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Chapter 23

EFFECT OF ON-ROAD PARKING ON TRAFFIC STREAM CHARACTERISTICS FOR A MIXED TRAFFIC CONDITION: A SUSTAINABLE SOLUTION FOR BETTER TRAFFIC MOVEMENT

Abstract

With an emphasis on urban settings, this study explores the complex relationship between on-road parking and its effects on traffic flow parameters. The study looks into how on- road parking affects vehicle speed and traffic volume. It uses novel methodology that combines license plate-based parking surveys, spot speed data collection techniques, and traffic volume data collection techniques. The study establishes correlations between parking-related parameters (like parking volume, parking duration, and effective road width) and traffic parameters through meticulous data analysis. On-street parking was found to have significant effect on traffic dynamics and that the effective road width is a key factor in determining the maximum traffic speed. Regression analysis used in the study's model shows these variables to be significantly correlated. Effective road width exhibits a positive correlation with maximum speed, whereas parking volume and average parking duration display a negative correlation. This study's findings emphasize the significant impact on urban traffic flow and safety of on-road parking through some sustainable solution. It emphasizes the necessity of careful urban planning and the formulation of parking policies to lessen negative effect of on-road parking. The suggested methodology provides useful insights for future research and urban policymakers attempting to balance the ease of parking with maintaining ideal traffic conditions.

Keywords: On-street parking, Traffic Characteristics, Traffic Flow, Sustainable parking fee model, Urban modelling

Authors

Saikat Deb
Symbiosis Centre for Management and Human Resource Development (SCMHRD), Symbiosis International (Deemed University), SIU, Pune, Maharashtra, India
saikat_deb@scmhrd.edu

Debasish Das
Civil Engineering Department,
JIS College of Engineering, Kalyani, Westbengal, India

Debargha Banerjee
Civil Engineering Department,
JIS College of Engineering,
Kalyani, Westbengal, India

Priyam Nath Bhowmik
Civil Engineering Department,
Madanapalle Institute of Technology and Science, India.

Fardeen Khan
Graduate Students, Department of Civil Engineering, JIS College of Engineering, Kalyani,West Bengal, India

Subham Sharma
Graduate Students, Department of Civil Engineering, JIS College of Engineering, Kalyani,West Bengal, India

Kriti Singh
Graduate Students, Department of Civil Engineering, JIS College of Engineering, Kalyani, West Bengal, India

Ishita Ghosh
Graduate Students, Department of Civil Engineering, JIS College of Engineering, Kalyani, West Bengal, India

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Ikbal Hassan
Graduate Students, Department of Civil Engineering, JIS College of Engineering, Kalyani, West Bengal, India

I. INTRODUCTION

On-road parking is often found in streets in urban area, extraordinarily close to the market region, as it is advantageous for customers not to use the space utilized by a committed parking area. Beside the customers, on-road parking is also used by the drivers of commercial vehicle used for freight transport. Unfortunately, on-road parking is additionally connected with slower speed of the vehicles, reduced capacity of the road section and ultimately higher rate of accidents contrasted with streets of a similar classification without on-road parking [1,2]. It is essential to recognize the causes for raised accident chances so as to configure proper countermeasures. Parked vehicles occupy significant portion of the road width which reduce pavement width, constraining to drive nearer to vehicles in the following lane or vehicles moving from opposite direction and forced to reduce their speed. Additionally, because of the narrow roads, lateral positions of the vehicles are shifted nearer to the center line which will ultimately increase the chances of accidents [3]. On road parking on the busy roads will cause stop-start condition for vehicles resulting in traffic congestion. Additionally, the unsettling influence brought about by drivers parking or un-parking in the road side increases the chances of accidents. In difficult urban conditions, drivers must observe both pedestrians and vehicles. Parked cars can impede the view of the road, making it more complicated to see pedestrian crossings. If on-street parking facilities and their locations were not carefully chosen and controlled, the capacity of the road network would be decreased considerably.

II. CONSIDERATIONS AND POLICES FOR ON-ROAD PARKING

Vehicles parked on-road generally uses hard shoulder or wide lane as parking spot. Parking facilities often include this as a component of their offerings. Clearly, it has favorable circumstances of being adaptable, space-sparing, and helpful compare to the off-road parking. However, on-road parking uses up pavement area, which effects the existing traffic condition. Cao, Yang and Zuo (2017)[4] estimated the impact of on-road parking on motorized and non-motorized vehicles. The study results identified on- road parking as a prominent factor effecting road capacity and safety. On-road parking essentially effect the speed dynamics of the vehicle by affecting the reaction time of the drivers. Mei and Chen (2012)[5] defined two parameters to estimate traffic speed characteristics in terms of on-road parking. Space impact, the first parameter, is influenced by the types of on-road parking. The second parameter, time impact, influenced by the time required because of the parking maneuvers. Edquist, Rudin-Brown and Lenné (2012)[6] conducted a study to explore how, on street parking and the visual complexity of the road environment impact travel speed and reaction time. Compared to very little on-road parking state, drivers said they felt more fatigued when driving in the full on-road parking condition. On-road parking slowed down the speed of ongoing vehicle and the vehicles are forced to move away from parked cars and turned into traffic. Drivers reacted more slowly to distant objects, and took longer to react when confronted by an unexpected pedestrian. These conditions also influence the efficiency of signalized intersections. Xiaofei and CHEN (2011)[7] found on-road parking maneuvers greatly affects the efficiency of

intersection. Yousif and Purnawan (2004)[8] studied the traffic operation adjacent to an on-road parking facility. The main parameters under consideration were the maneuver time for parking or un-parking and the gap acceptance to merge into the traffic stream when leaving a parking stall. The results showed that the design of on-street parking layouts strongly affects drivers' parking and un-parking behavior. If the on-road parking is totally prohibited, in that case it is required to provide additional off-road parking near the market places or business sector. In the city environment it is often not possible to allocate dedicated space for off-road parking. But off-road parking needs additional investments and resources. In some cases, material cost of setting the off-road parking can be minimized using recycled aggregate[9] but in the busy urban areas it would be difficult to find the space for off-road parking. Moreover, near the market area, freight modes also constitute a significant portion of the parked vehicles for the purpose of goods transportation in the adjacent market. Drivers of commercial vehicles used for freight transportation and other operations are severely impacted by a lack of parking space and, in many cases, a lack of parking laws that recognize those vehicles' distinct demands. Jaller, Holguín-Veras and Hodge, (2013)[10] studied the problem of parking heavy trucks in New York. They proposed an estimation method of curb parking demand by using the freight trip generation estimates. They discussed strategies for the management of freight parking by governmental agencies and other organizations.

Although several previous literatures estimated the effect of on road parking facilities on traffic parameters and driver characteristics, but they fail to address the effect of on road parking in complex traffic scenarios which prevails in most of the Indian cities. Moreover, in most of the Indian cities no dedicated spaces are available for on-road parking, which force the drivers to park their vehicle beside the road occupying some portion of the effective road width. Therefore, in this regard it is very much important to study the effect of parking in such mixed traffic conditions. In most of the Indian cities, maximum areas in the city limit does not have any provisions for on-road parking facilities, yet drivers parked their vehicle on road occupying the effective road width. This significantly affect the traffic parameters and, in some cases, results in accidents and different safety hazards. It is very much required to improve this situation by regulating suitable parking policies for different urban sectors. On-street parking is an essential component of the urban public parking system. A suitable parking charge structure helps to promote parking utilization and alleviate traffic congestion [5]. There have been a lot of controversy about in what condition should we use on-road parking. However, research in this subject has been lacking, especially considering the mixed traffic flow. Parking restrictions can play an important role in persuading users of the private vehicles to switch to transit or other viable options. But such restrictions will not be helpful for the vehicles used for freight transportation. Because, in most urban areas there do not exist any practical modal alternatives that could replace urban delivery trucks or freight transport modes. Therefore, it is needed to identify suitable policy for this type of vehicles. Moreover, if the on-road parking can be regulated, then it will enhance the revenue collection for the urban area. Therefore, in this study a detailed methodology is proposed to analyze parking related information in mixed traffic condition based on which a proper mechanism for parking regulations could be adopted.

III. CONSIDERATIONS AND POLICES FOR ON-ROAD PARKING

A comprehensive methodology was developed to gain an understanding of the influence of on-street parking on the traffic flow characteristic. On-street parking which in turn impacts

the traffic flow, ultimately affecting the capacity of the road network. It is very important to know the type and nature of vehicles playing on the roadway before any further consideration to be made on design perspective of any city. Fig. 1 shows the flow chart of the proposed methodology. The methodology is divided into two parts: Data Collection and Data Analysis.

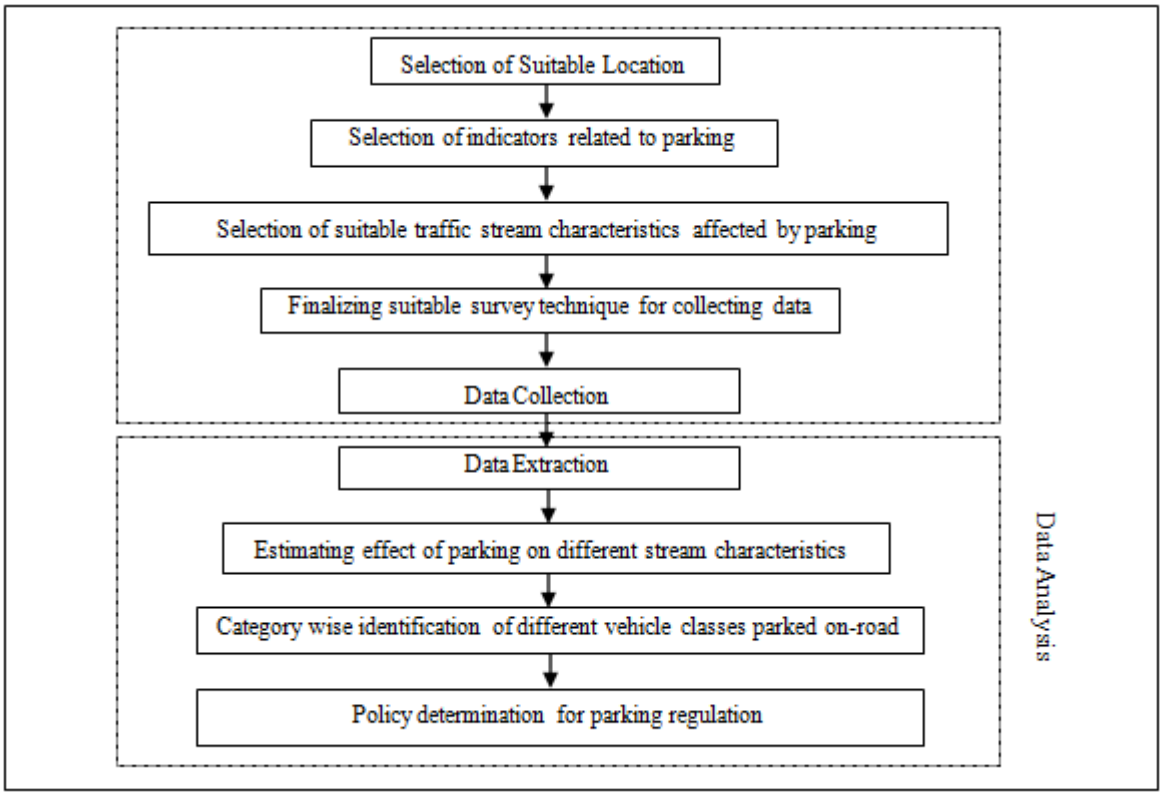

Figure 1: Methodology flow chart

1. Selection of Indicators Related to Parking

Parking volume, parking duration and effective road width are selected as indicators related to on-road parking. Parking accumulation is defined as the total number of vehicles parked in an area at a specified moment. The unit of parking accumulation is "number of vehicles parked". Parking accumulation is an important parameter which indicates total number of vehicles in different segment of time. Parking volume is defined as the number of vehicles parked in a particular area over a given period of time. This does not account for repetition of vehicles. The actual volume of vehicles entered in the area is recorded. Parking duration is defined as the duration of time a vehicle is parked on road. After getting the parking duration of each vehicle, the average parking duration for each vehicle categories can be identified. It will help to decide parking policy for different vehicle classes. Effective road width is defined as the actual width of the road when a considerable portion of the road width is occupied by parked vehicles.

2. Selection of Suitable Traffic Stream Characteristics Affected by Parking

Traffic volume and speed are selected as parameters indicating the characteristics of the existing vehicular traffic. Traffic volume and speed can be counted by video-photographic survey adjacent to parking spot at predefined time interval.

The study of interactions between vehicles, drivers, and infrastructure is known as traffic flow. This infrastructure includes highways, signage, and traffic control devices. Traffic phenomena are complex and nonlinear, due to the interactions of a large number of vehicles. Vehicles do not interact simply according to the laws of mechanics because of individual reactions of human drivers, but rather exhibit phenomena of cluster formation and shock wave propagation, both forward and backward, depending on vehicle density in a particular region. The condition of any traffic stream can be best described by analyzing speed; volume, density and the relationship exist between them. These parameters are connected with each other. When the density hits the maximum flow rate and exceeds the optimal density, traffic flow turns unstable, and even minor issues can result in long periods of stop-and-go driving. Calculations inside congested networks, on the other hand, are more difficult and require on empirical investigations and extrapolations from real road figures. Because these are frequently urban or suburban in character, other elements also contribute to the optimum situations.

Because drivers and passengers are more concerned with the speed of the journey than the design characteristics of the traffic, speed is a quality assessment of travel. Speed in traffic flow is defined as the distance covered per unit time.

Mathematically speed or velocity v is given by, $v = d/t$

Where, v is the speed of the vehicle in m/s, d is distance traveled in meter in time t seconds. Speed of different vehicles will vary with respect to space and time. Several types of speed can be defined. Spot speed, running speed, journey speed, time mean speed and space mean speed are important among them. For parking study, spot speed data are required to collect. Spot speed is the instantaneous speed of a vehicle at a specified section or location. Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. Spot speed can be measured using an endoscope, pressure contact tubes or radar speedometer or direct timing procedure or by time-lapse photographic methods. It may be calculated using speeds taken from video pictures by measuring the distance travelled by any vehicle between two frames.

3. Data Collection

- Data Collection. for Spot Speed Data and Traffic Volume Data. To begin understanding the influence of on-street parking zones on driving behavior within a portion of a road, a survey was required. The survey also gave an opportunity to gather information that was deemed as essential for observing qualitative affects and creating mathematical models to quantify consequences of speed. No survey technique has been utilized or created to accomplish the aforementioned goals, according to a thorough examination of the pertinent literature. As a result, a novel observational survey methodology was devised. A sample size of at least 50 and ideally 100 cars is typically acquired for a

spot speed study at a chosen site. Traffic counts are often undertaken on a Tuesday, Wednesday, and Thursday. Traffic counts performed during a Monday morning or a Friday peak time may reveal abnormally high volumes and are not typically employed in the research. Spot speed data may be gathered in several ways, including using stopwatches, radar devices, pneumatic road tubes, and more.

But as the parking study requires both the speed and traffic volume data, therefore video photographic survey can be used in such type of cases. This method can be successfully used to obtain speed data and traffic volume data. A suitable length on the preferred road section should be selected. The either side of the selected road section should be marked with any bright colour. A video camera along with a tripod stand should be placed on the side of the road such that both the distinct marks on the road section are visible to the video camera. Also, the chance of occurrence of error in this method is minimal.

As mixed traffic condition is considered, therefore, volume data will be collected in terms of Passenger Car Unit (PCU) per hour. Under a certain set of road, traffic, and other conditions, the PCU may be used as an indicator of a vehicle class's relative space demand in comparison to that of a passenger car. One vehicle of a certain type is deemed equivalent to one passenger car with a PCU value of 1.0 if it alters the flow of traffic in the same way as one additional passenger car would. The ratio of a roadway's capacity when there are just passenger cars on it to that same roadway's capacity when there are only vehicles in that class is regarded to be the PCU value of that vehicle class. The Indian Roads Congress has suggested a set of PCU values for several fast- and slow-moving vehicle categories that are typically seen on Indian urban roads. These PCU values have been suggested by the IRC while providing the guidelines for capacity of roads in urban areas given in Table 1.

Table 1: PCU values recommended by the IRC of different types of vehicle on urban roads

Sl. No.	**Vehicle type**	**Equivalent PCU factor**	
		Percentage composition of vehicle type in traffic stream	
	Fast vehicles	**5%**	**10% and above**
1	Two wheelers- motor cycle, scooter	0.50	0.75
2	Passenger car, pick-up van	1.0	1.0
3	Auto-rickshaw	1.2	2.0
4	Light Commercial vehicle	1.4	2.0
5	Truck or Bus	2.2	3.7
6	Agricultural Tractor - Trailer	4.0	5.0
	Slow vehicles		
7	Pedal cycle	0.4	0.5
8	Cycle rickshaw	1.5	2.0
9	Tonga (Horse drawn vehicle)	1.5	2.0
10	Hand Cart	2.0	3.0

- Data Collection for Parking Stream Related indicators. All parameters related to on-road parking can be collected by license plate method of survey. In this survey, every parking spot is observed at a constant interval of time and the license plate numbers of parked vehicles are noted down. By this survey, parking accumulation, category wise parking duration and parking volume data can be obtained. At the same time interval, the effective road width can be measured adjacent to the parking spot. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labour intensive.

  As in the mixed traffic condition, different types of vehicles will be parked on road, therefore it is necessary to convert all the vehicles parked in a particular parking area to a single unit so that parking volume could be estimated for mixed traffic condition. This particular factor is termed as Equivalent Car Space (ECS) Conversion Factor. The adopted ECS value are shown in Table 2.

Table 2: ECS values

Vehicle Type	Parking Slot Dimension	ECS
Car	5 m x 2 m	1.0
Two wheeler	2 m x 1 m	0.2
Cycle	2 m x 0.5 m	0.1
Autorickshaw	3 m x 1.5-2 m	0.6
Cycle rickshaw	2.5 m x 1 m	0.5
Bus	15m x 2.6 m	3.9
HCV	2.4m x 9m	2.2
LCV	2 m x 5m	1

4. **Data Analysis:** After collecting the data, some preliminary analysis will be conducted to estimate the different parking characteristics. Then a relationship can be drawn between traffic characteristics and parking characteristics by a regression analysis. The postulated model for the regression analysis is given in Eq. 1.

$$\boldsymbol{y = a_1 x_1 + a_2 x_2 + a_3 x_3} \quad (1)$$

Where, y is traffic characteristics

x1, x2 and x3 are parking volume, parking duration and effective road width respectively. This equation indicates how traffic characteristics are affected by on-road parking. After that, average parking duration of different vehicle classes will be estimated from the collected data. Based on the analysis, some parking policy will be decided.

IV. STUDY AREA SELECTION

The study was conducted in various locations of Guwahati. Guwahati is an important business hub in North East India and it is largest city in this region. The city is spread across the bank of the mighty Brahmaputra River with an estimated area of 216 sq km. In different localities in Guwahati, specially near the market area, on-road parking was found to be a

major issue. Maximum of the road sections are occupied the parked vehicles which create inconvenience for the adjoining traffic stream. For the survey purpose three important market areas are selected across the Guwahati city which are Narengi Market area (location 1), Bamunimoidan Market area (location 2), Six Mile Market are (Location 3).

V. RESULTS AND DISCUSSIONS

The data collected from the three survey locations have been extracted and the analysis of the data is conducted. The survey was conducted on the locations on weekdays from 8am to 8pm. The survey data include parking related data as well as traffic stream characteristics. The extracted data along with some initial analysis is shown in Table 3. In Table 3, the average speed of the vehicles, indicates the average speed of all the vehicles running in the adjoining road in different time intervals. Traffic volume column indicate the traffic volume data for the vehicles running in the adjoining lane. Effective width of the road indicates the available width of the road after considerable portion of the road is occupied by the parked vehicles. Parking volume data is calculated based on the ECS values. Initially classified parked vehicle count survey was conducted, then the number of different vehicle classes have been converted to ECS/hr as per Table 2.

For location 1 (L1) it is found that average speed of the vehicles are lowest in the time interval of 10 to 11 am. Within this time, effective width of the adjoining road is also found to be lower and parking volume is found to be higher. It indicates that with the increase of parked vehicles, the effective width of the road decreases and average speed of the adjoining road decreases. Similarly for location 2 and 3 similar situations are observed in the time interval of 10 to 11 am and 5 to 6pm respectively. It indicates that with decreasing effective width, parking volume increases and speed in the adjoining road decreases. Table 3 indicates the variation of traffic volume with parking volume data. It indicates that with an increase in parking volume in some instances traffic volume decreases. But the relationship is not strong as in the previous instances, because traffic volume data is not only dependent on parking volume. There are other factors too, on which traffic volume depends. The average parking duration for different types of vehicles is shown in Table 3. From the physical survey of different locations, it was found that, driver of the commercial vehicles, in most of the cases, haphazardly parked the vehicle occupying a significant portion of the road width, which in turn minimize the effective road width. Moreover, it is found that, in some instances, personal four-wheeler also parked over the road section occupying significant portion of the road width. But in case of personal vehicles, the parking duration is found to be very less. So, they cause minimum disruption of the existing traffic stream

Table 3: Traffic stream characteristics and parking characteristics for location 1 in different time interval

Time	Location	Avg. Speed of the vehicles (Kmph)	Traffic volume (PCU/hr)	Effective width of the road (meter)	Average Parking Duration	Parking Volume (ECS/hr)
	L1	15.89	976.2	4.1	13.8	32.2
	L2	21.31	831.6	4.6	26.77	37.7

8am-9am	L3	22	1007.6	5.97	22.01	16.6
	L1	14.82	1416.4	3.35	20.96	21.1
	L2	19.9	969.6	4.2	20.72	59.3
9am-10am	L3	19	1001.6	6.27	22.11	13.8
	L1	**6.82**	**1392**	**3.25**	**27**	**34.4**
	L2	**14.27**	**908**	**4.6**	**17.97**	**54.6**
10am-11am	L3	14.5	1012.4	6.05	25.26	37.8
	L1	9.28	1264.4	3.85	44.49	19.1
	L2	14.87	1154	5.8	27.36	22.3
11am-12pm	L3	14.1	1000.4	5.26	25.17	28.6
	L1	9.85	1134	3.8	25.66	29.8
	L2	14.31	983.2	4.3	26.12	43.1
12pm-1pm	L3	22.04	920.4	4.4	27.5	33
	L1	13.05	1085.6	4.15	38.02	23.5
	L2	23.33	1128.4	5.2	30.54	36.3
1pm-2pm	L3	23.53	840	6.44	20.17	16.5
	L1	13.37	1054	4.7	39.46	20.7
	L2	22.75	877.2	4.2	48.66	25.4
2pm-3pm	L3	23.57	593.6	6.15	24.7	22
	L1	14.2	951.6	4.65	32.52	21.4
	L2	20.25	972.4	5.2	30.95	54.5
3pm-4pm	L3	20.14	722.8	6.47	15.5	22
	L1	12.26	1207.2	4.5	32.92	17.3
	L2	18.46	1094.5	5.4	36.05	32.5
4pm-5pm	L3	18.19	884.8	4.48	20.77	17.3
	L1	12.42	1104.8	3.65	27.37	21.9
	L2	15.02	1082	5.8	31.82	50.7
5pm-6pm	**L3**	**13.97**	**946.8**	**4.37**	**21.02**	**52.4**
6pm-7pm	L1	14.19	892	3.52	19.25	18.5
	L2	15.85	1058.8	6	32	44.8
	L3	14.44	718.8	4.66	22.07	34.3
	L1	14.63	893.2	3.9	23.42	13.3
	L2	27.58	819	4.7	18.1	32.8
7pm-8pm	L3	27.7	713.2	4	2.67	40.3

VI. ESTIMATING RELATIONSHIP BETWEEN PARKING PARAMETERS AND TRAFFIC PARAMETERS

From the above discussion, it is clear that, traffic parameters like maximum speed of the passing vehicles and traffic volume have some relationship between parking parameters like effective width, parking volume and parking duration. But it is also evident from the above sections that the relationship between traffic volume and other parking parameters are not clear enough. In this regard, initially two separate models have been established for predicting the traffic volume and maximum traffic speed using the parking parameters. But from the analysis it is found that the regression coefficient for the relationship between traffic volume and parking parameters are very small. It indicates that the parking parameters considered in this study are not enough in predicting the traffic volume. Therefore, a

mathematical model is formed displaying the relationship between maximum traffic speed and parking parameters. For the regression analysis, the data from all the locations were considered together.

The coefficient values for the regression analysis for are shown in Table 4. From the coefficient values it can be seen that the most important parameter is effective width of the road section. Coefficient values for parking volume and average parking duration are found to be negative. It indicates that if the parking volume and average parking duration increases, the maximum speed of the vehicles will decrease. The coefficient value for effective width of the road section is found to be positive. It indicates that if the effective width increases, the maximum speed of the vehicles will also increase. The R2 value for the relationship is found to be 0.75 which is an acceptable value. The relationship between the maximum traffic speed and the parking parameters could be drawn using the following equation:

$$Maximum\ traffic\ volume = 87.86 - 0.38 \times Parking\ volume - 0.35 \times Average\ parking\ duration + 4.905 \times \text{Effective Width of the Road Section} \quad (2)$$

Table 4: Coefficient values for the regression analysis

Dependent variable	Independent variable	Coefficients	Sig.
Maximum traffic speed	Constant	87.86	0.001
	Parking volume	-0.38	0.007
	Average parking duration	-0.35	0.04
	ve Width of the Road Section	4.905	0.01

VII. CONCLUSIONS

Based on the available information, it can be concluded that on-road parking has a significant impact on traffic flow and safety. Parked vehicles occupy a significant portion of the road width, reducing the effective width of the road and forcing vehicles to drive closer to each other, which can increase the chances of accidents. On-road parking also causes stop-start conditions for the main traffic stream, resulting in traffic congestion. The duration of parking for personal vehicles is found to be very less, causing minimum disruption to the existing traffic stream. The study also highlights the need for careful selection and control of on-street parking facilities and their locations to avoid a decrease in the capacity of the road network. The study also suggests that video photographic survey can be used to obtain speed data and traffic volume data for parking studies.

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