THE CHALLENGE OF NAVIGATING LONG TUNNELS

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Abstract— one of the concerns that employers and contractors have in creating long tunnels is that when the excavation is completed, the tunnel will be exited in the correct position according to designed, the deviation of the tunnel from its path can have many costs for the employer and the contractor, lack of correct calculations by the surveying engineer or the employer and contractors lack of importance to the surveying team in guiding the tunnel can cause the tunnel to deviate from its path and this deviation becomes a disaster. But employers are able to make the right decisions so that the tunnel is guided with the highest precision if they consider some points.

We are investigating two tunnels with lengths of 12 and 18 kilometers that were dug by Tunnel boring machine machines to transfer water, how the contractor's decision to control the 12 kilometer tunnel caused the most accuracy of one centimeter to the next part of the tunnel will be connected. We will also investigate the reasons for the deviation of axis in the 18 km tunnel about 20 meters.

Also we review the calculations of surveyor engineers in both tunnels and what challenges there will be in the calculations and teach how to solve these challenges.

Surveying calculations are the most important part in controlling long tunnels.

Keywords—UTM, localization, scale factor, CARTEZIAN, traverse.

I. INTRODUCTION

LET'S take a look at Fig.1 and Fig.2 when the TBM comes out with 1cm error in the axis. The drilling diameter is 3.8 meter and there was not access tunnel in this project. Map projection is UTM, LA1 and TB1 are base station, S1 is start and F is end of tunnel. SABIR is contractor and MAHAB GHODSS is consulting engineers.

This tunnel is the first part of a 36 kilometer tunnel, the second part of which has already been built and must be connected to the second part. Therefore, if 1 meter error occurs at axis of the tunnel, it is necessary to destroy about 100 meter of the second part of the tunnel. And it will cost a lot for contractor. Therefore, the contractor's project manager invited another surveyor's consulting engineer as a second consultant. After doing the calculations, the second consultant announced the error of 2.5 meters at 500 meters to the end of the tunnel and the projection manager entered into a challenge to make a decision. Which calculations are correct? Due to the importance of this issue the project manager decided to invite the third surveyor consulting engineer for control. After performing the calculations, the third consultant announced the deviation of 1.5 meters from the axis.

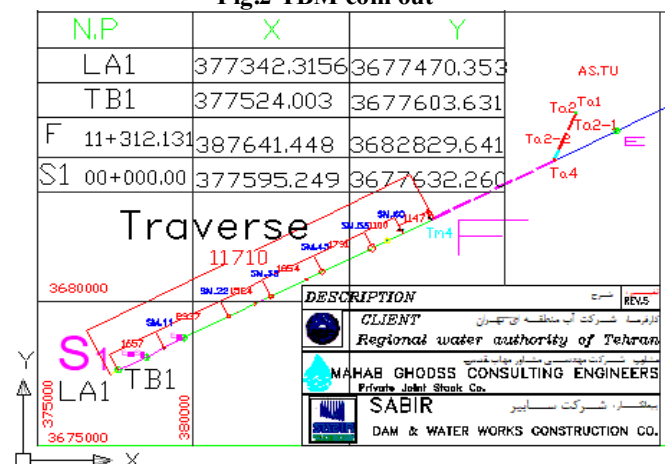**Fig.1 end of tunnel**

**Fig.2 TBM com out**

Fig.3 Tunnel map on WGS-84-UTM

Fig.4 The challenge for the project manager

The project manager held meeting between the consulting engineers and announced that 30 cm of error is acceptable for us at the end of the tunnel and more than that will cost us more, so share your calculations with each other and check the calculation method and announce the final result in the next meeting.

In the next meeting, MAHAB GODSS consultant engineering company withdrew and the second and third consultants did not accept other calculations. The project manager accepted the tunnel calculations for one reason only because the third consultant mentioned himself in the contract. If the error created at the end of the tunnel is more than 30 cm, no fee will be paid by the contractor, and mentioning this clause in contract gave confidence to the project manager. After about three months, the tunnel was opened with minimal deviation.

You can see when TBM com out in Fig.2.The surveyor measured error that was 1 cm. you can read the interview with the project manager and third consultant engineer in MAKAN News magazine [2].

THE CHALLENGE OF SURVEYING COMPUTING
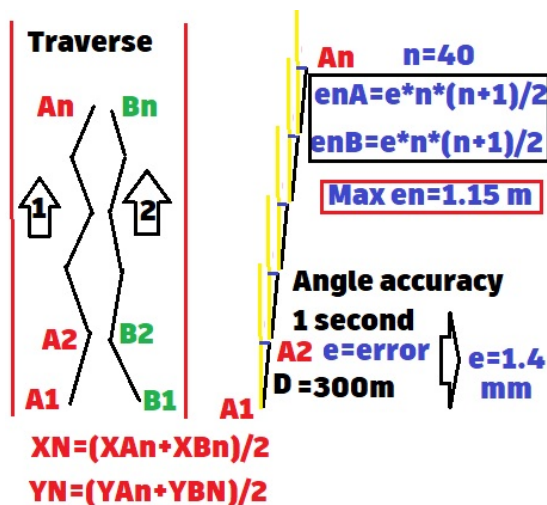
Fig.5 The calculation method

In the Fig.5 you can see the calculation method of traverse surveying by MAHAB GODSS consulting engineers. In this

method, you can not completely remove the wrong measurement and calculate and remove its amount. In this project TOTAL STATION angle accuracy was 1 second and minimum distant between two survey stations is 300 meter, map projection is **WGS-84-UTM. So** surveyor must calculate scale factor and enter it in TOTAL station because distance between two points on UTM is different from the actual value. In Fig.6 you can see both in the picture.
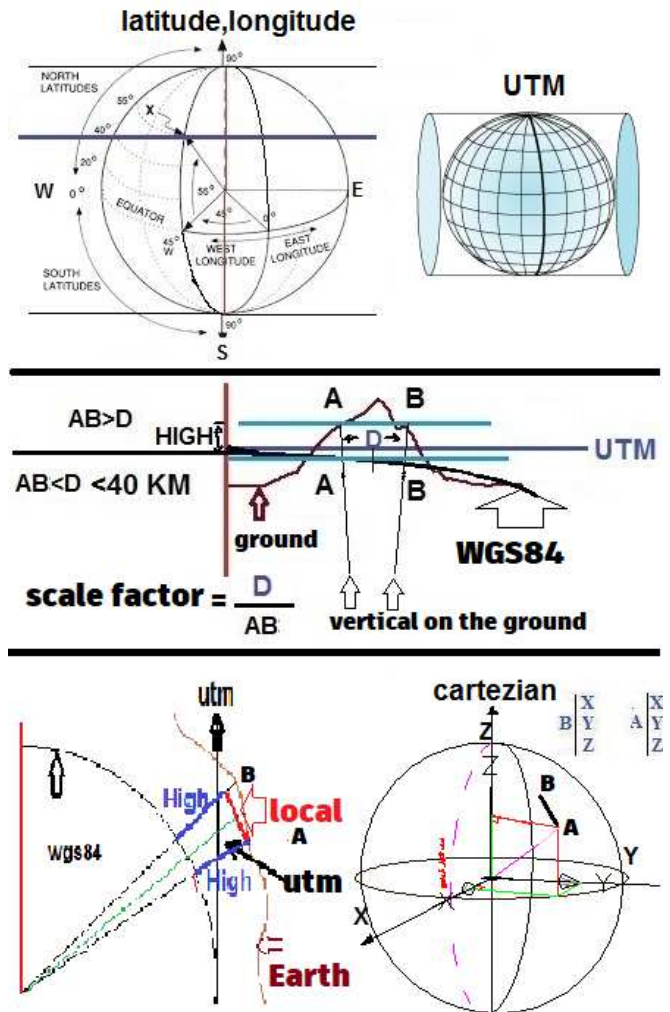
Fig.6 Longitude and latitude and UTM coordinates and localization

In Fig.6 you can see UTM map and the real distance is calculated from CARTEZIAN coordinate points. AB is real distance and D is UTM distance.

After applying the **scale factor** on the measured lengths, all the calculations are done on the UTM map projection.
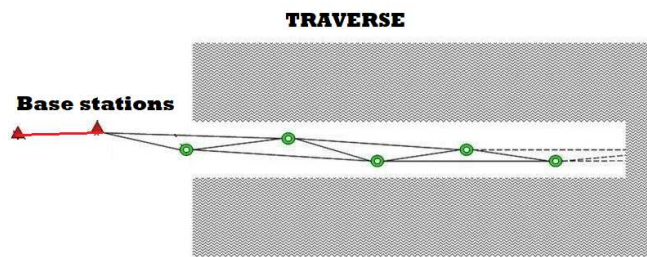
Fig.7 second traverse method

In the Fig.7 you can see the calculation method of traverse surveying by second consulting engineers which was calculated by GEOLAB. The latest innovations from GEOLAB give you greater power into your least squares adjustments and make the entire adjustment process easier. Perform least squares adjustments and simulations of all types of networks.
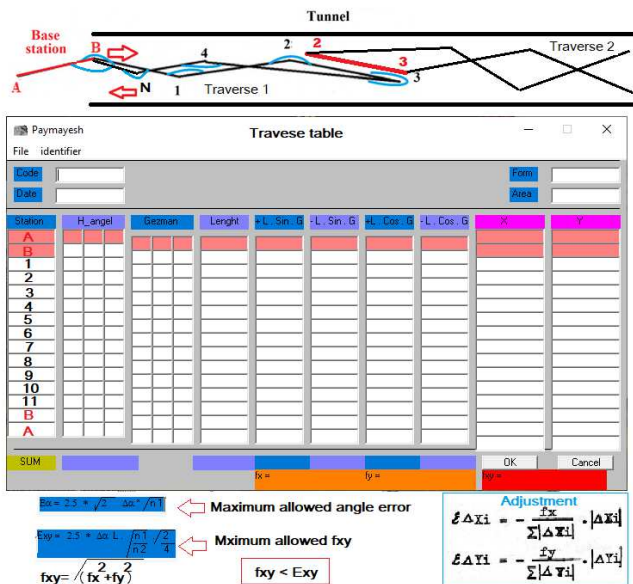

Fig.8

In the Fig.8 you can see the calculation method of traverse surveying by third consulting engineers which was calculated by PAYMAYESH table program. This method has been introduced in the books of Iranian universities to calculate the traverse.

In the Fig.10 you can see the calculation method of traverse surveying by third consulting engineers which was calculated by traverse table app that shows the first traverse done in the tunnel and for example app is placed. In this project, the third consultant used six Travers to reach the end of the tunnel and each Traverse shared a length with the next Traverse. This app designed by third consulting and you can download that from app store or telegram channel [1], [4].

When you use the triangulation method, you have to reduce the distance between the stations and use more lengths and angles. The length error will also change the angles, so the calculations of the second consultant are less accurate in the tunnel. You can see the calculations of the GEOLAB on the telegram channel [3].
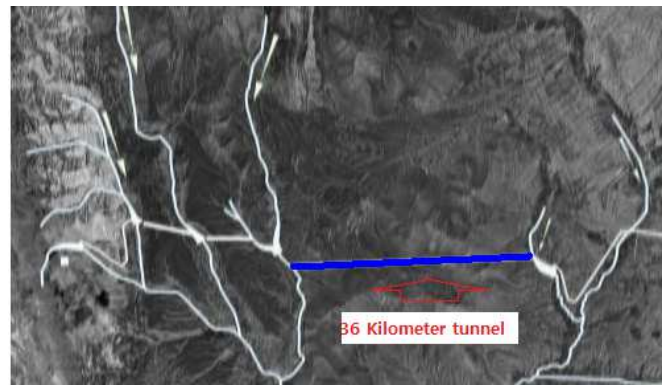

Fig.9 36 km of ALIGODARZ tunnel

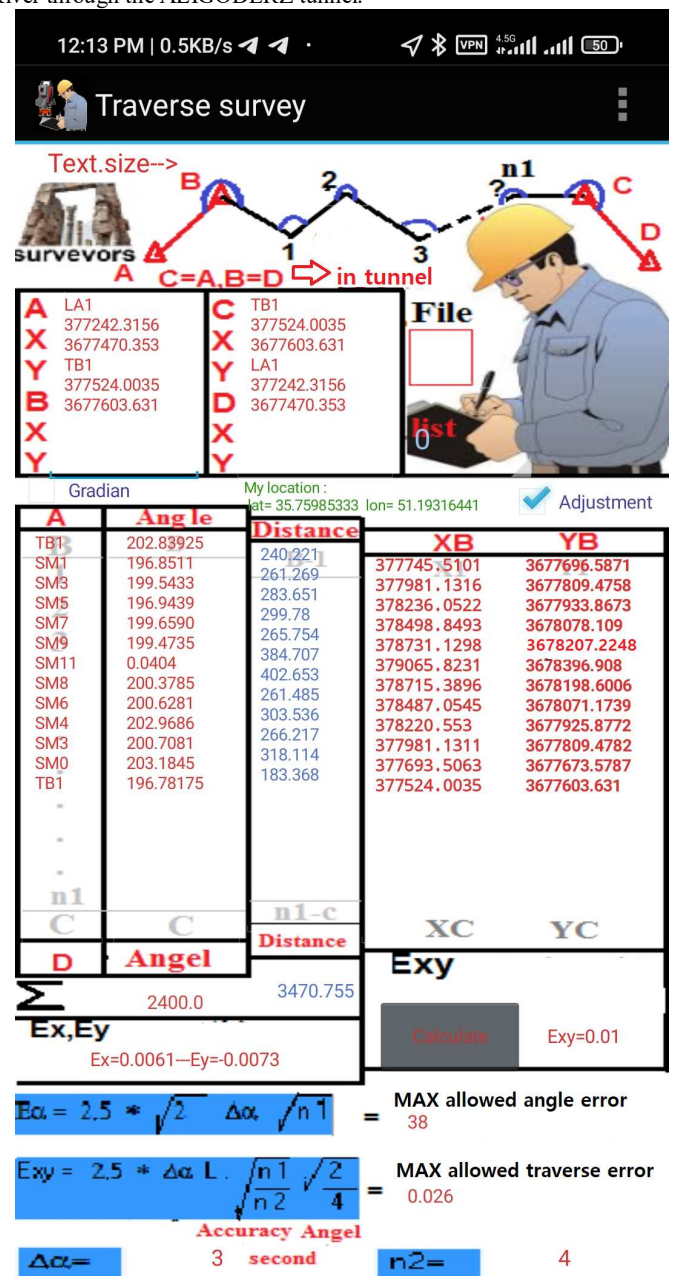In the Fig.9 you can see the water transfer route from the DEZ River through the ALIGODERZ tunnel.

Fig.10 Calculate the first tunnel traverse

In the Fig.10 surveyor must enter base coordinates, distance between stations and angles also enter angle accuracy and the number of readings of each angle, introduce the type of angle and click on the CALCULATE button. App calculates coordinates, traverse error and maximum traverse. Traverse error must be less than the maximum. This kind of calculation has been used in KHODA AFARIN dam, SIAH BISHEH dam, DARIAN dam, Tehran's subway. Navigating long tunnels is always a challenge for surveyors and employers, and the lack of importance to the surveying team can cause the tunnel to deviate and increase its cost, as we saw in the 18 km tunnels of URMIA Lake.

In the Fig.11 you can see plan in UTM map that it was excavated by two TBM machines from the entrance and exit side of the tunnel. They used MAHAB GODSS method in Fig.5 and the tunnel deviated from the path, you can see in Fig.12.

Fig.11 The route of the tunnel is designed

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Fig.12 First tunnel deviation

Fig.13 The path of the tunnel that deviated by 20 meters

In the Fig.13 you can't see TBM because it deviated 20 meters. The contractor created a shaft 2 kilometers before the end of the tunnel so that the surveying could be done with higher accuracy, but the surveying team moved the surveying stations from the shaft and their close distance, causing the tunnel to deviate after traveling a distance of about 200 meter, and they noticed when they cannot see the TBM in a direct path.
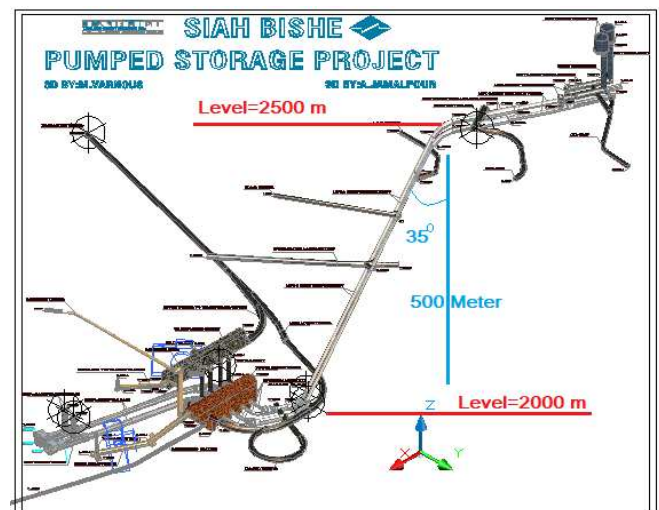

Fig.14

In the Fig.14 you see another challenge in tunnel with a slope of 35 degree. In this project, all coordinate calculations by observing the length and angle have more error than using the GPS, but you have to do localization because the lengths in UTM are different from the actual length and the method of applying the scale factor was described in Fig.6, for localization there is a challenge for selecting the page of surveying station in level 2500, level 2000 or 2250. All the surveying stations are located in the same UTM zone, so for localization we use UTM coordinates for calculation of angles and

the scale factor for calculation of actual lengths. In Fig.15 you can see the lower dam at the level of 2000. The interview with the surveyor in this project and the author is in MAKAN News magazine. [2]
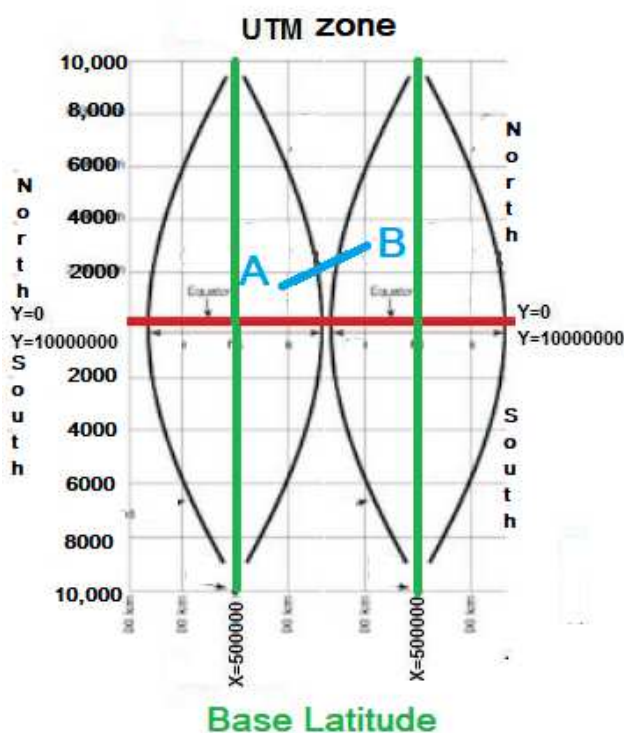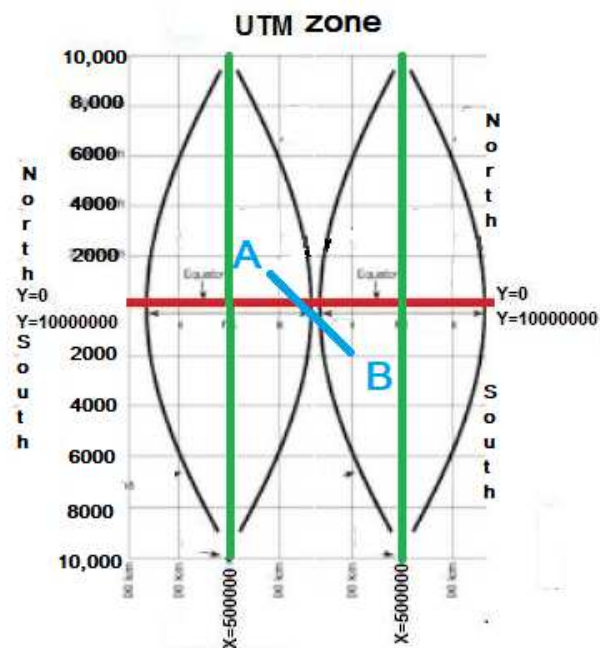

Fig.15 SIAHBISHEH lower dam

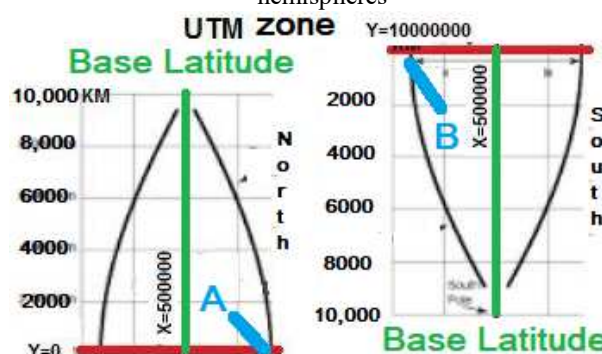Fig.17 The tunnel passes through two different zones and hemispheres

Fig.18 The problem of using UTM coordinates

There is another challenge, if tunnel is in two different UTM zone and cross the equator, Fig.17 and Fig.18 show this position.

In this position you can't calculate angle and distance between two points in two different UTM zone. For solving this challenge you can use Transverse Mercator projection for calculation angle points for localization, also you can see surveying app that I put in telegram channel. [1]

Fig.16 The tunnel passes through two UTM zones

There is another challenge if tunnel is in two UTM zone, you can see this challenge in Fig.16.

In this position you can't calculate angle and distance between two points in two different UTM zone. For solving this challenge you can change Base latitude and put map in one zone.

Traverse, localization points are the most important part of surveying in big projection, there are several examples of dams, tunnel and subway projects with the challenges in these projects and apps that designed to solve these challenges are available on the Telegram channel. [1]
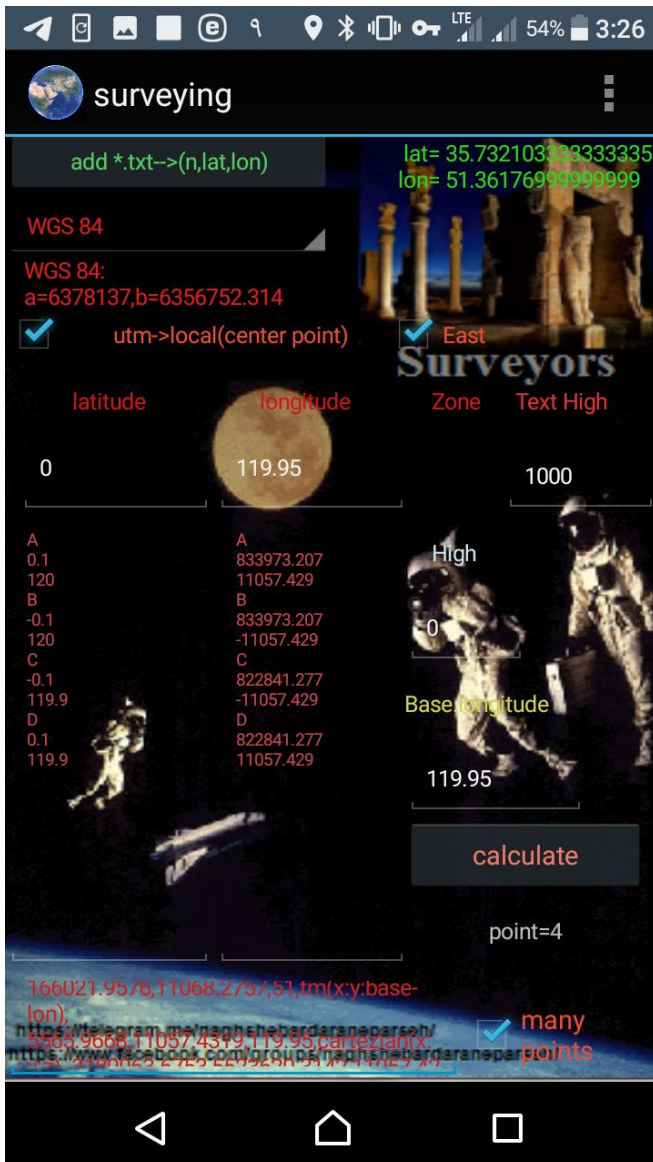

Fig.19 The problem of using UTM coordinates

Fig.2 Localization solves the challenge of UTM coordinates

Apps can be useful for calculating, you can see in Fig.20 that SURVEYING app did the localization related to fig.19, this app is in telegram channel [5]. In this app you must enter base point latitude and longitude, base level then enter name, latitude and longitude other points, click on Calculate bottom, app calculates local coordinate points.

The tunnel is in two different UTM zone and cross the equator.

REFERENCES

[1] https://t.me/naghshebardaraneparseh
[2] https://makannews.blog.ir/page/report
[3] https://t.me/naghshebardaraneparseh/949
[4] https://play.google.com/store/apps/details?id=traverse.parseh
[5] https://t.me/naghshebardaraneparseh/7857