



A GIS- ASSISTED PREDICTION TRAVEL DEMAND ON METRO NETWORK (BAGHDAD CASE STUDY)

Dr. Namir Ahmed Alkawaaz¹, *Dr. Noor Moutaz Asmael²

- 1) Assist Prof., Highway and Transportation Department, Mustansiriyah University, Baghdad, Iraq
- 2) Lecturer, Highway and Transportation Department, Mustansiriyah University, Baghdad, Iraq

Abstract: Baghdad Governorate is the most populated area in Iraq. It is experiencing rapid urbanization, economic growth, and motorization. The rapid increase in use private cars produced an increase in the traffic congestion, accidents, inadequate parking space and air pollution. Accordingly, it is important to investigate the need for a new transport policies and transportation projects based on Travel demand modeling. The present research methodology is based on update O-D matrix for Baghdad city and using it in travel forecasting to evaluate proposed urban mass rail services. In this study, three metro alternative routes were suggested, and according to demand estimation results, the best route will selected to meet future travel demand. It is concluded, peak hour ridership on proposed metro routes in the year 2014 is found to be 30000 passengers per hour per direction and the peak hour ridership on metro routes in the year 2035 reached 50000 passengers per hour per direction. On the other hand, it is concluded that travel demand on alternative route 1 equal 200000 and 400000 trips per day in two directions, while, load on alternative route 2 equal 360000 and 720000 trips per day in 2014 and 2035 respectively. It is concluded that, route alternative 2 and 1 recommended to be adopted to meet the travel demand requirements for the year 2035. The results of this study will provide the guide to the local transportation agencies to select the right decision, maximize their revenue and better allocate their resources.

Keywords: *Travel Demand, Metro Network, O-D Matrix, GIS, Transportation Planning, Transit Network.*

التنبؤ بالطلب على الرحلة لشبكة المترو مسندا بنظم المعلومات الجغرافية

الخلاصة: تعتبر محافظة بغداد هي المنطقة الأكثر اكتظاظا بالسكان في العراق. و تشهد هذه المنطقة، توسع حضري سريع، ونمو اقتصادي، وازدياد بعدد الرحلات. وأدت الزيادة السريعة في استخدام السيارات الخاصة إلى زيادة في الازدحام المروري والحوادث وعدم كفاية أماكن وقوف السيارات وتلوث الهواء. وبناء على ذلك، من المهم التحقيق في الحاجة إلى سياسات نقل جديدة اعتمادا على أساس نمذجة الطلب على الرحلة. منهجية البحث الحالية تستند إلى تحديث مصفوفة O-D لمدينة بغداد واستخدامها في التنبؤ بالطلب لتقييم خدمات النقل الجماعي المقترحة. في هذه الدراسة، تم اقتراح ثلاثة مسارات بديلة للمترو، ووفقا لنتائج تقدير الطلب، سيتم اختيار أفضل مسار لتلبية الطلب على الرحلة في المستقبل. وقد تم التوصل إلى أن ذروة ساعات الطلب على مسارات المترو المقترحة في عام 2014 هي 30000 راكب في الساعة، وبلغت ذروة ساعات الطلب على مسارات المترو في عام 2035 هي 50000 راكب في الساعة. من ناحية أخرى، تم الاستنتاج بأن الطلب على الرحلة على المسار البديل رقم 1 يساوي 200000 و 400000 رحلة يوميا في اتجاهين، في حين أن الطلب على المسار البديل رقم 2 يساوي 360000 و 720000 رحلة يوميا في عام 2014 و 2035 على التوالي. وتمت التوصية باعتماد المسار رقم 2 و رقم 1 لتلبية بمتطلبات الطلب على الرحلة للعام 2035. تزود نتائج هذه الدراسة الشركات المتخصصة بالنقل لاختيار القرار الصحيح والاستخدام الأمثل لايرادات والموارد بشكل أفضل.

* noor_moutaz@uomustansiriyah.edu.iq

1. Introduction

Baghdad Governorate is the most populated area in Iraq, which grows rapidly since the late seventies and the annual growth has reached a double rate. There has been a lack inefficient application of a transportation planning process since the end of the eighties. In the year 2030, it expected that about a 6 million increase of the Baghdad population [1]. The result is massive increases in demand for transportation services that are currently suffering from severe bad conditions. The deficiency in application of efficient transportation planning process in developing countries like Iraq, will lead to bad transport policies to overcome the transportation problems.

After the year 2003, more than half million cars registered which lead to a high value of the car ownership rate in Baghdad city, which estimated as average to be 1.68 car per household [2], this produced an increasing in private share which leading the congestion gets worse, bus trip times increases, and adverse impacts to comfort of passengers. For this reason and to assist the local related agencies and to figure out this problem, Urban rail mass transit like Metro is proposed as a case study in the form of attractive and effective strategy to reduce traffic congestion in cities with high levels of demand and congestions.

2. Background

The last efficient application of the transportation planning process for the Baghdad city occurred at the end of the seventies and eighties by Swiss Consultant – De Consul [3] and Scott Wilson and Partners [4]. The Mass transit system was proposed in these transportation planning studies besides the bus transit system to overcome the predicted higher demand requirement in response to rapid urban expansion and travel demand growth that would occur in 2000 [4]. In spite of these studies, metro project until now was not constructed and the forecasted travel data of these studies were out of date. Accordingly, it is important to update metro travel demand up to the year 2035 based on expected population and mobility changes.

Urban transportation planning is the process, which leads to decisions on transportation policies for long range planning. Ridership potential is a critical element in the feasibility stage of a transit travel modeling. Travel demand forecasting is used to predict the travelers and vehicles that will use a new corridor facility in the future based on the traditional approach which depends on the ‘four step model’ [5].

Verma and Dhingra [6], developed a model for identifying demand- urban rail transit corridor using GIS tools. The new proposed model consists of four stages: generation of base year O-D person trips matrices, base year travel demand modeling, forecasting of O-D person trips matrices, and the rail transit corridor identification. They try to select the new rail transit, which optimizes both the users and operator's point of view. Bernardin et al. [7], presented four step model development procedures used to develop the Genesee County Travel Demand Model. The model utilizes a GIS-based travel demand modeling software, Trans CAD. A household survey together with the 2007 transit on-board survey was analyzed to derive key modeling components such as trip

generation rates, trip length frequency distributions, mode shares, time-of-day distributions and vehicle occupancy rates.

Aldian, A. [8], attempted to improve the application of the aggregate model (four step models) by using fuzzy multiple attribute decision-making. The fuzzy multiple attribute decision-making method is applied to combine the variables affecting travel decision at each step to several single variables. The application of this approach improves the statistical significance of the traditional model.

Al-Mutasher [9], presented travel potential along the proposed alignment of Baghdad metro tube using data collection with aid of GPS at the major public transportation terminals, and suggested the possibility of optimizing the location based on the trip data collected. The study investigated a range of possible public transport corridors. Hammadi [10], proposed a new efficient approach for Transportation Network Design. Analytic Hierarchy Process (AHP) is subjected to select network elements based on their associated attributes and are used to rank alternatives. Routing is propagated using a tree branch, and then the whole transportation network is constructed. The Baghdad metro case study is presented.

Wu, Z., et al. [11], proposed a method that formulates the relationship between transit ridership and zonal population, employment, transit service level, and so on. In addition, the difference between transit counts and estimates for base year are considered in the development of the transit O-D for future year. It is expected to perform better than conventional models in terms of transit network evolutions. Mo, B. [12], estimated the ridership attracted and produced to each station using origin-destination travel patterns of residential and employment area. In his study, Service Area Zones (SAZ) were mapped to refer to the areas where the potential travelers should serve within a ten-minute walking interval by the existing stations.

Hamad, K., and Faghri, A. [13], present a new approach for implementing transportation planning studies in developing countries. The new model starts by calculating (O-D) trip table based on traffic counts. After that, a modified origin-destination trip table is estimated from a simple new procedure before the application of the traffic assignment. Gutiérrez et al. [14], developed a ridership forecast model, based on the use of (GIS), distance decay functions and multiple statistical regression models. Boarding at each station is estimated based on stations-related characteristics. Weighting the variables using distance-decay functions gives good results.

Basaria et al. [15], developed TBEST a custom modeling software for short term transit planning and developed using the ArcGIS software platform. The modeling tool uses population and employment projections for the area of transit service to estimate station level ridership for new transit routes.

Many cities around the world have its significant transportation system in which the metro is an active part. The following examples give an idea about the level of ridership around the world of urban rail system [16]:

- The most crowded section in the world can probably found on Hong Kong metro, where it stands at around 80,000 pphpd .
- Very crowded metro sections can also be found on Cairo metro lines, on Sao Paulo Line 1, on Paris RER Line A (around 60,000 pphpd for each).

- Mekah new metro line also reaches traffic of 80,000 pphpd, during the very specific period of the Hajj .
- The most crowded section in Tehran Metro does not exceed 45,000 pphpd (Line 7).

3. Methodology

The research methodology of this study is based on Origin- Destination matrix in 2014 that was developed by Asmael [2]. An Oigin –Destination matrix in 2014 is considered the base for current planning and was applied to predict travel demand on the metro network in future year conditions in 2035. The current approach will use the original O-D matrix with an update to the planning variables to obtain an O-D matrix for 2035. These updates and projection of the demographic and socioeconomic data can be the basis of an update of the metro traffic forecasts.

4. Identification Metro Route Alternatives

Dual metro lines proposed by Scott Wilson Kirkpatrick & Partners in 1986 are considered the base case in this study and was shown in Figure (1). Developing Metro route alternatives selected based on the routes proposed by Scott Wilson Kirkpatrick & Partners. These routes modified and extended to new areas where high residential population located to enhance travel demand.

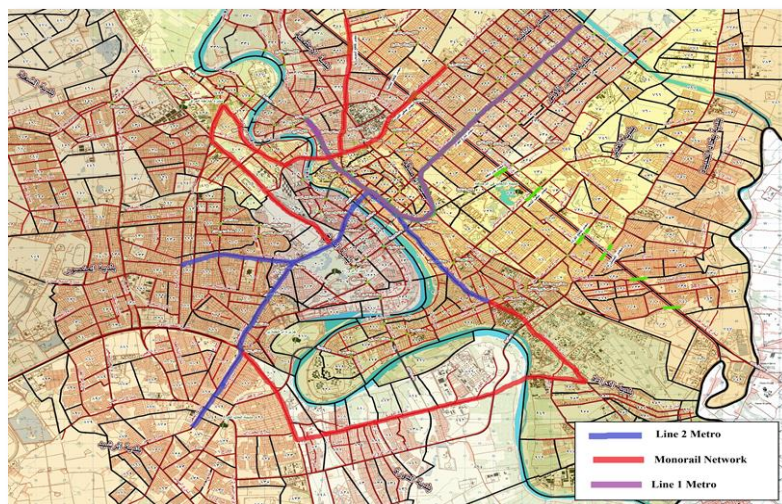


Fig.-1 Dual Metro Lines proposed by Scott Wilson Kirkpatrick & Partners in 1986.

Identification of metro route corridors and the destinations that will serve is based on several criteria as follows.

- Proposed alternatives should avoid tunnel and bridges.
- Proposed alternatives should pass through the main road.
- Proposed alternatives should serve high residential density and pass through a commercial area.

Based on these criteria, the following route alternatives are proposed:

4.1. Route Alternative 1

Route Alternative 1 include (Line 1 metro) as the base case with a length of about 23 km has 25 stations (including the extension to new Sadr City) and crosses Baghdad City from North East to North West through the Central Business District area (CBD). It starts from the New Sadr City, where the main depot is located and goes through Al Thawra street and continues to arrive at Al Maghrib Square before ending at the Antar Square in Al Adhamiya.

4.2. Route Alternative 2

Route alternative 2 includes (Line 2 metro, which suggested by Scott Wilson Kirkpatrick & Partners in 1986) and it is modified to extend to the new Baghdad area, which starts at Al-Hurah square and continues straight to Aqba Bin Nafi Square until reaching Garage al Amina square. Then it turns to reach new Baghdad through Cinema al Badhaa square and continues straight to the Al Mashtal area. The extension ends close to Al Mashtal Bridge. Route Alternative 2 is shown in Figure 2 - (a).

4.3. Route Alternative 3

This route alternative includes (Line 2 metro) and extension to Shulah area. It starts at the end of Al Mansour Branch of (Line 2 metro) and turns to reach Al Gazila Main Street, continues in a straight line and ends in Al-Hamazia mosque intersection. It is proposed to serve Shulah area, which represents a high demand area. Figure 2-(b) shows route alternative 3.

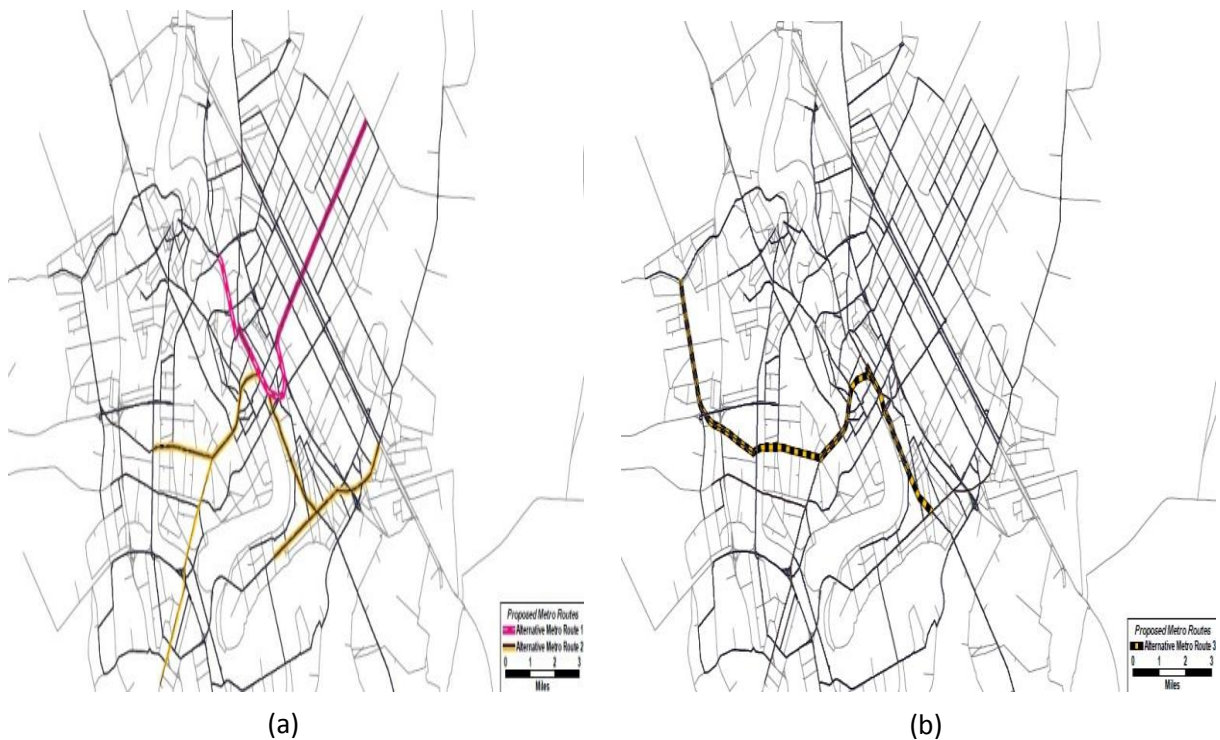


Fig.2- Proposed Metro Routes. a) Route Alternative 1 and 2, b) Route Alternative 3

5. Data Collection

Two main data source collected. Firstly, population data of 1997 year gathered from the central organization for statistics and technology information. Population Census of 1997 was the last real census occurred in Iraq; it represented relatively accurate information about the current socioeconomic context of Baghdad. Secondly, the total number of bus route services operated along the study area gathered from the General Company for Private Transport (GCPT), which is the main company that operates the buses within Baghdad city. Location of various public routes in Baghdad city collected using GPS and mapped using ArcGIS.

6. Traffic Analysis Zone

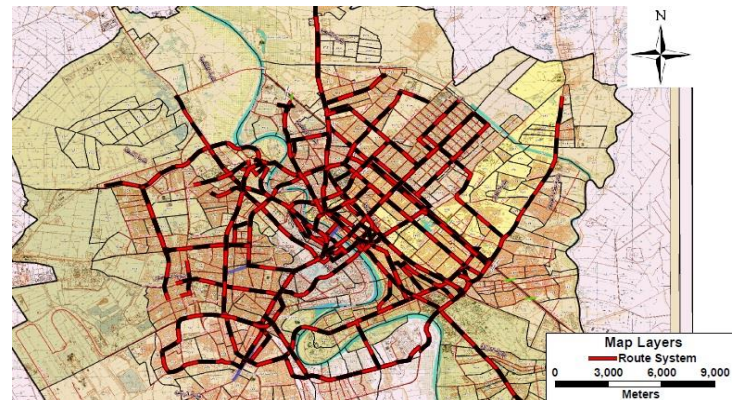
Study area divided into small geographic areas called Travel analysis zones (TAZ). TAZ used to subdivide the study area and for connecting land use to the highway network. TAZ used to represent areas of homogeneous land use and demographic characteristics and used to characterize demographic characteristics such as population, employment, etc. It represents the places where trips start at zone centroid, which is the start of activity in a zone, (trip producers), or end (trip attractors). TAZ created in TransCAD and the study area divided into 187 zones.

7. Transit Network Building

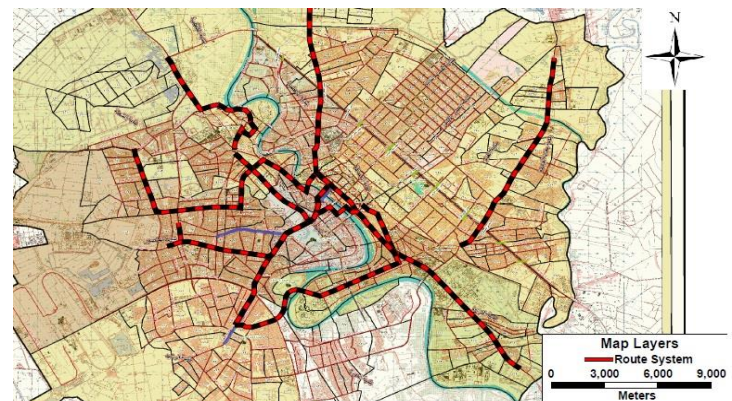
The road network of Baghdad City mapped using a transportation planning software Arc GIS and Trans CAD. Highway network was drawn in Arc GIS. Basic elements of a network are nodes and links. Links refer to actual highways (excluding most minor local roads) found in the highway network. Nodes are ends of links and connect links together. Nodes are usually located at intersections. These links coded with their characteristics such as speeds, length, capacities, and highway functional classification types. Determining actual capacities for each link in a network is extremely time consuming. Instead, generalized capacities were determined for links based on functional class, number of lanes, and area type. Link capacity was estimated following the Highway Capacity Manual (HCM). It is based on functional classification and area type. Capacity at Level of Service (LOS) C was used, LOS C is described as the operating conditions of "stable flow, high volume, speed and maneuverability determined by traffic conditions".

Centroid connector links created to link TAZ to highway network. Centroid connectors are representation for local streets within the highway network. Once the network created, it was checked to correct topology, and final checking was made for accuracy by performing the "shortest paths module" between any two pair of zones in the study area.

Public transport lines built based on road network and created using route system tool in TransCad. Public transport lines built based on road network and stored as geographic file. Figures 3 show the existing public routes, while Figure 4 shows the density of public routes.



(a)



(b)

Fig.3- Bus Routes: a) Mini bus Routes, b) High Capacity Bus Routes



Fig.4- Density of Public Routes

The O-D matrix in 2014 and mode share, which was developed by Asmael [2], was used in this study. An O-D matrix was assigned on the network to obtain the volumes on the various links of the network; mode share was used to split vehicle volume and public transport.

8. Travel Demand on Metro Network in 2014

Adding urban mass rail transportation network will change travel pattern. The total ridership for each route will be estimated for all identified alternative metro routes. The estimated public transit O-D matrix in 2014 was assigned on the existing route network. A result of an assignment is shown in Figure 5 that shows daily ridership of metro routes in 2014. Boarding values on all various stops is shown in Figure 6. According to the results, maximum peak hour ridership on metro routes in 2014 year equal to 30000 passengers per hour per direction. The higher ridership values are ideal for recommending metro route system.

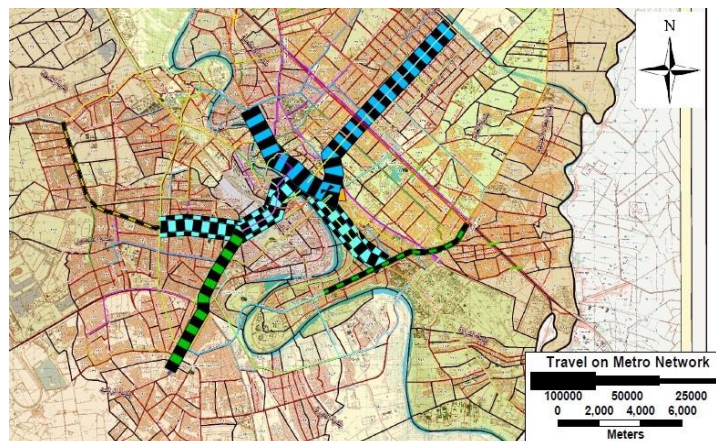


Fig. 5- Daily Travel Demand on Metro Network in 2014.

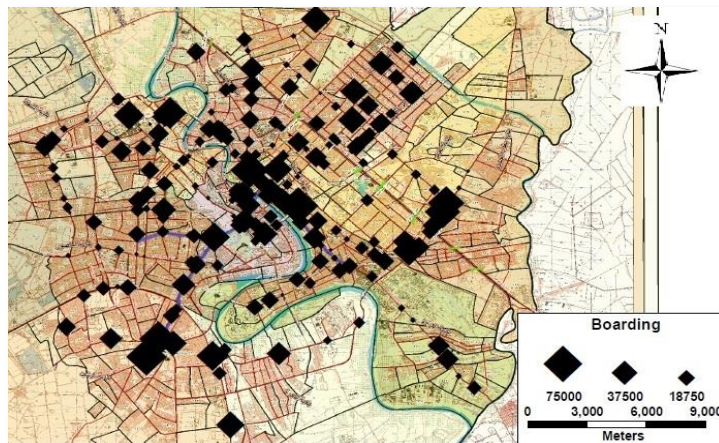


Fig. 6- Boarding at Stops of Various Routes

9. Travel Demand Forecast on Metro Network in 2035

Urban rail transport passenger volume forecast is a critical key input of urban planning. The travel has then forecasted up to the year 2035 based on expected population and mobility changes. The population of Baghdad expected to reach 11 million of inhabitants on year 2030 according to the Baghdad Comprehensive City Development study [1]. Prediction population of 2035 year is based on the medium growth scenario of Baghdad Comprehensive City Development Plan project (CCDP)

study. The forecasted matrix used to obtain the travel demand pattern for future year 2035. The O-D matrix on the year of 2035 derived from the matrix on year 2014 using the following formula:

$$T_{ij}^{2035} = T_{ij}^{2014} * \frac{P_i^{2035}}{P_i^{2014}} * \frac{PTm_{2035}}{PTm_{2014}} \quad (1)$$

Where

Tij : Trips from origin station i to destination station j

Pi 2035 : Population at station i in 2035

Pi 2014 : Population at station i in 2014

PTm: Public Transit mobility in 2035 and in 2014

A Catchment area of a transit station used in travel demand prediction involves creating service area around a metro station as with the method of Network service area used by Ahmed and Asmael [17]. The results of the catchment area of a metro transit station are shown in Table (1). Result of traffic forecasting on metro routes in 2035 is shown in Figure 7.

Table (1) Population prediction of Catchment area of a transit station of some routes

Station Name	Population 2014	Population 2035
Aqba	3186	6112
Al Masrah Al Watany	9691	18588
Mordjane Square	17316	33212
Firdaws Square	4888	9375
Nasser Square	5811	11146
Tahrir Square	10591	20313
Baghdad Municipality	11397	21861
L2 Station 8	7373	14142
Sharih Haifa	26461	50752
Medhaf Al Watan	31486	60391
Al Alamiya	8415	16141
Al Faris Al Arabi	896	1718
L2 Station 13	6779	13003
L2 Station 14	5576	10694
L2 Station 15	4161	7982
L2 Station 16	7149	13713
Nisur Square	4285	8219
Qahtan Square	5313	10191
Oum Toboul	17087	32773
L2 Station 20	11957	22933
Tamim	5157	9892
Al-Huriyah	9493	18207
Al-Karada	5378	10315
Al Masbah	6872	13181
Garage Al-Amana	10297	19750
Cinema Al-Bayda	24273	46555
Almushtal	18861	36176
Al- shulah	23106	44319
Al Gazila	7578	14536
Inter Gazila	5056	9699

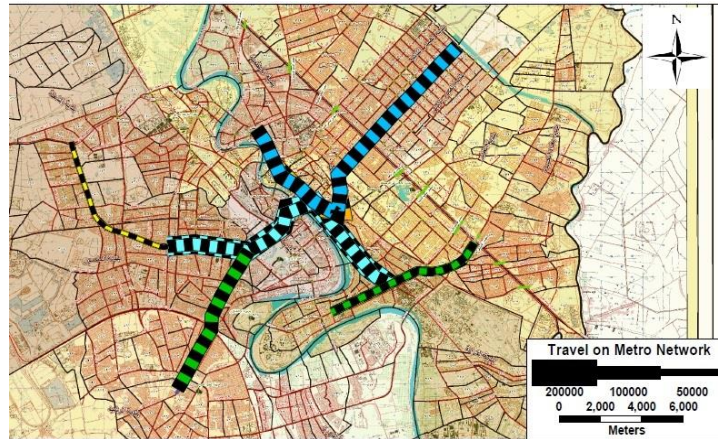


Fig. 7-Travel Demand on Metro Network in 2035.

Based on the assignment results, maximum peak hour ridership on metro routes in 2035 year equal 50000 passengers per hour per direction. Travel demand on alternative route 1 equal 200000 and 400000 trips per day in two directions, while, load on alternative route 2 equal 360000 and 720000 trips per day in 2014 and 2035 respectively.

10. Conclusions

Based on the research findings, the following conclusions are appropriate:

1. Travel demand of alternative route 1 is found to be equal 200000 and 400000 trips per day in two directions, while, it is estimated that, the load on alternative route 2 equal 360000 and 720000 trips per day in 2014 and 2035 respectively.
2. Estimated Peak hour ridership on metro routes in the year 2014 is found to be equal to 30000 passengers per hour per direction. Moreover, peak hour ridership on metro routes in the year 2035 will expect to reach 50000 passengers per hour per direction.
3. To meet the requirement of future travel demand in 2035, alternative route 2 and 1 are recommended to be adopted.
4. Upgrading public transport systems with newer technologies, like metro release massive congestion occurring for transport between main sectors of the city.

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