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The Effect of Barzan Highway Improvements on the Traffic Stream Parameters

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ABSTRACT: The rapid economic growth in Duhok City has resulted in high traffic volumes, increased the flow of stream traffic, and decreased the speed of running. Therefore, over the last few years, many roads have suffered from non-uniform traffic flow, traffic jams, and increased traffic accidents. There are several causes for the development carried out by the Duhok Governorate on the Barzan Highway, where signalized at-grade intersections were replaced by bridges and tunnels to prevent conflicts between vehicles on the highway. This study will evaluate how much improvement has been made to the Barzan Highway's main parameters after the improvements have been made. Based on the results of the study, it can be concluded that the underpasses have contributed to the creation of safer roads by reducing the accident rate by 47%, decreasing the average traffic flow from west to east (Imam Hamza underpass to Farmanda underpass) by 32%, and decreasing the average traffic flow from east to west by 10%, reducing travel time from west to east by 48%, and from east to west by 45%; moreover, the density improved from west to east by approximately 60%, while from east to west by 63%.

Keywords: Highways; Traffic Flow; Volume/Capacity Ratio; Capacity; Density; Travel Time; Accidents.

1. Introduction

Recently, the Dohuk Governorate has seen an increase in the demand for an alternative transport crossing to assist in the key reconstruction and investment tasks, as a result of the city's rapid urbanization, population growth, and status as a major tourist attraction in the Kurdistan Region and Iraq. This raised the need to expand road networks and improve services in Duhok. Due to the city's character and its geographical location, which is flanked on both sides by mountains, as well as the lack of sufficient space, expanding and growing its roadways is not possible. Therefore, rapid car growth needs the creation of fast solutions to the problem of urban traffic congestion.

There are a lot of variables that affect crash rates; road type, traffic volume, and geometric features all have different effects [1]. Traffic flow characteristics such as traffic volume, density, and volume-to-capacity ratio (V/C), especially a high vehicle density and V/C ratio, directly influence crash risk and severity [2][3].]. The two most important elements influencing crash rates are 'geometric design' variables and 'pavement condition' variables [4]. Furthermore, the total accident density increases due to an increase in average daily traffic (ADT) [5][6][7]. The crash rate rises steadily with increasing traffic volumes, especially at night when the severity is 17 percent higher[8].

Accident frequencies are significantly affected by annual average daily travel (AADT) and the percentage of combination trucks in the traffic stream with the proposed exposure to traffic conflicts [9][10]. Furthermore, increasing lanes on freeways initially improves safety, but this effect diminishes as congestion develops.[11].

higher speed are usually linked to the increase in severity and accidents (a 10 percent increase in the mean speed may result in a 30 percent increase in fatal and severe accidents) [1][12][13]. On the other hand, average density, average speed, and speed differential have just a minor influence [14][15]. Reducing the speed limit has a direct effect on traffic safety, especially in fatal accidents. The reduction of about 22.2% led to a 5% drop in the number of crashes and a 33% drop in injuries and deaths. [16].

The frequency of crashes increases with the congestion due to the increased of vehicle interactions. On the other hand, the severity of the crash decreases, as the congested traffic is at lower speeds and as a result, the crash is not serious [10][17]. Basic freeway segments has the highest influence on crash types as rear-end crashes are the most frequent (60%) to occur, followed by the sideswipe collisions and the collisions with highway accessories[18]. Increased congestion/traffic volume led to an increase in accidents, particularly fatal/killed and serious injury accidents [19][20]. Depending on the driver's behavior, heavy vehicles take a longer time to pass passenger cars in congested areas [21].

In this paper, an investigation has been done for the improvement of the Barzan highway following the construction of underpasses.

2. Case Study

This study demonstrates how the Barzan highway was significantly enhanced after changing the at grade intersections to interchanges.

2.1 Study Area

The case study was conducted in Duhok city of Iraq, in two different years 2018 and 2021. The population is approximately 1.5 million and Duhok covers 10715 km^2, and lies on landauite 36 north and longitude 43 east. The city includes approximately 3595 roads, with different types of highways[22][23]. Barzan highway is one of the main roads in the city, moreover, this highway is the only road for the entrance and exiting of the city Figure 1, this caused (70–80%) of the city's load to be on the highway, which led to high capacity, congestion, accidents, etc.

Severe traffic congestion refers to the disruption of a section of intersections with traffic lights, as well as those

Figure 1: Barzan road sections for study area, 2021

without traffic lights, particularly during morning and evening rush hours, and the need for solutions has become urgent. The proposed solution to the problem of congestion on this road was to change the intersections on the Barzan

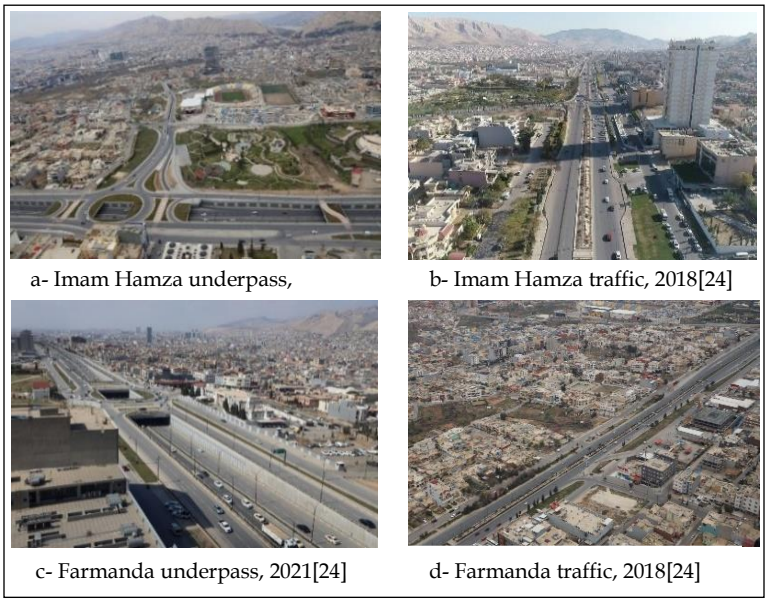

Figure 2: Study area segments.

highway, K.tv. -Imam Hamza, and Farmanda intersections to underpasses as show in Figure 2 (a, b, c, and d).

Due to a high number of accidents, lower speed, congestion at intersections, and long delay times, the road's planners and designers have decided to build underpasses to distribute traffic along the route, from 9th July 2019 to 14th March 2021. highway underpasses facilitate improved rates of uniform traffic flow and uninterrupted traffic

flow. However, it usually reduces traffic noise on roads or prevents traffic collisions, promoting safety and comfort. Underpasses are more convenient than ever because there are no delays and no need to wait for signals to change. This cuts down on travel time, reduces the number of accidents, makes it easier for drivers to get around, and makes them more comfortable and appealing.

2.2. Data Collection

In this research, two types of data were used: statistical data obtained from state departments and the data collected from the field.

2.2.1. Statistical Data

Since the Barzan highway is the main road, any improvement to the highway will help ease congestion and decrease the likelihood of accidents in the city. The traffic data was collected for (K.tv- Imam Hamza, Qaymqami, and Farmanda intersections) in 2018 by the Directorate of Static in Duhok and Municipality of Duhok before the improvement for these intersections which took in place at 2021. Several statistical data sets were used, including the number of accidents in each segment in 2018 and 2021 (Table 1 and 2), and traffic data for 2018 (Table 3 and 4) such as flow, capacity, speed, and travel time. [22][23].

Table 1: The total number of accidents, dies and injuries for each segment, for 2018 and 2021[24]

Location	**Number Of Accidents**			**Number Of Dies**		**Number Of Injures**
Year	**2018**			**2021**		
Locations	Speed	Driver's perception	Others	Speed	Driver's perception	Others
Imam Hamza	18	29	5	7	17	0
Qaymqami	7	12	2	10	7	0
Farmanda	8	9	2	3	5	0
Total	31	50	11	20	29	0

* Note: Others cover weather conditions, geometrical design errors, pavement issues, traffic signals, and vehicle malfunctions.

Table 3: Flow, speed, and density data of each segment, for 2018 and 2021[24]

Location		**Flow**		**Speed**		**Density**	
year		2018	2021	2018	2021	2018	2021
Imam Hamza		2896	1236	24.7	80	117.247	15.450

Location		**Capacity**		**Travel time**	
year		2018	2021	2018	2021
West – East	**Imam Hamza – Qaymqami**	1542.132	1217.812	3.586	1.656
	Qaymqami - Farmanda	1179.633	2134.342	1.731	0.998
East – West	**Farmanda - Qaymqami**	1425.671	1525.097	1.636	0.997
	Qaymqami - Imam Hamza	2647.134	1005.283	3.291	1.657

2.2.2. Field Data:

Following the construction of underpasses at Farmanda and Imam Hamza, data collection for basic highway segments was conducted in November 2021. Using video recording cameras, highway data including traffic volume,

speed, and travel time were collected during peak hours in the morning (8:00 to 9:00 am) and evening (5:30 to 6:30 pm) in each direction for a total of 60 minutes, as depicted in Figures 6 to 8.

Figure 6: Collecting the data for Imam Hamza underpass during peak hours, 2021.

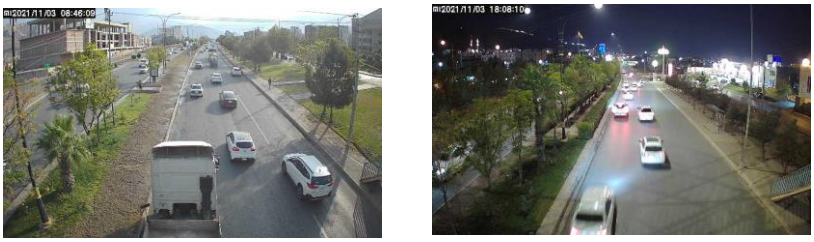

Figure 7: Collecting the data for Qaymqami during peak hours, 2021.

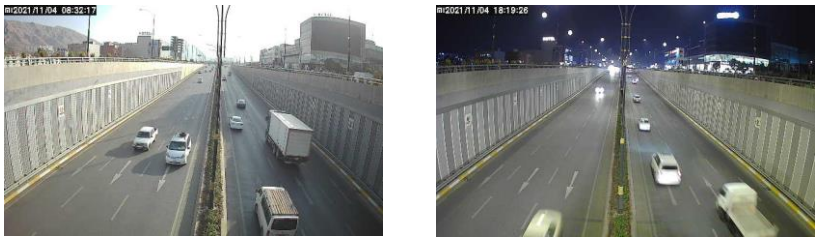

Figure 8: Collecting the data for Farmanda underpass during peak hours, 2021.

The density was calculated using the Speed-Flow-Density Relationship, Equation (1):

$$Q = K*V \quad (1)$$

Where:

- Q is the Flow of vehicles per hour.
- V represents the Speed (kilometers/hour)
- K represents the Density (vehicles/kilometer)

The hourly volume in Passenger Car Unit (PCU) varies between the morning and evening peak hours. Due to rush hour, evening peak hour traffic is heavier than morning peak hour traffic, as illustrated in Figure 9.

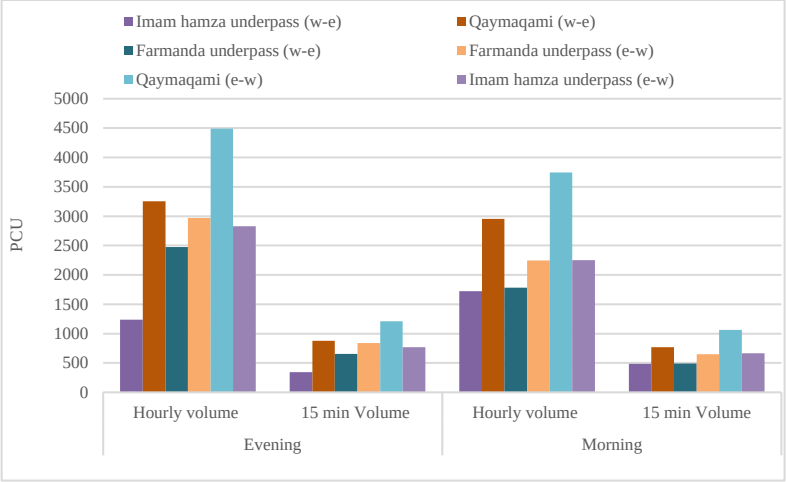

Figure 9: Traffic volume data in PCU for each segment and each direction, 2021

3. Result and Discussion

Through the analysis of the collected data, the efficiency of the improvements made on the Barzan highway will be evaluated by measuring the extent of improvement in the main parameters of traffic flow, which include traffic volume, speed.…

3.1. Traffic Flow

The volume of traffic had a significant effect on the road's performance and the number of collisions.

The results showed that (Figure 10) the flow in 2018 for the Imam Hamza intersection was 2896 veh/hr. despite the fact that this amount is close to the density of a traffic jam, it may gradually approach the maximum permitted capacity. Compared to the flow that was collected in 2021, after constructing the underpass instead of intersection, the flow became 1236 veh/hr. from west to east for Imam Hamza about 57% of the flow was reduced. At Qaymqami intersection, the reduction in flow is 18%. At Farmanda intersection, it was reduced by 21%. Lastly, from east to west, traffic flow declined to 14% but for Farmanda underpass it increased by 8% for the Qaymaqami due to the accumulation of traffic flow from the basic freeway section and the weaving section in this segment. Finally, it declined by 25% for the Imam Hamza underpass.

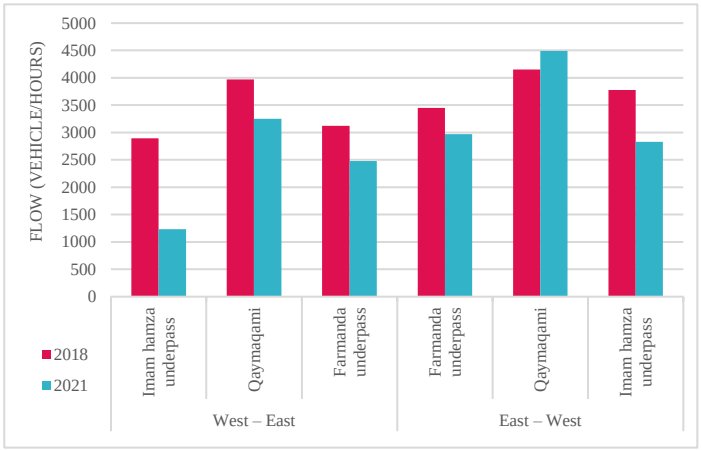

Figure 10: Flow data for each segment and each direction, 2018 and 2021.

3.2. Section Speed

Increasing the speed of the highway improves highway mobility and accessibility, decreases travel time, and decreases delay time. Along the highway, fixed cameras are utilized as part of a control system; this technique of control has led to a uniform average speed limit of around 80 km/h throughout the highway.

The speed statistics from 2018 and 2021 are substantially different, the improvement of west to east direction varies between 107-224%, while from east to west between 107-211%. As depicted in Figure 11, the total enhancement in speed from west to east is approximately 164%, whereas from east to west is approximately 150%.

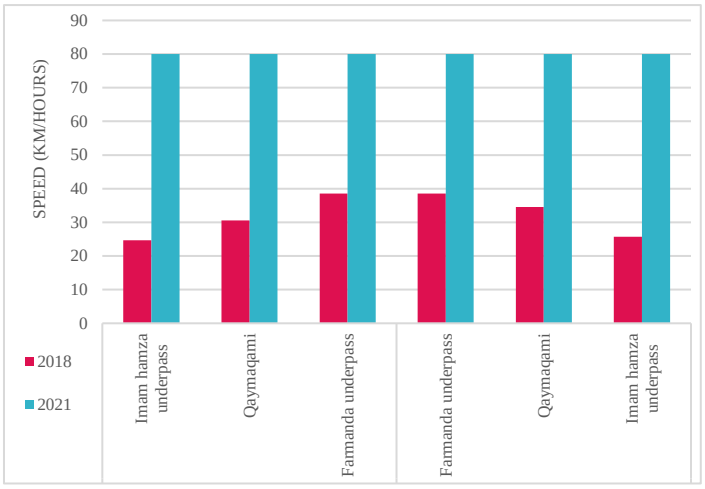

Figure 11: Speed data for each segment and each direction.

3.3. Density

For determining density, the Speed-Flow-Density Relationship equation is utilized. According to previous findings, which are depicted in Figures 10 and 11, a decrease in flow and an increase in speed lead to a decrease in density. As indicated in Figure 12, from west to east, Imam Hamza intersection improved by approximately 87%, Qaymaqami intersection by 31%, and Farmanda intersection by 62%.

Moreover, in the direction of east to west, it improved by 59% for the Farmanda underpass, 53% for the Qaymaqami underpass, and 76% for the Imam Hamza underpass.

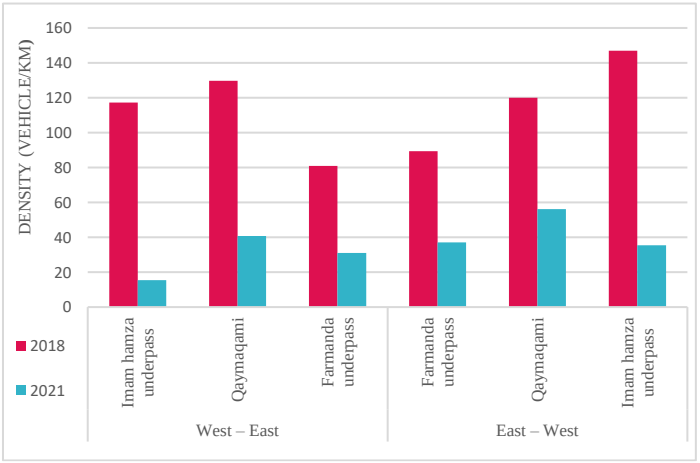

Figure 12: Density data for each segment and each direction.

3.4. Volume/Capacity Ratio

After 2021, the capacity of each segment improves; Figure 13 depicts the volume/capacity (v/c) ratio from one segment to the next; in west to east direction, from Imam Hamza underpass to Qaymaqami, the ratio decreased from 0.68 in 2018 to 0.50 in 2021, and from Qaymaqami to Imam Hamza underpass it decreased from 1.00 to 0.36. The v/c ratio in east to west direction, from Qaymaqami to the Farmanda underpass decreased from 0.81 to 0.67, whereas from the Farmanda underpass to Qaymaqami increased from 0.49 to 0.98 due to the accumulation of traffic volume from the basic freeway section and the weaving section in this segment.

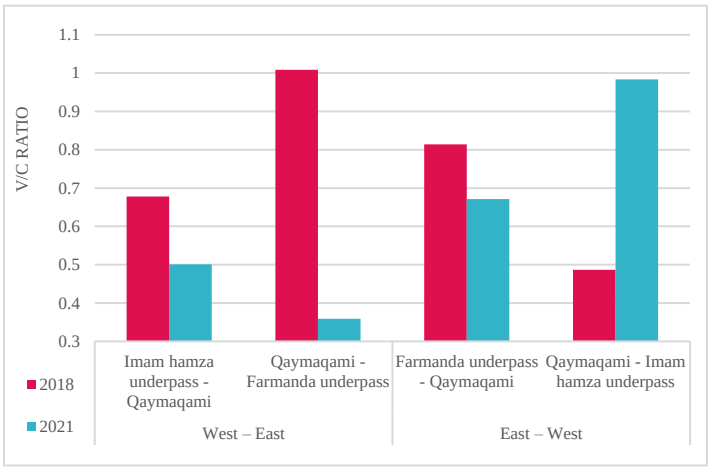

Figure 13: Volume/capacity ratio for each segment and each direction.

3.5. Travel Time

Travel time is the time it takes a vehicle to travel a roadway to reach the destination on time with the lowest delay time, because delays are the time wasted due to traffic friction and traffic control systems. In general, travel time decreased in all segments as a result of the increased speed and the elimination of the intersections, which were the primary cause of increased travel time. As shown in Figure 14, for the west-to-east direction between Imam Hamza underpass and Qaymaqami, the reduction in travel time is around 54%, while the reduction from Qaymaqami and Farmanda underpass is approximately 42%. Moreover, in the east-west direction, travel time drops by around 39% for Farmanda underpass-Qaymaqami and by approximately 50% for Qaymaqami-Imam Hamza underpass.

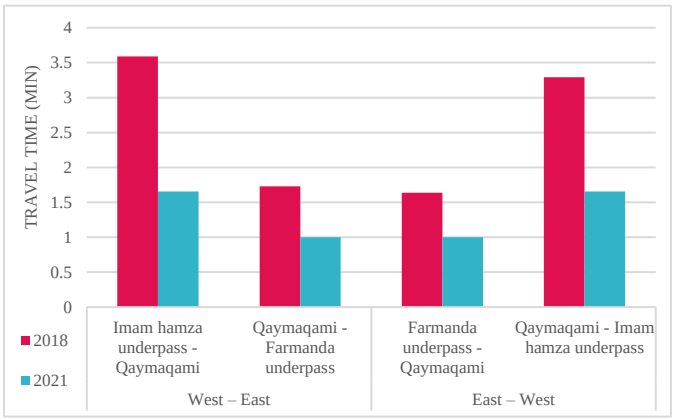

Figure 14: Travel time data for each segment and each direction.

3.6. Safety

A general correlation exists between an increase in the number of vehicles and an increase in the number of accidents. As seen in Figure 15 and Table 1, the reduction in the number of accidents for Imam Hamza is approximately about 54%, and for Qaymqami and Farmanda is about 19% and 58%. In general, the number of accidents decreases in each segment after the installation of underpasses due to reduced congestion, traffic flow, and speed [24].

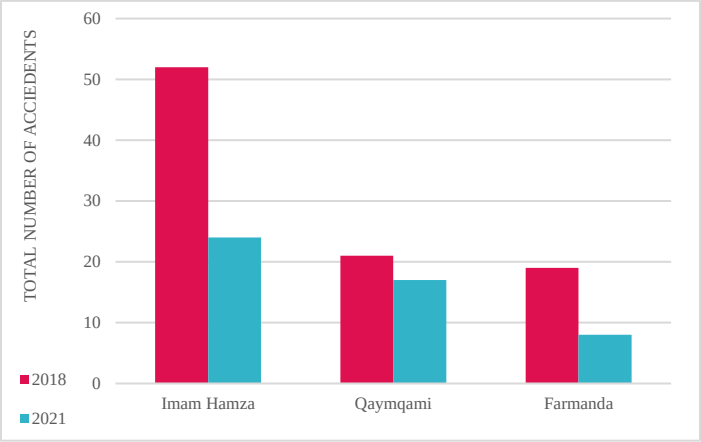

Figure 15: Reduction in the number of accidents in each segment between 2018 and 2021.

In 2018 as illustrated in Table 2 and Figure 16, 35 percent of accidents at Imam Hamza intersection, 34 percent at Qaymaqami intersection, and 42 percent at Farmanda intersection were caused by excessive speed. Compared to 2021, Imam Hamza underpass has a 29 percent accident rate due to the changes in speed, while Qaymaqami and Farmanda underpasses have 59 and 37 percent accident rates.

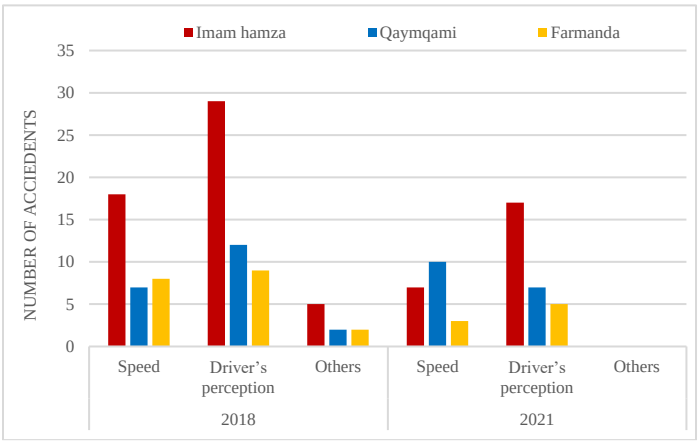

Figure 16: Reason of occurring accidents in all segments, for 2018 and 2021.

The driver's perception is crucial to the analysis of traffic studies, as the majority of accidents occur as a result of vehicles searching for the quickest route to their destination, such as by rapidly changing lanes or changing the road. In this study, accidents in 2018 that were caused by drivers' perception were: 56% at the Imam Hamza intersection; 57% at the Qaymaqami intersection; and a 47% rise in accidents at the Farmanda intersection. Compared to 2021, 71% of accidents happened at the Imam Hamza underpass, 41% at the Qaymaqami underpass, and 63% at the Farmanda underpass, Table 2 and Figure 16.

4. Conclusion

The following conclusions were observed based on the evaluation of traffic flow parameters after the improvement of Barzani Highway:

1. The amount of traffic in each section and direction decreased by about 32% in the west-to-east direction and about 10% in the east-to-west direction per hour. Since it is a major cause of car accidents, this change led to fewer accidents.
2. The total enhancement in speed from west to east is approximately 164%, whereas from east to west is approximately 150%. Moreover, this proportion improves mobility and reduces travel times and delay times for all segments and directions.
3. In a certain way, density went down by 60% in the direction from west to east and by 63% in the direction from east to west. This decrease is perhaps the most important safety improvement effect.
4. This study seeks to figure out how much the existing capacity ratio of 51% west-east and 35% east-west would enhance the safety of highway operations.
5. The (v/c) ratio from west to east direction in Imam Hamza underpass to Qaymaqami, the ratio decreased about 0.18, and from Qaymaqami to Imam Hamza underpass it decreased about 0.65. while in east to west direction, from Qaymaqami to the Farmanda underpass decreased about 0.14, whereas from the Farmanda underpass to Qaymaqami increased about 0.50, due to the accumulation of traffic volume from the basic freeway segments and weaving section.
6. 4. A 48 percent reduction in travel time from west to east and a 45 percent reduction in travel time from east to west, which results in a reduction in travel delay from arrival to the destination.
7. The accident rates reduced in each segment gradually due to reduction in speed, flow, and congestion, the reduction in imam Hamza was approximately about 54%, and for Qaymqami and Farmanda is about 19% and 58%.

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