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Article

Using materials of radar mapping from spacecrafts as a way to increase reliability, as well as to reduce the cost and time of site selection for extended linear construction projects

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Abstract: The article describes the use of publicly available materials of radar mapping from spacecraft as a way to increase the reliability, as well as to reduce the cost and time of work to select the site of linear construction projects situated in remote underdeveloped areas. Based on the results of theoretical study and practical application of radar mapping of the Earth's surface from spacecrafts the conclusion is made about the availability of these materials, their reliability (relevance) and accuracy in order to select the site of linear construction projects at the concept design stage.

Keywords: Preliminary Design; Site Selection for Linear Projects; SRTM; ASTER GDEM; ALOS AW3D; MERIT DEM; GeoTIFF

1. Introduction

The concept design stage is the first and fundamental stage in the implementation of any construction project.

The quality of the concept design is of primary importance, as the data obtained is the foundation on which the most important management decisions are made. The reliability of the information gathered determines not only the viability of the project in general, but also the required amount of investment, as well as the planning of all key aspects of implementation.

Site selection is one of the critical areas of work during the concept design stage. All possibilities and limitations of land parcels are taken into account, which makes it possible to find optimal options for the location of project facilities and the tracing of linear utilities. The correct solution of this matter directly affects the success of the entire construction project and its economic efficiency.

The site selection and assessment of site are one of the initial stages in any construction project. These processes are extremely important. Site selection indicates the usefulness of new facility location, both for business and government. Site selection involves matching the needs of a new project with the merits of potential locations, and it is one of the most important aspects of starting a business.

The site as the location of construction projects will have a huge impact on business, from taxes to wage rates, shipping costs, and everything in between so it is important to take your time and select the right one. Moreover, site selection is a strategic decision that usually involves several different but equally important criteria related to technical, economic, social, environmental, and sometimes political issues.

The aspect of the importance of site selection is fully validated both by the private experts with outstanding reputations [1] and by the public authorities [2].

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The critical importance of correct site selection is also recognized in the works of foreign researchers from Europe [3], North America [4] and others, as well as in the normative technical documentation of countries that are world leaders in the field of industrial construction work [5].

Extended linear facilities such as communication lines, main on-shore transmission lines, main gas and oil pipelines are one of the core foundations of sustainable development of any industrial state.

The specificity of the location of such facilities is that they are usually found in remote and poorly explored areas. Thus, topographic survey of the intended object locations, which is mandatory for site selection, requires a lot of time and financial resources.

Exacerbating the problem is the fact that financial capacity is significantly limited during the concept design stage, as core funding is only allocated after the results of this phase have been approved.

An effective solution, and sometimes the only practical option (especially in case of limited time of concept design stage), is the application of Digital Elevation Models (DEM), based on data obtained by radar sensing of the Earth.

Technological developments in the late XXth century, including advances in high-precision radiolocation, digital data storage and processing systems, global navigation systems, high-resolution optics and space technology, made it possible to start generating the first spacecraft radar sensing materials.

The most famous and the first project in the field of radar mapping from spacecraft was the international research project "Shuttle Radar Topography Mission" (SRTM) [6]. In February 2000, it successfully completed a survey aboard the U.S. space shuttle Endeavor (Figure 1).

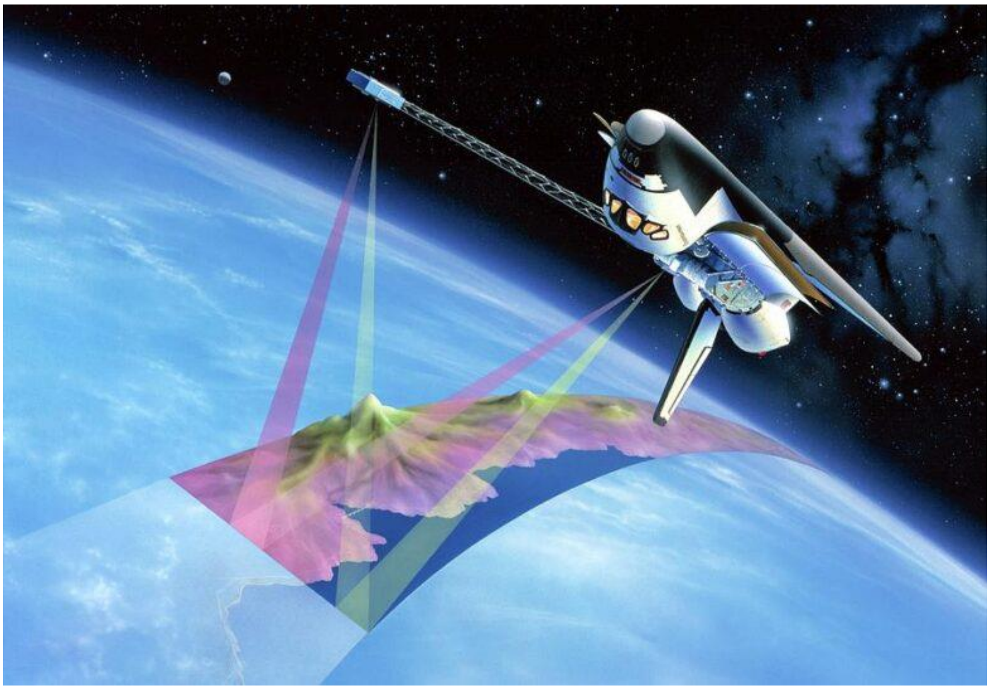

Figure 1. Shuttle Radar Topography Mission [7]

The generated array of information made it possible to create a DEM for 80% of the planet's land area, covering the region from 56 degrees South to 60 degrees North latitude (Figure 2).

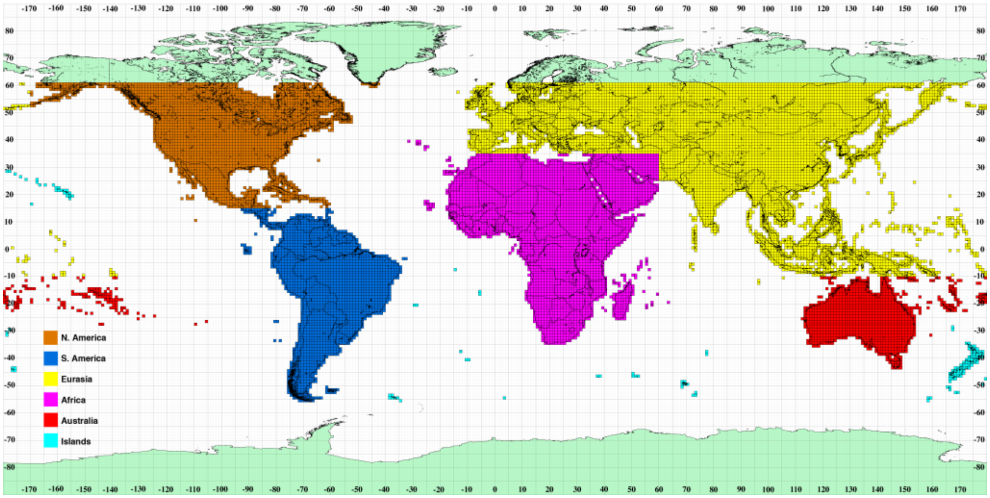

Figure 2. Earth coverage in the SRTM mission [8]

In the following years, a number of other large-scale projects on radar mapping from spacecraft were accomplished. Among them, the following most significant projects are distinguished:

- ASTER GDEM, year of creation – 2009;
- ALOS AW3D, year of creation – 2016;
- MERIT DEM, year of creation – 2018.

2. Methods

In order to determine the possibility of using radar mapping from spacecrafts for site selection of extended linear construction projects, the following matters were addressed within the framework of this article: availability of the materials of radar mapping, their accuracy, as well as their relevance and reliability.

The main research method chosen was the comparison of the available data on the accuracy of various materials of radar mapping from spacecrafts both among themselves and with the results of classical topographic survey, with subsequent analysis and generalization of the results obtained.

The available software for processing the materials of radar mapping from spacecrafts is considered in particular.

2.1. The availability of materials of radar surveys of the Earth's surface from spacecraft

All above mentioned digital elevation models are publicly available, information of them can be obtained from corresponding Internet sites (Table 1) with mandatory observance of license restrictions.

Table 1. Location of information on digital elevation models.

Digital elevation model	Access to information
ALOS AW3D	https://www.eorc.jaxa.jp/ALOS/en/index_e.htm
ASTER GDEM	https://asterweb.jpl.nasa.gov/data.asp
MERIT DEM	https://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/
SRTM	https://srtm.csi.cgiar.org/srtmdata/

2.2. Relevance (reliability) of the materials of radar mapping from spacecrafts

This aspect is significant. When making conclusions on preliminary design, one should not rely on information that does not correspond to real conditions.

It is important to note that the radar survey within the SRTM project was conducted 25 years ago. The more modern digital elevation model MERIT DEM appeared seven years ago.

However, the age of radar data does not play a decisive role in the preliminary design of facilities located in remote and underdeveloped areas. Under such conditions, changes of terrain due to natural factors are usually insignificant in the short term. They can be adjusted:

- by means of local topographic surveys, especially in areas of active coastal or river bed evolution;
- at the next stages of the project implementation.

Therefore, the use of older radar data in such cases is generally acceptable.

2.3. Accuracy of materials of radar mapping from spacecrafts

Different materials for radar mapping from spacecrafts have different initial accuracy (Table 2) [9].

Table 2. Accuracy of information on digital elevation models.

Parameter	SRTM	ASTER GDEM	ALOS AW3D	MERIT DEM
Spatial resolution	1" x 1"	1" x 1"	from 1" x 1" (30x30 m) – open source data; up to 0.1" x 0.1" (2.5 x 2.5 m) – commercial version.	3" x 3"
Coverage	60°N 56°S	83°N 83°S	All the world	90°N 60°S
Elevation accuracy evaluation	16 m	20 m	5 m	9 m
Accuracy evaluation in plan	20 m	30 m	5 m	12-14 m

There are a number of research works devoted to the evaluation of the actual accuracy of the materials of radar mapping from spacecrafts by comparing them both among themselves and with the results of classical topographic survey [10-12].

For large-area areas, we can mention the work “Vertical accuracy assessment of 30-m resolution ALOS, ASTER, and SRTM global DEMS over northeastern Mindanao, Philippines” [13], which compared the accuracy of ALOS, ASTER, and SRTM radar mapping, and the work ‘Comparing Ground Survey Data with SRTM Satellite Data: Case Study in North of Iraq’ [14], which analyses information on two land areas of 1,384,707.00 square metres and 549,041.00 square metres and concludes that the accuracy of spacecraft radar imaging is sufficient for concept design stage for projects.

For the preliminary design of sites of linear construction projects, we can mention the work “Evaluation of SRTM elevation matrix accuracy basing on topographical surveys” [15]. In this work a comparison of information according to SRTM with the information obtained as a result of classical topographic survey has been performed on the example of the route profile of a linear extended object with a length of 82 km [15].

The study showed that the mean deviation (MD) and standard deviation (SD) of all route sections differed by no more than 10% of their absolute values. Taking this into account, the following parameters for the whole trace can be accepted with certain assumptions: MD is 12.8 m and SD is 4.0 m.

To eliminate the systematic error in elevation differences, the values of orthometric altitudes were corrected by decreasing by 12.8 m. After this correction, the mean deviation was 1.0 m, while the standard deviation remained unchanged [15].

A more general statistical comparison of different data on radar mapping from spacecrafts is presented in "Comparison of digital terrain models" [16]. The results of this study are summarized in detail in the form of a table (Table 3) [16], and a graph (Figure 3) [16].

Table 3. Results of mathematical analysis of the compared topographic models.

Parameter	Topographic survey	ALOS AW3D	SRTM	ASTER GDEM
Mean	157.96	156.62	156.14	157.40
Variance	1,397.54	1,406.24	1,401.24	1,445.96
Mean error	0.51	0.51	0.51	0.52
Thickest value	134.00	130.00	147.00	139.00
Standard deviate	37.38	37.50	37.50	38.03
Kurtosis	-0.61	-0.59	-0.60	-0.57
Skewness	0.15	0.15	0.14	0.13

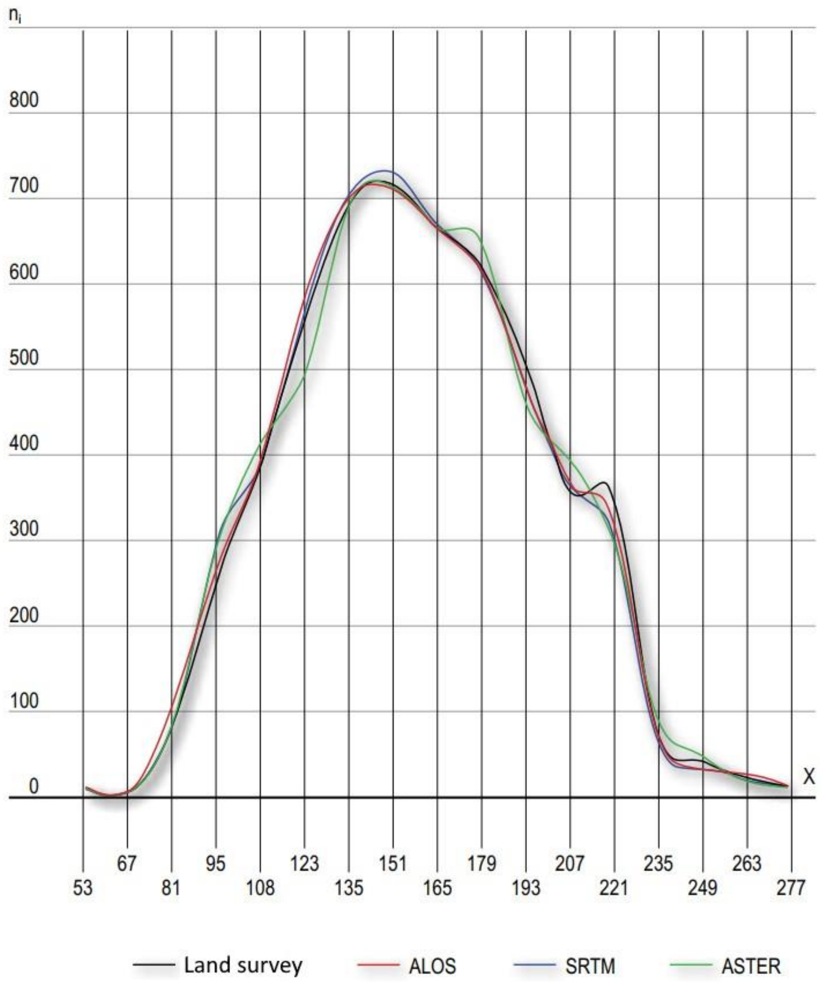

Figure 3. Distribution of sampling frequencies by the Sturges formula: ni is the frequency of occurrence, X - midpoint of the elevation interval.

The methodology of the American statistician Herbert Arthur Sturges, shown in the following formulas 1 and 2, was used as the main calculation method.

$$k = 1 + 3.322\log N, \quad (1)$$

$$i = \frac{x_{max} - x_{min}}{k}, \tag{2}$$

where N is the number of sample values,
k is the number of groups,
$x_{max/min}$ – means maximum and minimum values in the sample,
i is the interval.

It is reasonable to apply these formulas when the number of aggregate units is large and regular intervals are used.

Thus, basing on the results of comparison of radar mapping from spacecrafts with real profiles of land parcels of linear objects located in remote underdeveloped areas, we can conclude that the accuracy is sufficient for use for site selection purposes at the concept design stage.

2.4. Software for processing materials of radar mapping from spacecrafts

The information of radar mapping is usually generated as files in GeoTIFF format, the description of which is open and generally available.

GeoTIFF is based on the TIFF graphic file format. Additionally, GeoTIFF has information about the geographic coordinate system, geoid model and other specialized parameters.

To put it in simple terms, each pixel in a GeoTIFF file is precisely referenced to latitude and longitude, and the brightness of the pixel reflects the elevation (Figure 4).

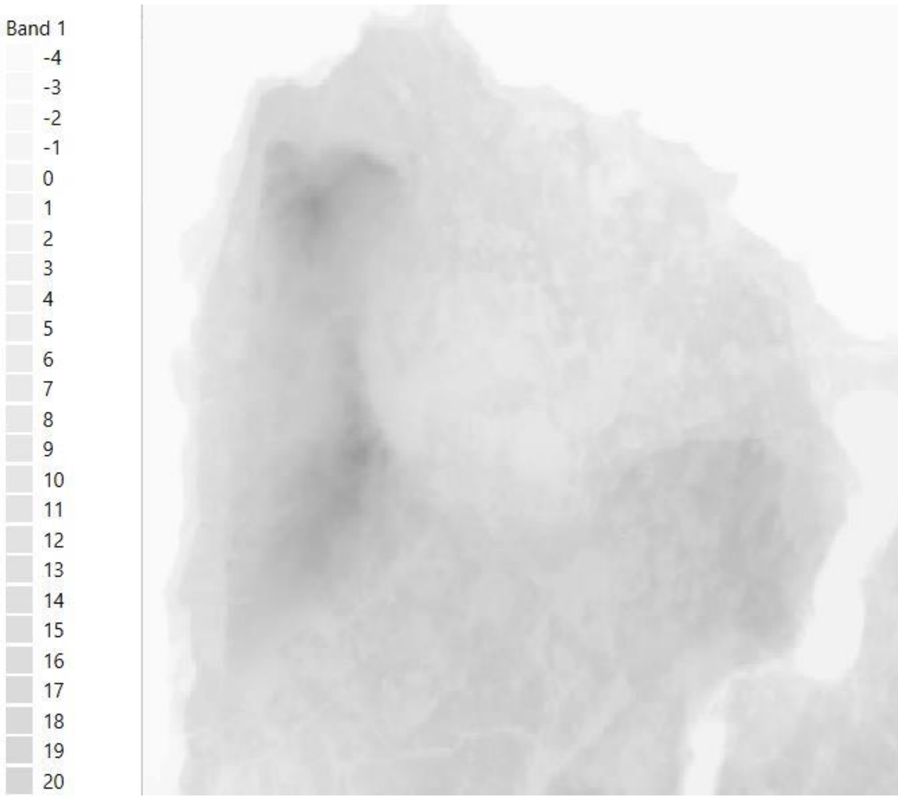

Figure 4. Displaying the surface relief in a GeoTIFF file.

Almost all modern geographic information systems (GIS), intended for work with geospatial data, support processing of GeoTIFF files.

A prominent example of such a system is the well-known QGIS, formerly known as Quantum GIS.

QGIS is a free and open source geographic information system that can be run on Windows operating systems and various Unix platforms, including Mac OS.

It is a powerful tool that supports many vector and bitmap formats, as well as various databases. The system has an extensive package of optional modules and includes a built-in algorithmic language, which makes it a universal approach to various geospatial data processing tasks.

QGIS provides a number of powerful tools for working with materials of the Earth`s surface radar imaging from spacecrafts.

One of these tools is the ability to create horizontals and elevation profiles for the areas of interest (Figure 5).

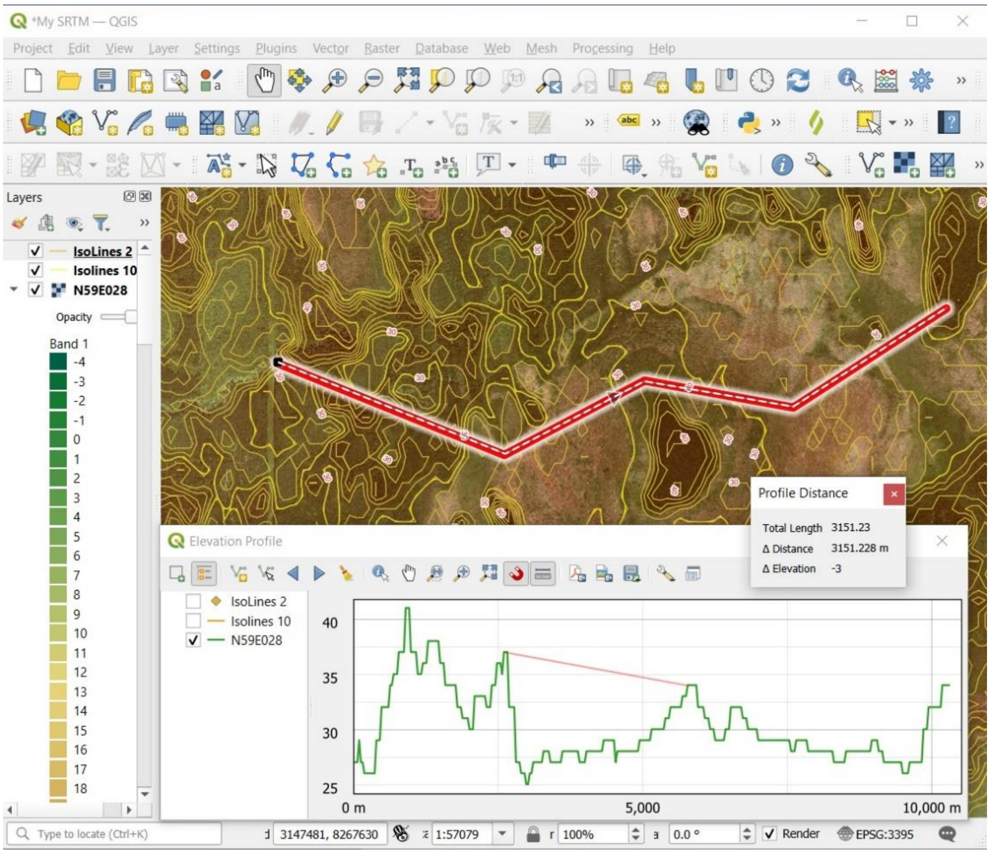

Figure 5. Plotting of land surface elevation profiles in QGIS.

With the QGIS it is also possible to visually assess the terrain of the land parcel with the construction of a virtual 3D model of the land surface area (Figure 6), based on radar imaging data from spacecrafts.

This allows to get a visual impression of the topographic features of the territory and to make a thorough analysis of its relief.

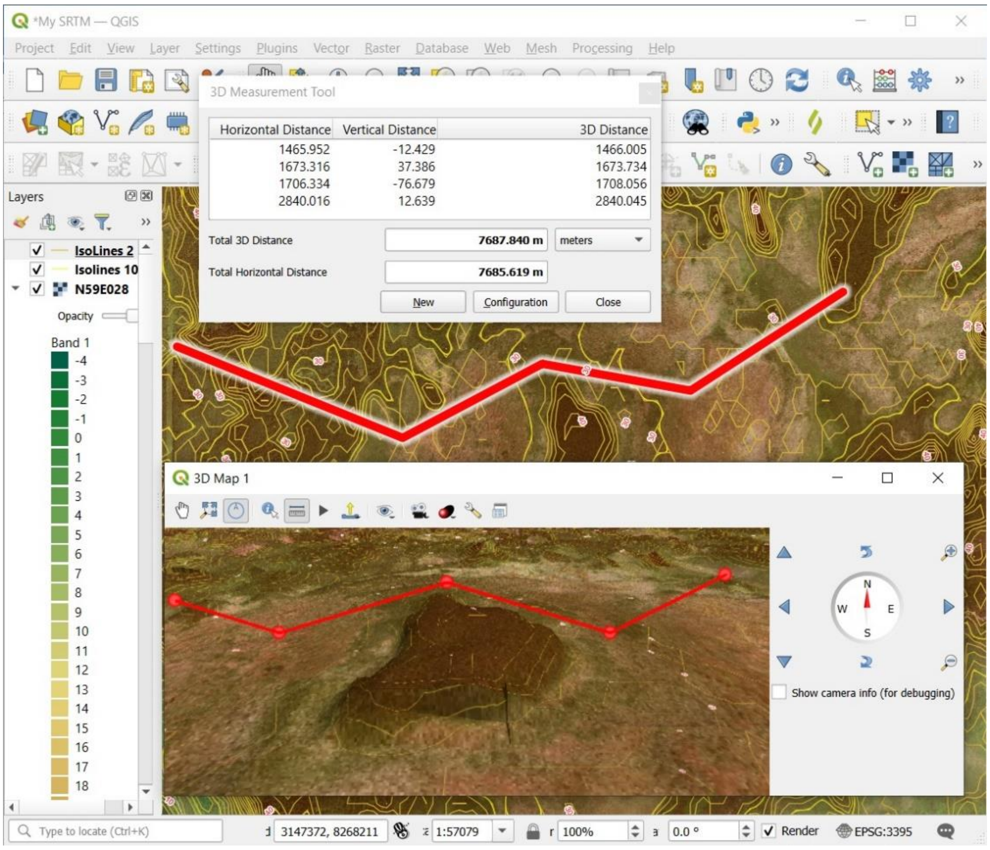

Figure 6. Building a 3D model of a land surface in QGIS.

Both horizontals and elevation profiles in QGIS and 3D-model of the investigated area are constructed on-line, which reduces the time spent on studying the relief of the land parcel and Site selection.

At present, scientific works are successfully conducted on even greater reduction of time costs through automation of selection of the most optimal location of RoW linear project using materials of radar mapping from spacecrafts.

As an example of such work one can name the "Automatic routing of water supply pipelines" [17], which allows to calculate the optimal route for laying pipelines both on flat and rugged terrain, taking into account additional restrictions on displacement, elevation differences and hydraulic pressure losses to be compensated by pumping equipment

When selecting pipeline diameters and calculating possible routes, the main criterion is to minimize annual costs. These costs consist of two components:

- capital investment in the acquisition of the pipeline;
- energy costs to keep the system running throughout its working lifespan.

The algorithm considers all key factors that affect the design of a pipeline system and helps to find the most cost-effective solution for laying a pipeline in a given environment.

This algorithm represents a complex model in which materials of spacecraft radar mapping are one of the main data sets in use.

The result of this algorithm is the most optimal tracing of the object by the selected parameters (Figure 7).

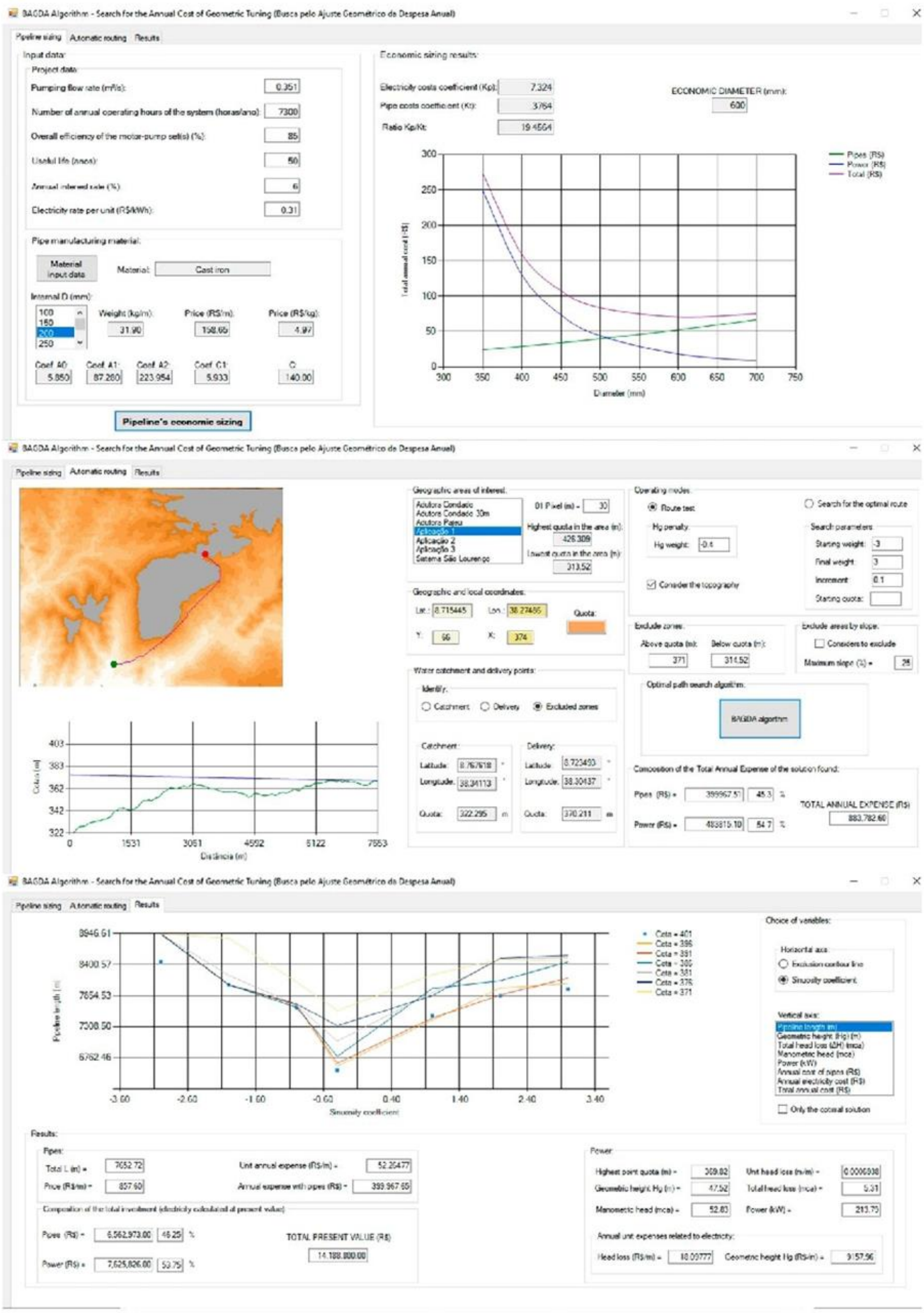

Figure 7. Automatic routing of water supply pipelines. Application interface screen [17].

3. Conclusions

Thus, by comparing the available data on the accuracy of various materials of radar mapping from spacecrafts with the further analysis and generalization of the results obtained, the following conclusions can be made:

- materials of radar mapping from spacecrafts are characterized by openness and transparency of the information structure;
- In the context of remote areas with minimal impact of human activity, land surface information remains reliable and relevant
- accuracy of the data received is quite sufficient for Site selection at the stage of preliminary design of extended linear objects construction;

– information processing is possible with free, legal and widely available software.

The use of materials of radar imaging from spacecraft significantly widens the possibilities of site selection for extended linear objects located in remote and underdeveloped areas, and also helps to reduce costs and time resources required for preliminary design of these objects.

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