

Evaluation Model for the Axes of Spatial Interaction Between the Center and Cities of the Dohuk District

By

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Abstract

Transport is a definite end result of existing or potential movements in any geographical region, provided that the elements of three-dimensional transmission systems are available from the nodes (cities) and the interconnected road routes approved for transport with the interaction of the center and cities of Duhok. This contributes to revealing the actual or expected size in order to achieve different economic, social, political and military transport objectives. This study aims to build a spatial model to measure the effectiveness of passenger transport and the commercial relations of cargo traffic between the center and cities of Dohuk district. These areas exhibit variation in the volume of transport traffic towards the city centers according to their size and functional activity as major human settlements in their regional framework or at the level of the neighboring districts and provinces. This has resulted in a situation of spatial disharmony in the functional interaction between the transportation nodes and their direction. This in turn is reflected in the limited geographic change throughout the district of Dohuk. The study required a major approach based on quantitative methods such as measurement indicators of the efficiency of the movement of passengers and goods as well as indicators of the model of gravity and interaction of transport traffic between the center and cities of the study area.

Keywords: Transport operations. Systems and Operations Analysis Methodology. Building a spatial model

1. Introduction

Transportation is considered one of the most important cultural manifestations that reinforce the various economic and social activities of any country given its effective role in ensuring communication and its impact on the wheel of development. Transportation traffic is considered an inevitable result of the human-to-earth relationship, and the first behavioral trend in interaction, spatial traffic, and commercial-to-trade relations in determining the scope of the contract's transportation service through public transportation routes and car-way networks in particular.

Transportation traffic shows the spatial heterogeneity of transport nodes and their capabilities to generate and attract traffic according to their positional, functional and spatial characteristics of the automobile road network, thereby contributing to the geographical features of the study area.

2. Research Problem

Is there spatial harmony between functional interaction and transport contract and traffic, and is there a discrepancy in the average volume of transport traffic towards cities in the district of Dohuk?

3. Research Objective

- Analyzing the spatial interaction of transport traffic and its trends across the main axes between the center and cities of Dohuk district.
- Analyzing the spatial structure, evaluating its functional interaction, classifying its paths, and determining the reality of the spatial distribution in Dohuk district.

4. Research Hypothesis

The scientific hypothesis has been determined as follows: the volume of transport traffic, its trends and its qualitative and quantitative composition in the district of Dohuk witnesses a spatial variation in its regional framework. This is due to the asymmetry of the volume of the spatial interaction of the transport traffic according to the sizes of the transport nodes (cities) in the district of Dohuk.

The ranges of the transport service also overlapped according to the direct relationship with the volume of transport traffic and inversely with the amount of transport distance between the center and cities of Dohuk district.

5. Research Methodology

The approach of systems and processes analysis was adopted in this study. It is considered one of the latest approaches used in the study of transport geography. It reveals the relationship between the inputs of transport traffic from road paths and transport media and their outputs that are disclosed by the quantitative and qualitative composition of the transport traffic. This approach has been adopted in analyzing the reality of transport traffic between the center and cities of Dohuk district and evaluating it quantitatively according to the indicators adopted in measuring the extent of spatial efficiency of transport traffic. It was adopted to build a spatial model to determine Interaction pattern for passenger traffic and commercial relations for the movement of goods and people.

5.1 *The Spatial and Temporal Limits of the Research*

The spatial limitations of the study area are the administrative boundaries of the district of Dohuk in the south of the governorate of Dohuk and the north-western part of the Iraqi Kurdistan region. The area is determined by the district of Amadiyah in the north-east, the district of Zakho in the north-west, the district of Al-Shaykhan in the south-east, and the district of Summeel in the south and south-west. Its area is estimated at 1,015.05 km². This corresponds to 12.54% of the total area of Dohuk governorate, which covers 8,093 km². In terms of coordinates, the study area (Dohuk district) is located between 30°36.47' and 00°37.77' N., and between two arches of 00°42.48' and 43.17.30 E..

The study of the transport traffic according to the methodology of transport geography flows in two directions: the first is related to the study of the geographical structure and the qualitative composition of the network of road transport by cars, and this is what was revealed in this research. The second is related to the study of the volume of motor transport traffic and its qualitative composition in the district of Dohuk,

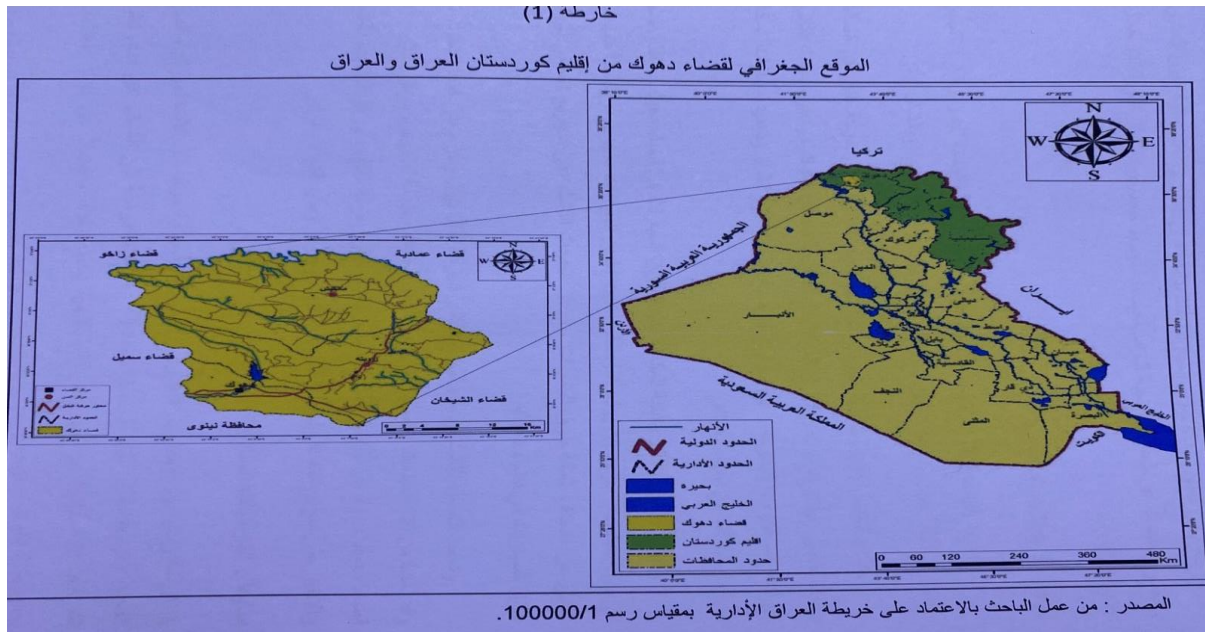


Figure 1

1. Spatial Analysis of the Transport Traffic Between the Center and Cities of Dohuk District

The average traffic volume by means of various means has been determined by field survey along the road axes.

To obtain data related to the transport traffic and its average flow through the motorway network in the study area, the monitoring sites were elected. These amounted to about (11) monitoring sites to survey the transport traffic during two months (January and June) in 2021. The average number of vehicles was calculated for three people during the daylight hours (7-8) in the morning, (1 2) in the afternoon, (7-8) in the evening. This is to determine the amount of daily transport traffic for the axes of transport routes represented by vehicles.

- Axis No. (1) includes the Duhok-Summeel-Zakho road.
- Axis No. (2) includes the Dohuk – Fayda road.
- Axis No. (3) includes the Duhok-Shekhan road.
- Axis No. (4) includes Dohuk – Zawita road.
- Axis No. (5) includes Zawita – Amadiya Road.
- Axis No. (6) includes Zawita – Mankish Road
- Axis No. (7) includes Mankish – Amadiya Road.
- Axis No. (8) includes the Mankish – Zakho road
- Axis No. (9) includes the Kurit Kavana-Mankish Road.
- Axis No. (10) includes the Duhok-Biski-Zakho road
- Axis No. (11) includes Dohuk – Badi – Zawita road

The purpose of this is to determine the amount of flow by using the average traffic volume, with different types of composition, and using it for the transport of passengers and commercial use of goods at the level of the axes of the motorways linking the district center with the cities under administrative control. See Figure (2).

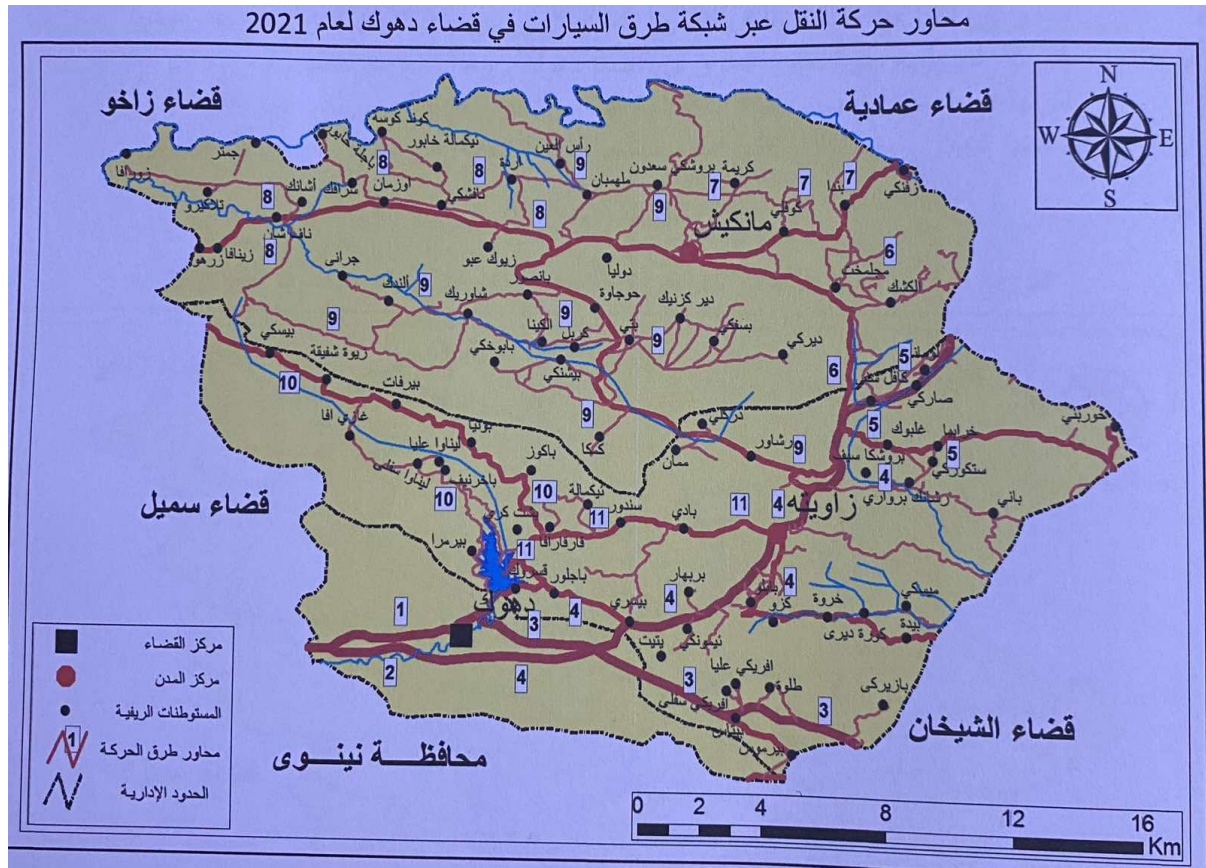


Figure 2

2. Transport Axes Between the Center and Cities of Dohuk District

In order to determine the average traffic volume on the car-road network in the district of Al-Qada, eleven monitoring points were identified. See Figure (3),

The first monitoring point: is located at the Dohuk Zakho junction near the University of Dohuk. The second monitoring point is located at the entrance to the city of Dohuk on the Dohuk-Mosul Road, while the third is at the Dohuk junction in Adhra near the Duhok area Nazarki. The fourth monitoring point is located at the Dohuk junction, Ba'Adra, near the village of Yatit and The fifth monitoring point is located at the Bakirat Amadiya junction near the village of Kifl Suna. The sixth monitoring point is located at the Bakirat Amadiya junction near the entrance to Bakirat while the seventh monitoring point is situated the end of the administrative borders of the city of Mankish near the village of Zvenki. The eighth monitoring point is located at the intersection of Kurit Kavana Petas near the village of Ziuk Abbo, and the ninth monitoring point: is located at the Kurit Kavana junction near the Kura complex, and the tenth point is located near From the Dohuk Dam at the village of Bisht Kri. Lastly, the eleventh monitoring point is located at the entrance to the city of Zawita near the center of Zawita district.

Through these points, the average traffic volume at each point and in both directions (To and from) is calculated. It is clear from the data of Table (1) that the average daily traffic

volume was approximately 87.7 thousand vehicles, and the average traffic volume went up to 47.5%, (To & From), about 52.5% of the total traffic volume on the road axes in the district of Dohuk. The average traffic volume from one axis to another also varied, as the first six axes had about 91% of the total traffic volume on the axes in the district of Dohuk. This is a result of the importance of connecting the district with the neighboring cities.



Figure 3

Based on a field survey

Axis No. (1)

This axis came first in terms of the average traffic volume compared to the rest of the road axes in the district of Dohuk. This axis is represented by the Dohuk-Sumeel-Zakho road, which connects the city center of Dohuk with the district of Sumeel and Zakho and its human settlements. The average traffic volume reached about 31.6 thousand vehicles, which constituted about 36.1% of the total average of daily traffic volume of vehicles, as the round-trip vehicles constituted about 39.6% (From) and about 60.4% (From) of the total average traffic volume within this axis. It was clear from the survey that the highest peak of traffic was in the second hour o'clock, which amounted to about 422,842 vehicles. This represents the period of employees and students returning from their work and schools respectively. In the third hour, it amounted to about 504,454 vehicles, representing the period of returning from work.

Table 1. *The Average Volume of Daily Vehicle Transportation on the Roads Leading to the Center and Cities of Dohuk District for The Year 2021*

Axes	Total vehicle traffic volume	The ratio%	The traffic volume (From) to the vehicle	The ratio%	Traffic volume (From)/vehicle	Total vehicles for transporting goods	Traffic volume of goods transport vehicles		Total passenger transport vehicles	Passenger vehicle/vehicle traffic		Percentage %
							To	From		To	From	
1	31608	60.4	1908	39.6	12528	2400	1536	864	29,208	17544	11664	36.1
2	17712	46.2	8184	53.8	9528	1872	1152	720	15840	7032	8808	20.2
3	6792	55.8	3792	44.2	3000	528	240	288	6264	3552	2712	7.7
4	11232	50.4	5664	49.6	5568	600	240	360	10632	5424	5208	12.8
5	7080	52.6	3720	47.4	3360	312	120	192	6768	3600	3168	8.1
6	5424	31.9	1728	68.1	3696	360	144	216	5064	1584	3480	6.1
7	1080	51.1	552	48.9	528	120	48	72	960	504	456	1.2
8	744	41.9	312	58.1	432	24	-	24	720	312	408	0.9
9	2016	61.9	1248	38.1	768	312	192	120	1704	1056	648	2.3
10	1848	40.3	744	59.7	1104	72	48	24	1776	696	1080	2.1
11	2184	46.1	1008	53.9	1176	240	96	144	1944	912	1032	2.5
Total	87720	52.5	46032	47.5	41688	6840	3816	3024	80880	42216	38664	100%

As for the first hour, there was a drop in the average traffic volume of vehicles by about 118, 294 vehicles (table (3-1-2)), while the average traffic volume of passenger carrying vehicles (To & From) for the second hour was about 422,844 vehicles. Table (3-1-3). It is clear from the data of Table (3-1-3) that private cars and taxis recorded the highest percentage of passenger traffic on all road axes in the district. It is clear from the data of Table (3-1-3) that private cars and taxis recorded the highest percentage of passenger traffic on all road axes in the district.

Private cars made up 66% (To) and (From) 65.6%, and taxis with a capacity of (4-seater) by about 29.3%, 31.1%, compared to passenger carrying vehicles with a capacity (22-seater) by about 1.4% and 0.9%, respectively, of the average daily traffic volume on the same axis. As for the average daily traffic volume of commercial trucks amounted to about 864 vehicles (To) and about 1.5 thousand vehicles (From) (Figure (3) as the commercial trucks of the type (4 tons or less) constituted the highest percentage of the traffic volume by about 36.1% (To) and 27.5% (From), as they are relied upon in transporting goods and light-weight goods such as industrial and agricultural products for short distances.

In addition, the large commercial trucks with a capacity of (20 tons) constituted about 8.3%, 13.6% of the total average number of commercial trucks passing on this axis. In addition, the commercial trucks with a capacity of (24 tons) amounted to about 30.6%, 34.8% compared to truck vehicles, which amounted to about 8.3% (To) and 15.9% (From) of the total average of daily traffic volume of carrying vehicles. It is clear from the data of Table (3-1-3) that private cars and taxis recorded the highest percentage of passenger traffic on all road axes in the district. Private cars constituted 66% (To & From) 65.6%, and taxis with a capacity of 65.6%. (4-seater) by 29.3%, 31.1%, compared to passenger transport vehicles with a capacity of (22-seater) by about 1.4% and 0.9%, respectively, of the total average of daily traffic volume on the same axis.

Table 2. *The Time Change of The Average Volume of Vehicle Traffic on The Road Hubs in Dohuk District In 2021*

Road axes	first hour		Second hour		Third hour	
	To	From	To	From	To	From
1	294	118	842	422	454	504
2	134	268	298	308	250	218
3	46	48	84	114	186	88
4	66	34	142	308	264	122
5	18	40	84	170	208	70
6	38	24	50	192	54	92
7	6	12	12	10	28	22
8	4	14	10	16	12	6
9	20	18	30	26	54	20
10	4	10	30	60	30	22
11	26	2	16	48	32	48

From the researcher's work based on the field survey:

- The first hour was from 7-8 am
- The second hour was 1-2 pm
- The third time was from 7-8 pm

While the traffic of vehicles on this axis was not free of empty vehicles, whether passenger carrying vehicles, which accounted for about 0.2% of the total average traffic volume of passenger carrying vehicles, or for commercial trucks, which accounted for 1% of empty vehicles. The average daily traffic volume of passenger carrying vehicles of all kinds reached about 29.2 thousand vehicles, as this axis witnesses a large average traffic of passenger carrying vehicles (PCV). This is because this axis works to connect the Dohuk district center with both the Summeel and Zakho districts located in the western parts of the study area. The average volume of daily traffic of commercial trucks amounted to about 2.4 thousand vehicles of different types and compared to other axes. This can be ascribed to the spread of economic activities, especially industrial activity, including large and medium industrial units such as the oxygen, concrete and aluminum plant and glass installation, which was reflected in the average volume of daily traffic of commercial trucks.

Axis No. 2

This axis is one of the important road axes in the district, which connects the center of Dohuk district with Nineveh governorate, id represented by the Dohuk-Fayda road, with a length of 7.77 km. It is one of the old roads in the district, as its completion dates back to 1968. This axis came in second place in terms of the relative importance of the average daily traffic volume of vehicles at 17.7 thousand vehicles, which constituted about 20.2% of the total average of the daily traffic volume of vehicles in the district. The movement of vehicles (To & From) accounted for about 46.2% of the traffic volume on this axis, while the highest peak of traffic in the second hour was about 308, 298 vehicles.

In the third hour it amounted to about 218, 250 vehicles, while in the first hour it amounted to about 268, 134 vehicles respectively of the volume of daily traffic of vehicles passing on this axis Table (3-1-2). This axis has witnessed high traffic for passenger carrying vehicles, with an average traffic volume of about 8.8 thousand vehicles (To) and about 7.1 thousand vehicles (From). Table (3-1-3) shows that private cars received round trip 78.4%, 74.3% of the total average volume of passenger traffic, as well as passenger carrying vehicles with a capacity of (4-seater). This accounted for about 16.7%, 21.2% compared to passenger carrying vehicles with a capacity of (22-seater), which accounted for about 1.3%, 2.6% of the total number of moving vehicles on the same axis. Table (3-1-3). While the average traffic volume of cargo transport vehicles was about 720 vehicles and 1,1 thousand vehicles (To & From) respectively). Table (3-1-4).

الأهمية النسبية لأعداد السيارات على محور الطرق (ذهاباً ، إياباً) من متوسط حجم حركة المرور اليومية طبقاً لأنواع السيارات في قضاء دھوك لعام 2021

محاور الطرق	نسبة سيارات نقل البضائع %										نسبة سيارات نقل الركاب %										
	إياباً					ذهاباً					إياباً					ذهاباً					
1	15.9	34.8	13.6	8.7	-	27.5	8.3	30.6	8.3	16.7	-	36.1	0.2	0.9	2.4	31.1	65.6	1.4	3.3	29.3	66
2	8.4	22.9	22.9	12.5	-	33.3	10	33.3	10	10	-	36.7	1.2	1.1	3.4	21.2	74.3	1.3	3.6	16.7	78.4
3	4.8	20	-	30	-	50	8.3	16.7	16.7	-	-	41.6	1.5	2.6	4.4	34.8	58.2	0.8	3.4	38.1	57.7
4	13.6	20	-	30	-	50	6.7	20	13.3	20	-	40	0.4	2.2	2.6	22.1	73.1	2.2	3.6	22.1	72.1
5	8.3	-	-	20	-	80	25	-	25	12.5	-	37.5	1.8	3.3	5.3	26.7	64.7	2.3	5.4	18.1	74.2
6	7.1	-	-	16.7	-	83.3	11.1	11.1	11.1	-	-	55.6	2.9	3	4.5	34.9	57.6	2.8	2.1	10.4	84.7
7	25	-	-	-	-	100	-	-	-	-	-	100	8.1	-	5	25	70	5.2	15.8	36.9	42.1
8	-	-	-	-	-	-	-	-	-	-	-	40	4.4	2.2	6.9	30.8	69.2	5.9	11.8	29.4	52.9
9	8.3	-	-	12.5	-	87.5	20	20	20	-	-	100	12.1	10	13.3	20.5	70.4	7.5	11.1	40.7	40.7
10	-	-	-	-	-	100	-	-	-	-	-	100	3.8	5.3	15.8	26.7	50	4.5	13.3	28.9	53.3
11	11.1	-	-	25	-	75	16.7	-	-	33.3	-	50	3.8	5.3	15.8	63.1	2.4	6.9	23.2	67.5	11

المصدر: بالاعتماد على المسح الميداني، لعام 2021.

(*) تشمل كل من البنية، الكبار.

(**) تشمل كل من الدائبة والقلاب.

(*** تشمل سيارات التوري.

(**** تشمل البراد.

(***** تشمل كل من العربات والتربل.

(-) عدم ملاحظة هذا النوع من السيارات.

Figure 4. The Average Traffic Volume of Passenger Carrying Vehicles (To And From) On The Main Highways Axes In Dohuk District For The Year 2021

These vehicles vary in their types and intensity of movement. Commercial trucks with a capacity of (4 tons and less) got about 36.7%, 33.3%, and those with a capacity of (16 tons) accounted for about 10%, 12.5%.

Commercial vehicles with a capacity of (20 tons) accounted for about 10%, 22.9% of the total volume of cargo traffic passing on this axis, while tank trucks accounted for about 10% (To) and 8.4% (From) of the total traffic volume of commercial trucks. The average volume of empty car traffic on axis No. (2) was about 1.2% of the total traffic of passenger vehicles and about 4% of the total traffic volume of commercial vehicles. In Duhok District. The average traffic of passenger carrying vehicles of various types was about 15.8 thousand vehicles.

The purpose of passenger traffic within this axis varies whether for economic, tourist or service purposes, and the average daily traffic of commercial trucks reached about 1.8 thousand vehicles, due to the movement of trade exchange between the district of Dohuk and the province of Nineveh through this axis.

Axis No. 3

This axis is represented by the road that connects the center of Dohuk district in Erbil governorate, which ranked fifth in terms of average daily traffic volume of about 6,7 thousand vehicles, forming about 7.7% of the total average of daily traffic in Dohuk district.

The car traffic has been over 44.2% (To) to 55% (From) of the average car traffic of Axis (3) and recorded the highest average for the traffic through the path of this axis during the third hour, which reached 88 vehicles (To) and 186 (From). On the 2nd hour, 2,400, 84 vehicles were recorded while the first hour recorded less than that at 68, 46 vehicles (To & From) respectively. Thus, this axis witnessed moderate traffic for passenger carrying vehicles, as the average volume of their traffic (To) reached about 2.7 thousand vehicles and about 3.5 thousand (From), as private transport vehicles accounted for about 57.7%, 58.2% and taxis with a capacity of (4-seater) are about 38.1%, 34.8% of the total average volume. This can be ascribed to the movement of passenger carrying vehicles is characterized by the speed and flexibility of the movement in comparison with 24-seater passenger vehicles that got about 0.8%, 2.6% of the average traffic of passenger carrying vehicles. The average traffic volume of vehicles allocated to the transport of goods and goods was about 288, 240 To-and-From of varying-sized vehicles. Table (3-1-4).

Commercial trucks with a capacity (4 tons or less) constituted about 41.6%, 50% and commercial trucks with a capacity (4 tons or less) while those with (16-ton capacity) accounted for about 16.7, 30%. Commercial trucks with a capacity of (24 tons) accounted for about 16.7%, 20%, and the same is true for tank trucks about 8.3% one-way, and no opposite movement was recorded for it on the same axis. Empty vehicles accounted for about 1.5% of the total average passenger vehicle traffic and about 4.8% of the total average of commercial trucks in the district, which extends within the territory of the Shekhan district, which has a wide range of human settlements.

Axis No. 4

This axis came in the third place in terms of the average daily traffic of vehicles in the district, which amounted to approximately 11.2 thousand vehicles and about 12.8% of the total average traffic of vehicles across all the roads in the district.

Car traffic accounted for 49.6% of vehicles and 40.4% of the total car traffic (To and from respectively) within this axis. The highest peak of the traffic on this axis was recorded during the second hour approximately 308, 142 vehicles (To and from), and in the third hour hit 122, 264 vehicles. This record dropped in the first hour to 34, 66 vehicles.

This is one of the major axes in the district, which links the center of Dohuk in Zawita City, which is an Dohuk- Zawita 16 km long road. This is a tourist road in the district. Thus, the average traffic of passenger vehicles (To & From) was about 5.2, 4,000. Table (3-1-3), with private cars accounting for about %72.1, %73.1.

Private cars accounted for approximately 72% %73.1, while the average traffic of 4-seater vehicles was approximately 22.1%, and 22.1% compared to 9-14-seater vehicles, which

accounted for approximately 3.6% and 2.6% of the average traffic of passenger carrying vehicles, respectively.

With regard to the average traffic of the commercial vehicles, it reached about 360, 240 vehicles, To & From respectively. These vehicles vary in movement according to its different types, as the small-capacity vehicles (4 tons and less) reached about 40%, 50%. This can be ascribed to the increase in its numbers because of the flexibility and speed that these vehicles enjoy compared to other commercial vehicles.

As for tanker trucks designated for transporting petroleum products, their movement was about 6.7%. This axis did not witness the return movement of tank trucks due to the fact that most of the drivers of tank vehicles are taking the Badriya-Waka road to reach the Dohuk district center in order to avoid the rough terrain that this axis passes through.

In addition, the presence of empty vehicles estimated at about 0.4% of the total average volume of passenger carrying vehicles traffic, and about 13.6% of the total traffic of commercial trucks. The average volume of daily traffic for passenger carrying vehicles within this axis reached about 10.6 thousand vehicles. The average volume of daily traffic for vehicles designated for transporting goods reached about 600 vehicles of different types.

Axis No. 5

The average daily traffic of vehicles passing through the routes of this axis constituted about 7.1 thousand vehicles, and about 8.1% of the total average volume of car traffic on the road axes in the district. The highest peak of the flow of vehicles within this axis was recorded in the third hour (To and From) by about 70, 208 vehicles. In the second hour, it amounted to about 170, 84 vehicles and decreased significantly in the first hour by about 40, 18 vehicles out of the total average of daily traffic volume of vehicles. This axis is considered as one of the tourist roads in the district, which connects the city of Zawita with the district of Amadiyah represented by the Zawita - Amadiyah road. Therefore, the average daily traffic volume of passenger carrying vehicles reached about 3.1 thousand vehicles and about 3,6 thousand vehicles (To and From respectively). Private passenger transport was about 74.2% and 64.7%, while 4-seater taxis accounted for about 18.1% 26.7% compared to 22-seater passenger vehicles which constituted about 2.3% and 2.2%, respectively, of the daily traffic volume of passenger vehicles. The average traffic volume of commercial trucks designated for transporting goods amounted to about 192, 120 vehicles. These varied in their movement according to their types, as small commercial trucks with a capacity of (4 tons and less) accounted for about 37.5%, 100%, and tanker trucks with a capacity of (16 tons) accounted for about 12.5% and 20% (To & From) respectively. Large commercial trucks with a capacity of (20 tons) constituted about 25% of the total movement of the commercial trucks across this axle, while the opposite movement was not recorded on this axis. The same is true for tanker trucks which made up about 25% of the total traffic volume of the commercial trucks on the same axis. In addition,

There are about 1.8% of the total average traffic of empty vehicles, and about 8.3% of the total average traffic of commercial vehicles, the average daily traffic of passenger vehicles was approximately 6,7,000, and the average traffic volume of the transport of goods passing through this axis amounted to approximately 312 vehicles of different types.

Axis No. 6

This axis is represented by Zawita – Mankish, which connects the city of Zawita to the center of the city of Mankish, where the average volume of daily vehicle traffic across the

routes of this axis reached about 5,4 thousand vehicles. This constituted about 6.1% of the total average volume of daily vehicle traffic in the district, and the movement of cars 68.1% and about 31.9% To & From respectively. This axis witnessed a high flow of vehicles during the second hour, which amounted to about 192, 52 vehicles, while in the third hour, the number of vehicles passing within this axis reached about 92, 54 cars. In the first hour, the number of vehicles dropped to about 24, 38 vehicles respectively.

This axis serves many human settlements spread along its extensions. These settlements are represented by the village of Kafel Sunni, the village of Kendak, the village of Majlmakht and the village of the kushk. Thus, the average daily traffic for passenger carrying vehicles To-and-From is about 3.4, 1.5 thousand vehicles. Table (3-1-3).

Private cars constituted about 84.7% and 57.6%, while 4-seater taxis were about 10.4%, 34.9% while 9-14-seater vehicles constituted about 2.1%, 4.5% of the total average of daily traffic of passenger carrying vehicles. The average daily traffic volume of commercial trucks for transporting goods was about 216 vehicles, and about 144 various vehicles, (To & From) respectively. It is clear from the table (3-1) that the average traffic volume of transport vehicles within this axis amounted to 5.1 thousand cars. This value is low compared to the previous road axes, because this axis depends on the movement of tourists during the tourist seasons.

The average volume of daily traffic for commercial trucks amounted to about 360 cars of the total average volume of daily traffic on this axis, while the axes of the other five roads formed about 10% of the total average of daily traffic volume of vehicles in the Dohuk district, as these axes link the centers of the cities of the Dohuk district with each other and their rural settlements. Moreover, some of these axes link the centers of the cities of the Dohuk district with the adjacent districts represented by axis number (7), (8) and (10) but less important than axis number (1). All these axes are considered as secondary road patterns in the district. However, these axes vary in terms of the average traffic volume on them, as Axis number (7) represented by the Mankish-Amadiya road has an average of traffic estimated at about 1.1 thousand vehicles (i.e., 1.2%) while the average traffic volume within Axis number (8) reached about 744 vehicles (about 0.9%). The average number of vehicles passing through two axes (10) and (11) reached about 1.8, 2.1 thousand vehicles (2.1%, 2.5%) respectively, of the average daily traffic volume on all road hubs in the Dohuk district. Axis number (9) is represented by the Kurit Kavana-Mankish road that connects the city of Zawita to the center of the city of Mankish. This axis witnessed an average traffic estimated at about 2016 vehicles and about 2.3% of the total average number of vehicles across all road axes in the district.

It is clear from the analysis of Table (3-1-2) that the highest peak of the flow of vehicles on the five axes ranged between the second and the third hour. For example, the average number of vehicles passing within Axis number (7) during the third hour is about 22, 26 vehicles, while the number of vehicles in the second hour reached about 12, 10 vehicles, and about 12, 6 in the first hour. Axis number (10) witnessed the highest flow of car traffic during the second hour by about 60, 30 cars, while in the third hour the number reached about 22, 30 vehicles, and dropped in the first hour to 10, 4 vehicles of the total traffic in the district. This can be ascribed to the variation of the human settlements served by these axes as well as the inactivity of economic transactions within the routes of these axes, particularly the industrial units of different qualitative structure, which were concentrated within axis No. (1) as we explained earlier. This had a great impact on the variation of these axes in terms of the average traffic volume of different types of vehicles, whether passenger carrying vehicles or commercial trucks.

The average traffic of passenger carrying vehicles on axis number (7) is about 456, 504 vehicles and axis number (8) About 408, 312 vehicles, (To & From), respectively. Axis number (9) had about 648 vehicles and about 1.1 thousand vehicles (To & From) respectively compared to Axis number (10) which had about 1.1 thousand vehicles and 312 thousand vehicles (To & From) respectively.

The average number of passengers carrying vehicles through the routes of axis number (11) about 1 thousand cars To and 912 cars From. Figure (3-1-3). For example, the highest percentage of passenger transport vehicles was recorded on axis number (11) at about 67.5%, 63.1%, and 4-seater taxis reached about 23.2%, 15.8%, while 9–14-seater vehicles reached about 15.8%, 5% of the total average traffic of passenger carrying vehicles (To & From) respectively.

The average traffic volume of vehicles through axis number (7) was about 72, 48 vehicles, and less than that within Axis number (8) approximately 24, 0 cars. This represents the lowest number of commercial trucks on all axes of roads in the district. Within Axis number (9), it formed about 120, 192 vehicles and less than that on axis number (10) and (11), which amounted to approximately 24, 48 and 144, 96 vehicles, (To & From), respectively. Figure (3-1-4).

Despite the differences in the size and type of vehicle, small-scale trucks with a capacity of 4 tons and less are among the most mobile vehicles on all these axes. This is due to the fact that this type of car can transport goods and low-weight commodities from animal products such as milk, meat and agricultural products such as fruits and vegetables from the production area to markets for consumption. This type of vehicles under axes 7 and 10 has acquired 100% of the total average traffic volume (To & From) the district. Axes 8 record 100% of vehicles going forward, while no reverse movement of the same vehicle has been recorded.

Less than that within axis No. (9) and (11) was recorded as well as large tanker trucks, such as those with a capacity of (20 tons), which accounted for about 20% round trip within axis No. (9). Tanker trucks designated for transporting petroleum products within axis No. (9) and No. (11) had about 20% of the total average traffic volume respectively.

It should be noted that these five axes were not devoid of the movement of empty vehicles, as the highest percentage of empty vehicles was recorded within Axis No. (10) with about 12.1% of the movement of passenger carrying vehicles through this axis. In axis No. (7), the percentage of empty vehicles amounted to about 25% of the average traffic volume of vehicles intended for the transport of goods and commodities, which represents the highest percentage of empty commercial trucks compared to all road axes in the district of Dohuk.

1. Spatial Interaction Model of Transport Traffic Between the Center and Cities of Dohuk District

Model is a study of the reality of geographical phenomena in a simplified way characterized by idealism. It explains in depth some of the salient features of this reality, in its spatial and temporal dimensions, which require obtaining the same results, as there are the same digital and logical inputs used to build the model. Modeling is a simulation of reality that leads to predicting the future of the studied phenomenon and its directions spatially (Qerba, 2014, p. 2). The model is one of the most important scientific methods adopted by the researcher to reach the ideal situation that needs to be accomplished. Spatial modeling requires the use of various tools, equations and mathematical formulas to build models, as well as

logical digital databases and information. It gives priority to the use of mathematical models for geographic research contexts. Thus, modern techniques, represented by information and computer software, are widely used in the construction of spatial models (Al-Samarrai, 2011, p. 198). It is also used to determine the average traffic volume of vehicles and the flow of passengers and goods through the routes of the road network in any geographical region by adopting the indicators of the gravity model in the movement theory presented by Edward Wallmann in 1965 through three indicators of the occurrence of spatial interaction (Al-Haddad, 2002, pp. 41-42).

1-: Interaction and movement model: this is a model of spatial interaction between cities, and the interaction takes multiple forms, such as the movement of goods, trips, the quantity of goods, the flow of traffic, or population migrations and shopping trips between cities and regions. Geographers borrowed this model from Newton's law of gravitation, which states that the force of interaction / attraction between any two cities is directly proportional to the population size of the two cities and inversely proportional between the two cities. The two of them are the most populous and the most interactive, while we find the farthest of them is the least interactive. The gravitational model takes the following mathematical formula (4):

$$\text{Reaction and transport} = H1 \times H2$$

q

Where: H1 = the population of the first city.

H2 = population of the second city

P = distance between the two cities

By applying this equation to the cities of Dohuk district, it becomes clear that the interaction between the two cities of Dohuk and Zawita is a greater than that between Dohuk and Mankish, assuming that the rest of the variables remain constant between the centers of the three cities as follows (Al-Sammak et al., 2012, pp. 76-77).

Table (3-3-1) shows that the volume model The interaction and movement between Dohuk & Zawiya amounted to about 58,383 thousand people, while the average volume of passenger vehicles traffic between the two cities amounted to about 3,412,000 cars, and the volume of passenger traffic amounted to about 7,004 thousand passengers.

This indicates that the volume of the interaction model is higher than the average traffic volume between the two cities, while the volume of interaction between the cities of Dohuk - Mankish reached about 43,538 thousand people. The average traffic of vehicles for transporting passengers was about 613.4 thousand cars that were able to transport about 1,439 thousand passengers. This indicates that the size of the model is more than the average traffic volume between the two cities, as well as the volume of interaction between the two cities of Zawita - Mankish, which amounted to about 515.5 thousand people, which is less than the average traffic volume between the two cities. The volume of passenger car traffic between the two cities is about 1,823 thousand, and the average passenger traffic is about 3,608 thousand.

Table 3-1. Results of the Interaction and Traffic Model Between the Center and Cities of Dohuk District In 2021

The cities	Variable area between cities / km		population size variable	Interaction size and movement
Dohuk	16	Dohuk Zawita	394,319	58383856
Zawita	41	Duhok - Mankish	2369	43538588
Mankish	20.80	Zawita - Mankish	4527	515599

Source: Relying on:

- 1- Kurdistan Regional Government of Iraq, Ministry of Planning, General Authority for Statistics, Dohuk Statistics Directorate, Population Statistics Division, unpublished data, 2020
- 2- Kurdistan Regional Government of Iraq, Ministry of Construction and Housing, Directorate of Roads and Bridges in Dohuk Governorate, Planning Division, unpublished data, 2020.

From the above, we can clearly see that the gravity model and its various modifications represent a useful method that can be used to study many patterns of spatial interaction, such as the movement of passengers, goods, number of trips, etc. It is limited to making suitable mathematical assumptions that serve only as a basis for theoretical discussion (Abdo, 2007, pp. 69-70). In sum, it is necessary to define the characteristics of movement within the city to understand its traffic problems, and it is of strategic importance to geographers and transport planners because it helps them in formulating solutions to them.

6. Law of Retail Gravitation

This law represents the interaction theory and is sometimes called Reilly's law of retail gravitation. It aims to measure the volume of economic interaction between cities, which takes the volume of retail trade as a variable to measure the amount of economic interaction between cities, using the following equation (Al-Sammak, 2012, p. 79):

The size of the business relationship between b, a, the population of a, the distance between b, c

$$\frac{I_{bc}}{I_{ac}} = \frac{P_b}{P_a} * \left(\frac{d_{bc}}{d_{ac}}\right)^2$$

The size of the business relationship between b, c the population of c the distance between a, b a

It is clear from the analysis of the data in Table (3) that the volume of the commercial relationship between the cities of Dohuk and Zawia is three times the movement of the commercial relationship between Dohuk and Mankish, with a ratio of 6,15,000 to 4,5 thousand beneficiaries. It amounted to about 216,000 vehicles, and the average volume of transported goods amounted to about 2,453 thousand tons. The average traffic volume of vehicles dedicated to transporting goods and commodities between the cities of Dohuk and Mankish was about 112.3 thousand vehicles while the average volume of transport trafficed goods was about 1,036 thousand tons. it is noted that the difference in the volume of dealings between cities is largely due to the effect of the distance factor on the volume of trade exchange. While the volume of the commercial relationship between the cities of Zawiyah and Dohuk amounted to about 66.7

thousand beneficiaries, a percentage that represents multiple times the volume of commercial dealings between the cities of Zawita and Mankish, which does not exceed 4.

The volume of the commercial relationship between the cities of Mankish and Duhok represents twice the volume of the movement of the commercial relationship between the cities of Mankish and Zawita, at a rate of about 10,1 thousand to 4,5 thousand beneficiaries. The average traffic volume of vehicles transporting goods and commodities between the cities of Mankish and Dohuk was 112,3 thousand vehicles out of the total traffic volume of commercial trucks in the district of Dohuk. The average volume of transport trafficked goods amounted to about 1,036 thousand tons, and that the average movement of commercial trucks between the cities of Mankish and Zawita amounted to about 129,6 thousand cars. The average volume of transport trafficked goods amounted to about 1,278 thousand tons of the total traffic volume in the district. The results of the gravity model of retail trade between the center and cities of Dohuk district in 2021.

the cities	Variable area between cities / km	population size variable	Retail Trade volume	
Dohuk	16	Dohuk Zawita	394,319	15555
Zawita	41	Duhok - Mankish	2369	66639
Mankish	20.80	Zawita - Mankish	4527	10133

Source: Relying on:

- 1- Kurdistan Regional Government of Iraq, Ministry of Planning, General Authority for Statistics, Dohuk Statistics Directorate, Population Statistics Division, unpublished data, 2020
- 2- Kurdistan Regional Government of Iraq, Ministry of Construction and Housing, Directorate of Roads and Bridges in Dohuk Governorate, Planning Division, unpublished data, 2020.

7. Break-Even Point Theory

The interaction theory determines the size of the economic relations between cities, without referring to the boundaries of the commercial areas of these cities. However, the break-even theory is an amendment to the interaction theory, and this amendment aims to determine the location that separates the commercial areas around two different cities in the size of their population (Al-Haddad, 2002, p. 52) and then represents the break point that we get by applying this boundary equation at which the force of gravitation between two competing cities is equal, by using the following equation:

After the point of break from the commercial centers = P

$$q = \sqrt{1 + \frac{P}{x \cdot y}}$$

This can be explained as follows:

P = the distance between the two commercial centers.

q = the population of a large city.
 xy = the population of the small town.

Based on this equation, the commercial area of the city of Dohuk extends 1.15 km towards the city of Zawita and 3.96 km towards the center of Mankish city, and the commercial area of the city of Zawita extends 8.77 km towards the center of Mankish city (Table 3).

Table 3

the cities	Variable area between cities / km	population size variable	Retail Retail Trade volume	
Dohuk	16	Dohuk Zawita	394,319	1.15
Zawita	41	Duhok - Mankish	2369	3.96
Mankish	20.80	Zawita - Mankish	4527	8.77

Source: Relying on:

- 1- Kurdistan Regional Government of Iraq, Ministry of Planning, General Authority for Statistics, Dohuk Statistics Directorate, Population Statistics Department, unpublished data, 2020.
- 2- Kurdistan Regional Government of Iraq, Ministry of Construction and Housing, Directorate of Roads and Bridges in Dohuk Governorate, Planning Division, unpublished data, 2020.

8. Research Summary

In addition to the variation in the number of vehicles passing through these axes according to their capacity and qualitative composition, private passenger transport cars and 4-seater taxis constituted the highest percentage of the average traffic volume of passenger carrying vehicles.

The road hubs in Dohuk district are witnessing an influx of cars transporting passengers and goods, as the average daily traffic volume of cars on these axes amounted to about 8,77 thousand cars, and the movement of cars To-to-From constituted about 47.5% and about 52.5% of the total volume of car traffic respectively., The axes vary in terms of the average traffic volume as Axis No. (1) ranked first with 36.1% of the total average volume of car traffic on all road axes in the district, while axis No. (7) ranked last with about 1.2% of the total average of daily traffic volume on all road axes in Dohuk district.

In addition, there is variation in the number of vehicles passing through these axes according to their capacity and their qualitative composition. Private passenger transport vehicles and 4-seater taxis constituted the highest percentage of the average traffic volume of passenger vehicles, as well as the case for commercial trucks as small-cargo vehicles with a capacity of 4 passengers (4 tons or less) had a high percentage of the traffic volume of the commercial trucks in comparison with the other commercial trucks. It was clear from the field survey that the highest peak of car traffic was at the second hour 1-2 in the afternoon and the third hour from 7-8 in the evening, where the second hour represents the period of employees leaving their work and students returning from their schools.

As for the third hour, it is represented by the journey back from work, and human activity had a clear impact on the daily traffic intensity for the areas served by these axes as is the case for Axis No. (1) and the opposite for the other axes. The field survey indicated that the average volume of car traffic towards city centers in Dohuk district was varied. The Dohuk city

center ranked first in terms of the average volume of car traffic at the district level, as it received an average transportation traffic of about 24,909 thousand cars, depending on their qualitative composition. Zawita came second, with an average traffic movement of about 5,287,000 vehicles.

The city of Mankish ranked last in terms of the relative importance of the average traffic volume amounting to about 1,382 thousand vehicles of various types out of the total average traffic volume in Dohuk district. The criteria for evaluating the transport movement axes between the center and cities of Dohuk district showed that the road network throughout the district is characterized by very low efficiency in terms of the road inflection index, which reached 159.2%. There are also some axes that are characterized by high efficiency such as Axis No. (1) which was reflected on the ease of access and communication, as the city of Zawita is the most connected network nodes and the city of Mankish is the least connected in the district. The diameter of the network is 1.46%. The spatial interaction model represents the study of geographical phenomena in a simplified way. It is one of the scientific methods adopted by the researcher in the geography of transportation to reach the ideal required state, and the gravity model is one of the oldest analytical models. This model shows that the interaction between the two cities of Dohuk and Zawita is more than that between the cities of Dohuk and Mankish, and that the volume of trade between the cities of Dohuk and Zawita is three times the volume of trade between Dohuk and Mankish. It shows that the commercial retail dealings between the cities of Zawita and Dohuk are multiple times the volume of commercial dealings with Mankish City, as the size of the retail trade between the cities of Mankish and Dohuk represents twice the volume of the movement of the commercial relationship between the cities of Mankish and Zawita. The average break point between the cities of Dohuk and Zawita was 1.15 km, and between Dohuk and Mankish is about 3.96 km, and between the cities of Zawita and Mankish about 8.77 km.

9. Conclusions and Recommendations

9.1 Conclusions

1- The district of Dohuk is the land bridge that connects the continents of the world with each other, and accordingly, the district has witnessed a quantitative and qualitative development in the length of roads and the number of cars.

In 1968, the district enjoyed the spread of about 56.62 km of the network of limited car roads in its extensions and directions, and the number of vehicles was very few as it did not exceed 77 vehicles and it is limited only to rich families. In 1990s, the district witnessed a development in the lengths of roads with a growth rate of about 4.5%. The growth rate of cars was about 14.9%, while the growth rates of roads began to decline at the end of 2020, reaching about 4.1%, and the growth rate of vehicles reached about. % 15.8% 4.

2. According to the results of the spatial model to assess the density of the road network in the district of Dohuk according to the divisions of geographical coordinates, which regulate the adequacy of roads based on area factors and population size, there are spatial patterns for the density of the road network in the district. These patterns are on three spatial levels, represented by each of the high-density pattern in which the degree of road density for the area ranges between 0.70 - 1.14 / km / 100 km². It worth noting that the density of roads for the size of the population ranges between 240.1 - 763.88 km / 1000 people, and the medium density pattern ranges between 0.48 - 0.69 km / 100 km. The degree of road density for the size of the population ranges between 97.4-240 km /1000 inhabitants, and the low-density pattern in

which the ratio of road density to the area ranges between 0.01 - 0.47 km / 100 km, and the ratio of road density to the size of the population ranges between 0.01 - 97.3 km / 1000 inhabitants. In addition, it is worth noting the ability of the model to isolate sections that have not seen the extension of the links of motor roads and are uninhabited due to the natural characteristics prevailing in them, especially in the southern parts of the district dominated by mountain heights.

3- The interaction and movement model showed that the interaction between the two cities of Dohuk and Zawita is higher than that between the two cities of Dohuk and Mankish. The traffic volume between the two cities reached 58,383,000 people, the average volume of passenger traffic between the two cities was about 3,412,000 vehicles, while the average volume of passenger traffic was about 7,004,000 passengers. This indicates that the size of the model of interaction is more than the average traffic volume between the two cities. The interaction between the cities of Dohuk and Mankish was about 43,538,00 people, and the average volume of passenger traffic was about 613,439,000 passengers. This indicates that the size of the model is higher than the average traffic between the two cities, whereas the size of Mankish was about 5,55,05,00000 people, which is less traffic between the two cities. The average traffic volume of passenger carrying vehicles was about 1,823,000, and the average passenger volume was about 3,608,000.

4- The retail gravitation model revealed that the commercial relationship between the cities of Dohuk and Zawita amounted to three times the size of the commercial relationship between the cities of Dohuk and Mankish, with a ratio of 15.6 thousand beneficiaries to 4,5 thousand beneficiaries compared to the average traffic volume of carrying vehicles. This amounted to approximately 216,000 vehicles and average commercial trucks of transporting goods amounted to about 2,453 thousand tons. The average volume of the movement of commercial trucks between the cities of Dohuk and Mankish was about 112.3 thousand vehicles while the average traffic volume of transporting goods was about 1,036 thousand tons.

5- It was found through the break-even point model that the break-off point between the cities of Dohuk and Zawiya was 1.15 km, and was 3.96 km between Dohuk and Mankish. The average break-off point between the cities of Zawita and Mankish was about 8.77 km.

9.2 Recommendations

Based on the conclusions reached by the study, the following can be suggested:

1) We see the importance of expanding the road network in the district by creating other additional corridors in order to accommodate the traffic volume of cars, passengers and goods and to reduce the traffic volume and frequent traffic accidents, for example, the Kurit Kavana-Mankish road, and the Zawita-Badi-Duhok dam road, and Zawita Road -Bakers – Mankish.

The requirements of development also necessitate periodic maintenance of roads in the district for all their main, secondary and rural types. The purpose of this is to maintain its durability and the smooth flow of traffic for vehicles on them, especially those affected by weather fluctuations, or roads that witness heavy traffic. Overloading of commercial trucks causes stress on the road and results in cracks and erosion in the asphalt layers of the road.

2) The study finds that it is necessary to have an accurate periodic system to monitor traffic on different roads. This is so that these studies help to assess the conditions of the road network and its efficiency in directing traffic, and then determining the scale of need which the network has in terms of expansion or finding alternatives.

3) The study finds it necessary to establish an integrated database on the road network in the district, through cooperation between road engineers, transport geographers, and those with experience in the fields of computer science and geographic information systems techniques. The database should include various and multiple data on road lengths and patterns, the number of lanes and the paths of each lane, the total width of the road body, as well as the speed and size of the design movement.

5. A number of bridges are erected at road junctions where the traffic of cars increases, as at the intersection of Zawita, Kurit Kavana.

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