Location of freight warehouses facilities: A GIS-based multi-criteria decision analysis

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Abstract. Freight transportation is of high importance and is used to determine the region’s economy. Typically, effective freight transportation systems are related to decreasing the costs of moving goods from and to the logistics facilities. The city of Baghdad suffers from many problems with the land transport system, especially the transportation of goods, and among the important things to reduce the current burden on the network is to find the most suitable sites for the establishment of warehouses distributed over each city of Baghdad. Understanding the assembly pattern of the truck’s trip ends can help improve the location of these facilities on space. This paper explores the best places for unloading (warehouses), using 4 criteria that affect taking the most appropriate location for warehouses to improve logistical facilities, which are (land use, population, current warehouses, road network). The weight of criteria was collected from the questionnaire using the Google form and obtain answers from Decision-makers to include them in the AHP hierarchical analysis process to obtain the weights for each criterion. Multi-criteria decision analysis is performed to create a suitable surface to identify potential locations where new logistical facilities can be established. The ArcGIS 10.7 software and its extensions (i.e. spatial analysis and network analysis) are used extensively in analysis for modelling site allocation. The results indicate that the most suitable sites from the group of sites that appeared in the analysis are (near the entrance to the Diyala Bridge and the entrance to the people on the outskirts of the city of Baghdad).

Keywords: Freight Transportation, AHP process, Warehouses, Spatial Analysis.

1. Introduction
Freight transportation is a major driver of economic prosperity as it has a direct impact on the performance of many economic sectors [1]. Also, transportation is providing a way for traveling to conduct day-to-day work activities, also it is vital for human activities, like recreation, commerce, and others [2]. Land transport, especially commercial transport of Freight vehicles is a vital and important service activity and one of the tributaries of the national economy in all parts of the world, and in Iraq in particular, where transportation of various forms has distinct importance from the rest of the elements of production in the country's economy. Economic activity transport is the tool through which to expand the market and employ human and material resources to move the production process.
towards increasing production and improving the quality and the movement of goods and labor. Transportation in Iraq occupies an important place in the process of national development and building economic and social edifice in the country [3]. Therefore, it plays the greatest role in the field of comprehensive economic development, providing a wide range of services in the field of transporting people, goods, and various materials between cities and production sites and consumption. In a common analysis method, the basic step is determining the goods which are moved as well as delivered, where they are originating, the type of transport services and vehicles are majorly utilized for. This helps to estimate and model the demand for freight, and then to simulate and predict the results related to potential policy measures [4]. The main objective of the presented work is to find the most suitable and optimal locations for new containers to be positioned all along with logistics facilities' limits to promote the distribution of goods between internal travels. Using a geographic information system (GIS) program provides the possibility to reach the goal.

2. Problem statement & objective of study
The supply and demand of goods, as well as the period of shipments, affect the performance of every freight transportation system. Since goods transportation is such an important part of the supply chain, the location of distribution centers concerning demand points must be carefully considered. This paper focuses on logistics clusters, which are large complexes or centers that manage large volumes of freight activity. This could include distribution centers, warehouses, and logistics firms, among other things. The main aim of this paper is to determine the best locations for warehouses that support freight transport efficiency using a GIS-based optimum location model for logistics facilities. To attain this purpose, the local patterns of truck trips are analyzed concerning these classes to comprehend cargo transportation performance in Baghdad.

3. Case study
Baghdad governorate lies between Salah Alden in north and Babil to south, and from Al-Anbar west and Diyala east in Iraq area and the zone (38N) based on the Universal Transverse Mercator (UTM) geographic coordinates system. The local area of the study lied from the (32°40' 00" to 34° 00' 00") latitude north and the (44°00' 00" to 44°20' 00") longitude east, Baghdad area is (5065.163 km2) that represents 1.04 % of Iraq’s total area [5]. The smallest governorate of Iraq in an area and in 2018 Baghdad comes first in terms of population, with 9 million people. The region of Baghdad is characterized by the passage of the Tigris River, during which it is divided into two parts, Al-Karkh and Rusafa, and the study is divided into 9 districts and will be mentioned later. As shown in figure (1).
4. Methodology

This research aims to find the best places to establish warehouses that serve the logistical facilities of the city of Baghdad through the application of the process of finding a model using geographic information systems (GIS) and to explore important sites and how to distribute them to include the entire city. The main goals are:

- Collecting information related to the study area to determine the criteria that will be included in the Hierarchical Analysis (AHP) process.
- Requisition the geographical database of the road network and districts of Baghdad city using the ARC GIS program.
- Creating a model for finding the best suitable areas for creating warehouses with spatial analysis tools for the ARC GIS program.

5. Data collection

Four criteria were used to predict the location of warehouse sites, these data include population, land use, access to airport & rail and current warehouses, and proximity to the highway network. The data of the criteria that are included in the spatial analysis of the work were geocoded in the gis environment. The criteria were pairwise comparisons using a questionnaire with (Google form) and the most important questions that distinguish the criteria from each other were asked. The criteria were coded using symbols as follows to easily collect the response of decision-makers.

Image 1. Google maps image for study area (Baghdad city).
4 variables were adopted as follows:
X: Population
Y: Land use
Z: Access to Airport & Rail & Current Warehouses
W: Proximity to Highway Network

The results for the relationship between each variable appeared in the following figure 1.

Figure 1. Pairwise comparison using AHP process.

6. GIS for location suitable sites
One of the most important steps of our study approach is to find the most appropriate place to create new repositories, this step is among the GIS applications. The most important thing it needed is criteria and their weights that are obtained from the questionnaire information (google form) in which the questions contain about which criteria are most important in creating the warehouses and the relationship between each criterion and are answered by decision-makers and according to then, the answers are entered into the hierarchical analysis method (AHP) to obtain Weights for each criterion.
6.1. Analytic hierarchy process

By the use of the analytical hierarchy method, multi-criteria programming is a decision-making methodology in dynamic situations in which several factors or criteria have been taken under consideration in prioritizing and collecting the programs or alternatives [6]. The AHP has been advanced by (T. L. Saaty) in the 1970s and since then, it was researched extensively and is presently utilized in the complicated scenarios in decision-making, in which the individuals work together for making decisions where the human perceptions, assumptions, and repercussions have long-term consequences [7]. The applications of the AHP start by a topic that is broken down to a hierarchy of the criteria to be more accurately evaluated and independently compared. Once this conceptual hierarchy has been developed, the decision-makers will perform a systematic comparison of alternatives for each of the selected parameters by making pair-wise comparisons. Relevant data from alternatives or individual decisions can be used in this comparison to include underlying details [8]. As illustrated in the previous figures.

The Comparison Scale (SAATY scale). The relation can be achieved in various ways between two components using AHP. However, as has been proposed by Saaty [9], the relative significance scale between the two criteria is the most commonly used. The scale, which assigns values ranging between 1 and 9, measures the relative significance of criteria in comparison with other criteria, as can be observed from table 1.

| Scale                        | Numerical Rating | Reciprocal |
|------------------------------|------------------|------------|
| Extremely Preferred          | 9                | 1/9        |
| Very Strong to Extremely     | 8                | 1/8        |
| Very Strongly to Preferred   | 7                | 1/7        |
| Strongly to Very Strongly    | 6                | 1/6        |
| Strongly to Preferred        | 5                | 1/5        |
| Moderately to Strongly       | 4                | ¼          |
| Moderately Preferred         | 3                | 1/3        |
| Equally to Moderately        | 2                | ½          |
| Equally Preferred            | 1                | 1          |

To ensure that there is a fair variance between the measuring points, it’s normal to only utilize the odd numbers from the abovementioned table. The use of even numbers can only be followed if negotiation between the evaluators is required. It increases the necessity for defining a middle point as an agreed solution if a natural consensus cannot be achieved (compromise).

Network analysis will be employed to determine the optimal location of creating new warehouses. To determine the optimal location for building new warehouses, network analysis would be used. In ArcGIS, the extension of the Network Analyze will be used to check the efficiency of the best warehouse site, the geospatial analysis process will be used, represented by the model builder of finding the best warehouse site using the spatial analysis tools as shown in figure 2. The first and basic step before starting with the model is to determine the standards that the model depends on and weigh them through the AHP process, which will be explained in detail, then the next step is to merge the layers and make each layer in the form of a raster and finally work with all the steps of the model, the explanation about it in detail follows.
Figure 2. model to find the new location of the warehouse.

6.2. Raster data analysis
To represent both fields and objects, Raster data models are used. To generate a specific output, Raster data analysis requires the use of one or more grid (raster) layers as input. It simply divides space into a series of grid units using cellular organization, each unit being equal in size to the other units [10], as shown in Figure 3. Although, Output is not necessarily dependent on basic input layer or parameter additions. The Raster's resolution is based on the pixel size of the grid cell or image element,
determining the level of spatial information in-ground units. A small grid cell dimension indicates a fine resolution and thus broad storage capacity. The analysis of raster data is based on operations applied to the raster cells. In the model analysis for our study, the cell size and processing extent were selected on the size of the layer of land uses.

Figure 3. Illustration of the raster data representation of real-world features [11].

A variety of raster models were produced for this analysis, representing different parameters (e.g. highways, rail, existing warehouses, land use, and origin-destination clusters, etc.). To determine a site suitability map that will include the potential location of logistics hubs in the study area, a mapping system has been developed for the various raster layers.

6.3. Model builder
Defines Model Builder as a “visual programming language for building Geoprocessing workflows”. Geoprocessing models automate and document your spatial analysis and data management processes. You can find the tool in all versions of ArcMap, a model is represented as a diagram, flowchart, or workflow that chains together sequences of processes and Geoprocessing tools, using the output of one process as the input to another process. It provides advanced methods for extending GIS functionality by allowing you to create and share your models as tools.
Color code: Blue represents the Inputs, yellow represent the tools, and the green represents the outputs, all connected by an arrow.
The first step is to configure the layers and call the criteria that enter the model (land use, population, current warehouses, road network) and each layer is represented in GIS as the shown in figure 4.
Figure 4. Illustration for Base Map.

The figure shows the red areas which represent the current warehouses and the road network with land use and population.

From the Geoprocessing analysis, the model builder is used and modify the properties of the model from Raster analysis, adjust the cell size and processing extent to output the layers one size. After modifying the output measurements for the model, the Arc toolbox is used the spatial analyst tool, and of which the first tool that will be used in the model is the Euclidean Distance twice, once for the current warehouse layer and once for the road network layer to extract a distance map and proximity to warehouses and from the road network as in the following
The next step for the model is to use the classify tool to arrange and classify the previous two layers, and after the output, the Weighted Overlay tool is used, and with this step, the other inputs are called (the land-use layer and the population layer) and from the properties of the tool, the inputs are classified in terms of importance and priority to extract the best place to set up a warehouse. Figure 6 shows distribution of land use types around Baghdad, the areas show the highest percentage for the agricultural areas. Table 2 shows the land uses for the city of Baghdad and based on its importance to choose a suitable site for the construction of new warehouses. The most suitable for establishing a warehouse is an open space, then the commercial areas, and then the areas closest to the roads, and they are sequenced as in table 2. The road and population layer is formed near the highest scale and the farther the scale is least. While the current warehouse layer is the farthest the highest scale and the closest is the least scale, then a work run.

**Figure 5.** (a) the distance from the road network, (b) the distance from the existing warehouses.
Figure 6. Landuse for Baghdad city.

Table 2. The scale of Landuse Criteria

| Land use       | Scale |
|----------------|-------|
| Open Space     | 9     |
| Commercial     | 8     |
| Road Network   | 7     |
| Other          | 6     |
| Industrial     | 5     |
| Transport      | 4     |
| Development    | 3     |
| Public Facilities | 2 |
| Public Utilities | 1 |
| Residential    | Restricted |
| Agriculture    | Restricted |

* Evaluation Scale = 9

As shown in Table 3, for determining the weights of each criteria entering the model, the results were taken from (Google Form) questionnaire that was answered by the decision-makers, and the results were analyzed using the AHP method, and from it, the weights of the criteria’s that entered the
Weighted overlay step in the model analysis were obtained, as shown in table 3. After running the model and producing a weighted overlay map. A weighted map appears in Figure 7 which identified the appropriate areas for the containers that showed many areas, these areas should be reduced with more conditions to determine more precisely the appropriate place.

| Criteria                | Weighted |
|-------------------------|----------|
| Landuse                 | 43       |
| Population              | 18       |
| Current Warehouse       | 20       |
| Road Network            | 19       |

**Figure 7.** A map showing the suitable areas for establishing a warehouse.

The red areas show the appropriate areas that are most needed to establish warehouses, but these large areas need to be reduced and more specific areas defined, so additional steps are taken using other tools (Condition, Majority Filter).

The conditioning tool determines the higher suitable places with a value of 8 from the suitable areas that were extracted from the previous step to produce a map with more accurate and high suitability.
locations. Finally, the Majority Filter tool, the input raster is the conditioning layer to filter places to get the result as shown in figure 8.

![Map showing suitable places to establish warehouses](image)

**Figure 8.** A map showing the suitable places to establish warehouses.

The blue places appear to be the most suitable for establishing warehouses, and the blue areas on the northern side are best suited in the Rashidiya area of the city of Sha'ab near the entrance to Radwaniyah, where this area is characterized by large areas and is predominantly decertified, as for the northern region, which is located near the tourist island of Baghdad and is called the Fahama area. Where it is suitable for establishing dumping warehouses in it to help reduce traffic momentum at Taji entrance.

From the east, the Al-Obaidi area was the best place to establish a warehouse towards the entrance to Khan Bani Saad.

From the south-west side of Baghdad, it was the most appropriate place to establish a warehouse on the banks of the Tigris River in the Zafaraniya area near the Jisr Diyala entrance. Hor Rajab is the most suitable area for establishing warehouses on the southeastern side of Baghdad, where the area is agricultural and that is largely empty spaces and trucks that enter from the southern entrance, the Yusifiya entrance, and the western entrance, Abu Ghraib.

As for in central Baghdad, suitable places are distributed to establish warehouses on Um Al-Khanazeer Island, which is located near the city of Al-Jadriya, where the area is characterized by large areas, and this area is also connected to the state's security zone (the green zone), where goods are entered from the entrance to the island and then to the green zone.

As for the rest of the blue places distributed inside Baghdad, they are of equal distribution, as it includes the Al-Amel and Al-Alam neighborhoods from the south-west and northwest from the Al-Ghazaliya and Al-Shuala areas, while the northeastern is Al-Obaidi, Al-Fadhiiya, and Al-Mashtal, the areas that are along the Army Channel.
7. Conclusions

- The most appropriate location for establishing new warehouses is to provide places far from the traffic crowds within the city. The sites were distributed in empty and open spaces, and they were completely distributed over the entire city of Baghdad to cover the entire network such as (near the entrances to the city and near Umm Al-Pigs Island and the tourist island of Baghdad). The proposed warehouses contribute to finding solutions for road users and especially (truck drivers) by facilitating the arrival of goods distributed on a larger scale to include the entire city.

- The results of the analysis of this study will aid the decision-makers to better understand truck freight transportation activities to implement the correct decision to solve current problems.

8. Recommendation

- Determine special hours for entering cargo vehicles for unloading in warehouses to reduce their impact on the traffic momentum of the city.

- Acting by the principle of (transport exchange), whereby goods are unloaded in warehouses and transferred to smaller vehicles for ease of movement during the peak hours of the transport network, especially the morning work hours.

- Regular maintenance of entrances, as it contributes to the rise in the service of entry and exit from the city.

- Determine the evening period for the entry of freight vehicles into warehouses to reduce their impact on the transport network.

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