Optimal Oil Pipeline Route in Kurdistan Region Taq Taq - Bazian Refinery as Case Study

Jafar A. Ali[#1] and Loghman Khodakarami[*2]

[#]Faculty of Engineering, Koya University, Koya, Kurdistan Region - Iraq

***Abstract*— There are only two oil and gas pipelines in Kurdistan Region, one is the international pipeline to Turkish Cihan harbor and the second is for national natural gas pipeline across the region. This paper is studying the process of finding an optimal pipeline to connect one of the biggest refineries in the region with an oil field of TTOPCO. The process is using Geographical Information Systems GIS. For constructing such pipeline several factors; slope, distance to roads, distance to villages, etc. were involved, prior to importance weights were applied to each factor. The higher weight was given to input slope, to avoid sharp slopes in the indicated direction. As a result an optimal route of length 58km was found to connect the refinery with the oil field. The aim of the project is to develop systematic, effective and environmentally friendly pipeline route. This will increase the reliability of the generated route and reduced the road accidents by the trucks that are transferring the crudes from the field to the refinery. The paper is for the benefit of the pipeline designers and the companies work in this field.**

***Keywords*— Pipeline, GIS, rout selection**

I. Introduction

Kurdistan Region is shown a fast growing in the fields of energy. The demand for fuel is also increased due to the dramatic raise in the number of vehicles on Kurdistan roads. One of the two largest refineries existed in the regions is Bazian refinery located 25km from city of Sulaymaniyah. Bazian refinery was established in 2009 its producing diesel, gasoline, kerosene and naphtha for the markets and industries. The production capacity of the refinery increased to 34000b/d in 2012 [1]. The refinery is receiving crudes from the regional oil fields via road trucks tankers. This method of transportation is considered the worst mode of oil transmission as the factors of death, fire and injuries are too high [2]. The main oil field that is supplying Bazian refinery with crude is Taq Taq Oil Production Company TTOPCO which is running by Genel Energy. Taq Taq field is located in the city of Koya, 60 km north of the giant Kirkuk oil field, 85 km south-east of the capital city Erbil and 120 km north-west of Sulaimaniyah [3].

Bazian refinery is planning to increase the production and design a pipeline for receiving crudes from the neighboring oil production fields [1]. The increasing of population has raised the demand of oil and gas, pipeline is safest and economical mode for transporting both of them [4].

In this paper the process of finding optimal pipeline route to connect Taq Taq field with Bazian refinery will be studied, the best selected rout using GIS is investigated. GIS provides a large number and a variety of analytical functions that are capable of replacing manual and traditional methods of route planning. It is a powerful tool to integrate thematic layers in an automated environment to compute possible shortest route with associated costs which eventually can reduce the cost and time of project execution and hence the operating expenses. Planning for the optimum route requires an extensive evaluation process to identify the best possible path. This path must comply with the requirements of the user in terms of safety and cost. With the fast development environment in gas industry, and with the increase in consumption of these products, the need for an optimum route becomes more important as this can reduce a huge operational cost [5]. GIS can gather and present relevant information for issues on which decisions must be made. Unlike traditional information systems, GIS allows the graphic presentation of data and provides reliable data for making sound decisions [6]. [7] studied an optimization model to build a trunk natural gas pipeline aiming in balancing the maximum operation benefit and the maximum transmission amount. The weight sum method was used to combine these two optimization goals into one hybrid objective function, and the weight value of each single objective function was determined by the scale method. In the current study the weight has been given to each factor and then input to GIS to find the cheapest rout. The aim of the current study is to provide an optimum route of the pipeline to pass through a hilly area and cross zab river to transmit crude from TTOPCO to Bazian Refinery, figure 1 illustrates the locations of the study area on map.

II. Modes of Hydrocarbon Transportation

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Oil and gas do not behave the same way when released into the environment, oil can spread rapidly and it is flammable under certain conditions. It can be harmful to the environment and seep into the ground, or sink in water, making recovery challenging as special equipment is needed to clean it up [8]. All these are subjected to the transport mode that is used to move the hydrocarbon and its products between the cities and plants.

Early producers shipped their oil to market in earthenware vessels aboard slow-moving barges. Since then, the need to move increasingly large quantities of petroleum has brought about some big changes in the industry [9]. Four modes of crude transportation are exist across the world; road trucks, ships, railways and pipelines. [6] Approved that the transporting oil by pipeline is safe and environmentally friendly. Furthermore, pipeline transportation is safer than transportation by road, rail, or barge, as measured by incidents, injuries, and fatalities even though more road and rail incidents go unreported [6]. Although the road trucks mode is the worst transportation mode of hydrocarbon [2] it's the only method that is used in Kurdistan Region.

III. Materials and Methods

A. Route Planning and GIS

Determining the best route through an area is one of the oldest spatial problems. This problem has recently been solved effectively using GIS and Remote Sensing technologies. During the last decade, a few attempts have been made to automate the route-planning process using GIS technology. GIS has many tools to analyze spatial networks, it's the most important tool is related to the shortest or optimal route determination [10].

GIS technology is increasingly being relied on in the oil and gas industries as an effective tool capable of finding an optimal route when sitting new pipelines. The use of GIS reduces construction and operational costs, in addition minimize damages to the environment during construction process [11]. Similarly, it helps protect the environment from accidental release of pipeline contents.

B. Data Processing and Analysis

1) Factors and data

Oil and gas industries are increasingly using GIS technology in designing new pipelines as a tool to reduce both construction and operational costs. The most important points in the process of route determination using GIS are identifying the effected factors on the route. Weights are given to each factor, then the total degree will be calculated and obtaining spatial data related to the minimum weight. The reliability of the GIS results for all applications is depending on the quality of the collected data in the route determination studies. Because the problem is required location detection of the route and this is perceived as a spatial problem. Therefore, each effected factor is linked to a set of spatial data in such kind of problems. So the first step is to carry out in the process of route determination using GIS is to find the needed spatial data considering the factors affect on the route.

Table 1 and figure 2 are presenting the spatial data that are used to determine the route of the pipeline for the current project.

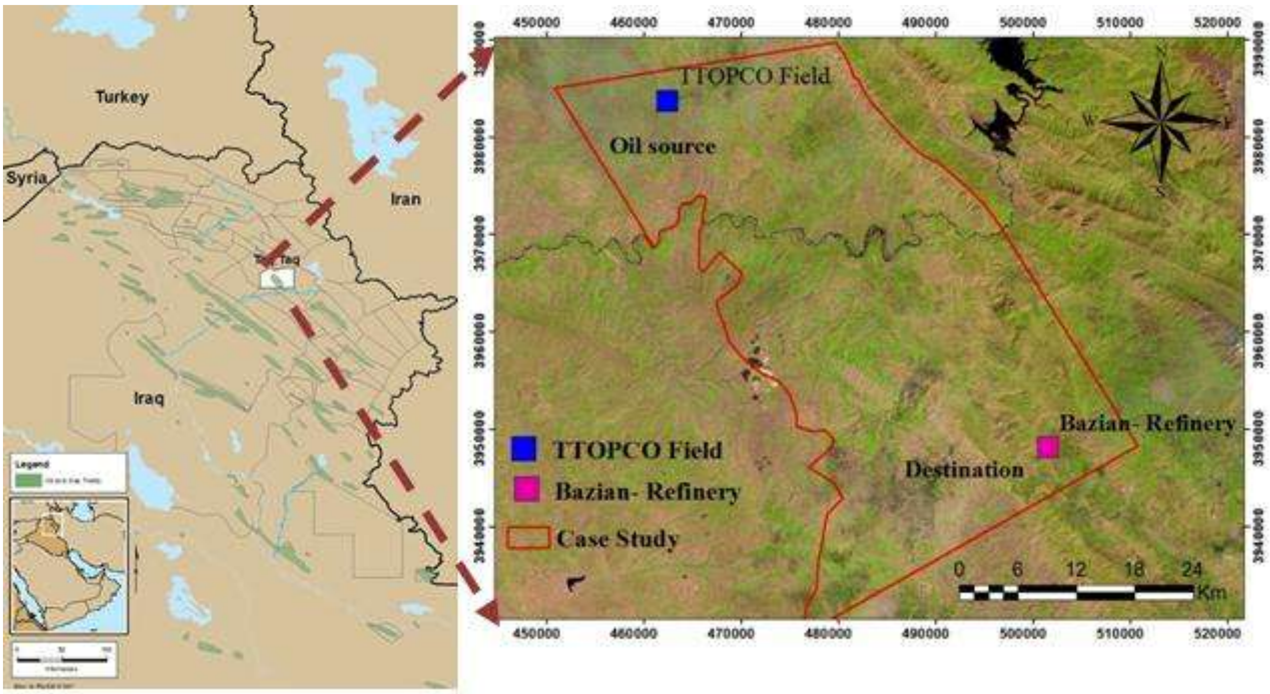

Figure1. Locations of the study area on the map, left hand side map abstracted from [3], right hand side map generated from [13].

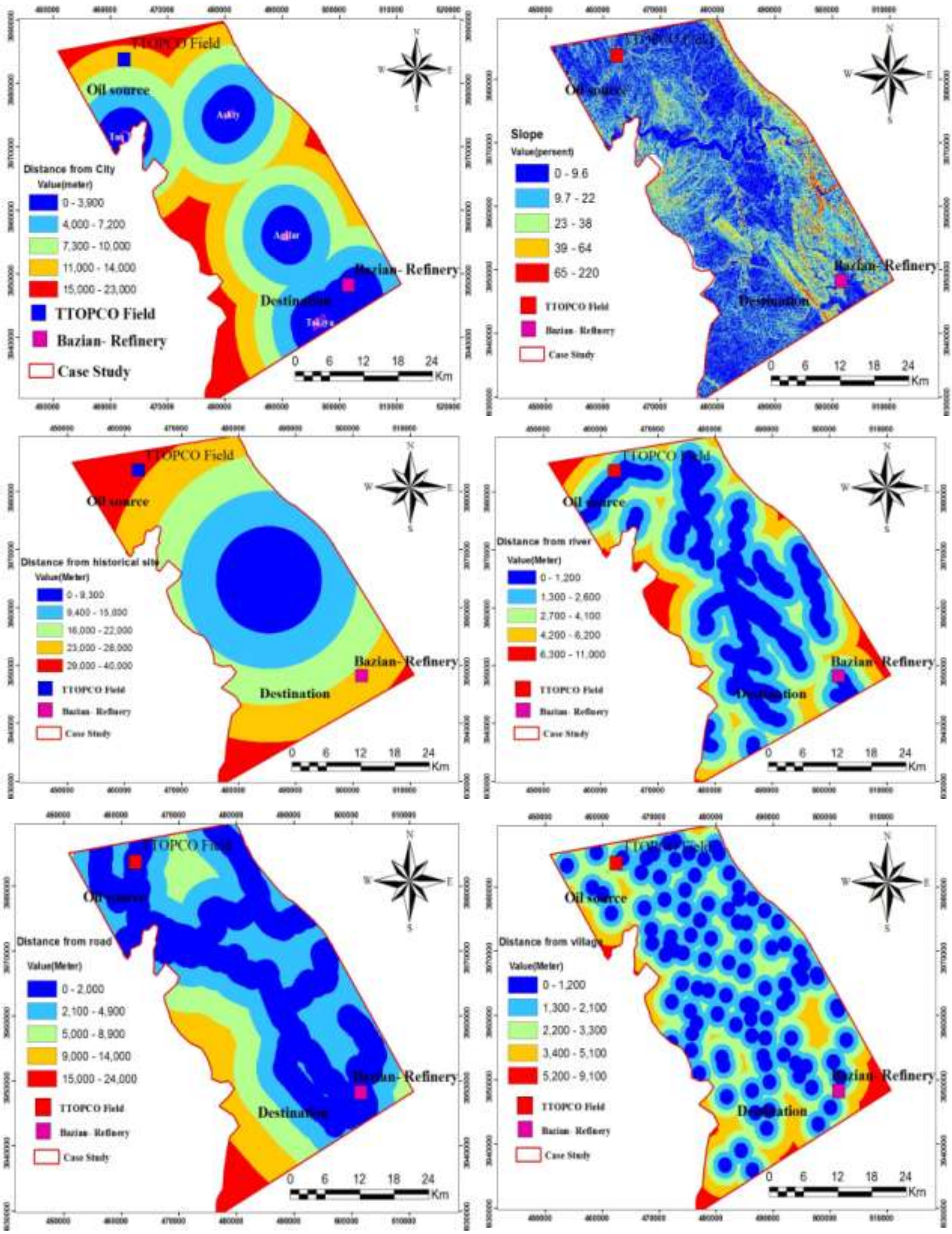

Figure2: Criteria for Design Oil Pipeline Route

TABLE 1

CRITERIA FOR DESIGN OIL PIPELINE ROUTE

Row	Criterion (factors)	Data Source	Data Type	pixel size(meter)
1	Appropriate slope	General Command of Mapping	Raster	28
2	Distance from city	General Command of Mapping	Raster	28
3	Distance from village	General Command of Mapping	Raster	28
4	Distance from historical site	General Command of Mapping	Raster	28
5	Distance from roads	General Command of Mapping	Raster	28
6	Distance from river	General Command of Mapping	Raster	28

2) Classified data set and determination of weights

In this section all the raster layers were set to a common scale, grades of odd number from 1 to 9 as illustrated in Table 2. Grade 1 is indicated to the best value or cheapest and worst or the expensive case scaled by grade 9. Similarly 3, 5 and 7 is for good, medium and bad respectively. The No data (ND) column is indicating to unauthorized areas, the pipe should not pass through. So, for the slop factor pi (pixel) smaller than 22 is the best case with grade 1, whilst grade 9 is the worst case when pi greater than 60. The next step is to produce the cost raster layer (weight) Wi is to add data collection classified together. Since there are various factors being involved in the process, it is considered different weights to the importance of some factors than others, i.e. avoiding sharp slopes, can be twice as important significance of terrain. Hence, all the factors in this project were weighted to prioritize them. This will help to determine the amount of influence that each of the factors (variables) has on the routing process. For instance, the importance of proximity to roads is not the same as the relevance of proximity to the rivers and so on. To fulfill this issue, surveys have been made to ensure the participation of the society living in the area where the pipelines will likely be routed through. Using questionnaires, their views are sought and incorporated in the weighting process since they will be directly affected if a pipeline failure occurs in future [12]. Each variable is assigned a weight Wi on a scale of 1 to 100 based on their cost, vulnerability to environmental degradation and total influence on the selected route. Wi 15% weight is given to the factor of the distance from the city, whilst Wi 10% is the weight given to the distance from rivers. The weighting procedure is shown in Table2.

3) Weighted cost surface and Total Cost Layer

The weighted cost surface is created by using pixel-based arithmetic processes on raster data layers formed for each surface separately. Weights Pw need for each layer is presented in Table 2. The total cost map is achieved using the weighted overlay arithmetic processes of overlapping layers raster that investigated and classified in criteria Table 2 including the weight of each layer Pw. The value of pixels on this total cost layer Pw describes the total transition cost that belongs to the area on the surface, Figure 3. In the current study, the pixel size was chosen to be 28m based on the scale of the data.

$$Pw = Pi \times Wi$$

$$TPw = \sum Pi \times Wi$$

Where Pi is ith grade data layer, Wi is ith data layer of weight and TPw is total cost layer.

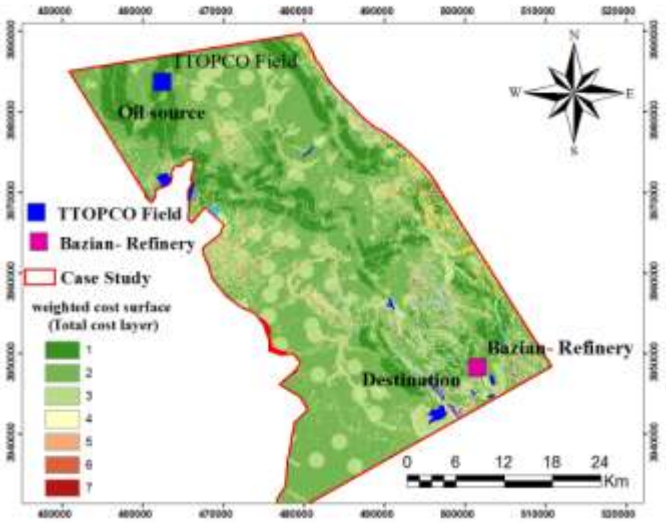

Fig. 3 Estimated weighted cost surface for Optimal Oil Pipeline

4) Route Determination

Cost Distance:The cost distance is the tool that calculates the minimum cumulative cost TPw in order to set the source location for each cell through the route. This function requires cost raster layer and a source to calculate the minimum cost, cheapest route, from each cell to the nearest source. The Source; is the starting point (origin) for analysis proposals, in this case the source is TTOPCO oil field. Whilst the cost raster layer; is identified the total cost per cell TPw although it is a single set of data but often used to present several criteria.

Shortest Path: The shortest path function is a spatial analyst that calculates the minimum cost to reach the destination point using the cost distance for the cost direction.

How the minimum cost path is obtained?

The route must find a minimum cost cell to pass through to reach the destination. The Cost Path function is used to find the best way to construct a new path with regard to rules of construction costs; it's guaranteed the cheapest route from the source to destination.

TABLE2

CLASSIFIED DATA SET AND ASSIGNING WEIGHTS TO THE ROUTING CRITERIA IN ORDER OF PREFERENCE

Row	**Criterion**		**Classified data**						Determination of weights
	Value		1	3	5	7	**9**	**No Data**	
		Unit	Best case	Good)	Medium	Bad	Worst	Forbidden	Weight (%)
1	Appropriate slope	percent	P<22	22<P<30	30<P<40	40<P<50	50<P<60	P>60 (ND)	35%
2	Distance from city	meter	P>3000	2000<P<3000	1500<P<2000	1000<P<1500	P<1000	Inside city (ND)	15%
3	Distance from village	meter	P>1000	500<P<1000	300<P<500	100<P<300	P<100	Inside village (ND)	15%
4	Distance from historical site	meter	P>3000	2000<P<3000	1500<P<2000	1000<P<1500	P<1000	Inside site (ND)	10%
5	Distance from roads	meter	500<P<1000	1000<P<1500 100<P<500	1500<P<2000 70<P<100	2000<P<3000	P>3000 P<70	NONE	15%
6	Distance from river	meter	P>500	300<P<500	200<P<300	100<P<200	P<100	NONE	10%

IV. RESULTS AND DISCUSSION

The accumulated weighted cost surface is formed by identifying the initial point and size of the pixel along the route. This has done according to the working principles of the raster-based network analysis algorithm. Therefore, surface cost values for each pixel were determined and direction data is formed. In the current implementation, the best route is found for optimal oil pipeline using spatial analysis model. The steps to produce such a path are outlined below.

- Create source, destination and cost datasets
- Generate a thematic cost map (classifying and weighting)
- Perform cost weighted distance
- Direction datasets were created
- Follow the shortest path with distance and direction datasets

To transport crude oil from the TTOPCO filed (source) to the Bazian Refinery (destination), there are several possible routes for the pipeline to pass through. However, based on the routing criteria and assigned weights, the best possible route with a length of 58km was generated as shown in Figure 4. This represents the optimal route for TTOPCO – Bazian Refinery pipeline to pass in-order to minimize the cost, public health hazards, environmental degradation, destruction of eco-system etc. Furthermore, construction costs and maintenance costs of the pipelines when operational will be lower if this route is adopted. Figures 4 and 5 show the optimal pipeline route from the TTOPCO field (source) to Bazian Refinery (destination).

V. CONCLUSIONS

This project is carried out to find the safer mode of crude oil transmission and the following was concluded: optimal pipeline route was found to connect Bazian Refinery with TTOPCO oil field in Kurdistan Region. The risk of the road trucks tankers accidents will be reduced as it will be replaced by an environmentally friendly pipeline. Increase the amount of crude oil for the refinery within a shortest period and low cost.

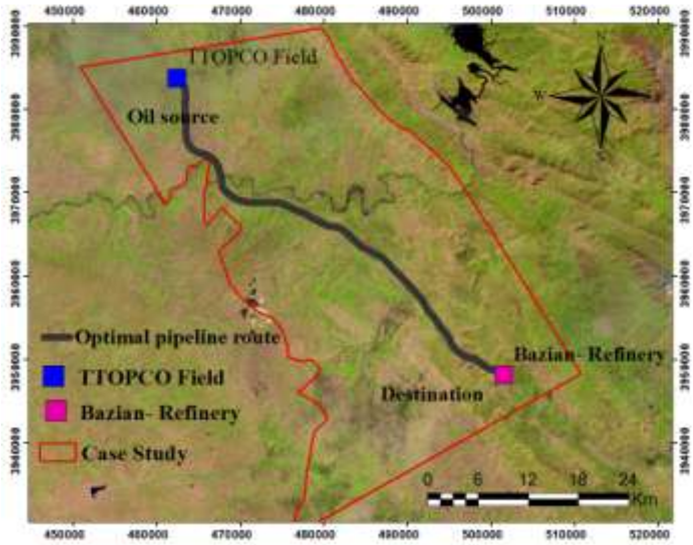

Fig. 4: Optimal pipeline route from oil source (TTOPCO field)To the final destination (Bazian Refinery), generated from [13].

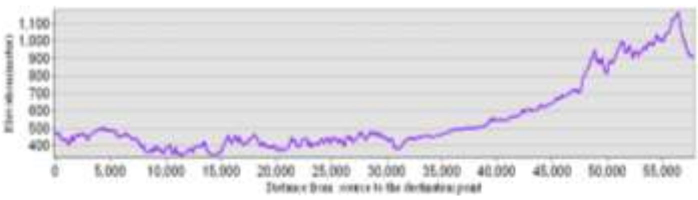

Fig. 5: Pipeline route profile graph from oil source (TTOPCO field) to the final destination (Bazian Refinery

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