Chapter

Building an Integrated Database of Road Design Elements

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Abstract

The road network is the main artery within the city structure, which requires designing of routes and classification within the standards. Hence, the importance of this chapter, which will focus on the standards and design elements of the engineering design of road in terms of road type system, functional classification system, traffic volume system, number of traffic lane system, road width design, side slopes and elevations of road layers, super elevation, design speed, overtaking and stopping sight distance, longitudinal and cross sections of the road path, design elements of horizontal and vertical curves, and intersections. The Civil 3D Land Desktop, GIS programs, and remote sensing technology will be used to design the path of major highway linking two urban areas in Mosul (Northern Iraq), which will be considered a case study. The path of the road and its elements will be designed according to special criteria that are compatible with the topography and nature of the area. The geometric data of the road will then be exported with all the design elements to the GIS program to build an integrated road database. The database is capable of spatial analysis and connectivity with other parts of the road network in the city.

Keywords: GIS, spatial database, road design, Civil 3D, AASHTO

1. Introduction

Transport has now become an important factor in determining the housing and workplaces of the largest segment of society. Transport has thus become an essential element in determining land uses; it is not affected by land uses only but affects them. The transport activities directly or indirectly lead to the transfer of civilization and civil landmarks to the farthest points in the country, open to human societies' paths to flow of science and knowledge, improve the health and social conditions and enjoy the joys of life and nature, and expand the perceptions of these communities and openness to ensure stability and development. In light of this, the efficiency of the transport system and roads requires continuous planning and design for the road, especially with respect to the design of engineering elements of the road, in order to provide the movement of society and maintenance at an acceptable level.

The engineering design of the road is defined as the process of finding the engineering dimensions of each road and arranging the visual elements of the road such as the path, distances of sight and passing, width, slopes, curves, super elevation, and other engineering characteristics. The horizontal and vertical design elements of the road are considered the most important elements of road design because their minimum limits are the basic for the design speed and the ruling slopes.

The horizontal and vertical roads' elements, the configuration of road path and grade affects safe operating speeds, and sight and passing distances for highway and roads' capacity establish the general character of a highway, more than any other design consideration. These components will significantly affect the safety, operational efficiency, and aesthetics of the highway.

Therefore, this chapter will focus on the design of the main elements of a road linking the city of Mosul and Makhmour (Northern Iraq) district south of Mosul. The surveying data was prepared by the Ministry of Municipalities for the proposed route of this road using a differential GPS device.

These surveys are a 900-m strip survey of the proposed route of the Mosul-Makhmour highway with a length of up to 20 km. Field surveying data will be used to prepare a geometric design for the proposed road linking for the two regions by using AutoCAD Civil 3D Land Desktop program and in accordance with international standards.

Initially, a path was proposed for this road depending on spatial analysis by GIS program to get optimum path linking between two areas. The stations, the type of road, the number of its lanes, its dimensions, its horizontal and vertical elements, and the slopes were defined according to the main design criteria of urban roads. The results were illustrated by longitudinal and cross-sectional plots showing the changes in the natural shape of the ground and all the elements of the horizontal and vertical curves of the road. After which, the volume of the earthworks was calculated for excavation and burial. Thus, a road connecting two urban areas was achieved in a manner that does not cause accidents and achieves the smooth flow of vehicles by making all elements of the road consistent with the expectations of drivers to avoid sudden changes in design specifications. Finally, all the designed road data were exported to the GIS program to build an integrated database for this road that can be linked to the rest of the city network, as well as all spatial analyses and network analyses.

2. Transportation planning

Transport is an important part of the planning process for cities and regions. Every planning activity, whether land uses, work centers, cultural, marketing, or leisure activities, depends in one way or another on transportation. The transport and traffic sector is considered an important sector in economic development, and this is reflected in the high expenses allocated to the development of this sector, which in Iraq up to 20% of the allocations of annual investment plans [1].

Transport planning is a structured approach to understanding traffic and transport characteristics. It aims to achieve an efficient and appropriate system that meets the current and future requirements of the community. We can define a number of objectives for this process [2]:

- Provide the most appropriate type of transport system according to the available potentials.

- Developing and increasing the efficiency of economic activity by reducing transport costs.

- Development of an integrated system of transport routes.

- Know how and when to improve the old road or build new roads according to future requirements.

- Optimal expenditures through the implementation of program cost and benefits for road projects to the general community.
- Development of programs and techniques for further urban and regional development.
- Reducing traffic accidents.
- To preserve and improve the environment.
- Also designed to design road networks according to planning standards, the most important of which are as follows [3]:
    - The network hierarchy, which is related to the functional classification of the different ways of fast, primary, and secondary traffic.
    - The network serves land use (residential, industrial, commercial, cultural, etc.) in a good way, providing easy access to parts of the city or regions.
    - The large and equivalent link between the city's internal network and the regional road network.
    - Network service for the gradual development of the city.
    - Avoid traffic jams that may occur at intersections by creating junctions at levels or any other planning solutions.

3. Road network classification systems

The systems adopted in the road network classification classify the network into four sections according to the following concepts [4]:

a. ***Road location systems and neighborhoods*:** The road is classified according to its location according to the following concepts: the type of use of the road, the date of construction of the road, the uses of the ground surrounding the road, topography of the area of the road, and nature of the area.

b. ***Road engineering design system:*** These systems are based on the engineering classification of the road network according to the following systems, number of road lanes, system dividing the road, and switching systems from one road to another.

c. ***Road administration systems:*** These systems work on road management according to the following concepts, road planning according to levels, road paving systems and maintenance, road ownership systems, and type of tiling material systems.

d. ***Vehicle traffic systems:*** The road network is classified according to the movement of vehicles and their relation to the type of vehicle, according to the following, traffic volume of the road, purpose of the trip, type of vehicle using the road, and the roads' functional classification.

4. Classification of road network according to the criteria of capacity and rank

- Free streets: These streets are designed for the purpose of speeding and long distances in international and regional trips, with a capacity of between 1800 and 2000 vehicles/h, with lanes ranging from 4 to 8 lanes, at a speed of operation ranging from 80 to 120 km/h.

- Express streets: The streets are meant to serve the largest number of citizens, high speed, long distances for regional trips, a capacity of between 1400 and 1800 vehicles/h, and lanes of 4–8 lanes, with a speed of operation ranging from 60 to 80 km/h.

- Arterial streets: The streets with medium-distance urban trips, easy access between parts of the city and a capacity of 800–1200 km/h, with a speed of 40–60 km/h.

- Collected streets: These streets mean short urban trips, easy access between the city, and a capacity of 600–900 vehicles/h, with a speed of 30–50 km/h.

- Local streets: For short transport service, at a low speed of 20–30 km/h, with a capacity of 500–700 vehicles/h [5].

5. Functional classification of urban roads

The importance of functional classification is determined by which the role of each road is defined for the traffic and transport service. The degrees of urban roads vary according to the areas they serve, whether residential, commercial, residential-commercial, etc. and also according to the total movement that will be generated from those areas served. Classification of roads in urban planning can be summarized as follows [6–8]:

a. Major urban roads: These roads link the main centers of activity in urban areas. They are connected to the regional network and take the largest traffic load in the urban area. These roads have width about 40 m or more.

b. Secondary urban roads: These roads collect the vehicles from the main roads and distribute them to the degree of lower roads, and their widths are about (16–25 m).

Degrees	Minimum speed (km/h)	The desired speed (km/h)
Local road	30	50
Collector road	50	60
General arterial road	80	100
Less disturbance	70	90
Tangible disturbance	50	60
Highway	90	120

Table 1.
Design speed of urban roads [6, 7].

c. Urban roads of the third degree (local): Collecting vehicles from the residential areas and areas of activity to the highest road degree and carrying the least amount of traffic in the network and is the lowest degree in the hierarchy of the road network and its widths about (12–16 m).

The design characteristics of the road must be commensurate with the design speed chosen and expected for environmental and terrain conditions, and the designer should choose the appropriate design speed based on the planned road degree, terrain characteristics, traffic volume, and economic considerations. Note **Table 1**.

6. Highway capacity and level of service

The capacity of the road is the maximum number of vehicles expected to pass over a particular part of a lane or road during a given period of time under the prevailing traffic conditions.

Service level is the qualitative measurement of the effect of a number of factors such as operating speed, travel time, traffic failures and freedom of maneuver, and crossing, driving safety, comfort, road suitability, and operating costs for the service provided by the road to its users. **Table 2** shows the characteristics of the service level according to the type of road [9, 10].

The level of service	Urban arterial	Two lanes road
A	The average speed is about 90% of the speed of free flow. Delay at intersections with traffic signals is minimal	The average speed of the road is 93 km/h or greater. Most of the crossings are carried out without delay. In the ideal case, the traffic volume is 420 vehicles/h for both directions
B	The average speed of traffic decreases due to the delay in intersections and the impact of vehicles on some of them and about 70% of the speed of traffic. Load factor at 0.1 intersections and peak hour factor 0.8	The average speed of the road is 88 km/h or more. The load coefficient may be up to 0.27. Traffic volume is 750 vehicles/h for both directions
C	Travel speed is about 50% of the speed of free flow. Run balanced. Long rows of cars when traffic signals are possible	The average speed of the road is 84 km/h or more. The flow rate in the ideal case is about 43% of the capacitance, with a mean traffic in ideal conditions 1200 vehicles/h in both directions
D	Average speed 40% of free flow rate. The flow rate is unbalanced, and delays at intersections may be comprehensive	The average speed is 80 km/h. The flow rate is about 64% of the capacity, with continuity in the imposition of overflow and flow of approximately 1800 vehicles/h for both directions
E	Speed of flow is 33% of free flow speed, volume at capacity, and flow is not balanced. The coefficient of load at intersections (0.7–1.0). The peak hour factor is 0.95	The average flow rate is about 72 km/h. The flow rate in ideal conditions is 2800 vehicles/h; level E may not be accessible as the operation is converted from service level D to F directly
F	The average speed of traffic between 25 and 33% of the speed of free flow, high delay times at the branches of intersections	The operating speed is less than 72 km/h, and the traffic are overcrowded and constrained with unexpected characteristics, volume less than 2000 vehicles/h in both directions

Table 2.
Service level characteristics by road type [9, 10].

7. Specifications and determinants of roads' design and general criteria

7.1 Stopping sight distance (SSD)

The distance traveled by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied and the distance required to stop the vehicle from the instant brake application begin or defined as the sum of distances from when the driver decides to apply the break until the car stop, as in Eq. (1):

$$SSD = (0.278 \times V \times t) + (0.039 \times \frac{v^2}{a}) \quad (1)$$

where (SSD) is the stopping sight distance in m, (V) is the initial speed (kph), (a) is the rate of deceleration (3.4 m/S2), and (t) is the Brake reaction time, which is assumed to be 2.5 seconds by AASHTO [11].

Table 3 can illustrate the stopping sight distance and its relation to the design speed, brake reaction distance, and braking distance on level. **Table 4** illustrates increment of the stopping sight distance and its relation to the design speed and brake in state of slope directed down [12–14].

Design speed (Km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	73.4	129
80	55.6	73.4	129.0	130
90	62.6	92.9	156.5	160
100	59.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	156.2	248.5	250
130	90.4	193.8	284.2	285

Table 3.
Stopping sight distance and its relation to the design speed and brake [12].

Design speed (km\h)	Increase the stopping sight distance in state of downslope (m)		
	3%	6%	9%
40	2	4	6
50	3	6	10
60	5	10	18
70	7	15	6
80	9	21	-
90	12	29	-
100	16	38	-

Table 4.
Relationship between design speed and increment of stopping sight distance in state of downslope [15].

Design speed (km/h)	Assumed speed (km/h)		Passing sight distance (m)	
	Passed vehicle	Passing vehicle	From exhibit 3–6	Rounded for design
30	29	44	200	200
40	36	51	266	270
50	44	59	341	345
60	51	66	407	410
70	59	74	482	485
80	65	80	538	540
90	73	88	613	615
100	79	94	670	670
110	85	100	727	730
120	90	105	774	775
130	94	109	812	815

Table 5.
Passing sight distance for the design of two-lane highways [16, 17].

7.2 Passing sight distance (PSD)

It represents enough free distance of traffic so that the driver can see the driver in front of him to be able to complete the process of circumventing without touching the car that passes without being intercepted by any counter vehicle may appear after the start of the bypass and then return to the right warm easily after the overtaking process. PSD is designed for two-lane highway as in **Table 5** which illustrate passing sight distance with respect to the design speed for passed and passing vehicle [16].

7.3 Horizontal planning of the road

The horizontal curve is a part of circular curves, which consist of intersection of two tangents of road. Horizontal curve has four types illustrated in **Figure 1**. The location and configuration of the horizontal curve are affected by some of the factors as follow [18]:

1. Physical condition: land uses, earth topography and geophysical conditions, intersection with waterway and man-made barriers.

2. Environmental circumstances: impacts on the adjacent land use, community-based impacts, and environmentally sensitive areas.

3. Economics condition: cost of construction, road ownership costs, effects of utility, costs of operating, and maintenance.

4. Road safety: distance of sight, alignment consistency, considerations of the human factor.

5. Classification and design considerations of highway: level of service, functional classification, design speed, and standards.

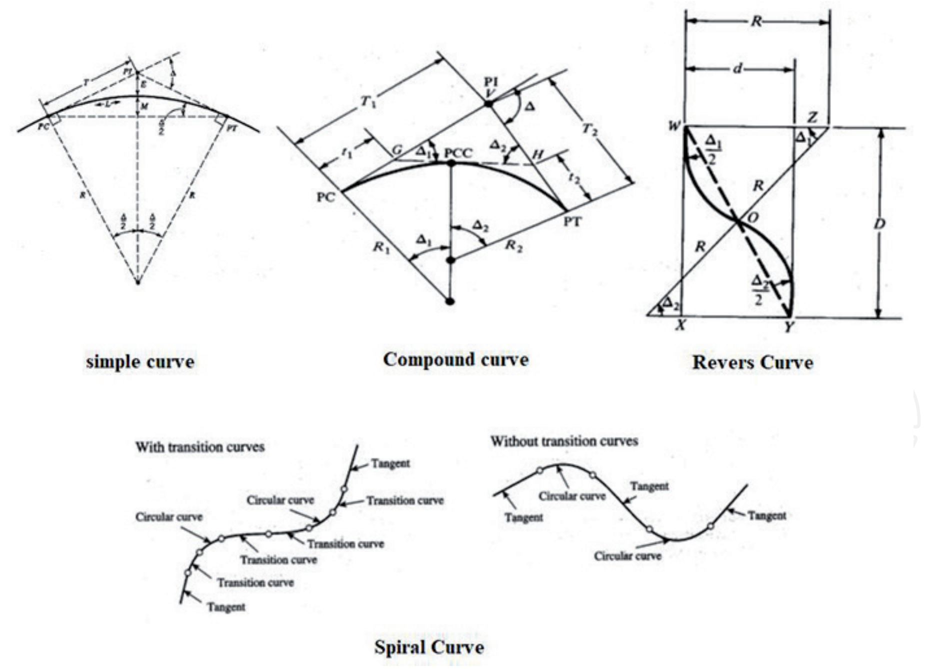

Figure 1.
Types of horizontal curves.

7.4 Vertical planning of the road

Vertical road planning consists of a series of longitudinal tendencies connected to each other by vertical curves (note **Figure 2**). Vertical planning is governed by a number of factors: safety, terrain, road speed, design speed, horizontal planning, construction cost, vehicle characteristics, and rain drainage. Visibility in all parts of the longitudinal sector must be met with the minimum distance required to stop (not overtaking), according to the design speed corresponding to the roadway. There are general considerations in the vertical planning of the road, which can be summarized as follows [19, 20]:

1. The goal should be to obtain an easy linear elevation design with gradual changes in line with the type of road or its degree and the nature of the land.

2. Avoid wavy vertical planning or vertical planning with hidden dips, because it is bad-looking and dangerous. Hidden dips cause accidents in overtaking, fooling the overtaking driver beyond the low, and thinking the road is free of anti-cars. But in the low-depth depressions, such as a longitudinal ripple, there is a lack of reassurance in the driver because it cannot determine the presence or absence of a vehicle likely to be hidden behind the high part. This type of longitudinal layout can be avoided by horizontal curvature or gradual change of slopes at light rates, possibly by increasing cutting and filling.

3. The longitudinal refraction bending planning should be avoided (two vertical curves in the same direction separated by a short tangent), especially in concave curves where the complete view of the two curves is not acceptable.

4. It is preferable for long slopes to have steep slopes at the bottom, and then the slope falls close to the top, or the continuous gradient is reduced by the introducing short distances where the slope is less than that of a regular full slope. This is especially relevant for low-design speed road conditions.

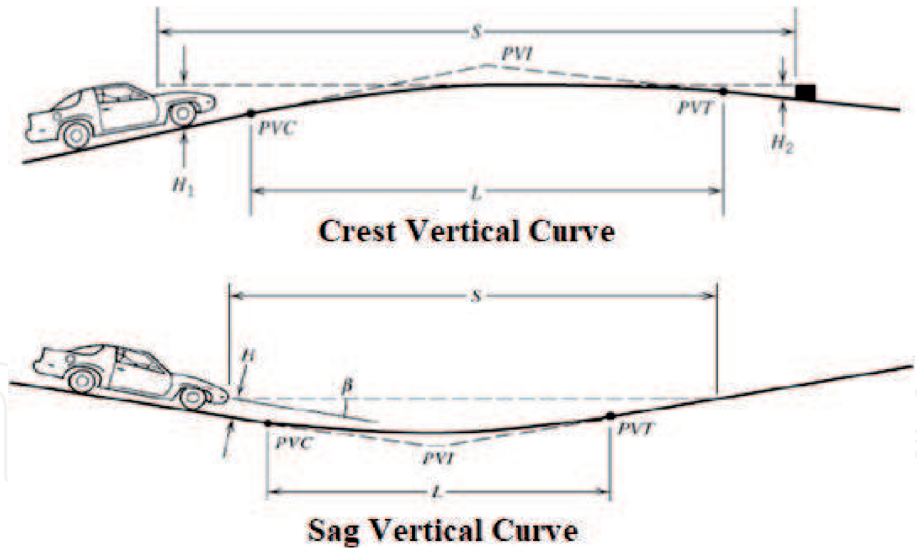

Figure 2.
Type of vertical curve [19].

5. K values can be used to compute the length of vertical curve for the crest and sag vertical curves. And vertical curve should have minimum length equal to three times the design speed.

6. SSD in most cases will be used for the length of vertical design, but for trucks it is not necessary because the driver of the truck is able to see farther than the passenger car. So, the SSD for trucks and passenger cars is balance.

Table 6 can illustrate the relationship between design control for SSD with respect to the K value for the vertical curve, while **Table 7** shows design controls for vertical curve based on PSD [21].

Design speed (km/h)	Stopping sight distance (m)	Rate of vertical curvature (K)	
		Calculated	Design
20	20	0.6	1
30	35	1.9	2
40	50	3.8	4
50	65	6.4	7
60	85	11	11
70	105	16.8	17
80	130	25.7	26
90	160	38.9	39
100	185	52	52
110	220	73.6	74
120	250	95	95
130	285	123.4	124

Table 6.
Design control for stopping sight distance with respect to the K value for vertical curve [20].

Design speed (km/h)	Passing sight distance (m)	Rate of vertical curvature (K) design
20	200	46
30	270	84
40	345	138
50	410	195
60	485	272
70	540	338
80	615	438
90	670	520
100	730	617
110	775	695
120	775	695
130	815	769

Table 7.
Design controls for vertical curve based on passing sight distance [21].

7.5 Super elevation

Super elevation allows the car to travel across a curve safely and at a higher speed than is possible with the natural crown section. The overall super elevation rate increases with speed and a sharper curvature (note **Figure 3**). **Table 8** can illustrate the maximum lateral lifting value of super elevation [22].

where Rv is the vehicle's traveled path radius, Ff is the force of side frictional, FC is the centripetal force, Wp is the weight of vehicle parallel to the road path surface, W is the vehicle weight, Wn is the vehicle weight normal to the road path surface, Fcn is the gravitational force that works naturally on the road surface, e is the number of vertical of rise per one horizontal station (100 m), and α is the incline angle [23].

7.6 Side slope of cut and fill

Side slopes are designed to ensure the stability of the road and to provide the opportunity to secure cars out of control. **Table 9** shows the relationship between

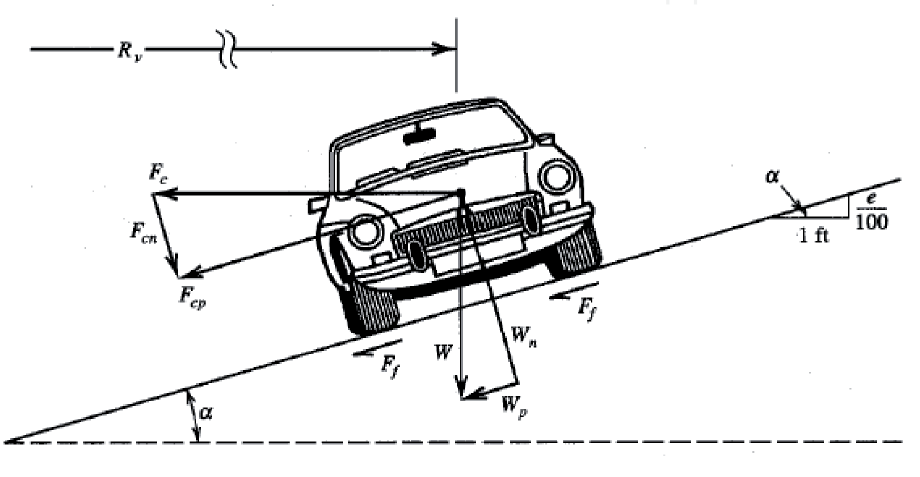

Figure 3.
Super elevation [22].

Degree of the road	Maximum side lifting value of the road is desirable (m/m)	Maximum lateral lifting value is absolute (m/m)
Highway	0.08	0.10
Arterial road	0.08	0.10
Collector road	0.08	0.12
Local road	0.10	0.12

Table 8.
Maximum lateral lifting value according to AASHTO [22].

Height (m)	Earth work	Plan		Wavy		Mountainous	
		Desired	Max slop	Desired	Max slop	Desired	Max slop
0–1	Cut	1:6	1:4	1:6	1:3	1:6	1:3
	Fill	1:6	1:6	1:4	1:4	1:4	1:4
1–3	Cut	1:4	1:3	1:3	1:2	1:3	1:2
	Fill	1:4	1:4	1:4	1:4	1:3	1:3
5–3	Cut	1:3	1:2	1:3	1:2	1:3	1:2
	Fill	1:4	1:3	1:4	1:3	1:3	1:1.5
5	Cut	1:2	1:2	1:2	1:2	1:2	1:2
	Fill	1:3	1:2	1:3	1:2	1:2	1:1.5

Table 9.
Side slope (horizontal to vertical) for the type of terrain except rocks [25].

the topography type and the height of the cutting or the filling, and the maximum side slope desired in the roads for the filling slope less than or equal to (2:1) depends on soil analysis [24, 25].

8. Spatial data of study area and method of processing

For the purpose of designing the proposed road elements of the study area between Mosul and Makhmour, the spatial data of the study area were obtained from the Ministry of Municipalities of Mosul City.

The spatial data is the field survey data of the route of the road, completed by a team of engineers from the Ministry of Municipalities. The survey data was conducted in the form of a strip width 900 m around the proposed route. A 900-m width was selected to cover all the places that the road path might pass, because the path was selected roughly, not accurately. The length of the strip survey is 20 km to connect the two urban areas.

The survey data contains a set of point coordinates (3626 points) observed with a high-precision equipment (Leica viva GS15). The coordinates' projection was WGS84-UTM-Zone38N. These data is an unprocessed raw data, unrelated to each other, and contains many coordinates that may not be connected to the pathway. For the purpose of processing these data and linking it together, adjusting the system of coordinates, adjusting the elevations, and creating a digital elevation model for the region, the Civil 3D Land Desktop program will be used to process this data and then export it to the GIS program.

Spatial analysis will be used in the GIS program to select the optimal path that connects the two study areas based on spatial data. The optimal path for the proposed road will be chosen according to planning and design criteria. This path will be exported to the Civil 3D program again to identify the rest of the design elements of the road.

In the Civil 3D program, all the design elements of the road will be defined according to the AASHTO standards, leading to the final stage where the road contains an integrated database ready for implementation.

9. Methodological steps for designing road elements using Civil 3D Land Desktop and GIS software

In order to define the proposed road path and all its horizontal and vertical and design elements, these points will be used in the definition and design of road elements according to the following methodological steps:

a. The civil 3D land desktop program has been configured to be in meter units, 1:1000 horizontal scale and 1:50 vertical scale, UTM, WGS 84 Datum as **Figure 4**.

b. The survey points were imported within the program and arranged and modified (point number, coordinates values, elevations) to be ready for the purpose of design road elements, as in **Figure 5**. Constructing a surface triangulated irregular network (TIN) and connecting the points' coordinates for the purpose of deriving the elevations of the road depending on it, as in **Figure 6**. The TIN surface is then exported to GIS as digital elevation model (DEM).

c. The Geographic Information system (GIS) program was used to select the best route for the road connecting the city of Makhmour with the city of Mosul, as in **Figure 7** which shows the sequence of steps to choose the path. The network of TIN has been reclassified according to the elevation values, so that the road passes from the flat areas as much as possible, as the land on which the road passes has steep slopes. The land use layer has been reclassified so as not to cross the road with any unwanted land use. The best and shortest route between the two urban areas was then chosen. The length of the best selected path was 18210.88 m. Its alignment, stations, width, and number of lanes were defined and exported to the civil 3D.

d. ASHTO standards were adopted in the design of horizontal elements of the proposed highway. These design elements were defined to the Civil 3D as follows:

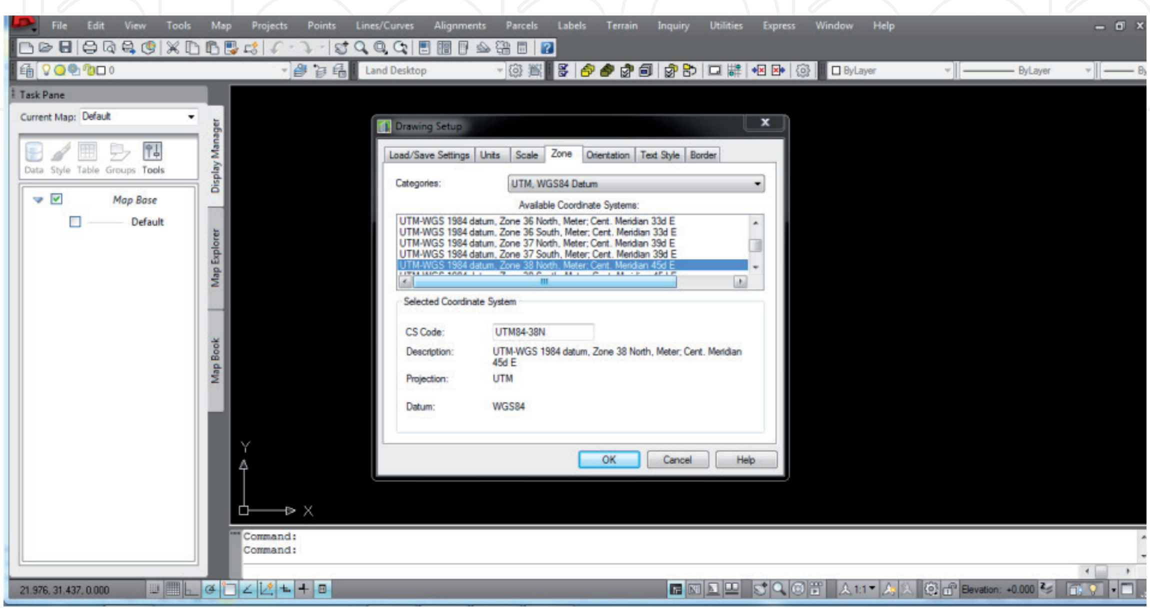

Figure 4.
Configuration of units, scale, projection of Civil 3D program.

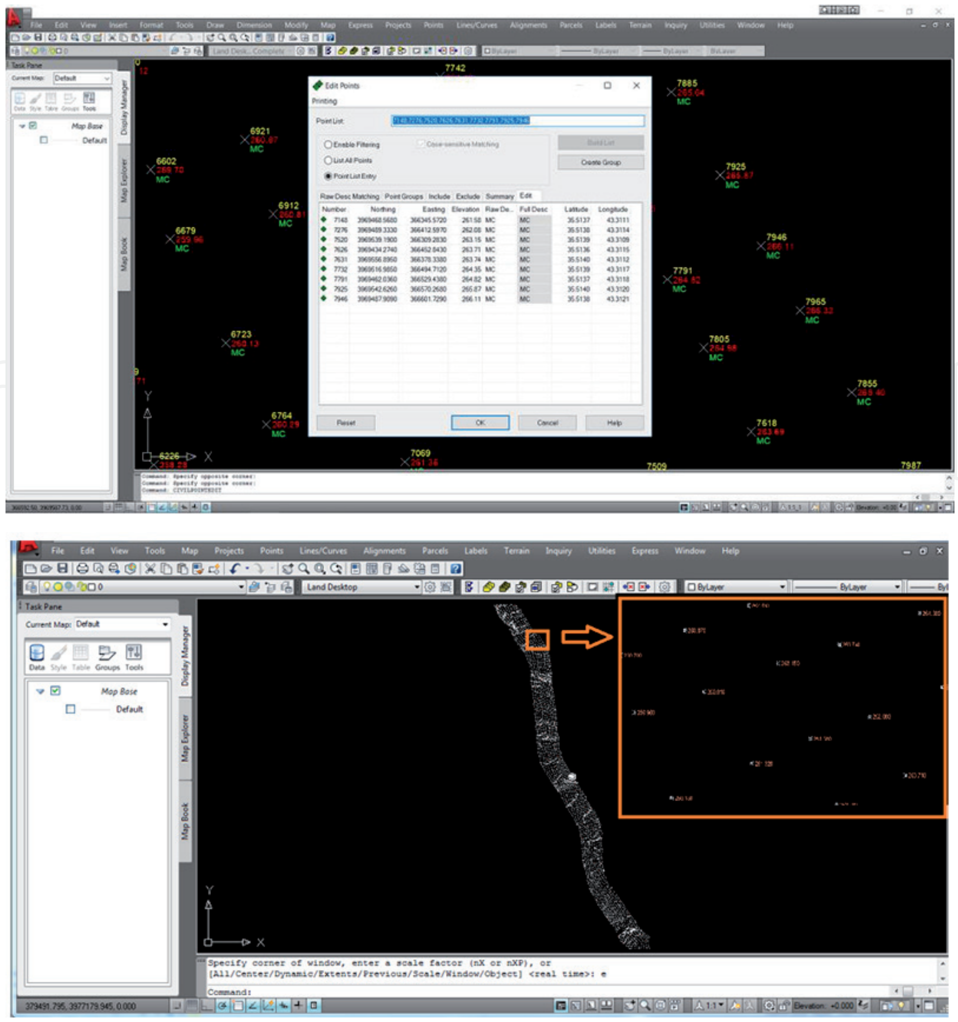

Figure 5.
Modify coordinates of survey points.

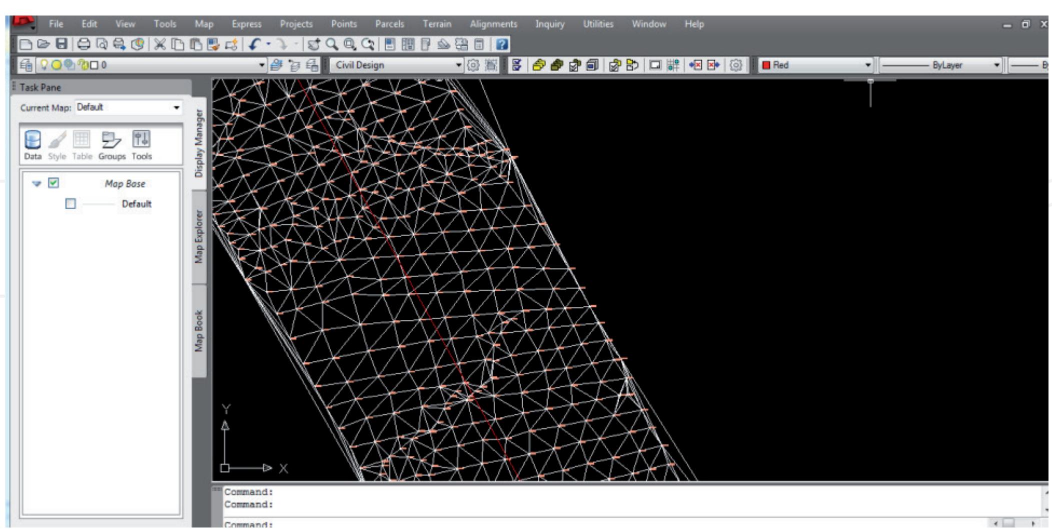

Figure 6.
Constructing the TIN surface to link between coordinates.

- The design speed = 100 km/h.
- Maximum longitudinal slope = 3%.
- Maximum side slope = 4/1.
- Stopping sight distance SSD = 185 m.

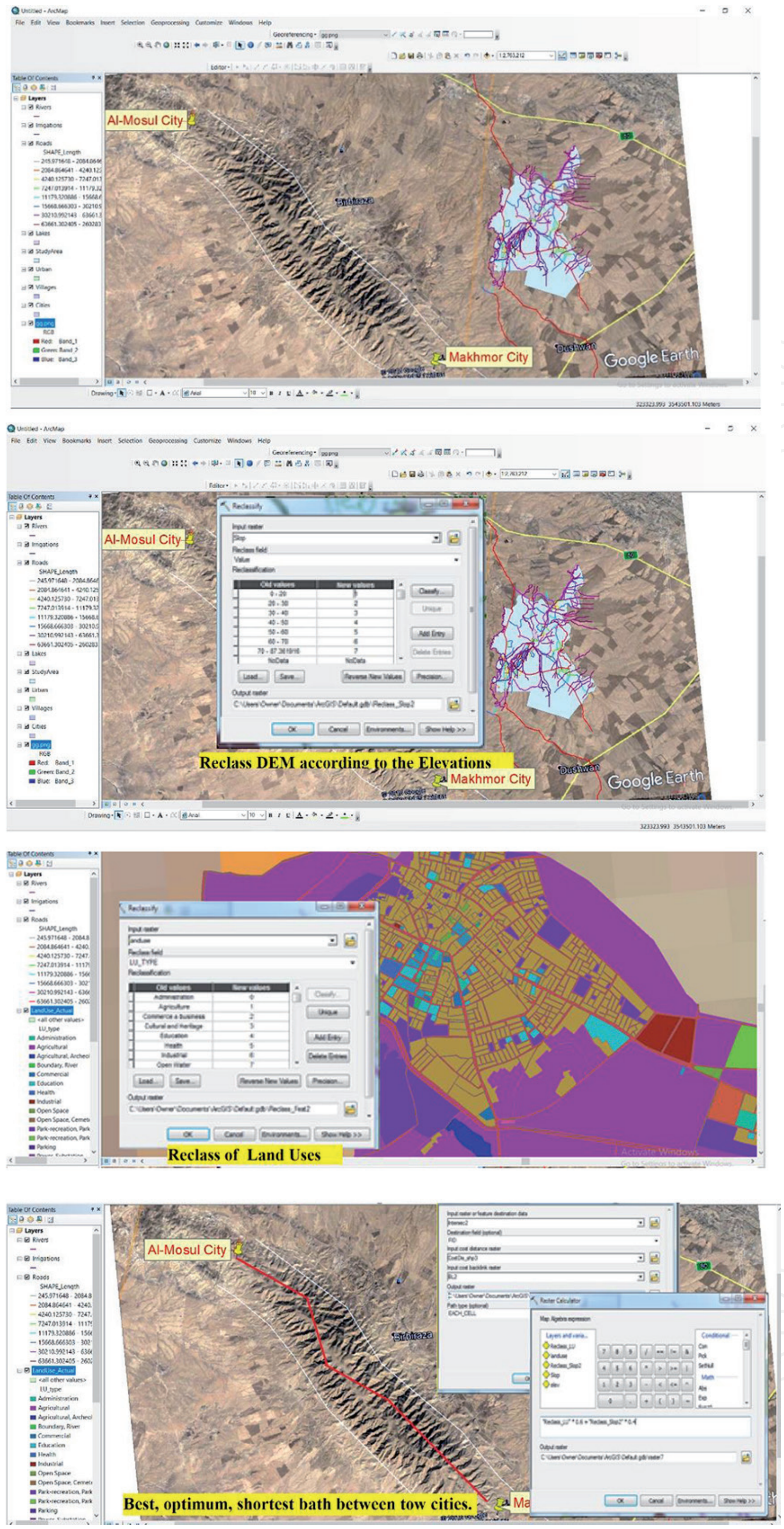

Figure 7.
Sequence of steps in GIS to select the best route for connecting the city of Makhmour with the city of Mosul.

- Supper elevation = 4%.
- Break reaction distance = 60 m.
- Break distance on level = 115 m.
- For concave and convex vertical curves (sag and crest), SSD = 185 m, PSD = 670 m, K = 45.

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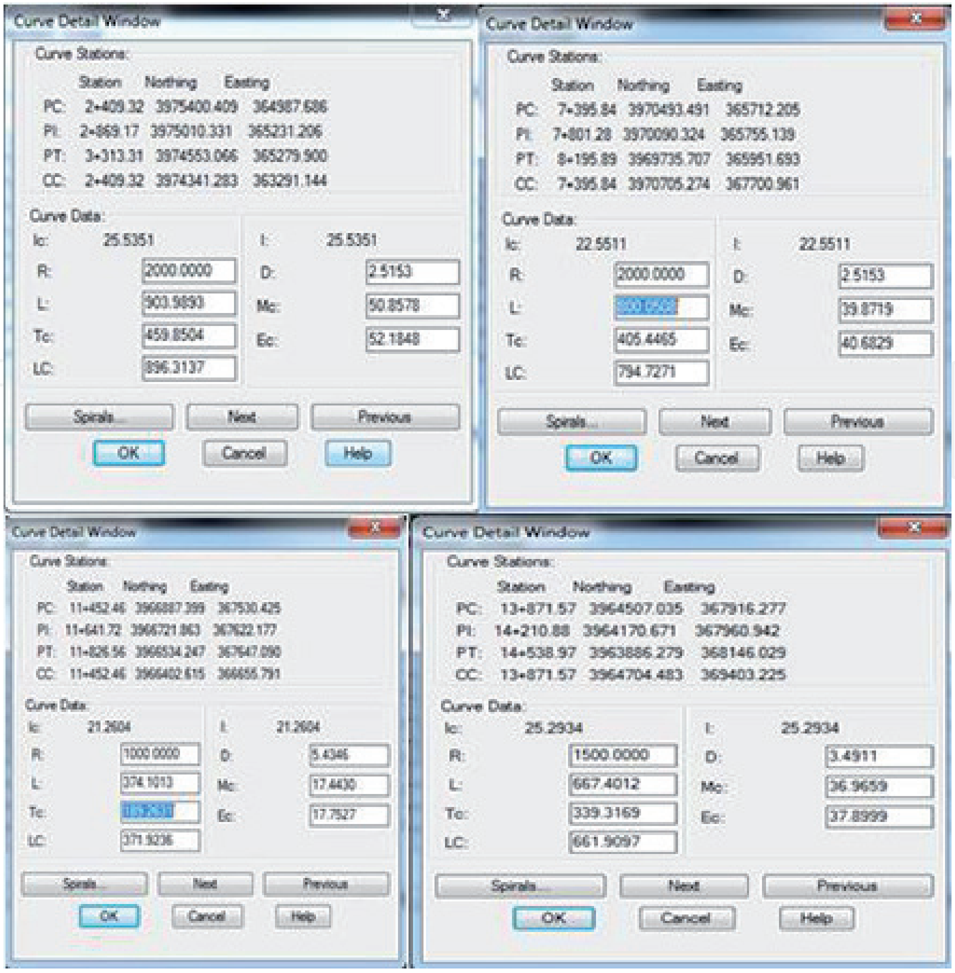


Figure 8.
Design elements for horizontal curves.

- Minimum length of vertical curve = 700 m.
- The level of service was A, the number of lane 2 was with two direction, the chosen width was 12 m per lane, and the traffic volume was 420 vehicles/h in both directions.

e. The design elements for the horizontal curves were illustrated as in **Figures 8** and **9**. Where the highway contained four horizontal curves designed according to the design standards. **Figure 10** can illustrate the proposed path of road after adding the stations. While, **Figure 11** illustrate the definition of the design velocity of horizontal curves.

f. A longitudinal section of the proposed road was produced on a horizontal scale (1:600) and a vertical scale (1:100), as in **Figure 12a** and **b**.

g. The construction line (formation level), which represents the final level of the road, has been defined so that it achieves the lowest proportion of cuttings and fill in the earthworks and with the lowest vertical curves and as in **Figure 13**, which illustrates the elements of vertical curves and stations of PVC, PVI, and PVT through the table stations, as well as the levels of these stations, their slopes, and the length of their vertical curves, and the type of curve. **Figures 14** and **15** illustrate the longitudinal section after adding the line of construction and vertical curves.

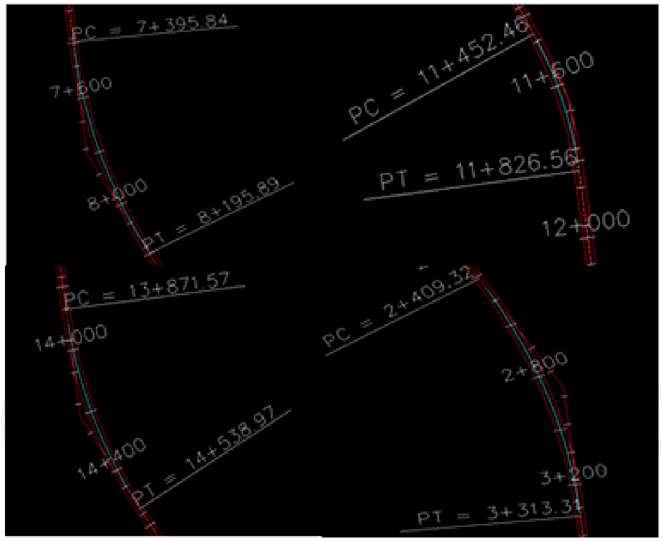


Figure 9.
Design elements for the horizontal curves.

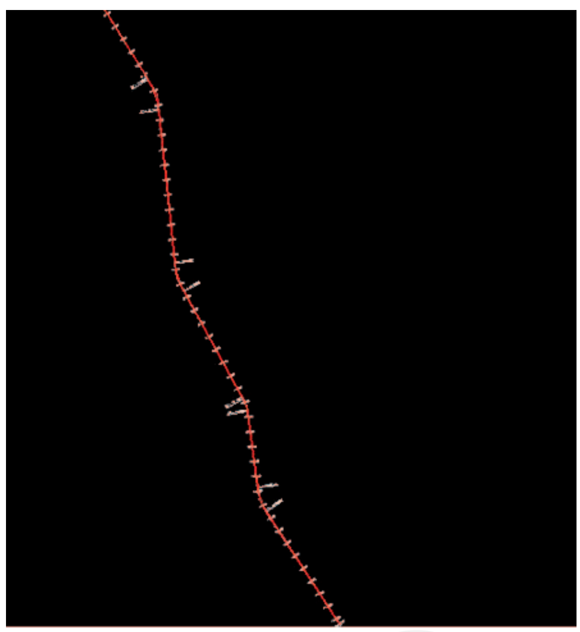


Figure 10.
The proposed path of highway after adding the stations.

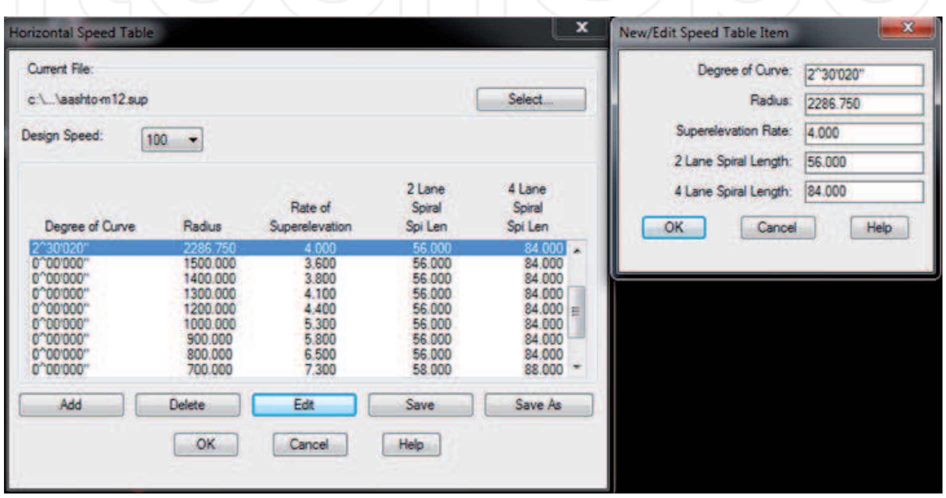
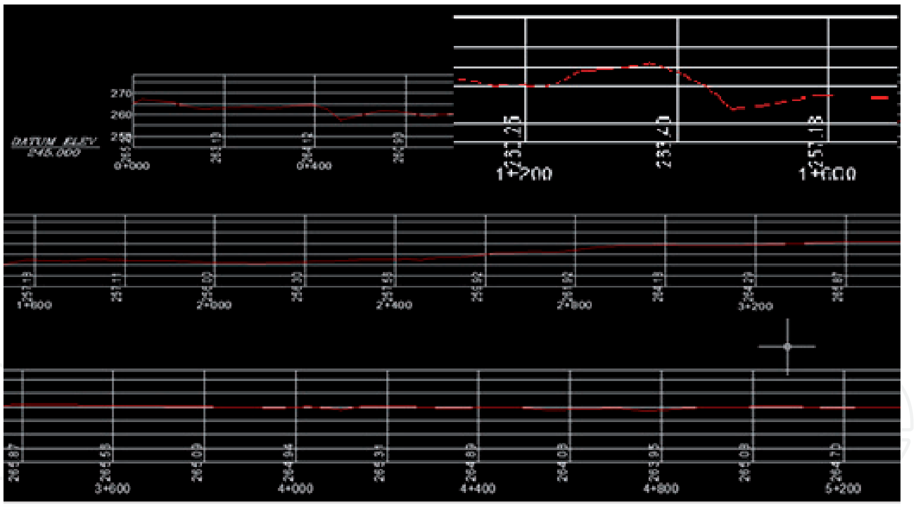
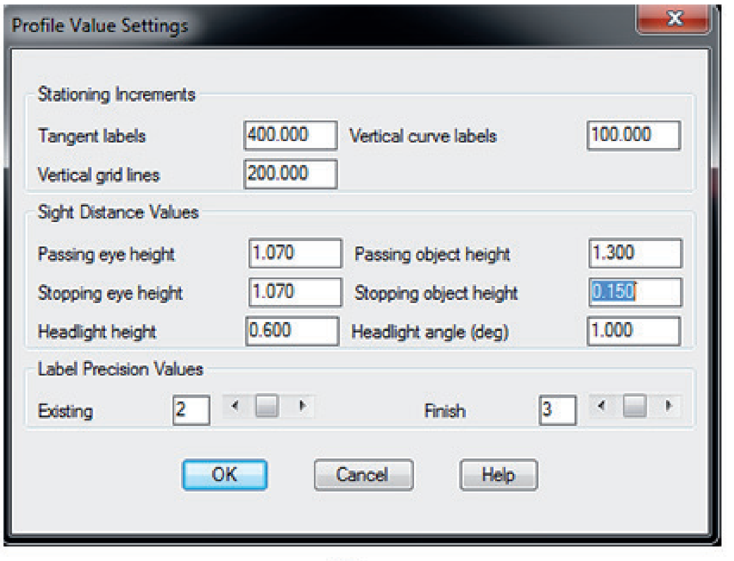


Figure 11.
Define design velocity of horizontal curves.

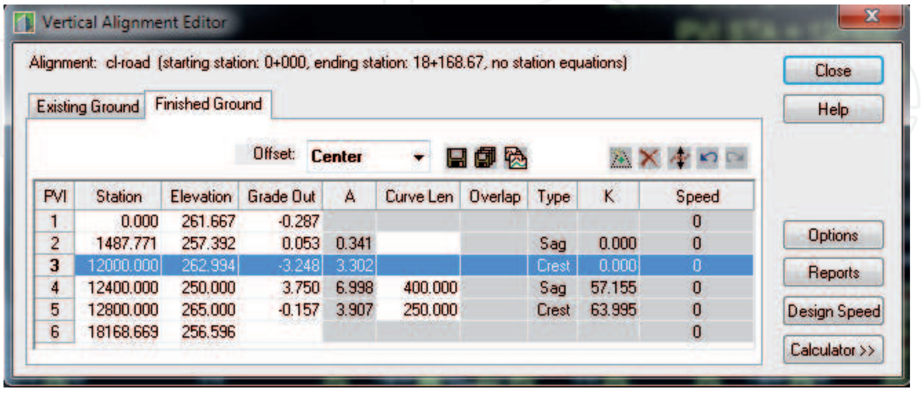


(a)



(b)

Figure 12.
(a) Longitudinal section of the proposed road and (b) profile's design elements.



PVI	Station	Elevation	Grade Out	A	Curve Len	Overlap	Type	K	Speed
1	0.000	261.667	-0.287						0
2	1487.771	257.392	0.053	0.341			Sag	0.000	0
3	12000.000	262.994	-3.248	3.302			Crest	0.000	0
4	12400.000	250.000	3.750	6.998	400.000		Sag	57.155	0
5	12800.000	265.000	-0.157	3.907	250.000		Crest	63.995	0
6	18168.669	256.596							0

Figure 13.
Define vertical curve elements of the road.

h. The cross sections of the proposed road were generated and designed according to the criteria that correspond to the cross sections of the reality of the case (width of the total road 24 m, shoulder length 1 m, side slope 1/2, supper elevation 4%, the thickness of the tiling was defined as 10 cm, thickness of the subbase 15 cm). Note **Figure 16** which illustrates the forms of some of cross sections.

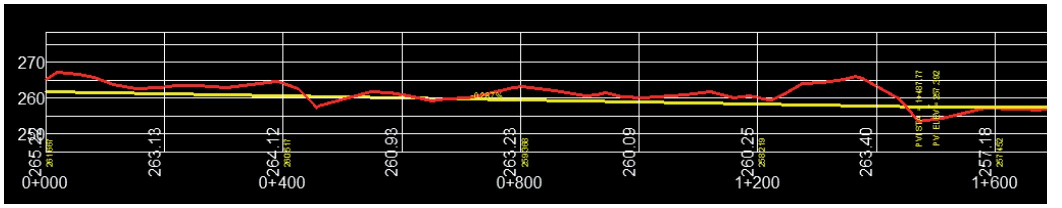


Figure 14.
The longitudinal section of the road after adding construction line.

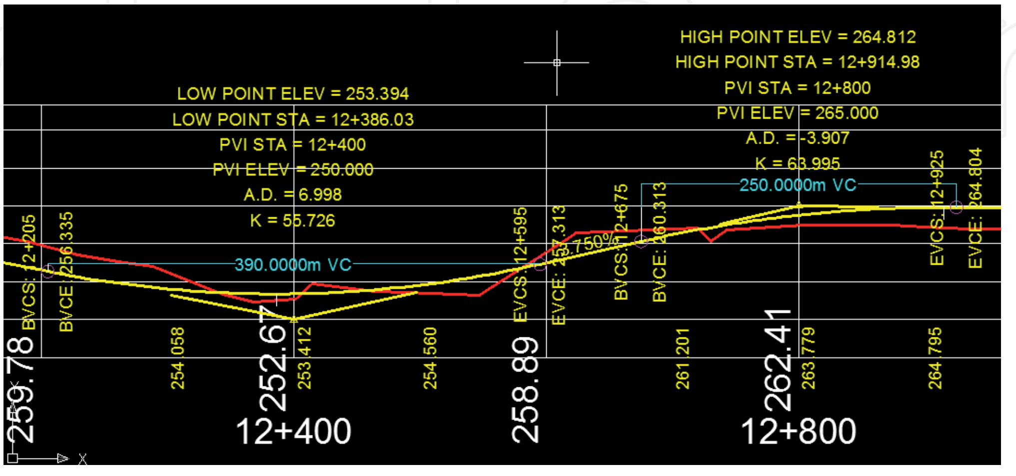


Figure 15.
Section of profile illustrates vertical curve elements.

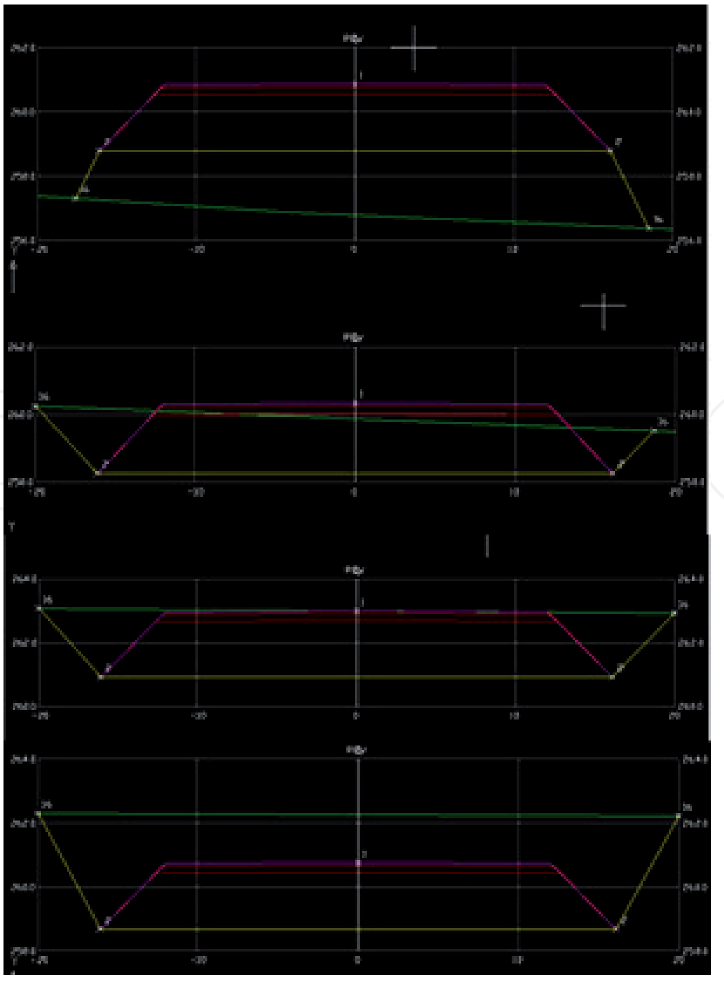


Figure 16.
Forms of some cross sections of the proposed road.

i. Calculated volume of the earth works in a way of prismoidal formula as shown in **Table 10**, which shows the volume of cut and fill for each station of the proposed road. These data of volume were exported from Civil 3D to GIS as attribute table.

STATION	AREAS Square Meters		VOLUMES Cubic Meters		CUMULATIVE VOLUMES Cubic Meters	
	CUT	FILL	CUT	FILL	CUT	FILL
0+000	145.151	0.000				
0+200	90.603	0.000	23575.485	0.000	23575.485	0.000
0+400	147.837	0.000	23844.042	0.000	47419.527	0.000
0+600	52.267	0.000	20010.439	0.000	67429.965	0.000
0+800	156.472	0.000	20873.955	0.000	88303.921	0.000
1+000	63.893	0.000	22036.510	0.000	110340.431	0.000
1+200	90.299	0.000	15419.150	0.000	125759.581	0.000
1+400	224.767	0.000	31506.509	0.000	157266.091	0.000
1+600	13.054	6.880	23782.063	688.023	181048.154	688.023
1+800	10.724	10.904	2377.797	1778.454	183425.950	2466.478
2+000	1.215	45.127	1193.871	5603.179	184619.821	8069.657
2+200	1.474	39.404	268.920	8453.158	184888.741	16522.815
2+400	12.326	7.576	1380.001	4698.038	186268.742	21220.853
2+600	86.949	0.000	9943.715	756.838	196212.457	21977.691
2+800	156.671	0.000	24367.669	0.000	220580.127	21977.691
3+000	232.884	0.000	38963.356	0.000	259543.483	21977.691
3+200	233.013	0.000	46597.423	0.000	306140.906	21977.691
3+400	286.345	0.000	51943.413	0.000	358084.319	21977.691
3+600	271.226	0.000	55757.114	0.000	413841.433	21977.691
3+800	250.393	0.000	52161.953	0.000	466003.386	21977.691
4+000	241.469	0.000	49186.241	0.000	515189.627	21977.691
4+200	250.824	0.000	49229.366	0.000	564418.992	21977.691
4+200	250.824	0.000	49229.366	0.000	564418.992	21977.691
4+400	231.797	0.000	48262.131	0.000	612681.124	21977.691
4+600	199.397	0.000	43119.390	0.000	655800.513	21977.691
4+800	190.153	0.000	38954.983	0.000	694755.497	21977.691
5+000	227.025	0.000	41717.828	0.000	736473.325	21977.691
5+200	209.558	0.000	43658.352	0.000	780131.677	21977.691
5+400	246.274	0.000	45583.177	0.000	825714.853	21977.691
5+600	224.133	0.000	47040.673	0.000	872755.527	21977.691
5+800	213.506	0.000	43763.894	0.000	916519.420	21977.691
6+000	183.222	0.000	39672.745	0.000	956192.165	21977.691
6+200	190.872	0.000	37409.391	0.000	993601.556	21977.691
6+400	174.304	0.000	36517.660	0.000	1030119.215	21977.691
6+600	48.769	0.000	22307.314	0.000	1052426.529	21977.691
6+800	181.369	0.000	23013.761	0.000	1075440.290	21977.691
7+000	10.700	11.373	19206.862	1137.284	1094647.152	23114.976
7+200	75.335	0.000	8603.477	1137.284	1103250.629	24252.260
7+400	70.033	0.000	14536.798	0.000	1117787.427	24252.260
7+600	72.421	0.000	14240.503	0.000	1132027.929	24252.260
7+800	71.390	0.000	14378.283	0.000	1146406.213	24252.260
8+000	0.000	126.003	7138.767	12602.797	1153544.980	36855.056
8+200	0.133	68.289	13.264	19437.703	1153558.244	56292.759
8+400	0.012	63.891	14.526	13217.996	1153572.770	69510.756
8+600	0.338	53.595	35.025	11748.638	1153607.795	81259.393
8+800	5.087	24.576	542.486	7817.149	1154150.280	89076.543
9+000	2.756	33.450	784.315	5802.622	1154934.596	94879.165
9+200	0.001	64.138	275.759	9758.794	1155210.355	104637.959
9+400	9.443	13.495	944.438	7763.315	1156154.793	112401.273
9+600	3.939	28.133	1338.242	4162.873	1157493.035	116564.146
9+800	4.911	24.861	884.978	5299.469	1158378.013	121863.614
10+000	5.262	24.130	1017.225	4899.184	1159395.239	126762.798
10+200	0.000	112.118	526.163	13624.804	1159921.402	140387.602
10+400	0.000	133.695	0.000	24581.235	1159921.402	164968.837
10+600	0.000	90.933	0.000	22462.803	1159921.402	187431.641
10+800	0.000	68.839	0.000	15977.188	1159921.402	203408.829
11+000	0.000	103.706	0.000	17254.468	1159921.402	220663.296
11+200	0.000	157.456	0.000	26116.178	1159921.402	246779.474
11+400	0.000	141.648	0.000	29910.354	1159921.402	276689.827
11+600	0.000	171.626	0.000	31316.229	1159921.402	308006.056
11+800	4.219	28.558	423.992	20001.096	1160345.394	328007.152
12+000	17.092	0.091	2131.032	2864.867	1162476.425	330872.019
12+200	135.411	0.000	15250.317	9.069	1177726.743	330881.088
12+400	14.049	13.930	14946.010	1393.011	1192672.753	332274.100
12+600	66.798	0.000	8064.698	1393.011	1200757.451	333667.111
12+800	2.149	36.350	6894.742	3635.028	1207652.193	337302.139
13+000	0.000	79.201	214.906	11555.121	1207867.099	348857.260
13+200	0.641	45.393	64.076	12459.372	1207931.175	361316.632
13+400	0.752	44.625	139.251	9001.733	1208070.427	370318.365
13+600	0.094	54.466	84.598	9909.067	1208155.024	380227.432
13+800	2.238	35.127	233.209	8959.320	1208388.233	389186.751
14+000	0.000	66.148	223.562	10128.635	1208611.795	399315.386
14+200	0.000	59.495	0.000	12564.774	1208611.795	411880.160
14+400	0.000	63.980	0.000	12349.121	1208611.795	424229.281
			0.000	13171.093	1208611.795	437400.374

Table 10.
Calculated volume of cut and fill for each station of the proposed road.

10. Conclusion

1. The length of the proposed road was 18210.88 m according to the data of the Ministry of Municipalities, 24 m width with two corridors, and the coordinates system was UTM.WGS 1984 and Zone 38N.

2. The TIN is the basis of the accuracy of the roads' coordinates, because it is observed with accurate GPS devices.

3. All horizontal and vertical road elements are defined through the CIVIL 3D program, facilitating and accelerating the design process in accordance with international standards.

4. Four horizontal curves and three vertical curves were proposed for the proposed road, according to the topography of the earth, which required this number of curves.

5. The design of the roads using Civil 3D and GIS in all its components makes the design process highly efficient through the speed of time, little effort, and low cost.

6. Civil 3D has all the international standards used in road design and has all the tools that can easily define all design elements for roads and export it to GIS.

7. The program provides us with longitudinal and cross sections that show the change in ground and construction line levels very accurately, which facilitates the process of proposing tiling and cladding levels.

8. The volume calculated by using the program is very precise. The earthwork produced by the pieces can be used to bury the areas that need to be buried. The construction line chosen to represent the proposed road level was chosen at the same depth as the depth of the burial.

9. The road data exported to the GIS program has created an integrated road database. This database can be performed on any kind of spatial analysis or network analysis of the roads within the environment of the GIS.

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