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Assessing Urban Parking Challenges: Impact on Traffic Speed and Road Capacity in Nekemte City, Ethiopia

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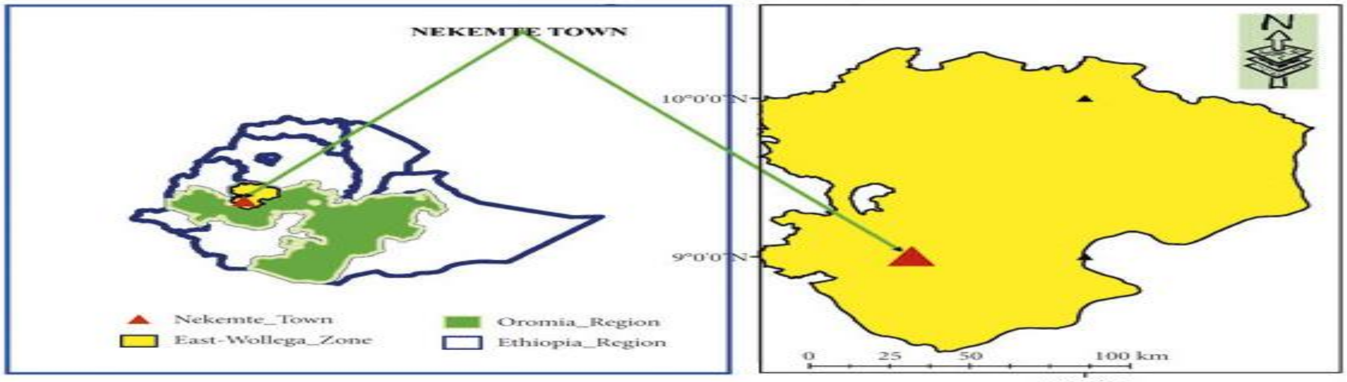
Abstract: This study evaluated the impact of on-street parking on traffic speed under mixed traffic conditions in Nekemte City, Ethiopia. Data on the traffic volume, speed, and parking parameters were collected at selected mid-block locations during peak hours. The results showed that the speed of vehicles, particularly heavy vehicles and trucks, decreased significantly with increased traffic volume compared with other categories. The vehicular speed noticeably diminished as parking levels increased. A multiple linear regression model was developed using the SPSS software to analyze the percentage reduction in speed. The model indicated that for a given road width at a location with on-street parking, as parking turnover, duration, accumulation, or traffic volume increased, the percentage reduction in speed also increased. Conversely, as the road width increased, the percentage reduction in speed decreased, and vice versa, whereas the other parameters remained constant. The study concluded that the volume-speed relationship capacity of each road in the parking area and away from it could be determined, and models for percentage speed reduction could be developed using road width, parking parameters, and traffic composition. This study provides recommendations for maintaining a maximum speed reduction of 40% at selected locations for street parking based on the road width, traffic volume, parking turnover, duration, and accumulation.

Keywords: On-street parking, traffic speed reduction, traffic volume, parking parameter, passenger car unit (PCU), Linear regression model

I. Introduction

Parking plays an important role in the transport system, because all vehicles require a storage location when not in use. A crucial issue in Nekemte, which is located in the Oromia region of Ethiopia and East Africa, is the scarcity of parking spaces. The car parking sector is significant for urban mobility and serves as a fundamental element in achieving a high level of accessibility in city centers. Many businesses and municipalities recognize that an adequate parking supply, particularly for visitors, is vital for competitive growth. Enhancing the urban environment also partly depends on effective parking management (Napier University, December 2008). This has been a key issue for many municipal governments in Africa as they undergo rapid motorization. These parking-related problems are alarming in developing countries and will be frightening if parking policies are not reviewed [2–4]. In rapidly urbanizing cities, on-street parking has become a pressing issue because of its impact on traffic congestion, road safety, and urban land-use efficiency. Despite its growing significance in urban transport systems, parking remains an under-researched area in the transport field, particularly in developing countries [1, 5]. though automobiles spend over 95% of their time “parked” [6] every day in three distinct parking places on average [7]. The American Association of State Highway and Transportation Officials (AASHTO 2011) states that the road capacity of four- to six-lane arterial roads can be increased by 50–80% by removing kerbside on-street parking [8]. On-street parking can affect road capacity, with a reduction in available lanes to accommodate it being the primary factor that diminishes road capacity. Furthermore, on-street parking maneuvers can cause significant delays, particularly on heavily trafficked roads. This results in stop-start traffic flow behavior for lanes adjacent to the parking lane, thereby affecting the capacity of the road section [9]. Parking is a serious problem for urban planners and traffic engineers. With a growing population of motor vehicles, parking issues are considered severe [9]. Identifying the effects of on-street parking on traffic speed and pedestrian safety requires engineering judgment. Therefore, this study aimed to address the current parking challenges in cities.



NEKEMTE STUDY AREA

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Study Area

Nekemte is located in the western part of the Oromia National Regional State, 328 km from the eastern part of Finfinnee and 250 km from Jimma City. Nekemte has a latitude and longitude of 9°5′N 36°33′E and an elevation of 2,088 m.

Its astronomical location is 9°460″ N and 36° 31’ E, at an elevation of 2088 m above sea level. The city is situated along a road that connects Finfinnee to Assosa, the capital.

II. Materials and Methodology

A comprehensive methodology is developed to investigate the impact of on-street parking on the capacity of urban transport corridors. Adjoining land use along these corridors often generates demand for on-street parking, which can disrupt traffic flow and ultimately reduce the effective capacity of the road network [10]. Field data were collected from selected mid-block locations without the manipulation of variables, and statistical analysis using multiple linear regression was conducted to assess the relationships among parking parameters, traffic volume, and vehicle speed.

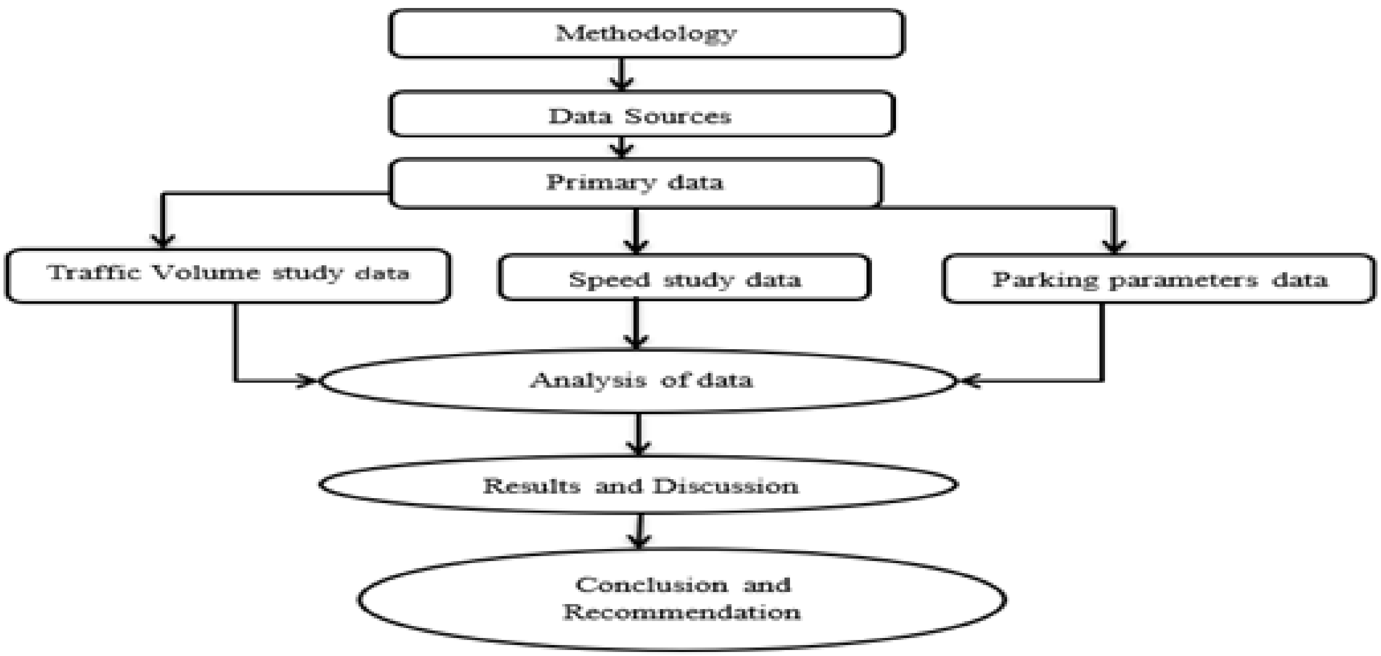

Figure 2: Methodology in the Flow chart

Data Sources

The study was based on data collected from primary sources [11]. Primary data were used to analyze social and environmental situations based on the effects of on-street car parking. Questionnaires and interviews were also employed to understand the importance, satisfaction, scarcity, and unfair road use of on-street parking.

A passenger car unit (PCU) is a metric used in transportation engineering to assess the traffic flow rate on highways. This interference value was used to convert a vehicle into an equivalent passenger car unit. The equivalent PCUs of different vehicle categories do not remain the same under different circumstances.

Table 1: PCU Factors for Different Vehicles (Source: HCM, 2000)

Vehicle category	Values of PCU
Car	1.0
Motor Cycle	0.5
LCV	2.2
Bus, Truck	3.5

Site Selection

To examine the impact of on-street parking on traffic speed and road capacity, four locations were selected based on varying road width, as mentioned in Table 2

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Table 2: Widths of selected mid-block sites studied.

Sub-city location	**Board**	**In front of Nekemte Auditorium**	**In front of Ethio Telecom**	**2nd roundabout (Desalegn)**
The width of each road in meters	8	12	8	10

Several traffic characteristics and parking parameters were then investigated and counted, including the traffic flow volume, parking duration, parking turnover, parking accumulation, and speed data. The data collected in these studies were primarily primary. Necessary field visits and data collection were conducted in the mid-block sections of the study area. The collected data included the volume, speed, lane widths, and parking parameter data to achieve the following objectives:

Table 3: Mid-block PCU hourly variation volume data collection at each location

Time in Hours	**Board**	**In front of Nekemte Auditorium**	**In front of Ethio-telecom**	**2nd roundabout Desalegn**
	PCU hourly variation of Traffic			
8:00 - 9:00 am	1541	1484	1376	1376
9:00 – 10:00 am	1454	1119	1063	1063
11:30 – 12:30 am	1199	771	659	659
12:30 – 1:30 pm	1078	643	543	543
5:00 – 6:00 pm	1,170	693	638	638
6:00 – 7:00 pm	1042	773	480	480

Table 4: Mid-block average speed in km/hr of vehicles at and away from parking

Time in sec.	**Board**		**In front of Nekemte Auditorium**		**In front of Ethio-Telcom**		**In front of the Desalegn hotel**	
	Average speed at parking **(km/hr)**	Average speed away from parking **(km/hr)**	Average speed at parking **(km/hr**	Average speed away from parking **(km/hr)**	Average speed at parking **(km/hr**	Average speed away from parking **(km/hr)**	Average speed at parking **(km/hr**	Av.Speed away from parking **(km/hr)**
8:00-8:15	32.2	47.62	25.4	33.6	22.4	45.62	21.5	34.8
8:15-8:30	27.6	39.56	22.2	32.2	21.4	40.5	20.2	32.2
8:30:8:45	27.06	41.06	26.1	35.1	27.06	41.06	26.1	35.1
8:45-9:00	28.24	37.44	23.4	30.8	28.24	37.44	23.4	30.8
9:00-9:15	27.5	36.92	22.3	29.7	27.5	36.92	22.3	29.7
9:15-9:30	24.4	32.06	23.8	32.06	22.2	36	23.8	32.06
9:30-9:45	22.7	30.88	24.3	30.88	22.7	30.88	20.1	33.5
9:45-10:00	20.8	28.5	28.4	29.5	20.8	28.5	23.6	37
11:30-11:45	23.9	37.8	23.9	33.3	23.9	37.8	23.9	33.3
11:45-12:00	23.8	33.8	23.3	31.8	23.8	33.8	23.3	31.8
12:00-12:15	23.3	32.7	24.9	32.7	23.3	32.7	24.9	33.3
12:15-12:30	27.3	37.5	27.4	37.5	22	38.5	27.4	37.5
12:30-12:45	24	34.02	24	34.02	24	34.02	24	34.02

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12:45-1:00	23.1	41.08	23.1	41.08	23.1	41.08	23.1	41.08
1:00-1:15	27	40.6	22	33	27	40.6	23.6	38
1:00-1:30	25.6	45.6	23.8	34	21.5	38.2	23.3	36.9
5:00-5:15	25.9	38.3	22	38.3	25.9	38.3	22	38.3
5:15-5:30	25.98	37.98	22.5	37.98	25.98	37.98	22.5	37.98
5:30-5:4	25	34.94	21	34.94	25	34.94	22.1	34.94
5:45-6:00	27.1	43.1	19.3	32	27.1	43.1	19.8	31.3
6:00-6:15	26.6	40.2	24.2	35	26.6	40.2	24.2	35
6:15-6:30	26.5	40.5	21.7	38.5	22.5	43	21.7	38.5
6:30-6:45	24.5	35.6	23.2	35.6	24.5	35.6	20.3	35.6
6:45-7:00	23.6	35.02	22.4	32	22	43	21.2	37

III. Results and Discussion

An extensive examination of the processed data reveals the efficacy of on-street parking. The parking characteristics show the daily performance of parking, such as parking parameters. An important characteristic of street parking is the vehicle location scheme, which depends on the complexity and duration of pulling into and out, as well as the speed and delay of the main flow [12, 13, 14]. These characteristics help to reveal the problems that occur in parking facilities. Recommendations were offered to help manage these discoveries. The collected data were also analyzed using multiple linear regression models to analyze and present the data. In addition, it is necessary to consider a range of additional factors such as parking fees, information on the degree of occupancy of the parking lot, and the existence of public transport routes [15].

Multiple Linear Regression Model

The multiple linear regression method attempts to represent the percentage reduction in the speed of a traffic stream as a function of several variables. For example, the percentage reduction in speed can be represented as

% Reduction Speed= $a_0+TVc_1-c_2 RW+c_3 PT+c_4 PD+c_5PA$

Where

VT denotes the number of vehicles in Pcu/h.

RW Was the width of the road

PT Was the parking turnover

PD Was The parking duration,

PA Was parking accumulation

The coefficients c_1 to c_5 represent the relative sizes of the percentage of speed reductions for each vehicle type. In general, in the above model, the reduction speed is a dependent (output) variable and the measured parameters, such as the volume of traffic, road width, and parking parameters, are independent (input) variables. The data collected from the field were used to construct a regression model to obtain the speed prediction values. The model was validated and used to demonstrate the influence of the traffic volume and composition on the classified speeds.

Analysis of total average reduction speed at mid-block

Table 5 clearly shows that the average reduction speed and percentage of reduction speed at the mid-block around the board area are 12.04 km/hr and 32%, respectively.

Table 5: Percentage reduction of average speed

Width of Road	**12m**				
Time Intervals	**Volume Pcu/hr.**	**Average speed at parking**	**Average. Speed away from the parking**	**Reduction of speed in km/hr.**	**% of reduction**
8:00- 8:15	362	32.2	47.62	15.42	32.38%

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8:15-8:30	491	27.6	39.56	11.96	30.23%
8:30-8:45	325	27.06	41.06	14	34.10%
8:45 – 9:00	363	28.24	37.44	9.2	24.57%
9:00-9:15	461	27.5	36.92	9.42	25.51%
9:15 – 9:30	564	24.4	32.06	7.66	23.89%
9:30 – 9:45	222	22.7	30.88	8.18	26.49%
9:45 – 10:00	207	20.8	28.5	7.7	27.02%
11:30-11:45	233	23.9	37.8	13.9	36.77%
11:45 -12:00	451	23.8	33.8	10	29.59%
12:00- 12:15	364	23.3	32.7	9.4	28.75%
12:15 -12:30	151	27.3	37.5	10.2	27.20%
12:30 -12:45	246	24	34.02	10.02	29.45%
12:45 - 1:00	174	23.1	41.08	17.98	43.77%
1:00 -1:15	237	27	40.6	13.6	33.50%
1:15 – 1:30	421	25.6	45.6	20	43.86%
5:00 -5:15	396	25.9	38.3	12.4	32.38%
5:15 – 5:30	242	25.98	37.98	12	31.60%
5:30 -5:45	317	25	34.94	9.94	28.45%
5:45 – 6:00	215	27.1	43.1	16	37.12%
6:00 – 6:15	440	26.6	40.2	13.6	33.83%
6:15 – 6:30	246	26.5	40.5	14	34.57%
6:30 -6:45	193	24.5	35.6	11.1	31.18%
6:45 -7:00	163	23.6	35.02	11.42	32.61%
Average reduction speed and percentage reduction				**12.04 km/hr**	**32%**

As shown in Table 5, the motorcycle is more effective than the other vehicles because the data shows that the motorcycle speed is faster than that of the other vehicles. The average reduction in speed and percentage reduction of trucks are less effective than those of other vehicles, because the data show that the speed of trucks is lower than that of other vehicles.

Table 6: Average Speed of each vehicle at and away from the parking

Time Interval	**Motorcycle (Away)**	**Motorcycle (At)**	**Car (Away)**	**Car (At)**	**Van (Away)**	**Van (At)**	**Bus(Away)**	**Bus (At)**	**Truck (Away)**	**Truck (At)**
08:00–08:15	40.2	28.2	45.0	30.0	60.6	40.6	53.0	33.0	39.3	29.3
08:15–08:30	33.8	23.8	34.1	24.1	52.9	32.9	40.5	30.5	36.5	26.5
08:30–08:45	36.5	26.5	40.8	30.8	57.2	27.2	37.1	27.1	33.7	23.7
08:45–09:00	38.0	28.0	43.5	33.5	39.1	29.1	34.9	28.9	31.7	21.7

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09:00–09:15	43.0	33.0	39.6	29.6	37.0	27.0	36.0	26.0	29.0	22.0
09:15–09:30	31.8	29.8	33.0	23.0	35.5	25.5	32.0	22.0	28.0	21.5
09:30–09:45	33.5	23.5	34.0	24.0	32.9	22.9	28.3	22.3	25.7	20.7
09:45–10:00	32.0	22.0	40.0	20.0	42.3	22.3	30.2	20.2	29.5	19.5
11:30–11:45	56.5	26.5	35.7	25.7	33.7	23.7	30.9	20.9	32.6	22.6
11:45–12:00	45.6	25.6	36.1	26.1	33.5	23.5	25.5	21.5	28.7	18.7
12:00–12:15	39.6	26.6	37.3	27.3	34.0	24.0	29.9	20.9	22.6	17.6
12:15–12:30	38.9	28.9	39.1	29.1	40.0	29.0	36.7	26.7	33.0	23.0
12:30–12:45	33.5	23.5	35.2	25.2	32.8	22.8	38.0	28.0	30.6	20.6
12:45–13:00	40.2	20.2	43.7	23.7	42.4	22.4	40.0	20.0	39.1	29.1
13:00–13:15	45.9	25.9	39.7	29.7	40.3	20.3	38.8	28.8	38.3	30.3
13:15–13:30	52.5	22.5	48.4	28.4	45.7	25.7	43.3	23.3	38.0	28.0
17:00–17:15	43.5	23.5	37.1	27.1	39.5	29.5	40.9	28.9	30.6	20.6
17:15–17:30	45.0	25.0	36.1	26.1	34.5	24.5	41.7	31.7	32.6	22.6
17:30–17:45	35.6	25.6	36.2	26.2	34.1	24.1	37.9	27.9	30.9	20.9
17:45–18:00	52.3	32.3	45.1	25.1	44.6	24.6	36.8	26.8	36.7	26.7
18:00–18:15	53.0	23.0	36.1	26.1	34.6	26.6	37.2	27.2	39.9	29.9
18:15–18:30	43.6	23.6	44.2	24.2	39.6	29.6	38.1	28.1	37.2	27.2
18:30–18:45	39.5	29.5	44.7	24.7	33.8	23.8	34.8	24.8	25.0	19.8
18:45–19:00	37.8	27.8	43.4	23.4	32.6	22.6	33.5	23.5	27.8	20.8
Average Reduction speed	**15.3km/hr**		**13.1km/hr**		**13.7km/hr**		**10.7km/hr**		**8.9km/hr**	
	35%		**33%**		**34%**		**29%**		**27%**	

The average speeds of individual vehicles away from on-street parking and on-street parking are shown in Figure 2.

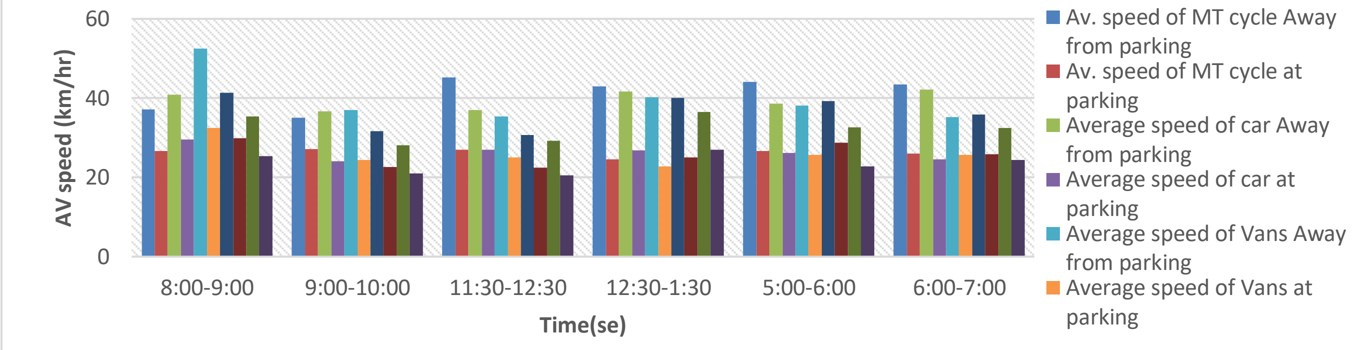

Figure 3: Average speed distribution at and away from the parking board location

As shown in Table 6, as the traffic volume increases, the speed of vehicles, particularly trucks, decreases more quickly than that of other types of vehicles. Conversely, two-wheelers are less affected by changes in volume owing to their compact size and excellent maneuverability. As a result, the speed–volume curve for two-wheelers is the least steep, whereas the rate at which the speed decreases for cars is slightly greater than that for buses, owing to the slightly larger size of buses. Cars, being larger, experience more interaction in high-volume conditions, resulting in a smaller speed reduction compared with vans. The speed of a vehicle is affected by the makeup of its traffic stream. To demonstrate this speed variation, the traffic composition was modified, while maintaining a constant traffic volume at a set level. Owing to the constraints of the graphical representation, the proportions of the average speed of vehicles at and away from parking can be adjusted in a complementary manner, whereas the other proportions of the traffic mix remain unchanged.

Hourly Variation of Traffic

From Table 7 below, the collected volume data at each mid-block during peak hour period, the collected volume data at board location was more when compared to other locations, and collected volume data around Ethio-telecom and Desalegn hotel are almost equal and less when compared to other location., the detail data collected is shown in the table below.

Table 7: Hourly total number of vehicles at each selected location at mid-block

Time in Hours	**Board**	**In front of Nekemte auditorium**	**In front of Ethio-Telcom**	**In front of the Desalegn hotel**
	PCU hourly variation of Traffic			
8:00 - 9:00	1541	1484	1376	1376
9:00 – 10:00	1,454	1119	1063	1063
11:30 – 12:30	1,199	771	659	659
12:30 – 1:30 pm	1078	643	543	543
5:00 – 6:00 pm	1,170	693	638	638
6:00 – 7:00	1042	773	480	480

The table above shows the total volume counted from the field in each mid-block. Based on the collected volume, the hourly variation in traffic during the peak hours is shown in Figure 3.

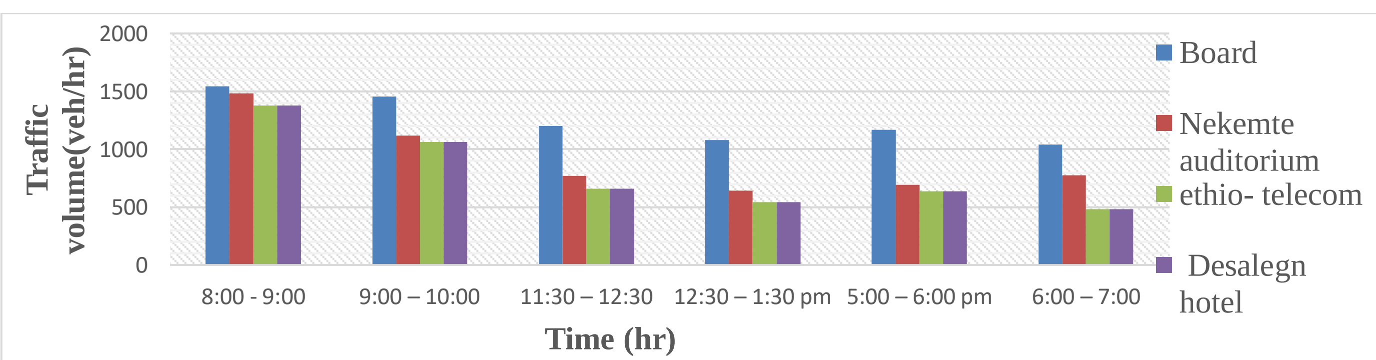

Figure 4: Hourly Variation of Traffic

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Hourly variation is required to determine the peak hour traffic, which helps improve mid-block measurement. A classified volume count of vehicles was performed in the field. From Figure 4, during the peak hour volume, the collected data for each mid-block location was the highest at 8:00–9:00 because it indicates that during this time, all government workers went to the office for work at the same time, and the volume collected at 6:00 -7:00 was the lowest compared to other peak hours because this indicates that at this time, the volume has been decreasing since the evening.

Analysis of Vehicles by percentage at each mid-block

From the table below, the percentage of volume presented data for each location, total number of trucks, and total number of buses that were collected for every 15-minute consecutive intervals were categorized as one because both of them decreased the road width. The percentage of volume collected data for each location, total number of cars, total number of vans, and total number of motorcycles that were collected for every 15-minute consecutive intervals are summarized and presented in the table below.

Table 8 Percentage composition of each vehicle at each location

Vehicle categories	**board**	**In front of Ethio Telecom**	**2nd Roundabout Desalegn**	**Nekemte city auditorium**
TW	6%	8%	6%	7%
Car	36%	37%	7%	10%
Taxi and minibus	37%	35%	9%	11%
buses	16%	15%	6%	6%
truck	5%	5%	9%	5%

Table 8 lists the different traffic compositions at different locations and the percentages of each vehicle category at different locations.

Volume –Speed relationship at on-street parking

The interplay between speed and volume as well as between speed and volume is a vital factor in evaluating a road's capacity to handle traffic. Owing to the difficulties in gauging traffic density in mixed traffic situations, studies have consistently focused on the speed-volume relationship across different road types. To assess this relationship under varying traffic conditions, the total number of vehicles in each period was converted to an equivalent number of PCUs, as presented in Table 1. In mixed-traffic settings, there is a notable variation in the speed between slower and faster vehicles. Therefore, the spot speed or space mean speed, which is typically calculated for uniform traffic, must be adjusted to reflect the diverse conditions of heterogeneous traffic.

From Table 9, the volume-speed relationship at different locations on the mid-block road and the capacity of that road are determined by plotted curves, with the X-direction written as the values of volume and the Y-direction recorded as the values of the average speed of each vehicle.

Table 9: Speed-Volume relationships at on-street parking for each location

Time in hour	**Board**		**In front of Ethio-telecom**		**Desalegn hotel**		**Nekemte city auditorium**	
	Total Av.Speed at parking in Km/hr.	Total Volume Pcu/hr.	Total Av. Speed at parking in Km/hr	Total Volume Pcu/hr	Total Av.Speed at parking in Km/hr	Total Volume Pcu/hr	Total Av.Speed at parking in Km/hr	Total Volume Pcu/hr
8:00-8:15	32.22	362	25.42	223	22.42	223	21.48	331
8:15-8:30	27.56	491	22.16	325	21.36	325	20.16	325
8:30:8:45	27.06	325	26.06	451	27.06	451	26.06	451
8:45-9:00	28.24	363	23.44	377	28.24	377	23.44	377
9:00-9:15	27.52	461	22.32	392	27.52	392	22.32	392
9:15-9:30	24.36	564	23.8	325	22.16	325	23.8	325

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9:30-9:45	22.68	222	24.28	199	22.68	199	20.08	240
9:45-10:00	20.8	207	28.4	147	20.8	147	23.64	162
11:30-11:45	23.88	233	23.88	129	23.88	129	23.88	203
11:45-12:00	23.08	451	23.28	200	23.08	200	23.28	209
12:00-12:15	23.28	364	24.88	169	23.28	169	21.88	183
12:15-12:30	27.34	151	27.34	161	22.34	161	27.34	176
12:30-12:45	24.02	246	24.02	116	24.02	116	24.02	178
12:45-1:00	23.08	174	23.08	110	23.08	110	23.08	144
1:00-1:15	27	237	22.8	135	27	135	23.6	145
1:00-1:30	25.58	421	23.76	182	22.58	182	23.36	176
5:00-5:15	25.92	396	21.92	180	25.92	180	21.92	235
5:15-5:30	25.98	242	22.78	156	25.98	156	22.78	156
5:30-5:45	24.94	317	21.24	158	24.94	158	22.14	158
5:45-6:00	27.1	215	19.3	144	27.1	144	19.7	144
6:00-6:15	26.56	440	24.16	151	26.56	151	24.16	205
6:15-6:30	26.54	246	21.74	133	22.54	133	21.74	215
6:30-6:45	24.52	193	23.16	108	24.52	108	20.28	212
6:45-7:00	23.62	163	22.42	88	22.82	88	21.22	141

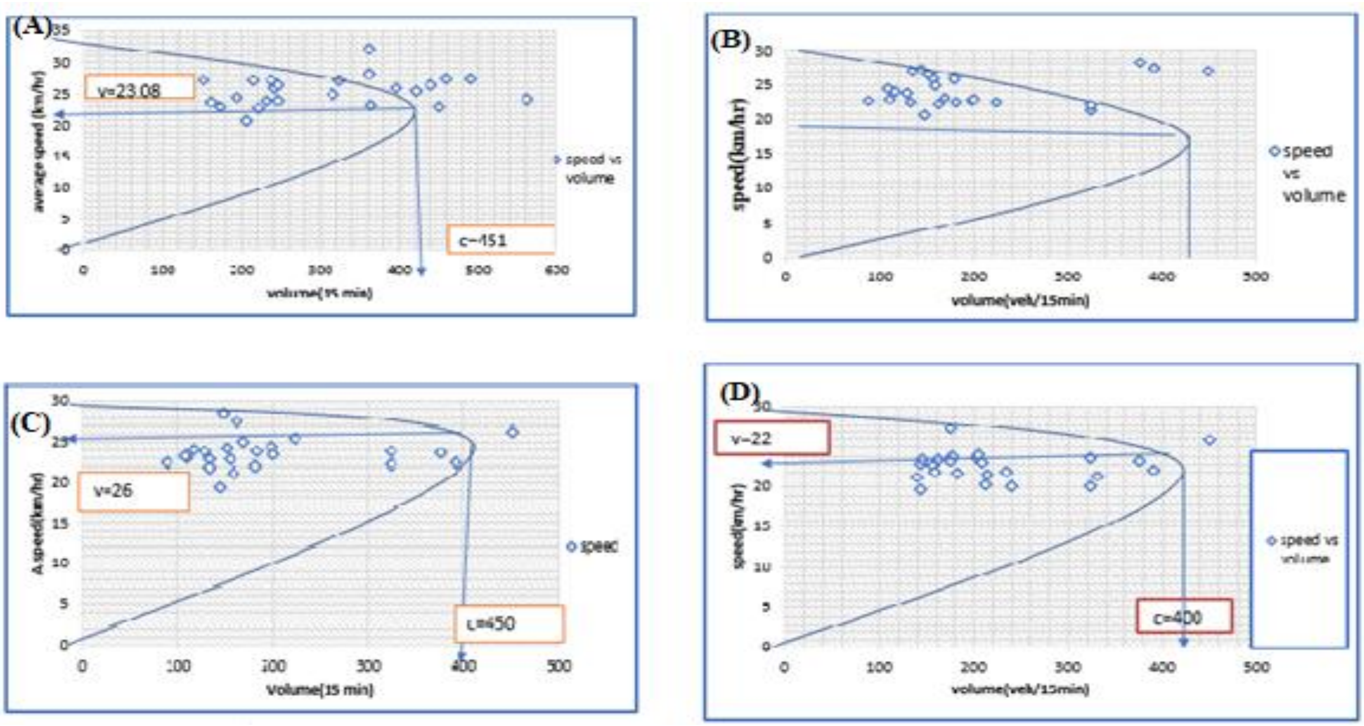

Figure 5: Speed Volume relationship at parking in front of (A) Board, (B) Dasalegn (C) Ethio Telecom (D) Nekemte Auditorium.

As shown in Figure 5, with an increase in speed, the traffic volume also increases up to a certain limit. However, as the speed increases further, the spacing between the vehicles becomes so large that the time headway between the vehicles also increases; thus, the volume decreases. The relationship between speed and volume of traffic is represented by a parabolic curve, as shown in Figure 5. It can be observed that there is an optimum speed at which the flow or volume is maximum, and at higher speeds, the flow starts to decrease.

Determination of Volume Capacity Ratio or v/c at the parking

From Table 10, the determination of the volume-to-capacity ratio that provides a level of service of the road for every 15-minute consecutive interval was different, indicating a mixed level of service. From Table 10, below the level of service of each location at every 15-minute intervals, on-street parking was higher when compared to the level of service away from on-street parking because

The capacity of the road was less because of on-street parking.

Table 10: Volume to Capacity ratio table at the parking area for each location

Time	**Board**			**In front of Ethio-telecom**			**Desalegn hotel**			**Nekemte city auditorium**		
	V.	C	v/c	V.	C	v/c	V.	C	v/c	V.	C	v/c
8:00-8:15	362	451	0.802	223	1033	1.02	223	1000	1.03	331	900	0.73
8:15-8:30	491	451	1.088	325	1033	1.06	325	1000	1.08	325	900	0.89
8:30:8:45	325	451	0.720	451	1033	0.87	451	1000	0.98	451	900	0.86
8:45-9:00	363	451	0.804	377	1033	0.75	377	1000	0.72	377	900	0.57
9:00-9:15	461	451	1.022	392	1033	0.81	392	1000	0.71	392	900	0.44
9:15-9:30	564	451	1.250	325	1033	0.63	325	1000	0.76	325	900	0.61
9:30-9:45	222	451	0.492	199	1033	0.85	199	1000	0.64	240	900	0.71
9:45-10:00	207	451	0.458	147	1033	0.51	147	1000	0.68	162	900	0.59
11:30-11:45	233	451	0.516	129	1033	1.22	129	1000	0.92	203	900	1.00
11:45-12:00	451	451	1.001	200	1033	1.21	200	1000	0.99	209	900	1.04
12:00-12:15	364	451	0.807	169	1033	1.00	169	1000	0.83	183	900	0.89
12:15-12:30	151	451	0.334	161	1033	0.81	161	1000	0.81	176	900	0.90
12:30-12:45	246	451	0.545	116	1033	0.68	116	1000	0.67	178	900	0.50
12:45-1:00	174	451	0.385	110	1033	0.65	110	1000	0.63	144	900	0.48
1:00-1:15	237	451	0.525	135	1033	0.89	135	1000	0.88	145	900	0.63
1:00-1:30	421	451	0.933	182	1033	0.95	182	1000	0.98	176	900	0.70
5:00-5:15	396	451	0.878	180	1033	1.04	223	1000	0.97	235	900	1.08
5:15-5:30	242	451	0.536	156	1033	0.90	325	1000	0.83	156	900	0.92
5:30-5:45	317	451	0.702	158	1033	0.79	451	1000	0.70	158	900	0.80
5:45-6:00	215	451	0.476	144	1033	0.65	377	1000	0.77	144	900	0.75
6:00-6:15	440	451	0.975	151	1033	0.98	392	1000	0.50	205	900	0.55
6:15-6:30	246	451	0.545	133	1033	0.54	325	1000	0.36	215	900	0.40
6:30-6:45	193	451	0.427	108	1033	0.62	199	1000	0.34	212	900	0.49
6:45-7:00	163	451	0.361	88	1033	0.65	147	1000	0.31	141	900	0.45

From Table 10 above, the volume-to-capacity ratio (v/c) of each location should be summarized in Figure 6 below.

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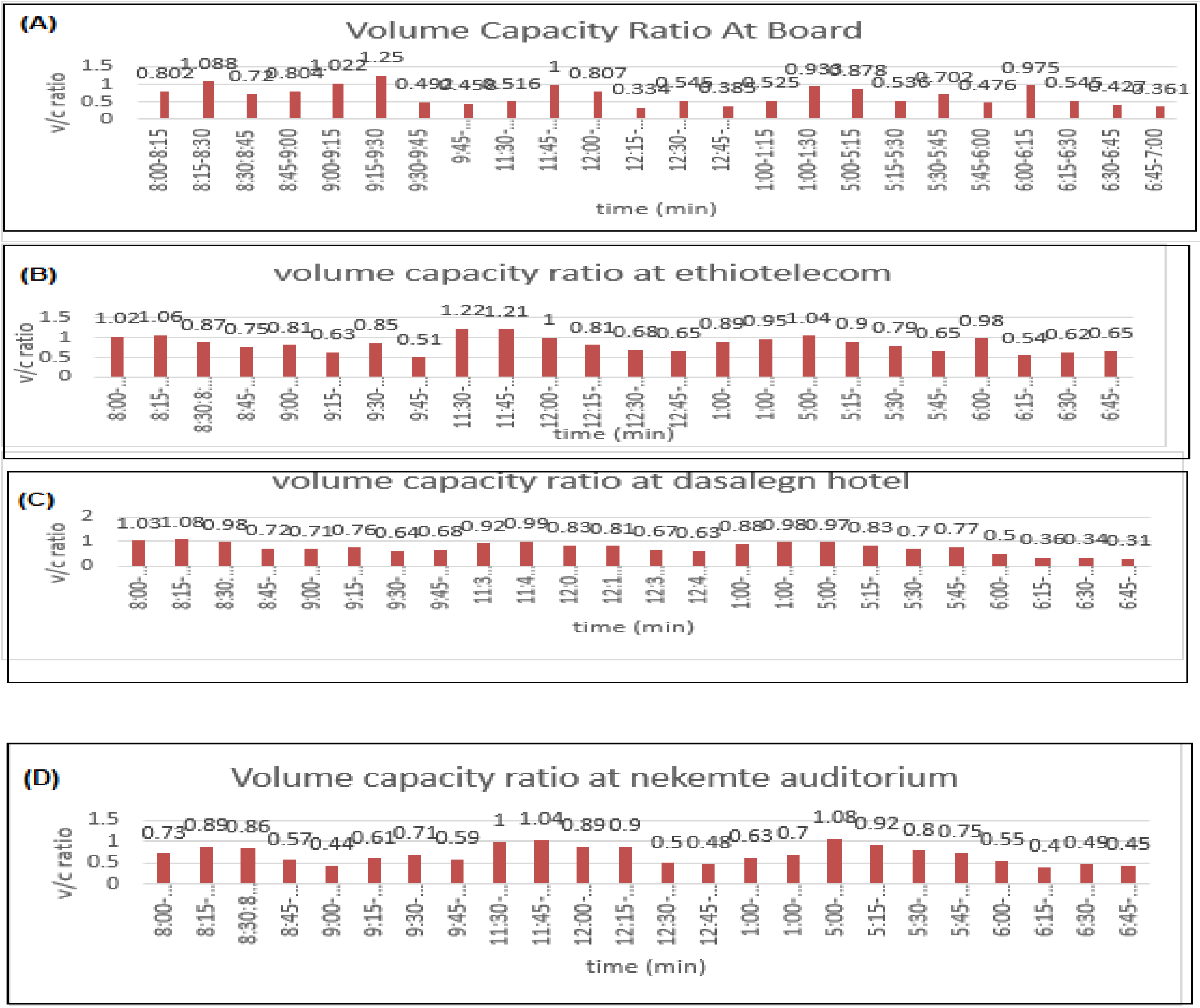

Figure 6: Volume to Capacity ratio graph at the parking area at (A) Board, (B) Ethio Telecom, (C) Dasalegn, (D) Nekemte Auditorium

Analysis of Parking Parameter

A parking survey was conducted at four locations to study existing parking traffic conditions. The peak parking hours occurred between 8:00 am and 7:00 pm. A parking lot is installed on one side of the road. The data collected from an on-street car parking location can be summarized as follows:

$$Parking\ duration = \frac{Parking\ load}{Parking\ Volume}$$

$$Parking\ turnover = \frac{Parking\ Volume}{no.of\ bays\ available}$$

Table 11 Details of parking parameters at each location of work

S.No	Location	Parking Parameters		
		Parking Accumulation	Parking Turnover	Parking Duration(min/veh)
1	Board	12	2.4	123
2	Ethio telecom	13	2.2	104

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3	Desalegn hotel	14	2.33	106
4	Nekemte city auditorium	15	2.5	107

Linear regression and correlation Analysis by SPSS

Linear regression was used to predict the value of an outcome variable Y based on one or more input predictor variables X. The aim is to establish a linear relationship between the predictor variable (s) and response variable; therefore, this formula can be used to estimate the value of response Y when only the predictor (Xs) values are known.

Regression analysis was performed using the Statistical Package for the Social Sciences (SPSS) software to evaluate the fit of various models (equations) to the relationship between the percentage of reduction speed (dependent variable) and the independent variables. The best-fitting equation among the five independent variables was selected for this study.

The correlation coefficients measure the reliability of the relationship (goodness of fit of the data for the mathematical relationship). This is a measure of how well one variable can predict another (given the context of the data), and determines the accuracy that can be assigned to the relationship.

Multiple linear regression analysis was used to understand the influence of various parking-related parameters on the traffic speed. This statistical method predicts the value of a **dependent variable** (Y), in this case the *percentage reduction in traffic speed*, based on the values of multiple **independent variables** (X_1, X_2, ..., X_n)—including traffic volume, parking turnover, parking duration, parking accumulation, and road width.

The analysis was performed using **(Statistical Package for the Social Sciences)** software to identify the best-fitting model that explains how these factors jointly affect traffic speed. The general form of the multiple linear regression model used is

Y=β0+β1X1+β2X2+⋯+βnXn+εY = \beta_0 + \beta_1X_1 + \beta_2X_2 + \cdots + \beta_nX_n + \varepsilonY=β0+β1X1+β2X2+⋯+βnXn+ε

Where:

YYY = Percentage reduction in traffic speed (dependent variable)

β0\beta_0β0 = Intercept term

β1,β2,...,βn\beta_1, \beta_2, ..., \beta_nβ1,β2,...,βn = Regression coefficients for each independent variable

X1,X2,...,XnX_1, X_2, ..., X_nX1,X2,...,Xn = Independent variables (predictors)

ε\varepsilonε = Error term (residual)

Assumptions of the Regression Model

To ensure a valid interpretation of the regression results, the following ***key assumptions*** were made:

Linearity: The relationship between the dependent variable and each independent variable is linear.

Independence of Errors: Observations are independent, and residuals (errors) are not correlated with each other.

Homoscedasticity: The variance of the residuals is constant across all levels of independent variables.

Normality of Residuals: The residuals were normally distributed.

No Multicollinearity: Independent variables are not highly correlated with one another.

These assumptions were evaluated using diagnostic tests and plots in SPSS, including residual plots, normal probability plots, and variance inflation factors (VIFs) to ensure the reliability and validity of the model.

Correlation Analysis

In addition to regression, **Pearson's correlation coefficients (r)** were calculated to assess the strength and direction of the linear relationship between each predictor and the response variable. The value of rrr ranges from -1 to +1.

r=1r = 1r=1: perfect positive correlation

r=−1r = -1r=−1: perfect negative correlation

r=0r = 0r=0: no linear correlation

A high absolute value of rrr indicates a strong relationship between the variables, which supports their inclusion in the regression model.

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Analysis of Variance (ANOVA) and Summary of the percentage of reduction Speed model in the combined location

Analysis of Variance using the SPSS software package was used extensively to establish a general descriptive percentage of reduction in speed statistics as well as the 95% Confidence Intervals (95% CI) for the mean % reduction in speed values.

To examine the percentage of speed reduction with respect to traffic volume, the road width, parking turnover, parking accumulation, and average parking duration at each location (board, in front of Ethio Telecom, and Desalegn) were combined to obtain the predicted value of this model. The mean reduction in the speed range was calculated. A strong relationship between the mean volume and the reduction in vehicle speed was identified. It was found that the traffic volume increased with an increase in the reduction speed, and when the width of the road decreased, the RS increased. Similarly, when parking accumulation, parking duration, and parking turnover increased, the RS also increased.

Thus, a regression analysis using traffic volume, road width, parking turnover, parking accumulation, and average parking duration as independent variables and percentage reduction speed as the dependent variable showed an excellent fit at the 0.000 level of significance. This relationship can be expressed using the following equation:

Speed reduction = $a_0 + (TV \times C_1) – (RW \times C_2) + (PT \times C_3) + (PD \times C_4) + (PA \times C_5)$.

where $a_{0 \text{ is a}}$ constant; TV = Traffic Volume, RW = Road Width, PT = Parking turnover; PD = Parking Duration and PA = Parking Accommodation; and c_1, c_2, c_3, c_4, and c_5 are the coefficients of each parameter.

Therefore,

% of Reduction of Speed = $a_0 + (TV *C_1) – (RW *C_2) + (PT * C_3) + (PD *C_4) + (PA *C_5)$

% of Reduction of Speed = 72.033+ 0.002TV – 2.479RW + 10.509PT + 0.340PD + 3.494PA

Table 12: ANOVA Results of Model Summary Regression Analysis

Model		Sum of Squares	df	Mean Square	F	Significance
	Regression	435.817	5	87.163	1.711	.000
1	Residual	3362.051	66	50.940		
	Total	3797.867	71			

a. Dependent Variable: % of Reduction in speed

b. Predictors: (Constant), Road width, Parking Duration, Parking Turnover, Traffic Volume, Parking Accumulation

Table 13: Coefficients Results model summary Regression Analysis

Model	Unstandardized Coefficients	Standardized Coefficients	time	Significance		
	B	Std. Error	Beta			
1	(Constant)	72.033	18.516		3.890	.000
	Traffic Volume	.002	.004	.065	.482	.001
	Parking Turnover	10.509	12.020	.316	.874	.005
	Parking Duration	.340	.791	-.051	-.430	.009
	Parking Accumulation	3.494	2.287	-.569	-1.527	.008
	Road width	-2.479	1.173	-.321	-2.113	.004
a. **Dependent Variable: % of Reduction speed**						

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IV. Conclusion

From the collected data, a volume-speed relationship graph was drawn to obtain the capacity of each road at each location. The parabolic curve, which shows the capacity of the road, shows that the traffic flow or volume is also low at very low speeds. Zero speed indicates zero flow or zero volume. With an increase in speed, the traffic volume also increases to a certain limit. However, as the speed increased further, the spacing between the vehicles became so large that the time headway between the vehicles increased; thus, the volume decreased. It can be observed that there is an optimum speed at which the flow or volume is at a maximum, and the flow starts to decrease at higher speeds.

Generally, the volume-speed relationship capacity of each road in the parking area and away from the parking area was determined. The capacity and traffic volume for every 15 consecutive minutes of the service level were determined. The percentage of speed reduction models was developed using the road width, parking parameters, and traffic composition. These models were found to be statistically sound, can be used for the reduction of speeds, and thereby speed reduction caused by each of the parking parameters

Recommendations

Maintaining a maximum reduction speed of 40% at the selected location for street parking, the following guidelines are recommended.

For a road width of 8m, the traffic volume should not exceed 1000 Pcu/h, parking turnover should be less than 0.6, parking duration should be less than 10 min, and parking accumulation should be less than 4.

For a road width of 10m, the traffic volume at the parking location should not exceed 1500 Pcu/h, parking turnover should be limited to 0.6, parking duration should be limited to 10 min, and parking accumulation should be limited to 4.

When the road width increases to 12m at a parking location, the traffic volume should not exceed 1900 Pcu/h by limiting the parking turnover to 0.3, parking duration to 12 min, and parking accumulation to 4.

To establish a curb-parking area, it is advisable to select road sections free of traffic congestion. When congestion occurs during peak times, implementing a time-restricted parking policy in curb-parking zones during these hours is recommended. This approach can help minimize the impact of curb-parking on traffic conflicts and enhance the safety of motor vehicles.

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