

TransCAD and GIS Technique for Estimating Traffic Demand and Its Application in Gaza City

Essam Almasri, Mohammed Al-Jazzar

Department of Civil Engineering, Islamic University of Gaza, Gaza, Palestine
Email: emasry@iugaza.edu.ps

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ABSTRACT

In the early nineties of the last century, the transportation system in Gaza Strip was born and new infrastructure projects, especially road networks, were constructed. However, the construction lacked efficient application of a transportation planning process. Transportation planning relies on traffic demand forecasting process. The conventional process is impeded by extensive amount of socioeconomic data. One of the most widely-used models which mitigate this problem is the TransCAD Model. This model is rarely used in Gaza Strip for traffic demand forecasting, and most of the practices depend mainly on a constant growth rate of traffic. Therefore, the main objective of this research is to apply this model in Gaza City for traffic estimation. This model estimates the origin-destination matrix based on traffic count. The traffic count was carried out at 36 intersections distributed around Gaza City. The results of traffic flow estimation obtained from TransCAD are assigned to the Gaza maps using the GIS techniques for spatial analysis. It is shown that the most congested area at present is the middle of the city especially at Aljala-Omer Almkhtar intersection. Therefore, improvement scenarios of this area should be carried out. The results of calibration of traffic flow estimation show that the differences between the estimated and the actual flows were less than 10%. In addition, network evaluation results show that the network is expected to be more congested in 2015. This work can be used by transportation planners for testing any network improvement scenarios and for studying their network performance.

Keywords: Transportation Planning; Traffic Demand Forecasting; Origin-Destination Estimation; Gaza; GIS

1. Introduction

Gaza Strip is situated at the southern part of the Palestinian Territories. As shown in **Figure 1**, it includes five governorates namely, Rafah, Khan-Younis, Middle, Gaza and North Governorates [1]. The area of Gaza Strip is about 365 km². It is a narrow coastal strip of land with a length of 40 km along the Mediterranean Sea in the Northwest direction. It has 58 km borders with An-Naqav Desert to the East and South and 12 km with Egypt to the Southwest. It takes its name from its main city Gaza [2]. According to the census conducted by the Palestinian Central Bureau of Statistics (PCBS), the total number of population of Gaza Strip at mid 2011 was 1.59 millions. Gaza is the most densely populated governorate in Gaza Strip with a density of 0.75 inhabitants/hectare. The area of Gaza City is 7259.3 hectares and the number of population at mid 2011 is 552,000 [3].

Gaza Strip transportation system is limited by small

and poorly developed road network. Before 1967, it had a single railway line running from North to South of Gaza Strip along its centre. However, currently it disappears and little trackage remains. There is only a small port which is limited to fishermen. Gaza International Airport was opened in November 1998; however, it was closed in October 2000. After the arrival of the Palestinian National Authority from Diasporas in the early nineties of the last century, the transportation system in Gaza Strip was born and a dramatic and unprecedented increase in the possession of the vehicles was observed. In consequence of that, new infrastructure projects, especially road networks, were constructed. However, the construction lacked efficient application of a transportation planning process. This led to deficiency in adopting the suitable transport policies to mitigate the transportation problems resulting from urbanization and rapid increase of population [4].

Transportation planning relies on travel demand fore-

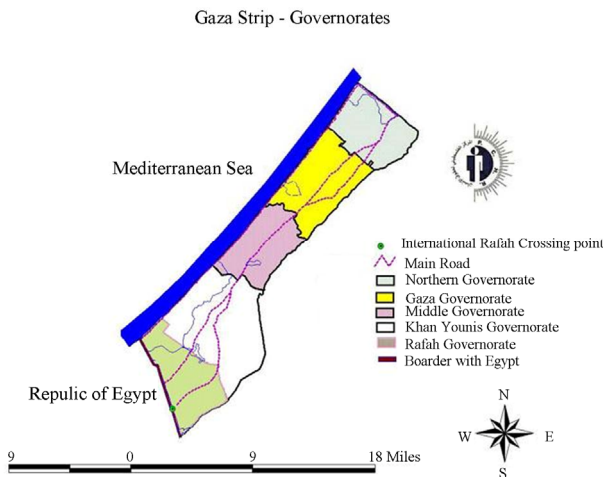


Figure 1. Governorates of Gaza Strip [1].

casting which involves prediction of the number of vehicles or travellers that will use a particular transportation facility in future. Since 1950's, many travel demand forecasting processes were developed, including conventional four-stage travel demand forecasting process. This process begins with collection of extensive data on land use, socioeconomic, demographic, and network characteristics [5]. The four steps of the process are sequenced as trip generation, trip distribution, mode choice, and traffic assignment. Trip generation determines the number of trips starting or ending at an area (zone) within a given time such as per day or per hour. It is based on determining a relationship between trip making and land uses, household demographics, and other socioeconomic factors. Trip distribution is the process by which the planner calculates the pattern of trips between the zones. It describes the number or proportion of trips from an origin zone spread amongst all destination zones. Mode choice computes the patterns of trips between origin and destination zones that use a particular transportation mode. Traffic assignment determines the volume of travel for each individual movement at intersections of the transportation network [6].

From the time when the conventional four-stage travel demand forecasting was developed, a number of highly critical reviews to the model have been seen. In response to criticisms, improvements have been made on the four-stage modeling approach and new modeling approaches have come out [7]. According to [7], few of the developed models have already been tried in cities of developing countries. An example of work is shown in [8] in which different Work-Trip Mode-Choice Models for South Africa were tested. A second example is shown in [9] in which different trip generation models in developing countries were analyzed and calibrated. A third example is shown in [10] in which two types of gravity model for trip distribution in India were calibrated. A

fourth is [11] which is a transport study of Amman, Jordan.

One of the criticisms of the sequential four-step model is the extensive amount of land use, socioeconomic, and demographic data needed for the first step of trip generation. Because of that, many models have been developed which skipped this step and started directly from step 2. They estimate the origin-destination (O-D) matrix based on traffic counts. Traffic counts are much easier to obtain and are often already available for other traffic related purposes. Therefore, many computer models have been proposed and applied for O-D matrix estimation to investigate the relationship between traffic counts and O-D matrix. One of the most widely-used models is the TransCAD Model [12].

This model is rarely used in Gaza Strip for traffic demand forecasting, and most of the practices depend mainly on a constant growth rate of traffic. Therefore, the main objective of this research is to apply the TransCAD model for traffic estimation. The results will be assigned to the Gaza maps using the GIS techniques available in TransCAD for spatial analysis to be used as guidelines for transportation planner to determine the congested locations in Gaza, and hence to help in developing policies for congestion mitigation.

2. Methodology

In order to achieve the objectives of this study the work is divided into six phases. The first phase is data collection. The data includes network road characteristics and traffic data for the base year. The traffic count was carried out in 18/4/2010 by more than one hundred observers under the supervision of the researchers. The count was conducted to from 7:00 am to 12:00 am to determine the exact network peak hour. It was done at 36 intersections distributed around Gaza City as shown in Figure 2.

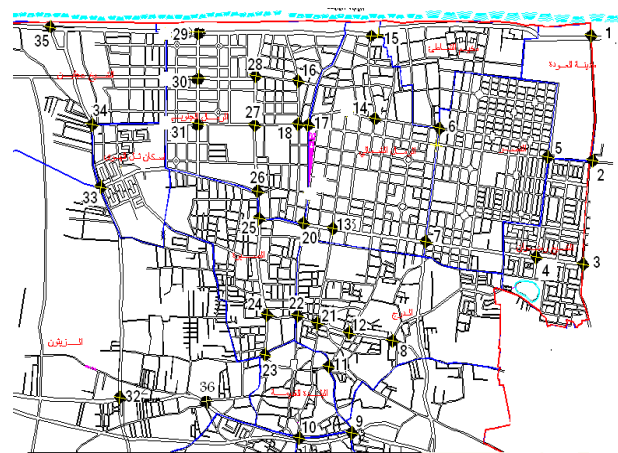


Figure 2. Locations of traffic counts in Gaza City.

The second phase is network building and data entering. An aerial photo of Gaza was geo-referenced and digitized using ArcGIS. The resulted ESRI shape file was transferred into TransCAD and used as a background to draw the network and the zones. Zoning system for Gaza City was very essential for the O-D matrix estimation and traffic assignment. For that purpose, the land use characteristics of the City was studied.

The third phase is matrix estimation for the base year. It is done using TransCAD Model which is based on Nielsen's Model [13], who independently developed it as a procedure for TransCAD 2.1. The model has the advantages of handling counts as stochastic variables, as well as working with any traffic assignment method. Thus, it is appealing for use with the Stochastic User Equilibrium Assignment method, as well as with User Equilibrium Assignment. Nielsen's model is an iterative (or bi-level) process that switches back and forth between a traffic assignment stage and a matrix estimation stage [14]. To use the O-D Matrix Estimation procedure, the base O-D matrix and a geographic file of both area and line layers are prepared. In line geographic file, each link data should be input, and a network for the line layer should be created. It should include all the relevant attributes. In area geographic file, connectors of zones' centroids must be created to connect line and area geographic layer. Because there is no available prior O-D matrix, a unit matrix (each O-D pair has a value of 1) was used as initial matrix. Based on traffic counts at the intersections, the O-D matrix was estimated and validated. A base O-D matrix serves two purposes. The first purpose is to set the dimensions for the output matrix. The second purpose is to provide initial values for the estimated O-D matrix.

The fourth phase is model calibration to ensure good representation of the traffic network. The aim is to estimate O-D matrix that should be as real as possible. Model calibration was conducted by adjusting locations of zones' connectors, locations of zones' centroids and turn penalties. The observed traffic flow and the modeled traffic flow at the intersections using the traffic assignment should be close to each other. Traffic flow difference of 10% could be acceptable.

The fifth phase is future O-D matrix estimation. For that purpose, it is recommended to use uniform growth factor method by multiplying all O-D pairs by the same amount as shown in Equation (1) [6]:

$$T_{ijf} = T_{ijp} \times M_{pf} \quad (1)$$

where, T_{ijf} is trips for O-D pair ij in future year f ; T_{ijp} is trips for O-D pair ij in present year p ; and M_{pf} is expected growth in trips between year f and p .

When information about the expected growth in trips produced in each zone is available, the singly constrained

growth factor method might be used ([6,15]). This is performed by multiplying different growth factors to different rows (or columns) in the O-D matrix. According to [6,16], the growth factors might be determined based on land use or socioeconomic data. Because of little amount of socioeconomic and land use data, forecasting in this research is simply based on uniform growth factor method. The estimates of rate of growth in vehicle ownership over the forecasting period are used to develop the end product of passenger traffic trip matrix. They are directly input to the modelling process as a value by which existing base year vehicle trip matrices are factored to develop future year trip matrices.

The sixth phase is network evaluation. TransCAD model offers three network performance measures. The first one is vehicles hours of travel which is the summation of travel time spent by all vehicles in the network. The second one is the total vehicle kilometers travelled which is the summation of the total distance travelled by all the vehicles over the network in one hour. These two measures can be used in different scenario evaluation and comparison, where the best scenario should have the lowest values. The third performance measure is volume over capacity ratio which is a direct indication of the network level of service.

3. Results and Analysis

This section presents the results obtained when applying the methodology discussed in the previous section. It includes five parts. The first one presents geometric and traffic data. The second part concerns the network building. The third part discusses the obtained results of base year O-D matrix estimation and model calibration, while the fourth part discusses the results of future O-D matrix estimation. The last part presents the results of network evaluation.

3.1. Data

The geometric data collection focused on the main streets and intersections which were involved in the traffic count. **Figure 2** presents the intersections' names and locations.

Geometric data for some of the intersections are presented in **Table 1** which are the intersections located along Aljala Street. The first column is intersection serial number. The second column shows the names of the intersections while the third shows the names of the streets intersecting Aljala Street. The next columns present the number of lanes in each approach before arriving at each intersection. It is noted that the lanes before arriving intersections is less than at intersections because of either widening of the intersections or using nearside lane for parking between intersections. **Table 2** presents the carriageway widths of the streets.

Table 1. Geometric data for intersections located along Aljala Street.

No.	Intersection		Number of lanes							
	Name	Aljala St. with...	Before intersection				At intersection			
			NB	SB	EB	WB	NB	SB	EB	WB
25	El-Tiaran	Jamal Abed Alnaser	-	2	2	2	-	3	3	2
20	El-Saraya	Omer Almokhtar st	2	2	2	2	3	3	3	3
13	Dabeet	Alwehda	2	2	2	2	3	3	2	2
7	El-Ghifary	Alababidy	2	2	2	2	3	3	3	3
4	1st st.	1st st.	2	2	2	2	3	3	3	3
3	Akher Aljala	3rd st.	2	2	2	2	2	2	2	2

Table 2. Carriageway widths of streets intersecting Aljala Street.

No.	Streets names	Carriageway width (m)
1	Aljala Street	10
2	Jamal Abed Alnaser Street	8
3	Omer Almokhtar Street	10
4	Alwehda Street	6
5	Alababidy Street	9.5
6	The 1st Street	9
7	The 3rd Street	7

The traffic count at the 36 intersections was carried out manually and simultaneously by 132 observers. At each approach in each intersection, an observer stood and counted vehicles that left the intersection and went left, through or right. **Figure 3** presents locations of the counted intersections. The flows at the intersections are shown in **Figure 3** on GIS spatial map where the diameter of the circle represents the summation of traffic flow for all approaches at the intersection. Based on this representation, it can be easily seen that the most congested area is the middle of the city and that the intersections and the streets in this area should be taken into consideration.

Figure 4 presents graphically the values of total five-hour traffic flow and the peak hour flow at the intersections. It is observed that Aljala-Omer Almokhtar intersection (Alsaraia) has the highest traffic flow. On the other side, Alrashed-the third intersection (Almokhabarat) has the lowest traffic flow. Network peak hour flow is essential input in TransCAD to model the Gaza traffic network. Based on the traffic count conducted to from 7:00 am to 12:00 am, the network peak hour was between 7:30 and 8:30 am.

3.2. Network Building

Network building in TransCAD is done by constructing line geographic and area geographic layers. In line geographic layer, roads are represented by their centerlines. For that purpose, an aerial photo of Gaza City was geo-referenced and then the roads were digitized out of the map by ArcGIS as shown in **Figure 5**. The process of representing an image by a discrete set of its points is known as the digitization process. The resulted ESRI shape file was transferred into TransCAD. The geo-referenced ESRI shape file was then used as a background to draw the network.

A zone area geographic layer is needed to complete the traffic network modeling. Thirty four zones were built in this layer. The resulting layer of zones and streets is shown in **Figure 6**.

The selection of zonal boundaries was based on the following criteria that were adopted in previous studies such as [11,17]:

- The area of Central Business District (CBD) should have relatively small zone sizes while larger zone sizes are used for outside CBD. This is due to the dense trip activities within CBD.
- The use of main roads as zone boundaries should be avoided to facilitate the trip assigning for the zones on or near the main roads.
- Each zone should have homogenous socio-economic characteristics.
- The zoning process should take the Municipality district's boundaries into consideration.

3.3. Base Year Matrix Estimation and Model Calibration

Based on the process of matrix estimation discussed in the methodology section, the estimated O-D matrix for base year 2010 is shown in **Table 3**. The number of columns and rows is the number of zones. The zones in

Table 3. Estimated O-D matrix for base year in the peak hour (7:30-8:30).

		To																																			
From	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	20	21	22	23	24	26	27	28	29	30	31	32	33	34	35	36	*37			
1	0	63	44	15	112	0	9	2	2	2	2	1	2	1	2	10	80	11	11	155	4	1	12	51	79	6	7	1	7	1	15	24	39	6			
2	48	0	5	8	2	11	1	7	36	3	2	8	5	6	10	11	35	9	9	244	5	2	5	5	214	9	5	5	5	5	34	23	2	17			
3	25	7	0	14	108	1	7	1	1	2	1	2	2	1	2	5	41	7	7	11	5	1	9	6	9	7	8	1	8	1	13	23	6	7			
4	22	11	13	0	1	5	1	2	0	1	0	105	3	100	111	25	15	33	33	8	2	1	30	4	5	3	2	2	2	2	5	12	2	3			
5	30	2	43	8	0	2	0	0	2	3	2	3	3	3	4	9	45	2	2	4	6	2	1	1	1	2	2	1	2	1	5	4	1	3			
6	26	3	32	12	84	0	7	4	3	4	3	2	4	1	3	9	56	4	4	2	20	1	5	2	2	27	22	1	22	1	12	22	3	22			
7	13	1	10	6	0	2	0	0	1	2	2	3	3	2	3	4	15	2	2	3	5	1	1	1	1	1	2	1	2	1	3	3	1	2			
8	7	2	1	11	0	1	0	0	2	4	3	4	4	3	4	4	3	4	4	7	2	2	1	1	1	2	3	3	3	3	10	6	2	3			
9	6	97	2	1	1	1	1	4	0	49	23	5	3	3	7	5	3	112	105	32	2	1	110	22	22	4	2	2	2	2	63	165	533	5			
10	8	2	6	0	1	3	1	1	0	0	511	7	2	8	8	8	5	7	7	2	1	1	6	1	2	1	1	1	1	1	2	1	1				
11	7	1	2	0	2	2	1	6	275	116	0	4	1	6	6	6	4	6	6	2	1	1	5	1	1	1	1	1	1	1	70	1	0	1			
12	1	10	1	24	4	6	3	10	53	4	3	0	12	85	149	1	1	7	7	4	4	3	18	11	13	5	5	53	5	53	47	82	70	7			
13	1	10	0	23	0	81	0	5	7	8	6	24	0	15	31	0	0	10	10	6	5	299	5	5	5	8	9	24	9	24	9	8	5	8			
15	1	8	0	33	1	5	1	9	21	6	4	192	8	0	162	1	0	6	6	3	3	1	9	9	10	3	3	36	3	36	25	13	9	4			
16	1	12	1	30	5	7	3	12	60	6	4	120	16	100	0	1	1	9	9	5	5	6	20	13	15	7	7	69	7	69	52	85	75	10			
17	2	12	0	20	1	0	1	0	1	1	1	10	2	8	11	0	72	488	1	3	3	1	2	13	13	4	5	1	5	1	42	48	11	13			
18	93	57	1	11	3	0	1	0	1	1	1	1	1	1	0	1	2	0	4	4	424	1	0	6	40	82	2	3	0	3	0	8	19	28	3		
20	11	1	4	6	1	12	0	2	1	4	2	4	4	3	5	304	1	0	1	84	97	2	28	0	0	1	3	3	3	3	205	8	1	3			
21	11	8	4	19	1	12	0	2	1	7	5	8	13	6	9	22	1	1	0	84	97	7	28	5	24	33	24	24	24	205	80	6	10				
22	32	9	10	8	2	6	1	5	25	4	3	8	10	6	10	41	13	191	191	0	141	4	5	5	5	22	18	18	18	18	22	15	5	12			
23	1	23	0	3	0	28	0	5	11	17	12	8	12	5	11	0	0	26	26	7	0	4	5	5	6	154	30	30	30	30	15	11	5	31			
24	1	30	0	14	1	15	0	8	19	5	4	7	161	2	12	0	0	35	35	19	67	0	11	11	14	84	40	1	40	1	19	16	10	45			
26	15	6	6	18	1	19	1	11	1	6	5	7	9	6	8	25	3	81	81	72	5	4	0	3	5	10	11	11	11	11	205	106	4	9			
27	37	12	6	18	1	9	1	11	1	6	5	9	13	7	11	25	22	81	81	57	10	6	1	0	21	50	27	27	27	205	106	9	14				
28	41	19	6	9	1	8	1	8	33	4	3	9	12	6	11	16	25	17	17	300	7	4	5	5	0	137	30	30	30	30	30	22	6	16			
29	1	16	0	2	0	12	0	12	5	12	7	6	8	3	8	0	0	11	11	3	1	2	26	26	313	0	15	15	15	15	39	32	16	9			
30	1	44	0	5	1	12	1	15	24	29	23	32	6	22	39	0	0	14	14	6	7	0	28	28	58	32	0	1	1	1	37	32	21	188			
31	1	11	0	24	0	5	0	5	7	6	4	26	6	5	43	0	0	11	11	5	4	0	5	5	5	8	3	0	3	1	10	8	5	8			
32	1	11	0	24	0	5	0	5	7	6	4	26	6	5	43	0	0	11	11	5	4	0	5	5	5	8	3	1	0	1	10	8	5	8			
33	1	11	0	24	0	5	0	5	7	6	4	26	6	5	43	0	0	11	11	5	4	0	5	5	5	8	3	1	3	0	10	8	5	8			
34	31	111	4	35	3	2	2	19	46	44	38	17	12	15	20	259	20	194	194	4	17	8	3	2	2	26	16	16	16	16	0	217	187	43			
35	30	82	16	5	12	44	5	69	52	2	1	13	9	11	15	42	20	98	98	36	12	5	103	29	27	19	11	11	11	11	79	0	170	31			
36	26	30	6	11	2	9	1	10	66	4	3	9	6	7	11	15	16	16	16	20	7	3	9	9	12	11	6	6	6	6	88	112	0	19			
37	1	20	0	2	0	8	0	14	4	13	7	5	3	3	8	0	0	8	8	3	1	0	21	21	32	2	1	1	1	1	17	26	17	0			

*Note that: zones 14, 19 and 25 do not exist and the total number of zones is 34.

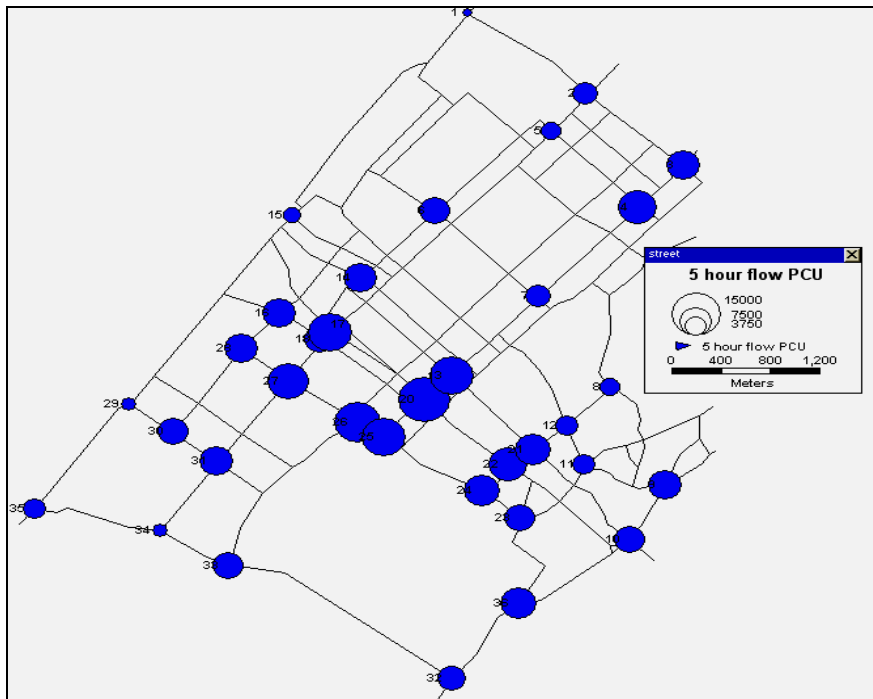


Figure 3. Intersection locations and flows.

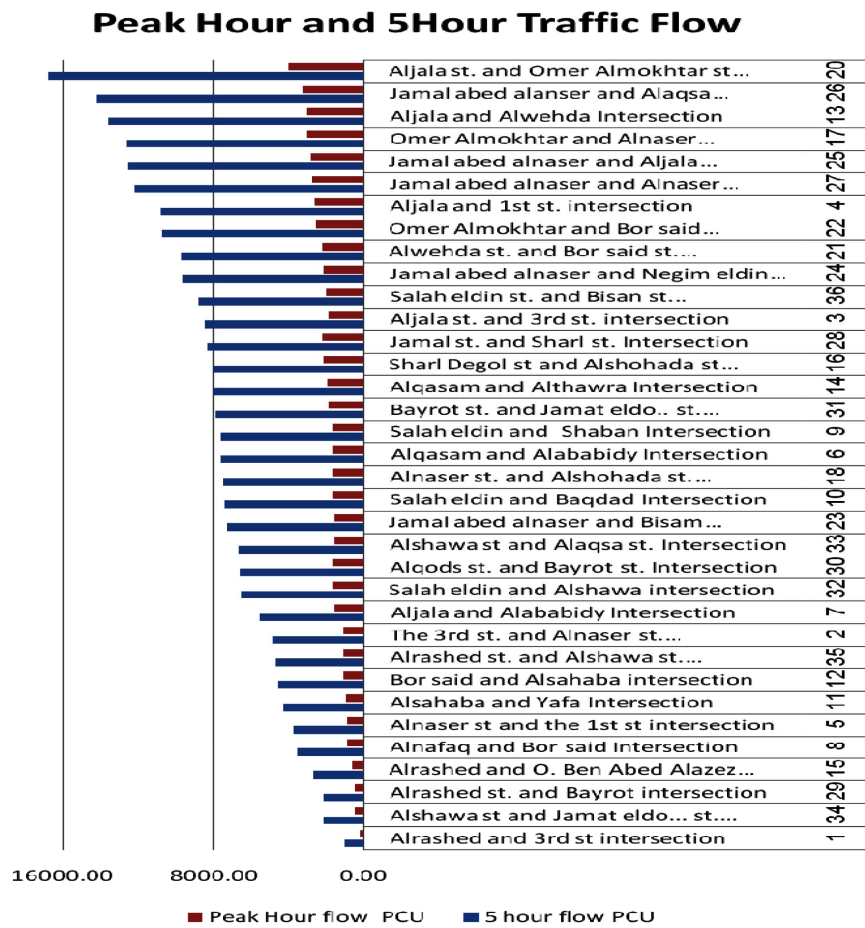


Figure 4. Peak hour (7:30-8:30) flow and 5 hour (7:00-12:00) traffic flow for the counted intersections.



Figure 5. Street layer digitizing by ArcGIS.

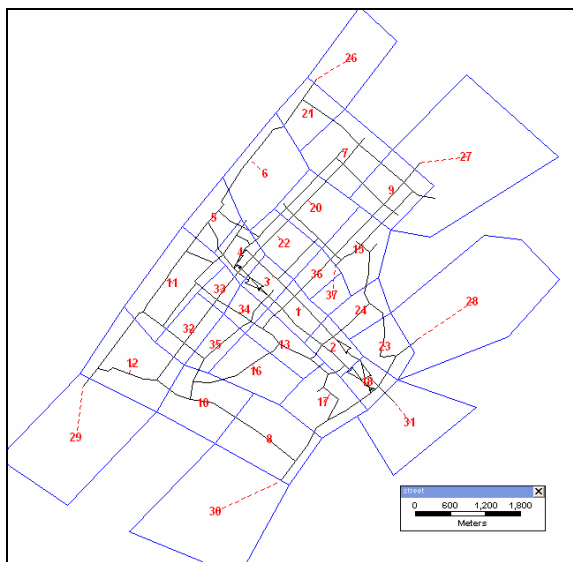


Figure 6. Layers of streets and zones.

the first column are the origins and the zones in the first row are the destinations.

The model should be calibrated to ensure good representation of the traffic network. Calibration is the process of adjusting network items to bring the modeled traffic flow and the actual traffic flow to match each other as much as possible. Many trials were done to reach the best results. The flow differences for one direction and an opposite direction were 9.15% and 7.51% respectively; which is acceptable as it is less than 10%. **Figure 7** shows the modeled traffic flow for the base year in each link in GIS spatial map where the traffic flow is represented by line width.

3.4. Future O-D Matrix Estimation

In using the uniform growth factor method for future

O-D matrix estimation, it was assumed that the number of vehicle trips made is a function of the number of vehicles available. **Figure 8** summarizes the available statistics of the number of registered vehicles in Gaza Strip. The statistics show that there was a very sharp and sudden increase of more than 20% in the number of registered vehicles between 1993 and 1994. In 1995, the increase in the number of registered vehicles was the greatest, where it was about 35%. This dramatic increase in the number of registered vehicles is due to the economical and political invigoration during the period from 1993 to 1995, associated with the start of the Palestinian Authority.

It is noticed that the increase in the number of registered vehicles slowed down substantially after 1995 returning to a rate of change similar to that before 1987. The growth rate of the number of motor vehicles is increased uniformly at the beginning and highly fluctuated between the years 1985 to 1995. Then, it seems to be steady at the last six years between 1999 and 2004.

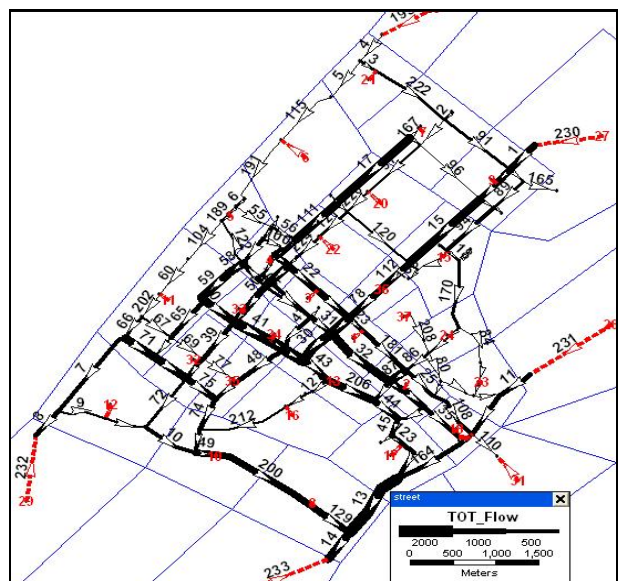


Figure 7. Modeled traffic flow for links in Gaza City network for base year in the peak hour (7:30-8:30).

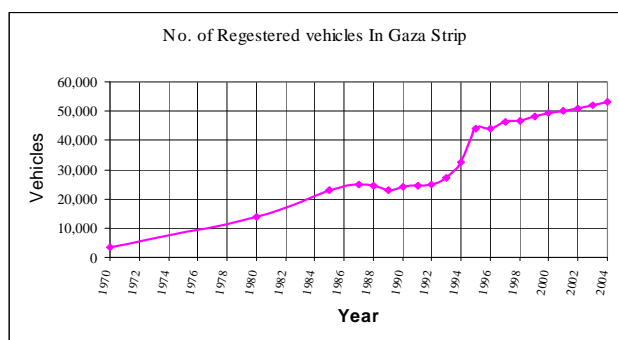


Figure 8. Number of registered vehicles in Gaza Strip [3].

Therefore, this region is used for calculating the growth rate. The average yearly growth rate in this period is equal to 2.2%. The future O-D matrix is obtained by multiplying each base year (2010) O-D matrix cell by the growth rate for the year 2015 using Equation (1).

Where:

$$M_{pf} = (1 + 0.022)^5 = (1.12)$$

Network traffic assignment was done based on future O-D matrix for the year 2015 to estimate the future traffic flow of this year. **Figure 9** shows modeled future traffic flow in each link in GIS spatial map where the flow is represented by line width.

3.5. Network Evaluation

The results of total vehicle hours and the total vehicle kilometers traveled for both base year and the year 2015 is summarized in **Table 4**. The results show an increase in the network performance measures of about 10% when doing nothing in the network. Thus, the network is becoming more congested. The results of the third network performance measures (volume/capacity ratio) are presented in **Table 5**. The same finding of more congested network could be obtained, as higher percentage of links that have high volume/capacity ratio of the year 2015 is seen. Therefore, network improvement scenarios should be carried out.

4. Conclusions and Recommendations

Based on the findings of this research, it is observed that the peak hour is from 7:30 to 8:30; thus, this hour is used

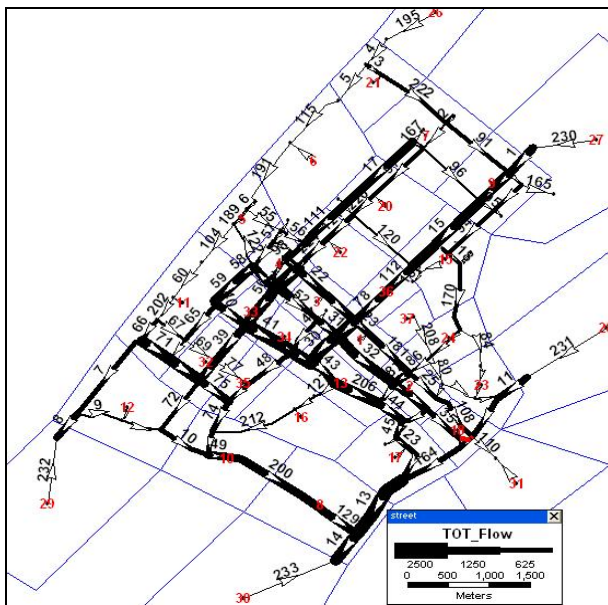


Figure 9. Modeled traffic flow for links in Gaza City network for year 2015 in the peak hour (7:30-8:30).

Table 4. Total vehicle hours and the total vehicle kilometers for base year and 2015.

	Base year	2015	% Increase
Total vehicle hours (hours)	76,899	85,659	10.2
Total vehicles kilometers (km)	49,488,073	54,993,616	10.0

Table 5. Volume over capacity ranges for base year and 2015.

Volume over capacity ranges	AB-Direction Percentage of links (%)		BA-Direction Percentage of links (%)	
	Base year	2015	Base year	2015
0 to 0.2	45	44	47	42
0.2 to 0.4	30	27	24	31
0.4 to 0.6	19	21	27	21
0.6 to 0.8	5	5	1	5
0.8 to 1	2	2	0	0
>1	0	0	0	0
Total	100	100	100	100

for analysis in this study. The results of data analysis and GIS spatial maps show that the most congested area is the middle of the city and the most congested intersection is Aljala-Omer Almkhtar intersection. Therefore, improvement scenarios of this area and for these intersections should be carried out for the responsible authorities. The calibration of network building and traffic flow estimation based on TransCAD show good results of estimation. The flow differences for one direction and an opposite direction are 9.15% and 7.51% respectively; which are acceptable as they are less than 10%. The results of network evaluation show that the network is becoming more congested in 2015. In total, the outcomes of this work can be used by transportation planners for testing any network improvement scenarios and studying their network performance.

Several recommendations have emerged from this research. First, this work is recommended to be carried out for daily evening peak hour and for daily traffic. Second it is recommended to apply the suggested process to other governorates in Gaza Strip in addition to the inter-city Trips. Third, the O-D matrix and the traffic assignment should be updated every few years based on new traffic count.

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