THE SELECTION OF OPTIMUM ROAD PATH USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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ABSTRACT
In this research a modern scientific procedure was used utilizing geographic information system GIS in selecting the optimum road path between two cities . All the programming facilities offered by ArcView GIS software with its extensions of spatial analysis and 3D analysis to solve the problem .The solution take a form of geographic map graduated in colors from best to bad portion of land that the suggested road could pass through.
The proposed procedure was checked by conventional mathematical solution used in such problems and the results were both agreed.

الخلاصة

في هذا البحث تم طرح أسلوب علمي حديث بالاستفادة من استخدام منظومة المعلومات الجغرافية GIS في اختيار أفضل مسار لطريق مقترح بين مدينتين وذلك باستخدام كل الإمكانيات البرمجية التي يوفرها برنامج Arc View GIS بملحقاته المتعلقة بإجراء التحليل المكاني والثلاثي لحل المسالة حيث يتم إنتاج خارطة جغرافية متدرجة لونيا من الأفضل إلى الأسوء التي يمكن أن يمر فيها الطريق المقترح, وقد تم التحقق من فعالية هذه الطريقة باستخدام الأساليب الرياضية التقليدية المتبعة في حل هكذا مسائل وكانت النتائج متوافقة.

KEYWORDS
TIN, GIS, 3D analyst, spatial analysis, model builder

INTRODUCTION

The problem of selecting and designing new roads between cities is considered a common problem in transportation engineering ,many papers presented in a try to solve the problem depending on many techniques like mathematics, optimization or/and logic.
In this paper a new technique is presented depending on the new computer technology which is known as model builder of geographic information system (GIS), the new method applied to real hilly Iraqi regions to construct new road between sulaymaniya province and qala desi district and the results were very promising, effective and successful.

SPATIAL MODEL IN GIS

In general terms, a spatial model is a representation of reality .The purpose of a model is to help you understand, describe, or predict how things work in the real world. By representing only those

factors that are important to some study, a model creates simplified, manageable view of the real world.

Geographic information systems (GIS) have not only made it easy to process, analyze and combine spatial data, but they have also made it easy to organize and integrate spatial processes into larger systems that model the real world. However, the more complex a spatial model becomes, the more difficult it is to keep track of the various datasets, processing procedures, parameters, and assumptions that you have used, and that was the reason to use ArcView ModelBuilder which is a technology from Environmental System Research Institute, Inc. (ESRI) that helps to create and manage spatial models that are automated and self – documenting. A spatial model in ModelBuilder is easy to build, run, save, modify, and share with others.

In ModelBuilder, a spatial model is represented as a diagram that looks like a flowchart **Fig (1)**. It has nodes that represent each component of a spatial process. Rectangles represent the input data, ovals represent functions that process the input data that is created when the model is run. The nodes are connected by arrows the shows the sequence of processing in the model.

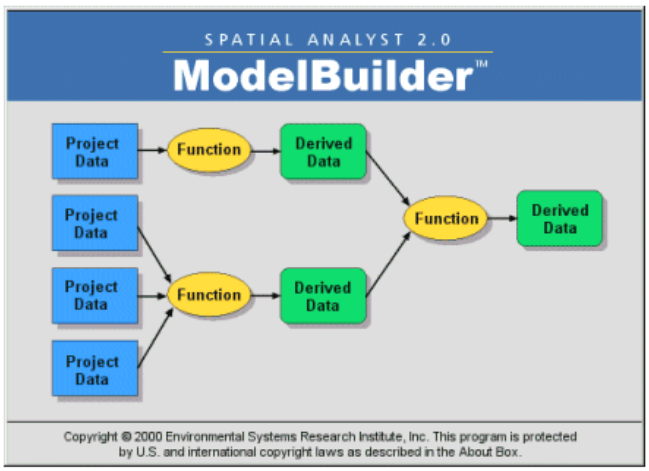


Fig. (1)

CASE STUDY

To explain the proposed method it was decided to select a case study to design a new road between sulaymaniya province and qala desi district northern Iraq due to the availability of topographic maps and the hilly nature of the region.

From the existed topographic maps and by scanning techniques the map of the whole region were recreated by AutoCAD and then converted to shape files by the ArcView GIS. The surface model was created by TIN (triangulated irregular network) command through the use of ArcView *3D surface analyst* with all feature themes as shown in **Fig.(2)** and **Fig. (3)** below.

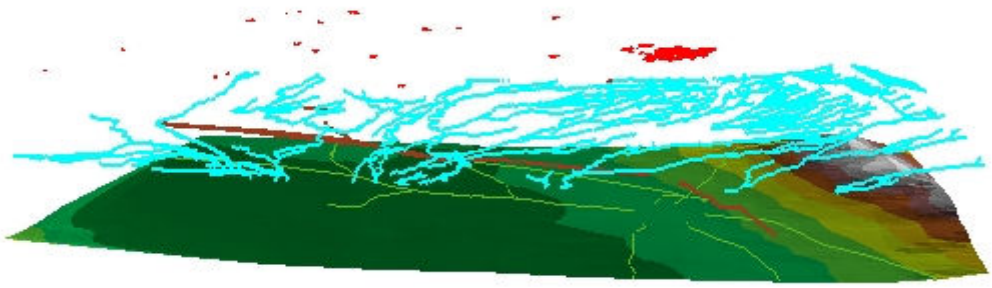


Fig. (2)

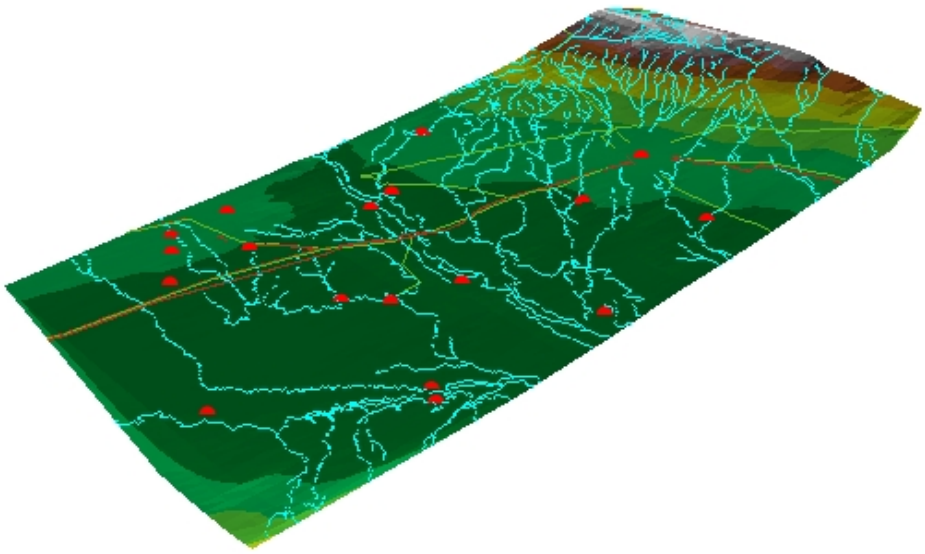


Fig. (3)

SPATIAL ANALYSIS

The GIS *spatial analysis* role is to select a suitable path for the new road by taking all possible constraints to establish the road in a way that gives the best results from economical and logical point of view, and also coincide with the national standards for designing highways.

The GIS *model builder* was used to arrange the spatial analysis for the problem and **Fig. (4)** illustrates the model that has been used in analyzing for the possible best road path.

The factors contribute in the model were slope of terrain, short path, existed forests or farms, cities, and existed roads or rivers .These factors were considered enough for theoretical study and many other factors like the soil types could be included in real practical problems.

The model below takes into account avoiding steep areas, farms, and rivers, also the model assign high weights for short paths, existed roads, and villages.

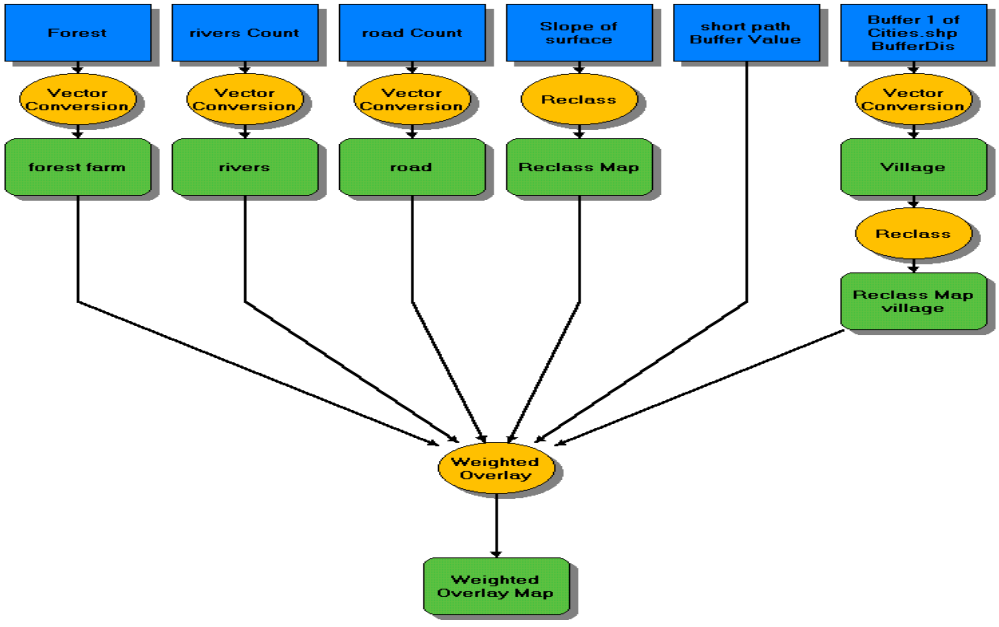


Fig.(4)

It is obvious from the model diagram above that a process of converting all the vector themes to grid themes is necessary to perform the analysis **Fig. (5)**

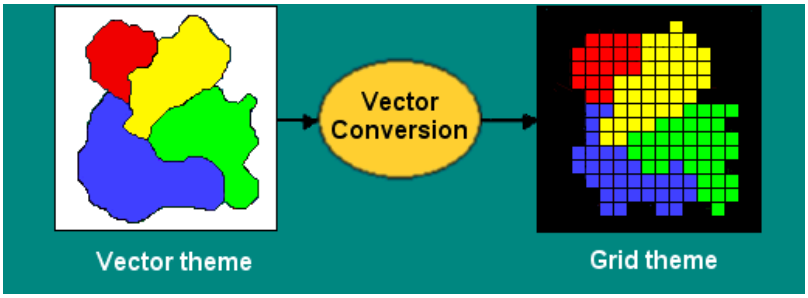


Fig. (5)

The buffering process in the model above is to create buffer zones around the short path between the two locations at some specific distance and around each city to assign that the proposed roads are preferred to be short, also pass through or near cities. **Fig. (6)** shows a part of the weighted overlay table that assigns different weights and scale values for each input theme to produce the final overlay map.

Weighted Overlay

Evaluation Scale | Overlay Table

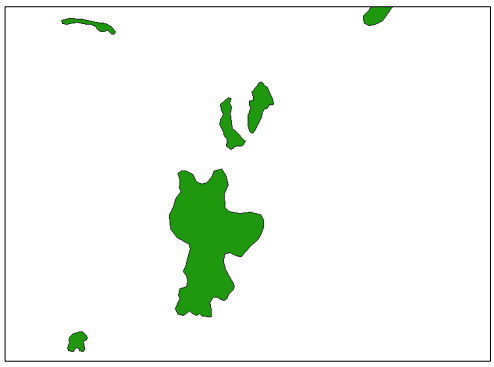
Define the weighted overlay table

Specify the Percent (%) Influence for each theme and a Scale Value for each input Field value. Scale Values will be multiplied by the % Influence value before they are added to other themes. To edit a % Influence value, click on it and type a new one. To edit a Scale Value, click on it, then use the dropdown list or type a value. Cells with a Restricted value are not added to other themes and retain the Restricted value in the output theme. To add a new input theme, click the Add Theme button. To delete an input theme, click on its name, then click the Delete Theme button.

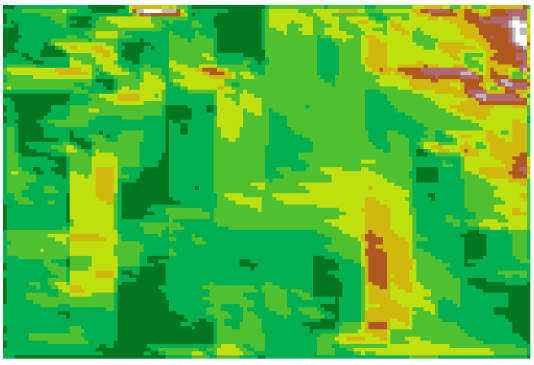
Input Theme	% Inf	Input Field	Input Label	Scale Value
forest farm	15	Value		
		1	1	1
		NODATA	No Data	9
rivers	15	Value		
		0	0	1
		NODATA	No Data	9
road	10	Value		
		0	0	8
		NODATA	No Data	1
Reclass Map	30	Value		
		1	0 - 0.6	9
		2	0.6 - 1.2	8
		3	1.2 - 1.8	7
		4	1.8 - 2.4	6
		5	2.4 - 3	5
		6	3 - 3.6	1
		7	3.6 - 4.2	1
		8	4.2 - 4.8	1
		9	4.8 - 5.4	1
		10	5.4 - 6	1
		NODATA	No Data	Restricted
short path Buffer	15	Value		
		1	1	9
		2	2	8
		3	3	7
		4	4	6
		5	5	5
		6	6	4
		7	7	3
		8	8	2

Fig. (6)

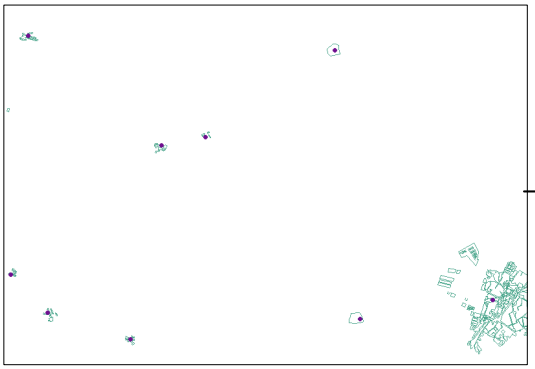
All the themes used in the analysis are shown in **Fig. (7)** below.



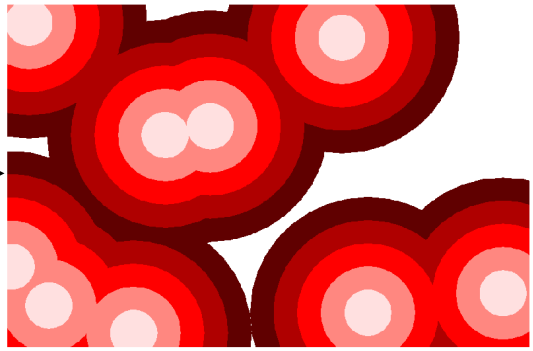
Farms or forests theme



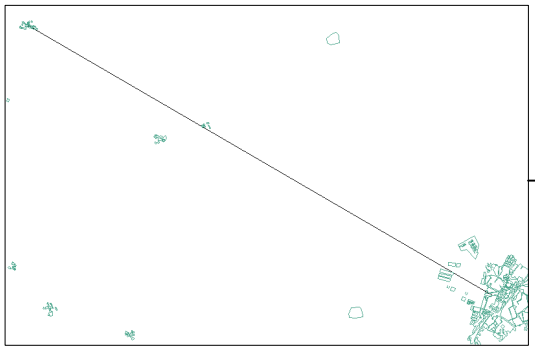
Slope of terrain theme



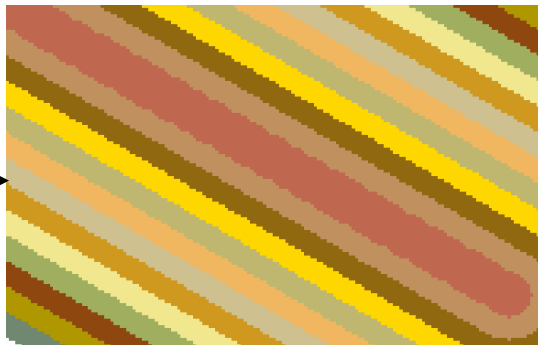
City, village theme



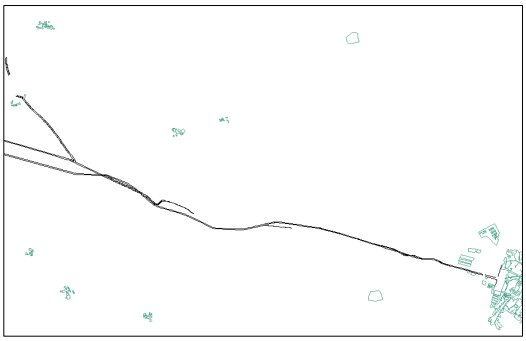
City buffer grid theme



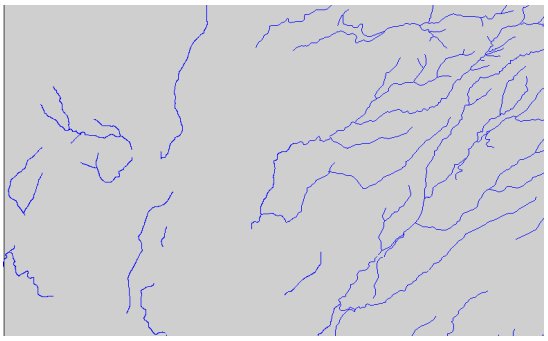
Short path theme



Short path buffer theme



Existed roads theme



Rivers theme

Fig.(7)

The result after analysis is a map showing the different colored regions classified from very good to bad portion of land representing the suitability for selecting the road path as in **Fig. (8)** .The light green areas were assigned very good, yellow areas assigned good, green areas were assigned middle, orange areas were assigned bad, and red areas were assigned too bad.

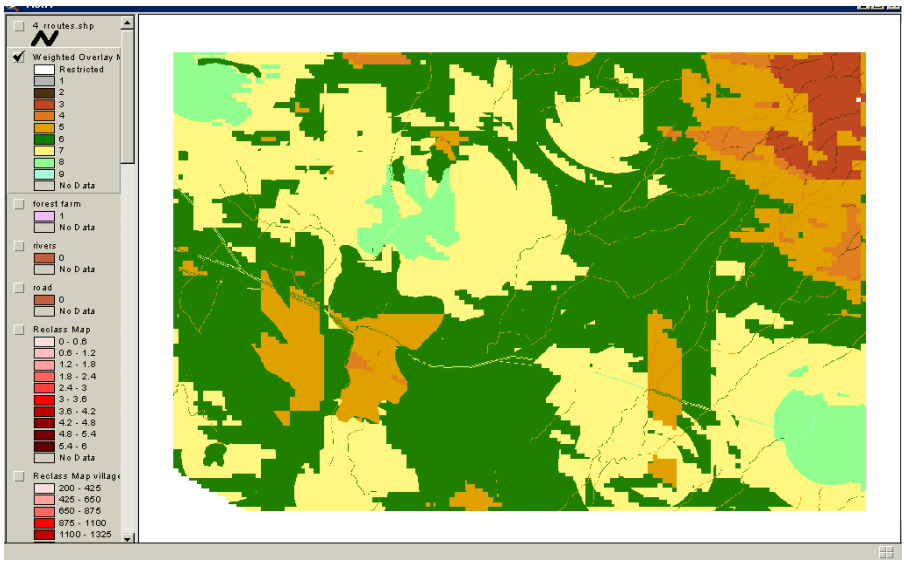


Fig. (8)

From the resulted weighted overlay map it could be decided to choose the optimum road path by carefully trying to design the path to pass through the colored areas that are indicated by good avoiding the bad one.

For verification goal it was decided to select four road paths labeled in red as illustrated in **Fig. (9);** the fourth road were selected carefully to pass through the best regions ,and according to the analysis map it must be the optimum road path, and that should be checked by conventional mathematical optimization techniques.

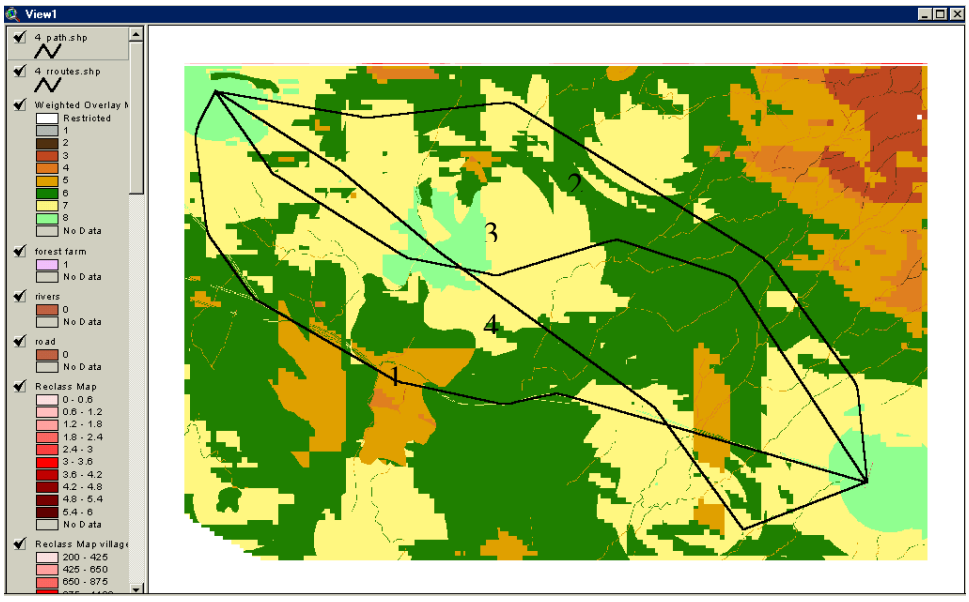


Fig. (9)

GEOMETRIC DESIGN OF PROPOSED ROADS

The next step is to geometrically design these suggested road paths including vertical and horizontal alignment, and then computing volumes which is an important factor in selection since it is proportional to cost, this is done by software like AutoDesk Survey, the resulted CAD drawings are then converted to shape files by ArcView GIS.

Profiles for these suggested paths could be also interpolated by ArcView GIS 3D analyst easily as shown in **Fig. (10)**

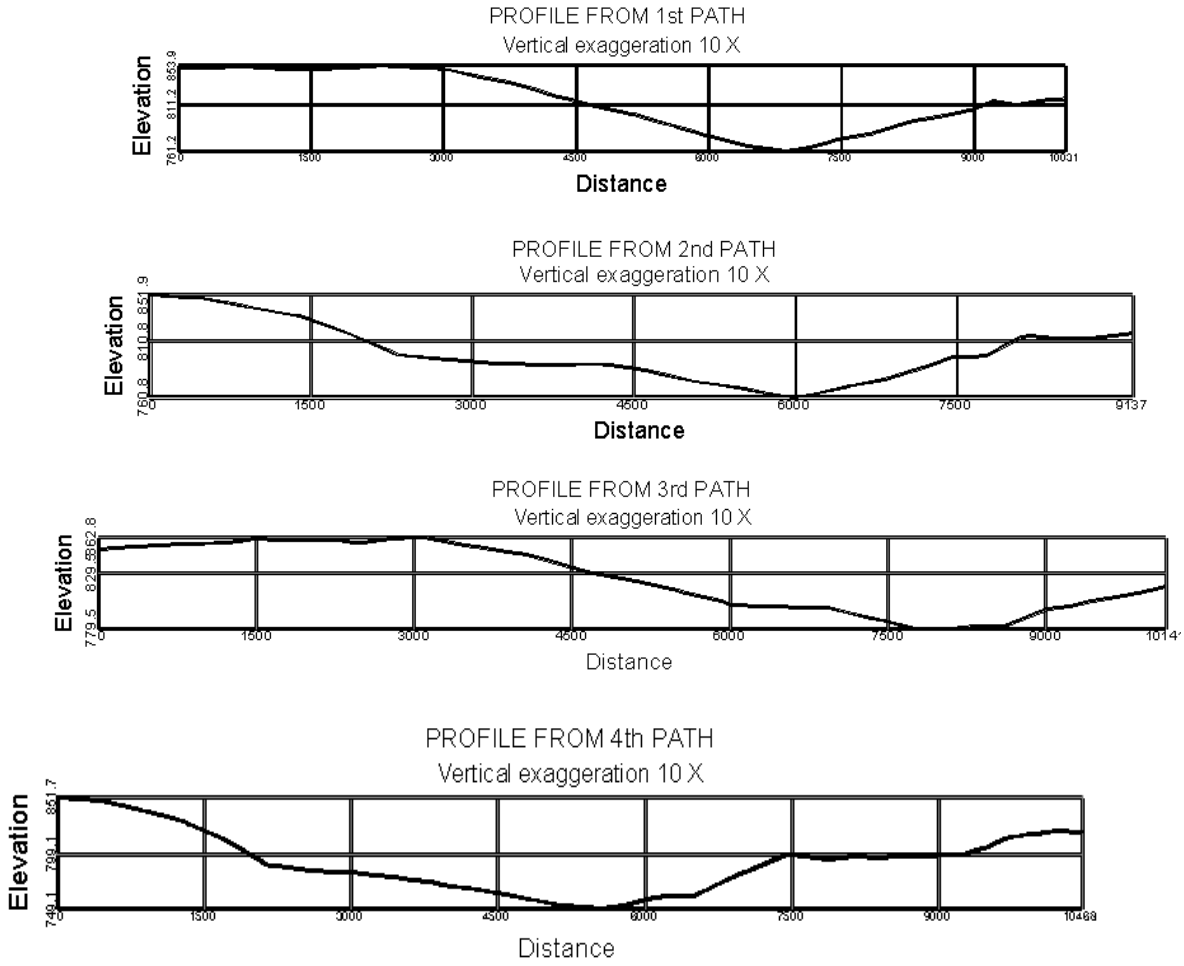


Fig. (10)

It was found that highway with two lanes **Fig. (11)** is the appropriate type for designing the four proposed roads in the presented problem, **Table (1)** illustrates the characteristics of two lane highways

Table (1) Highway Characteristics – Two Lane

CLASS			WIDTH (in meter)			
Letter symbol	**W (m)**	**Design speed(km/h)**	**a**	**v**	**c**	**e**
D2	9.5	70,60,50	3.00	0.25	1.25	0.25
***C2**	**11**	**80,70,60**	**3.50**	**0.25**	**1.25**	**0.50**
B2	12	80,70,60	3.50	0.25	1.75	0.50
A2	13.5	100,80,70	3.75	0.25	2.25	0.50

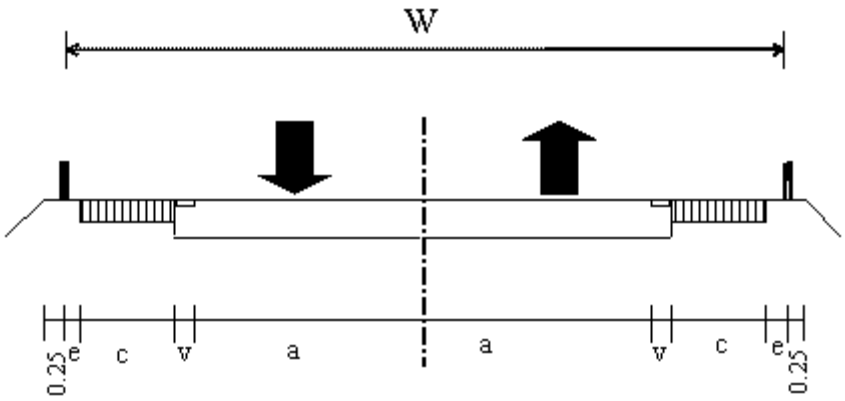


Fig. (11)

Where:-

W – Total width of highway.
a – Width of traffic lane.
c – Width of paved shoulder.
e – Width of unpaved shoulder.
c – Latter symbol of class
2 – Number of traffic lanes
v - Width of marginal strip

To prepare the road selection factors, it is necessary to study the designing elements for different classes of highways in different types of topography **Table (2)**.

Table (2) Design Elements for different classes

Class Of Highway		Type Of Topography								
		Flat			Rolling			Mountainous		
	Velocity	g	s(e)	r	g	s(e)	r	g	s(e)	r
D2	V	70			60			50		
		5	5.5	6.5	6.5	6.5	8.5	8	7	10
C2	V	80			70			60		
		4	5	6	5.5	6	7.5	7	6.5	8.5
B2	V	80			70			60		
		4	5	6	5.5	6	7.5	7	6.5	8.5
A2	V	100			80			70		
		3.5	4.5	5.5	4.5	5.5	6.5	5.5	6	7

MATHEMATICAL CHECK

The volumes, slopes, curves, lengths, population, bridges or culverts, and cities are all represents the important factors in selecting the final optimum road path and this is done by the usual mathematical techniques in transportation engineering**. Table 3** below explains these computed different factors for each suggested route and the final results.

Table (3) Road Selection Factors

Properties		The weights	First Suggested Path		Second Suggested Path		Third Suggested Path		Fourth Suggested Path	
			Properties	%	Properties	%	Properties	%	Properties	%
Length (km)		20%	10.5	18%	10.1	19%	10.0	19%	9.5	20%
NO. of horizontal curves		16%	6	10%	4	16%	5	13%	5	13%
No. of vertical curves		10%	13	5%	13	5%	10	7%	7	10%
Max. slop		8%	5%	5%	3%	8%	3%	8%	3%	8%
Cut Fill (m^3)	Cut(m^3)	13%	89345		132702		219273		206680	
	Fill(m^3)		87390		97907		148117		187223	
	Cut>fill 10%(fill)		93%	12%	123%	10%	135%	10%	100%	13%
No. of population		20%	21000	18%	20000	17%	19000	17%	23000	20%
No. of culverts		13%	9	9%	11	7%	10	8%	6	13%
Sum		100%		77 %		82 %		82 %		97 %

The final result shows that the fourth suggested road represents the optimum path with a success percent of 97%, and this result match the analysis map of **Fig. (8)**, the same results were obtained when using the method of *mini-max* in optimization

CONCLUSIONS

From the presented problem it was easy to conclude how a vital role the GIS analysis could play in selecting road paths, because of its effectiveness and its logical visual (geographic) solutions for such problems.

The weighted overlay analysis offered by the model builder technique is easy, logical, and flexible since it offers the facility to add new factors, change weights, scale values, and run the constructed model every time you need to get new solutions in a very short time.

It is also important to mention that GIS not only gives the solution for selecting optimum path, but also gives the geometric design that contains types of curves and the geographic coordinates necessary to set out the optimum road.

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