

GENERATING 3D TERRAIN MODEL FOR ROAD DESIGN USING GIS METHODS

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Abstract: Digital terrain modeling is basically the creation of a digital representation of the terrain topography. Although maps that presented topographic information have been collected in a precise digital form to allow the creation of digital terrain topography models, such a model can be made using ArcMap software. In order to prepare the digital terrain model, there are used graphic and script data - a *.dwg file that includes the road section and geographical coordinates of the points of interest extracted from Google Earth. The geographical coordinates were converted into cartesian coordinates, this conversion being made using The World Coordinate Converter application. Based on the extracted data, a three-dimensional elevation model can be generated, and further used in various fields and applications. The generation of longitudinal and transversal profiles, with related details, is essential for better understanding the land configuration and a proper road design.

Keywords: three-dimensional model, elevation, Google Earth data extraction, ArcMap modeling

1. Introduction

The road represents the element of road infrastructure that is at the same time the technological support, vector of civilization and element of economic development. The development of transport infrastructure is a necessary condition for the successful implementation of other development priorities of rural areas, contributing to increasing the mobility of people, combating the isolation of underdeveloped areas and last but not least the development of regional and local transport infrastructure. An efficient transport infrastructure, connected to the European transport network, contributes to increasing economic competitiveness, facilitates integration into the European economy and allows the development of new activities in the internal market [11].

For the practical approach in the paperwork, a forest road from Avram Iancu commune, Alba County was chosen as a case study (Fig. 1). The existent road sector is in poor condition, degraded, and a new section should be designed and built [11], [12].

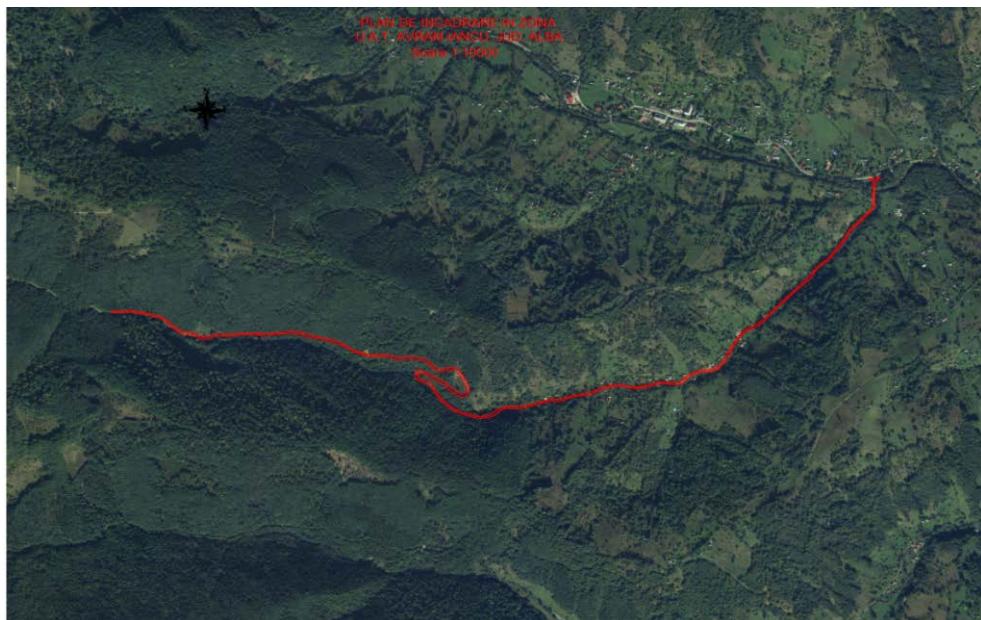


Fig. 1 The area of interest, Avram Iancu, Apuseni Mountains

2. Materials and Methods

The production of 3D models integrated in GIS systems has consistently become much higher in the space data market than traditional 2D GIS models [3], [4]. The advantages of using 3D models are plenty: they are more intuitive and richer in detail, they are considered an essential visualization method for presenting environmental data with spatial content, based on them one can better appreciate the anthropic impact on the environment, their use is not restricted [1], [2].

The capacity of a GIS is to integrate data from different sources (topographic plans, thematic maps, photogrammetry data, remote sensing data, data obtained based on GPS measurements) and to perform their analysis in order to achieve a more objective description of reality, [2], [8].

The process of creating the 3D terrain model that should represent the base for road design and rehabilitation requires several steps: importing the road section from CAD to GIS (Fig. 2), establishing the area of interest in Google Earth and extracting geographical information, converting geographical coordinates to cartesian coordinates, generating the 3D model of the terrain in ArcMap and the realization of longitudinal and transversal profiles [5], [8].

Google Earth provides geographic data that consists of latitudes and longitudes, but altitudes as well. This can be a reliable data source especially when: the GPS device does not log altitude, there is poor satellite reception when recording the track, the GPS device does log altitude, but it's not very accurate, drawing a track using the drawing tools in Google Earth or a similar application, having a file that came from Google Maps or Google Earth's "driving directions" feature, creating a route in Google Maps and have the URL of that route [9], [14].

There are programs that could instantly add elevation data — from a DEM (digital elevation model) database — to certain type of files. Therefore, it is possible to use the extracted geospatial information for 3D terrain modelling, drawing profiles, or convert a single data file to different type of files, as needed [10], [14].

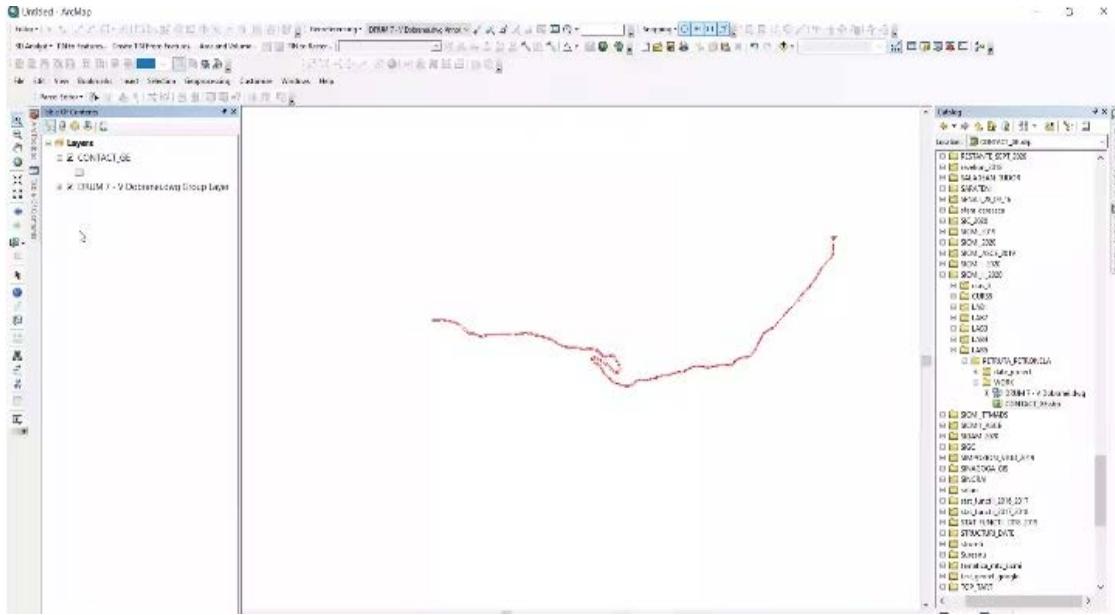


Fig. 2 The import of road section

In order to extract data from Google Earth, the first step is to mark up the interested area with lines and polygons. By simply dragging on the map, a path or a polygon can be drawn for extracting elevation data, measuring distances and areas (Fig. 3). All these information is necessary for 3D terrain modelling [6], [14].

Google Earth also offers a helpful method for extracting script data, which is the basis level for the purposed modelling [14].

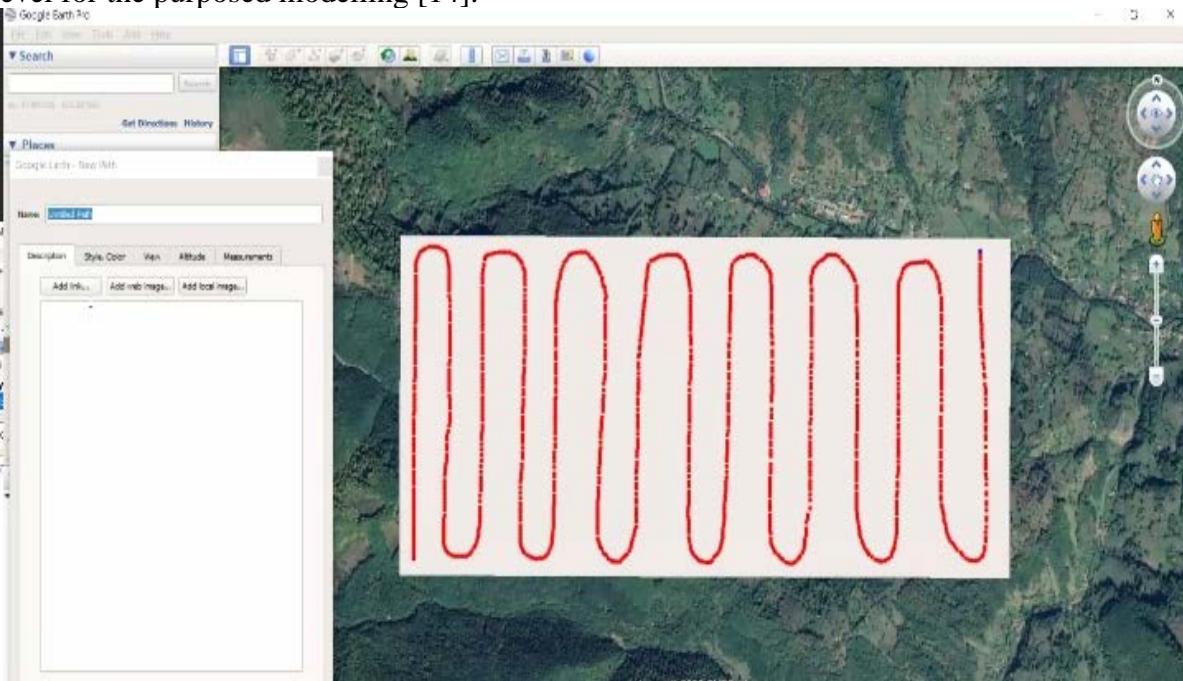


Fig. 3 Adding path to the area of interest

All the information extracted from Google Earth – the path covering the area of interest where the road should be designed and the script data necessary for the road design – are now imported in ArcMap, for 3D terrain modeling (Fig. 4) [14].

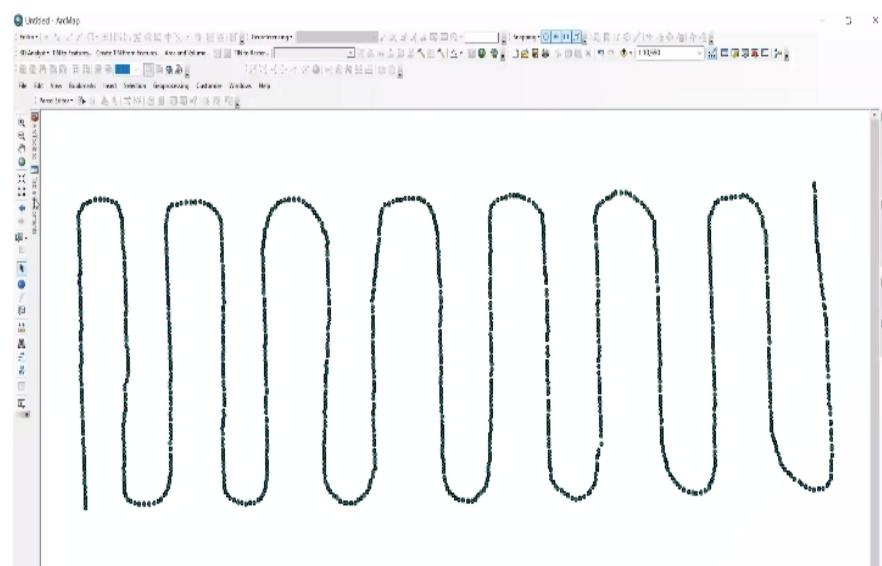


Fig. 4 Extracted data from Google Earth imported in ArcMap

A 3D terrain model is required to be as close to the reality as possible. In order to achieve such a model and furthermore to use it in different fields of applications – such as road design – it is necessary to pass all the check steps and complete an attribute worksheet (Fig. 5) [7], [14].

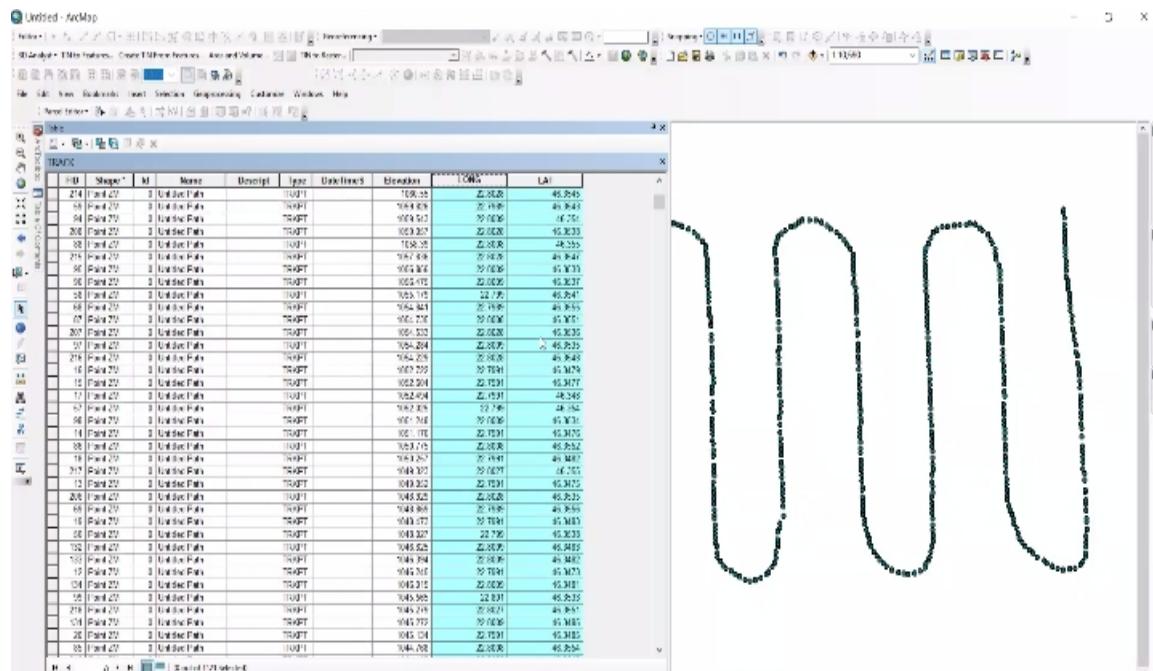


Fig. 5 Attribute worksheet

In the attribute worksheet, there can be added fields in order to complete the database information. In this case, there are required two more fields representing the geographic spatial location of the points defining the path drawn in Google Earth – latitude and longitude. The geographic coordinates are then converted into Cartesian coordinates in WGS 84 reference system, Stereographic 1970 projection system (Fig. 6). Now, the Cartesian

coordinates of the points defining the path are associated with their elevation, obtaining a (x, y, z) worksheet [2], [10], [14].

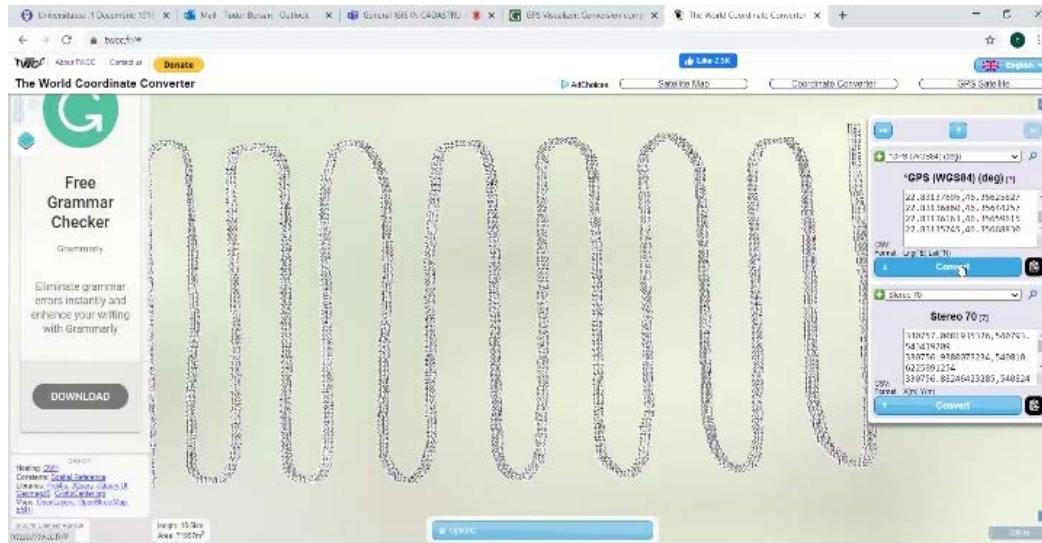


Fig. 6 Conversion to Cartesian coordinates

Based on the data obtained so far, a three-dimensional terrain model can be generated in ArcMap, which will represent the basis for the road design, considering the design area features (Fig. 7). All necessary data for the road design are stored systematically in the ArcMap database, using 3D coordinates describing the shape and all the features of the interested area, allowing the estimation of the shape and features in new points, prediction and simulation [3], [10], [14].

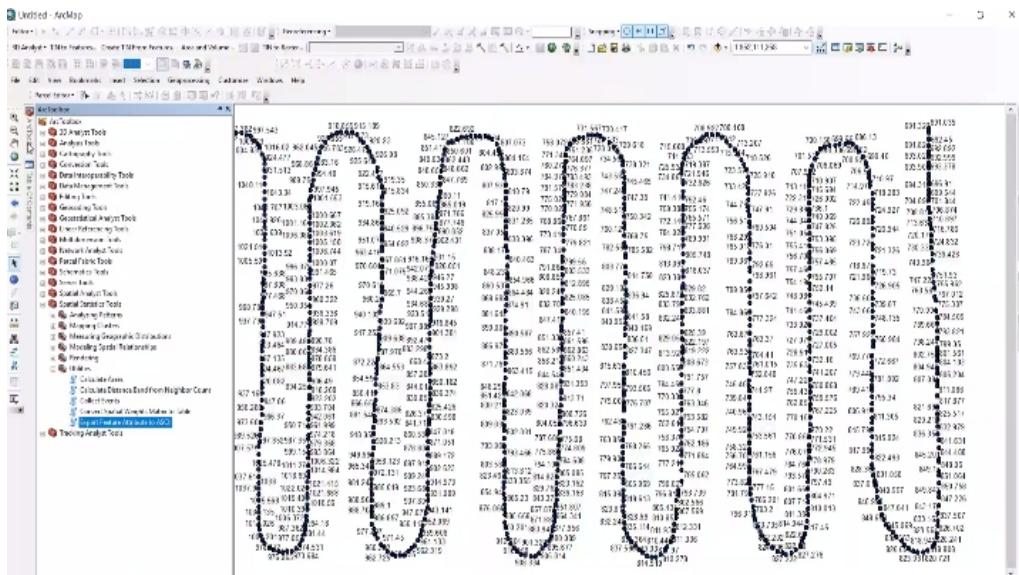


Fig. 7 Interpolation of the path elevation

ArcMap software allows the users to generate longitudinal and transversal profiles based on 3D elevation models. These profiles are used for exploring the slope, elevation, and distance along a certain path (Fig. 8) [1].

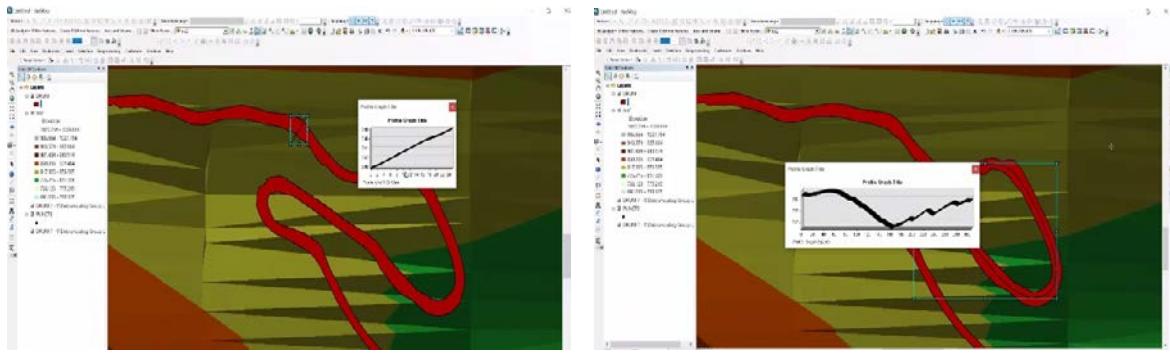


Fig. 8 Longitudinal and transversal profiles

3. Results and Discussion

The obtained 3D terrain model (Fig. 9) is in correspondence of direct resemblance to the real terrain it substitutes, described through mathematical relations, through algorithms and programs implemented on a computing system, through the technique of digital modeling. It represents a "computer tool" consisting of field information and calculation programs, including modules for processing, sorting, storing, retrieving and editing, in order to achieve the goals – the road design, construction and maintenance [9].

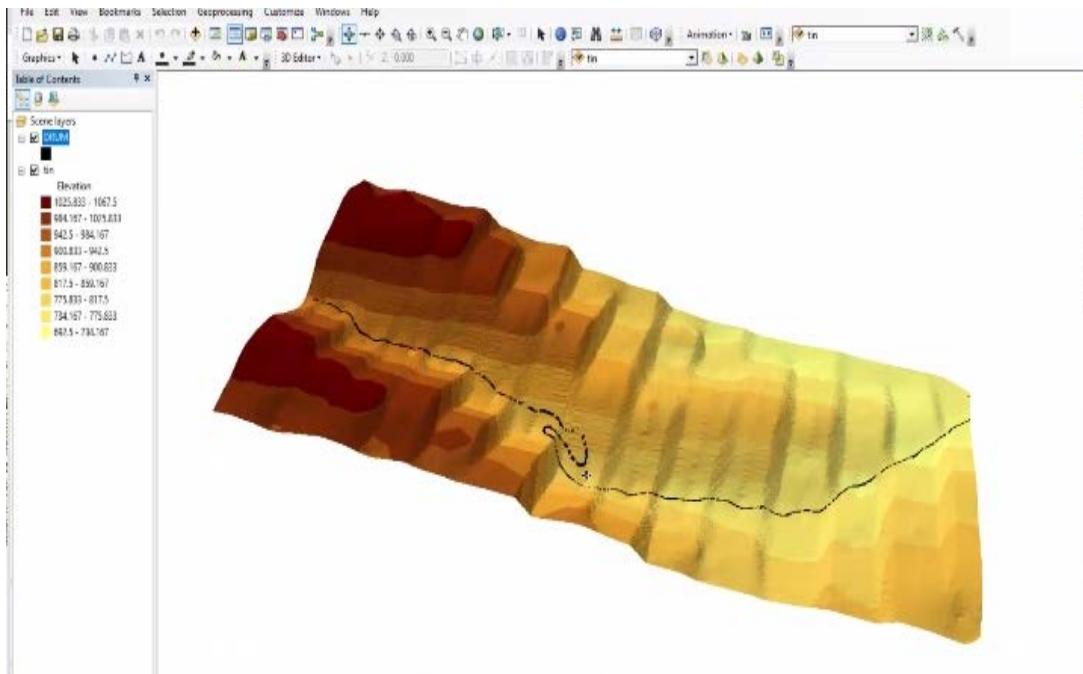


Fig. 9 3D terrain model

The main objectives in achieving a 3D terrain model is to highlight the topographic characteristics and the area relief features of the land, and by generating and using longitudinal and transversal profiles, to highlight the characteristic elements of the road.

The generated 3D terrain model was drawn up in color tones, taking into account the elevation of the area of interest. Studying it, one can draw up the conclusion that the generated 3D terrain model reflects the characteristics of a rugged terrain, given that it is located in a mountainous area (Găina Mountain) [11].

Such a 3D terrain model may have applicability in practice in order to rehabilitate the existing road and design new sections. At this moment, the existing road section needs serious repairs, restoration, consolidation, drainage, as it has potholes, landslides and crumbling [11].



Fig. 10 The actual condition of the existent road section

These degradations of the existent road section were caused by natural factors (water action, frost-thaw, rugged relief – highlighted by the modelling result), but also by anthropic factors (massive deforestation, wood transportation) [11].

The rehabilitation of the existent road section, as well as the design and execution of new sections have a major importance from the point of view of controlled forestry exploitation, forest maintenance, but also from the point of view of tourism, because it makes possible much easier access to Mountain Găina [11], [13].

4. Conclusions

The emergence of geographic information systems has generated a new stage in the processing of spatial information. The usefulness of the geographic information system is that it allows the association of spatial and non-spatial data. The geographic information system can integrate spatial and non-spatial data with other sources that it organizes and manages.

In general, a digital 3D terrain model could be used to model water flow, to run simulated avalanches or landslides, or to study land use, transportation system planning, and geological applications. Other uses include creating physical thematic maps with varied relief, flight simulator programs or other visualization and modeling applications. Digital 3D terrain models are included in geographic information systems.

The deplorable situation of the roads or their lack in the Apuseni Mountains is a first factor in terms of living standards, lack of jobs, which obviously led to the depopulation of rural areas. In this context, any interest directed towards the design, construction and rehabilitation of national, communal and exploitation roads can add to the disadvantaged areas.

In this sense, the present study could be continued by creating a geographic information system specific to the roads serving rural areas and areas with forestry and tourist potential in the Apuseni Mountains, so as to create an articulated network of infrastructure.

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