Geodetic frame for railways infrastructure works

Sorin I. Herban[1], Adrian Alionescu[2], Carmen Grecea[3], and Beatrice C. Vîlceanu[4]

***Abstract*—**Nowadays, in Romania a great accent is placed on the development and improving of both the modern road and railway networks that should offer superior comfort, safety and efficiency in traffic and should respect current policies in sustainable development. It is also known that a modern and sustainable transport infrastructure represents the development "engine" for national economy, thus allowing the enhancement of economic sector, the expansion of economic competition and integrating the national Romanian economy into the European and worldwide economy. In this context, the surveyor engineer, beside his quality of supplier of measured geometric data, has a significant contribution, through his abilities regarding modeling of dynamic systems like constructions or roads and data interpretation. An eloquent example is represented by the present paper, in which the authors describe the methodology for achieving the geodetic support network used for the rehabilitation of the Sighişoara-Aţel railway section, part of Pan-European Corridor IV.

***Keywords*—**topographic survey, modern technologies, satellite survey, railway network, survey processing.

I. Introduction

In Europe, the current tendency in global transport development is generated by the reasons that drive states to build a high-speed and safe railway infrastructure, which first and foremost implies the shortening of travel time on long routes and improving inter-regional accessibility from/to far-away regions with a view to stimulate European integration. [1], [2]

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The E.U. has 28 member states, out of which only 26 have railways. The map of the European railway routes (Fig. 1) shows a relatively homogenous distribution, with good line quality and capacity. Within the European development strategy, creating a Pan-European transport network represents a major objective. Nowadays, there are various types of railway, as regards structure, organization, financing, as well as growing movement demands. Throughout its history, the railway has evolved continuously, fundamental changes in technology and mentality being involved in modern lines today. [2]

Due to its favourable geographical position, Romania represents a pillar that supports the connection between European Union member states on the one hand and, on the other hand, Parts of the Basic Multilateral Agreement regarding International Transport for the Development of the Europe-Caucasus-Asia Corridor, signed in Baku on the 8th of September 1998, through the Europe-Caucasus-Asia Transport Corridor, as well as Pan-European Transport Corridor IV (road and railway) and VII (the Danube).The Pan-European Corridor IV (Fig. 2) is one of the 10 Pan-European transport corridors defined at the second conference of Pan-European transport (Crete, March 1994). [3]

The investment project targets an increase in travellers by train, as well as the quantity of merchandise transported on the railway, by means of ensuring higher-quality services and superior speed. [3], [4]

Fig. 1. Pan-European Corridors in Europe [3]

Corridor IV was recognized as being one of the routes in Central and Eastern Europe that require major investments in the following years. The Pan-European Corridor IV starts from Dresden/Nuremberg and ends in Istambul, going through Prague – Vienna – Bratislava – Budapest – Arad – Bucure□ti - Constanța/ Craiova - Sofia - Salonic/Plovdiv – Istambul, crossing the following countries: Germany, the Czech Republic, Slovakia, Romania, Bulgaria, Greece and Turkey. [3], [4]

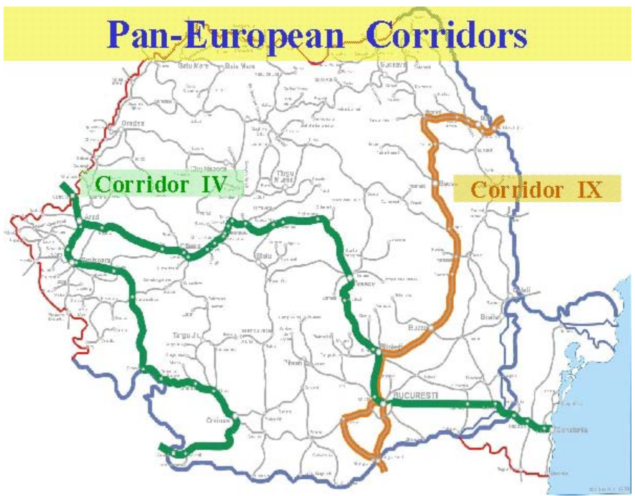

Fig. 2. Pan-European Corridors in Romania [4]

II. THE DEVELOPMENT OF RAILWAY INFRASTRUCTURE IN ROMÂNIA

Railways are generally credited with a major role in the delayed modernisation of south-eastern Europe. In examining their impact in Romania up to the First World War, it is evident that the railways themselves constituted a major industry and they stimulated a good deal of business through demands for materials which were met increasingly from the within the national economy. There was also a major change in mobility and the selective development of towns and rural centres shows a strong correlation with railway services. Trends in manufacturing, agriculture and tourism also bring out strong correlations with the developing railway network. However, it is stressed that the railways were crucial through satisfying a precondition for economic growth and a range of other factors must also be recognised as underpinnings of the capitalist system in Romania over the half-century before the First World War. [12]

After the First World War, Romania and other newly-constituted or greatly-enlarged states of East and Central Europe faced a problem with the inherited infrastructure that was not only worn out and heavily damaged but also needed thorough integration on account of the new provinces acquired from defeated powers – in Romania's case: Banat, Crișana, Maramureş and Transilvania from Hungary, Basarabia from Russia and Bucovina from Austria. [13]

The authorities aimed to expanding the railway system as the country doubled its size, even though there were many inherited deficiencies. In contrast to grandiose visionary schemes, specific plans were always relatively modest in scope but were a considerable extent realised, sometimes after considerable delay which may be attributed to capital shortage wartime pressures, changing international circumstances and, above all, the engineering difficulties in dealing with mountainous and unstable terrain. Furthermore, the interest in new projects had to be balanced against the need to modernise the existing network. Given the limited resources and a measure of conflict between economic and strategic objectives, the progress was substantial and many of the defects in the inherited network in terms of indirect routes from the capital city, Bucureşti to some large population centres were satisfactorily addressed (Fig. 3). [13]

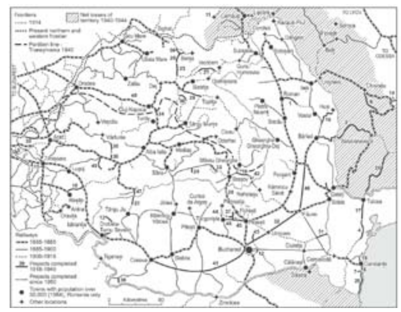

Fig. 3. The Romanian railway system highlighting the projects completed during 1918-1949

Four decades of communist central planning brought little further expansion of the network except in new coalmining areas and the emphasis placed on widening and electrification points to the rationality of earlier decision making. However, the network still shows many signs of its origins in a territorial context very different from that of the present. [13]

III. THE RAILWAY SECTION SIGHIŞOARA – AȚEL

The railway line Sighişoara – Ațel (Fig. 4) is part of the Sighişoara – Coşlariu section, which is part of Corridor IV Helsinki, and which on Romanian territory has the following route: Curtici - Arad - Simeria - Alba Iulia - Coşlariu - Sighişoara - Braşov - Bucureşti - Constanța.

The section analyzed has a length of 94.75km (out of 871km on Romanian territory) and is part of the main railway that represents 10.87% of the total length of Corridor IV. [3]

Fig. 4. Railway stations on the Sighişoara-Aţel section [4]

In 2011, the average technical travel speed was situated between 58.00km/h and 109.00km/h. At the end of the modernization works, the maximum speed for passenger trains will be of 160km/h and that for trains transporting goods of 120km/h. [5]

IV. Topographic works necessary for carrying out the investment

The design and construction-installation works, in an increasing number of fields, but especially in overland communication ways domain, are not feasible without using the technique of geodetic measurements with all that it involves. [11] The specifics of the construction and modernisation of the communication ways requires specialized surveying assistance in all phases of implementing those projects (roads, railways, water streams, artwork etc.) [14]

The geodetic network, determined in a classical measurement system, has served for more than half a century to carry out topographic surveys, making up an important cartographic and geodetic background for engineering and administrative record works. The implementation and use of modern technologies in determining superior support networks in topographic engineering works represents a particularly complex and useful process, coming as an addition to classical topography, and offering higher precision and control when it comes to terrestrial measurements.

Considering the high-precision requirements and the special character of this type of work, it was decided that a new geodetic infrastructure should be designed and created, appropriate from the viewpoint of the accuracy level and the easy access to the points. In this reference system needed for detailed surveying measurements, old geodetic points have being integrated within the new created network, points identified following land recognition.

The design system used for the works is the national 1970 Stereographic Projection System with unique secant plan.

The altitude system used for completing the works is the 1975 Black Sea Altitude System.

A. Projection and implementation of the planimetric geodetic network

Upon drawing up the study regarding the enclosing within the 1970 Stereographic System of the geodetic network, the WGS 84 System (World Geodetic System 1984), respectively the Local Projection System that would be used for execution works, it was necessary that a technical execution project be drafted that was to fit the purpose, namely to facilitate topographic marking works. For the implementation of the execution project, we had at our disposal, at first:

- magnetic support with trapeze 1:25.000 from working area, orthophotomap;
- existing support network;
- layout of the railway with the designed axis;
- inventory of the geodetic points coordinates' from the studied area;
- inventory of the levelling benchmarks from the Romanian Geodetic Network.

The geodetic studies necessary for reaching this aim were realized starting with 1st order geodetic points, considering the fact that linear deviations for superior order points (I, II, III) fall within the precision 1...15cm, respectively Class A Geodetic Network (permanent stations) and Class B points (materialized on the ground) that have a determination precision of 1cm (Fig. 5).

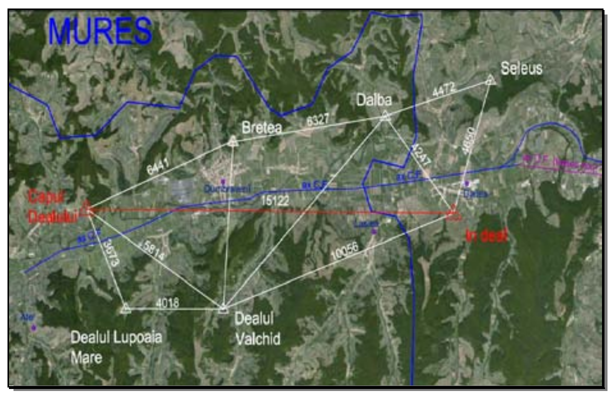

Fig. 5. Points in the National Geodetic Network along the C.F. Sighişoara-Aţel section

Given the fact that the points of the support network were determined by means of satellite surveys, there is also the problem of enclosing the support network in the National Geodetic Network for which the transformation parameters were determined from WGS 1984 to the 1970 Stereographic Projection using 4 points from the National Geodetic Network and 5 reference stations GNSS (Global Navigation Satellite System) within the Romanian Global Positioning System "ROMPOS" (Fig. 6).

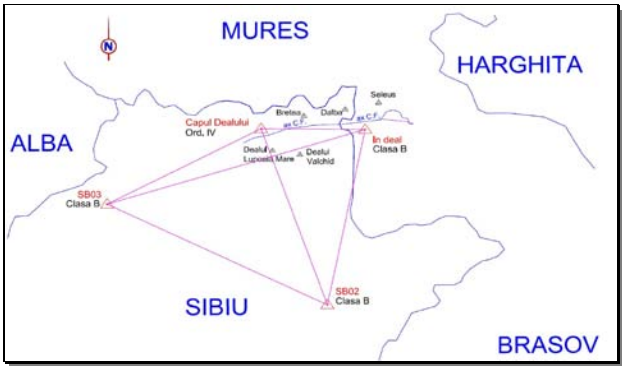

Fig. 6. Points in the National Geodetic Network used to determine the transformation parameters

Upon designing the support network, the following criteria regarding point placing were taken into consideration:

- not to be any obstacles obstructing the horizon over the 15° elevation, since they can diminish the number of available satellites;
- that there are no reflective surfaces near the antennas, as they can lead to the multipath effect (reflective surfaces are considered to be surfaces with asperity lower than 2cm);
- that there are no high-power electrical appliances near the satellites or emission relays, as they can disrupt satellite signals;
- to be easily accessible;
- not to be exposed to destruction;

As a solution, a support network was proposed in the form of chains of triangles and quadrangles with both diagonals observed.

Based on a technical project, the final marking of the support network points was effected by means of benchmarks placed in secure areas, with low degradation risk as time passes.

B. Satellite survey implementation and processing

In the past 2 decades, modern measurements techniques in the field of engineering geodesy have seen an unprecedented development and a higher degree of automation. [15] The Global Positioning System (GPS) technology collects and processes signals from GPS satellites in orbit around the earth to determine the location of points of interest on the ground.

Owing to the advantages of high accuracy, all-weather conditions, no requirements of inter-visibility between measuring points, GPS is playing more and more important role in high precision positioning missions in structure/construction health and in determining geodetic support networks. [10] As a consequence, the coordinates of the network points were determined using GPS technology.

During session planning the use of time intervals with smaller GDOP (Geometric Dilution Of Precision) was proposed. Survey planning was done in the GNSS Planning online application (Fig. 7). [6]

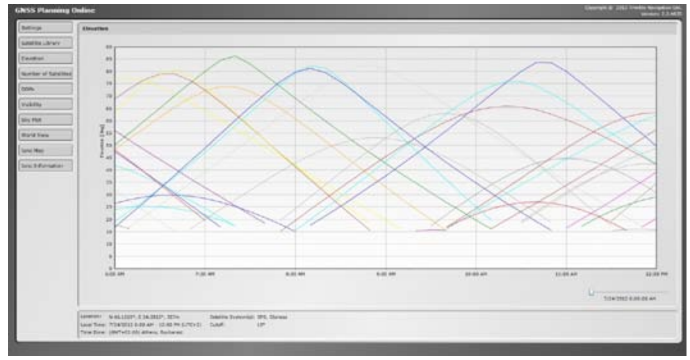

Fig. 7. Elevation satellites

For the main network observations, 8 satellite survey sessions were performed using the static surveying method and for the secondary network observations, 8 GPS measurements sessions were performed using the rapid-static surveying method.

For the most accurate results and to assure the stability and reliability of the obtained solutions a specialized software was used for geodetic measurements processing, namely Leica Geo Office Combined version 8.2. This application (Fig. 8) allows data processing and compensation to be performed and it is based on the least squares method. [7]

In Romania the official coordinates system is the 1970 Stereographic system based on the Krasovski ellipsoid. For the acquisition of WGS 84 system coordinates from the 1970 Stereographic system cross calculation parameters can be used, either country wide parameters or local used parameters. For superior precision, a set of local parameters were assessed, their calculation being based on a GPS session consisting of current network benchmarks on the Aţel-Sighişoara route. These benchmarks have 1970 Stereographic System coordinates.

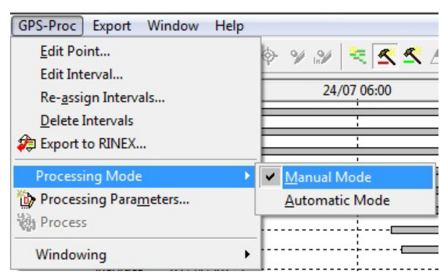

Fig. 8. Data processing mode

The transformation parameters were determined with the same Leica Geo Office Combined 8.2 software using the Helmert transformation. Table 1 shows the resulting parameters (3 translations, 3 rotations, scale factor) that have been applied to the main and secondary network, thus obtaining the coordinates in the 1970 Stereographic projection system for all the points.

Table 1. The resulting parameters

No.	Parameter	Value	rms
1	Shift dX	-177.7238m	0.0465m
2	Shift dY	17.0265m	0.0307m
3	Shift dZ	181.3714m	0.0530m
4	Rotation about X	74.94026"	0.00121"
5	Rotation about Y	-171.13774"	0.00216"
6	Rotation about Z	327.55862"	0.00028"
7	Scale	-6.8791ppm	0.0010ppm

C. The altimetric geodetic network implementation

In order to obtain precise results, for this type of surveys, modern equipment should be used, namely levels that meet several advantages such as:

- allows correction for curvature of the Earth;
- allows correction for collimating error;
- offers the possibility to use 3 survey modes – singular, median or medium;
- offers the possibility to reduce the field of view.

Before the survey began an identification of benchmarks belonging to the state elevation network was performed. 8 benchmarks were identified from which the elevation values were transmitted to the new benchmarks of the supporting network (Fig. 9).

Fig. 9. A benchmark placed in a railway station

To acquire the required results, beginning with the technical stage of the project, a strict inspection of all the benchmarks by the use of high precision geometric levelling both ways performed with DNA03 Digital Level and 2m invar levelling rods was necessary. The materialization of the levelling points (foot plates for geometric levelling) was effected on stable ground, without running the risk to degrade over time, protected against mechanical actions.

On the route of the main geometric levelling lines, 29 benchmarks were created to ease the transmissions of elevation values to the benchmarks belonging to the supporting network.

For data processing and elevation network compensation the same software was used, Geo Office Combined, Version 8.02, using the least squares method. The software allows for block compensation of elevation measurements. All measurements performed with the electronic level are marked as lines that are defined on the level when a new project is created.

The precision of the obtained network is 1.51mm on the Ațel-Sighişoara route (Fig. 10). Length 25km.

V. Conclusion

The rehabilitation of the railway route would increase the comfort and safety of traffic, and the services would be significantly improved, passenger railway service covering a good part of the transport market. [8], [9]

Even though technology of railway building has greatly evolved, the role of the specialist in topography has kept its importance, growing with the need to control the equipment that performs various activities automatically.

By means of presenting state of the art technologies, like satellite-based positioning the paper shows its high level of topicality. Moreover, the paper's originality is given by the proposal that the surveyor should always take part in reaching decisions regarding courses of action in projects that imply creating geodetic support networks for rehabilitation of railways in Romania.

The need for a valid control system for the infrastructure is naturally met by topography, the latter being the only viable alternative to the current control and monitoring systems described above.

Technological evolution and space-ground combination allow for adequate results regarding topographic activities performed normally.

An "absolute system", from the topographic point of view, implies the existence of a benchmark network that covers the railway satisfactorily and allows for the framing of the railway in the coordinates system.

Implementing and using accurate geodetic technologies in determining superior support networks is a very complex process. The present paper wishes to be a contribution to this process, aiming to make topo-geodetic works more efficient by adopting efficient work methods based on spatial data.

Among the benefits of using accurate geodetic technologies for the rehabilitation of railways, we mention:

- planimetrically (the X and Y coordinates) the precision is met, the authors aimed to determine all new points with accuracy above 1cm – a value smaller than the one required in the project stage;
- the precision of the levelling measurements complies within the required limits, with values, after block compensation for the entire network, of 1cm and 2cm, respectively;
- the materialization of the benchmarks was effected on stable ground, without running the risk to degrade over time, protected against mechanical actions offering the possibility to be used for future works;
- all technical conditions have been met and, based on the obtained values; the topographic surveys can be performed.

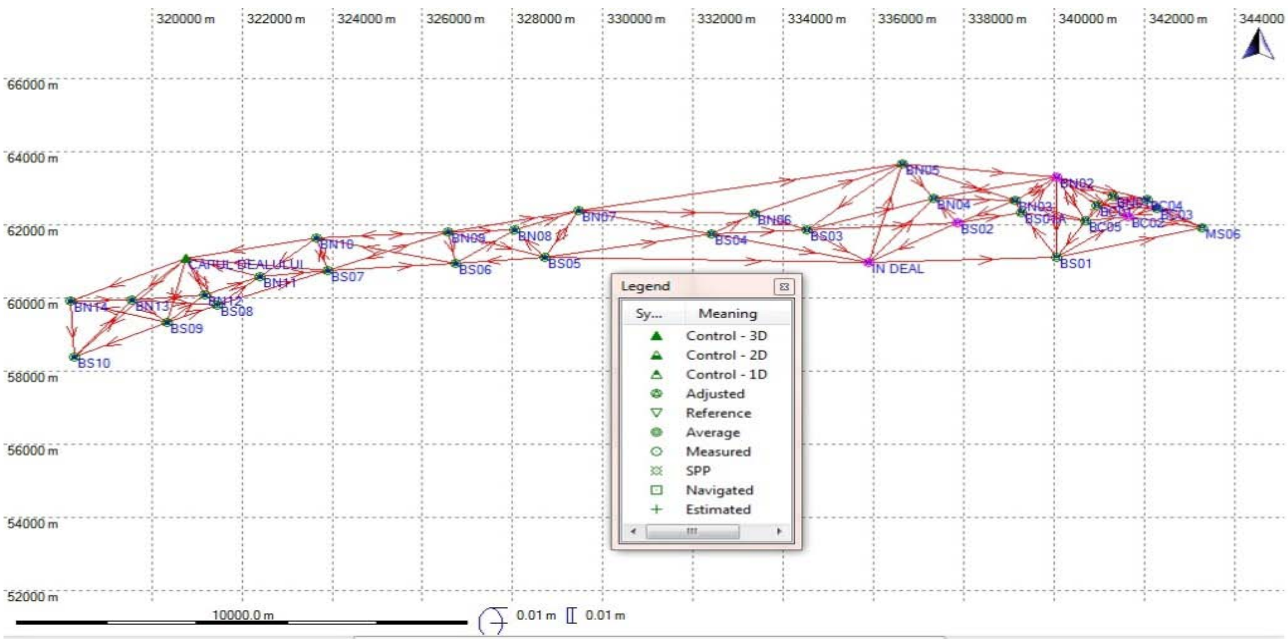

Fig. 10. Sketch of the geodetic support network

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