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DESIGNING A SUITABLE TRAMWAY ROUTE AT RAMADI CITY

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Abstract: Tramway system is the issue of this research project. Tramway can be defined as a system of transport used wholly or mainly for the carriage of passengers, which employs parallel rails that provide support and guidance for vehicles carried on flanged wheels, and has been designed to have a significant element which operates on line-of-sight on a highway. The main objective of this research project is focused on the determination of the best route for proposed tramway into Ramadi city. It also focuses on the other important design considerations. Origin-destination stations and four proposed routes have been selected based on navigation, surveying, and specifications by using GPS device, total station device, Civil 3D program and GIS software. Six main criteria with their sub criteria have been chosen, which are: accessibility, safety, economic, environment, population density and trips, and security. A comparative form for these criteria has been designed to facilitate the comparison process to select the best proposal among the four proposals. Multi-Criteria Decision Making (MCDM) method has been used to evaluate the proposals. The results of the analysis explained that the proposal1 is the best alternative among four alternatives to be an acceptable tramway route at Ramadi city.

Keywords:*Tram, tramway, light railway, route selection, GIS, Civil 3D, track alignment design, MCDM.*

تصميم طريق ترام مقبول لمدينة الرمادي

الخلاصة: نظام الترام هونظام نقل يستخدم بصورةعامة او رئيسية لنقل المسافرين والذي يكون مزودا بسكة توفر لها لاسناد والأرشاد للعربات المحموله على السكة والمصممه بكونه اذات اهميه والتي تعمل على خط البصر للطريق .اهداف هذا المشروع تتركز على ايجاد افضل مسار مقترح لترام مدينة الرمادي وكذلك تتركز على ايجاد المعايير التصميمية الاخرى. تم تحديد محطتي الأصل والمقصد واربعة مسارات مقترحة لترام مدينة الرمادي بالأستناد على التحريات الموقعية والملاحة والمسوحات والخصائص المطلوبة وتم ذلك باستخدام جهاز (GPS) وجهاز التوتلستيشن ومجموعة برامج .(GIS) ولغرض المقارنة بين المسارات الاربعة المقترحة تم تحديد سته معايير رئيسية وكل معيار له معاييره الخاصة وهذه المعاييرهي: الوصولية، الأمان، المحددات البيئية، المحددات الاقتصادية، الكثافة السكانية وعدد الرحلات، والمحددات الأمنية. تم تصميم استمارة مقارنة تحتوي على المعاييرالسته والمعايير الخاصه بكل معيار لتسهيل عملية جمع المعلومات والمقارنة لأيجاد المسار الأفضل بين المسارات الاربعة المقترحة .طريقة التحليل المتعدد المعايير استخدمت لتحليل المسارات الاربعة المقترحة لأختيارالمسار الافضل بينها، لانه هذه الطريقة تمثل اداة متطورة لاختيار البديل الافضل من بين مجموعة من البدائل المرشحة. نتائج التحليل بينت ان يعتبر المسار الاول هو المسار الافضل بين المسارات الاربعة المقترحة ليكون المسار المقبول لترام مدينة الرمادي.

1. Introduction

Transportation means the movement of people, goods, and other things from one allocated

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location to another. The Main functions of transportation are: links residents with employments; links producers of good with their users; and provides the options for work, shopping and recreation, and give access to health, education, and other facilities [1].

Transportation services are represented by either private transport or public transport. Tramway system is a public transport and it is the issue of this research project. Tramway can be defined as a system of transport used wholly or mainly for the carriage of passengers, which employs parallel rails that provide support and guidance for vehicles carried on flanged wheels, and has been designed to have a significant element which operates on line-of-sight on a highway [2].

Tramways have several advantages, which are: relieve traffic congestion; convenient transportation means, since it is provided comfortable, fast, and safe transport; environmentally friendly without air pollution; and in addition, it is reflected aesthetic aspect in the areas passing through them. While on the other hand, tramway has several disadvantages, which are: at infrastructure: (such as island platforms) occupy urban space at ground-level, sometimes to the exclusion of other users, including cars; at stop stations: there is not enough space for the passengers, or the passengers are collected in a limited space; and at tram: may be noisy when crowded with people [3].

This research aims to find the suitable tramway route to Ramadi city, but the route selection process required a wide range of navigation, surveying, and other to collect data. Several proposals through this process could be selected by using several tools, devices and programs. Finally, Multi–Criteria Decision Making (MCDM) method was adopted to select the most suitable and the optimum route among several proposals, and several criteria should be assigned to facilitate the comparison among the proposals [12].

2. Objective of Study

The main objective of this research is to determine the best route for a proposed tramway in Ramadi city. To accomplish this main objective, the following objectives should be achieved:

1- Collect, process, analyse sets of data in the area on which the proposed tramway pass, in a manner that can be considered as a guide in the process of choosing the best route of a tramway with its main design considerations such as the stop stations and platforms.
2- Explain the assumptions, specifications, and the limitations that should be considered for choosing the best tramway route during the collection of data.
3- Develop a set of design criteria that are considered as discriminating factors necessary to determine the best alternative route.
4- Express the importance of using the recent transportation tools, such as GIS, GPS, AutoCAD, in conjunction with the using of MCDM method, and show how they will affect the quality of best route choice.

3. Area of Study

Ramadi city (the capital of Anbar province) is the study area of this project. It is located in the western part of Iraq. Ramadi city occupies an important strategic location where it is located about 110 kilometres west of Baghdad.

This city is also characterized as located on the main expressway, which is leading to the Syrian and Jordanian borders.

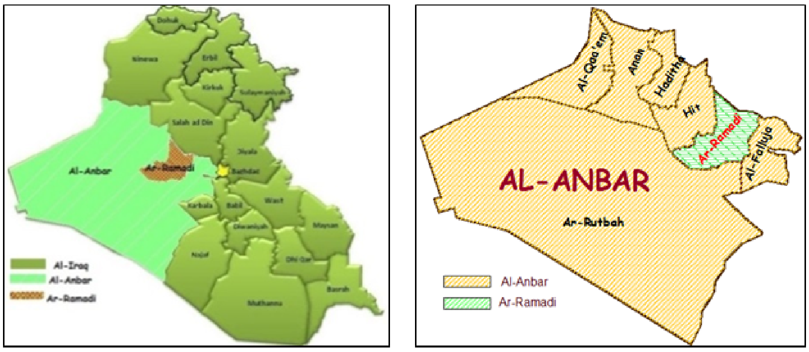


Figure1: Location of Ramadi in Iraq [14].

4. Specification and Limitation

To select an appropriate and secure track, proper and accurate assumptions and limitations must be adopted. The assumptions and limitations governed by several factors, which are: the geometric design of the track which depends on the length and shape of tram vehicle, and the location of the track which governed by land use; population density; traffic density and congestions; and the existence of important positions, generation, and attraction positions.

Ramadi tramway has been decided to select the track to be in the median of the roads with a single rail due to several reasons which are:

- Since the track is a single rail and the median width will be sufficient; therefore, it's considered more economic.
- The choice of median route will not affect on the carriageway width.
- It is free from the water and sewage networks (Ref. The Directorate of Anbar Sewer, The Directorate of Anbar Water).
- In addition, it reflects a beautiful view to the regions in which it passes through.

Based on global references, the limitations of track geometric design are: [4,5,6,7]

- Minimum Radius of track = 25 meters.
- Minimum Cross-Section along the track = 20.80 meters.
- Minimum Cross-Section at stop platform = 27 meters.
- Vertical Clearance = 4.10 meters.

5. Surveying and Data Collection

The first step in this research included a wide range of navigation and exploration of the study area, so as to: assign the origin and destination of the tram station, select the suitable proposed routes based on the specifications and limitations, and select the appropriate platform (stop stations).The navigation and surveying include two important field works, which are: origin-destination selection and candidate route selection. So, different tools and devices were used to facilitate and manipulate an accurate collected data which are: measuring tape, GPS device (Garmin etrex GPS), total station device (Leica TC 1202), and GIS program (Arc GIS10). Figure2 explains the tools that used in surveying of this research. Also, other data are used through the navigation of route selection such as: Master Plan (2012 and 2033) for Ramadi city from the Department of Urban Planning; and the contour Lines Map of Ramadi, which obtained from Turkish Company that achieved the overall surveying for the City in 2012[15].

The origin – destination selection is considered as the most important step in the route choice process; therefore, the selection of the origin and destination of the tramway route is very necessary to select the suitable candidate tramway routes. These two points must be selected accurately in order to serve the requirements of the city, based on the specifications and limitations. The origin position was selected to be located after the new gate by about (700) meters for the reasons: it is the largest vacant area, which is needed for constructing the main station in addition to the wide car parking; this position is surrounded by residential with the high population density area; and it is easy reachable for rural users. While the destination station was decided to be located on the western side of Ramadi city in the 18 kilo region based on the comprehensive master plan 2033[16].The coordinate's positions of origin and destination have been saved using a GPS device and then represented on Ramadi satellite image by GIS program, figure [3] explains the origin-destination position.

Figure 1: Surveying tools and devices.

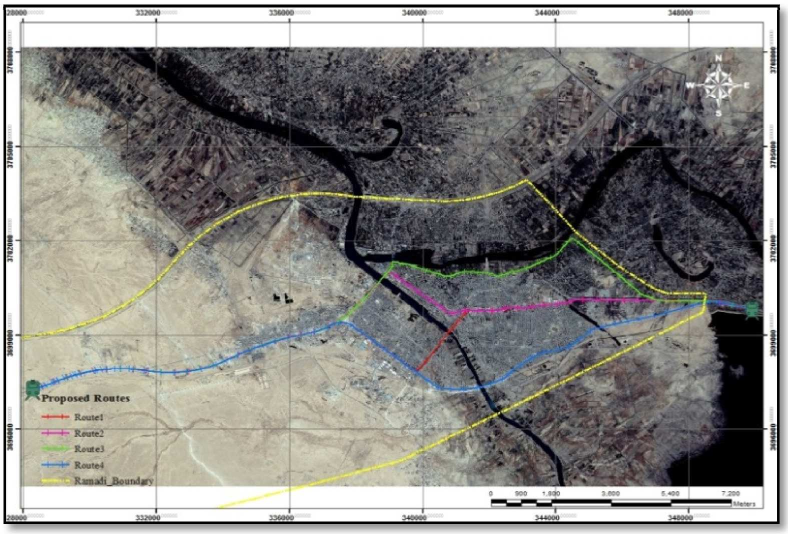
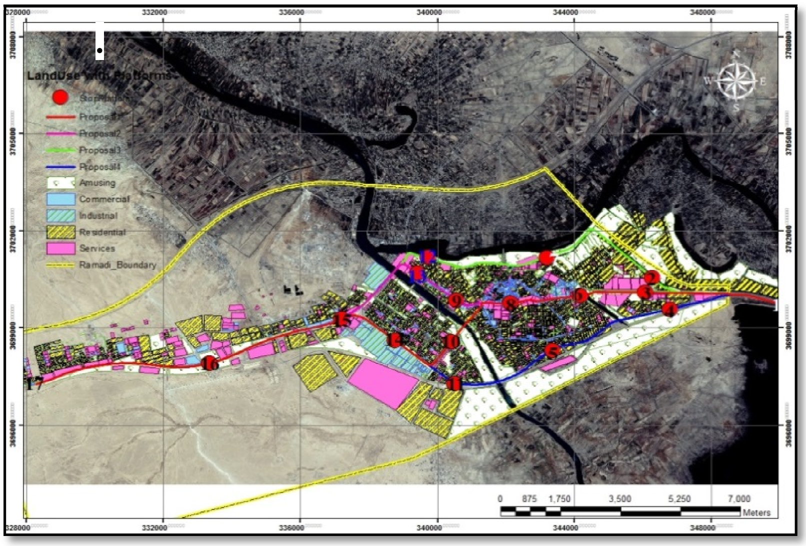


Figure 2: Origin-Destination selection and Proposed routes.

6. Platform Selection

The stop stations (Platforms) were selected depending on the land use layer, and based on the decided specifications and limitations, especially according to generation and attraction zones. Land use layer for the study area was made using Arc Map and depending on Ramadi master plans. The layer was divided into five categories, which are: residential area " generation zone"; commercial area "attraction zone"; services area "which includes schools, hospitals, and others of governmental departments, and it also considered as an attraction zone"; amusing area "which include the agricultural and recreational areas"; and Industrial areas. Figures [4] and [5] illustrates the land use categories and the platform locations respectively, which are draw by Arc Map 10.



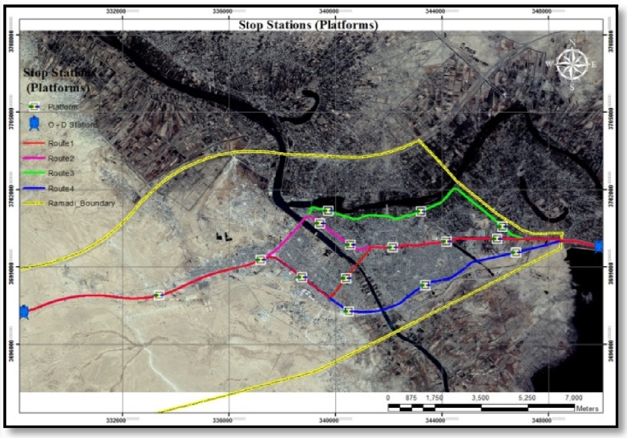


Figure 4: Land use categories. Figure 5: Platform locations

7. Selection of Comparison Criteria

7.1. General

Four routes have been proposed to Ramadi tramway, but to choose the suitable and best one among them, the properties and the characteristics of each route should be identified and then making a comparison among them. Six main criteria have been selected for comparison purpose, which are: accessibility, safety, environment, economic, population density, and security. A comparison's form has been designed accurately with great interest to include the proposed routes with their criteria and sub criteria in order to facilitate the comparison process to select the best proposal.

7.1.1. Accessibility

Accessibility can be defined as the relative ease of reaching particulars locations or areas. It is selected to include two important sub-criteria, which are: travel time and land use.

❖ **Travel Time**: means a specified period of time spent in traveling. Travel time can be expressed in the formula:

$$\text{Travel Time} = \frac{Route's\ Length}{Average\ Running\ Speed} + \text{Stop Time} \quad (1)$$

- The route's length was measured using Arc Map.
- Average running speed has been assumed 70 km/hr.
- Stop time represents the stopping times of tramway at each stop platform. So, it can be calculated by multiplying the number of stop stations on each route by the stop time in one station. The stop time in one stop platform has been assumed equal to 2 Minute.

Depending on equation (1) and its parameters calculation procedures, table [1] shows the travel time values "in minutes" for the proposals.

Table 1: Travel time calculations.

Routes	3D Length (Km)	Average Running Speed (Km/hr.)	Stop Time (Minute)	No. of stop platforms	Travel Time (Minute)
Route1	23.513	70	2	9	38.15
Route2	23.170	70	2	9	37.86
Route3	24.122	70	2	7	34.67
Route4	31.756	70	2	8	43.22

- **Land Use**: The land use is subdivided into five categories which are: residential, commercial, services; amusing, and industrial. The study area was divided into seventeen (equal areas) circular sectors. The radius of each sector was taken to be (350 meters). This value is recommended by the Iraqi specification for the maximum distance that pedestrians can walk[9]. Each sector was surveyed to calculate the existing land use categories as follows; the residential area was expressed by sectors, each sector approximately includes 16 residential units, service category was represented as a unit, while commercial, industrial, and amusing areas were expressed as percentages from the total area of the sector, table [2] explains the results of land use calculation.

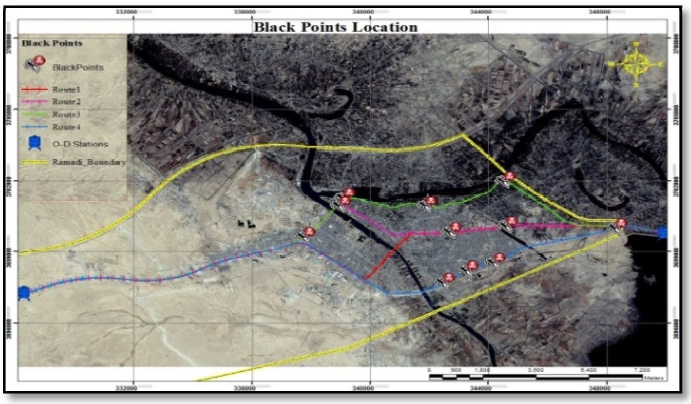
Table 2: Land use calculations

Route	Sectors	Residential	Services	Commercial	Industrial	Amusing
1	$S_1+S_3+S_6+S_8+S_{10}+S_{14}+S_{15}+S_{16}+S_{17}$	162	58	55%A_T	47%A_T	19%A_T
2	$S_1+S_3+S_6+S_8+S_9+S_{13}+S_{15}+S_{16}+S_{17}$	144	69	62%A_T	9%A_T	17%A_T
3	$S_1+S_2+S_7+S_{12}+S_{15}+S_{16}+S_{17}$	96	28	22%A_T	7%A_T	22.6%A_T
4	$S_1+S_4+S_5+S_{11}+S_{14}+S_{15}+S_{16}+S_{17}$	161	23	24%A_T	45%A_T	22.8%A_T

7.1.2. Safety

Safety criterion is represented by three sub criteria which are the following:

- **No. of black points:** means the locations on the roads that have largest number of accidents. The data which related with this criterion was collected from Ramadi traffic directorate and the black points on proposed routes were assigned according to an interview and discussion with the manager of traffic directorate. The point's positions were saved by GPS and then inserted on Ramadi satellite image by Arc Map10, figure [6] and table [3] explains the distribution of black points.



Figur 6: Black points positions

Table 3: No. of black points on each route.

Route	No. of Black Points
Route1	4
Route2	5
Route3	6
Route4	5

- **No. of Intersections :** The No. of intersections with road and the No. of intersections with river are the sub divided of this criterion. The tramway routes were selected to be located on the median of the roads; therefore, intersections points between tramway and roads existed, especially on roundabouts and rotaries. At these points, accidents may occur. So these points should be minimized as possible. Intersections points assigned by saving position by GPS and then inserted on Ramadi satellite image by Arc Map. Figure [7] and table [4] explain the distribution of intersection points.

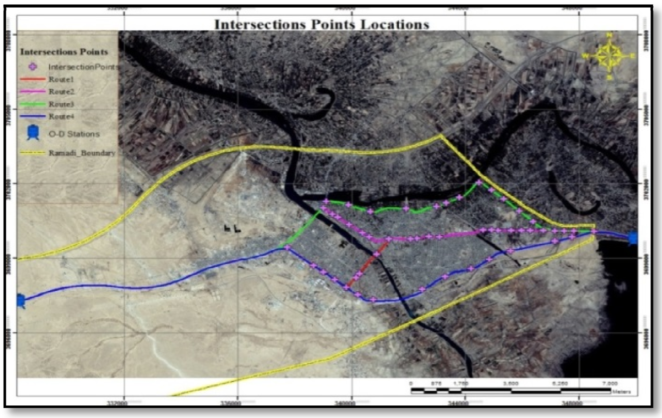


Figure 7: Intersections points locations.

Table 4: No. of Intersection points on each route.

Route	*No. of Intersections Points*
Route1	24
Route2	23
Route3	19
Route4	15

- **Alignment**: The numbers of horizontal curves, numbers of vertical curves and maximum grade for each route have been considered as factors affecting on track safety, figure [8] explains the parts of alignments.
  - No. of horizontal curves: The horizontal alignment for each route was designed using AutoCAD Civil 3D program 2013, where the necessary data for horizontal alignment design collected through surveying, by using total station and GPS devices.
  - No. of vertical curves: vertical alignment for each route was designed using AutoCAD Civil 3D program. For this purpose, the contour lines for Ramadi city were drawn, where the data was taken from ACAD's Company as a list of points included easting, northing, and elevations[15]. These points were inserted in Civil 3d program. The contour lines and profiles were created and then the vertical alignment was designed.
  - Max. Grade %: the maximum percentage of grade was assigned for each proposed route by using Civil 3D program, tables [5] and [6] explain the results of parameters of route alignments.

Table 5: Geometric parameters for parts.

Parts	*No. of H-Curve*	*No. of V-Curve*	*Max. Grade%*
Part 1	5	4	0.48%
Part 2	16	19	0.33%
Part 3	6	13	0.62%
Part 4	1	11	1.2%
Part 5	5	15	2.52%

Part 6	5	12	2.91%
Part 7	21	21	1.08%
Part 8	38	30	0.37%

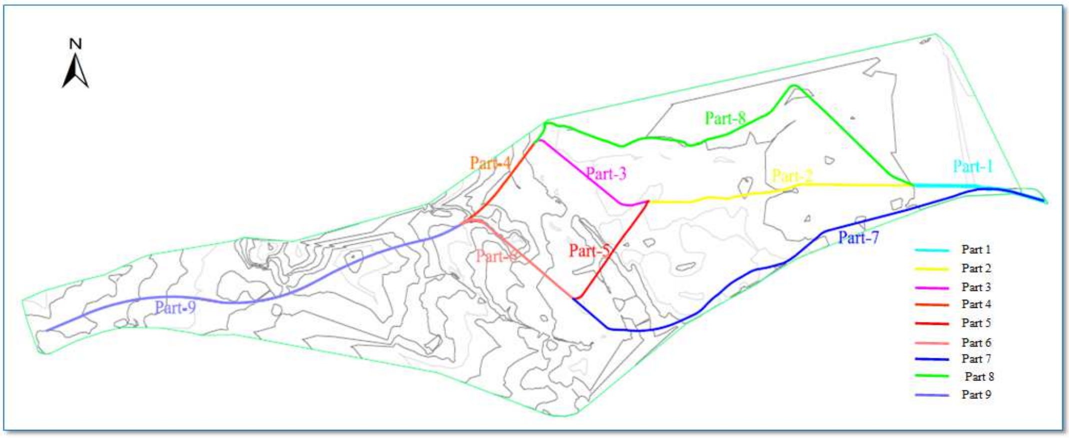


Figure 8: Alignment parts

Table 6: Parameters of routes alignments

Routes	*Parts of each route*	*No. of H-Curve*	*No. of V-Curve*	*Max. Grade%*
Route1	Part $_1$, Part $_2$, Part $_3$, Part $_4$	28	47	1.2%
Route2	Part $_1$, Part $_2$, Part $_5$, Part $_6$	31	50	2.91%
Route3	Part $_1$, Part $_8$, Part $_4$	44	45	1.2%
Route4	Part $_7$, Part $_6$	26	33	2.91%

7.1.3. Environment

Generally, environmental factors that may affect on the selection of the best routes are:

- **Noise and vibration**: The noise and vibration that occur by the tramway may trouble people who live close to tramway route. The length of residential area on which the tram pass was considered as the length of noise. From the data collected by GPS surveying that are represented in figure [9], the length of each part has been calculated by using Arc Map. Then the noise and vibration have been calculated as a percentage of the total length of its own route length based on equation (2), table [7] explains the calculation of noise and vibration effect.

$$\text{Noise \& Vibration} = \frac{\text{Sum of Parts on route}}{\text{Route length}} * 100\% \qquad (2)$$

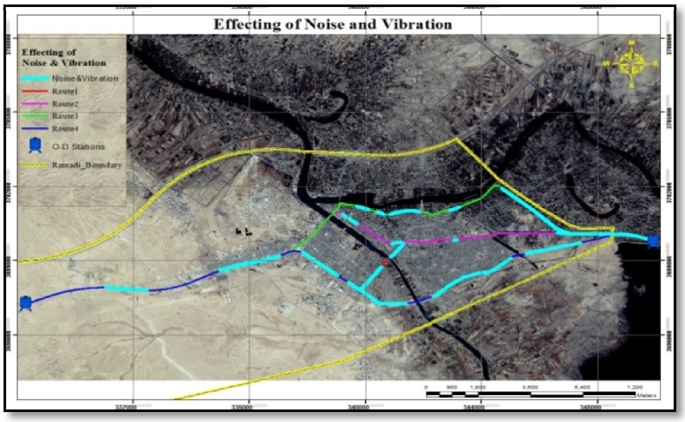


Figure 9: Effecting of noise & vibration

Table7: Calculations of noise and vibration effect.

Route	*Noise length*	*Route length*	*Percentage*
Route1	9226.210	23513.239897	39.2%L_1
Route2	7677.002	23170.629635	33.1%L_2
Route3	11393.415	24122.05539	47.2%L_3
Route4	11393.415	31756.456497	35.9% L_4

- **Aesthetic Aspect along the track**

  The passage of the tramway should be in the regions of aesthetic feature to grant the passenger’s comfortable feeling. The value of this criterion has been expressed as a portion of the path length, where the length of path that passed through the aesthetic regions has been recorded by GPS and then inserted on satellite image by using Arc Map 10; figure [10] and table [8] explain the calculations of aesthetic aspect.

$$\text{Aesthetic Aspect} = \frac{\text{Sum of Parts on route}}{\text{Route length}} \times 100\% \quad (3)$$

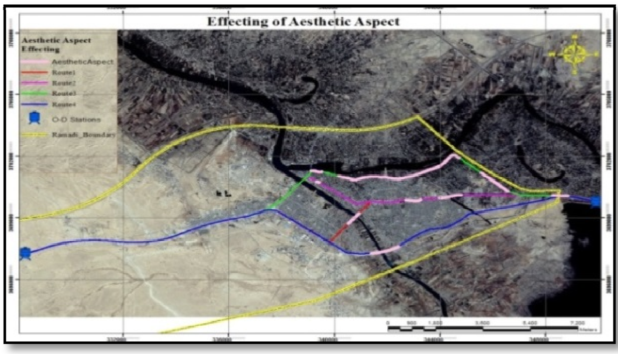


Figure 10: Effecting of aesthetic aspect.

Table 8: Calculations of aesthetic aspect along route

Route	*Aesthetic aspect length*	*Route length*	*Percentage*
Route1	2610.846	23513.239897	11%L_1
Route2	2064.416	23170.629635	9%L_2
Route3	7344.110	24122.05539	30%L_3
Route4	1647.023	31756.456497	5%L4

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7.1.4. Economic

The main subdivisions that are taken under the economic criterion are:

- **Path length**: The length of each proposal has been calculated as a surface length (3D) using a python window in Arc Map. The cost for the track length will be measured according to the amount of each unit length. The route that has the longest value will score less weighting value. Table [9] explains the route length in kilometers**.**

Table 9: Length of proposed routes.

Route	*3D Length (Km)*
Route1	23.513
Route2	23.170
Route3	24.122
Route4	31.756

❖ **Cost of construction**: Several things will affect on the economic aspect of the project when intended its construction which are:

- Length of bridge: The length of each bridge that exists on each route has been measured by the GPS device. Table [11] explains the length of the bridge on each route.
- No. of stop station: The number of stop platforms that are located on each route has been taken into consideration when estimating the economic factor. Table [10] explains the number of platforms on each route.
- Geometrical improvements: The required geometric improvements along the track have been calculated as a percentage of the total length of its own route length, where the length of each part is calculated by using python window by Arc Map. Figure [11] explains sections along the routes which need the improvements, while table [10] indicates their statistics. The lengths were recorded by GPS and their position was saved by GPS and inserted by GIS on the satellite image[16].

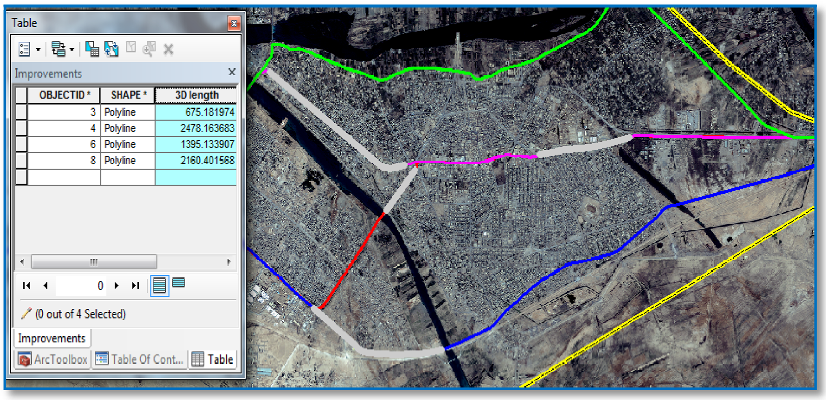


Figure 11: Calculation of geometric improvement.

Table 10: Calculation of geometric improvement.

Route		*Geometric improvement [m]*	*Route length [m]*	*Percentage*
Route1	1395.134+675.182	2070.316	23513.239897	9 $\%L_1$
Route2	1395.134+2478.164	3873.298	23170.629635	17 $\%L_2$
Route3	—	—	24122.05539	0 $\%L_3$
Route4	2160.402	2160.402	31756.456497	7 $\%L_4$

Table 11: Cost of construction

Routes	*Length of Bridge*	*No. of Stop Platform*	*Geometric improvement %*
Route 1	150 m	7	9 %L_1
Route 2	200 m	7	17 %L_2
Route 3	200 m	5	0 %L_3
Route 4	100 m	7	7 %L_4

- Cut and Fill quantities: The earthworks quantities of cut and fill have been taken into consideration to evaluate which route is more economic. These quantities have been calculated using AutoCAD Civil 3D 2013 through several steps in program based on the alignment design sample lines, and compute material options in the program for each part and then for each route. Tables [12] and [13] explain the results of each part and of each route respectively.

Table 12:Quantities results for parts

Parts	*Cut (Cu.M.)*	*Fill (Cu.M.)*
Part 1	9,086.62	4,529.81
Part 2	2730.8	4660.37
Part 3	299.37	4743.66
Part 4	752.84	7117.75
Part 5	4216.62	4850.76
Part 6	5662.03	6128.41
Part 7	35724.88	53585.85
Part 8	747.51	30850.56

Table 13: Quantities results for routes

Routes	*Parts of each route*	*Cut (Cu.M.)*	*Fill (Cu.M.)*
Route1	Part $_1$+Part $_2$+Part $_3$+Part $_4$	12,869.63	21,051.59
Route2	Part $_1$+Part $_2$+Part $_5$+Part $_6$	21,696.07	20,169.35
Route3	Part $_1$+Part $_8$+Part $_4$	10,586.97	42,498.12
Route4	Part $_7$+Part $_6$	41,386.91	59,714.26

7.1.5. Trips and population

The estimation of population and trips of each route explains the impact of the people who will use the tram through the calculation of the population density of the people who will use the tramway and determine the percentage of the population who wish to establish the tramway as well as the number of Trips on each track.

- **Population Density :**means the number of people living per unit of an area or the number of people relative to the space occupied by them, so to be able to calculate the population density, the layer of Ramadi segments distributions has been made by using geographic information systems (GIS), which based on the Ramadi master plan and on the divisions (zones) that created by Wassan Mehdi [10].

The distribution of population density has been made by Arc Map based on the collected data of the statistics population distribution, total number of people in 2010, and total number of people in 2012. Several steps were made to estimate the population density that each route can be served, those steps are:

Step1: Calculation of growth factor that should be calculated to estimate the population density for the year 2013 and 2033. The available statistics of the population are only for the years, 2010 and 2012[17]. The growth factor has been calculated, as follow:

Let: $X_{1}= \sum No. of\ people\ at\ 2010.$, and

$X_{2}= \sum No. of\ people\ at\ 2012.$

Where, The Growth Factor [r] $=\frac{X2-X1}{X2}$;

$r = \frac{452267-420666}{452267} = 0.0698$ Growth Factor for two years.

$r = \frac{0.0698}{2} = 0.0349$ Growth Factor for one year.

Step2: Calculation of population densities of zones for the year 2013, depending on the statistical data of 2007, where the number of people for each zone has been calculated based on the equation:

$$\text{No. of people}_{\text{Future}} = \text{No. of person}_{\text{presents}} \times (1+r)^{n} \quad (4)$$

Where, n= No. of years.

r= Growth Factor.

The population density was calculated by inserting the equation of population density in the field calculator window in Arc Map, where:

$$\text{Population Density (P.D.)} = \frac{No.of\ people\ in\ zone}{Area\ of\ the\ zone} \quad (5)$$

Figure [13] illustrates the graphically distributed of calculated population density for all Ramadi zones.

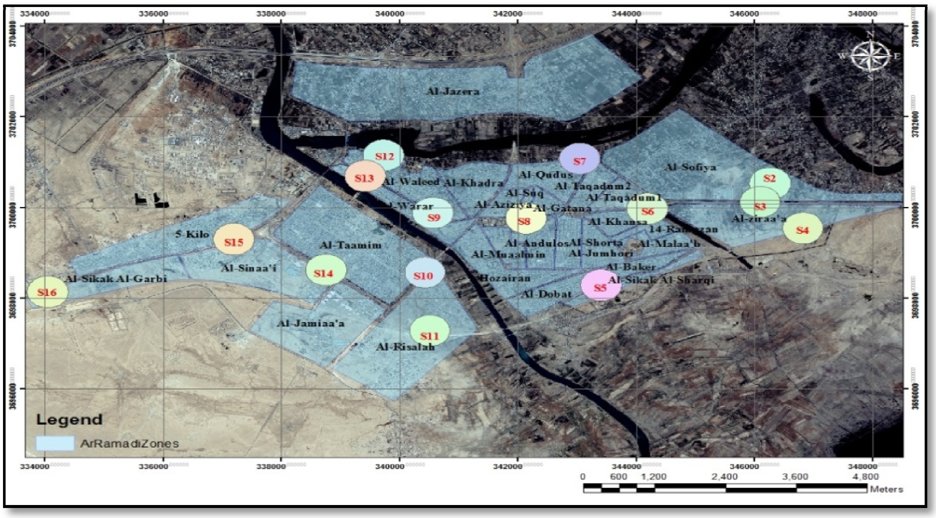


Figure 13: Locations of sectors on the zones.

Step3: Population density is calculated for each route from the estimated population of sectors. Figure [14] assigns the sector's location in the study area, and tables [14] and [15] indicate the calculated population density for each sector in year 2013 and for the alternative routes respectively.

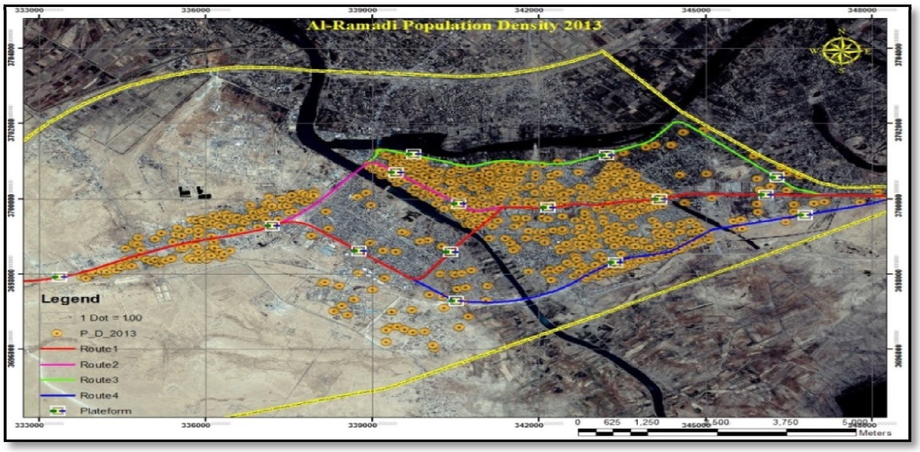


Figure 14: Ramadi population density 2013 distribution.

Table 14: Population density 2013 in each sector

No.	*Sectors*	*P.D. (Person/Km^2)*	*No.*	*Sector*	*P.D. (Person/Km^2)*
1	Sector 1	1704	9	Sector 9	7304
2	Sector 2	1704	10	Sector 10	2217
3	Sector 3	1344	11	Sector 11	2599
4	Sector 4	931	12	Sector 12	4944
5	Sector 5	3244	13	Sector 13	6423
6	Sector 6	11964	14	Sector 14	5389
7	Sector 7	5715	15	Sector 15	3611
8	Sector 8	3760	16	Sector 16	8489

Table 15:Population density on each route (Person/Km2)

Routes	*Sectors*	*P.D. (Person/Km^2)*
Route 1	$S_3+S_6+S_8+S_{10}+S_{14}+S_{15}+S_{16}$	36,774
Route 2	$S_3+S_6+S_8+S_9+S_{13}+S_{15}+S_{16}$	42,895
Route 3	$S_2+S_7+S_{12}+S_{15}+S_{16}$	24,463
Route 4	$S_4+S_5+S_{11}+S_{14}+S_{15}+S_{16}$	24,263

- **Percent of acceptance to construct tramway**: A simple questionnaire form has been designed to be able to calculate the percentage of people who desire to construct tramway and the numbers of trips for each of proposed routes, these forms have been distributed to the people who live in a residential sector for each of proposed routes.

  To estimate the acceptance of people to construct the tramway in Ramadi, a questionnaire form has been designed as explained previously, where the form has been distributed to several sectors, especially the generation sectors "that was having a high population density". These sectors are (1, 2, 3, 5, 6, 7, 9, 10, 11, and 16). So, for these sectors sample size will be calculated. Thompson formula is used to calculate sample size of the population proportion, where the sample size formula based on the normal approximation gives [11]:

$$n=\frac{N\,P\,(1-P)}{(N-1)\left(\frac{d^2}{z^2}\right)+P\,(1-P)}$$ Thompson formula

Where; n: sample size.

N: number of people in sector.

P: population proportion, since no estimation of P is available prior to the survey, a worst – case value of P= 0.5 has been used in determining sample size because the sample size assumes its maximum value when P=0. 5.

z: is the upper α/2 point of the normal distribution, which equal to (1.96).

d: error proportion, which is equal to (0.05).

So, the number of people (N) in each sector should be calculated to estimate the sample size. The number of people is calculated by multiplying the areas of residential by the population density of its own sector. Tables [16] and [17] demonstrate the calculations and the percentages of acceptance for the sixteenth sectors and the alternative routes, respectively.

Table 16: Percent of acceptance to construct tramway for sectors.

Sectors	*P.D.*	*R. Area (Km^2)*	*No. of people [N]*	*Sample size [n]*	*Distributed form (lost)*	*Forms which get [Yes]*	*Percent of acceptance to construct tramway*
Sector 1	1,704	0.05	84	69	80 (8)	69	96 %
Sector 2	1,704	0.13	179	122	130 (6)	120	97 %
Sector 3	1,344	0.033	44	39	45 (5)	36	90%
Sector 5	931	0.13	121	92	100 (9)	91	100 %
Sector 6	11,964	0.073	873	267	270 (13)	257	94 %

Sector 7	5,715	0.053	302	169	170 (9)	134	83 %
Sector 9	7,304	0.12	850	265	270 (11)	246	95 %
Sector 10	2,217	0.11	617	237	240 (13)	227	100 %
Sector 11	2,599	0.18	81	67	70 (6)	56	88 %
Sector 16	8,489	0.06	486	215	230 (38)	192	100 %

Then the acceptance of each route has been calculated by taking the average of acceptance percent of its own sectors:

Table 16: Percent of acceptance to construct tramway for Routes.

Route	*Sectors*	*Average of acceptance %*
Route 1	$[S_1+S_3+S_6+S_{10}+S_{16}]$ /5	96%
Route 2	$[S_1+S_3+S_6+S_9+S_{16}]$ /5	95%
Route 3	$[S_1+S_2+S_7+S_{12}+S_{16}]$ /5	94.6%
Route 4	$[S_1+S_4+S_5$+S11+S16] /4	96%

- **No. of Trips**: To estimate the generated number of trips for each route, an analysis process was made in the questionnaire form, where they are 1610 copy of the form had been distributed in September 2013 to the population inside the sectors boundary. The generated trips of each sector have been determined and then the trips of each route have been calculated from total led trips of each sector of its own route. Tables [18] and [19] explain the calculation of trip generation of proposed routes.

Table 18:Trip generation calculations.

Sectors	*Total Trip Generation in Sector*	*(Total of Trips / Month) Routes*			
		Route 1	Route 2	Route 3	Route 4
Sector 1	4188	2359	1186	58	585
Sector 2	2136	0	0	2136	0
Sector3	1203	755	448	0	0
Sector5	1719	0	0	0	1719
Sector6	4159	3058	1101	0	0
Sector7	2032	0	0	2032	0
Sector9	5628	0	5628	0	0
Sector10	4072	4072	0	0	0
Sector11	1058	0	0	0	1058
Sector16	4993	3556	511	287	639
Total Route Trips		13800	8874	4513	4001

Table 19: Trip generation of proposed routes.

Routes	*Average of sectors*	*Trips/Month*
Route 1	$(S_1+S_3+S_6+S_{10}+S_{16})/5$	2,760
Route 2	$(S_1+S_3+S_6+S_9+S_{16})/5$	1,775
Route 3	$(S_1+S_2+S_7+S_{16})/4$	1,128
Route 4	$(S_1+S_5+S_{11}+S_{16})/4$	1,000

7.1.6. Security

The security criterion represented the locations of security building in Ramadi city, which have been identified in cooperation with security centers, police stations, and through navigation and surveying. This criterion was assigned as points, where the locations were saved by GPS and then inserted on satellite image by GIS. Figure [15] and table [20] indicate the security stations.

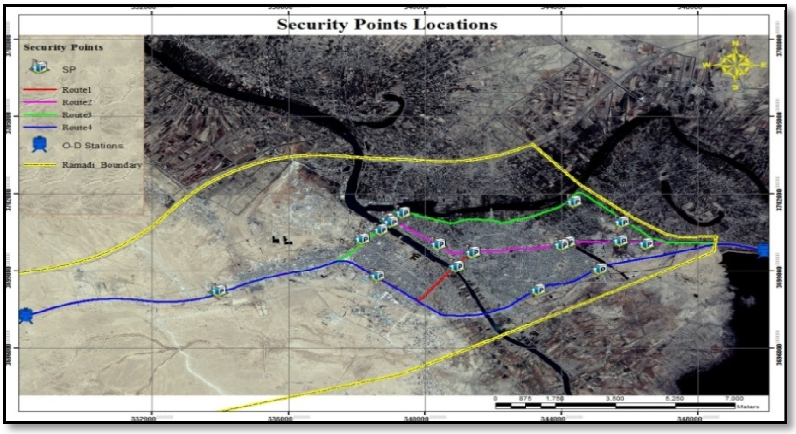


Figure 15: Security points locations

Table 20: No. of Security Points

Route	*No. of Security Points*
Route1	8
Route2	10
Route3	8
Route4	5

Finally, the six criteria and sub criteria were arranged in a comparison form. A review form has been designed to evaluate the comparison form and submitted to a group of transportation experts with a copy of comparison form in order to evaluate its suitability to find the optimum route of Ramadi tramway.

8. Data Analysis

Multi-Criteria Decision Making (MCDM) method has been chosen to evaluate the proposals for selecting the optimum route among the four proposals, because the (MCDM) method represents a tool that has been developed for selecting the best option among several candidates. The procedure of analysis by using this method includes[12,13]:

8.1. Identify alternatives

Based on the navigation, surveying and validity of track location and geometric design of the track, four paths have been identified as proposed routes to Ramadi Tramway.

8.2. Identify decision / selection criteria

Six main criteria have been identified with their sub criteria to facilitate comparison among the four proposals, which are: accessibility, safety, environment, economic, population and trips, and security. Each one of the main six criteria has sub criteria. Each criterion and sub criterion has been calculated as hereinbefore.

8.3. Assign weights

A questionnaire form containing the project summary and a list of the main criteria with their definitions were designed to evaluate the criteria weights. A group of experts formed of three decision makers (civil engineers) in Anbar city and the authors evaluated the criteria and weighted them. The nature of the study area was taken into weighting considerations. The final weighted values were averaged to be used in the following sections. The weightings of the adopted criteria are located in table [21].

Table 21: Evaluated values of decision-makers

Criteria	*Supervisor*	*Associate Administrator the Municipality*	*Member of the Council*	*President of the Council*	*Average*
Accessibility	20%	13%	15%	10%	20%
Safety	25%	15%	23%	10%	15%
Environment	10%	12%	20%	10%	10%
Economic	15%	20%	15%	50%	20%
Population Density	20%	20%	15%	10%	25%
Security	10%	20%	12%	10%	10%
Total	100%	100%	100%	100%	100%

The weightings of the main six criteria have been divided into sub weighting to prepare it for analysis process. To achieve the main research objective which is the selecting of the best route for the proposed tramway, a hierarchical tree for the main six criteria with their sub-criteria were drawn, figure [16] explains the tree of criteria and sub criteria with their weighting.

8.4. Design a scoring system

The criteria and sub-criteria values for each alternative have been normalized by a scaling factor (ß), which calculated by equation (4) or (5) taking into consideration the desirable value among alternatives. Table [24] explains the calculation of scaling factor based on the table [23]:

If a high criterion value is desirable (e.g. Population density, Trips…. etc.):

$$ß=\frac{Calculated\ Value}{Max.Value} \times 100 \qquad (6)$$

If a low criterion value is desirable (e.g. Travel time, Cost… etc.):

$$ß =\frac{Min.\ Value}{Calculated\ Value} \times 100 \quad (7)$$

8.5. Rate of scores of alternatives

The rate of each criterion for each proposal has been calculated by multiplying the scaling factor (ß) of the criterion by its own weighting factor (ωi). Table [23] explains the results of the score rating for each criterion based on the table [22].

$$\text{Rating of Score} = \text{scaling factor } (\boldsymbol{\beta}) \times \text{weighting factor } (\boldsymbol{\omega_i}) \quad (8)$$

8.6. Total the scores

The concluded weights of the selected criteria were totaled for each alternative route. The route having the highest score among the four alternatives represents the best one.

The results of the totaled scores as explained in the table [4.26] are (85.73) for poposal1, (77.08) for proposal2, (70.84) for proposal3, and (68.06) for proposal4. Proposal1 has the highest score (85.73); therefore, proposal1 may be considered the best alternative among the four alternatives to be an acceptable tramway route at Ramadi city. Figure [18] explains a comparison of the final results for route proposals.

Figure 16: Tree of criteria and sub criteria with their weighting.

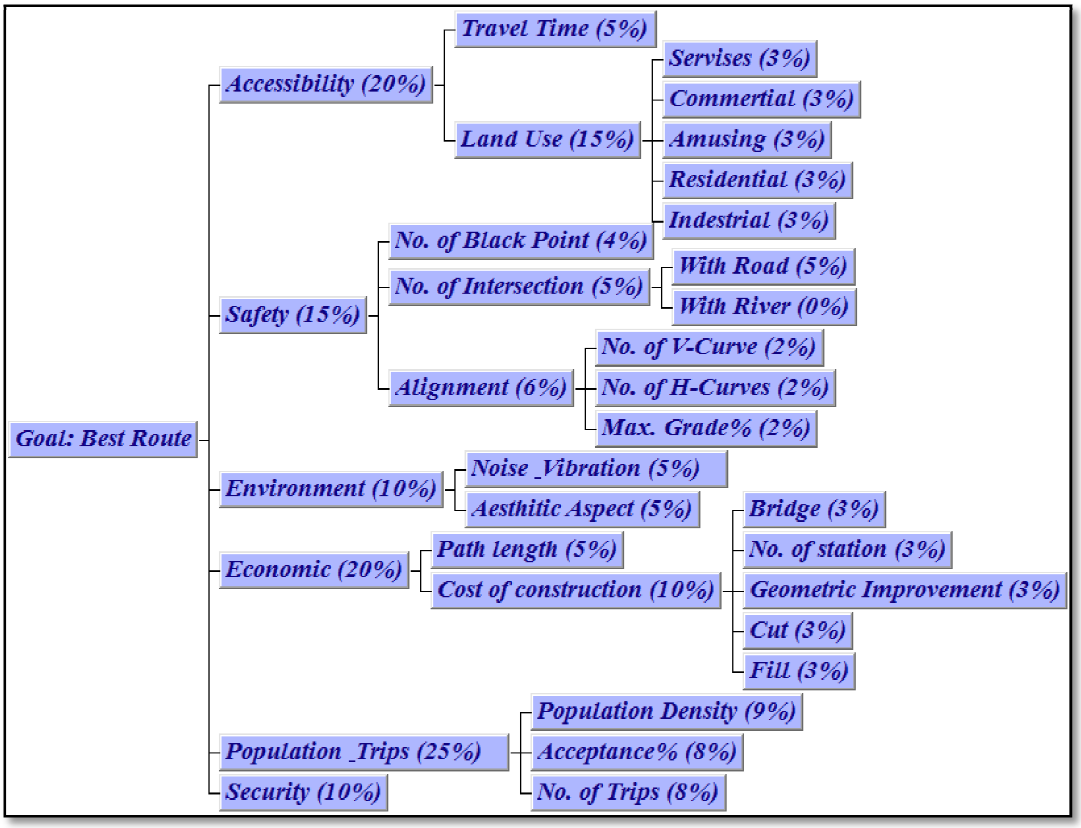


Table 22: calculated values of criteria and sub criteria

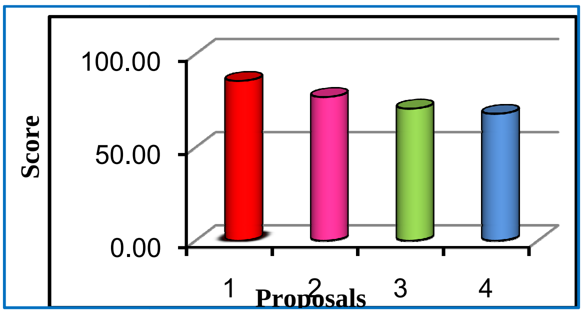
Goal	Criteria	weight	Sub Criteria		Weight	Calculated Values			
						Proposal 1	Proposal 2	Proposal 3	Proposal 4
Best Proposal	Accessibility	20%	Travel Time (min)		5%	38.15	37.86	34.67	43.22
			Land Use	Services	3%	58	69	28	23
				Commercial	3%	55	62	22	24
				Amusing	3%	19	17	22.6	22.8
				Residential	3%	162	144	96	161
				Industrial	3%	47	9	7	45
	Safety	15%	No. of black points		4%	4	5	6	5
			No. of Intersection	With Roads	5%	24	23	19	15
				With River	0%	1	1	1	1
			Alignment	No. of V-Curve	2%	48	50	45	33
				No. of H-Curve	2%	28	31	44	26
				Max. Grade %	2%	1.20%	2.91%	1.20%	2.91%
	Environment	10%	Noise & Vibration effect		5%	39.2	33.1	47.2	35.9
			Aesthetic Aspect		5%	11	9	30	5
	Economic	20%	Path length (Km)		5%	23.513	23.17	24.122	31.756
			Cost of Construction	Bridge Length (m)	3%	150	200	200	100
				No. of stations	3%	7	7	5	7
				Geometric Improvement	3%	9	17	0.1	7
				Cut (m^2)	3%	12869.63	21696.07	10586.97	41386.91
				Fill (m^2)	3%	21051.59	20169.35	42498.12	59714.26
	Population Density	25%	Density of people		9%	36774	42985	24463	24263
			Acceptance %		8%	96	95	94.6	96
			No. of Trips/month		8%	2760	1775	1128	1000
	Security	10%	No. of security points		10%	4	5	6	5

Table 23: Calculation of comparison results

Scaling Factor				Rating of Score = Scalling Factor*Weight			
(Min. Value/Value)*100		OR	(Value/Max. Value)*100				
Proposed 1	Proposed 2	Proposed 3	Proposed 4	Proposed 1	Proposed2	Proposed3	Proposed4
90.88	91.57	100.00	80.22	4.54	4.57	5.00	4.01
84.06	100.00	40.58	33.33	2.80	3.33	1.35	1.11
88.71	100.00	38.71	38.71	2.66	3.00	1.16	1.16
93.41	85.71	94.51	100.00	2.50	2.23	2.97	3.00
100.00	88.89	59.26	99.38	3.00	2.67	1.78	2.98
100.00	19.15	14.89	95.74	3.00	0.57	0.45	2.87
100.00	80.00	66.67	80.00	4.00	3.20	2.67	3.20
62.50	65.22	78.95	100.00	3.13	3.26	3.95	5.00
1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
68.75	66.00	73.33	100.00	1.38	1.32	1.47	2.00
92.86	83.87	59.09	100.00	1.86	1.68	1.18	2.00
100.00	41.24	41.24	41.24	2.00	0.82	0.82	0.82
84.44	100.00	70.13	92.20	4.22	5.00	3.51	4.61
36.67	30.00	100.00	16.67	1.83	1.50	5.00	0.83
98.54	100.00	96.05	72.96	4.93	5.00	4.80	3.65
66.67	50.00	50.00	100.00	2.00	1.50	1.50	3.00
71.43	71.43	100.00	71.43	2.14	2.14	3.00	2.14
1.11	0.59	100.00	1.43	0.03	0.02	3.00	0.04
82.26	48.80	100.00	25.58	2.47	1.46	3.00	0.77
95.81	100.00	47.46	33.78	2.87	3.00	1.42	1.01
85.55	100.00	56.91	56.45	7.70	9.00	5.12	5.08
100.00	98.96	98.54	100.00	8.00	7.92	7.88	8.00
100.00	64.31	40.87	36.23	8.00	5.14	3.27	2.90
100.00	80.00	66.67	80.00	10.00	8.00	6.67	8.00
1984.56	1655.58	1599.47	1556.34	**85.06**	**76.36**	**70.97**	**68.20**

9. Result

The results of analysis explain that proposal1 is an acceptable tramway route to Ramadi city. Figure [18] explains the acceptable tramway route to Ramadi city. However, this result depends mainly on the following assumptions and limitations; therefore, the result is considered acceptable within these limitations and assumptions.



1- Figure 3: Final result

2- Regarding the traffic conditions, the research depends mainly on the geometric characteristics of Ramadi road network due to the limitation of the study period.
3- The lack of information about population by Ramadi authorities may restrict the results for comparison purposes. For example, the available statistics is only for the two years, 2010, and 2012.
4- Due to the security situation of the city, very limited information about the security points was got by a researcher.
5- The weighting values for the main criteria with their sub-criteria set by the legislative bodies of governments were very limited and may highly vary from one to another, which make it difficult to maintain their weightings. The selection of the best route will strongly be affected by this point. Finally,
6- The researcher selected the multi criteria decision making (MCDM) method to evaluate and choose the best proposal, which depends on methodology that may differ from another procedure; however, this method is recently widely used by transportation planners and Engineers.

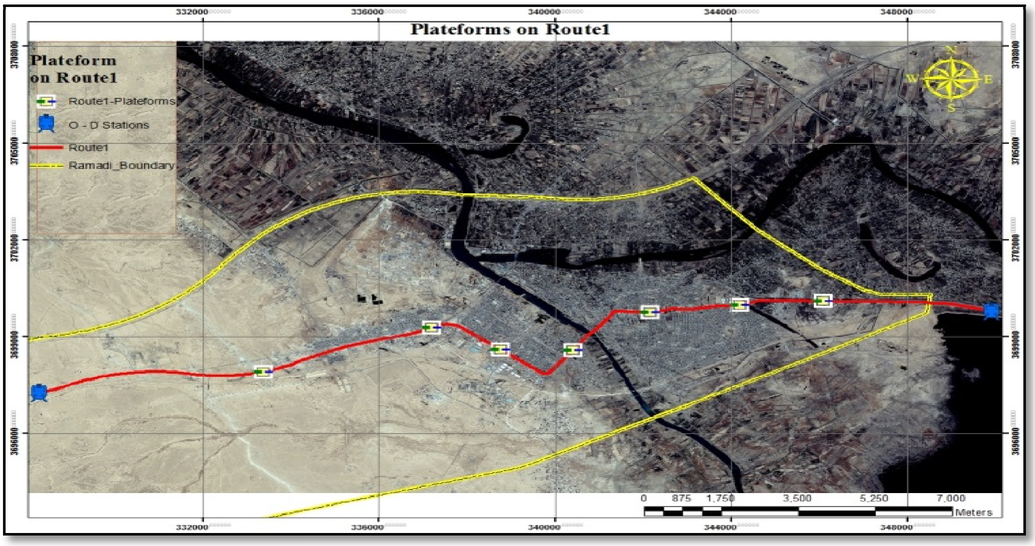


Figure 18: An acceptable tramway route at Ramadi city

10. Conclusion and recommendation

This research introduces an acceptable tramway route at Ramadi city which is represented by proposal1. The results of this analysis indicated clearly that many of the technical challenges of implementing, the tramway systems in various corridors of the city can overcome. Furthermore, it demonstrates that Tramway is a feasible and efficient transportation mode for Ramadi city.
Based on the general results of this research, the following points could be concluded:

- Collecting, analysing, and processing of data for areas on which the proposed tramway pass, besides, explaining the factors with their limitations for the socioeconomic and land use features reveal that they play a crucial role in selecting the suitable route.
- It is essential to identify the main criteria with their sub criteria that govern the weighting process to select the best route depending on the ambient conditions and existing facilities of the area on which the tramway will pass. The expressed criteria in this research project are; (accessibility, safety, environment, economic, population density, and security).
- The weighting values that are assigned for each criterion, decided by the experts in the region and the decision makers, are considered the key factors scoring the suitable route.
- The findings of this research are convenient to be a guide to Al-Ramadi province planners and designers in taking the suitable and logical decision in case of applying tramway project.
- The design of the layout of a tramway and the location of stop stations (platforms) are experienced as a multidisciplinary activity and composition of urban layers.
- The research reflects the importance of the multi criteria decision making (MCDM) method of supporting the planners in evaluating the route candidates.

Based on the experience gained during this research, the software of GIS is a very useful tool in surveying and representing data, GPS device is a very good tool in saving location and coordinates, and the program Civil 3D is very useful in alignment design and in calculations of cut and fill quantities.

There are several important notes which can be listed as future recommendations, which are:

- Performing a study to connect tramway mode with other modes of transportation.
- Performing a study to find the suitable and the closer garages to the tram stop stations.
- Finding the traffic flow, designing speed, and level of service (LOS) to Ramadi roads' network, and then checking the proposed routes because the proposed tram routes are based on traffic data which are expected to be more efficient than those based on land use only.
- Evaluating Ramadi roads' network, and studying the effect of tramway on the network improvement.
- Performing a comparative study about the cost of tram and the costs of other modes, and checking their effect on standard living.
- Testing other methods and tools to select paths, analysing them, and choosing the best path among them, and then comparing results.
- Performing a study about the tramway structural design and underlying layers for tram infrastructures.

Abbreviations

R	Radius of curve.
θ	Degree of curve.
L_C	Curve length.
V	Design speed.
X_1	No. of persons 2010.
X_2	No. of persons 2012

N	No. of years.
R	Growth factor.
P.D.	Population density (person/Km^2).
[n]	Sample size.
R.A.	Residential area.
N	No. of persons in sector.
P	Population proportion.
Z	Upper α/2 point of normal distribution.
D	Error proportion.
MCDM	Multi Criteria Decision Making.
ß	Scalling factor.
ω_i	Weighting factor.

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