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A Case Study on the Influence of New Residential Apartments on a Busy Traffic Intersection in Erbil City

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Abstract: This paper focuses on the rapid urbanization of Erbil City and emphasizes the importance of collecting and analyzing traffic flow data for a new residential project. When evaluating a new apartment in relation to the surrounding traffic, factors such as carriageway width, speed limits, and the number of lanes significantly influence traffic flow. The report is based on manual surveys conducted at 13 stations around the new apartments. The analysis reveals actual traffic flow during peak hours and proposes solutions to increase capacity from 7,766 passenger cars per hour (pc/hr) to 23,864 pc/hr. Key proposals include constructing a new underpass and roundabout at the Ankawa-40m road intersection, adding eight main entrance gates, and implementing minor changes to flow direction. The major roads are 10 meters wide, while the minor roads are also 10 meters wide, allowing a total traffic flow of 28,800 pc/hr. Curve fitting indicates that the optimal flow is 1,750 pc/hr per lane, with a free-flow speed of 26 km/hr and a jam density of 225 pc/km. The methodology also considers factors that reduce flow capacity, including carriageway width, lane width, and pavement quality. For instance, Section S1 has a carriageway width of 7.16m, while Sections S2 and S3 measure 19.28m and 16.03m, respectively. Wider roads can handle more traffic but may encourage higher speeds, whereas narrower roads can lead to congestion. These factors should be considered when selecting an apartment, as they involve balancing concerns about noise, commute ease, and safety.

Keywords: *Traffic; Flow; Speed and Density*

1. Introduction

Traffic volume data is essential for planning new apartments and for designing and managing roadways [1]. In recent years, rapid urbanization and population growth have worsened traffic congestion in the city [2]. Traffic Survey data and road condition surveys are used to collect data on travel behavior patterns and characteristics throughout the new apartment area [3]. This document discusses the minimum possibility of the traffic volume for the entrance of the new apartments. It also recommends the most convenient solution to get the high-performance traffic around the apartment [4]. The main objectives of these traffic surveys are to grasp the trip characteristics of residents in the study area, which enables to provide of various sources for setting up the integrated transport plan and offer the necessary data for transport modeling and discuss the most convenient solution to choose the location of the entrance gate of the project within minimum traffic volume. The transportation system has been evolutionary, not the result of a grand plan [5]. The construction of new residential apartments in urban cities can be affected by several factors: population density, location of the development, existing traffic conditions, public transportation, parking facilities, road infrastructure, pedestrian, economic factors and technological advancements [6]. Understanding these factors and performing thorough traffic impact studies can assist urban planners and policymakers in managing the effects of new residential developments on traffic at intersections. However, the aspect of public transportation may be overlooked as it is not available in the urban areas being studied [7]. These transportation projects were chosen because it was concluded that they would lead to overall improvements to the system, as indicated in Figure 1 [8].

2. Methodology

Roads were selected based on various traffic flow conditions, including the number of access points and mobility along the main roads, as well as turning movements and traffic congestion [7]. This study focuses on the main road connecting the two parts of MRF to Quatro Tower, specifically the Gulan and Ankawa roads in Erbil City, Iraq see Figure 1 below.

2.1 Work Items

2.2 Preparatory Work

Preparatory work comprised of preparation of survey forms, recruitment of surveyors and supervisors, and their training. One day a training program was organized to instruct surveyors on the survey details and how to conduct it.

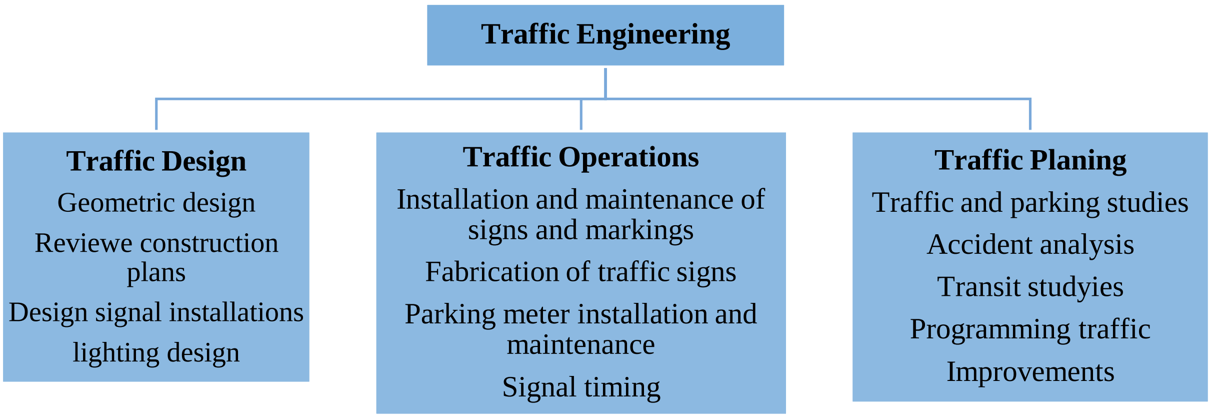

Figure 1: Grouping of Functions Within the Traffic Engineering Organization.

2.3 Field Survey

The supervisors directed the surveyors to various traffic junctions. Each day, different surveyors gathered data at a specific station [8]. Geometric data measured with tape is an important factor needed for the calculation of traffic analysis [9].

2.4 Data Collection

Observe all the turning movements in the specified directions for the junctions shown in Figure 2 below. Traffic movement counts (TMCs) were recorded for two peak periods over the course of one week, every day. These peak periods include AM Peak - 7:30 a.m. to 9:30 a.m. (2 Hours Period) and the LT Peak from 3:30 p.m. to 6:30 p.m. (2 Hours Period). Data collection was conducted over five days a week, from Sunday to Thursday, for two consecutive hours each morning and evening [10]. Additionally, geometric measurements were taken on-site using tape to measure the width of the carriageway and the number of lanes. The relationships between each parameter were found to be linear [11].

$$q = (n)/T \quad (1)$$

Where:

q = Flow rate (veh/hr)

n = The number of vehicles passing a point on the roadway (vehicles)

T = Average time headway (hour, min., sec.)

The time mean speed measured by:

(2) $$Us=\frac{nL}{\sum_{i=1}^{n} ti}$$

Where:

n = Number of vehicles

L = Length of the segment (km)

ti = Time takes the ith vehicle to travel across a section of highway (sec) [12].

(3) $$k= q/U$$

Where:

K= Traffic density (veh/km)

q = Flow (veh/hr) or (pc/hr)

U = Speed (km/hr)

All types of vehicles changed to passenger cars according to PCU [13, 14]. See Table 1 of traffic flow measured in field.

3. Data Analysis and Results

The characteristics of traffic flow were obtained through field measurements of flow and speed, followed by the calculation of density based on the relationship between these variables [15]. The main purposes of analyzing these characteristics are as follows:

1. To measure flow and speed on urban roads.
2. To explore the relationships between various characteristics of traffic flow.
3. To determine the relationship between flow, speed, and width of the carriageway.
4. If the width of the carriageway remains constant, there will be no changes in speed or flow.
5. It is also important to adhere to standard specifications for the width of the carriageway and each lane.

3.1 Flow and Speed Measured

The basic survey data and the number of car passenger units collected in each area are presented in Table 1 below.

- 40m-Ankawa Traffic Road (S1): This is a two-lane road as shown in Figure 2 below, where the maximum passenger car unit is approximately 1357 pc/hr.
- 40m-Ankawa Traffic Road (S2): This two-lane road has a maximum passenger car unit of about 2548 pc/hr.
- 40m-Ankawa Traffic Road (S3): This is a three-lane road with a maximum passenger car unit of about 2590 pc/hr as shown in Figure 2 below.
- 40m Road near MRF towers (S4): This two-lane (Two-way) road has a maximum passenger car unit of about 445 pc/hr as shown in Figure 2 below.
- 40m Road near MRF towers (S12): This two-lane road has a maximum passenger car unit of about 113 pc/hr as shown in Figure 2 below.
- 40m Road near MRF towers (S13): This two-lane road has a maximum passenger car unit of about 1531 pc/hr as shown in Figure 2 below.

At the 40m-Bahrka intersection, traffic data was collected in two directions as follows:

- 40m-Bahrka Road Intersection towards the project (S5): This two-lane road as shown in Figure 2 below, has a maximum passenger car unit of about 3840 pc/hr.
- 40m-Bahrka Road Intersection opposite the project (S6): This two-lane road as shown in Figure 2 below, has a maximum passenger car unit of about 5376 pc/hr.

The results are shown in Table 2.

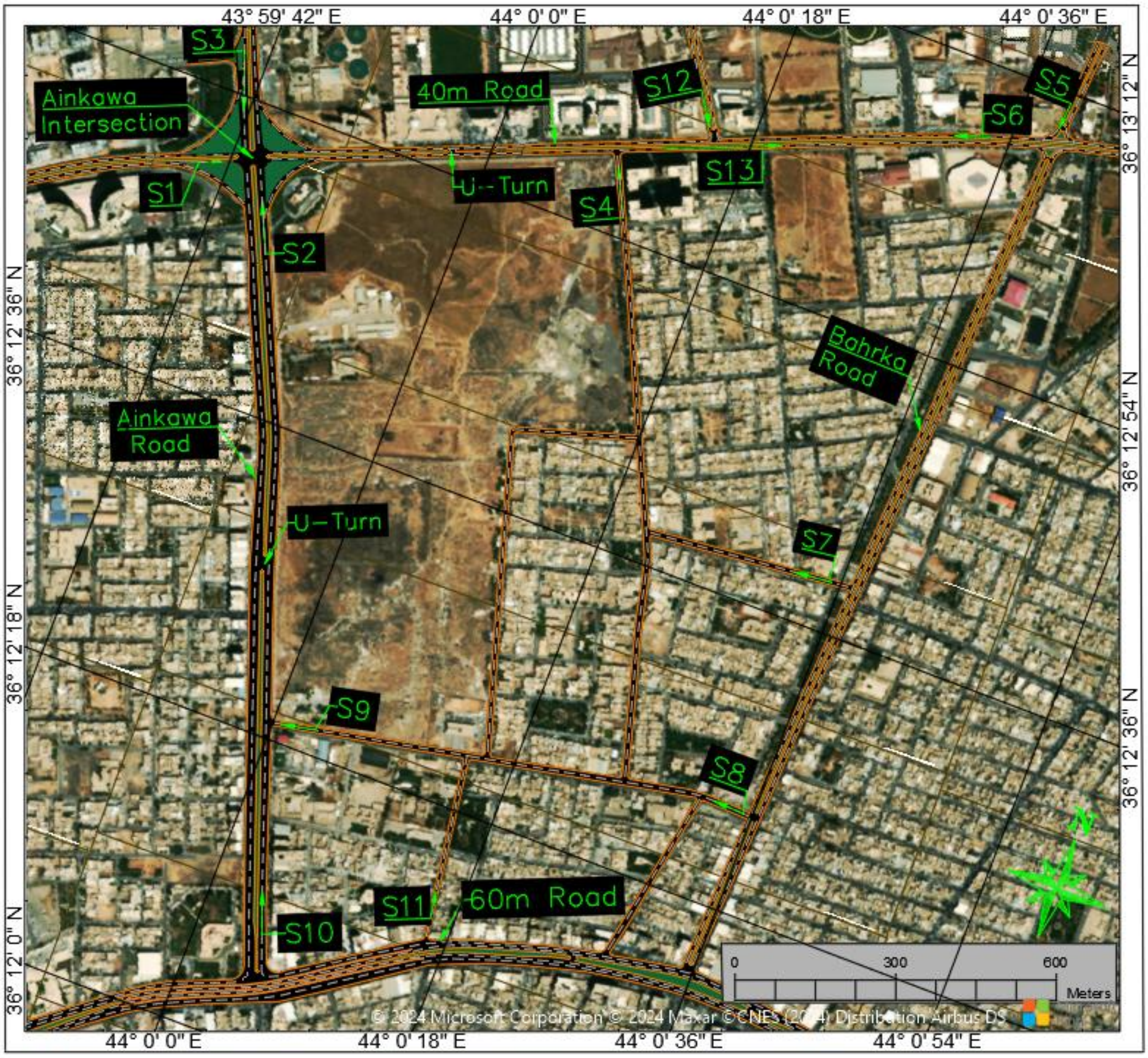

Figure 2: Locations of traffic points around the project.

Table 1: Traffic flow for passenger cars per hour per lane (pc/hr/ln) measured in location study

Time	*S1*	*S2*	*S3*	*S5*
7:30-8:00 am	439	616	658	1550
8:00-8:30 am	601	751	761	1681
8:30-9:00 am	557	775	819	1689
4:00-4:30apm	729	1105	910	1911
4:30-5:00 pm	628	1111	1010	1928
5:00-5:30 pm	661	1285	928	1884
5:30-6:00 pm	631	1263	1114	1865
6:00-6:30 pm	626	1121	1476	1838
7:30-8:00 am	439	616	658	1550
8:00-8:30 am	601	751	761	1681
8:30-9:00 am	557	775	819	1689

- The S7 Traffic points is a two-way, two-lane road located on Bahrka Road leading towards the project as illustrated in Figure 2. The maximum capacity for passenger car units at this point is approximately 124 pc/hr.
- The S8 Traffic point is also a two-way two-lane road located on Bahrka Road towards the project as shown in Figure 2. Here, the maximum capacity for passenger car units is about 387 pc/hr.
- The S9 Traffic point is a two-way two-lane road located alongside the project boundary towards the Ankawa Road as shown in Figure 2. This point has a maximum capacity of approximately 404 pc/hr for passenger car units.
- The S10 Traffic point is a 60-meter Ankawa traffic intersection with a four-lane road leading towards the project as shown in Figure 2. The maximum capacity for passenger car units is about 2863 pc/hr.
- The S11 Traffic point is a two-way, two-lane road on t 60-meter road that leads towards the project, as shown in Figure 2. The maximum capacity for passenger car units is approximately 168 pc/hr.

The results are shown in Table 2 below.

Table 2: Data collected in location study

TrafficRoad	Flow, pc/hr/ln	Speed, km/hr	Width of Carr. (meter)	Type Road
S1	679	22	7.1598	Two Way
S2	850	26	19.279	Two Way
S3	864	26	16.0326	Two Way
S4	445	28	10.0316	Two Way
S5	1920	46	8.6699	Two Way
S6	2688	55	7.7734	Two Way
S7	124	20	8.3609	Two Way
S8	387	33	6.0123	Two Way
S9	404	32	6.9415	Two Way
S10	955	30	14.90	Two Way
S11	168	40	5.6977	Two Way
S12	57	28	6.2355	Two Way
S13	766	35	6.7181	Two Way

Analysis of the peak hour flows in the current situation has been compared to the standard flow for Passenger Car Units per hour (pc/hr) as presented in Table 3 below. This analysis focuses on peak hours from Sunday to Thursday, with Table 1 displaying the highest average flow counts for cars by site. The AM peak period is identified as 07:30 to 09:30 and the PM peak period is from 3:30 to 6:30 at each site there is a clear peak period between 08:00 and 09:00 and 5:00 and 6:00 in terms of the peak hour.

Therefore, to calculate the saturation flow rate more accurately, several factors are taken into consideration, including intersection geometry, traffic conditions, and signal control. Highway capacity manuals are tailored to specific circumstances, resulting in varying saturation flow rates [15].

These adjustment factors, as detailed in the Highway Capacity Manual (2000) [16], include lane width, the presence of heavy vehicles in the traffic stream, approach grade, nearby parking lanes and activities, bus stops within the intersection area, lane utilization, turning traffic, and pedestrian crossings affecting turning traffic. Researchers have extensively analyzed the impact of these factors on the saturation flow rate. The outcomes of the current flow capacity analysis are summarized in Table 3 below.

Due to the facts above, it is highly recommended to construct either an underpass or overpass at the Ainkawa-40m intersection. An underpass would significantly enhance flow capacity for S3 and S2, potentially reaching approximately 2000 pc/hr/ln. Furthermore, all passenger cars from the 100-meter Road can reach the project at the entrance gates on the Ainkawa-60m road directly without any traffic junctions.

Table 3: Improved flow capacity directed to new residential apartments project.

TrafficRoad	Current pc/hr. Per Lane	Standard pc/hr. Per Lane	Number of Lane	Total pc/hr, Flow Capacity
S1	679	1900	2	2242
S2	850	2000	2	1452
S3	864	2000	3	2808
S4	445	1800	1	1355
S5	1920	1800	2	0
S6	2688	1800	2	0
S7	124	1800	1	1676
S8	387	1800	1	1413
S9	404	1800	1	1396
S10	955	1800	4	4336
S11	168	1800	1	1632
S12	57	1800	2	3486
S13	766	1800	2	2068

Additionally, all passengers entering through the gates on the 40m road and the Ainkawa-60m road will have direct access to the 100m road, as shown in Figure 3 below. Regarding the roundabout, the flow capacity of the S1 station can be increased to 1900 pc/hr/ln. The construction of the underpass and the roundabout will also impact on the existing U-Turn located opposite the project. Therefore, the U-turn can be closed, as indicated in Figure 3, and will be relocated near the roundabout. This change is expected to increase the flow capacity of the 40m road to approximately 2,000 pc/hr/ln.

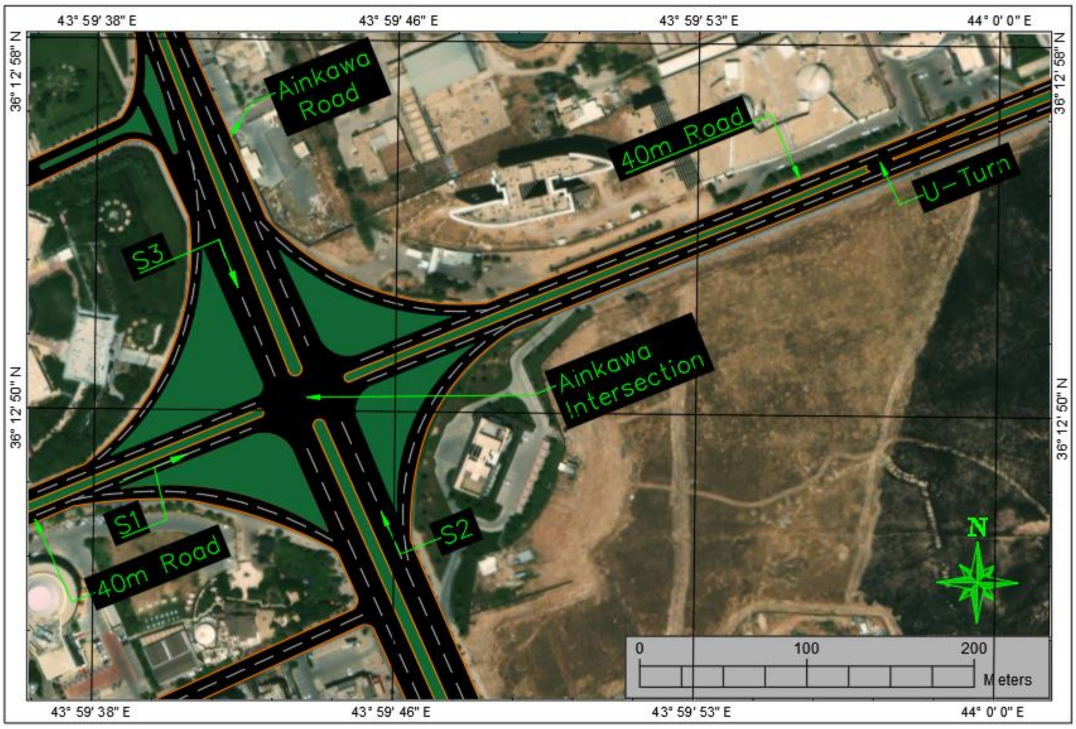

Figure 3: Traffic Road for S1, S2 and S3 direction

Moreover, if eight main entrance gates could be opened on all four sides of the project, with two gates on each side, the flow capacity would be distributed almost equally around the area. For instance, the locations near stations S7, S8, S9, S10 and S11 as shown in Figure 4 below, would utilize gates along the Ainkawa-60m road. This arrangement would allow passengers to access and exit the new apartments without encountering significant flow difficulties, as these stations experience relatively low traffic. Specifically, station S7 has a flow of 124 passenger cars per hour per lane (pc/hr/ln), while station S8 has a flow of 387 pc/hr/ln on Bahrka Road, as indicated in Figure 4 and Table 5 below. Furthermore, the S11 station on the 60m road can also facilitate entry and exit at the gates near station S9, as S11 currently has a low flow of 168 pc/hr/ln.

Figure 4: Traffic Road for S7, S8, S9, S10 and S11 direction

To Sum up, constructing the underpass and roundabout as described will make the entrance gates on the Ainkawa-60m road and the 40m road are the most effective access point for the project. These gates are strategically located on the Ankawa-60m road, and the underpass is designed to enhance flow capacity, as detailed in Table 5 below.

Regarding the project plan, it includes four major roads, each designed to be two-way with a width of 10 meters per lane, resulting in three-lane roads for each direction. In addition, the plan features five minor roads, each also 10 meters wide. The standard flow rate for each lane is 1,800 passenger cars per hour (pc/hr/ln). Consequently, the layout of the roads in the project plot plan will result in a total flow capacity of 28800 pc/hr.

3.2 Flow - Speed – Density Relationships

The primary objective of this analysis is to clarify the relationship between various factors. The correlation between speed and density is weak, with an R^2 value of less than 0.5. This indicates that the relationship between the number of vehicles per kilometer and the speed of those vehicles is unsatisfactory. Several variables, including the same section of the main road, road types, turning patterns, driving directions, traffic light timing, and pavement quality, all influence the outcomes of this study [17]. The relationships are detailed in Table 4 and illustrated in Figures 5 and 6.

Table 4: Flow, speed and calculate density with width of carriageway

TrafficRoad	*Flow, pc/hr/ln*	*Speed, km/hr*	*Density, km/hr*	*Width of Carriageway (meter)*
S1	679	22	30.86	7.1598
S2	850	26	32.69	19.279
S3	864	26	33.23	16.0326
S4	445	28	15.89	10.0316
S5	1920	46	41.74	8.6699
S6	2688	55	48.87	7.7734
S7	124	20	6.2	8.3609
S8	387	33	11.73	6.0123
S9	404	32	12.63	6.9415
S10	955	30	31.83	14.900
S11	168	40	4.2	5.6977
S12	57	28	2.04	6.2355
S13	766	35	21.89	6.7181

3.3 Effective Width of Carriageway on Speed and Flow

A reasonable relationship was found between the carriageway width and speed, as illustrated in Table 2, which presents both average travel speed and percentage Flow rate. The carriageway width ranges from 6 to 10 meters, while for each width, the flow rate varies between 50 and 900 pc/hr/ln. This variation makes managing traffic problematic, as shown in Table 6.

The relationships between width and flow are lower compared to the relationship between width and speed, as indicated by the R^2 values for the linear correlations between the two axes. Sections S5 and S6 exhibit high flow rates, but when compared to the carriageway width, they do not surpass the values of other sections in the study. If we ignore these two points, the R^2 value increases to about 0.3, suggesting a stronger correlation. Although the carriageway width remains between 6 to 10 meters, speeds for the same width range from 22 to 55 km/h. This variability creates challenges in transportation, particularly involving the interactions among the number of vehicles, speed, and density, with results shown in Table 7. Figures 5, 6, and 7 further illustrate these relationships. The findings prove that the width of the lane directly affects traffic flow.

Table 5: Current flow (pc/hr/ln) compared to standards

Traffic Road	Current Flow, pc/hr/ln	Standard Flow, pc/hr/ln	Factors based on its circumstance	Difference pc. in ideal condition	Difference pc. in realistic condition	Note
S1	679	1800	0.2	1121	224	Due to signaled intersection and approach grade not smooth for free
S2	850	1800	1	950	950	has no obstacles
S3	864	1800	0.2	936	187	Due to signaled intersection
S4	445	1800	0.65	1355	881	healthy road for secondary gate as locates near to crawdad resident
S5	1920	1800	0	-120	0	unhealthy traffic
S6	2688	1800	0	-888	0	unhealthy traffic
S7	124	1800	0.6	1676	1006	due to parking activity, lane width, pedestrian crossing and turning
S8	387	1800	0.6	1413	848	traffic
S9	404	1800	0.95	1396	1326	due to parking activity, lane width, pedestrian crossing and turning
S10	955	1800	1	845	845	indirect affect to the study area.
S11	168	1800		1632	0	Due to signaled intersection, having
S12	57	1800	0.65	1743	1133	U-turn and speed bump.
S13	766	1800	0.35	1034	362	Due to signaled intersection

3.4 Geometric Design Effect of Traffic

The number and width of traffic lanes, including dedicated turning lanes, play a significant role in traffic flow. Adequate lanes, turning, merging, and through traffic can help prevent bottlenecks on the road. While pedestrian movement is generally less prioritized since many people rely on cars, but access management for controlling the number and location of driveways and entrances to new residential apartments can minimize disruptions to traffic flow on main roads at intersections. Table 8 shows the number of lanes and width of the carriageway. However, the pavement markings are unclear, making it difficult for drivers to determine the exact width of each lane. According to Highway Capacity Manual (2000) [16], the ideal width of each lane should be 3.75m. For example, in section S1, which has two lanes, the total width is 7.1598 meters, resulting in each lane being 3.58 meters wide.

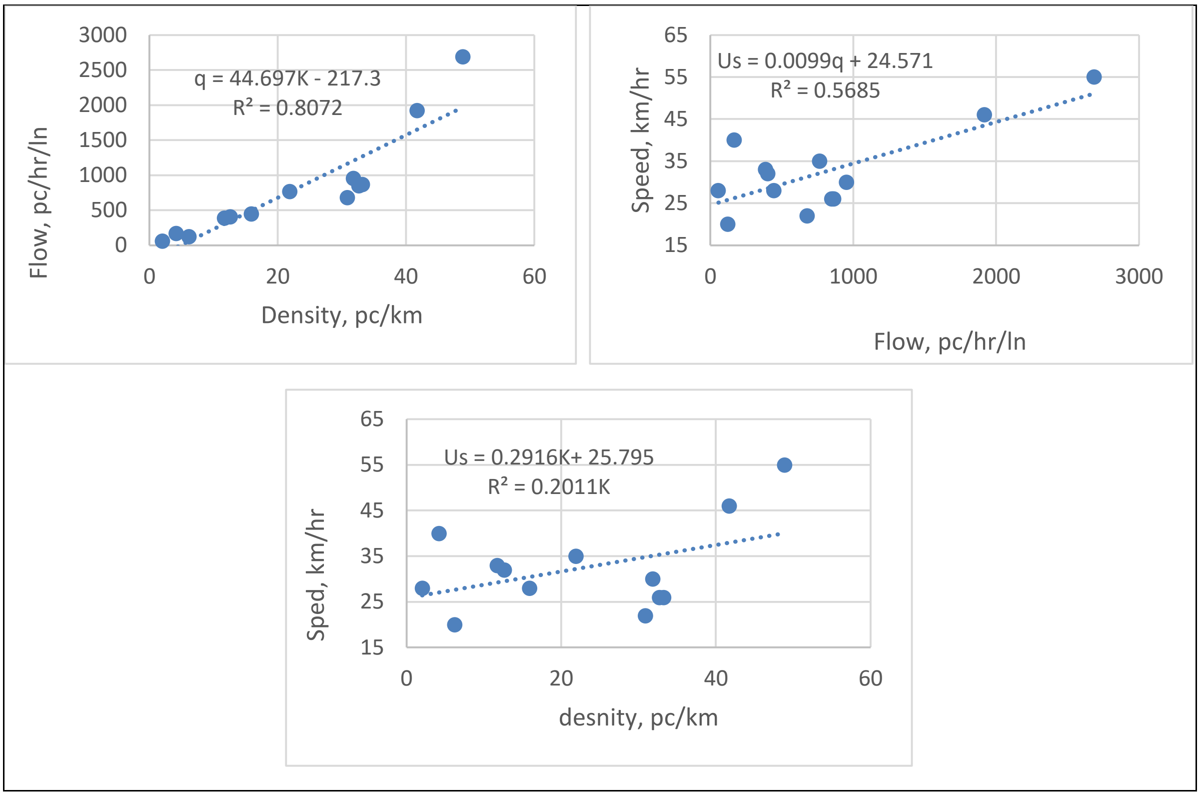

Figure 5: Fundamental diagram of speed-density-flow.

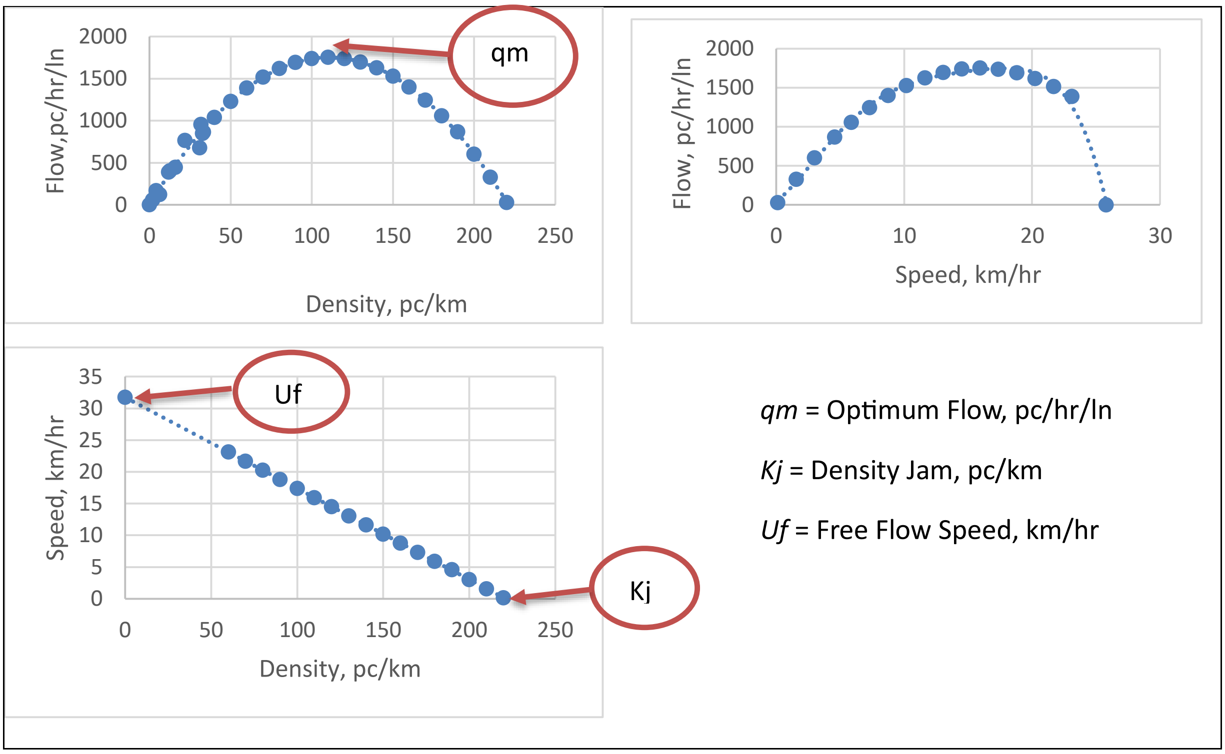

Figure 6: Curve fitting fundamental diagram of speed-density-flow.

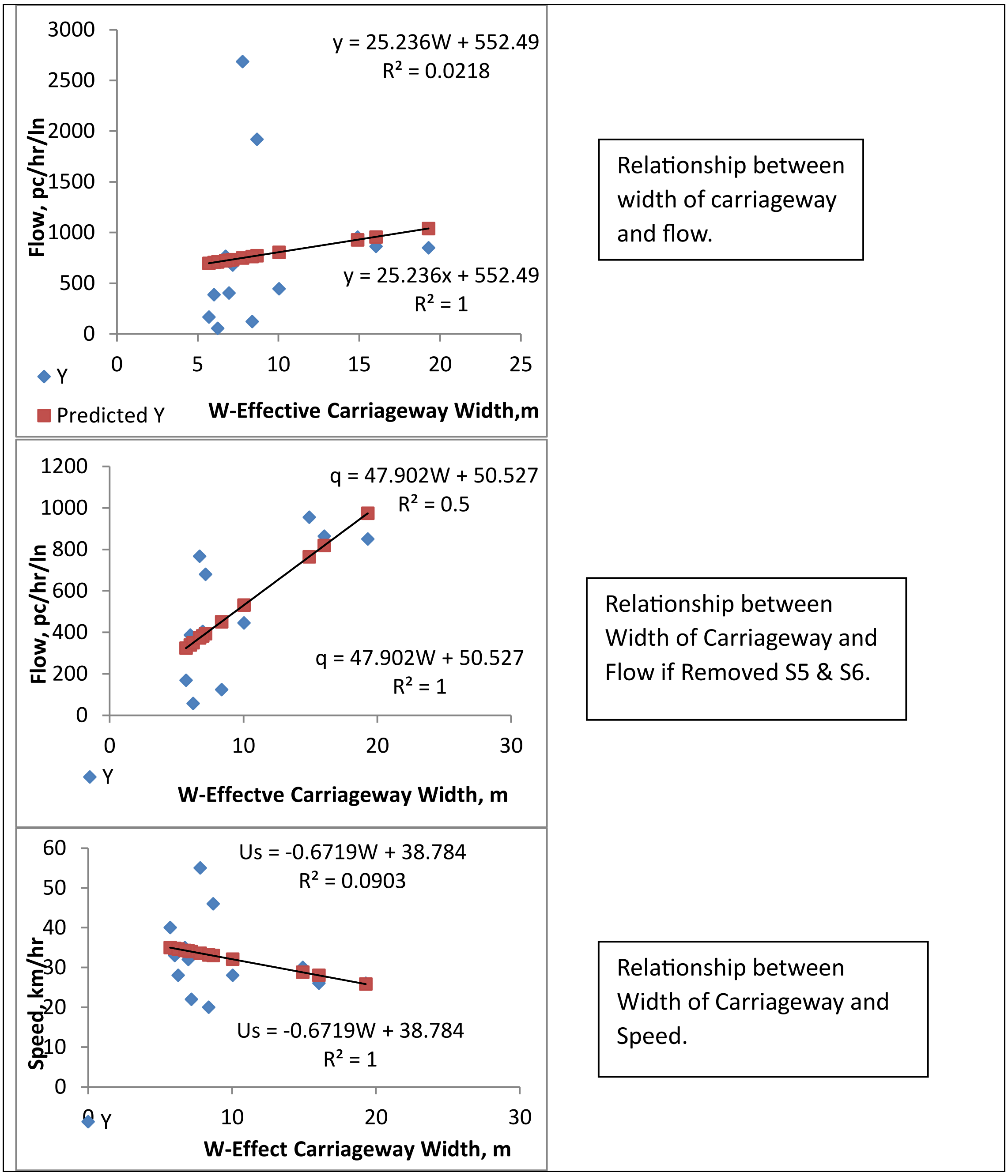

Figure 7: Relationship between Fundamentals of Traffic

Table: 6 Predicted Flow according to Width of Carriageway.

Traffic Road	Current Flow, pc/hr/ln	Predicted Flow, pc/hr/ln	Residuals
S1	679	733.1818	-54.1818
S2	850	1039.026	-189.026
S3	864	957.0989	-93.0989
S4	445	805.6555	-360.656
S5	1920	771.2912	1148.709
S6	2688	748.6668	1939.333
S7	124	763.4932	-639.493
S8	387	704.2231	-317.223
S9	404	727.6727	-323.673
S10	955	928.5162	26.4838
S11	168	696.2837	-528.284
S12	57	709.8558	-652.856
S13	766	722.0349	43.96511

Table: 7 Predicted Speed according to Width of Carriageway.

Traffic Road	Current Speed, km/hr	Predicted Speed, km/hr	Residuals
S1	22	33.97319	-11.9732
S2	26	25.83002	0.169977
S3	26	28.01135	-2.01135
S4	28	32.04356	-4.04356
S5	46	32.95852	13.04148
S6	55	33.5609	21.4391
S7	20	33.16614	-13.1661
S8	33	34.74422	-1.74422
S9	32	34.11987	-2.11987
S10	30	28.77237	1.227626
S11	40	34.95561	5.044391
S12	28	34.59425	-6.59425
S13	35	34.26998	0.730021

Table 8: Geometric Data Collected in Location Study

TrafficRoad	Number of Lane	Width of Carr. (meter)	Type Road
S1	2	7.1598	Two Way
S2	2	19.279	Two Way
S3	3	16.0326	Two Way
S4	1	10.0316	Two Way
S5	2	8.6699	Two Way
S6	2	7.7734	Two Way
S7	1	8.3609	Two Way
S8	1	6.0123	Two Way
S9	1	6.9415	Two Way
S10	4	14.90	Two Way
S11	1	5.6977	Two Way
S12	2	6.2355	Two Way
S13	2	6.7181	Two Way

4. Conclusions

The following conclusions can be drawn from the data analysis:

1. The relationship between speed and density is weaker than expected, with an R^2 value of 0.2011, which is below the standard threshold of 0.5. Factors such as the number of parking spaces, the number of lanes, the direction of traffic, and taxi parking contribute to this outcome.
2. The width of the carriageway significantly impacts the transportation system, planning, and traffic flow. For instance, sections S5 and S6 have higher flow rates, ranging from 1920 to 2688 pc/hr/ln, despite their carriageway widths between 6 and 9 meters respectively.
3. The quality of the pavement and the direction of movement also influence traffic quality. For example, section S12 has a lower range of flow but maintains a speed of 28 km/hr.
4. The sections S1, S2, S3, S5, S6, and S10 are major roadways. Therefore, the number of lanes, lane width, turning points, and access routes all play a role in determining traffic outcomes.
5. Time of intersection and a roundabout between S1, S2, S3, and S12, S5, and S6 is another problem for delayed transportation.
6. The after-draw curve fitting range indicates an optimal flow range between 1500 to 2000 pc/hr/ln, a free flow speed range of 20 to 30 km/hr, and a density of congestion between 200 to 250 pc/km.
7. Gulan Road lacks designated parking areas for vehicles, leading many drivers to use the main road for parking. This creates significant traffic issues in the city and negatively impacts the relationship between density and speed.
8. Technology is another crucial element that can be utilized to manage the network across all road sections during peak hours, helping to reduce traffic congestion at intersections.

5. Recommendations

Based on the accomplished data, the paper recommendations have been summarized in the following points:

1. Location studies should consider eliminating traffic lights for overpasses and underpasses.
2. The width of the carriageway should be standardized for the same section, using the median width to increase the number of lanes and the width of each lane.

3. Time of traffic according to number of vehicles and time of peak hours should be controlled.
4. Allocating special parking lots for vehicles.

6. Authors' Contribution

We confirm that all designated authors have read and approved the manuscript. Each author has thoroughly reviewed and endorsed the paper, contributing equally to its development. Additionally, all authors have agreed on the order in which their names appear in the manuscript.

7. Conflict of Interest

The authors declare that this paper does not have any conflict of interest.

8. Acknowledgment

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