ASSESSMENT OF THE CADASTRAL DATABASE INTEGRATION ACCURACY FROM THE LOCAL COORDINATE SYSTEM INTO THE STEREOGRAPHIC - 1970 PROJECTION, IN IASI CITY

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***Abstract*:** *The Real estate information system from the urban area is drawn up and updated based on the primary technical, economic and legal data of all the real estates from the territory of an administrative-territorial unit.*

The representation of the real estates included in the cadastral plan and registered in the Land Registry of Iasi city was performed between 1950 and 2010, using a local system of coordinates. For the territory of Iasi city, the local system was used, the origin of the coordinate axes being set in the geodetic triangulation point GOLIA, the ordinates axis being oriented in the direction North – South.

For assessing the integration accuracy of the graphic and textual database from the local projection system into the official Stereographic projection system – 1970, it has been used the transcalculation of plane rectangular coordinates from one system into the other, and also the control of the transformation based on the topo-cadastral field measurements.

Key words: *cadastral database, coordinate system, transcalculation of coordinates between cartographic projections, transcalculation accuracy assessment*

1. Introduction

Cadastre and land registration have become official through **Law 7/1996** with its subsequent modifications, which has been used for setting up the unitary and compulsory system of technical, economic and legal records of all the real estates from Romania's territorial-administrative units (7). Putting up the bases of a modern cadastral and land register system requires the existence of new geodetic, photogrammetric, topographic and cadastral measurements for identifying, making the maps and recording all the real estates in the cadastral documents (1). For obtaining the primary data base of the information cadastral system, all the cadastral works specific to the **technical** (topographic measurements), **economic** (cadastral assessment, assessment of both fields and constructions) and **legal functions** (land register) are going to be performed.

For the territorial-administrative units where there was no unitary cadastral and land registration system, the temporary registration of the legal documents referring to the real estates was performed based on the documentations from the land register (3). These technical documentations have been drawn up in both the official and the local system of coordinates. Using the present methodology the two basic cadastral entities, the **real estate and the owner** are identified and represented in the official reference system of Romania's territory (2).

2. Material and method

The topographic measurements for the territory of Iasi city performed between **1950 - 1987**, as well as those from the second phase, between **1988 - 1991,** have been drawn up and included in the **local system of coordinates**, with the origin in the **Golia** point. The local triangulation network was been created in two different time periods, between **1950-1952** and **1969-1970** by the topographic office of *D.S.A.P.C. Iasi* (*S.C. "Habitat Proiect" S.A., Iasi)*.

The calculation for the geodetic support network of the topographic measurements at large and extra large scales has been performed using rigorous methods. In the first phase, a polygon with six peripheral points and one central point **Golia** has been drawn up **(X_0= 10 000 m; y_0= 10 000 m)**. Reported to the origin of the coordinates system, the following have been considered: **OY axis**, North - South direction, being given by the image of the geographical meridian; **OX axis**, West – East direction, being given by the geometrical tangent to the parallel passing through the **Golia** point **($\varphi_0 = 47^0\ 09'\ 52''$; $\lambda_0 = 27^0\ 35'\ 37''$)**.

The basic topographic plane for the territory of Iasi city, **scale 1:1000**, drawn up between **1950-1970** and updated between **1988-1991**, was drawn up in the **Local – Iasi** system of plane coordinates**.** The topographic documentations made between 1991 and 2009 have also been drawn up in the **Local – Iasi** system of coordinates. Among the technical topographic and cadastral documentations drawn up between 1991 - 2009 are mentioned: the measurement and the assessment of some fields owned by commercial companies with state capital; the assignment of property titles; the assignment of temporary cadastral numbers to be used for the registration in the land register and others.

Between 2005 – 2008 a series of technical cadastral works have been performed for the territory of Iasi city, being mentioned: the border limits for the territorial – administrative unit and the limits of the incorporated area; creating the spatial geodetic network using GPS technology; aerophotography of the entire territory using an **ADS – 40** laser scanner for drawing up the topographic plane at large and extra large scales (6).

For assessing the integration accuracy of the cadastral database from the **Local – Iasi** system into the **Stereographic – 1970 system**, the cadastral documentation drawn up in 2005 was taken into consideration for registering in the land register the **real estates** belonging to the University of Agricultural Sciences of Iasi. The records of the real estates included in the cadastral plane and in the land register was codified using the following notations: **CF_1 – veterinary clinics and student hostels; CF_2 – central area, CF_3 - the rugby stadium; CF_4 – green houses; CF_5 – meteorological station; CF_6 – student's canteen** (3).

The present **case study** includes the specific phases for drawing up the cadastral works, according to the official methodology, in the following order:

- **cartographic framing**, in the sheets of the basic cadastral plane, scale 1:1000;
- **calculation of the cartographic base** for the geodetic trapeziums, scale 1:1000;
- **thickening the geodetic support network** in the Local – Iasi system, in 2005;
- **topographic measurements** for the six real estates, based on the recordings obtained from the TC 705 total station and after using the radiation and traverse methods in the Local – Iasi system, in 2005;
- **transformation of plane rectangular coordinates** from the Local-Iasi system into the Stereographic – 1970 system using the *Goliath* software, in 2013;
- **repeating the topographic measurements** for the six real estates, based on the information obtained with the South S82T receiver and using the RTK method, in the network of ROMPOS permanent stations (5) in the Stereographic - 1970 system, in 2013;
- **assessing the coordinates transformation accuracy in the 2D space;**
- **calculation of the surfaces and assessment of the database integration accuracy.**

3. Results and discussion

Putting together and/or updating the documentation necessary for drawing up the cadastral plane and for registering the real estate in the land register must be correlated with all the existent cadastral documentations from the other systems of coordinates as well.

3.1 The cartographic framing in map sheets and cadastral planes

Î After the cadastral delimitation of the territory of Iasi city in 2005, the boundaries have been established with the following limitrophe units *Popricani, Aroneanu, Holboca, Tomești, Bârnova, Ciurea, Miroslava, Valea Lupului and Rediu* (6).

The information system of the geospatial database of Iasi city included, after the cadastral delimitation, the total surface of **9366 ha**, **6741 ha** of which represented the present incorporated area. The cartographic documentation of the city is characterized by the following structure of graphic data: **4 map sheets**, scale 1:50 000, **6 map sheets**, scale 1:25 000, **14 plane sheets**, scale 1:10 000, **34 plane sheets**, scale 1:5 000 (Figure 1), **103 plane sheets**, scale 1:2 000 and **347 plane sheets**, scale 1:1 000.

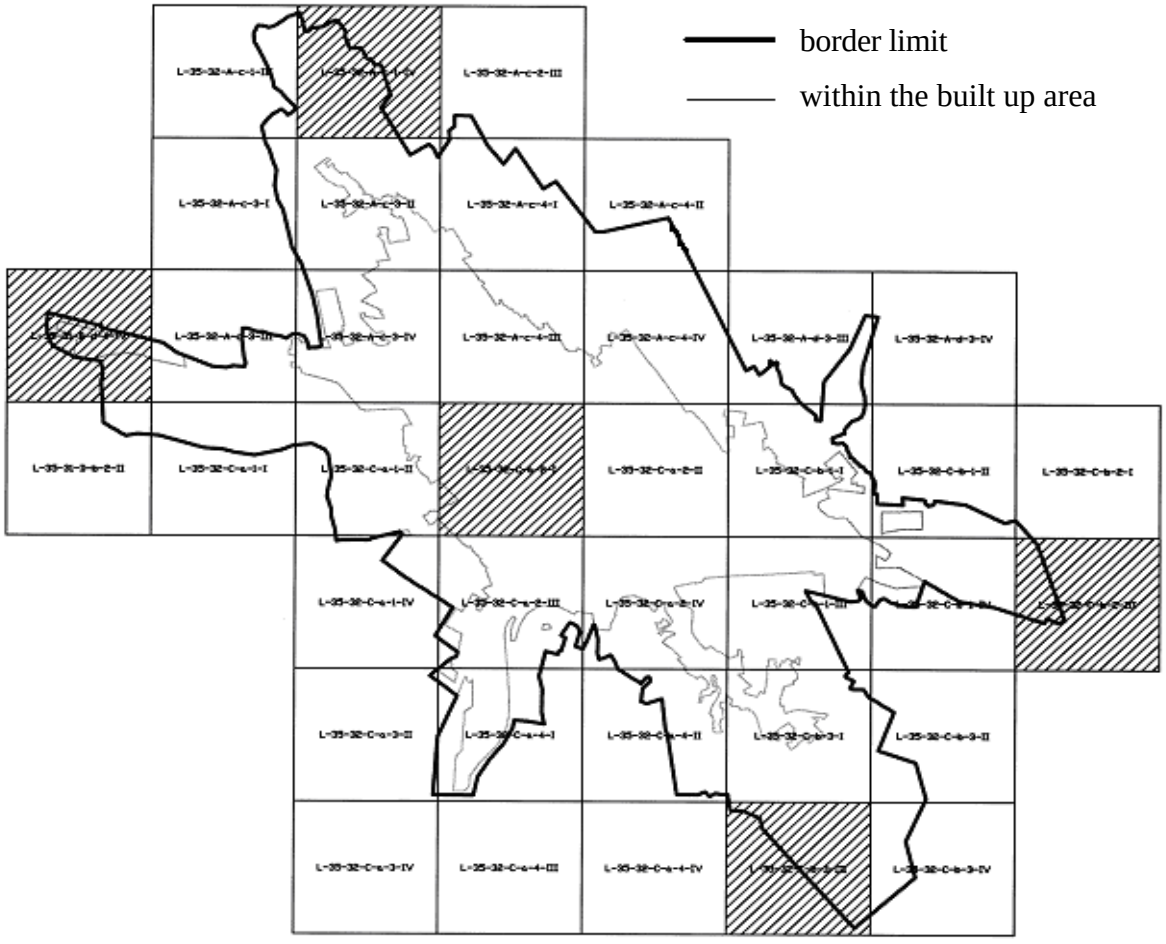

Fig. 1 – Cartographic framing of Iasi city, on trapeziums, scale 1: 5 000

The boundaries of the city of Iasi have been framed in the following trapeziums, corresponding to the geographical points: **at the North** L-35-32-A-c-1-IV; **at the East** L-35-32-C-b-2-III; **at the South** L-35-32-C-b-3-III; **at the West** L-35-31-B-d-4-IV; and **the central area** which also includes the **Golia point** L-35-32-C-a-2-I (4).

3.2 Calculation of the cartographic base of the geodetic trapeziums scale 1:1000

Based on the cartographic framing of the six real estates on the trapeziums resulted from the plane elevations, scale 1:1000, it was first calculated the mathematical base on the surface of the Krasovski -1940 reference ellipsoid according to the geographical coordinates used to establish the length of the meridian arcs, the length of the parallel arcs, the diagonal and the trapezium's area (Figure 2).

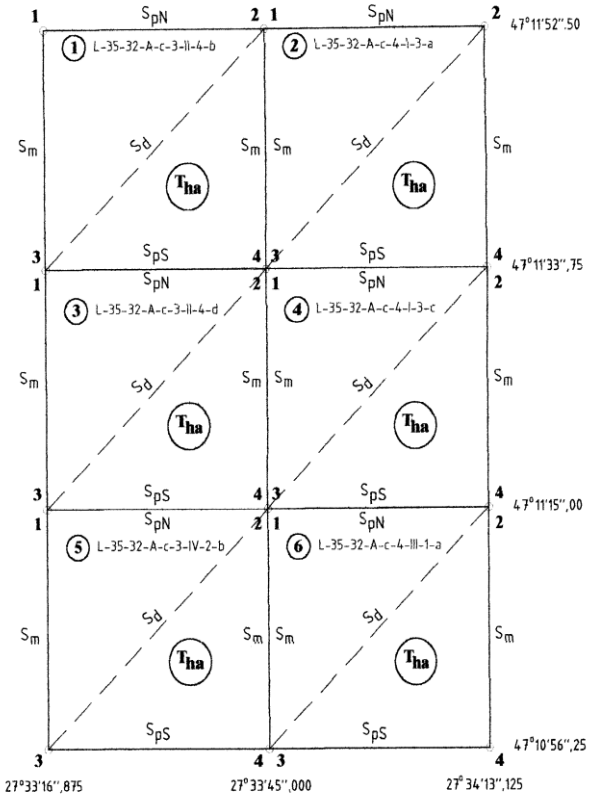

Fig. 2 – The dimensions and the trapeziums area on the Krasovski – 1940 ellipsoid

- Length of the meridian arcs

$$S_m = M_m \frac{(\varphi_N - \varphi_s)''}{\rho''} = \frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2\varphi_m)^3}} \cdot \frac{(\varphi_N - \varphi_S)''}{\rho''} \quad \text{(m)}$$

where: M_m- mean radius of curvature;
a - large equatorial semi axis;
e^2 - first eccentricity;
φ_m – mean latitude;
φ_N – latitude of the North side;
φ_S - latitude of the South side;
$(\varphi_N - \varphi_S)''$ – latitude difference;
$\rho'' = 206264''.8062471$.

- Length of the parallel arcs (S_{pN}, S_{pS})

$$S_{pN} = r_N \frac{(\lambda_E - \lambda_W)''}{\rho''} = \frac{a}{\sqrt{1-e^2\sin^2\varphi_N}}\cos\varphi_N \cdot \frac{(\lambda_E - \lambda_W)''}{\rho''} \text{ (m)}$$

$$S_{pN} = r_S \frac{(\lambda_E - \lambda_W)''}{\rho''} = \frac{a}{\sqrt{1-e^2\sin^2\varphi_S}}\cos\varphi_S \cdot \frac{(\lambda_E - \lambda_W)''}{\rho''} \text{ (m)}$$

where : r_N – the curvature radius of the parallel of latitude (φ_N);
r_S - the curvature radius of the parallel of latitude (φ_S);
$(\lambda_E - \lambda_W)''$ – the longitude difference between meridian arcs.
$\rho'' = 206264''.8062471$.

- The length of the diagonal (S_d) depended of the length of the meridian arc and of the length of the parallel arcs and it was obtained using the following formula:

$$S_d^2 = S_m^2 + S_{pN} \cdot S_{pS} \quad \text{or} \quad S_d = \sqrt{S_m^2 + S_{pN} \cdot S_{pS}} \quad \text{(m)}$$

- The ellipsoid area (T) was calculated considering the geographic coordinates of the two parallels and the two meridians that delimit the trapezium taken into consideration:

$$T = \left[\Delta T(\varphi_N)_{\Delta\lambda=1'} - \Delta T(\varphi_S)_{\Delta\lambda=1'}\right] \cdot (\lambda_E - \lambda_W)' \quad (km^2) \text{ or (ha)}$$

where: $\Delta T(\varphi_N)_{\Delta\lambda=1'}$ - the element of ellipsoid area between the Ecuador and the North parallel of the trapezium on the difference of longitude equal to one minute ($\Delta\lambda=1'$);

$\Delta T(\varphi_S)_{\Delta\lambda=1'}$ - the element of ellipsoid area between the equator and the South parallel of the trapezium on the longitude difference equal to one minute ($\Delta\lambda=1'$);

$(\lambda_E - \lambda_W)'$ - the difference between the meridian arcs of the trapezium, expressed in minutes and parts of minutes.

The values obtained for the ellipsoid sides and areas, according to the geographic coordinates of the corners of the geodetic trapeziums represented the **undeformed cartographic base** of the cadastral plane sheets, scale 1:1 000 (Table 1).

Table 1. The dimensions and the areas of the trapeziums on the Krasovski – 1940 ellipsoid

Trapezium nomenclature	Sides and diagonal of the geodetic trapezium (m)				Area (ha)
	S_m	S_{pN}	S_{pS}	S_d	T
L-35-32-A-c-3-II-4-b	579.045	592.000	592.058	828.125	34.2811
L-35-32-A-c-4-I-3-a	579.045	592.000	592.058	828.125	34.2811
L-35-32-A-c-3-II-4-d	579.044	592.058	592.115	828.166	34.2845
L-35-32-A-c-4-I-3-c	579.044	592.058	592.115	828.166	34.2845
L-35-32-A-c-3-IV-2-b	579.043	592.115	592.173	828.206	34.2877
L-35-32-A-c-4-III-1-a	579.0453	592.115	592.173	828.206	34.2877

The areas of the geodetic trapeziums (T) calculated on the Krasovski – 1940 ellipsoid are considered to be undeformed and they are used as **control surfaces** for the compensation operations of the real estates from within the trapezium taken into consideration.

Depending of the plane rectangular coordinates of the corners of the geodetic trapeziums at scale 1:1000 from the **Local – Iasi system** (Figure 3) and from the **Stereographic – 1970 projection system** there have been calculated the dimensions and the areas of the trapeziums from the two reference systems.

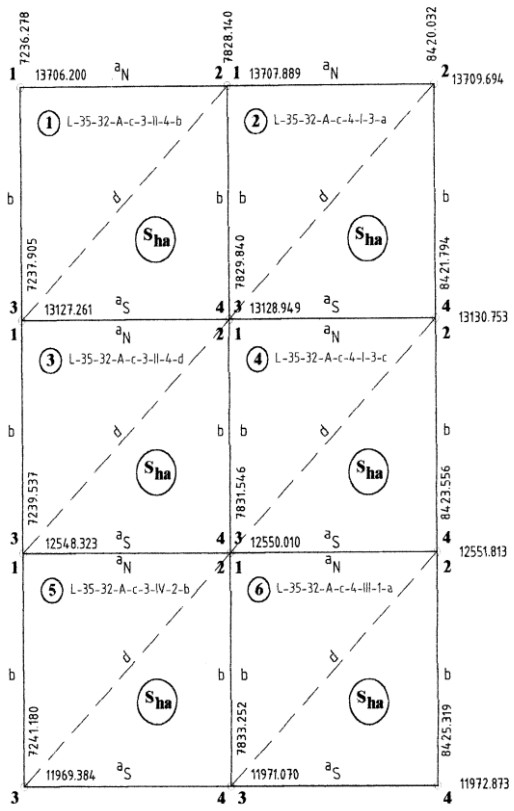

Fig. 3 – The dimensions and the area of the trapeziums from the Local –Iasi system

- The length of the unparallel sides (b)

$$b_{31} = \sqrt{\Delta x_{31}^2 + \Delta y_{31}^2}\,; b_{42} = \sqrt{\Delta x_{42}^2 + \Delta y_{42}^2}\ \text{(m)}$$

- The length of the parallel sides (a_N, a_S)

$$a_{N_{1-2}} = \sqrt{\Delta x_{12}^2 + \Delta y_{12}^2}\ ;\ a_{S_{3-4}} = \sqrt{\Delta x_{34}^2 + \Delta y_{34}^2}\ \text{(m)}$$

- The length of the trapezium's diagonal (d) was obtained with the geometric mean:

$$d = d_{32} = \sqrt{b^2 + a_N \cdot a_S} \quad \text{(m).}$$

- The area of the geodetic trapeziums (S) from the projection plane was established using the plane rectangular coordinates of the trapeziums' corners, scale 1:1000, from the Local-Iasi system (Figure3) and from the official system of the Stereographic projection – 1970, with the general formulae:

$$\pm 2S = \sum_{i-1}^{n} x_i\left(y_{i+1} - y_{i-1}\right) = \sum_{i=1}^{n} y_i\left(x_{i+1} - x_{i-1}\right)$$

where: S is the trapezium's area expressed in hectare (ha);

The cadastral documentation made in the **Local-Iasi system** between 1950-1970 and updated between 1988-1991 was related to the basic plane sheets of the geodetic trapeziums, scale 1:1000. The reference of the inner frame of the trapeziums was verified using the dimensions from table 2, within the graphical error limits of ±0.2 at the scale.

Table 2. Dimensions and areas of the trapeziums in the Local – Iasi system, 1: 1000

Trapezium no.	The sides and the diagonal of the geodetic trapezium (m)					Area (ha)
	b_1	b_2	a_N	a_S	d	S
1	578.941	578.942	591.864	591.937	827.953	34.2676
2	578.942	578.944	591.895	591.957	828.004	34.2691
3	578.940	578.941	591.937	592.011	828.000	34.2718
4	578.941	578.943	591.957	592.013	828.043	34.2725
5	578.941	578.942	592.011	592.074	828.045	34.2758
6	578.942	578.943	592.013	592.070	828.083	34.2758

From the analysis of the dimensions of the trapeziums which were calculated on the surface of the **Krasovski – 1940** ellipsoid (Table 1) and those established using the plane coordinates (Table 2) it was noticed obtaining negative deformations of lengths and surfaces.

Using the previously mentioned formulae, there have been calculated the dimensions and the areas of the trapeziums in the **Stereographic – 1970 projection** (Table 3).

Table 3. Dimensions and the areas of the trapeziums in the STEREO – 70 projection, 1:1000

Trapezium no.	The sides and the diagonal of the geodetic trapezium (m)					Area (ha)
	b_1	b_2	a_N	a_S	d	S
1	579.098	579.099	592.025	592.098	828.177	34.2862
2	579.099	579.101	592.054	592.116	828.229	34.2877
3	579.097	579.098	592.098	592.172	828.224	34.2904
4	579.099	579.101	592.116	592.172	828.267	34.2910
5	579.099	579.100	592.172	592.235	828.269	34.2944
6	579.100	579.101	592.172	592.229	828.307	34.2943

Depending of the surface of the geodetic trapeziums which has been calculated on the reference ellipsoid (**T**) in the Local-Iasi system (**S_1**) and in the STEREO – 70 system (**S_2**), there have been calculated the total areolar deformations on the six trapeziums (Table 4).

Table 4. The total areolar deformations on geodetic trapeziums, scale 1:1 000

Trapezium nomenclature	Areas of the geodetic trapeziums (ha)			Total deformation (ha)	
	T	S_1	S_2	(S_1-T)	(S_2-T)
L-35-32-A-c-3-II-4-b	34.2811	34.2676	34.2862	**-0.0135**	**0.0051**
L-35-32-A-c-4-I-3-a	34.2811	34.2691	34.2877	**-0.0120**	**0.0066**
L-35-32-A-c-3-II-4-d	34.2845	34.2718	34.2904	**-0.0127**	**0.0059**
L-35-32-A-c-4-I-3-c	34.2845	34.2725	34.2910	**-0.0120**	**0.0065**
L-35-32-A-c-3-IV-2-b	34.2877	34.2758	34.2944	**-0.0119**	**0.0067**
L-35-32-A-c-4-III-1-a	34.2877	34.2758	34.2943	**-0.0119**	**0.0066**
Total trapeziums	**205.7066**	**205.6326**	**205.7440**	**-0.0740**	**0.0374**

The total areolar deformation considered for the six trapeziums, scale 1:1 000 ranged between 0.0119 ha and -0.0135 ha in the Local-Iasi system and between +0.0051 ha and +0.0067 ha in the Stereographic projection –1970.

3.3 Thickening the geodetic network and performing the topographic measurements in the Local-Iasi system of coordinates

Thickening the support geodetic network was performed using the retrointersection method and the *Leica Geosystems TC 705* total station. For this purpose, the following old points from the local geodetic triangulation network have been used: *Cetatuia Church, Galata Church, Miroslava Church, Agricultural High school Landmark and Zootechny Landmark*. Relying on the old points, **two new points 51 and 52** have been identified.

The detailed topographic elevation consisted in: identifying, measuring and graphically representing the limits and the parcels that form the **six real estates** that were permanently registered in the land register. For the **CF_2 real estate** there have been identified **64 contour points**, based on which the area and the perimeter were calculated (Figure 4).

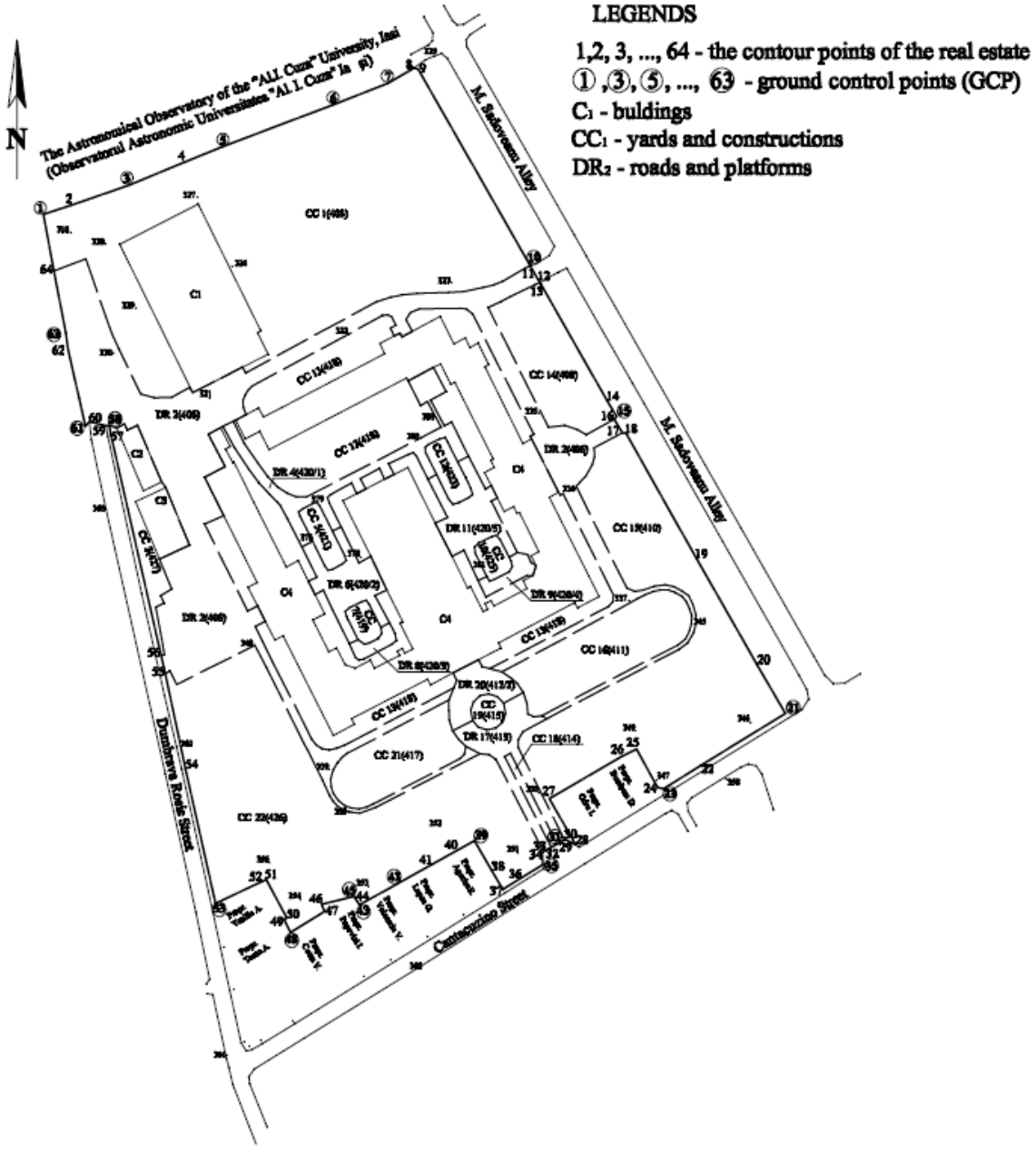

Fig. 4 – Location plan and cadastral delimitation of the real estate CF_2 – Iasi

3.4 The transformation of the coordinates and the execution of topographic measurements in the official Stereographic – 1970 projection system

The technical cadastral documentation drawn up for the permanent registration in the land register of the fields and the constructions corresponding to the **six real estates** included the following data: technical report, layout plan, emplacement plan and real estate delimitation, coordinates inventory of the thickening, support and elevation points, coordinates inventory of the points from the border of the real estates, cadastral numbering and surface calculation for the real estates.

By introducing both cadastre and land register to the incorporated area of Iasi city, in the Stereograhic - 1970 projection, it is impetuous necessary to properly include the spatial and textual data base from the Local-Iasi system into the official system. In 2009 the "*Goliath"* programme was adopted; it ensures the transformation of plane coordinates from the Local-Iasi system into the Stereographic – 1970 system. The "*Goliath"* calculation program is used by both the *Office of Cadastre and Land Registration Iasi* and all the legal and authorized physical people from Iasi city.

The present case study consists in the transformation of the plane rectangular coordinates from the Local – Iasi system into the Stereographic – 1970 system; it included all the points situated on the border limit of the real estates: **126 points**/CF_1; **64 points** /CF_2; **29 points** /CF_3; **24 points** /CF_4 ; **17 points** /CF_5; **20 points** /CF_6. For the border of CF_2 real estate, the coordinates of 64 points have been transformed, **20** of them being chosen as **ground control points** to be tested based on the field topographic measurements (Table 5).

Table 5. Local and Stereographic plane coordinates on the boundary of the real estate CF_2

Point no.	Measured local coordinates (m)		Calculated stereographic coordinates (m)		Measured stereographic coordinates (m)	
	X_r (East)	Y_r (North)	X_r < 70 >	Y_r < 70 >	X_i < 70 >	Y_i < 70 >
1/1	7374.079	13124.088	693692.805	635695.431	693692.600	635695.371
2/3	7404.713	13134.321	693723.131	635706.567	693723.137	635706.779
3/5	7437.630	13147.600	693755.651	635720.817	693755.590	635721.238
4/6	7476.637	13162.054	693794.224	635736.421	693794.133	635736.752
5/7	7496.100	13169.507	693813.464	635744.448	693813.464	635744.448
6/10	7546.155	13107.029	693865.356	635683.459	693865.356	635683.459
7/15	7577.027	13054.252	693897.783	635631.603	693897.555	635631.641
8/21	7636.914	12951.573	693960.693	635530.710	693960.627	635530.805
9/23	7593.664	12925.562	693918.219	635503.426	693918.001	635503.494
10/31	7556.017	12906.439	693881.143	635483.193	693881.139	635483.193
11/35	7551.088	12899.313	693876.426	635475.923	693876.490	635475.921
12/39	7526.799	12907.551	693851.897	635483.442	693851.829	635483.648
13/42	7499.474	12892.610	693825.018	635467.696	693824.985	635467.787
14/43	7485.995	12885.328	693811.757	635460.017	693811.632	635459.864
15/45	7484.080	12888.264	693809.709	635462.956	693809.579	635462.990
16/48	7461.642	12875.839	693787.688	635449.810	693787.656	635450.228
17/53	7435.006	12885.967	693760.757	635459.149	693760.779	635459.201
18/58	7397.370	13051.134	693718.247	635623.177	693718.200	635622.864
19/61	7389.065	13050.916	693709.950	635622.714	693709.819	635622.777
20/63	7382.093	13083.274	693702.023	635654.860	693701.818	635654.792

For assessing the transformation accuracy of the coordinates from the local system into the official system there have been made various field measurements using a GPS receiver. The field measurements consisted in **the absolute positioning** of the points from the border of the **six real estates**. For this, a single dual frequency **South S82 T** was used.

The field observations were made using the real time kinematic positioning method of the unknown points (*RTK – Real Time Kinematic)*, accompanied by the *Romanian Position Determination System* - ROMPOS which provides the necessary corrections for point positioning. Using the SurvCE field software, there have been obtained coordinates of the points from the contour of the six real estates, into the STEREO - 70 projection (Table 6).

Table 6. The calculated and measured stereographic coordinates on the border of the CF_2

Point no.	Calculated stereographic coordinates (m)		Measured stereographic coordinates (m)		Differences (m)		
					(x_r-x_i)	(y_r-y_i)	RMSE
	X_r < 70 >	Y_r < 70 >	X_i < 70 >	Y_i < 70 >	XR_i	YR_i	R_i
1/1	693692.805	635695.431	693692.600	635695.371	0.205	0.060	0.214
2/3	693723.131	635706.567	693723.137	635706.779	-0.006	-0.212	0.212
3/5	693755.651	635720.817	693755.590	635721.238	0.061	-0.421	**0.425**
4/6	693794.224	635736.421	693794.133	635736.752	0.091	-0.331	0.343
5/7	693813.464	635744.448	693813.464	635744.448	0.000	0.000	**0.000**
6/10	693865.356	635683.459	693865.356	635683.459	0.000	0.000	**0.000**
7/15	693897.783	635631.603	693897.555	635631.641	0.228	-0.038	0.231
8/21	693960.693	635530.710	693960.627	635530.805	0.066	-0.095	0.116
9/23	693918.219	635503.426	693918.001	635503.494	0.218	-0.068	0.228
10/31	693881.143	635483.193	693881.139	635483.193	0.004	0.000	0.004
11/35	693876.426	635475.923	693876.490	635475.921	-0.064	0.002	0.064
12/39	693851.897	635483.442	693851.829	635483.648	0.068	-0.206	0.217
13/42	693825.018	635467.696	693824.985	635467.787	0.033	-0.091	0.097
14/43	693811.757	635460.017	693811.632	635459.864	0.125	0.153	0.198
15/45	693809.709	635462.956	693809.579	635462.990	0.130	-0.034	0.134
16/48	693787.688	635449.810	693787.656	635450.228	0.032	-0.418	0.419
17/53	693760.757	635459.149	693760.779	635459.201	-0.022	-0.052	0.056
18/58	693718.247	635623.177	693718.200	635622.864	0.047	0.313	0.317
19/61	693709.950	635622.714	693709.819	635622.777	0.131	-0.063	0.145
20/63	693702.023	635654.860	693701.818	635654.792	0.205	0.068	0.216
Total Root Mean Square Error - RMS							**0.221**

3.5 Assessment of coordinates' transformation accuracy in the 2D space

Depending of the coordinates transformed from the local system into the official system of the Stereographic projection – 1970 (**X_r<70>, Y_r<70>**) and considering the coordinates measured in the field with GNSS receivers (**X_i<70>, Y_i<70>**) there have been calculated the transcalculation accuracy parameters of **ground control points** from the border of the real estate **CF_2** (Table 6).

Root Mean Square Error (**RMSE**) is calculated with a distance equation:

$$RMS_{error} = \sqrt{(x_r < 70 > - x_i < 70 >)^2 + (y_r < 70 > - y_i < 70 >)^2} \quad \text{(m)}$$

where: x_i<70> and y_i<70> are the input source coordinates;

x_r<70> and y_r<70> are the retransformed coordinates.

The RMS error of each point is calculated and reported to evaluate the GCPs. This is calculated with a Euclidean distance formula:

$$\mathbf{R_i} = \sqrt{XR_i^2 + YR_i^2} \qquad \text{(m)}$$

where: $\mathbf{R_i}$ – the RMS error for GCPi;

$\mathbf{XR_i}$ – the X residual for GCpi; $\mathbf{YR_i}$ – the Y residual for GCpi.

The individual error ($\mathbf{R_i}$) evaluated during the test performed on the **20 control points** ranged between **0.000 m** *(points 5/7 and 6/10)* and **0.425 m** *(point 3/5).*

For the residuals, the following calculations are made to determine the total RMS error, the **X RMS error**, and the **Y RMS error**:

$$R_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n} XR_i^2} = \mathbf{0.115\ m} \qquad \text{and} \qquad R_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n} YR_i^2} = \mathbf{0.188\ m.}$$

where: $\mathbf{R_x}$ – total X RMS error; $\mathbf{R_y}$ – total Y RMS error;

n – the number of GCPs and **i** – GCP number;

The total RMS error (T) evaluated for the 20 control points.

$$T = \sqrt{R_x^2 + R_y^2} = \mathbf{0.221\ m}.$$

The total root mean square error (total RMS error) calculated for the **20 control points** (**GCPs**) was evaluated using the value of **0.221 m**. The total error (T) confirmed the integration of the transformation of the plane coordinates from the local system into the official system within the initial measuring accuracy limits of the control points.

3.6 Assessing the cadastral database accuracy integration from the local system into the official projection system

Based on the plane rectangular coordinates of the points situated on the geometrical contour of the real estates and measured on the field in the Local-Iasi system (**X_r - East, Y_r - North**) the surface have been calculated**,** with the following types of general formulae:

$$2S = \sum_{i-1}^{n} x_i \left(y_{i+1} - y_{i-1} \right) \quad \text{and} \quad -2S = \sum_{i-1}^{n} y_i \left(x_{i+1} - x_{i-1} \right) \qquad (\text{m}^2)$$

In a similar manner there have been determined the surfaces of real estates as well, based on the plane rectangular coordinates transformed with the "*Goliath*" programme from the Local-Iasi system into the Stereographic – 1970 system (**X_r<70>, Y_r<70>**).

The areas resulted from the rectangular coordinates of the two reference systems and the differences between their surfaces are presented for the six real estates. From the analysis of these results it was confirmed that the differences from the surfaces in the official system ($\mathbf{S_2}$) and the Local – Iasi system ($\mathbf{S_1}$) respect the tolerance limits admitted at the calculation of the areas on geodetic trapeziums (Table 7).

Table 7. Calculation of the surfaces on real estates and reference systems

System of coordinates	Area of the real estates in the local system **(S_1)** and in the official **(S_2)** (ha)						
	CF_1	CF_2	CF_3	CF_4	CF_5	CF_6	**Total**
Local – Iasi	12.2848	4.5602	1.5168	0.8839	0.3587	0.3030	**19.9074**
Stereo – 70	12.2915	4.5626	1.5177	0.8843	0.3589	0.3032	**19.9182**
(S_2- S_1)	**0.0067**	**0.0024**	**0.0009**	**0.0004**	**0.0002**	**0.0002**	**0.0108**

The cadastral works performed between 1988-1991 and 1991-2009 for the technical documentation of land register have been done and drawn up using the Local-Iasi system of coordinates with the official nomenclature of the trapeziums at scale 1:1000 (Figure 5).

Officially speaking, all the topographic measurements performed in the Local-Iasi system are to be included into the Stereographic-1970 projection system. The discrepancies between the areas of the case study ranged between **2 m^2**, for the real estate **CF$_6$** with the area of **0.3030 ha** and **67 m^2** for the real estate CF_1, with an area of **12.2848 ha** (Table 7).

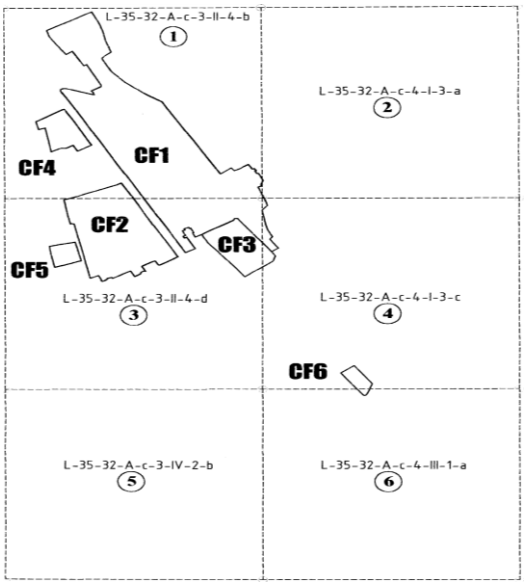

Fig. 5 – Sheets of geodetic trapeziums

Based on the technical norms used at drawing up the documentation of the real estate, the cartographic framing of the six real estates has been performed on the control area of trapeziums, scale 1:1000, both in the Local-Iasi system and in the STEREO-70 system.

Depending of the dimensions and the geometrical shape of each site plan and cadastral delimitation which were reported on the scheme of the trapeziums, scale 1:1000, resulted the following distribution in space: **CF$_1$**/ four trapeziums; **CF$_2$**/ two trapeziums; **CF$_3$**/ two trapeziums; **CF$_4$**/ one trapezium; **CF$_5$**/ one trapezium and **CF$_6$**/ two trapeziums.

The distribution of the surface of the real estates according to the cartographic sheet of trapeziums from the local and the official systems are presented in table 8 and table 9.

Table 8 – Real estates framing on the trapeziums, scale 1:1000 in the Local – Iasi system

Trapezium no.	Distribution of the surface of the real estates on geodetic trapeziums (ha)						
	CF_1	CF_2	CF_3	CF_4	CF_5	CF_6	**Total**
1	9.6311	0.3388	-	0.8839	-	-	**10.8538**
2	0.0046	-	-	-	-	-	**0.0046**
3	2.4506	4.2214	1.3880	-	0.3587	-	**8.4187**
4	0.1985	-	0.1288	-	-	0.2692	**0.5963**
5	-	-	-	-	-	-	**-**
6	-	-	-	-	-	0.0340	**0.034**
Total	**12.2848**	**4.5602**	**1.5168**	**0.8839**	**0.3587**	**0.3030**	**19.9074**

Table 9 – Real estate framing on the trapeziums, scale 1:1000, in the STEREO - 70 system

Trapezium no.	Distribution of the total surface of the real estate, on geodetic trapeziums (ha)						
	CF_1	CF_2	CF_3	CF_4	CF_5	CF_6	**Total**
1	9.6364	0.3389	-	0.8843	-	-	**10.8596**
2	0.0046	-	-	-	-	-	**0.0046**
3	2.4520	4.2237	1.3888	-	0.3589	-	**8.4234**
4	0.1985	-	0.1289	-	-	0.2692	**0.5966**
5	-	-	-	-	-	-	**-**
6	-	-	-	-	-	0.0340	**0.0340**
Total	**12.2915**	**4.5626**	**1.5177**	**0.8843**	**0.3589**	**0.3032**	**19.9182**

4. Conclusion

Through the cadastral works performed in 2005, the administrative territory of Iasi city was officially delimited with the following cadastral units: *Popricani, Aroneanu, Holboca, Tomești, Bârnova, Ciurea, Miroslava, Valea Lupului and Rediu* with a total surface of **9 366 ha**, **6 741 ha** of which being part of the incorporated area.

The cadastral database created between 1950-2009 and represented by a number of **347 geodetic trapeziums**, scale 1:1000 and **103 geodetic trapeziums,** scale 1:2000, in the local system of coordinates of Iasi city, with the central point at Golia.

By introducing the unitary cadastre and land registration, in the STEREO –70 projection, the integration of the database from the Local-Iasi system into the official system becomes necessary, and it considers the accuracy conditions of the topographic measurements performed using the technical norms for drawing up the cadastral documentations.

On the site plan of the six geodetic trapeziums, scale 1:1000 with a total surface of **205.7066 ha,** on the Krasovski – 1940 reference ellipsoid it resulted a total areolar deformation of **-740 m^2** in the Local-Iasi system and a total areolar deformation of **+374 m^2** in the official projection system, respectively.

The assessment of the cadastral database integration accuracy from the local system into the official system has been analyzed using the transformation process of the coordinates between the two systems as well as the field measurements performed with GNSS receptors.

The total error of **0.221 m** that was evaluated for the 20 control points of the geometrical contour of one real estate confirmed the possibility of transforming the plane coordinates within the initial measuring accuracy limits of the points taken into consideration.

The differences between the areas of the six real estates that ranged between the minimum value of **2 m^2** for **CF$_6$**, with the area of 0.3030 ha and the maximum value of **67 m^2** for **CF$_1$** with the area of 12.2848 ha, can be compensated in the case of relatively small surfaces, on the undeformed control area of the geodetic trapezium, scale 1:1000.

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