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STUDY ON TOPO-GEODEZIC WORKS FOR THE REHABILITATION OF THE TRAMLINE IN THE FORD-CRAIOVA AREA

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ABSTRACT

The present paper addresses a very complex and difficult research topic, but of great current importance and wide applicability in practice. We affirm this because it is very well known that the road and rail infrastructure 30 years after the revolution is in a very precarious state, we can say very sad, because its rehabilitation and modernization has been done at a very slow pace. Therefore, the working team considered that approaching such a topic of great interest, is beneficial first of all for the practice, since the volume of works of such nature must increase considerably in the future and not lastly it is very valuable from the academic and scientific point of view. In order to solve the thematic approach, the working team used the latest and topographic devices and programs for processing the measured data, which allowed to obtain relevant and very correct results. The working methodology was perfectly adapted to the objective pursued, the situation existing on the ground and the precision imposed by the beneficiary, an aspect that led to obtaining a high execution efficiency of the works, but also to a high economic efficiency, because the time of execution, the volume of works and the number of personnel was greatly reduced.

INTRODUCTION

As it is known, the Ministry of Development, Public Works and Housing (MLPTL) technically, economically and legally coordinates the specialized cadastre works of the railways. The approval of the annual specialized cadastre programs of the railways is carried out by the General Direction of the real estate cadastre and the management of the localities within the MLPTL on the basis of the foundation note signed by the management of the railway units (Calinovici I., 2009). In accordance with the obligation regarding the integration of the specialized cadastre into the general cadastre, all the procedures of the railway cadastre must comply with the provisions of the Cadastre Law and the real estate advertising no. 7/1996, with the subsequent modifications, the technical norms and regulations elaborated by ANCPI (Alipour, H. et al, 2019).

The materialization of the points of the geodetic support and survey is made by concrete landmarks, according to the standard types provided in the Order of the Minister of Public Administration no. 534/2001 regarding the approval of the Technical Norms for the introduction of the general cadastre, or other types of landmarks approved by ANCPI, as the case may be. The geodetic lifting networks are created in order to ensure the number of points necessary for topographic and cadastral measurements of detail (Badescu, G. et al, 2018). The density of a geodetic lifting network is determined in relation to the surface on which the works are being carried out and for their purpose and is 1 point/km in the area of the plains, 1 point/2 km in hilly areas, 1 point/5km in mountain areas.

Regardless of the instruments and the technical procedures used to perform the measurements, the geodetic lifting network is compensated as a network constrained on the points of the support and thickening networks (Braun, J. et al., 2018). The standard deviation for determining a point should not exceed: ± 10 cm in the interior and in the extra-urban area ± 20 cm in the plain areas; ± 30 cm in hilly areas, ± 50 cm in mountainous areas (Calinovici I., and Călina Jenica, 2008).

PURPOSE AND METHOD OF WORK

The purpose of the work was to determine precisely the characteristic points of the studied tram line section, from Craiova locality, Dolj county, from the Ford factory area, for the purpose of rehabilitation. The need to rehabilitate this section of tram line, 1.66 km long, arose due to the deterioration of the rails, joints and crosspieces on which the rails are mounted, for which the traffic of the trams was hampered towards and from some of the economic points interest of Craiova, with a large number of employees using public transport, such as the Ford Factory.

The final purpose of the measurements is the drafting of the topographic situation plans, which consists in representing the topographic points with the elements by which they are determined: poles of the high voltage line responsible for supplying the trams, poles of the air electrical network, the railway, the gutters, the road footprint, the road axis. , boundaries of neighboring properties, poured concrete slabs and other elements encountered on the railway section route.

In order to be drafted in the best conditions all these plans were divided into 10 x 10 cm squares, unique and obligatory in the topography. The resulting grid is attached to the rectangular coordinate system, with the x-axis on the abscissa and the y-axis on the ordinate. Further the design is executed according to the design theme and includes: the technical-economic study of foundation; field research; studies; surveys; existing projects. Using this documentation the technique prior to the design, the development of the project is usually done in two phases: a. The technical-economic study S.T.E .; b. the execution project P.E.

From the point of view of the research methodology it is known that the topo-cadastral documentation of the cadastral of the railways is drawn up and handed over to the beneficiary and to the OCPI. This should include the following: the approval to start the works, issued by OCPI or ANCPI; the theme of the work; technical report; minutes of handing over all the objectives, accompanied by the corresponding sketches, signed by the representatives of the beneficiary and the executor; the inventory of coordinates of the radiated points; inventory of coordinates and sketches of the support and lifting network; the topographic descriptions of the support and lifting network points; calculating and compensating the coordinates of the points in the support and lifting network; the digital cadastral plan; the delimitation file; the file of the technical verification of the work; the final reception report.

RESULTS AND DISCUSSIONS

In order to be able to achieve the desires proposed in the work, the topographic specialists correctly identified and positioned the route along the tram line, proposed for the rehabilitation, which starts from the intersection of Decebal Boulevard with the E70 road, where it leaves the motorway part, ending at the tram return area, immediately after the Ford Craiova factory (figure. 1).

The topo-geodesic works consisted first in the thorough study of the land in the area, in the execution of the topographic works, the development of the geodesic base and the location on the map of the alignments. The peculiarity of the topo-geodesic works carried out for the purpose of the construction is that they precede and accompany all the stages of the construction, in the broad sense of the word. Preliminary design studies start on maps, within field studies, the topographic works occupying an important part, ensuring the "bringing" in analogue and digital format to the designer level all the necessary information, and based on them he can study the variants regarding the location of the works construction and choose the optimal solution. This project provides the order of execution of the topographic works of tracing, the necessary equipment, the method of field application of angles, lengths, and point dimensions, the way of marking and signaling on the ground the control points and the tracing works, the terms and documents required. The actual execution of the topographic survey consisted of the movement on the ground, where the points to be raised were established and were materialized by metallic picks, signaled with orange paint. All detail and breaking points were determined using the polar coordinates method. The next stage of execution precedes its application in the field and the detailed tracing of the rehabilitation works of the tram line. Also during the execution of the constructions, the topographic works have a significant role and become indispensable on the construction sites.

The topographic works for the execution of the constructions consists in determining the topographic elements necessary for the tracing on the field of the construction projects, an operation called "the topographic preparation of the execution projects". As a result of the topographic preparation, the characteristic points of the projected construction to be drawn on the ground are obtained, the X, Y and Z coordinates.

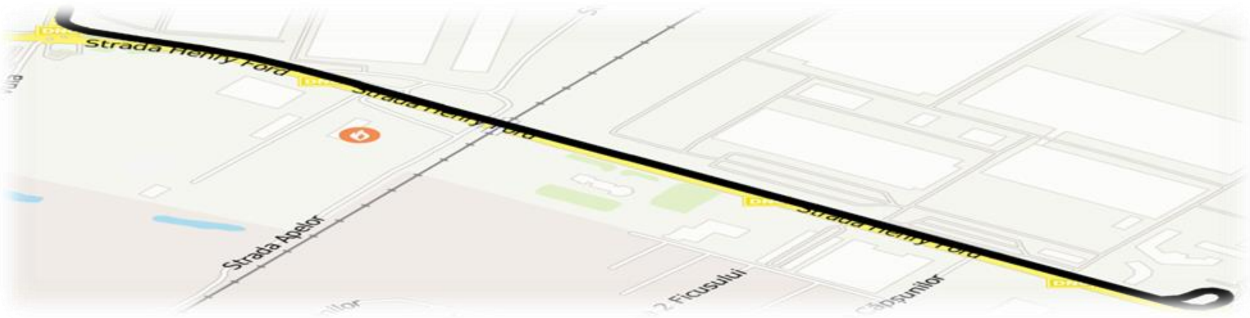

Figure 1. The tram line route

The following steps were taken along the route of the work at the station points: centering of the device, it is specified that if the operation of fitting the device was not performed correctly, it will give an error message and will not record any measurements. After placing the device in the station, the GPS antenna is screwed on, the controller is switched on, then all the data regarding the present location will be set and stored, in the way of determining points: STATIC - 6 points. The stationary time for Static determination of points 1308, 2737, 1448, 1, 2 and 3 was 30 minutes for each station point, compared to the following permanent fixed GNSS stations: CRAI (Craiova) and SLTN (Slatina). The Controller is started by pressing the ON button and the main menu appears on the display, the operator being able to choose, depending on the purpose of the work, the desired submenus, programs or subprograms.

The first program of the main menu, which is launched at the beginning of the work, requests information about the work to be performed, the operator enters in turn data regarding: name of the work, operator name, type of instrument; the date and time of the beginning of the work and the height of the device, this program being called every time at the beginning of a new measuring session; By launching a special correction program, the operator checks and sets certain parameters such as: index error, horizontal collimation error, date and time. All of these are saved in JOBS, which are similar to directories - jobs contain data measured on each session and can be individually managed, displayed, edited or deleted separately.

All the data that is recorded after the job definition is stored in this directory, and the date and time are automatically entered by the system and cannot be changed - it is validated with the OK key. By using the values recorded in the internal memory, the user of the device is protected from the possibility of entering the data incorrectly. Within the programs are used both points with known coordinates and points measured statically 1308, 2737, 1448, 1, 2 and 3. For each determined point RTK can be entered an identification code, and these codes are useful in the development of the situation plans.

Topo-geodesic operations consist of the use of the 1970 Stereographic projection system, local quota system, GNSS systems, that is, two Trimble R8S GPS devices and the Trimble S6 total station. For calculating the ETRS 89 coordinates, we used the files in RINEX format (Sui D., 2014), with recordings at 1 second, superimposed on the stationary times with the data collected in the field, from the permanent GNSS fixed stations: CRAI (Craiova) and SLTN (Slatina).

The processing of GNSS data was done with the help of the specialized software Magnet Field. For the calculation of the determined points, the observations from the virtual station RO_VRS_3.1.GG (GPS & GLONASS) were used. Subsequent transformation of the new points determined from the ETRS 89 projection system into the STEREOGRAPHIC 1970 projection system was done using the program imposed by A.N.C.P.I. TransDat RO var. 4.04. (Table 1.).

Table 1

The coordinates of the stationed points in ETRS 89 system

Point no.	NORTH (B)	EAST (L)	Z (m)
1308	44°17'57.26510"N	23°49'56.13995"E	151.663
2737	44°17'57.63585"N	23°49'54.22084"E	151.303
1448	44°17'58.27450"N	23°49'55.50892"E	152.272
1	44°17'32.75674"N	23°50'48.99551"E	156.777
	44°17'31.44698"N	23°50'52.59189"E	156.677
3	44°17'31.52394"N	23°50'52.58630"E	156.667

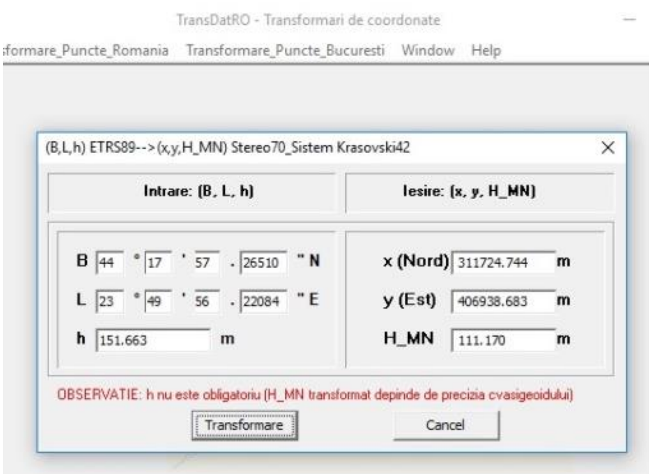

Figure 2. Transforming the coordinates of the ETRS 89 system into Stereo 70

In order to determine the support network, a supported routing was carried out at both ends starting from station point 1308 oriented on 1488 and verified on 2737, through stations 1204, 940, 809, 692, 527, 171 and closed on station point 1, oriented on point 2 and verified on point 3. From the station points 1308, 1204, 940, 809, 692, 527, 171, 189, 125 and 1 the necessary measurements were made for the preparation of this documentation (figure 3).

Figure 3. The route of supported traverse

The compensation method used was the method of weighted indirect observations, which implies the block compensation for the coordinate differences (ΔX, ΔY and ΔZ), resulting from GPS data measurements and processing. Stations 1308, 2737, 1448, 1, 2 and 3 were also determined GNSS (GPS), using the static method according to Decision no. 1 of 2010.

At the actual accomplishment of the lifting method, an initial recognition was made in the field of the route and the choice of the location of the points to be stationed with the GPS equipment, taking into account the regulations in force. The measurement operations met the following criteria (Salagean, T., et al, 2011): - there are no obstacles obstructing the horizon; - there should be no reflecting surfaces near the antennas, as these can lead to the multipath effect; - be easily accessible; - be protected from destruction.

Table 2

The coordinates of the support points located in the Stereo '70 system

Număr punct	Coordonate Stereografice 1970		Număr punct	Coordonate Stereografice 1970	
	X(m)	Y(m)		X(m)	Y(m)
1308	311724.770	406936.890	1	310951.491	408097.710
2737	311736.829	406894.516	2	310909.928	408176.861
1448	311756.127	406923.352	3	310912.305	408176.771

On the field there was also a thickening network marked with metal bolts that rests on the previously constructed support network. The points of this network are located on the route of the studied tram section, at convenient distances to perform topographic surveys with high accuracy.

An important step in solving this traverse is the calculation of the orientation of the station points and the compensation of all the measured directions, according to tables 3, and 4.

In making it, the same norms regarding stability, conservation, accessibility and efficiency for surveying are taken into account. For the points of the lifting network, the method of planimetric routing supported at ends on known coordinate points (table 5.) was used, as well as the method of geometric leveling. The device used to perform the planimetric traverse is the total station Trimble S6 with the following characteristics: - the angle measurement accuracy: 2 seconds; - accuracy of measuring distances: 2mm + 2ppm; - range of measurement of distances with a single prism: 2500-5500m (Radu, O. et al, 2017).

In each traverse station, the directions were measured by the horizon tour method. The distances were determined by electronic measurements back and forth. The calculation of the traverse was done on a separate section, closing on a base of the support network (tab. 5). The network processing was performed with specialized software (Raza, H., et al, 2017). The closures obtained on this section fall within the tolerances imposed by the norms in force, as can be seen from the presented calculations (table 6.).

Table 3

The difference between reading and orientation points 1308, 1488 and 2737

No.	Station point	Target point	Reading (g)	Orientation (g)	Differences (g), (col. 3 – col. 4)
0	1	2	3	4	5
1	1308	1488	147.3445	297.1293	-149.7848
2	1308	2737	167.8628	317.6506	-149.7878
RESULTS OF THE CALCULATION AND DIFFERENCE BETWEEN THE TARGETED POINTS					0.0030
* A correction is applied on both directions of 15 seconds					
Directions read offset, points 1308, 1488 şi 2737					
1	1308	1488 (-0.0015)	**147.3430**	297.1293	-149.7863
2	1308	2737 (+0.0015)	**167.8643**	317.6506	-149.7863
RESULTS OF THE CALCULATION AND DIFFERENCE BETWEEN THE TARGETED POINTS					0.0000

Table 4

The difference between reading and orientation points 1, 2 and 3

No.	Station point	Target point	Reading (g)	Orientation (g)	Differences (g), (col. 3 – col. 4)
0	1	2	3	4	5
1	1	2	381.0188	130.7827	250.2361
2	1	3	379.5285	129.2944	250.2341
RESULTS OF THE CALCULATION AND DIFFERENCE BETWEEN THE TARGETED POINTS					0.0020
* A correction is applied on both directions of 10 seconds					
Directions read offset, points 1, 2 and 3					
1	1	2 (-0.0010)	**381.0178**	130.7827	250.2351
2	1	3 (+0.0010)	**379.5295**	129.2944	250.2351
RESULTS OF THE CALCULATION AND DIFFERENCE BETWEEN THE TARGETED POINTS					0.0000

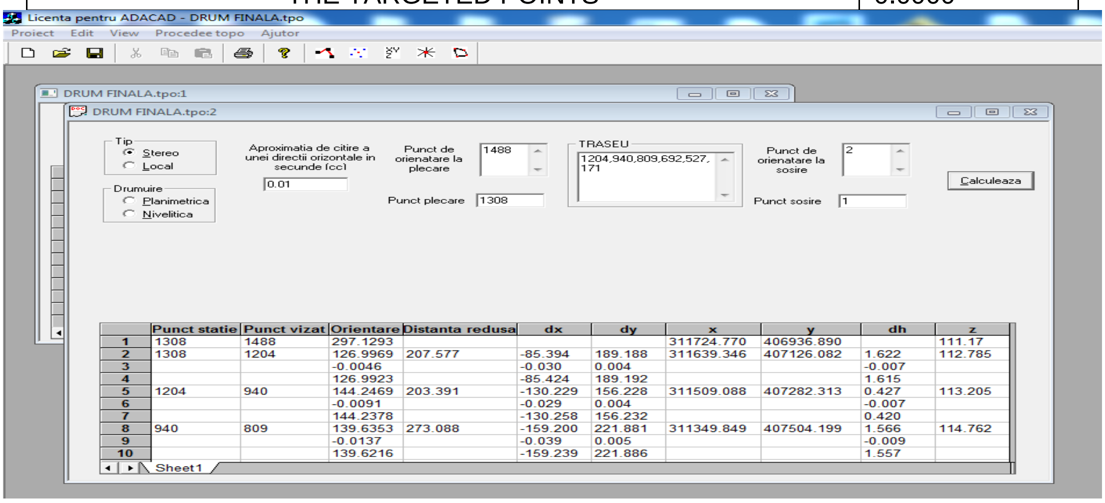

Figure 7. Calculation and definition of the traverse using the TOPO CALC program

Table 5

Calculation of the supported traverse

Start point	1308
Arrival point	1

Orientation to departure Θ	1488
Arrival orientation Θ	2

Traverse route	1308,1204, 940, 809, 692, 527, 171, 1

Station point	Target point	Orientation Θ	Reduced distance	ΔX	ΔY	X	Y	ΔZ	Z
1308	1488	297.1293				311724.770	406936.890		111.170
1308	1204	126.9969	207.577	-85.394	189.188	311639.346	407126.082	1.622	112.785
		-0.0046		-0.03	0.004			-0.007	
		126.9923		-85.424	189.192			1.615	
1204	940	144.2469	203.391	-130.229	156.228	311509.088	407282.313	0.427	113.205
		-0.0091		-0.029	0.004			-0.007	
		144.2378		-130.258	156.232			0.420	
940	809	139.6353	273.088	-159.2	221.881	311349.849	407504.199	1.566	114.762
		-0.0137		-0.039	0.005			-0.009	
		139.6216		-159.239	221.886			1.557	
809	692	128.3197	153.527	-66.028	138.61	311283.799	407642.812	2.927	117.684
		-0.0182		-0.022	0.003			-0.005	
		128.3015		-66.05	138.613			2.922	
692	527	139.9365	170.345	-99.938	137.946	311183.84	407780.76	-0.417	117.261
		-0.0228		-0.024	0.003			-0.006	
		139.9137		-99.962	137.94			-0.423	
527	171	141.6205	146.747	-89.198	116.524	311094.62	407897.29	-0.410	116.846
		-0.0274		-0.021	0.003			-0.005	
		141.5931		-89.219	116.527			-0.415	
171	1	139.5047	246.258	-143.092	200.419	310951.49	408097.71	-0.559	116.279
		-0.0319		-0.035	0.004			-0.008	
		139.4728		-143.127	200.423			0.567	
1	2	130.8083							
		-0.0365							
		130.7718							

Table 6

Error calculation and tolerance

Azimuthal error	-0.0365	Coordonates error	0.2015
Orientation tolerance	0.0566	Coordinates tolerance	0.3925
kx	-0.00014	kz	-0.0000328
ky	0.000017	Er. z	-0.046
Dif. x:	-0.2000	Tol. z	0.2367
Dif. y:	0.0243		

The detail points were raised by the polar coordinates method, using as station points 1308, 1204, 940, 809, 692, 527, 171, 173, 189, 125 and 1, from where were targeted the detail and outline points necessary for the preparation of the situation plan (tab.7). The coordinates of the points were calculated quickly and accurately with the help of the specialized program TopoCalc (Şmuleac, A., et al, 2017) and passed to table 7, which is simplified.

The constructive elements of the tram line were rendered by the profile method, being prepared for the surveyied section longitudinal and transverse profiles, perpendicular to the direction of the tram lines, in all the characteristic points, according to the specification.

The length of the studied tram line section proposed for rehabilitation is 1661 m and is rendered by longitudinal profile, performed at the stairs imposed in the specification Sc. H. 1: 100 and Sc. L. 1: 1000 (figure 8). At the request of the beneficiary, the longitudinal profile was made from all the joints and braking points of the route, on one of the four railway tracks.

Table 7

Calculation of details coordinates

Station	**Target point**	**Direction**	**Orientation Θ**	**Inclined distance**	**Zenith angles**	**Reduced distance**	**ΔX**	**ΔY**	**X**	**Y**	**ΔZ**	**Z**
1									310951.491	408097.710		116.279
Acord	2	381.0178	130.7831	89.400	100.1048	89.400	-41.563	79.151	310909.928	408176.861	-0.104	116.175
149.7653	3	379.5292	129.2945	88.240	100.1072	88.240	-39.186	79.061	310912.305	408176.771	-0.106	116.173
	4	372.7570	122.5223	48.256	100.2130	48.256	-16.718	45.267	310934.773	408142.977	-0.118	116.161
	5	205.1114	354.8767	14.977	97.5044	14.965	11.361	-9.741	310962.852	408087.969	0.630	116.909
...	...	...	...	...	...	...	...	...	...	...	...	...
527									311183.837	407780.760		117.261
Acord	563	397.7594	147.5303	51.504	100.7132	51.501	-34.977	37.802	311148.860	407818.562	-0.522	116.739
149.7709	564	393.6426	143.4135	51.294	100.6334	51.291	-32.329	39.820	311151.508	407820.580	-0.455	116.806
	565	392.3516	142.1225	51.117	100.6882	51.114	-31.406	40.328	311152.431	407821.088	-0.498	116.763
	566	390.4688	140.2397	51.136	100.6934	51.133	-30.211	41.254	311153.626	407822.014	-0.502	116.759
...	...	...	...	...	...	...	...	...	...	...	...	...
1308									311724.770	406936.890		111.170
Acord	1310	377.2088	126.9983	207.579	99.3808	207.569	-85.413	189.181	311639.357	407126.071	1.615	112.785
149.7895	1311	375.1888	124.9783	114.635	100.6536	114.629	-43.831	105.918	311680.939	407042.808	0.431	111.601
	1312	374.6204	124.4099	114.245	99.4992	114.241	-42.738	105.946	311682.032	407042.836	0.495	111.665
	1313	373.9902	123.7797	113.530	99.5122	113.527	-41.427	105.698	311683.343	407042.588	0.466	111.636

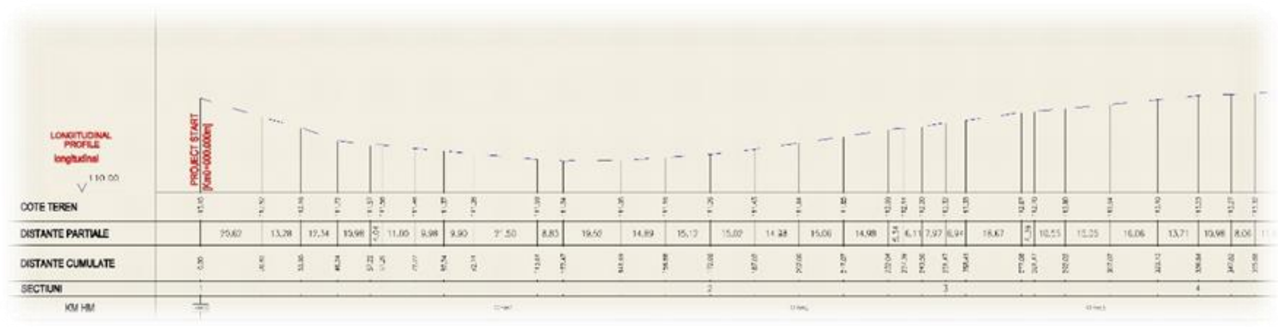

Figure 8. Longitudinal profile scale: H 1: 100 - L 1: 1000

Conclusions In order to reproduce the constructive section of the tram line as accurately as possible, the topographic specialists carried out transverse profiles in all the characteristic points, as follows (fig.9.): Near the high voltage poles between the tram directions; near the joints on the railway lines (the joints are the points where two railings are joined and welded); profiles as often as possible in the tram return area, respectively in the places where the railway line is curved.

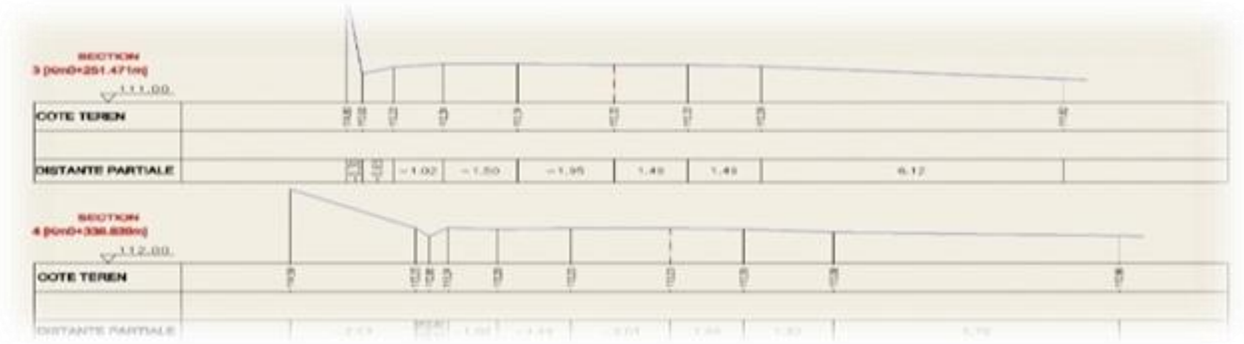

Figure 9. Type of cross-sectional profile made at the characteristic points

The drawing up of these types of profiles is absolutely mandatory in the case of engineering works of this nature, because the following obligatory points must be given: fence (where it exists); quota points; gutter; CF (provided we mark each place on the railway where there are joints, ie the place where the tram tracks are welded); the pillars belonging to the electrical network responsible for the power supply, with the current of the trams; sidewalk; road; axis (Călina, J. et al, 2018).

In order to obtain the complete topographic plan, it was necessary to carry out additional elevations through which the following details were reproduced with great precision and fidelity: the kilometric terminals; hectometric terminals; property limits; fireplaces, sewage; hydrants; electricity poles, internet; tram shelters (stations); annexed buildings of RAT Craiova. To all the above, at the operator's decision, any other details necessary to be included in the situation plan are added, so that they are finally complete and correct (Călina, J. et al, 2014).

The final result of this work was the comprehensive situation plan, consisting of 11 sheets of A1 format, realized on scale 1: 200 (figure10.), stipulated in the specifications, together with the beneficiary of the work.

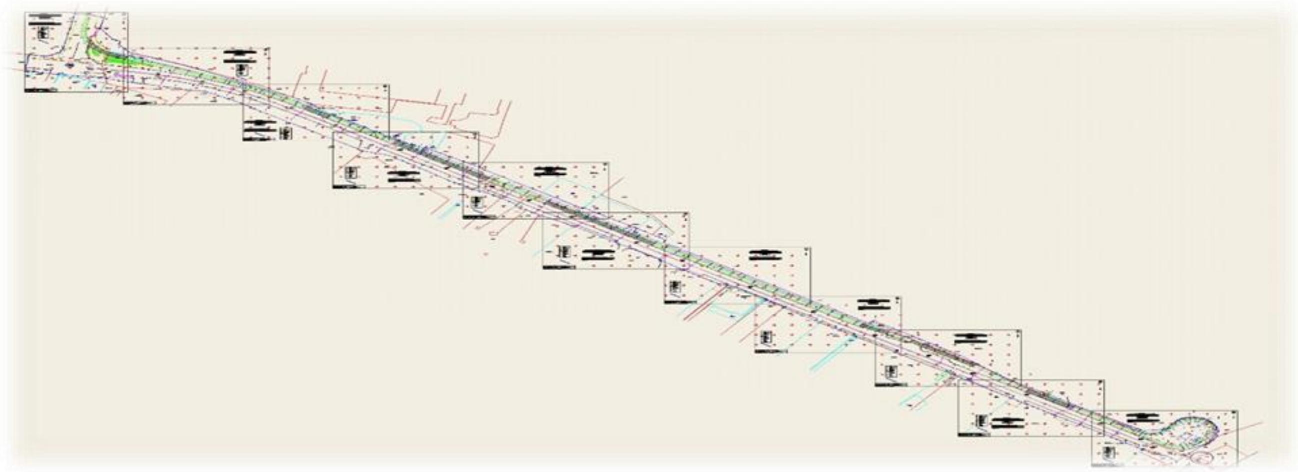

Figure 10. Situation plan realized on scale 1: 200

CONCLUSIONS

In order to prepare the topographic project, the work team first performed a preliminary study which consisted of land recognition, establishing the route of the secondary network and the number of stations required to raise all the detail points, after which the geodetic network of thinning and lifting was carried out to ensure the density of points necessary to perform all the topo-geodesic works, in the best conditions of quality and precision.

Also, with the drafting of the execution project, the specifications including requirements strictly related to the area occupied by the tram tracks were constructed, the beneficiary subsequently adding the road part of the European road E70, which led to the inclusion in it of all the characteristic elements. presented during the paper. While carrying out the work of organizing the site, new requirements appeared, such as the short execution time for the completion of the work, which could be achieved only by using high-performance, fast and high-precision work equipment such as GPS and the total station.

A relevant and very specific aspect only for such works is the degree of difficulty of the topographic works, which were greatly hampered by the intense traffic on the road associated with the studied tram section, which led to the need to take security measures in the type of work, to avoid the accident, were used transmitting-reception stations and reflective equipment.

The final technical documentation drawn up after the execution of the geodetic networks of support, thickening and lifting subject to the reception operations includes: the technical memory, (including the general description of the work, working methods, tools used, data processing, the obtained precision, etc.); the diagram of the measurements made; ASCII files, on magnetic media, with the data resulting from the field measurements (name / number of station point, name / number of target points, directions measured, distances measured); topographic description and sketching drawings for old and new points; inventory of coordinates including on magnetic support. Based on this very well-documented documentation, in compliance with all legal and precision requirements, the approval and approval of ANCPI was obtained, thus being able to start the execution of the works.

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