе

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Introduction

Congestion on the roads in cities is one of the biggest transportation issues. Traffic congestion is a very intrusive activity for people and is brought on by high degrees of saturation of traffic flow. Due to the longer journey duration, congestion will have a detrimental effect on the driver or other road users. A population with a wide range of activities would have resulted in a mobility flow that needed suitable roadways to match [1; 2]. Jalan Raya Mandala, a major thoroughfare in metropolitan areas, frequently experiences saturation traffic flow at one specific location due to some form of pull traffic. Shopping centers are one type of high-traffic attraction. This is because the effectiveness of roads is significantly impacted by the impact of roadside barriers. Parking activity that uses the road is one type of side barrier that is frequently seen in the shopping district (on street parking). The width of the roadways utilized for park activities would result in a reduction in the capacity of the roads to handle the flow of passing cars, or, to use another phrase, a reduction in the capacity of roadways [3; 4]. HCM has provided comprehensive instructions for estimating Based on speed and other factors, capacity, and level of service. Adjustment factors for evaluating the capacity for various parameters are provided if the HCM handbook does not include side friction parameters for determining capacity and level of service [5]. Munawar made a comparison between the numbers reported by IHCM (1997) and the values found in the field data collected in Indonesia. He concluded that, as suggested by IHCM, there had been a considerable shift at high side friction values in the capacity trend (1997) [6]. Chiguma conducted a thorough investigation to determine the side friction's impact on urban arterials in Dar-es-Salaam, Indonesia. The research examined how side friction affected section capacity and mean speed. The weighing variables of the side friction parts were quantified through the use of multiple linear regression analysis [7]. Using Indonesian Highway Capacity Guidance, or IHCG 2014[1], the level of service for DI Panjaitan Street was evaluated, and the most important component impacting side friction was found using multiple linear regression analysis in SPSS. The study found that levels from *C* to *D* were experienced from Tuesday through Friday, while levels of F were experienced on Mondays from 7 AM to 9 AM and between 5 PM and 7 PM Equation (1) was used to determine the side friction's most important variable.

$$SF = 0.157 + 0.002\,X1 + 0.001\,X2 + 0.002\,X3. \quad (1)$$

The study demonstrates that a non-motorized vehicle park's stops, enters, and exits substantially match the degree of saturation with a correlation value (*R*) of 0.792 [8]. The goal of the study is to understand the various effects of side friction on the capacity of Yosodipuro Street, level of service (LOS), and saturation level. The Indonesian Highway Capacity Manual (IHCM) 1993[2] is the basis for the analysis. The survey was conducted over the course of one day, primarily between 6 A.M. and 12 P.M., along three different sections of Yosodipuro Street, each of which is 200 meters long. Geometric, data on side friction and traffic counting were collected from the field. According to the data, Yosodipuro Street has a maximum hourly volume of 2058.83 pcu/hour. This circumstance occurs in Location 1 around 6:30–7:30, and this roadway can accommodate 2118.32 pcu each hour. Location 1, Location 2, and Location 3 each have a degree of saturation (DS) of 0.972, 0.638, and 0.632, respectively Each location's LOS is: Locations 1 and 3 are D-Level, and Locations 2 and 3 are C-Level, according to the degree of saturation (DS). This indicates that while Locations 2 and 3 are in good shape, Location 1 is getting close to capacity [9]. The total capacity and the LOS of the roadway are impacted by the impedance that various types of HVs create for other vehicles in mixed traffic [10]. The most crucial factor in traffic control is on-street parking management so that the degree of saturation of traffic can be reduced. Road speeds and levels of saturation determine the service level [11][3]. The goal of the research was to evaluate how on-street parking is currently functioning. The analysis's findings showed that both locations' peak parking hours were in the late afternoon, notably after 4:00 PM, and that this was because of the concentration of activity at that time. The findings also revealed that, for both roads, most of the parked cars (80 percent) had wait periods of more than 30 minutes. They also stressed the fact that there was a lot of unlawful parking along the two streets they had inspected, both on the weekends and throughout the workweek [12].

Based on a combination of data and Greenshield's theory, the capacity value of arterials showed a 9 percent decrease in value when

[1] Indonesian Highway Capacity Guidance, or IHCG 2014.

[2] Indonesian Highway Capacity Manual (IHCM) 1993.

[3] Menteri Perhubungan Republik Indonesia 2015 Peraturan Menteri Perhubungan Republik Indonesia Nomor: PM 96 Tahun 2015 Tentang Pedoman Pelaksanaan Kegiatan Manajemen dan Rekayasa Lalu Lintas 1–45.

considering side friction and established that pedestrian activity, which is one of the events that cause side friction, has the greatest impact on the traffic stream's average speed across all study sections. Side friction levels ranged from very low to very high. 34 km/h was recorded as the average speed at low levels of side friction, and 19 km/h was recorded at higher levels. Therefore, the reduction was estimated at 51%, which is a significant amount [13]. The impact of side friction on an urban street's capacity that is not divided. Side friction is a composite variable that describes how much regular traffic flow interacts with other nearby activities. Side friction significantly reduces capacity, with reductions ranging from 11.05 to 60.73 percent [14]. In general, it can be said that the presence of different side friction elements along the sides of urban roads causes a decrease in capacity and speed. on-street parking, Bus stops, and pedestrians, vehicles' average speed significantly decreased by 21 percent, 27 percent, and 15 percent, respectively [15]. Founded effect of side friction on capacity, flow density, and free-flow speed in urban streets of Baghdad [16] On-street parking and non-motorized vehicles' effects on an urban road's performance as a side friction parameter on capacity have been implemented to overcome the randomness observed in capacity values [17]. average decrease due to roadside friction Stream speed can be observed in all study sections because of side friction. Bus stops and bus bays caused a stream speed reduction of 49–57%. While on-street parking decreased stream speed by 45–67%. Due to transient bottlenecks resulting from on-street parking, buses exiting and entering bus bays, and buses at the kerbside bus stop, roadside friction also reduced capacity. When using both kinds of PCUs, bus bays and bus stops reduce capacity by 10 to 53%. On-street parking reduced urban roads' capacity by 28–63%, which had an adverse effect on their usability [18]. Urban multilane highways' capacity and LOS for heterogeneous traffic may be evaluated based on a study of the segment capacity and level of service. The LOS's of most of the segments are between *C* and *D*, and the segments' base capacities range from 1850 to 1900 pc/h/ln [19]. The presence of side friction impairs the overall performance of traffic parameters. Roadway capacity and traffic speed can be increased by making some adjustments. Heterogeneous traffic, which includes slow-moving vehicles and non-motorized vehicles, reduces the effective road width as a result of vehicle parking along the side of the road, among other parking and unparking operations. These events are typically seen at a nearby market or commercial area. The side frictional parameter has already been taken into account by IHCM when calculating speed and capacity. Generally, in Indian urban cities, there are heterogeneous traffic conditions [20]. The increase in side friction in many urban streets led to an decrease in the speed in road networks, The aims of this study to know the influence of side friction on speed by using the Indonesian Highway Capacity Manual (IHCM 1995)[4].

Methodology

This study uses the Indonesian Highway Capacity Manual (IHCM 1995) to calculate the side friction levels to determine the level of side friction. In this study, side friction data during peak hours between 7:30 and 9:30 in the morning and between 4 and 6 in the evening. Numerous actions on the road were recorded using the videography technique. Roadside activities were observed over a 200-meter section to determine the direction of the traffic under consideration. By observing the frequency of various activities, such as traffic flow rate, pedestrian movement, and parking, U-Turn movement and Entire-Exit operations. The SF data and traffic flow are extracted from the video film at 5-minute intervals. Results of a traffic survey and a side friction survey were processed using IHCM 1995 [22].

[4] Indonesian Highway Capacity Manual (IHCM) 1995.

1. Determine side friction

For measurement of side friction, procedure followed by Pal and Roy is used in present study [21]. This method uses the pedestrian influencing area as standard parameter to calculate equivalent pedestrian units for the events other than pedestrian. The stopped vehicles are converted into equivalent number of pedestrian units for standardizing the static side friction activity.

The frequency of all stopped vehicles was converted and added with frequency of pedestrians observed in the field. The equation (2) is used to estimate the Pedestrian equivalency unit (***PEU***) for converting all stopped vehicles into equivalent number of pedestrians. The ***PEU*** is multiplied with the frequency of events to convert the vehicles into pedestrian units. Projected area of pedestrians, vehicle type and ***PEU*** is shown in Table 1.

Table 1

Projected area and *PEU* for different mode

Mode	Projected area, m^2	*PEU*
Pedestrian	0.50	1.00
2W	1.2	2.5
3W	3.9	7.8
Car	7.3	14.5
Bus	31.2	62.4
LCV	5.4	10.7
Jeep/Van	9.3	18.6
Bicycle	1.1	2.2

Source: [21]

$$\boldsymbol{PEU_i} = \frac{7.27}{0.5}; \quad (2)$$

$$\boldsymbol{PEU_i} = 14.53 , \quad (3)$$

where, $\boldsymbol{PEU_i}$ is the pedestrian equivalency unit of the subject vehicle, PA_i is the projected area of the subject vehicle and PA_p is the projected area of the pedestrian. The number of pedestrian events and stopped vehicles are added to calculate total static side friction frequency in terms of *PSPU* (events/hr) which is estimated by using the equation (4).

$$N_{PSPU} = N_p + \sum\left(\boldsymbol{PEU_i} \times N_i\right), \quad (4)$$

where, N_P is the frequency of pedestrians, $\boldsymbol{PEU_i}$ is the pedestrian equivalency unit of the subject vehicle and N_i is the frequency of the subject vehicle. Entry-exit vehicular movement and wrong movement of vehicles those are moving activities that contribute to side friction on the road. Side friction (*SF*) was calculated by estimating weighing factors of the events observed on the roadside. To estimate the weighing factor for each roadside activity, L. Chiguma [7] estimated the standardised coefficients and weighing factors using regression method by taking average stream speed as a performance measure variable. Similar methodology is adopted in the present study to find the relative weights of roadside activities. By taking stream speed as a performance measure, the relative weighting factors of each activity was estimated for determining SF (Events/hr) on the selected road sections. The SF (Events/hr) for each section was calculated by using the equation (5). SF is the side friction which is the sum product of roadside events frequency of different activities and their estimated weighing factors [7].

$$SF = \left(RW_1 \times N_{PSPU}\right) + \left(RW_2 \times N_{EE}\right) + \left(RW_3 \times N_{WM}\right), \quad (5)$$

where, N_{PSPU} is the frequency of pedestrians and parked vehicles in equivalent pedestrian units, N_{EE} is the frequency of entry-exit vehicles, N_{WM} is the frequency of wrong movement vehicles and *RW* is the relative weights of each activity type.

1.1. Fatima Al-Zahraa Street

Table 1 shows the frequency distribution of the side friction data for the second segment. It is noted that pedestrian activity increases significantly compared to the activity of parked vehicles. The highest value for pedestrian crossing is reached 504 (Event/hr), while parked vehicles are 276 (Event/hr), the U-Turn movement vehicle element's frequency peaked at 600 (Event/hr) and the Enter-Exit vehicle element's frequency peaked at 540 (Event/hr). We observed that the side friction components in this street do not have a zero value.

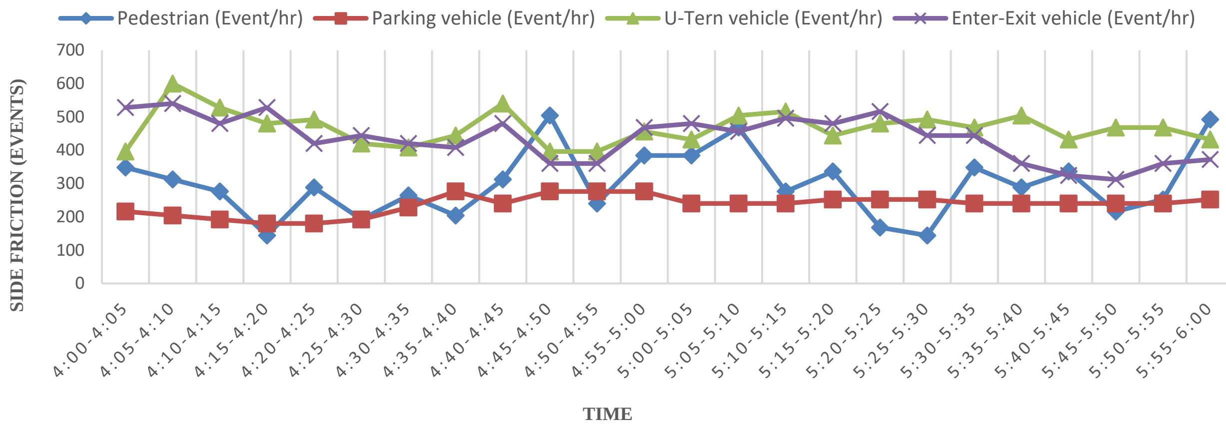

Figure 1. Variation of side friction events at road Fatima Al-Zahraa in the evening period
Source: made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

1.2. Al-Iskan Street

Figure 2 showed how often the side friction elements occur on Al-Iskan Street at its peak period. In the figure, it can be observed that the parked vehicle values for this segment are gradually rising as their values range between (60–252 (Event/hr)), whereas the pedestrian crossing element's values are repeatedly high asthey range between (96–492 (Event/hr)), the U-Turn movement element's values are repeatedly high as they range between (492–840 (Event/hr)) and the Enter-Exit element's values are repeatedly high as they range between (256–486 (Event/hr)).

1.3. Ramadan Street

Figure 3 Often showed the side friction elements occur on Ramadan Street at its peak period. In the figure, it can be observed that the parked vehicle values for this segment are gradually rising as their values range between (0–216 (Event/hr)), whereas the pedestrian crossing element's values are repeatedly high as they range between (84–408 (Event/hr)), the U-Turn movement element's values are repeatedly high as they range between (840–1080 (Event/hr)) and the Enter-Exit element's values are repeatedly high as they range between (624–792 (Event/hr)).

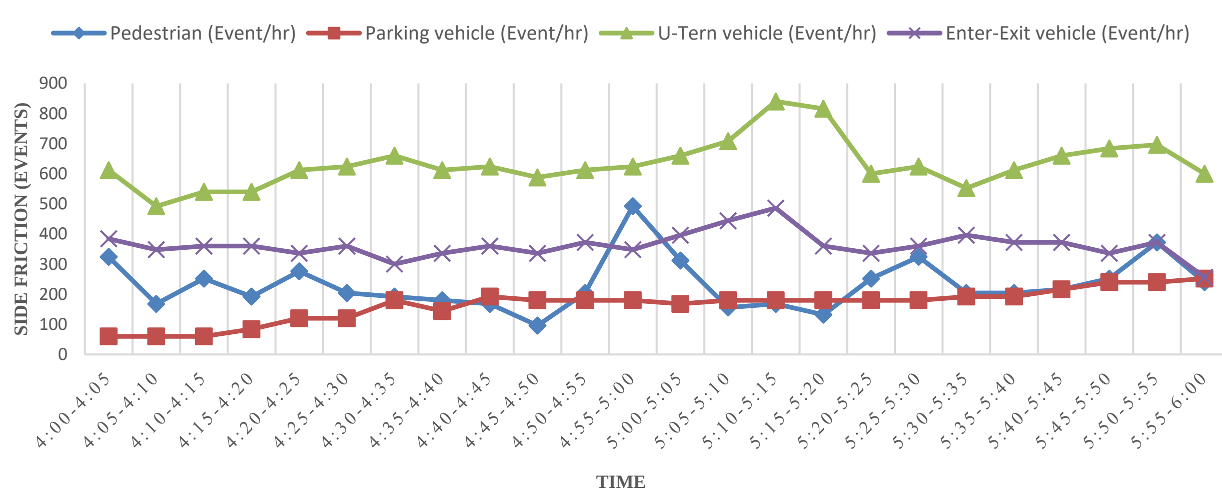

Figure 2. Variation of side friction events at Al-Iskan Street in evening period
Source: made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

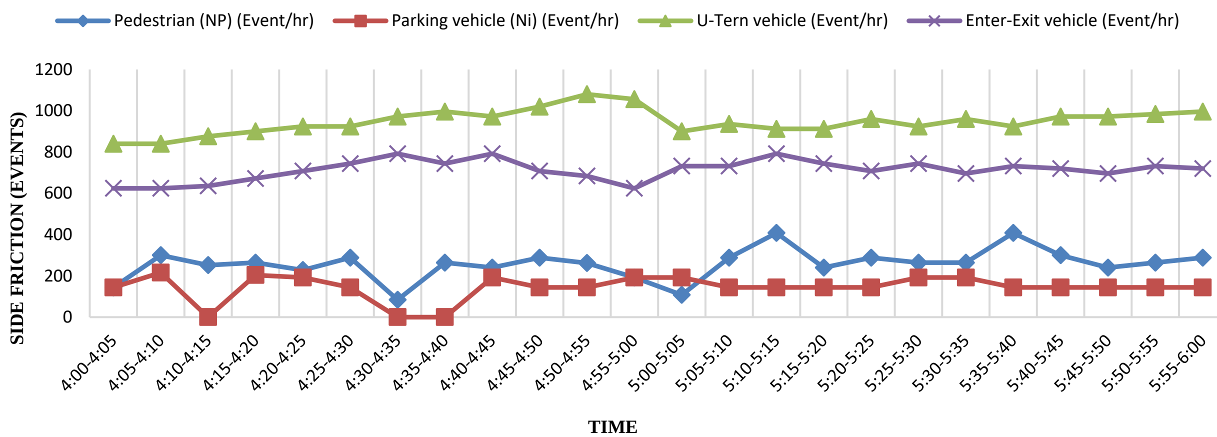

Figure 3. Variation of side friction events Ramadan Street in evening period
S o u r c e : made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

1.4. Al-Tarbia street

Figures 4–6 show that there is a clear difference in the values of the side friction elements for both segments of Al-Tarbia street during the morning and evening. During the morning period, the side friction values begin to increase and gradually decrease during the evening until they reach the lowest values.

The highest value of the pedestrian crossing component of the first segment during the morning period was 1140 (Event/hr) at the period between 9:15 am to 9:20 am, is higher than the vehicle parking component, which had the highest value of 348 (Event/hr) at the period between 8:55 am to 9:00 am. During the evening period, the highest value of pedestrian crossing reached 912 (Event/hr) at the period between 12:55 pm to 1:01 pm. The highest value of parked vehicles reached 324 (Event/hr) at the period between 12:45 pm to 12:50 pm.

Figure 4. Site of AL-Tarbia Street
S o u r c e : photo by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

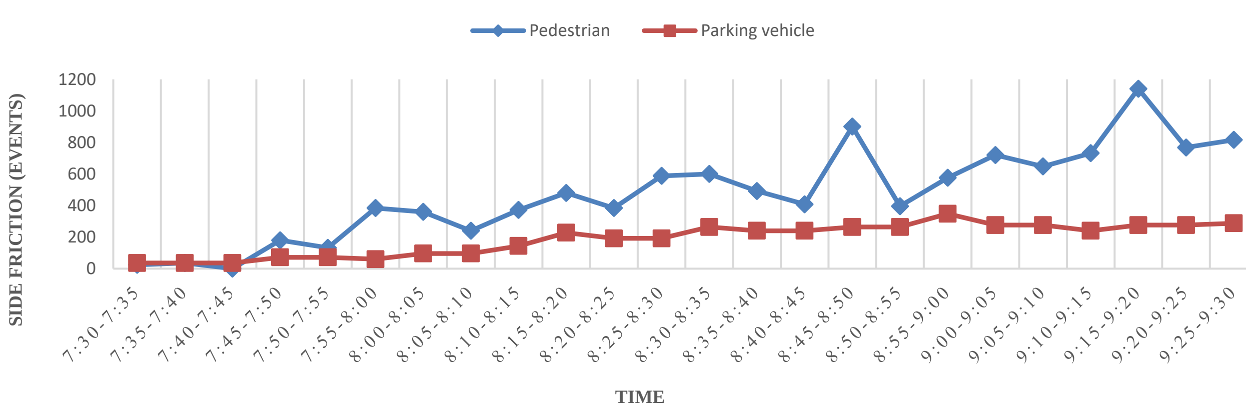

Figure 5. Variation of side friction events Al-Tarbia street in the morning period
S o u r c e : made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

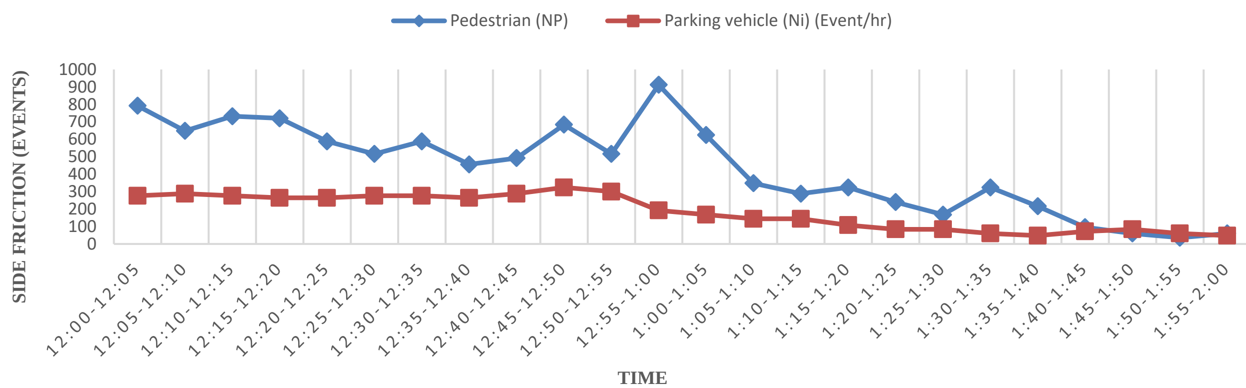

Figure 6. Variation of side friction events Al-Tarbia street in the evening period
S o u r c e : made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

1.5. Al-Abbas Street

Figures 7, 8 show the recurring distribution during the morning and evening period for the first segment of Al-Abbas Street, where it was observed an increase in the parked vehicles component at the morning period. Its value ranges between 0–300 (Event/hr) and decreases in the evening period, where the value of the parked vehicles ranges between 120–204 (Event/hr).

Through the figures, it can mention that the value of the pedestrian crossing element is higher than the element of parked vehicles, as it reaches the highest value during the morning 804 (Event/hr) and the evening 372 (Event/hr).

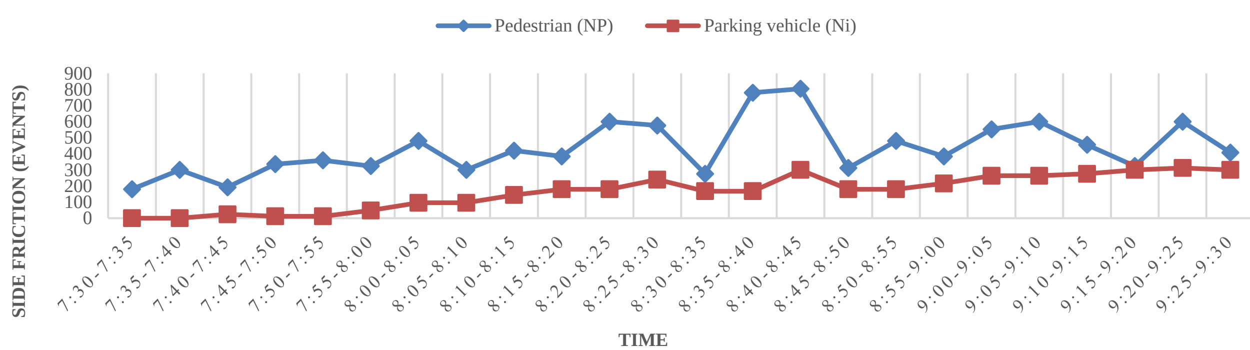

Figure 7. Variation of side friction events Al-Abbas Street in the mourning period
S o u r c e : made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

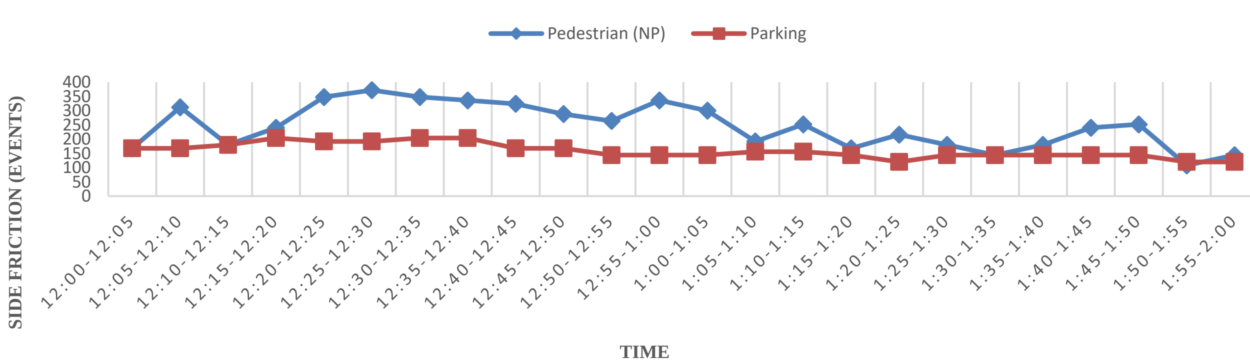

Figure 8. Variation of side friction events Al-Abbas Street at evening period
S o u r c e : made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

2. Analysis of urban street side friction

The IHCM has defined side friction levels as High and Low Levels since 1993. The IHCM lays out the roadside friction aspects that must be considered when calculating flow and capacity. The side friction was divided into four categories based on the fluctuation in the speed data in Table 2.

Tables 3–5 shows the effect of SF on all streets selected during the morning and evening periods was very high, which affected the capacity of the street and reduced the speed by about 51%.

Table 2

Levels of side friction

SF, Events/hr	Level of SF
0–500	Low
500–1000	Medium
1000–2000	High
> 2000	Very high

Source: Indonesian Highway Capacity Manual (1997). Directorate General of Highways, Republic Indonesia, Jakarta

Table 3

Levels of side friction at different speeds

SF, Events/hr	Level of SF	Average stream speed, km/hr	Percentage reduction in average speed, %
0–500	Low	34	–
500–1000	Medium	31	20
1000–2000	High	24	38
> 2000	Very high	19	51

Source: [13]

Table 4

Level of SF in the evening period

Road Name	Max. SideFriction, Event/hr	Level of sidefriction	Percentage reduction in average speed, %
Fatima Al-Zahraa Street	3764	Very high	51
Al-Iskan Street	3164	Very high	
Ramadan Street	2498	Very high	
Al-Tarbiastreet	4792	Very high	
Al-AbbasStreet	3825	Very high	

Source: made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

Table 5

Level of SF in the morning period

Road Name	Max. SideFriction, Event/hr	Level of sidefriction	Percentage reduction in average speed, %
Al-Tarbiastreet	4976	Very high	51
Al-AbbasStreet	4498	Very high	

Source: made by H.S. Khudhair, H.A.E. Al-Jameel, V.N. Konoplev

Conclusion

1. All the side friction values were very high for urban streets during the evening and morning peak periods as a result of the presence of schools and government departments, therefore, it requires traffic engineering solutions.

2. The highest value of SF was 4976 (Event/hr) during the morning period of Al-Tarbia Street.

3. The highest value of SF was 4792 (Event/hr) during the evening period of alsoAl-Tarbia Street.

4. The study found that the percentage reduction in average speed is 51% because of the side friction was very high on all urban streets.

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About the authors

Hayder S. Khudhair, Postgraduate student of the Department of Engineering and Transport Technologies, Academy of Engineering, RUDN University, Moscow, Russia; ORCID: 0000-0002-6833-7780*;* E-mail: hyder.s@ uokerbala.edu.iq

Hamid Athab E. Al-Jameel, Doctor of Technical Sciences, Professor of the Department of Civil Engineering, Faculty of Engineering, University of Kufa, Iraq; ORCID: 0000-0002-1367-4421; E-mail: hamid.aljameel@uokufa.edu.iq

Vladimir N. Konoplev, Doctor of Technical Sciences, Professor of the Department of Engineering and Transport Technologies, Academy of Engineering, RUDN University, Moscow, Russia; eLIBRARY SPIN-code: 3876-1534, ORCID: 0000-0003-1662-6254; E-mail: konoplev-vn@rudn.ru

Artur R. Asoyan, Doctor of Technical Sciences, Professor of the Department of Transport, Academy of Engineering, RUDN University, Moscow, Russia; Professor of the Department of Operation of Road Transport and Car Service, Moscow Automobile and Road Construction State Technical University, Moscow, Russia; eLIBRARY SPIN-code: 1020-5089, ORCID: 0000-0002-1976-9376; E-mail: asoyan-ar@rudn.ru

Сведения об авторах

Худхаир Хайдер Салман, аспирант кафедры техники и технологий транспорта, инженерная академия, Российский университет дружбы народов, Москва, Россия; ORCID: 0000-0002-6833-7780; E-mail: hyder.s@ uokerbala.edu.iq

Аль-Джамиль Хамид Адаб Идан, доктор технических наук, профессор кафедры гражданского строительства, инженерный факультет, Университет Куфы, Ирак; ORCID: 0000-0002-1367-4421; E-mail: hamid.aljameel@uokufa.edu.iq

Коноплев Владимир Николаевич, доктор технических наук, профессор кафедры техники и технологий транспорта, инженерная академия, Российский университет дружбы народов, Москва, Россия; eLIBRARY SPIN-код: 3876-1534, ORCID: 0000-0003-1662-6254; E-mail: konoplev-vn@rudn.ru

Асоян Артур Рафикович, доктор технических наук, профессор департамента транспорта инженерной академии, Российский университет дружбы народов, Москва, Россия; профессор кафедры эксплуатации автомобильного транспорта и автосервиса, Московский автомобильно-дорожный государственный технический университет, Москва, Россия; eLIBRARY SPIN-код: 1020-5089, ORCID: 0000-0002-1976-9376; E-mail: asoyan-ar@rudn.ru