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PREDICTION ORIGIN-DESTINATION MATRIX Of FREIGHT TRAVEL DEMAND IN BAGHDAD CITY

Summary. Efficient freight transportation systems typically reduce the cost of moving goods to and from logistics facilities. The demand matrix (O-D) is used to load or allocate the flow of traffic on a network, usually defined as a matrix that detects the number of trips. The objective of this study is to contribute to road freight modeling in Baghdad in general and estimate the O-D matrix for truck traffic using the freight transport data collected. Freight data was collected through roadside and interview surveys at the seven entrances of Baghdad city. In addition, the analysis was performed using Trans CAD ver. 4.5 software. The results provide an analysis of the freight travel demand. The output of this study is useful for decision-makers in the evaluation and execution of freight transportation activities and aids the application of correct decisions.

1. INTRODUCTION

Understanding and forecasting freight travel behavior and movement are critical to planning for future transportation activities [1]. Efficient freight transportation systems are typically associated with reduced costs of moving goods to and from logistics facilities [2, 3]. The process of forecasting freight transport demand began with the collecting of comprehensive data, which included demographic, network, socioeconomic, and land use variables [4]. The traditional travel demand forecasting process is done through a four-step sequential model (trip generation, trip distribution, mode choice, and traffic assignment). For a good understanding of freight movement, geospatial and statistical models form the basis for developing a comprehensive view [5]. The results of a freight study have been a key component of the travel demand process and are used in many applications, such as air quality impact analysis, benefit estimation, traffic safety models, and model selection analysis [6]. There is little literature dealing with freight transport around the world. Some of these studies are as follows: [7] evaluated road freight in Turkey by estimating the origin-destination O-D matrix from data collected by roadside surveys. Regression analysis was used to construct trip production, and attraction using socioeconomic data, the results show low statistics for both travel time, and distance impedance representing that truck distribution was controlled by other parameters. [8] introduced a freight demand framework to estimate the O-D matrices for the Marmaray Project. The developed model was used to predict passenger and freight transportation between Istanbul and other provinces. These results are useful for estimating the number of trains passing through the Marmaray corridor daily.

[9] evaluated the feasibility of truck activities using GPS data and used a statistical approach to determine and analyze the trip characteristics of different commodities. [10] calculated freight demand for 604 retail establishments in the city of Lisbon, Portugal, using a freight survey. The relationship between independent variables (supply chain characteristics and store sales area) and the total number

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of deliveries was established. The results show that the number of employees is a better predictor than the other variables. [11] proposed a methodology for increasing logistics centers' performance by creating suitability maps for the location of the logistic center using spatial statics and a fuzzy analytic hierarchy process. [12] used a freight O-D matrix to study the impact of urban consolidation centers (UCCs) on freight flow using a mixed logit model. The results recommended accurate planning of UCCs. [13] modeled mode choice of freight transport in a Brazilian city using stated preference data was used to study the mode elasticities. The results show shippers' preferences have low reactivity to changing factors. [14] evaluated the impacts of the city sprawl on freight transport and showed that an increase of 40% in trip lengths occurred; therefore, there is a need to improve the efficiency of freight transport. [15] assessed the city network of Nasiriyah, Iraq. The assessment was carried out utilizing Geographic Information System GIS applications. The output showed considerable congestion on a number of links, with v/c greater than 1.0, but other routes in the city had LOS (B), indicating good condition. [6] used TransCAD to simulate traffic conditions in Al-Amarah city. The analyses revealed that the majority of roads in the city in the base year (2015) had LOS D. The road network, on the other hand, suggested that LOS (F) was discovered for the majority of the roadways in 2035. Even though the aforementioned studies have been conducted in a few Iraqi cities, most Iraqi cities have limited or no thorough published transportation, planning, or even traffic management studies [16].

Baghdad Governorate is the most densely populated area in Iraq and has grown rapidly since the late 1970s. Its annual growth has doubled. The increase in economic activity and population with the rapid transformation of land use led to an abnormal increase in trips created, causing traffic congestion at various locations of the transport network. In recent years, the growth rate of vehicle ownership in Baghdad has increased by 5.5% since 2003, and the growth has been stable at 3.5% since 2006 [17]. This high growth of private vehicles conflicts with a high increase in truck travel, which makes the condition worse in Baghdad city. Therefore, Baghdad city was selected as a case study. Locally, there are no studies dealing with freight demand in Baghdad. Trucks traveling along major roads in the city cause a lot of congestion, and their movement must be replanned to decrease demand in the city center by studying freight movement and then changing the network by either adding new roads or relocating freight movement. As a result, the current research aimed to generate the current O-D matrix, assign it to each important road in the city, and investigate network characteristics. The study is divided into introducing the subject, defining the study area, representing the methodology of the study, and finally, showing results and conclusions.

2. STUDY AREA

The demand for transporting goods has increased significantly with the development of Baghdad over past decades, the rise in its population density and its connection to land use. Baghdad Governorate is located between Salah Alden to the north and Babil to the south and appeared in the Iraq area in the zone (38N) with spatial reference GCS_WGS_1984. Baghdad area is (5065.163 km^2) which represents 1.04% of Iraq's total area [18]. Baghdad city has the smallest area among Iraqi governorates, and in 2018, Baghdad increased its population to 9 million people. The region of Baghdad is divided by the Tigris River into two areas: Al-Karkh and Rusafa. The study area should be divided into a group of homogeneous traffic area zones, the characteristics of which must be defined by uniform socioeconomic and land use properties. They represent the unit basis for travel analysis, for the movement inside, within, and outside the study area, and that is why the city of Baghdad was divided into sectors, as shown in Fig. 1.

3. METHODOLOGY

The following are the main steps in this study:

1. Establish and characterize the study area's limits.
2. Using GIS software, identify the network's required links and nodes.

3. Use field surveys and questionnaires to acquire the necessary freight demand data and general information.
4. Generate an O-D matrix of freight demand from currently collected traffic data.
5. Finally, using TransCAD's all-or-no model, evaluate the current traffic network and show the future network assignment.

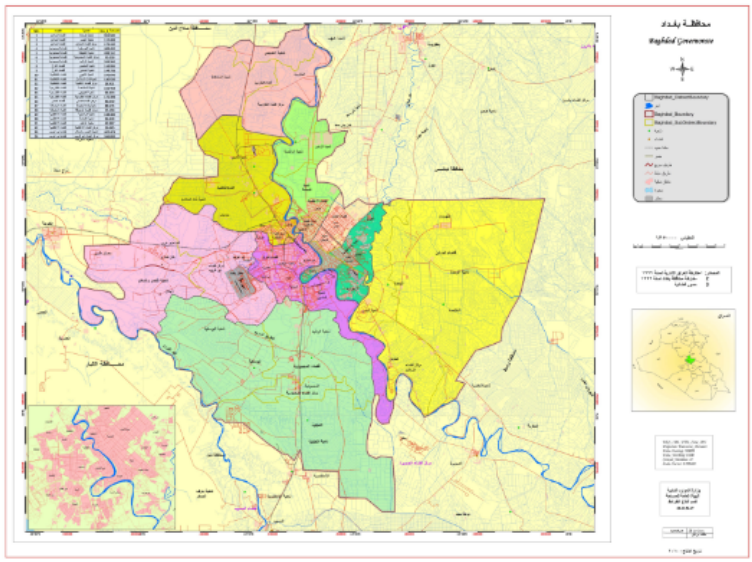


Fig. 1. The map of Baghdad Governorate

4. IDENTIFICATION OF THE MAIN ROAD ENTRANCES IN BAGHDAD CITY

This study focuses on vehicles transporting goods, so the study uses the main road network and arterial roads, and it focuses on the main entrances to the governorate.

Baghdad city has seven main entrances that link external and internal traffic and then connect traffic outside the city center to administrative districts. Although Baghdad is the node of the road to central Iraq, it serves as a traffic area for many vehicles from the rest of the surrounding provinces. The main entrances are as follows:

- The first entrance is in the northeast, which has been referred to as Khan Bani Saad entrance EX1. This connects the axis to traffic that comes from the north and east of Iraq, including the governorate of Kirkuk and Diyala.
- The second entrance is in the northwest and has been referred to as Taji entrance EX2. It represents the city traffic connection axis to traffic that comes from north and west governorates, such as Salah Aldin and Naynawa.
- The third entrance is in the north and has been referred to as (Rashdiya) EX3. It represents the connection axis to the traffic that comes from northern governorates.
- Regarding the fourth (southern, EX4) and fifth (western, EX5) entrances, the first entrance depends on the second because the southern entrance works the enter government trucks only from the southern and middle governorates, and non-governmental trucks are transferred to the other (entrance to Abu Ghraib new). Thus, the latter connects incoming traffic from the southern and central governorates and western governorates such as Anbar Province.
- The sixth entrance (EX6) is the southeast entrance and is also known as Jisr Diyala. It links the internal traffic from Baghdad with the eastern provinces such as Diyala and Wasit, and it enters Baghdad through cities. The last entrance is the entrance of the old Abu Ghraib, which is not studied because it is used to enter private and small vehicles, and trucks are not entered from it.

- The seventh and last entrance (EX7), which is known as the Al-Sha'ab entrance, combines the northern and northeastern roads leading to Baghdad through the governorates of Baquba, Kirkuk, Sulaymaniyah, and Erbil, Mosul, and Dohuk, as shown in Fig. 2.

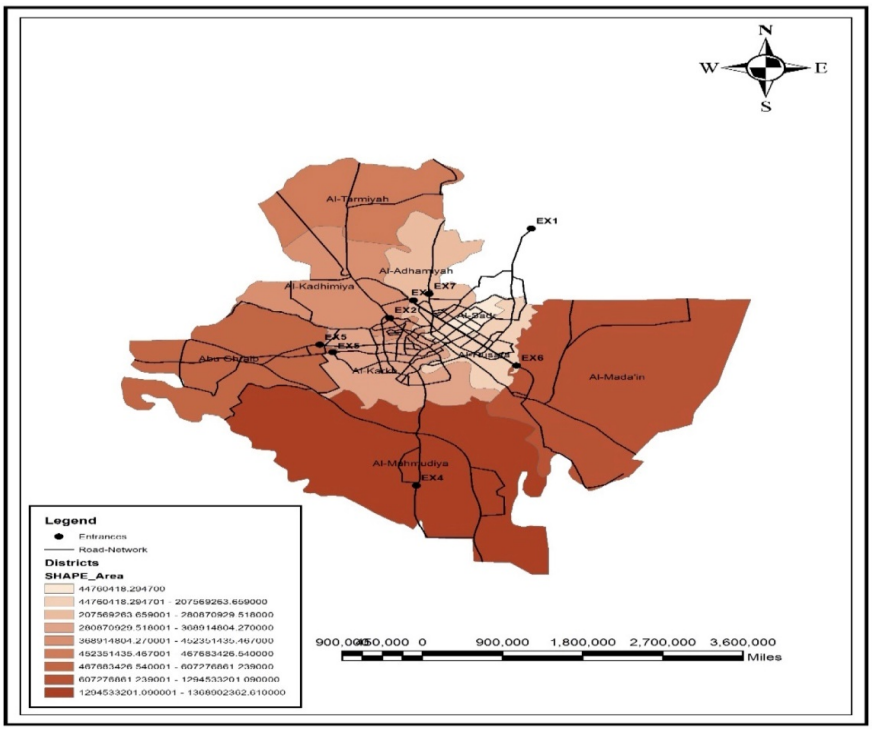


Fig. 2. Entrances of Baghdad

5. DATA COLLECTION

The freight demand data required for the study was collected at the seven road entrances of the Baghdad network using the manual count for a period from 9:00-10:00 p.m. Data include the number of truck vehicles entering Baghdad city and other information data necessary for modeling the network. One of the most important characteristics needed to construct the matrix is the freight volume at a certain hour. Secondary characteristics and other attributes, such as name, classification, length, travel time, direction, and speed, were collected. The characteristics of the region contain their warehouses, represented by the destination collected by a questionnaire at the entrances to the city and according to the factors of travel demand.

6. BUILDING A FREIGHT DEMAND DATABASE USING GIS

Arc GIS 10.7 was used to build a database of freight networks using three shapefiles. Shapefiles, including nodes, links, and sectors, were created over the satellite image accuracy of 60 cm type Worldview satellite-2. The world view-2 satellite image provides eight multispectral and monospectral images, and this product is considered one of the most advanced products due to its high accuracy (0.5 meters for mono spectral and two meters for multispectral). The database was built as shown in Fig. 3. [19] divided Baghdad city into nine districts. Also, various attribute data have been entered, including the width, length, and speed limits of roads, as represented in Fig. 3.

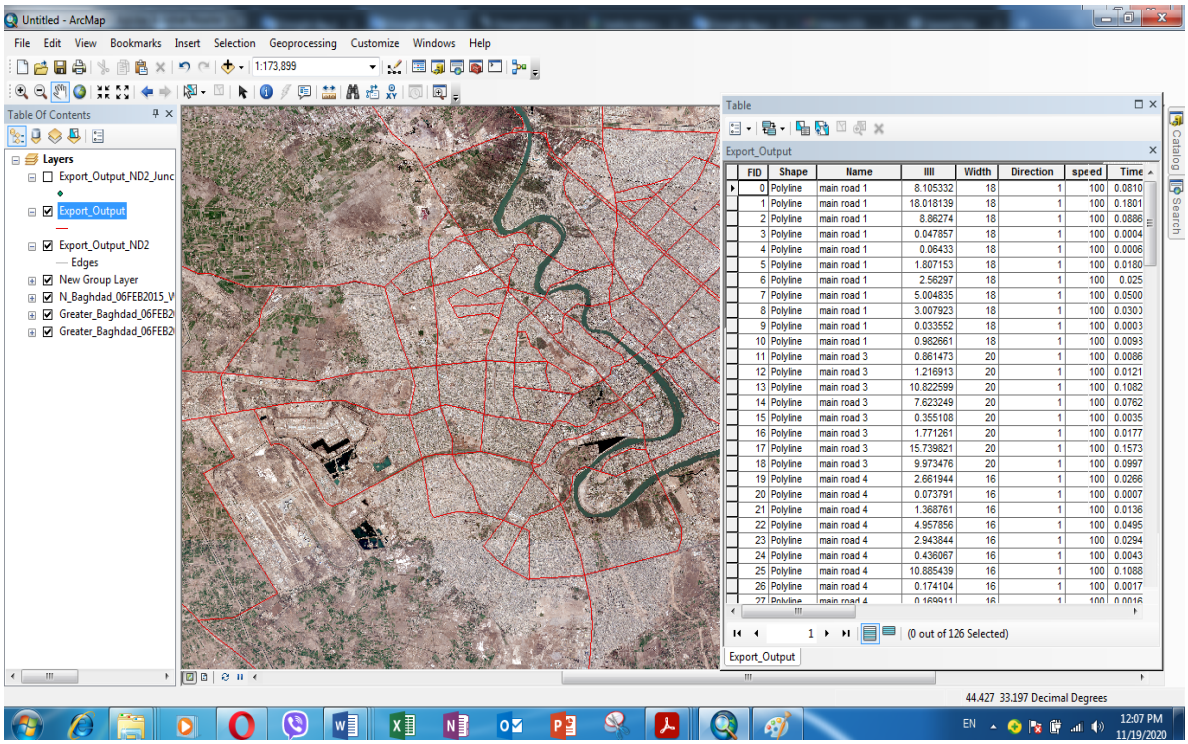


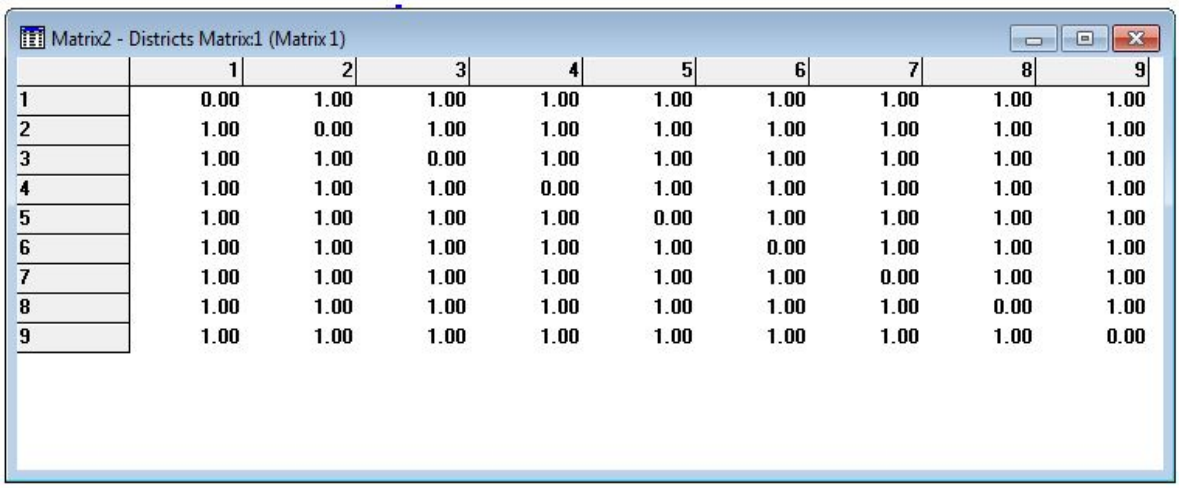
Fig. 3 Database of Baghdad Road Network

One entry required for the O-D matrix estimation is a network. TransCAD applies a geographic file for mapping transportation systems as well as networks to solve transportation problems. When creating a network, two network links are created: one for the linear features and the other to represent flow in every direction. Then, correlation can be specified as one method. In our work, the entire network was created with its features in GIS (called the TransCAD) while blending the layers into one with its features and determining the directions of the road, and the symbols used by TransCAD were previously included in the GIS, such as the direction of movement, which is 0, meaning the road is two-way. Centroid Connectors were created to access the highway network, and they represent local roads. Centroids represent the center of the zone area created by the software to connect the zone with the existing network.

7. GENERATE FREIGHT DEMAND O-D MATRIX

The traditional travel demand prediction process consumes much data and time. Especially in developing countries, it requires a lot of time and money due to a shortage of detailed social and economic data. Because of this, it is not appropriate to apply them in Baghdad. The process is based on estimating the O-D matrix from the traffic counts. When using the O-D matrix estimation procedure in TransCAD, the base O-D matrix should be prepared in addition to the geographic file of the two shapefiles (line and area layer) from GIS, and every link data should be entered. A network for the line layer should be created, which must involve all relevant attributes. Regarding the area geographic file, a zone centroids connector should be created to connect the line and area geographic layer. The matrix was determined on the area layer, which was represented by the districts, dividing the study area into nine districts. The current base matrix (9*9) was created, in which districts are represented by numbers for the matrix and according to the following sequence: Abu Ghraib, Adhamiya, Rusafa, Sadr, Tarmiyah, Kadhimiya, Karkh, Mahmudiyah, and Al Mada'an entrances. Because there is no available prior O-D matrix, a unit matrix was utilized (see Fig. 4). The primary purposes of a unit matrix are as follows:

- The output matrix dimensions are represented by a matrix containing rows and columns, and the cell number refers to a specific zone. Each row represents the origins, and each column represents the destination areas.
- The prior matrix of O-D is represented by an initial value (one unit) if there is no previous matrix [20].


Matrix2 - Districts Matrix:1 (Matrix 1)

	1	2	3	4	5	6	7	8	9
1	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00

Fig. 4. Base Matrix

7.1. Current O-D Matrix

To perform an estimate of an O-D matrix, a preload of truck data must be entered. Under the O-D settings, 10 iterations were used as criteria for the simulation. An all-or-nothing short path method was used because the course of action is for interior trips to the city. The potential default value was the difference between the expected and observed numbers of trips must be in the range of 10% of actual counts. The preload of the truck number on specific links on the network was used in the matrix estimation process. These flows are shown in Fig. 5. A successful current matrix procedure results in a new matrix file and link table file with the traffic generated by the current matrix. Fig. 6 shows the estimated O-D current matrix. In the current matrix, the represented number of vehicles from every district to the other district per hour is presented for every cell.

The traffic movement experienced at the entrance to Jisr Diyala EX6 and Al-Sha'ab EX7 is very high due to the high number of personal vehicles and cargo vehicles (trucks) entering Baghdad city through these entrances. These entrances have many problems with traffic movement and need specific planning for improvement [21].

7.2. O-D Matrix Projection for 2030

The statistics show that there has been an extremely sudden and sharp increase of over 20% for government trucks and 40% for non-government trucks in Baghdad between 2015 to 2019 [22], as can be seen in Fig. 7. In 2015, the highest increase was for the number of trucks (approximately 22% for government trucks and 30% for non-government trucks). This is because of the political and economic invigoration between 2015 and 2019 related to openness with other countries and purchasing power in the country.

The truck growth rate uniformly increased at the beginning and then stabilized between 2016 and 2018. Then, it increased again in 2019. The growth rate between 2018 and 2019 was -2.1% for government trucks and 43% for non-governmental trucks. The average growth rate for the two categories is 20% according to the equation 1.

The average growth rate of government trucks = -2.1 %;

The average growth rate of non-government trucks =43%.

$$\text{The average growth rate} = \frac{43+(-2.1)}{2} = 20.45\%. \quad (1)$$

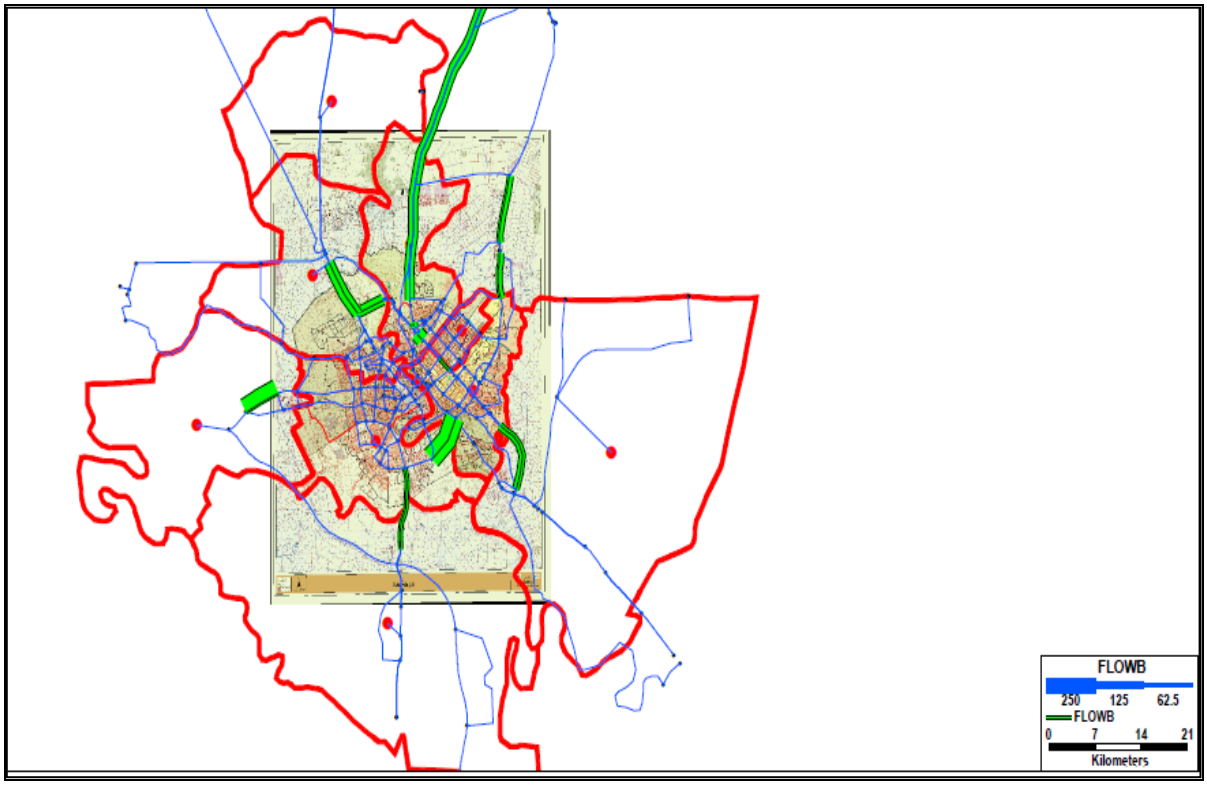
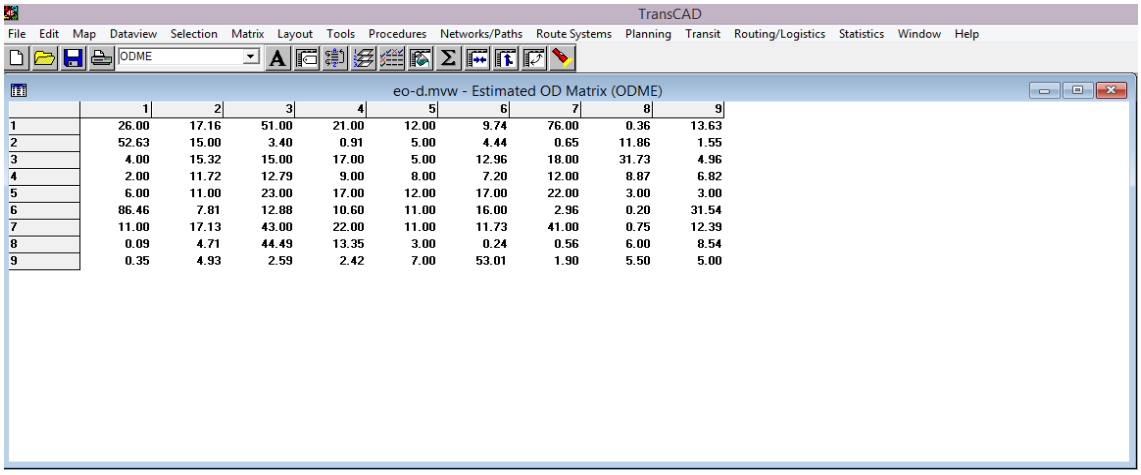


Fig. 5. Current Truck Flow



	1	2	3	4	5	6	7	8	9
1	26.00	17.16	51.00	21.00	12.00	9.74	76.00	0.36	13.63
2	52.63	15.00	3.40	0.91	5.00	4.44	0.65	11.86	1.55
3	4.00	15.32	15.00	17.00	5.00	12.96	18.00	31.73	4.96
4	2.00	11.72	12.79	9.00	8.00	7.20	12.00	8.87	6.82
5	6.00	11.00	23.00	17.00	12.00	17.00	22.00	3.00	3.00
6	86.46	7.81	12.88	10.60	11.00	16.00	2.96	0.20	31.54
7	11.00	17.13	43.00	22.00	11.00	11.73	41.00	0.75	12.39
8	0.09	4.71	44.49	13.35	3.00	0.24	0.56	6.00	8.54
9	0.35	4.93	2.59	2.42	7.00	53.01	1.90	5.50	5.00

Fig. 6. Estimated O-D Current Matrix

The potential projection O-D Matrix was forecasted to depend on the average truck growth rate in the city of Baghdad, which is 20%, according to the review of the available data mentioned previously. Therefore, each existing (2019) O-D cell was multiplied by the 2030 growth factor to obtain the potential O-D matrix. The 2019 data were used for 2020 due to the lack of any statistics for this year due to the outbreak of Covid-19. Thus, the projection matrix was calculated for 10 years and computed for 2030. As shown in equations (1) and (2):

$$\text{O-D projection matrix} = \text{O-D current matrix} * (1 + G \cdot r)^t \quad (2)$$

G.r = Growth Rate of Trucks; t = number of years;
O-D matrix 2030 = O-D matrix 2020 * $(1 + 0.20)^{10}$

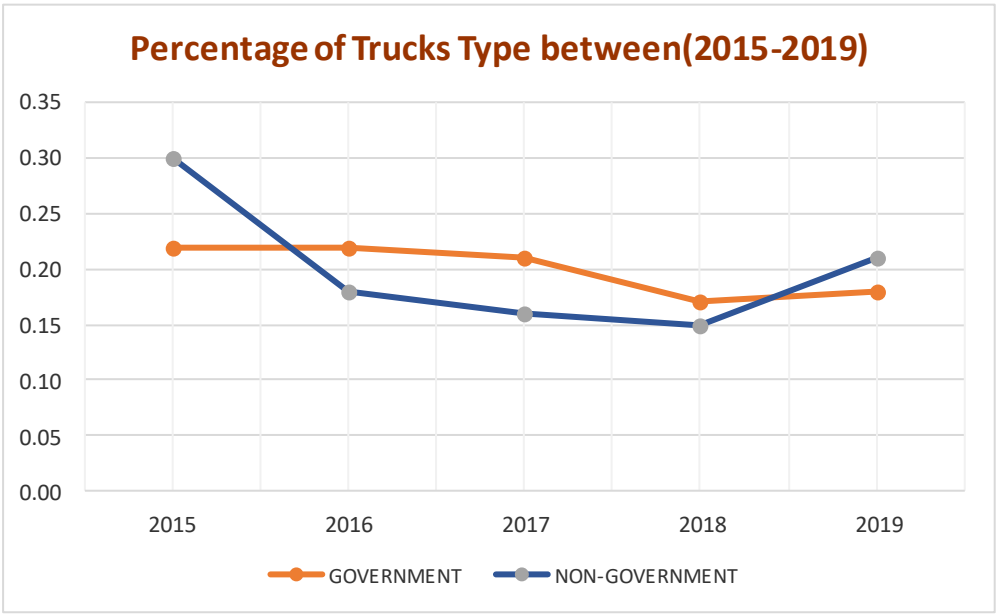
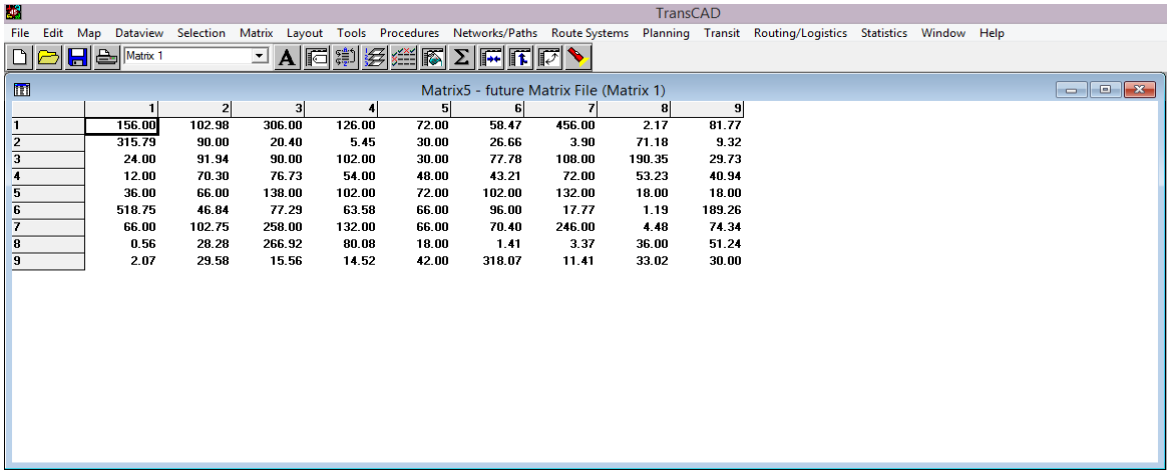


Fig. 7. Percentage of trucks for the years between (2015-2019)

The projection matrix is shown in Fig. 8.



	1	2	3	4	5	6	7	8	9
1	156.00	102.98	306.00	126.00	72.00	58.47	456.00	2.17	81.77
2	315.79	90.00	20.40	5.45	30.00	26.66	3.90	71.18	9.32
3	24.00	91.94	90.00	102.00	30.00	77.78	108.00	190.35	29.73
4	12.00	70.30	76.73	54.00	48.00	43.21	72.00	53.23	40.94
5	36.00	66.00	138.00	102.00	72.00	102.00	132.00	18.00	18.00
6	518.75	46.84	77.29	63.58	66.00	96.00	17.77	1.19	189.26
7	66.00	102.75	258.00	132.00	66.00	70.40	246.00	4.48	74.34
8	0.56	28.28	266.92	80.08	18.00	1.41	3.37	36.00	51.24
9	2.07	29.58	15.56	14.52	42.00	318.07	11.41	33.02	30.00

Fig. 8. Projection Matrix for 2030

By estimating the O-D matrix, an assignment of traffic will be made. TransCAD usually estimates the volume of each link in the highway network. Fig. 9 shows the future assignment flow.

8. CONCLUSIONS

The main significant conclusions of this study are as follows:

1. According to the allocation of trips, the network suffers from inflated traffic at the Al-Sha'ab entrance.
2. Regarding the Jisr Diyala entrance, it suffered from traffic congestion due to the narrow road to enter. Thus, there is a need to raise its efficiency.

3. A high proportion of freight vehicles enter from the Abu Ghraib entrance toward Adhamiya, Kadhimiya, and Karkh.
4. The output of this study represented by O-D freight demand is a key point for planners when selecting alternative proposals to enhance the transportation network in the future.
5. It is recommended to add the fourth ring road to enhance traffic and the movement of trucks entering the city center without the use of major roads to enter the Central Business District CBD, which could reduce congestion.

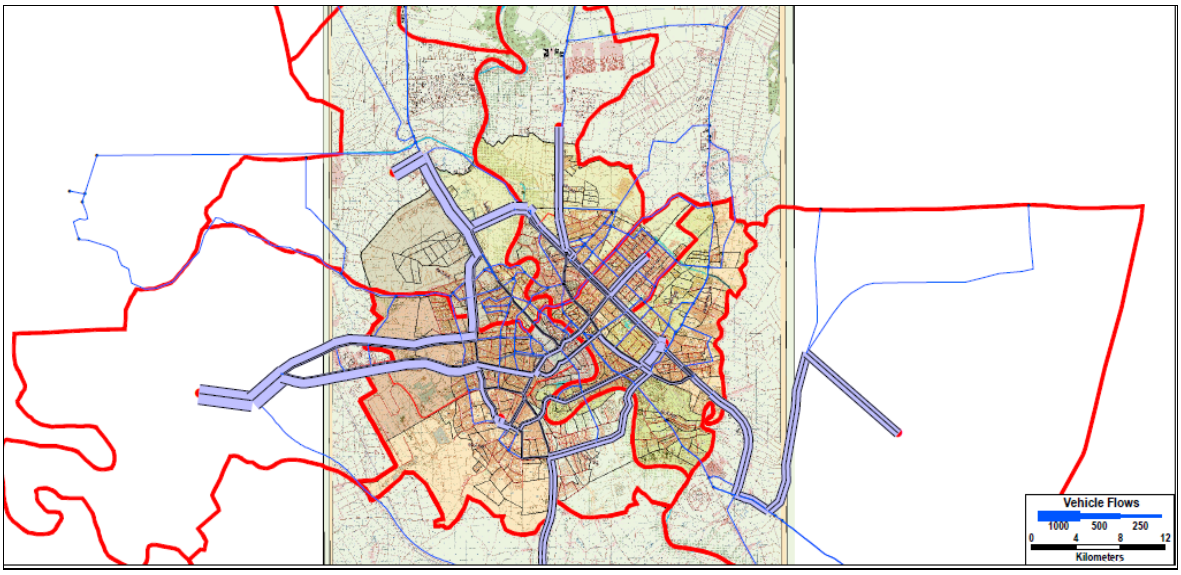


Fig. 9. Truck Assignment for Future O-D Matrix

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