Using GIS-Based Travel Potential Data for Alignment Design of Baghdad Subway

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Baghdad transportation authority had required the development of a Geographic Information System - based public transport network, which will spatially and temporally track and compare the travel potential for the proposed underground metro transportation system. The numbers of passengers using the present public transportation system from each bus terminal and for each route to various destinations have been recorded. The passenger supply points have been indicated by latitude and longitude that define the bus stop and the proposed subway route stop using GPS. A passenger counting data were collected concerning the present use of public transport. A line indicates travel from one area to another and a grid was constructed. The present bus routes were identified, and the major public transportation terminals, which represent the passenger trip origin-destination nodes were detected using GPS. Data were assigned on a digital map; A general corridor is made up of a collection of routes, pattern and segments. The pattern is a spatial representation of the exact space traversed for a given trip; it is made of a numerous segments. Analysis of different corridors has been conducted and five major corridors have been detected. The collected trip direction and potentials were fed to the constructed database in the GIS environment. Data were visualized in the GIS on the digital map of Baghdad. The best routes for the subway, using different corridors, were optimized and aligned using the GIS software and network optimization model, then improved with the aid of land use data, and compared to the old proposed alignment of the subway. The study evaluates the proposed routes and access points to the subway, the length of each route has been detected through GIS system and the estimated travel time on each route was presented.

Introduction

Cities in developing countries like the case of Baghdad – Iraq, are facing congestion and urban growth. However, there is a sense of urgency in that this growth is far more rapid as both urbanization and motorization are ongoing processes that have not yet peaked. Land use is changing and its relationship with transportation infrastructure and other planning related variables in a spatial Context must be examined [6]; [7]. Traffic congestion in the city is high and Private car ownership is on the rise, though it is low compared to developed countries. The mix of vehicles on the roads is unique in that road space is shared by non-motorized, pedestrian, as well as motorized vehicles, while unavailability of mass public transport causes inconvenience. The excessive dependence on private cars, mini bus, and taxi, leads to heavy traffic, a large number of accidents, and high individual expenditure on transport. The GIS based transportation system got many advantages which include analytical capabilities, visual power, efficient data storage, integration of spatial database, and capabilities for spatial analysis.

A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data. Geospatial data, or geographically referenced data, describe the locations and characteristics of spatial features, [3]. The ability of a GIS to handle and process geospatial data distinguishes GIS from other information systems. It also establishes GIS as a technology important to geoscientist, cartographers, environmental engineers, and urban and regional planners, [7]. There are several studies which have been carried out for the development of transport system in the city of Baghdad starting from 1967 to 2001, but due to changes in land use and increments of population, it was felt that a new study...
and proposal of metro transportation system will be vital for the present condition. Esri [1] developed 3-D Geographic Information System (GIS); it could help in analysis and display the geospatial data. The objective of this research work was to access the travel potential and proposed alignment of Baghdad metro tube, using data collection at the major public transportation terminals, and suggests the possibility of optimizing the location based on the trip data collected.

## Methodology and Field Work

The collection of passenger trips data have been conducted with the aid of GPS. A mobile hand held instrument is used for acquiring the GPS data, [5]. The navigator GPS Garmin 72H instrument was used as a tracking instrument for streets and mapping and locating the position of bus stations within Baghdad city. Figure 1 shows the GPS instrument. The researcher used to take each of the trips from each terminal with the GPS at on position, and capture various routes traversed by the public transportation buses. GPS field data were collected during the period between (February 2012 to June 2012), on ordinary working days of the week, during the morning and afternoon rush hours (7-9 AM, and 4-5 PM).

![Navigator GPS Garmin 72H](image)

Figure 1. Navigator GPS Garmin 72H

As many as 219 trips were made along the city streets and 29 bus stations for this purpose. Each track is converted into a vector line map. The many tracks along a single street consist of a bunch of adjacent lines. The location of main public transportation terminals, trip direction potentials at different terminals, and various possible routes between different nodes which were usually used by the drivers, have been detected and stored using GPS. The GIS program opens a base map stored

![Legend adopted in the study](image)

Plate 1. Legend adopted in the study
in the specified directory and imports the GPS data in the form of single GIS point layer and line layer using DNR software, [2]; [4]. Within this layer, each trip is marked within a selection set. A number of different output files are produced; including a trip summary file and distance check output files for both inward and outward directions. Figure 2 illustrates the location of the major public transportation terminals as detected by GPS and transformed to Baghdad digital map.

On the other hand, figure 3 shows the urban roadway network of Baghdad, and the terminals; such data have been captured with the aid of GPS and field measurements. Data were transferred to the digital map stored at the GIS database. Typical legend adopted is demonstrated in plate 1.

In Iraq, the selected global projection system is (UTM Projection) for calculation of Cartesian coordinate based on the (CLARCK 1880) Ellipsoid as main datum used. In this work the satellite imagery were projected on WGS 84. A three bands raster image of Baghdad city is taken from IKONOS satellite with a spatial resolution of 1 meter, but the owner of the image did a re-sampling for the image and it became with a spatial resolution of 1.5m and it was taking in 2008. The image swath is 11.3Km. The image used in this study was corrected geometrically and originally on spheroid WGS84.

![Figure 2. Public transportation terminals](image-url)
The travel potential at each terminal and the trip direction from each terminal has been visualized using the GIS as demonstrated by figure 4. The major roadway network were also visible, the blue lines represents moderate occupancy of vehicles, while the red lines indicates high traffic density. The travel potential was transferred to origin-destination matrix shown in figure 5.
The study was conducted in the form of a public needs assessment, and spatial and temporal data collection through three phases. The first phase of the study utilized desk research, observations, and informal discussions with knowledgeable individuals (users of the present public transportation system), to assess the situation and arrive at some hypotheses to be tested. The second phase concentrated on the travel data collection with the aid of GPS regarding the main public transportation terminals (garages) location; trip at various possible route locations between different nodes which were usually used by the drivers were detected.

The third phase consisted of the transfer of collected GPS data to the GIS database and digital map, conducting the corridor analysis for different routes, and analysis of the travel potential along the proposed alignment of the subway.

Central to this methodology is the calculation of a GIS-based suitability index for proposed terminal park-and-ride facilities, which is used to rank locations based on the catchment areas of each facility. The calculation of this index is achieved using basic statistical techniques, a commercial GIS, and a basic model of travel potential.

The methodology starts by quantifying the demand for subway transit in the study area. As mentioned previously, many of the existing methodologies for determining the catchment areas of travel potential facilities use origin/destination matrices and downtown employment rates for their calculations.

**Corridor Analysis**

Five different corridors could be detected, and the corridor analysis for different routes has been conducted. The first corridor was that of AL-Sader city, north east of Baghdad, it has fewer obstacles to service development than many of the other corridors and has high transit ridership on existing routes. It serves 52463 trips. The corridor would allow easy connections to the proposed development. Figure 6 illustrates the location of the corridor. This track will be (12km) long with (13) proposed stations starting from the buses station of AL-Sader, where the main metro trains terminal could be located, across Al_chwader street up to Bab-Al_Sharqi (the common main station),it serves a vast residential area.
The second one was located on the North-West direction; it connects the city center terminals with those at the far residential areas at the North West as illustrated in figure 7. Such corridor has the greatest potential for enhanced transit service to facilitate transit oriented development, particularly in the area of the corridor east of Al-shula city. It captures a total trip potential of 46108, and the corridor connects directly to downtown Bab al-sharky, serves the densely populated area, University campus of Al-Mustansiriah and could facilitate further TOD development in that corridor. This track will be (18km) long with proposed (18) stations starting from the buses station of AL-Umma (the common main station) and Al_Khilani square and traverse under Al_kfaah street up to buses station of Bab Al-Muadham and passing near of the square (Antar) in the city of Adhamiya and toward to Kadhimiya city and to shoal city.
The third corridor was that of AL-Saib city, at the north, it has significantly lower population and employment densities and the existing transit ridership was 30620 trips. This corridor is (11 Km) long with (10) proposed stations beginning from bus station of Bab Al-Muadham towards Al-shaib city and reaching the bus station of Ur sector. most of the other proposals at the same corridor that were examined have multiple issues that would make them less desirable choices for development of premium transit service. Figure 8 illustrates the location of the corridor.

Figure 8. The developed subway route for north Corridor.

The fourth corridor is Al-jadriya- karada which is located at the south- east direction, it has highest existing transit ridership of 65311 trips, high residential and employment densities, and a relatively flat alignment over its western areas nearer to downtown. Perhaps most importantly, the wide right of way on karada would make implementation of premium transit service in the corridor relatively simple. Its connection to downtown is indirect but the connection to the downtown transit center is adequate. This corridor would make an excellent location for transit improvements, either instead of or in addition to improvements along karada regions. This corridor is (18 Km) long with (16) proposed stations beginning from bus station of Al-jadriya, Baghdad University campus through Al-Karrada city towards to Baghdad Al-jadeda city to buses station of Al-Mushtel. Then, the route turns and ends at buses station of Bab-Al-Sharqi. Figure 9 demonstrates its location.

The fifth corridor was at the south- west direction. The major challenges to the AL-Bayaa corridor come in the residential areas west of al-bayaa , al-mansor cities as well as the current development plan for the corridor. Aljaderiah- bayaa corridor also has relatively high transit ridership of 63169 trips, and higher than average population and employment density. The connection to downtown via al-sinak Bridge is good. The terrain of some of the surrounding areas could make development/redevelopment difficult since it is close to the international green zone region. This corridor is (40Km) long with (37) proposed stations beginning from buses station of Al-Umma and passing in Al-alawia city towards to Al-mansour city, traversing through Al-Bayaa city to buses station of Al-Bayaa, then goes towards Abo Dsher region, passing Al-Dora city and end this corridor in buses station of Al-jadriya where Baghdad university after crossing the river. Figure 10 shows its location. Table 1 shows a summary of the ridership on each metro tube proposal.
Figure 9. Proposed and developed subway routes for South-west Corridor

Table 1. Travel potential along each corridor

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Direction</th>
<th>Travel potential</th>
<th>Length (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1</td>
<td>North- east</td>
<td>52463</td>
<td>12</td>
</tr>
<tr>
<td>Corridor 2</td>
<td>North- west</td>
<td>46108</td>
<td>18</td>
</tr>
<tr>
<td>Corridor 3</td>
<td>North</td>
<td>30620</td>
<td>11</td>
</tr>
<tr>
<td>Corridor 4</td>
<td>South- east</td>
<td>65311</td>
<td>18</td>
</tr>
<tr>
<td>Corridor 5</td>
<td>South- west</td>
<td>63168</td>
<td>40</td>
</tr>
</tbody>
</table>

Network Analysis Using ArcGIS

Network Analyst can solve shortest path, closet facilities, service area (allocation), and origin-destination cost matrix problems. These analytical functions are found on the Network Analyst toolbar and in the Analysis toolset of Network Analyst Tools. The turn feature class toolset of Network Analyst Tools has tools for creating and editing turn feature class as well as a tool for converting a turn table into a turn feature class, [8].

Arc Info Workstation has commands for solving the location-allocation problem. The model includes the minimum distance model, the maximum covering model, and their variation. And the computer algorithms include GRIA (global regional interchange algorithm). Both algorithms are heuristics. These algorithms can solve location-allocation problems reasonably quickly but may not produce optimal solutions, especially with many supply and demand points. The network optimization technique of the ArcGIS software was utilized to select the best metro route for each corridor. The software output was represented in the following figures. It can be noted that the routes utilizes the existing roadway network and shows many sharp angles at the connections, such sharp angles were soften by the software and developed after taking the existing land use into consideration. One case is presented at figure 9. The route proposed by the software is shown in blue color, while the developed final route was illustrated in purple color.

Another case was shown in Figure 10, the proposed route was in dark blue color, while the final developed route was demonstrated in dark brown color.
Figure 11 demonstrates the developed metro route alignment of the proposed metro tube location for Baghdad urban area.

Figure 10. Proposed and developed subway routes for south-east Corridor

Figure 11. The developed subway routes for Baghdad urban area.
Conclusions

Based on the fieldwork and office analysis, the following conclusions may be drawn:

1- The use of GPS in the spatial and temporal location of the existing public transportation terminals and routes has proved to be accurate enough for such investigation.

2- The use of GIS for visualization of data and for optimization of subway routes location is beneficial, more accurate, and can be a good substitute of other optimization methods.

3- The proposed subway routes based on traffic data are expected to be more efficient than those based on land use only.

4- The corridor analysis has proved to be an efficient mean in the selection of metro route location.

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References


