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GIS Based Multi Criteria Dicesion Analysis for Industrial Site Selection in Al-Nasiriyah City in Iraq

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Abstract— Site selection is one of the primary decisions in the start-up process and town planning, development or relocation of industries of all kinds. Building of a new industrial system is related with long term investment, and in this sense planning the site are a significant point on the road to progress or failure of the industrial system and that effect on all other services in the city. One of the main objectives in industrial site selection is finding the most suitable site with required conditions. A large number of researchers depend on GIS because the availability and its wide uses in site selection. GIS is a combination with other systems and methods such as the method for multi-criteria decision making (MCDM). Multi-criteria decision analysis (MCDA) techniques can be used below such conditions to classify and rank options for subsequent complete evaluation, or to specify acceptable from unacceptable potentiality for many sites. Analytical Hierarchy Process (AHP) can beneficially be used for assigning weights to various criteria in MCDA. The aim of the present study is to develop a methodology to use GIS and MCDA for a new industrial site in Al-Nasiriyah city. In this paper, we will try to find optimum solution for industrial estates site selection and applying solution in GIS

Index Terms— Multi criteria Decision Analysis MCDA, Geographic Information System GIS, Industrial site selection, AHP, Iraq

1 Introduction

Urban development is always concurrently with industrial progress. Notwithstanding the important purpose of industries in employment and economic issues, they have large impacts on environmental pollution. Making decisions on location for industries is a principal aspect of strategic and logistical decision-making for manufacturers Location decision making must study a wide series of factors in order to regulate socioeconomic benefits and environmental sustainability. Site selection can be defined as the process of finding the best sites for a project establishment depending on socioeconomic and environmental criteria. (K. Eldrandaly, 2013). Principally in developing countries or big cities, a number of directors took the initial step of creating special regions for industry, essentially to isolate them from heavily populated or affected areas. Government agencies, in charge of regulating the industry site selection commenced considering the inclusion of environmental criteria in the selection process as a measure to lessen potential environmental impacts to local communities. In the past, site selection was based almost purely on commercial and technical criteria. Today, a higher degree of refinement is expected. Selection criteria must also meet a number of social and environmental elements, which are enforced by law and government regulations (Aleksandar Rikalovic, Ilija Cosic and Djordje Lazarevic, 2013). GIS is an efficacious tool for the management and analysis of data required for any land development activity (Manish KUMAR1, Vivekananda BISWAS1, 2013). Such GIS system has the ability of display needed in the context of decision making. A set of tools has been used to manage the proper site for a city improvement facility, including Geographic Information Systems (GIS), and Multi-Criteria Decision Making (MCDM) techniques (Zahra Nazeri, Javad Mirzaee, AliRostami, 2014). To determine the most suitable industrial site, one of the MCE techniques is called Analytical Hierarchy Process (AHP) was combined with a GIS to examine twenty criteria are Distance from Highways , Distance from Settlements Areas ,Other Roads ,Airport Villages , Railway , River , Forest Plain , Slop ,Landfill site , Heritage site ,Oil pipes. The relative importance weights of criteria were estimated using AHP and criteria maps were developed by using GIS spatial operations. A Final suitability map was generated which shows suitability for the location of the industrial site (Anurag O, P. Kumar S. and Priyanka K. S., 2010).

2 Study Area

Al-Nasiriyah is a city in Iraq located to the east of ThiQar governorate. It is on the Euphrates River. About 225 miles (370 km) southeast of Baghdad, near the ruins of the ancient city of Ur. According to the 1987 census, the city had a population of 265,937. The population in 2014 was 560,968. (Figure 1)

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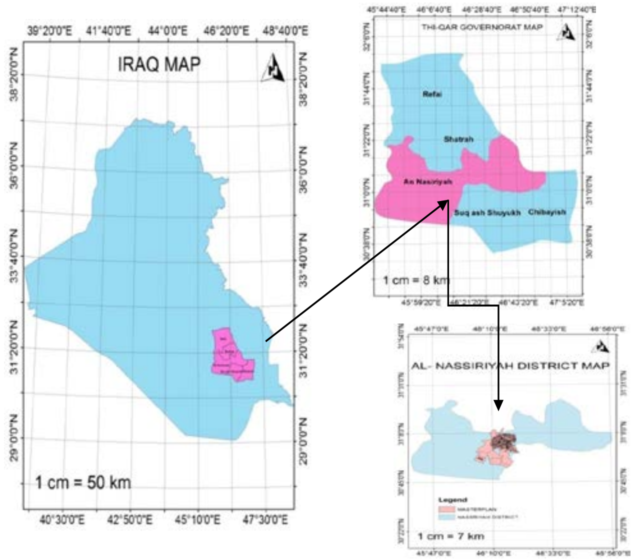

Fig. 1: study area Iraq map, ThiQar map, and Al-Nasiriyah map

3 DATA RESOURCES AND METHODOLOGY

The criteria of industrial site selection in Al-Nasiriyah city was identified from department guideline for Nasiriyah municipality (http://www.thiqarpc.gov.iq/), guideline from the department of Environment (http://thiqar.gov.iq/), and Local guidelines of Town and Country Planning (http://www.thiqarpc.gov.iq/). To identify the best industrial site, we used twelve criteria. The used criteria were Urban centers, Land use, Surface Water Rivers, Natural Resource, Heritage sites, Airports, Oil Pipes, Highways, Railways, network Roads, Slope and landfill site [Table 1]. We used GIS and MCDA to select a new industrial site. For imaging and analysis of spatial data, ARCGIS 10.1 software from (http://www.esri.com/) is used. Many GIS analysis tools used in the study such as buffer zoning, Euclidean distance, reclassify and overlay analysis. In order to evaluate the site selection, MODEL BUILDER technique designed to display all tools used and to explain the result of each tool until display final results. MCDA used to measure the relative importance weights for individual evaluation criteria (JOSHUA *et al*., 2013; Bakhtiar Feizizadeh *et al*., 2014). MCDA dividing the decision problems into smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner. Analytical Hierarchy Process (AHP) can beneficially be used for assigning weights to various criteria [Table 2].

Criteria	Reasons and zoons
Urban	Prevent the negative impact on the environment and its public health (Anurag O, P. Kumar S. and Priyanka K. S., 2010). Distance of at least 500-2000mfrom urban
landfill site	The industrial site may include Industries cannot tolerate any contamination rate. (M. A. Alanbari, N. Al-Ansari, Hadeel K. J. and Sven K., 2014). Distance of at least 2-5 km
Heritage site	To protect , preserve heritage of the surrounding areas of the cities heritage candidate to enter the tourism development.(MohamedR.Bualhamam,2 (Baqer Al-Ramadan and Yusuf Aina. ,2002). Distance of at least 5 km
Airport site	Prevent the negative impact on the airport environment (Dano Umar Lawal , 2011). Distance between 7 - 12 km to the airport site boundary
Rivers	Industry must be located at some safe distance from river and other water bodies Waste water from industry is one of the major sources of pollution in river (P. Negi and K. Jain 2008). Distance of at least 1000m
roads network	Cost of raw material transportation, finished goods transportation etc. is dependent on the proximity to transportation facility. Transportation network bears the greatest importance in the site selection process. (H. Ebadi, R. et al, 2014). All roads and the areas within 1500 m of them are considered unsuitable
Slope	Slope relates to the variability of the ground surface and gives an idea if the pollutant will run off or remain on the surface in one area long enough to infiltrate. The area with low slope leads to retaining water longer. This allows greater Infiltration of recharge water and greater potential for contaminant migration. Area with steep slopes having large amount of runoff and smaller amount of infiltration.(Anurag O, P. Kumar S. and Priyanka K. S., 2010). (Strong (1988) considered land less than 2% slope for industrial site selection, as greater slope will require digging or filling for site preparation.)
Natural resources	The preservation of biodiversity is essential for the sustainable development and stay away from these areas and maintain a clean environment

	(N. Eldin1et al, 2013). Distance of at least 2000m
Railways	Rail is used only 25 % for industrial purposes. Therefore Railways are given less importance than other mode of transportation (Agrawal M.L. and Dikshit A.K., 2002). Distance of at least 100-500m
Land use	Undersigned, in boundary, open space and free lands is preferable (N. Eldin1et al ,2013). The master plan boundary.
Oil pipes	Sensitive area and incombustible (M. A. Alanbari, N. Al-Ansari, Hadeel K. J. and Sven K., 2014). Distance of at least 1000-1500 m
highway	The highways are used 75% of the time for industrial purposes. Therefore highways are given more importance than other mode of transportation (Agrawal M.L. and Dikshit A.K., 2002). All roads and the areas within 1500 m of them are considered unsuitable.

Tabl1: used criteria

Intensity of importance	Description	Suitability class
1	Equal importance	Lowest suitability
2	Equal to moderate importance	Very low suitability
3	Moderate importance	Low suitability
4	Moderate to strong importance	Moderately low suitability
5	Strong importance	Moderate suitability
6	Strong to very strong importance	Moderate high suitability
7	Very strong importance	High suitability
8	Very to extremely strong importance	Very high suitability
9	Extremely importance	Highest suitability

Tabl2: used criteria

1.1 Criteria Weights

The Analytical Hierarchy Process - AHP is one of the multiple criteria decision-making techniques that were basically developed by Prof. Thomas L. Saaty (1977). AHP presents measures of judgment consistency to derive priorities among criteria and alternatives finally; AHP simplifies preference ratings among decision criteria. AHP steps are shown in the following steps.

A- Pair wise comparison matrix formation

The AHP is considered to be an sufficient mathematical method for analyzing complex decisional problems (Jacek Malczewski, 2004). It determines the weights by comparing the relative importance of the criteria in a pair wise manner through a pair-wise comparison matrix [Table 3].

Table 3: Pair-wise comparison matrix

Cr	Ur	Lu	Sw	Nr	Hs	Ai	Ro	Rw	Si	Oi	Hw	Lf
Ur	1	2	3	3	4	4	5	5	6	7	7	8
Lu	0.5	1	2	3	3	4	4	5	5	6	7	7
Sw	0.33	0.5	1	2	3	3	4	4	5	5	6	7
Nr	0.33	0.33	0.5	1	2	3	3	4	4	5	5	6
Hs	0.25	0.33	0.33	0.5	1	2	3	3	4	4	5	5
Ai	0.25	0.25	0.33	0.33	0.5	1	2	3	3	4	4	5
Ro	0.2	0.25	0.25	0.33	0.33	0.5	1	2	3	3	4	4
Rw	0.2	0.2	0.25	0.25	0.33	0.3	0.5	1	2	3	3	4
Si	0.16	0.2	0.2	0.25	0.25	0.3	0.3	0.5	1	2	3	3
Oi	0.14	0.16	0.2	0.2	0.25	0.2	0.3	0.3	0.5	1	2	3
Hw	0.14	0.14	0.16	0.2	0.25	0.2	0.2	0.3	0.3	0.5	1	2
Lf	0.12	0.14	0.14	0.16	0.2	0.2	0.2	0.2	0.3	0.3	0.5	1

In [Table 3] , Cr : criteria , Ur: Urban centers, Lu: Landuse ,Sw: Surface water, Nr: Natural Resource, Hi, Heritage Ai: Airports, Ro: Roads ,Ra: Railways, Sl: slope, Oi: Oil pipes, Hw: High way, Lf: Land fill which represent all criteria used in study.

B- Computation of the criterion weights

After the formation of pair-wise comparison matrix, computation of the criterion weights has been done. The computation involves the following operations:

- Finding the sum of the values in each column of the pair-wise comparison matrix.
- Division of each element in the matrix by its column total (the resulting matrix is referred to as normalized pair-wise comparison matrix).
- Computation of average of elements in each ow of the normalized matrix, i.e. dividing the sum of normalized scores of each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared. It should be noted that for preventing bias thought criteria weighting the consistency ratio (CR) was used (Cay and Uyan, 2013)

C- Estimation of the consistency ratio

The next step is to calculate a consistency ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments. The AHP deals with consistency explicitly because in making paired comparisons, just as in thinking, people do not have the intrinsic logical ability to always be consistent for estimating consistency; it involves the following operations (W. Lai, LI H.L., LIU Q., CHEN J. and CUI Y., 2011):

- Determination of the weighted sum vector by multiplying matrix of comparisons on the right by the vector of priorities to get a new column vector. Then divide first component of new column vector by the first component of priorities vector, the second component of new column vector by the second component of priorities vector, and so on. Finally, sum these values over the rows.
- Determination of consistency vector by dividing the weighted sum vector by the criterion weights. Once the consistency vector is calculated it is required to compute values for two more terms, i.e. lambda (λ) and the consistency index (CI). The value for lambda is simply the average value of the consistency vector. The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive, reciprocal matrices and λ = n, if the pair-wise comparison matrix is consistent matrix. Accordingly, λ-n can be considered as a measure of the degree of inconsistency in this study Lambda (λ) = 13.5. CI measure can be normalized by using equation (1):
  $$CI = (\lambda - n) / (n - 1) \quad (1)$$
- The term CI, referred to as consistency index, provides a measure of departure from consistency. To determine the goodness of C.I., the analytical hierarchy process compares it by random index (R.I.) from Table [4] and the result is what we call consistency ratio (C.R.), which can be defined by using equation(2) :
  $$CR = CI/RI \quad (2)$$
- Random index is the consistency index of a randomly generated pair-wise comparison matrix of order 1 to 10 obtained by approximating random indices .The obtained the value of RI=1.51, then we use equation (1) to calculate CI (CI = 0.136). By apply equation (2) we calculate the Consistency ratio (CR): CR= 0.09 <0.10

Table 4: Random index table

Order Matrix	R.I.	Order Matrix	R.I.
1	0.0	6	1.24
2	0.0	7	1.32
3	0.58	8	1.41
4	0.9	9	1.45
5	0.12	10	1.49

CR indicated a reasonable level of consistency in the pair wise comparisons. Therefore, the values obtained satisfy the noted conditions, which denote that the weights obtained are agreeable. As explain in Table [5] the final resulting weights for the used criteria. These weights will used in MCDA to select the best industrial site

Table 5: Final resulting weights

Criteria	weights
Urban Area	**0.20**
Basic master	**0.172**
River	**0.15**
Natural recourse	**0.110**
Heritage	**0.084**
Airport	**0.07**
Roads	**0.051**
Railway	**0.031**
Slop	**0.032**
Oil pipes	**0.04**
Highway	**0.04**
Landfill	**0.03**

1.2 Analysis Techniques

In this study we used Many tools and analysis techniques to implements MCDA and to select the best industrial site The process passed in the following analysis (Chattopadhyay et al., 2009).

A- Euclidean distance analysis

The Euclidean distance tools describe each cell's relationship to a source or a set of sources based on the straight-line distance. The outcome of this tool is raster map include specific number of areas classes depend on its distance from known feature .Euclidean distance calculated from the center of the source cell to the center of each of the surrounding cells. True Euclidean distance calculated in each of the distance tools. Conceptually, the Euclidean algorithm works as follows: for each cell, the distance to each source cell is determined by calculating the hypotenuse with x_max and y_max as the other two legs of the triangle (figure 3). This calculation derives the true Euclidean distance, rather than the cell distance. The shortest distance to a source is determined, and if it is less than the specified maximum distance, the value assigned to the cell location on the output raster. After entering all the layers used to select the best location for the establishment a landfill in the study area in Euclidean distance analysis we will get the maps shown in (Figure 4a and 4b). Each raster map divided into many areas depends on distance. The use of yellow color to encode the nearby area and the blue color-coded remote region.

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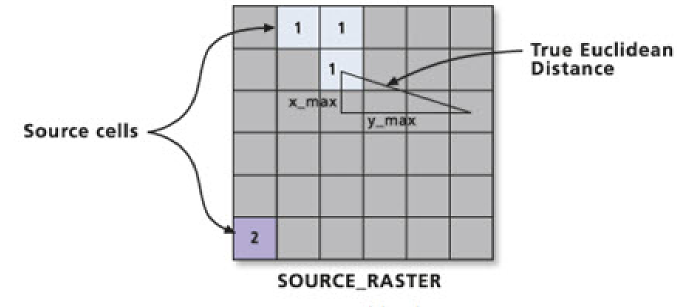


Figure 3: Euclidean distance algorithm

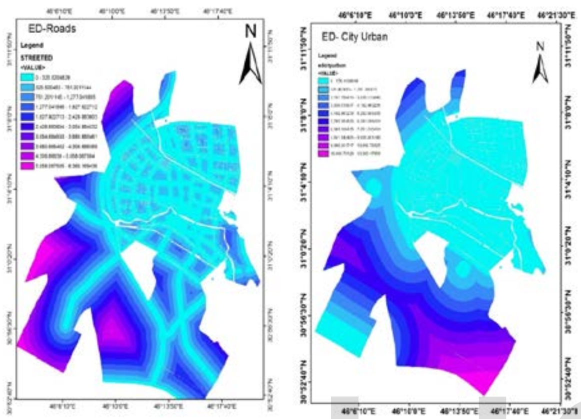
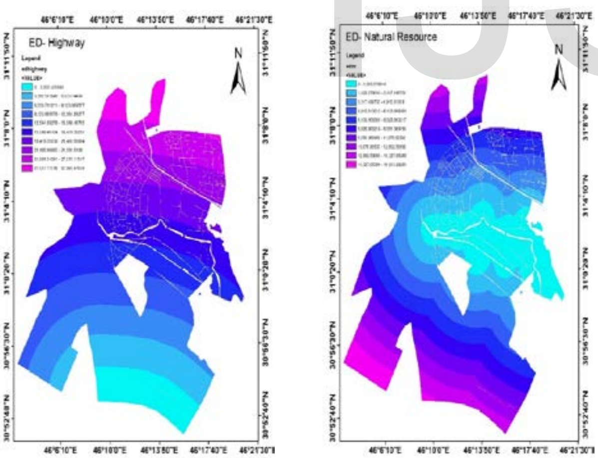


Figure 4a: Euclidean distance analysis result maps



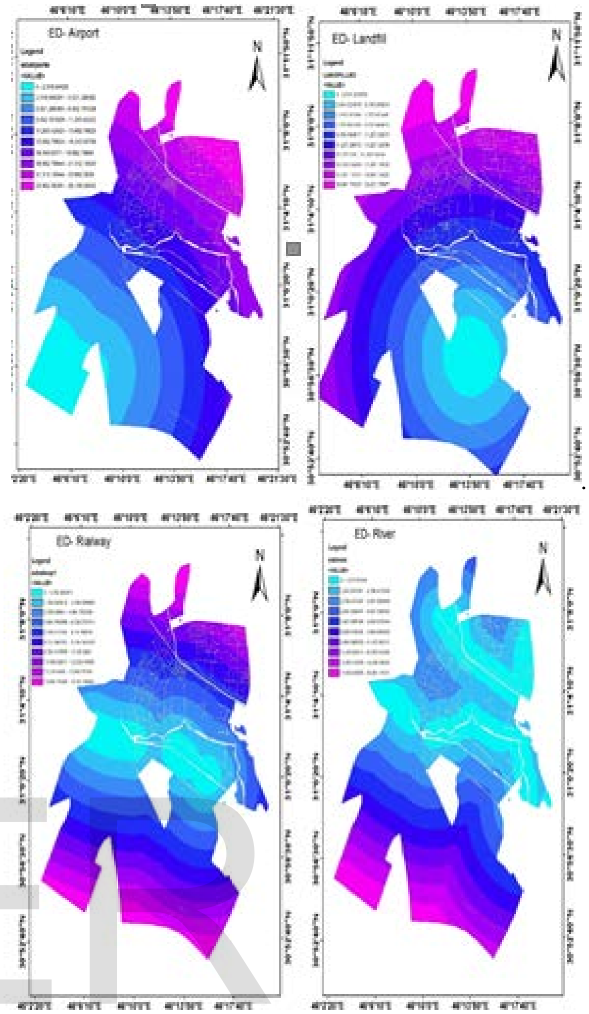


Figure 4b: Euclidean distance analysis result maps

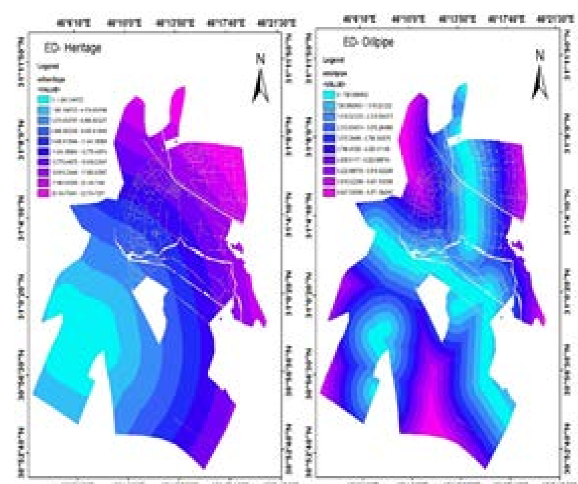


Figure 4c: Euclidean distance analysis result maps

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B- Reclassify analysis

Slices or reclassifies the range of values of the input cells into zones of equal interval, equal area, or by natural breaks. Slice works best on data that is normally distributed. When using input raster data that is skewed the output, result may not contain all of the classes that you had expected or specified. (Figure5a and 5b) explain the output of this tool for each layer used.

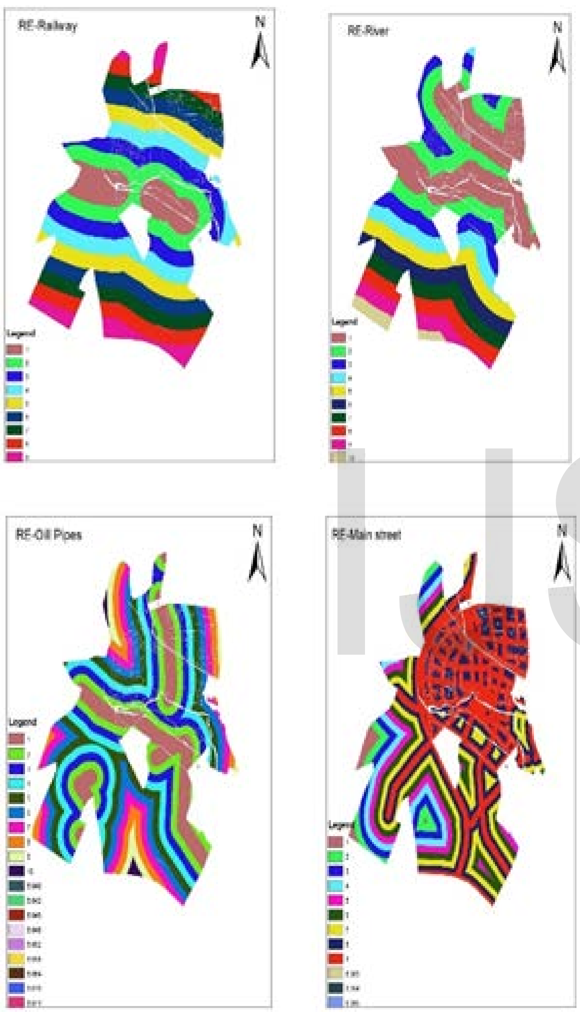

Figure 5a: Reclassify analysis result maps

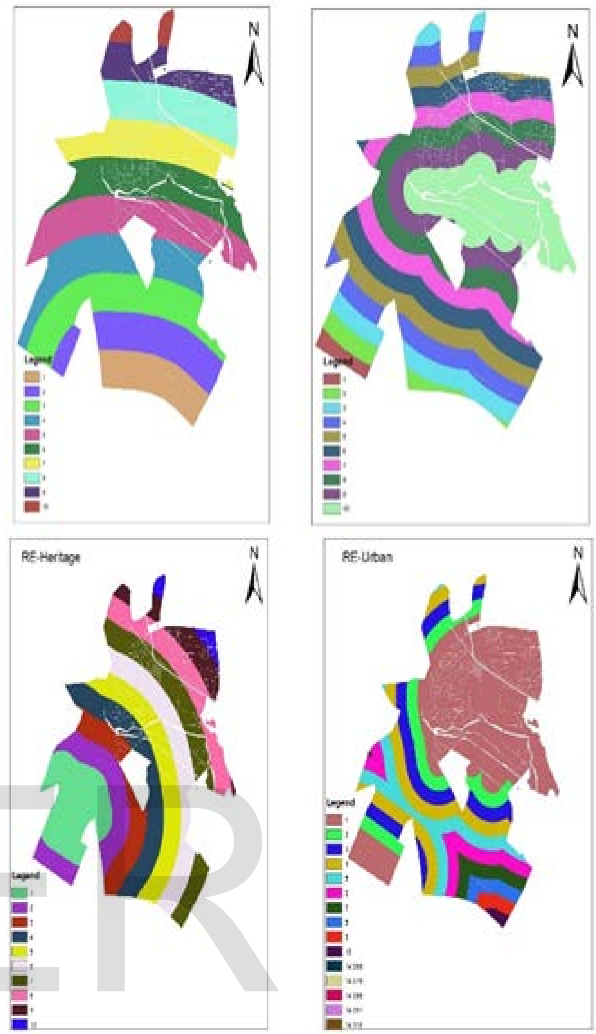

Figure 5b: Reclassify analysis result maps

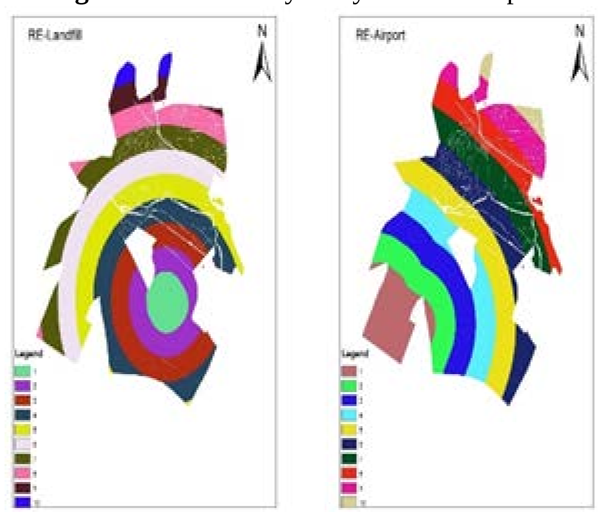

Figure 5c: Reclassify analysis result maps

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C- Surface analysis

Spatial analysis tool used to convert DEM map to SLOPE raster map to indicate situation of study area. A slope used as criterion as shown in Table 1.

D- Weighted overlay analysis

Spatial analyst tool from used to overlays several rasters using a common measurement scale and weights each according to its importance (figure 6) explain the illustration of this analysis

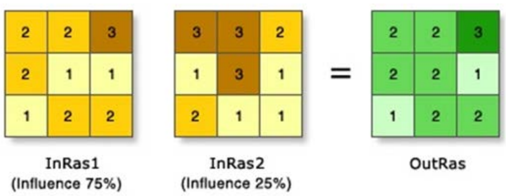

Figure (6): overlay analysis illustration.

E- Model builder technique

Through this technique, which collects all analyzes used in a special environment. As shown in (figure 7) we can get the result on the outcome of the study. After applying all these analyzes on the layers used to determine the best location for the establishment of an industrial site we get the result of the analysis to get the final map. In (figure 7) , Blue ellipse represents layers (criteria) used in study, (Eculid.D) is Euclidean distance analysis stage, (Reclass. A) is reclassify analysis stage and finally, the outcome of these stages were used as inputs for overlay analysis stage which give us the results.

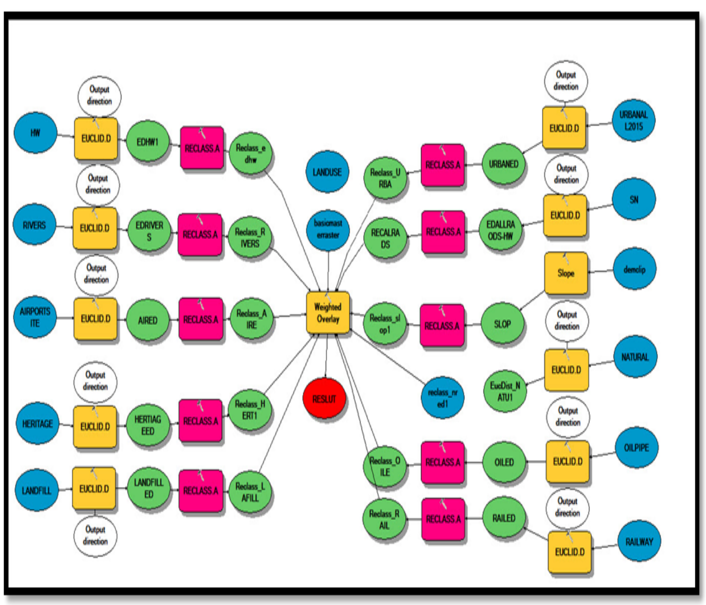

Figure (7): the study model builder.

2. Results

After apply all analysis described above, we get the result map which shown in (figure 8). Each pixel in final map of the study area has a degree from 1 to 10 with special color varies from dark red to dark green. The dark green represents the suitable sites and dark red represent unsuitable sites. (Figure 9) shows the final result map statistics percentages.

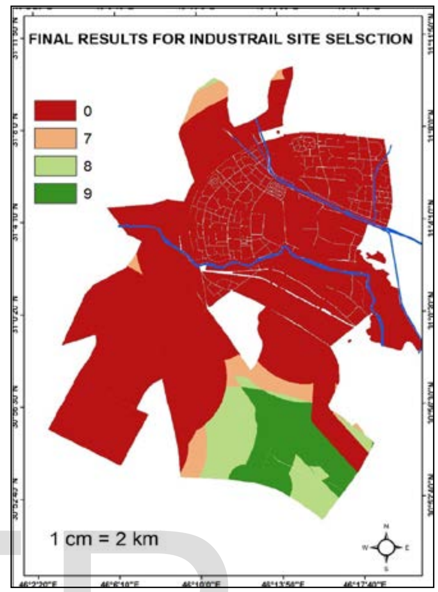

Figure (8): final result map.

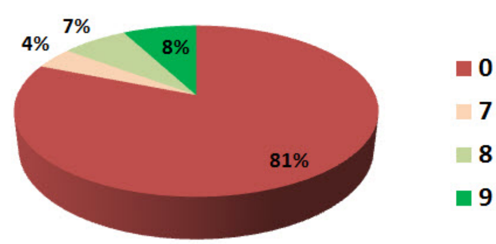

Figure (9): final result percentages.

3. Discussion and conclusions

The result of the study shows that any increasing in the used criteria leads to decrease the suitable area also, leads to the best selection. The criteria which represent a real challenge will take the high weights, therefore, affecting on the final result. 81% from total area of Al-Nasiriyah city is unsuitable to select as industrial site while only 19% from total area is suitable. The GIS-based multi-criteria technique is very clear and flexible which can be used to analyze the potential sites for urban development in Al-Nasiriyah city. The model used can also help public participation in the urban decision-making process and support various planners and authorities to formulate suitable sites. The developed model permit us to make a decision and select the needed site in specific steps, with produce alternatives and assessment of alternatives using GIS and MCDM methods based on AHP analysis for industrial site selection. Optimizing the number of criteria and alternatives, standardization of criterion scores and making suitability map for each criterion gives us the opportunity to observe each criterion individually and together through final suitability map after overlay analysis tool. Suitability maps as methods for visualization problem providing by GIS and MCDA, which processes images much faster than classical methods. Finally, we notice that GIS and MCDA give good solutions for site selection problems and town planning

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