Improving the transportation system in Baghdad city

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Abstract. Baghdad has suffered from lack of new major infrastructure in transportation sector for many decades, compounded by a huge increase in the number of roads user. This has led to problems with out-of-date networks causing congested roads and pavement exceeding its design life, increasing travel time with negative effects on users, the economy, and the environment due to increased emission rates and massive fuel consumption. Accordingly, this study seeks to develop a sustainable transportation system to handle a large number of users with minimum effect on the environment to promote economic achievement. Based on the literature, a rail transportation system emerged as the most sustainable system, and such a system is thus proposed for Baghdad, with suggested route and station positions designed to ensure efficient interactions with the current road network. To assess the proposed system, the city was divided into fifteen zones, eight zones on the east side and seven on the west side, and travel times between zones were calculated using GIS software both with and without application of the proposed system. The results revealed that considerable savings in travel time between most zones with the system. Furthermore, the proposed system would change the land use adjacent to access points (stations), boosting investment in housing and encouraging people to leave the overcrowded city centre.

1. Introduction

Baghdad is the capital of Iraq as well as the country’s largest city [1]. It has had no major infrastructure development related to transportation projects for the past 30 years, however, despite many proposals to enhance the condition of the city [2]. This has led to significant issues with congested roads, especially those leading to the centre of the city [3; 4]. It thus remains increasingly necessary to find a solution for the city’s movement issues by proposing a sustainable transportation system. Accordingly, this study has developed a system to address the transportation problems experienced by Baghdad.

GIS Arc Map version 10.4 was used in this study as supporting software to facilitate assessing the proposals by dividing the city into zones, measuring the distances between the centres of these zones, and calculating relevant travel times and other spatial data as required for comparison. The results showed that the proposed system is a good solution to the congestion problems of Baghdad, and that it would decrease the environmental problems of this city and encourage people to move out from the densely populated centre to an improved periphery created by the proposed project.
2. Study aims

Baghdad is a very dense city with an over-capacity, out-of-date transportation network that urgently needs a new sustainable transportation system [2]. Such a system must handle the increasing demand for travel, redistribute land use of Baghdad to a more balanced mode, increase the areas of vegetation, reduce greenhouse gas phenomena, and improve the city’s environmental conditions. Moreover, any new transportation system must be considered in terms of its use as a base for a new city master plan.

3. Baghdad city expansion, population, land use and transportation problems

Baghdad was the capital of the Abbasid Caliphate, being founded by Abbasid Caliph al-Mansour more than a thousand years ago [5]. The city has since continuously grown in all directions, especially after 1920, when modern planned streets and sectors were implemented. Since 1958, land cover patterns in Baghdad have undergone several essential changes due to its accelerated expansion, leading to a disappearance of agricultural land and increases in urban growth that have placed extreme stress on the local environment [1; 6]. After 2003, such problems expanded with the explosion in the number of imported vehicles and increases in residential areas. Many green areas were also changed to urban usage, increasing the damage done by air pollution [7].

It is thus appropriate to focus on finding a solution to this city’s transport issues through identifying, implementing, and assessing a sustainable transportation system to overcome traffic congestion, environmental pollution, and the economic stagnation of the city.

3.1 Population, Geographic and Spatial Information on Baghdad city

Baghdad is the second densest city in west Asia after Tehran (capital of Iran), with more than seven million people. About 20% of all Iraqi people live in about 200 to 210 km², creating a density of more than 30,000 head of population per km² [1]. Baghdad has expanded to more than five times its original size since 1960 and its population has increased linearly, from half million in 1950 to 7.2 million in 2018, as shown in Figure 1. The increase in population with time to 1997 was demonstrated by from Saleh [1], while the increase in population from 1997 to 2018 was specified by the World Population Review webpage [8].

This city growth has had some economic advantages; however, it has had many other disadvantages, particularly with regard to the environmental consequences, as this growth has increased climate change and global warming, which negatively affects human lives [9; 10; 11]. Such urban expansion is a common concern throughout the world as people leave rural areas and accumulate in major cities [7]. Moreover, the transformation of vegetation or bare land to impervious surfaces (buildings) has generated additional negative environmental phenomena such as urban heat islands [9; 12].
The spatial conditions of Baghdad have been compared with those of London [7]. Accordingly, some mitigation processes to improve Baghdad’s transport conditions, to at least prevent these from getting worse, are possible. Figure 2 shows a thermal satellite image of Baghdad; the key is as shown in Table 1.

**Figure 1.** Baghdad Population with Time

**Figure 2.** Thermal image of Baghdad City
Table 1. Baghdad spatial analysis

| Spatial          | % range of land key | Average Radiant temperature °C |
|------------------|---------------------|-------------------------------|
| Water            | 3-6                 | 30                            |
| Vegetation       | 5-10                | 34                            |
| Open area        | 15-25               | 42                            |
| Commercial       | 7-10                | 50                            |
| Low-density residential | 12-15    | 44                            |
| Medium-density residential | 30-40       | 47                            |
| High-density residential | 10-15       | 50                            |

It is clear from Table 1 that residential areas cover a high percentage of land and produce highly radiant temperatures as compared to vegetation; however, such results are dependent on image size and the analysis technique used to obtain them [1]. Nevertheless, Saleh concluded [1] that Baghdad has expanded randomly in all directions and that many previously green areas are becoming extensively urbanised. He also found that the city had expanded to about five times the size in 2002 as in 1961.

More specifically [7] reported the percentages of land cover in Baghdad city, as shown in Table 2. This confirms that the built-up area takes up the highest percentage of land (43.62%), followed by vegetation cover (28.15%).

Table 2. Percentages of land cover in Baghdad city

| Land Cover | Percentage  |
|------------|-------------|
| Built-up   | 43.62%      |
| Vegetation | 28.15%      |
| Soil       | 25.3%       |
| Water      | 2.93%       |

The high percentage of built-up land is the main reason behind recent increases temperatures during the summer, as green areas (vegetation) have previously played an important role in mitigating the greenhouse phenomenon, protect the soil from erosion and resisting desertification.

Such spatial and environmental difficulties are another reason for assessing the proposed system of limiting the available transport choices in the city to help reduce the effects of the current situation or at least to prevent the situation from getting worse.

3.2 Current Transportation network

Baghdad is one of the most congested cities in the world [13], with a population of more than seven million people. Transport in Baghdad depends mainly on roads; the traffic conditions in Baghdad are as shown in Figure 3.
Figure 3. Traffic conditions in the main arterial roads of Baghdad on typical working days at 9:00 AM [14]

It is clear from Figure 3 that traffic condition on the main arterial roads of Baghdad are over capacity in many sections, especially close to the city centre. The Baghdad network has reached this point for many reasons:

- The city was expanded randomly in all directions without any pre-planning, leading to increases in the number of network users without any additional facilities being provided, particularly over the last thirty years. Individual projects here and there have been applied to “spot” problems, and many of these have increased the overall network problems.
- The city infrastructure has seen no major improvements related to transportation projects since the 1990s.
- The city’s transport depends solely on the road network, which is insufficient; Baghdad thus needs other transport systems to help meet increased demand.
- The city has faced many economic problems due to politics and conflicts, which are reflected in the current situation.
- Between 2003 and 2008, the government imported hundreds of thousands of road vehicles, without any restrictions.
- A lack of maintenance has resulted in decreases in network efficiency and capacity.
- Intelligent transportation systems have not been adopted in any of the current network, though such systems could help in solving some problems or improving general network capacity through organising traffic movement to make it more efficient.
- The main airport of Baghdad lies on the west side of the city. Many routes connect this airport with other Baghdad zones, yet most of these pass through the centre of the city. This increases the demand on the network, which in turn decreases the network efficiency and its level of service.

Accordingly, Baghdad requires the development of another transportation system to share the transportation demand with the current worn-out road network. The overall aim of this research is thus to make an assessment of one such proposed system.

4. Study methodology

Based on problems presented above, the city requires a new sustainable transportation system. This study thus proposes a transportation system to address multiple traffic, environment, land use, and economic difficulties. According to the News European Parliament website [15], rail systems are the most sustainable transport systems, as shown in Figure 4.

![Figure 4. Emissions Breakdown by Transport Mode in the EU (2016).](image)

After selection of the optimum rail network, the following steps were used to assess the proposed system:

1. The Baghdad city map was digitised in GIS software;
2. The city was divided into a number of zones;
3. The centroid of each zone was specified;
4. The number of stations required by the proposed rail system was identified;
5. The distances from the centre of each zone to the nearest train station were measured;
6. The smallest travel time for each trip between zone centres was calculated;
7. The travel time between zones in Baghdad city under the proposed system was calculated;
8. The resulting travel times under existing conditions and after adopting the proposed system were compared and any time saving identified.

4.1 Proposed transportation system

According to the literature, a rail transportation system is the most sustainable transport method as compared to other systems. To satisfy sustainability requirements, train speed should be high as possible to minimise travel time and to increase the frequency of trains at each station.

High-speed rail allows valuable savings in terms of travel times for train users [16], which could in turn improve the performance of other transport modes.

To choose the optimum path for the proposed system, the following points were considered:

1. The city formation was estimated as a round shape with random expansions in all directions;
2. Requirements to be safer, faster, and cheaper than the current network, to attract the people to leave the current network, were built in;
3. Limits on length to decrease the construction costs and travel time were set;
4. Accurate and intelligent systems with a high degree of flexibility that provide many choices to users, allowing smooth transport with minimum delay and inconvenience and which interact with existing road networks were required;
5. Minimum effect on land use and the cost of land required for the project were specified;
6. Spatial analysis was performed to locate much of the system on barren areas around the city;
7. A booking system is required to let people plan their journeys by choosing the most relevant options according to their requirements, paying online or using cell phones or e-tickets to reduce access time and simplify the interface.
8. The stations of the proposed system will be centres for new residential investments.

Scott Wilson [17] studied a proposed system of five ring roads for Baghdad city. The fourth suggested ring road was chosen as a path for the proposed rail system, as it satisfies most of the points for consideration noted; additionally, construction of the proposed system adjacent to the fourth ring road will reduce costs, especially for land acquisition. The travel time needed to complete a full path of the system, including stoppage times in all stations, is less than 1 hour, with a train speed of 220 km/hr and a stop time per station of 2 min.

Figure 5 shows the proposed rail system, with a length of about 100 km, and its 8 stations around Baghdad city. Based on its operational and geographic properties, the proposed system was named the High Speed Ring Rail Project.
4.2 Proposal importance

In addition to improving the efficiency of the transportation system by decreasing congestion in the current network and increasing the capacity of the city transportation networks, several further benefits may be achieved through the construction of the proposed system:

1. Developing vacant land adjacent to the system access points stations by changing usage;
2. Transport of heavy loads (goods, fuel, and wastes) during off-peak hours;
3. Reorganisation of the city master plan to redistribute and improve land use;
4. Increased city security from the perspective of a rail network as city fence;
5. Increased job opportunities due to the need for multiple stations that can act as market centres;
6. Decreases in city pollution based on saved energy, and decreased carbon dioxide emissions, reducing global warming and environmental pollution.
7. Improvements in the green belt around the city; decreasing sand storm frequency and intensity in addition to improving climatic condition;
8. Investment opportunities with regard to constructing new residential neighbours to help evacuate some excessively dense residential zones near the city centre and creating open green zones to act as lungs for the city to improve the environmental conditions;
9. Increases in the pavement life of the current road network based on decreasing the required number of heavy vehicles; and
10. Increased ease of movement for visitors to Baghdad seeking to use facilities such as airports, hospitals, and main markets;

5. Proposal assessment

GIS software was used to assess the proposed system, which stretches around 100 km in length around Baghdad city; selected station positions were aligned with arterial roads on the current road network.
The proposal was then analysed by calculating the travel time savings as compared to under the existing conditions.

5.1 Case 1: East side zones to west side zones

Baghdad was divided using GIS Arc Map version 10.2 software into 15 zones. Eight zones were on the east side of the Tigris River (Rasafa) and seven zones were on the west side of Tigris River (Karkh). Table 3 and Figure 6 identify the 15 zones in more detail.

Table 3. Baghdad Zones

| Rasafa (east of Tigris River) | Zone No. | Karkh (west of Tigris River) | Zone No. |
|-------------------------------|----------|-------------------------------|----------|
| Baghdad Al Jadeeda            | 1        | Mansour                       | 09       |
| Palestine St.                 | 2        | Kadhimiya                     | 10       |
| Karada                        | 3        | Karkh                         | 11       |
| First Sadr                    | 4        | Dora                          | 12       |
| Second Sadr                   | 5        | Al Shuala                     | 13       |
| Al Rasafa                     | 6        | Al Rasheed                    | 14       |
| Adamiyah                      | 7        | Baghdad International Airport | 15       |
| Sha’ab                        | 8        |                               |          |

Figure 6. Baghdad Zones and their Centroids.
Google maps [14] was used to estimate the smallest travel time, for each trip between any origin and destination in Baghdad city. The application allows a choice of the mode of travel from five selections: flying, cycling, walking, transit, and driving. In this study, the transit mode was thus used to estimate the time (in minutes) to travel between any chosen origin and destination. Table 4 shows the smallest times (in minutes) needed to travel between Rasafa zones to Karkh zones.

**Table 4. Lowest Travel Time for Trips between Rasafa zones (Origin) and Karkh zones (Destination) - Existing Case**

| Origin Rasafa side | Karkh side |
|--------------------|------------|
| 1                  | 37 39 25 43 32 47 |
| 2                  | 32 30 32 33 33 43 |
| 3                  | 19 41 22 37 28 41 |
| 4                  | 48 32 43 42 45 54 |
| 5                  | 43 28 35 37 39 48 |
| 6                  | 21 10 34 24 24 35 |
| 7                  | 44 36 45 42 43 55 |
| Average            | 34.9 30.9 33.7 36.9 34.9 46 |

The proposed rail system provides two lines in opposite directions to decrease the travel time between zones. The centroids of all zones of Baghdad city were located using GIS software, as shown in Figure 6, and the distance from the centre of each specified zone to the nearest access point (station) was measured using either the straight-line distance or the road network distance [20 and 21]. The GIS package was then used to estimate the travel time between zones.

The average speed of a high-speed train ranges between 250 and 350 Km/hr [16]. For the purposes of this study, a speed of 220 Km/hr was adopted as an average speed in order to take into account acceleration and deceleration speed losses in the proposed system, with the waiting time in each station assumed to be 2 minutes. The travel times (in minute) produced by adopting the proposed system are presented in Table 5.

**Table 5. Lowest Time for the Trips between Rasafa zones (Origin) and Karkh zones (Destination) after adopting the proposed system**

| Origin Rasafa side | Travel Time (min) |
|--------------------|-------------------|
| 1                  | 34.9 30.9 33.7 36.9 34.9 46 |
| Origin | Destination | Tooth | Zone 9 | Zone 10 | Zone 12 | Zone 13 | Zone 14 | Zone 15 |
|--------|-------------|-------|--------|---------|---------|---------|---------|---------|
| Rasafa side | Karkh side | 1     | 31     | 25      | 28      | 26      | 29      | 24      |
|        |             | 2     | 29     | 22      | 25      | 24      | 26      | 22      |
|        |             | 3     | 29     | 33      | 22      | 33      | 33      | 22      |
|        |             | 4     | 27     | 20      | 23      | 22      | 24      | 20      |
|        |             | 5     | 27     | 21      | 24      | 22      | 25      | 20      |
|        |             | 7     | 22     | 20      | 25      | 21      | 29      | 23      |
|        |             | 8     | 18     | 14      | 19      | 15      | 23      | 17      |

Average Travel Time (min)

- Existing Case: 26.1
- Proposed Case: 22.1
- Zone 12: 23.7
- Zone 13: 23.3
- Zone 14: 27
- Zone 15: 21.1

Figure 7 illustrates a comparison between travel times under the existing condition and after adopting the proposed system.

**Figure 7.** Comparison between Average Travel Time (minutes) for Zones 9 to 15 for the Existing Condition and under the Proposed System.

According to Figure 6, the highest saving in the average travel time would be for zone 15 (Baghdad International Airport); being equal to about 25 min. This is a valuable result, as this zone receives a great deal of daily traffic from multiple other parts of Baghdad.

It is important to mention, however, that this study has excluded zones located adjacent to the city centre as they are too far from the proposed system to benefit.
5.2 Case 2: West side zones to east side zones

Table 6 shows the estimated travel time (in minute) for trips between Karkh zones and Rasafa zones under existing conditions, while Table 7 shows the travel time for trips between the same zones under the proposed system.

**Table 6. Lowest Time for Trips between Karkh zones (Origin) and Rasafa zones (Destination) - Existing Case**

|          | Destination |          |          |          |          |          |          |
|----------|-------------|----------|----------|----------|----------|----------|----------|
|          | Rasafa side | 1        | 2        | 3        | 4        | 5        | 7        | 8        |
| 9        |             | 27       | 20       | 19       | 47       | 41       | 16       | 47       |
| 10       |             | 28       | 14       | 26       | 35       | 27       | 7        | 30       |
| 12       |             | 24       | 27       | 16       | 40       | 36       | 34       | 55       |
| 13       |             | 40       | 30       | 34       | 48       | 38       | 25       | 41       |
| 14       |             | 28       | 25       | 19       | 43       | 34       | 21       | 39       |
| 15       |             | 45       | 36       | 31       | 55       | 45       | 33       | 52       |
|          | Average     | Travel   | 32       | 25.3     | 24.2     | 44.7     | 36.8     | 22.7     | 44       |

**Table 7. Lowest Time for Trips between Karkh zones (Origin) and Rasafa zones (Destination) - Proposed Case**

|          | Destination |          |          |          |          |          |          |
|----------|-------------|----------|----------|----------|----------|----------|----------|
|          | Rasafa side | 1        | 2        | 3        | 4        | 5        | 7        | 8        |
| 9        |             | 30       | 28       | 30       | 24       | 24       | 24       | 17       |
| 10       |             | 26       | 23       | 34       | 21       | 22       | 22       | 14       |
| 12       |             | 29       | 26       | 23       | 24       | 25       | 25       | 26       |
| 13       |             | 27       | 25       | 34       | 23       | 23       | 23       | 14       |
| 14       |             | 30       | 28       | 25       | 26       | 26       | 26       | 21       |
| 15       |             | 29       | 25       | 22       | 25       | 23       | 23       | 20       |
| Zones | Existing Case | Proposed Case |
|-------|--------------|---------------|
| 1     | 27           | 22.9          |
| 2     | 25           | 18.4          |
| 3     | 26           | 23            |
| 4     | 23           | 23            |
| 5     | 23           | 22            |
| 6     | 23           | 22            |
| 7     | 23           | 22            |
| 8     | 23           | 22            |

A comparison between average travel times from Karkh to Rasafa side under the existing condition and with the proposed system is presented in Figure 8.

![Bar chart showing comparison between Existing Case and Proposed Case for Zones 1-8](chart.png)

**Figure 8.** Comparison between Existing Case and Proposed Case for Zones 1-8

According to Figure 8, savings in average travel time are seen for zones 1, 4, 5 and 8. The highest savings in average travel time are for zones 4 and 8; however, there is no saving in the average travel time for zones 2, 3, and 7.

### 6. Discussion

Valuable results regarding the savings in travel time under the proposed system were obtained, indicating potential for savings in energy consumption and decreases in congestion and environmental pollution. Moreover, many other benefits from the proposed system are expected:

- Rail systems are safer from an accident point of view and allow people to reach destinations more rapidly. Accordingly, it is important to attract people to use such systems and thus abandon current transportation modes;
- The capability of a rail system to transport a considerable number of people economically is large;
- Transporting a large volume of population during religious occasions with no negative effect on the current road network would offer many advantages;
- The proposed transport system offers good opportunities to improve land usage that are adjacent to its access points or terminals. [22; 23; 24; 25; 26; 27; 28; 29; 30; 31; 32; 33; 18 and 34].
- Access points play an essential role in the economic development of adjacent land [35] due to decreases in transport costs and time, which may increase the economic activities of adjacent land and increase its value.

### 7. Conclusion

The following main conclusions can be drawn from this study:
1. The savings in average travel time produced by using the proposed rail system were up to half the time required to travel between Baghdad zones under the existing conditions.

2. Baghdad International Airport, in the west side of the city, showed particularly good savings in average travel time, at about 25 minutes, based on adopting the proposed system.

3. The proposed railway transportation system is would allow many trips to avoid passing through the crowded Baghdad centre, decreasing the traffic congestion and environmental pollution, and reducing energy consumption.

4. Adopting the proposed system would directly affect travel times for trips between fringe zones, and indirectly improve central zones by reducing traffic densities.

5. There is a high possibility that the change in land use near the system access points will help in the regeneration of the city, evacuating some dense urbanised regions in the centre that may then be changed to green zones.

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