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# Application of Internet of Things, Terrain, and Geology for Selecting Optimum Oil Pipeline Network

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## ABSTRACT

The characteristics and properties of the terrain and geological factors of the Earth are important factors in selecting an oil pipeline network. This paper highlights the study of these factors and how to choose the appropriate geographical location to establish the pipeline network for transporting oil between five Iraqi governorates. This study aims to choose the shortest path between these governorates by applying the special branch and bound algorithm in solving the traveling salesman problem (TSP), where the theoretical concept of this problem is similar to the study prepared in this research in terms of choosing the shortest path between the governorates starting from the starting point and passing through the four governorates, and then returning to the same point. In this context, the process of determining the coordinates of the longitude and latitude of the geographical location after completing the study of all geological factors is done by using a GPS module, whose method of operation is based on its work that depends on the sensors used with the Wi-Fi IoT device, called particle photon. The study also aims to find out the errors related to the distortion of the transmission signal in the GPS unit, such as high buildings, rocks, and satellite interference. The importance of this study is to prepare a team that combines computer science and Internet of Things applications with geologists and oil experts, because oil exploration requires practical experience in geology and topography, with the possibility of implementing algorithms and applications by computer engineers.

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# تطبيق انترنت الأشياء والجيولوجيا والتضاريس في الاختيار الملائم لشبكة انابيب النفط


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**الملخص**

تعد خصائص التضاريس والعوامل الجيولوجية للأرض من العوامل المهمة في اختيار شبكة خطوط أنابيب النفط. يسلط هذا البحث الضوء على دراسة هذه العوامل وكيفية اختيار الموقع الجغرافي المناسب لإنشاء شبكة الأنابيب لنقل النفط بين خمس محافظات عراقية. تهدف الدراسة الحالية إلى اختيار أقصر طريق بين هذه المحافظات من خلال تطبيق خوارزمية الفرع والربط الخاصة في حل مشكلة البائع المتنقل (TSP). اذ يشبه المفهوم النظري لهذه المشكلة الدراسة المعدة في هذا البحث من حيث اختيار الطريقة الأقصر. ان أقصر طريق بين المحافظات يبدأ من نقطة البداية ويمر بالمحافظات الأربع ثم يعود إلى نفس النقطة. في هذا السياق تتم عملية تحديد إحداثيات خط الطول وخط العرض للموقع الجغرافي بعد الانتهاء من دراسة جميع العوامل الجيولوجية باستخدام وحدة GPS التي تعتمد طريقة عملها على أجهزة الاستشعار المستخدمة باستخدام جهاز Wi-Fi IoT، المسمى بفوتون الجسيمات. تتضمن الدراسة ايضا معرفة الأخطاء المتعلقة بتشويه إشارة الإرسال في وحدة GPS مثل المباني العالية والصخور وتداخل الأقمار الصناعية. تكمن أهمية هذه الدراسة في إعداد فريق يجمع بين علوم الكمبيوتر وتطبيقات إنترنت الأشياء مع الجيولوجيين وخبراء النفط، لأن التنقيب عن النفط يتطلب خبرة عملية في الجيولوجيا والطوبوغرافيا، مع إمكانية تنفيذ الخوارزميات والتطبيقات من قبل مهندسي الكمبيوتر.


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## Introduction

One way to think of the branch and bound method is as a generalization of undoing optimization issues. A salesman has visited a predetermined number of towns, with a gap between each pair of towns. He can start in any of these towns and must continue his tour, stopping only once in each of the other governorates before arriving at the destination. The completion of this task must minimize the overall distance traveled. A computational problem with an improvement-focused approach, the traveling salesman problem (TSP) is frequently used in computer science to determine the most effective way to transfer data between various nodes. Numerous uses, like hardware optimization techniques or network identification, etc. Irish mathematician W. R. Hamilton created TSP initially. In the 19th century, British mathematician Thomas Kirkman developed a game that could be solved by identifying the Hamilton cycle, which is a non-overlapping path between all nodes of TSP, studied by several researchers for decades, and many solutions have been theorized. This has been proposed (Rajarajeswari P. and Maheswari D. 2020).

Trying every option is the easiest way to find a solution, but it is also the costliest and time-consuming. Numerous heuristics involve problems with probabilistic outcomes. Results are not always perfect and are only approximations. In this research, the branch and bound method is used to find the optimal solution, in addition to integrating Internet of Things applications to contribute to obtaining the values of geographic locations faster and more accurately by connecting an integrated circuit.

## Previous studies

Recently, several studies have dealt with topics related to the optimal method for selecting oil pipelines and determining their routes based on taking into account the geological and topographical characteristics of the Earth’s surface. Some of these studies will be addressed because their content is related to the topic of the present study.

Ranjana (2018) had proposed a solution to the traveling salesman problem with the same principle as the branch and bound algorithm, but it is somewhat different, which is reduced branch-and-bound (RBB)that uses graphs to reduce the length of the tour. The results showed that when using a small number of governorates, not exceeding 5, the implementation is faster, less than 60 seconds. In addition, it is possible to use this algorithm in more than 45 governorates.

According to Duka (2018), an application of the branch-and-bound (Band B) algorithm has been suggested to solve the traveling salesman problem containing an asymmetric cost matrix called ATSP, which consists of five governorates in the United States of America. In addition, Lingo Programming was used to implement the algorithm and to find the optimal solution. The results showed that the solution was repeated 20 times at a time rate of approximately 0.72 seconds, the elapsed execution time.

The study of Jain and Prasad (2017) dealt with finding a solution to the traveling salesman problem using the greedy genetic algorithm, which is implemented using Java. The algorithm was implemented using JDK 1.7 and NetBeans 8.0.2. TSP-Lib on 48 nodes, where the results showed that this algorithm can be applied to a large group of nodes.

Mussafi (2023) study, presented by the Holy Quran Illiteracy Eradication Association, aimed to reduce transportation expenses by reducing the number of miles using the branch-and-bound algorithm, which will provide a solution to the street vendor problem using a GUI MATLAB to collect and analyze data. The study was conducted in 12 governorates, and the results showed a finding that the shortest path is 152.9 km, starting from Sidorejo, passing through 11 governorates, and returning to the starting point.

Eelagh and Ali (2023) study, in which the multi−criteria decision−making (MCDM) approach, the hierarchy process, and Dempster-Shafer methods have been used to design gas and oil transmission lines.

Cosford et al. (2014) provide an overview of topography analysis for pipeline projects with examples of how it might be applied to specific pipeline routing and design difficulties.

## Study Area

The study area is in the north and middle of Iraq, including 5 governorates (Baghdad, Diyala, Kirkuk, Mosul, and Erbil). This area covers about 116998.78 $km^2$ and it is situated geographically between latitudes (33°0'0.0-37°6'0.0) N and longitudes (41°22'30.0-45°30'0.0) E (Fig. 1).

Geologically, the study area is characterized by the presence of mountainous and gentle slope areas, both extend over large areas. It is noted that the mountainous regions increase towards the north, northeastern, and northwestern parts, and are characterized by asymmetrical, cylindrical, and extended folds. Several structural elements are exposed at the surface along these areas. According to the Iraqi Geological Survey (Sissakian and Fouad, 1993), as shown in (Fig.2), the stratigraphic units exposed in the study area consist of various geological formations. The oldest exposed rocks date back to the Triassic and the recent deposits of the

Quaternary. The area under investigation has a semi-arid climate. The topographic setting of the area is characterized by gentle, moderate, and steep slope terrains with elevations ranging from 92 to 3570 m above sea level as measured on the digital elevation model (Fig.3).

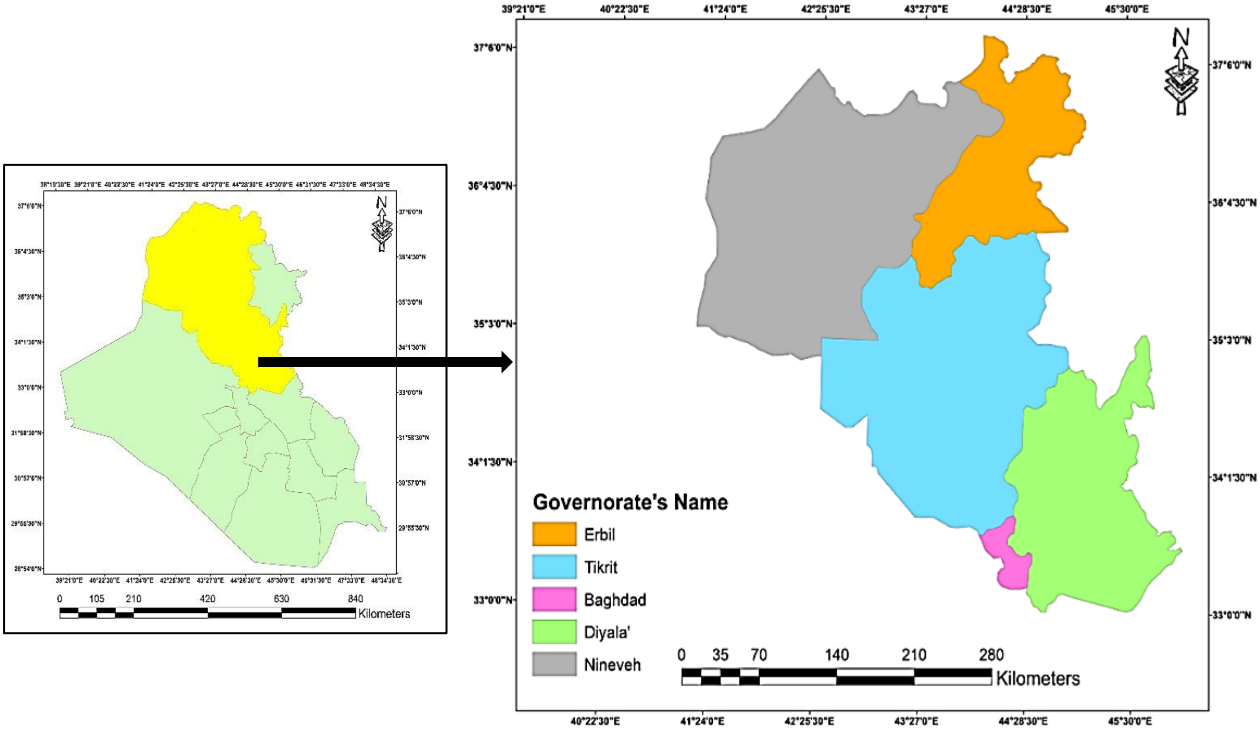


**Fig. 1. Location map of the study area in Iraq (Sissakian and Fouad, 1993)**

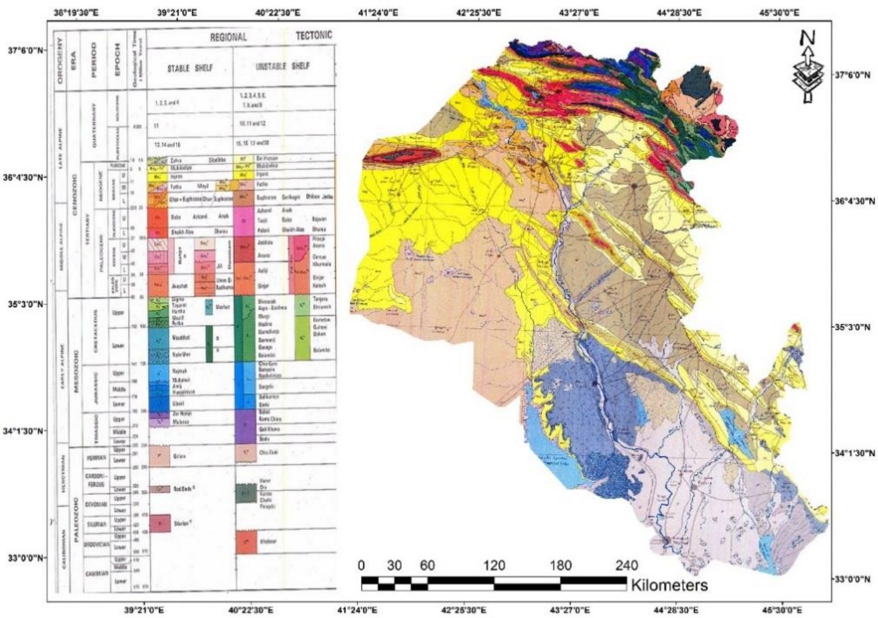


**Fig. 2. Geological characteristics of the study area ( Sissakian and Fouad, 1993).**

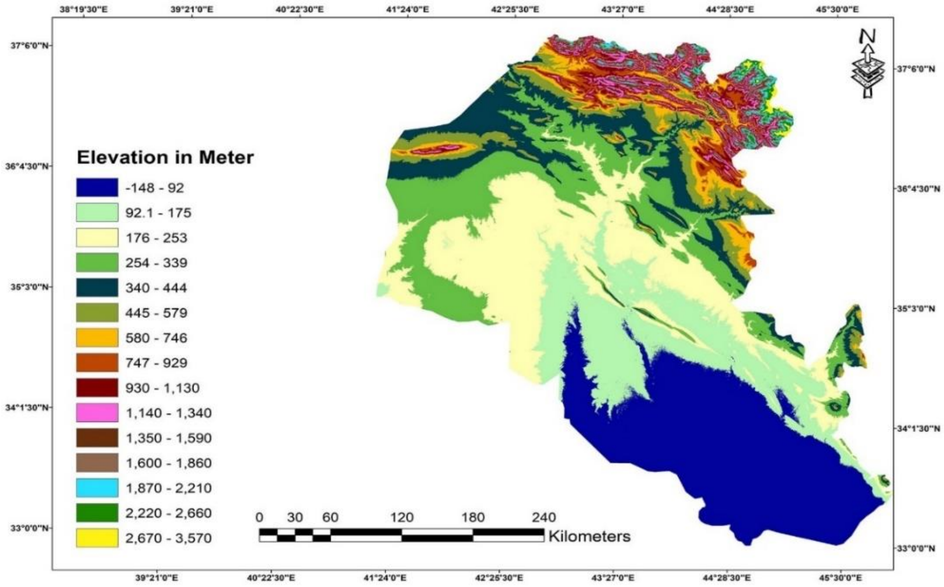


**Fig. 3. Topographic characteristics of the study area.**

## The Impact of Geology and Terrain on the Pipeline Extensions

Geology and terrain have a significant impact on the pipeline extensions and must be considered during pipeline project planning, design, and construction (He et al., 2021). Each of these considerations has a substantial impact on the safety, feasibility, and overall success of pipeline extension.

Effective pipeline extensions require an extensive understanding of terrain, geology, and soil. For the safety, integrity, and environmental sustainability of the pipeline project, appropriate evaluations and engineering solutions must be put into place to deal with the problems presented by each of these elements (Cosford et al., 2014). The following statements summarize how each factor affects pipeline extensions:

### Impact of geology

The presence of rock type along the pipeline route may affect the excavation process during construction. Tunnels or boreholes may be required in rocky terrain, which affects building costs and deadlines. Geological features such as fault lineaments and seismic activity can jeopardize pipeline integrity. Pipelines in seismically active areas may require additional engineering procedures, flexible materials, or unique construction techniques to withstand ground movement.

### Topographical impact

Elevation variations affect pipeline design and construction. Pipelines frequently need to negotiate hills, valleys, and slopes, which may necessitate changes to the pipeline path, working procedures, and support structures.

## Methodology

The research article methodology is based on finding the appropriate solution to the TSP by explaining the mechanism of this problem and the method of applying the branch-and-bound algorithm based on mathematical equations to calculate the shortest path to connect the oil pipeline network in the five governorates.

### Travelling Salesman Problem

People are interested in finding the shortest distribution route because of the Traveling Salesman Problem (TSP), a combinatorial optimization problem (Mussafi, 2023). The reason for the fame of the TSP is that it appears simple, but it is not. Since calculating routes in Google Maps is currently the most used real-world problem, the problem can be stated as follows: Start the seller in one city you want to visit and return to each of the other n-1 governorates (Ranjana, 2018) as shown in Figure (4), the mathematical solution to the traveling salesman problem converts it into graph theory.

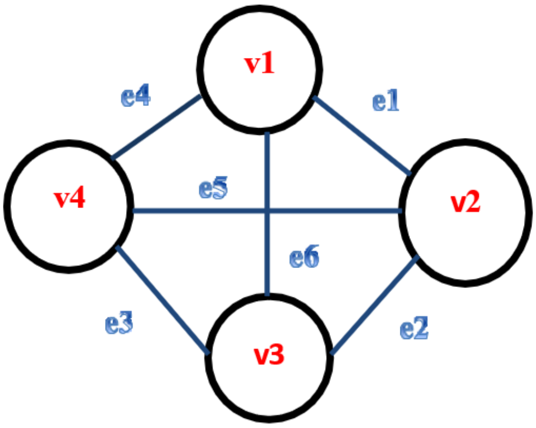


**Fig. 4. TSP Graph (Ranjana, 2018)**

The traveling salesman problem is a mathematical problem that can be converted to graph theory. (Fig.4) shows the traveling salesman problem, where v1, v2, v3, and v4 are considered governorates and the edges that connect them, e1, e2, e3, e4, e5, and e6 are considered roads (Ranjana, 2018). The Traveling Salesman Problem must be translated into the language of graph theory to be solved mathematically. The salesman who travels to every city and seeks to find the shortest tour by going to each city exactly once and then returning to the starting city is known as the "traveling salesman problem". A graph with (n) nodes for the governorates and (e) edges for the distances between them can be used to illustrate this issue. Determining the minimum Hamiltonian cycle is the aim. The shortest tour, which makes one exact visit to each node before returning to the starting node, is the Hamiltonian cycle. A path in a graph that contains every vertex in the graph is called a Hamiltonian cycle. TSP's goal function is to reduce the overall distance traveled. Equation (1) provides a mathematical representation of this (Ranjana, 2018).

$$\sum\sum C_{ij} X_{ij} \qquad (1)$$

Where $Cij$ is given by the cost taken by the distance traveled. For the symmetric TSP, the distance traveled can be given by (Ranjana, 2018) for j=1 to n; $\Sigma Xij=1$ for all i, for i =1 to n, $\Sigma Xij=1$ for all j $Xij= 0$ or 1.

For every (n) node in the TSP, there are (n-1)! as the workable solutions; the challenge lies in identifying the ideal one. Asymmetric traveling salesman, multiple traveling salesman, and symmetric traveling salesman are some of the primary categories among the many TSP variants with extensive applications. Under these categories, traveling salespeople are categorized according to a single depot or several depots, multiple salespeople, the number of governorates, the salesperson must visit, and other factors. There are numerous uses for each TSP variant, and the global navigation system is one of them. You can view the other uses and variations of TSP in Ranjana (2018).

## Branch-And-Bound Algorithm

There are two ways to solve the traveling salesman problem. The correct solution is to implement the first step, which is to determine the ideal Hamiltonian cycle with the least weight must be determined by finding all the cycles in the graph, and this is possible, although a problem will arise if there are only a few nodes. That is, Formula (n-1)! represents the number of lines or cycles in the graph, where (n) represents the number of nodes or governorates represented on the graph. The number of possible cycles for n=7 is 720 (Mataija et al., 2016).

The second step is to follow the approximate “reliable adequate” solution. The branch and bound method provides the correct solution to the given problem. It works well when the number of nodes installed on the graphs is less than 60, which is sufficient when it comes to problems such as parcel delivery. The idea of this method depends on dividing groups into two separate subgroups at each procedure step, called branching. Moreover, one subset contains the route between the two selected nodes, while the other subset does not contain the route between the two selected governorates. For each of these subgroups, the lowest (binding) period restriction is calculated. The subgroup that is greater than the minimum permissible limit is deleted. The process of branching in a tree is done by indicating the highest branching points of the set of solutions, and the edges define the path between two adjacent nodes in the graph that is used to model the problem and within which the shortest Hamiltonian cycle is followed. Nodes in the branching tree are labeled “etiquettes” that represent the lowest anchor point of the objective function. Edges are assigned "weights" and are determined with (p, q) on the traversed paths or without (p, q) on the traversed ones. The spreadsheet used in this method is illustrated and represented because it is easy to use on any future computer application or software for any upcoming software programs as well. (Fig.5) shows the flow chart of the algorithm.

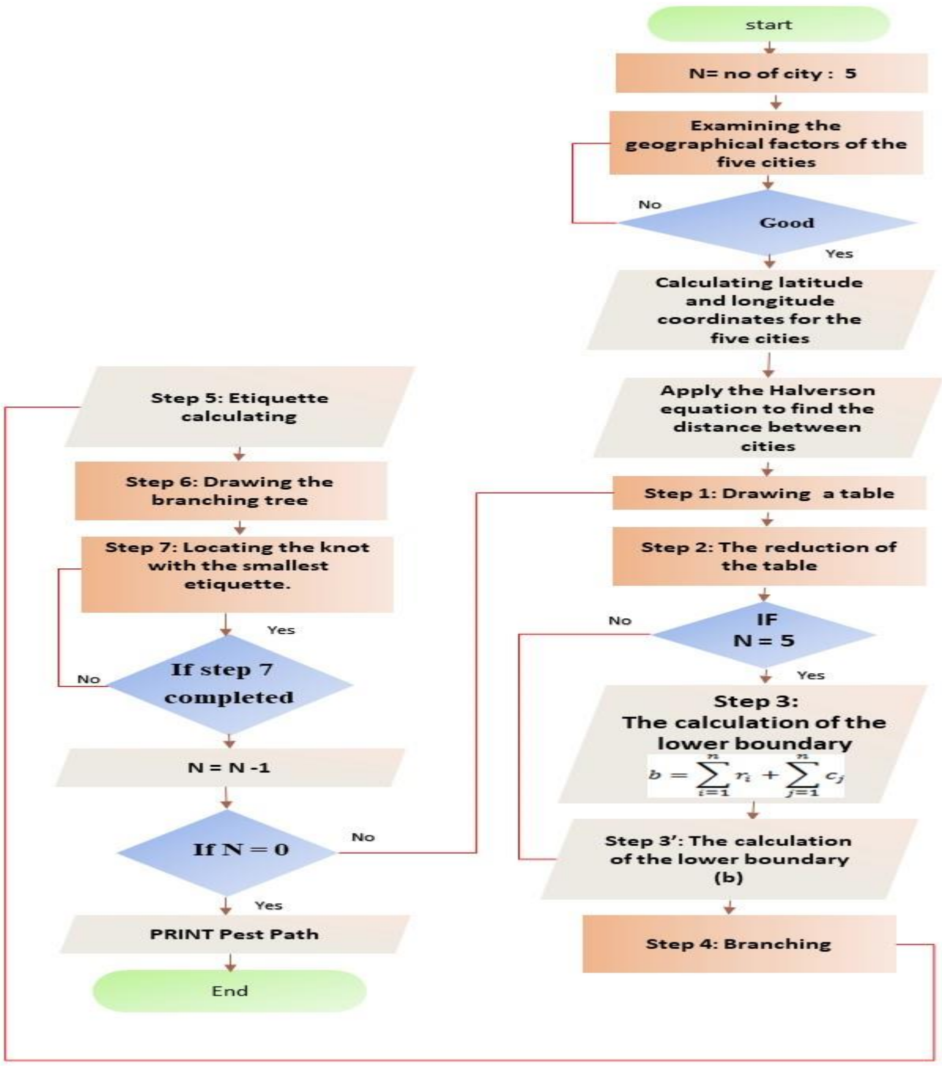


**Fig. 5. Flowchart of the proposed study algorithm.**

The above flowchart of the algorithm consists of the following steps according to Equations (2-7) (Mataija et al., 2016):

1- A table is created with the distance between the designated vertices plotted. The separation of vertices i and j is tagged with $d_{ij}$. If the two vertices are not contiguous, they are marked with $d_{ij}$. When $d_{ij} = \infty$, it indicates the algorithm for selecting the appropriate course $i \rightarrow i$ is also appointed.

2- The smallest element is found and indicated using the table's reduction in each row:

$$r_i = min_j \, d_{ij} \, , j=1,.....,n \qquad (2)$$

The following formula is used to find the smallest elements in columns:

$$C_j = min\,(d_{ij} - r_i) \qquad (3)$$

The formula is used to calculate the table's reduction:

$$d'_{ij} = d_{ij} - r_i - C_j \qquad (4)$$

3- The computation is performed to determine the lower bound of the travel time:

$$b = \sum r_i + \sum C_j \qquad (5)$$

and allocated, which, as etiquette is confined to the branching tree knots. 3': The lower boundary's computation is equivalent to the knot's etiquette, where the branching is carried out (Mataija et al., 2016).

4- The top is selected to serve as the starting point for branching. Every address in the $(i, j)$ condensed table

can be found routes, for which it is possible to say that $d'_{ij} = 0$ for every "penalty" incurred for failing to use the trajectory, the penalty is calculated with the formula:

$$x_{ij} = \min_j d'_{ij} + \min_i d'_{ij} \qquad (6)$$

The trajectory that has been given the highest "penalty" is the one that starts the branching.

$$X = \max_{ij} x_{ij} \qquad (7)$$

$(p, q)$ They are used to mark the route with the maximum penalty(Mataija et al., 2016).

5- The manner of the knot adjacent to the edge that has a “weighting.” Are calculated. In the reduction the $d_{qp} = \infty$ the table is assigned to signify the restriction towards the traveler, stopping him from going back to town p from town q. Moreover, it is necessary to prevent any chance of ending the cycle before reaching every vertex in the graph. The next action is to repeat steps 2 and 3 after removing the p line and q column from that table. The total of the lowered elements is marked with (Mataija et al., 2016)

6- Sketch the branching tree.

The node in the branching tree that started the branching is designated using the B etiquette, and weightings are also applied to the adjacent knot for the edges that exit it. Edge is assigned the $b+\pi$ etiquette. The contiguous knot to the $(p,q)$ edge is on the other hand assigned with the $b+\sigma$ etiquette.

7-In this step, the minimum node is chosen, and all six steps are repeated except for the third step, which is replaced by step 3'a. The algorithm terminates when the table includes only unused paths, resulting in the solution being an infinite path duration (Rinaldi et al., 1994; Mataija et al., 2016)

**Problem Solution**

The goal of this paper is to apply the sub- and constrained algorithms to solve the traveling salesman problem to choose the shortest route for transporting oil via pipelines distributed in the five governorates. In addition, it is possible to apply the algorithm easily and without using a computer

In this research, a model of the traveling salesman's problem will take to reach the goal of transporting oil to a group of governorates, starting from the city of Baghdad, choosing the best path with the shortest transport distance, and returning to the starting point, (N0: Bagdad, N1: Mosul, N2: Erbil, N3: Kirkuk, N4: Diyla). As shown in Fig. 6, which is obtained from Google Maps, the governorates are clear in which the oil pipeline network will be established. In addition, the process of obtaining the distance between two points is done by finding the longitude and latitude of each point, and then calculating the difference between the two points. The process of finding coordinates in this study is divided into two methods: software and hardware.

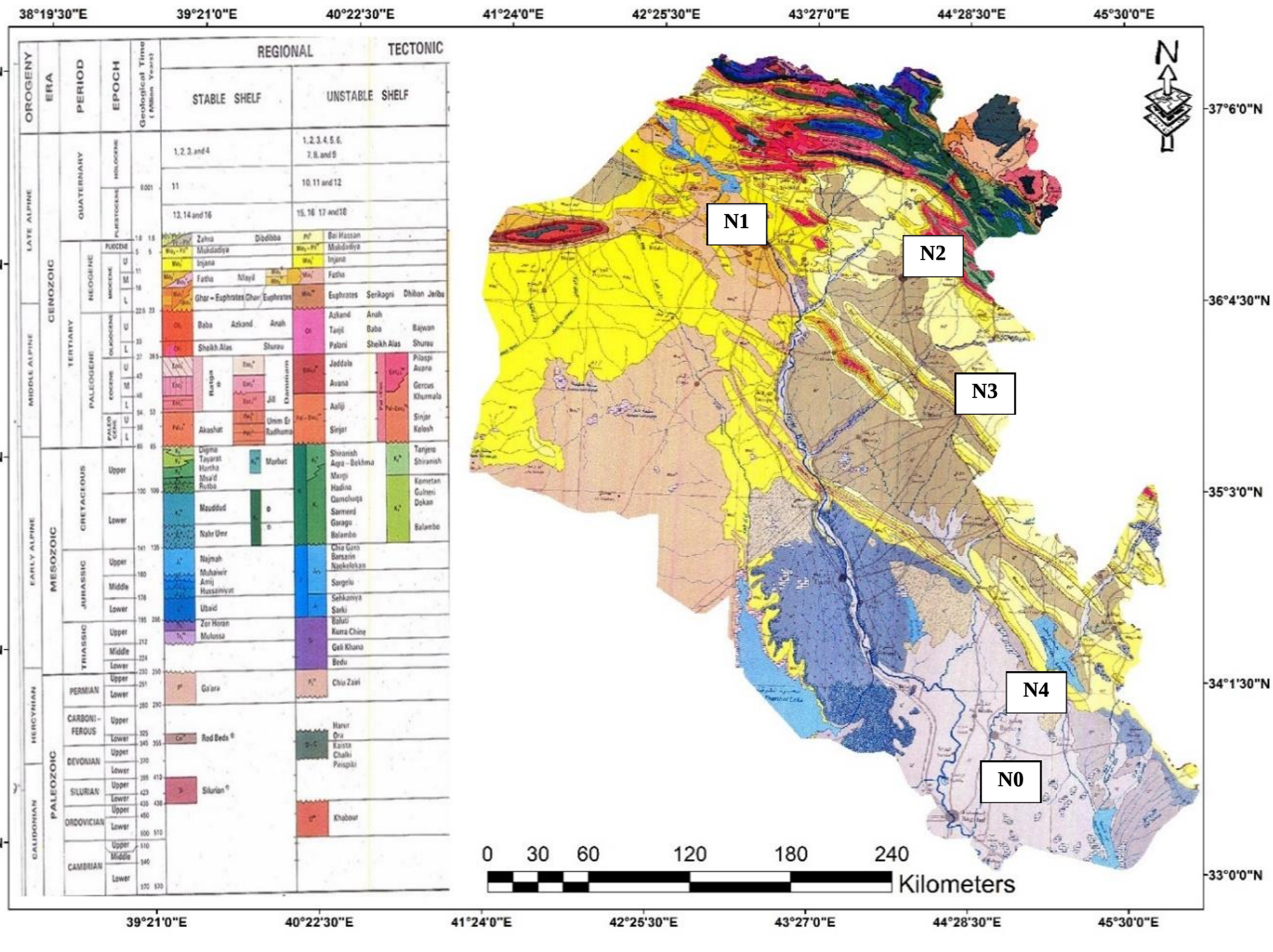


**Fig. 6. Location of the 5 governorates.**

The first method (software) to calculate distances between governorates is to use Google Maps to obtain the latitude and longitude coordinates for each city and to calculate that distance according to the Halvorson equation (Winarno et al., 2017), which will give the real results for those distances. In this study, it is possible to use both methods because the locations used are governorate coordinates, not company websites or precise locations.

The second method (hardware) for calculating distances between governorates is more accurate than the first method because it uses a unit Global Positioning System GPS as shown in (Fig.7), with the Internet of Things devices to calculate the longitude and latitude of each location. The pipeline network is created in the governorates, and the distance is calculated.

Related to the accuracy of selected GPS, the Neo-6m GPS module, compared to Google Maps, depends on a set of standards based on a set of experiments conducted in research.

- *Distance difference*: through previous studies, a distance difference between the Neo-6m GPS module and Google Maps was observed at a rate of 1 to 2.5 m.

- *Average delay*: depends on the signal quality of the Neo-6m GPS module. When the signal is good, it is 0.326 seconds, and when the signal quality is average, it is 0.472 seconds. Finally, when the signal fades or is bad, it rises to 0.472 seconds (Luthfi et al., 2019)

This is done by preparing 5 GPS units and 5 Internet of Things devices according to Table 1, such as the Particle Photon or ESP32, distributing them to all branches, and sending the readings to the main center to apply the Halvorson equation, which will give real and accurate results for those distances. In this method, it is not needed to use Google Maps to find the coordinates.

**Table 1: The components used in designing a circuit are listed.**

| No | Name of component | No. of pieces |
|---|---|---|
| 1 | Particle photon | 5 |
| 2 | Neo-6M GPS Module | 5 |
| 3 | Breadboard | 5 |
| 4 | Battery lithium | 5 |
| 5 | Modem | 5 |
| 6 | Wire | 20 |

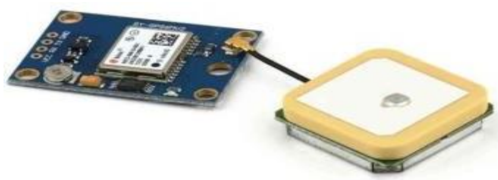

**Fig. 7. Neo-6M GPS Module (Luthfi et al., 2019).**

To obtain the results and coordinates for the longitude and latitude lines, five pieces of particle photon are required, where each photon is linked to a GPS module, and this circuit is distributed in every branch of the company to give the true location to obtain the difference in distances between the points accurately; the VCC pin and GND pin of GPS module are connected with VCC pin and GND pin of particle photon, TX pin of the GPS module connect RX pin of particle photon as shown in Figure 8.

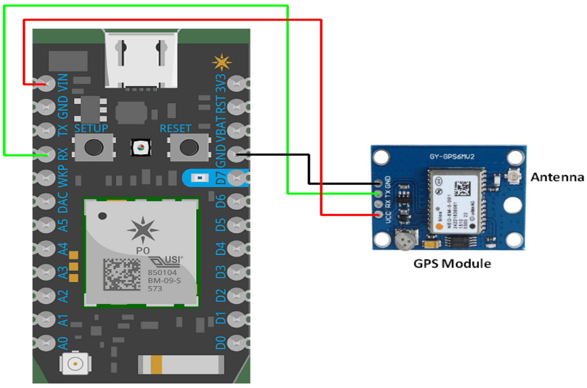


**Fig .8. The circuit is equipped with a geographical location.**

When the latitude and longitude coordinate values for each point are complete, whether using Google Maps or the Neo-6 M GPS Module, the process of calculating the difference between the two points begins by entering the values into Google Maps and recording the results. In this study, it is possible to know the number of connection lines between governorates using the formula (n-1)! Note that the value of n = 5, so the number of lines = 10 as shown in (Fig. 9).

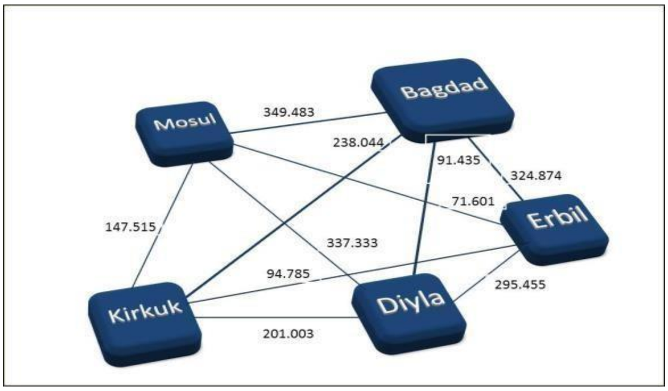


**Fig.9. The Hamilton cycles for 5 governorates.**

Create a square matrix whose dimensions consist of the number of points. In this study, the number of points = 5, so the matrix becomes 5*5. The values resulting from the difference between the distances are placed in the matrix, except for the diameter of the matrix according to Table (2).

**Table 2: Distance between cities.**

| No. | | Bagdad | Mosul | Erbil | Diyala | Kirkuk | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 1 | Bagdad | **0** | 349.483 | 324.874 | 91.435 | 238.044 | 33.332071937069074 | 44.35026042090044 |
| 2 | Mosul | 349.483 | 0 | 71.601 | 337.333 | 147.515 | 36.480723233965804 | 43.13851198159972 |
| 3 | Erbil | 324.874 | 71.601 | 0 | 295.455 | 94.785 | 36.228310034987445 | 44.00166820400537 |
| 4 | Diyala | 91.435 | 337.333 | 295.455 | 0 | 201.003 | 33.79922176804768 | 45.177013727329786 |
| 5 | Kirkuk | 238.044 | 147.515 | 94.785 | 201.003 | 0 | 35.47139475262862 | 44.34554480363118 |

In this context, the process of finding the best route to pass through sites for laying oil pipelines in the Iraqi governorates is explained in a specific block diagram as exhibited in (Fig. 10).

## The main components used in this study

In this research paper, a set of components is used, they are:

- A laptop with high specifications for processing and executing installed applications.
- An Android or iOS smartphone to monitor the results of the latitude and longitude coordinates of geographical locations.

- GPS Unit: Neo-6M GPS Module, 5 distributed among the governorates to provide the main center with updates on the longitude and latitude of each branch of the oil company to calculate the difference between points.
- IoT device: the particle photon A device that combines a microcontroller, ARM Cortex M3, and a Broadcom Wi-Fi chip, called P0, and has two power supplies: 3.3V and 5V (Aryal 2021). The purpose of using this device is to connect a GPS module as shown in Fig. 11.

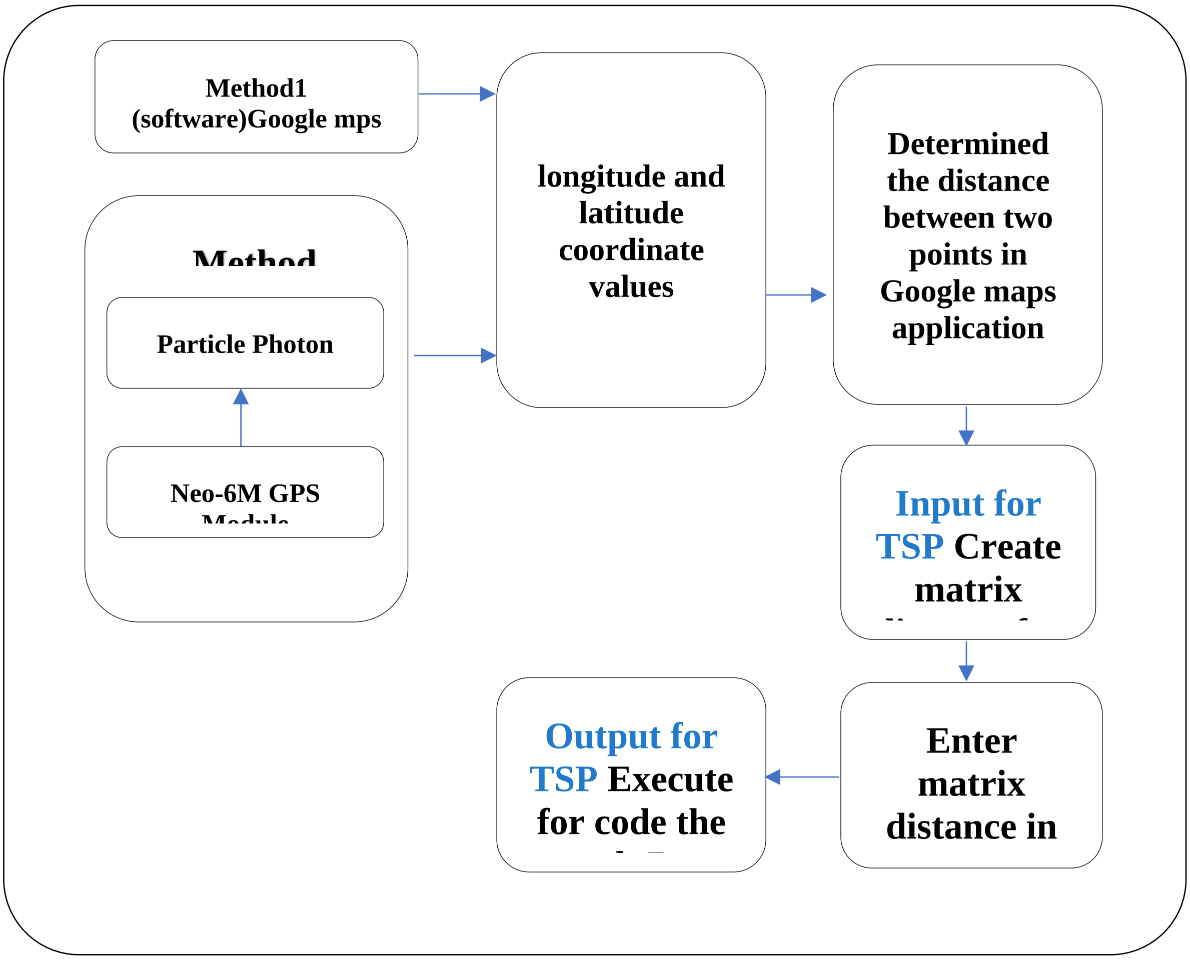


**Fig. 10. The block diagram for the best path.**

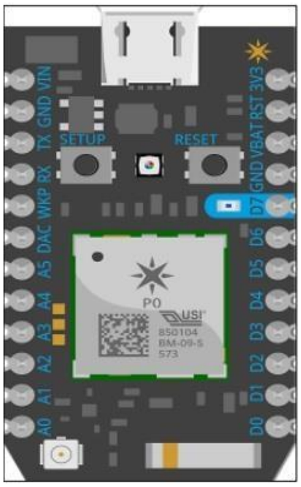

**Fig.11. particle photon (Alhajji et al., 2021).**

- Download the Blynk platform IoT: Blynk: a low-code IoT software platform for businesses and developers on smartphones and laptops to display the result from the GPS Module with particle photons.
- Portable modem to provide the particle photon with Internet service.
- Install the PuTTY program on the laptop to configure particle photons.
- Install the Google Maps application.
- Install the PyCharm Integrated Development Environment (IDE): A set of multiple scripts that interact with each other, and it is specific to the Python IDE language, where the programmer can develop any application related to computer and data sciences by creating a software application in Python (Alhajji et al., 2021). In this research paper, the code for the traveling salesman problem is programmed.

## Results

The results obtained by implementing the special code of the solution of the TSP show the best path to starting from Baghdad through the other four Iraqi governorates and back to the starting point as shown in Figure (12), which is a screenshot of the matrix of distances between governorates, which is entered in the code; and Figure (13) is a screenshot of the outcomes that emerged from running the code?

```
# Adjacency matrix distance between cities
adj =[[0,349.483,324.874,91.435,238.044],
      [349.483,0,71.601,337.333,147.515],
      [324.874,71.601,0,295.455,94.785],
      [91.435,337.333,295.455,0,201.003],
      [238.044,147.515,94.785,201.003,0]]
N = 5
```

**Fig.12. Screenshot for matrix distance.**

From Figure 12, all the values in the matrix are not integers, and this is due to the latitude and longitude of each city. In addition, store the value (0) instead of infinity (∞) in the diagonal of the matrix because the code in phyton language only accepts numbers.

```
Distance : 808.307 KM
Best Path :  0  1  2  4  3  0
Process finished with exit code 0
```

**Fig.13. Screenshot of the output of the best path.**

From Figure 13, the best path is found with the least possible distance traveled by the traveling salesman. So, the path that will pass through the traveling salesman will be (Baghdad "0", Mosul"1", Erbil "2", Kirkuk "4", Diyala "3", Baghdad "0"), and the minimum distance is 808.307 Km. The final map for the best route for transporting oil via pipeline across the five governorates is as shown in Figure 14.

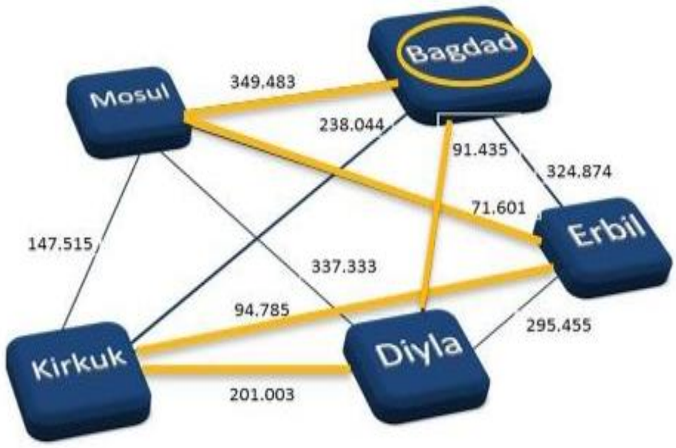


**Fig.14. Final map for the best path.**

The correct reading of latitude and longitude values has an important impact on the results of the algorithm used in the study, and several factors cause errors in the geolocation system, as follows: (Stephan et al., 2005)

Errors resulting from satellite orbits.

Satellite convergence errors.

Atmospheric properties.

Accuracy in choosing GPS receivers.

Errors in choosing altitudes.

Reflection of GPS signals.

The geological and terrain factors are essential elements in determining the appropriate path. In this context, some elements related to the geological impact on the pipeline are discussed. For monitoring the specifications of the rocks and sediments over which the pipeline will extend. The coordinates of the proposed pipeline were projected onto the geological map after applying the geometric correction. As shown in Fig. 15, it can be noticed that the proposed pipeline route corresponds to areas with gentle slopes that are in areas adjacent to structural highlands, such as folds (especially in the northern and northeastern parts). If the pipe is intercepted by a river channel or any stream, such as the Tigris River or the Greater Zab River, it can be dealt with by constructing bridges carrying the pipe with suitable engineering specifications, or it is possible to extend the pipe across the bottom of the river channel, and this requires geotechnical studies. Related to the specifications of the rocks and sediments carrying the pipe, it is noted that most parts of the pipe extend over the Fatha, Injana, Bay Hassan, and Muqdadiyah formations and slope deposits. The Fatha formation rocks, which consist of gypsum and limestone rocks, are somewhat suitable for housing the oil pipeline because they appear in a massive form and with appropriate thicknesses. However, problems may occur when the rocks of this formation are exposed to the surface. However, this can be processed by specifying water paths or creating barriers to prevent water accumulation in piped areas. Regarding the rocks of the Injana Formation, they are suitable because of their thick sandstone rocks in most parts of the formation, which appear as cohesive rocks that can bear the weight of the pipe. The stratigraphic units of the Muqaddiya and Bay Hassan formations could be an important factor because they contain conglomerates and pebbles bonded together with cement materials that make them cohesive and able to bear weight. Quaternary sediments, including slope deposits, constitute suitable areas for housing pipes because they contain rock fragments of formations with hard rocks that were stripped from the top of the slopes and cemented with the soil at the bottom of the slopes.

## Conclusion

The Internet of Things has been introduced as an essential part of finding the values of the distance matrix for the branch and bound algorithm using the GPS module and implementing the algorithm for the input and output values of the traveling salesman problem.

*Input TSP solver*: The method of using software using Google Maps to find distance values between governorates obtained using latitude and longitude coordinates, according to the Halvorson equation, is more accurate than other methods. As for the method of using materials using a GPS unit connected to a particle photon, it is more accurate than other methods because the coordinates will be given in real-time and from the location itself, and this is what distinguishes this method. When comparing the methods used in this study, generally, the process of finding coordinates using a GPS unit is easier because the values are real and not virtual when they are on Google Maps.

*Output TSP solver*. The logical solution is closest to the path we got after executing the code because of the clarity of the map governorates in which the traveling salesman will start his work, choose the best path, and like the path that appeared in the results. This will provide optimal solutions when the number of governorates is more, and solving them only by using the computer. In this code, it will help us to find the shortest distance when the number of governorates increases, and impossible to calculate it manually. Apart from the sheer quantity of governorates, it is also challenging to obtain longitude and latitude coordinates using Google Maps. As a result, GPS units are placed in each location to transmit those coordinates to the main center. Here lies the role of the Internet of Things in facilitating the task of creating a distance matrix.

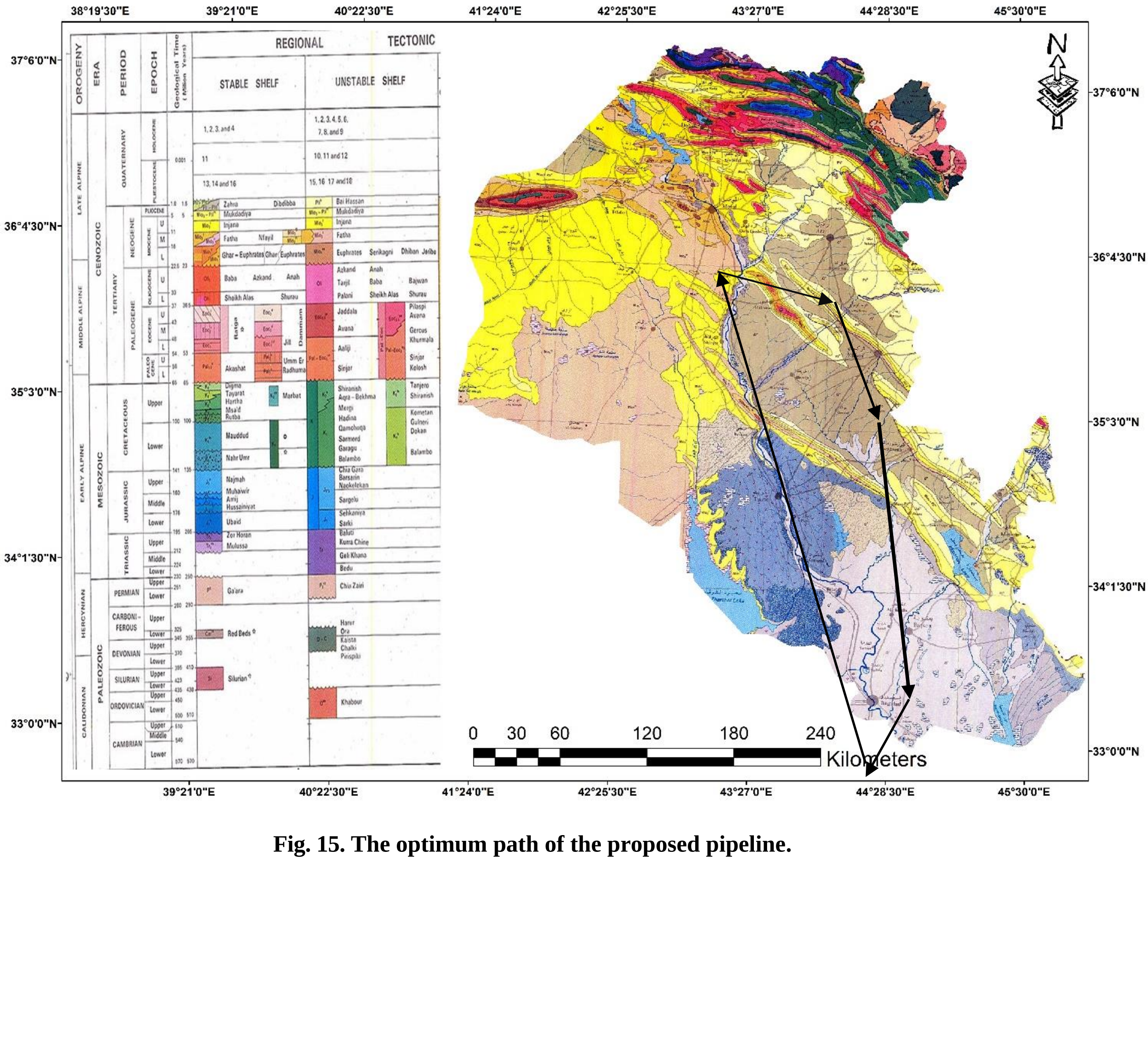


**Fig. 15. The optimum path of the proposed pipeline.**

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