THE USE OF MAP PROJECTIONS IN THE TOPOGRAPHIC AND CADASTRAL WORKS OF IASI CITY

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Abstract

For creating the geodetic support networks for the topographic and cadastral elevations made in the administrative territory of Iasi city a set of map projections have been used for various time intervals. Practically speaking, the official introduction of a projection system relied on the hypothesis of obtaining the smallest deformations possible for the cartographic representation of angles, distances and surfaces. In this context, for the city of Iasi it resulted necessary the use of the local map projections and the official projections for Romania's territory. The analysis of the deformations identified for the projections used between 1950-2015 in Iasi city focused on establishing the accuracy of framing the graphic and textual databases from the local projection into the official projection. The case study included the comparative analysis of linear deformations and surfaces on geodetic trapeziums and real estates registered in the land register of Iasi city. For this, the specific deformations of the following systems were identified: the local stereographic projection of Iasi; the transverse cylindrical projection, conformal, Gauss-Krüger; stereographic perspective projection, oblique, conformal, on the unique secant plan – 1970; the stereographic projection on the local secant plan of Iasi, that derived from the 1970- stereographic projection. After finishing the implementation of the new unitary cadastre and real estate system, the cadastral recordings of real estates from the existent documentations must be correlated with the ones from the official 1970-Stereographic projection system.

Key words: map projection, linear deformation, areolar deformation, geodetic trapezium

The integral general cadastral works on administrative territorial units ensure the technical, economic and legal evidence of all the real estates in the country. The basic entities of general cadastre are: *real estate, parcel, construction and owner* (Law no.7/1996).

The real estate is identified on the cadastral sectors of each administrative territorial unit. Officially, it represents the land, with or without buildings, in the property of one or more owners. Each real estate is identified by its property borders with a *unique cadastral number* that is registered in the land register.

The general cadastre works are to be conducted and completed within the *National Programme for Cadastre and Land Registration* that is to be implemented between 2015-2023.The major objective of the *National Programme for Cadastre and Land Registration* created by the *National Agency for Cadastre and Land Registration* consists in the systematic registration of all real estates. At national level, all the real estates from the *2337 administrative territorial units* – urban and rural areas (*villages, cities, and municipalities*) are to be registered in the cadastral plan and the land register.

The systematic cadastre and land registration activity require the existence of field measurements in a unitary system of coordinates.

In addition, it is necessary to increase the number of reference points from the *national geodetic GPS-GNSS support network* so to ensure the existence of rigorous cadastre measurements and the complete mapping of the existent lands (Păunescu V. *et al*, 2015).

Simultaneously, it is recommended the correlation of the graphic and textual database obtained from the new cadastral measurements with the one from the old cadastre and land registers. Generally, the cadastral works of systematic registration of real estates include the areas obtained from the measurements.

In the case of Iasi city and its two distinct areas (*incorporated and unincorporated*) the set of technical documents representing the legal ground of real estate records was created in an interval of almost 65 years. These documents used in the cadastral plan and the real estate register were drawn up in various systems of coordinates, depending of the map projections used.

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The present case study points out the advantages as well as some of the disadvantages of the local and official map projection systems used in the city of Iasi: the local stereographic projection of Iasi; projection Gauss - Krüger; stereographic projection - 1970; the stereographic projection on the local secant plan of Iasi, that derived from the 1970- stereographic projection.

MATERIAL AND METHOD

The introduction and the use in the city of Iasi of plane system of coordinates, corresponding to different map projections lead to the apparition of different *Coordinate Reference Systems* and to the diversification of plan and map creation. For the existence of a unitary system of *General Cadastre* and different *Information Systems* – that are necessary to various practical activities, the measurements must be rigorous and made with modern methods and techniques.

For updating the geodetic support network the *Global Navigation Satellite System – GNSS* is used. It provides a rigorous database and an accurate cadastral record at the level of the territorial administrative units of Romania (Boş N., Iacobescu O., 2007).

The present case study was conducted to correlate the present *Coordinate Reference System* of Romania with other type of data coming from older measurements – made at different moments in time in the city of Iasi. In this context, the analysed elements were the mapping principle and the specific parameters for the map projections used in the city of Iasi between 1950 - 2015, respectively.

The four map projections used at different time intervals in various geodetic, topographic, photogrammetric, cadastral and other types of measurements were part of the *"Local Projection System"* and the "*National Projection System".*

The Local Stereographic Projection of Iasi, with the central point of the geodetic triangulation network on the platform of the large square tower from the entrance of ***Golia Church***, former convent, was officially used between 1950 – 2009 (Moca V., et. al., 2013).

Among the specific elements of the *Coordinate Reference System* from this local projection system, we can mention:

- *the geographic coordinates* of the *Golia point* on the surface of the *1940 – Krasovski* reference ellipsoid: $\varphi_0=47^0\,09'\,52''$; $\lambda_0=20^0\,35'\,37''$;

- *the plane rectangular coordinates* in the local system with the origin of the axes in the *Golia point*: X_0= 10 000.000 m; Y_0= 10 000.000 m;

- *the East – West orientation of the OX axis* is given by the tangent to the parallel with latitude $\varphi_0 = 47^0\,09'\,52''$, passing through the *Golia point*, where the values of the *abscissas (X)* increase from the origin towards East and decrease from the origin towards West;

- *the OY axis orientation corresponds to the direction of the meridian* with longitude $\lambda_0=20^0\,35'\,37''$, passing through the Golia point, where the value of the ordonates (Y) increase from the origin towards North and decrease from the origin towards South;

- *the reference system* used for normal quotas: Baltic Sea (1950-1975) and Black Sea, respectively, (1975 – 2015).

The cadastral and cartographic documents made for the territory of Iasi city between 1950 - 2009, in the *Iasi – Golia local projection* system of coordinates, included:

- *the basic cadastral plan, scale 1:1000, with the Baltic Sea quota system*, was first made between 1950-1970 and then updated between 1988-1991, during the implementation of the *"Land Cadastre in Iasi City";*

- *the basic topographic plan, scale 1:2000 and 1:5 000 with the Black Sea quota system,* was made using aerophotogrammetric methods between 1982-1983;

- *cadastral plans* made for the land property of commercial companies, for awarding them property titles and assigning temporary cadastral numbers for registering them in the land register and for other types of activities.

The *transversal cylindrical projection, conformal, Gauss-Krüger* was adopted in Romania in 1951, along with the 1940 – Krasovski ellipsoid, being officially used between 1951-1973 (Munteanu C., 2003). The cartographic documents made using the Gauss projection system of coordinates for the territory of Iasi city are:

- *the basic topographic plan, scale 1:5 000 and 1: 10 0000 with the reference plan for the Baltic Sea quotas,* was made by the Military Topographic Division (DTM) using aerial photography methods, first between 1964-1966, and afterwards between 1977-1979;

- *the basic topographic map, scale 1:25 000 and 1: 50 000 with the reference plan for the Baltic Sea quotas* was made by DTM (1977 -1979).

The stereographic perspective projection, oblique, conformal, on the unique secant plan – 1970 also known as the "*STEREO – 70 Projection*" was adopted and started being used in 1973 when the basic topographic plans scale 1: 2 000, 1:5 000 1: 10 000 and maps scale 1: 50 000 were made.

This projection system relied on the characteristics of the *1940 - Krasovski* ellipsoid and the 1975 reference plan for the Black Sea quotas. The cartographic documents made for the city of Iasi in the *STEREO – 70* system are:

- *the basic topographic plan, scale 1:2 000, 1: 5 000 and 1:10 000* and *the basic cadastral map,* scale 1:50 000, made by I.G.F.C.O.T. Bucharest, between 1973 – 1990;

- *the basic topographic plan, scale 1:500* was made using the aerial photographs of the territory of Iasi. The photographs started being made in 2006 with the digital camera Leika ADS-40 and the activity was part of the project entitled

“*The Real Estate Cadastre and the Development of a Database for the Administrative Territory of Iasi City”* (Sălceanu, Gh., 2009).

The stereographic projection on the local secant plan of Iasi that derived from the 1970-stereographic projection was adopted in the city of Iasi in the idea of cancelling and/or reducing the relative linear deformation below ***± 5 cm/km*** (Moca V., et. al., 2006).

RESULTS AND DISCUSSIONS

The city of Iasi includes the *geographic territory from 47^0 06' 45” South latitude and 47^0 13' 30” North latitude and 27^0 28' 45” West longitude and 27^0 41' 50” East longitude.* With the cadastral delimitation of the territory of Iasi city conducted in 2005 there have been determined on the field almost *200 border points* using the 1970 – Stereographic projection system of coordinates.

From the data collected after the cadastral delimitation made in 2005 resulted a total surface of ***9 366 ha***. The incorporated area of Iasi city consisted of *6741 ha (72%)* and the unincorporated area *2 625 ha (28%).*

The border limits of Iasi city were officially established using the 9 *border sections* with the 9 bordering territorial administrative units represented by the following communes: *Popricani, Aroneanu, Holboca, Tomeşti, Bârnova, Ciurea, Miroslava, Valea Lupului, Rediu.*

The extreme points for the cadastral delimitation are represented by the following territories: *Popricani, in the North; Tomeşti, in the East; Bârnova, in the South and Miroslava, in the West.*

a. The cartographic framing of Iasi city

For the comparative study of the areolar deformations resulting from the representation of the geodetic trapeziums from the surface of the reference ellipsoid onto the plane surface of a cartographic projection*, the cartographic database of the cadastral plan, scale 1:5000 was used.*

The cartographic framing for the city of Iasi started from the nomenclature of the four trapeziums, scale 1:50 000, with the dimensions of the sides in angular values of *10' 00” latitude* and *15' 00” longitude.*

To continue, the trapezium at scale 1:50 000 was divided into *four map sheets*, scale 1:25 000, *16 map sheets* scale 1:10 000 and *64 map sheets* scale 1:5 000 and afterwards at scales: 1:2 000; 1:1 000; and 1:500 (Moca V., et. al., 2006).

From the distribution and the numbering of map and plan sheets resulted the following cartographic framing for the city of Iasi: *4 map sheets* scale 1:50 000; *6 map sheets* scale 1:25 000; *14 plan sheets*, scale 1:10 000; *34 plan sheets*, scale 1:5 000; *103 plan sheets*, scale 1:2 000 and *347 plan sheets*, scale 1:1 000 (Figure 1).

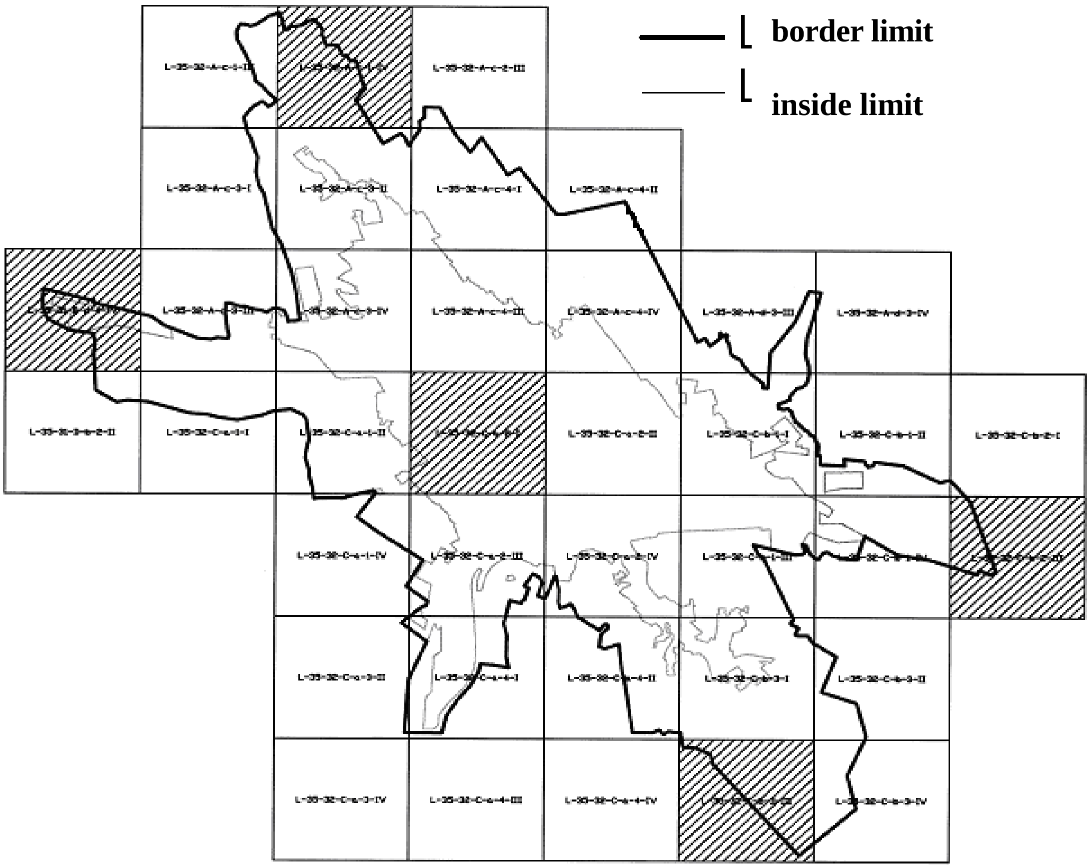


Figure 1 **Cartographic framing of Iasi city, on trapeziums, scale 1:5 000**

b. Calculation of the areas of the trapeziums from the 1940- Krasovski reference ellipsoid

The areas of the geodetic trapeziums scale 1:5000 were calculated using the constant coefficients relation for the 1940 - Krasovski reference ellipsoid. The calculations also considered the geographic coordinates.

The ellipsoid area (T) between two longitude parallels $\boldsymbol{\varphi_i}$ and $\boldsymbol{\varphi_j}$ and longitude meridians $\boldsymbol{\lambda_m}$ şi $\boldsymbol{\lambda_n}$ respectively, was obtained with the relation:

$$T = \left[\Delta T(\varphi_N)_{\Delta\lambda=1'} - \Delta T(\varphi_S)_{\Delta\lambda=1'}\right] \cdot (\lambda_E - \lambda_W)'$$

where : $\Delta T(\varphi_N)_{\Delta\lambda=1'}$ and $\Delta T(\varphi_S)_{\Delta\lambda=1'}$ - elements of ellipsoidal area, in km^2;

$(\lambda_E - \lambda_W)'$- longitude difference.

The case study included the calculation of *the ellipsoidal areas for 8 trapeziums*, scale 1:5000, from the central area of the incorporated territory of Iasi city. (Figure 2).

c. Calculation of the areas of the trapeziums from the plan of cartographic projections

Based on the algorithm used in other papers too (Moca V., Oniga Ersilia, 2011) we first proceeded at the transformation of the geographic coordinates of the corners of the geodetic trapeziums into plane rectangular coordinates of the projections studied.

The plane area (S) placed between the plane images of the two parallels and the two meridians was established considering the rectangular coordinates (**x_i, y_i**) of the corners of the trapeziums, scale 1:5 000, with the general relations:

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

The ellipsoidal and plane areas of the *8 geodetic trapeziums*, scale 1:5000 of the four map projection systems included in the case study are presented in Table 1.

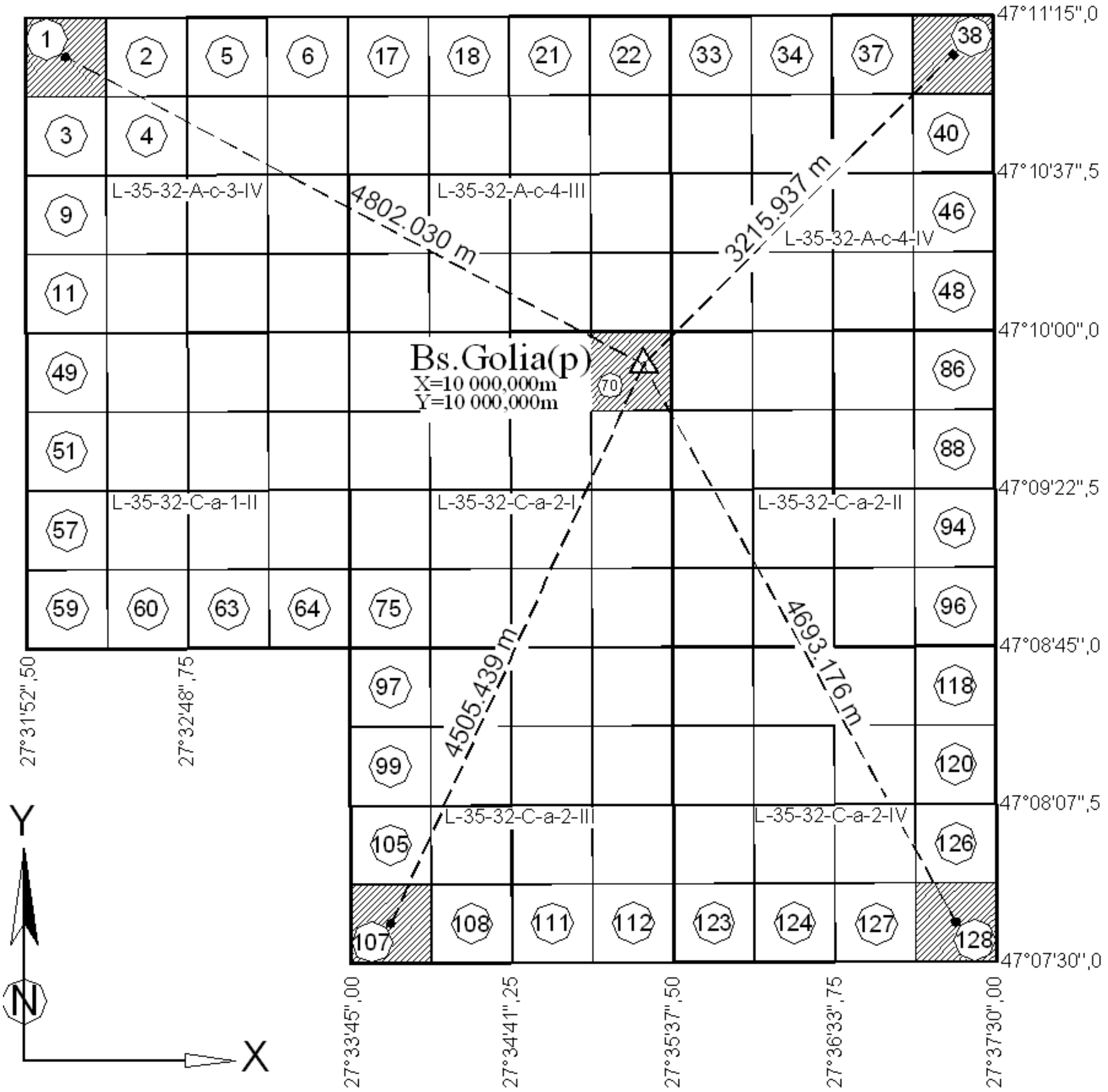


Figure 2 **Cartographic base of geodetic trapeziums, scale 1:5 000**

Table 1

Area of trapeziums scale 1:5 000 from the reference ellipsoid (T) and the projection plan (S)

Trapezium nomenclature	Krasovski - 40 Area (T)	Area of trapeziums from the cartographic projection plan (S)			
		Local Golia	Gauss-Krüger	Stereo-1970	Stereo-derived
	ha	ha	ha	ha	ha
L-35-32-A-c-3-IV	548.6835	548.5261	548.7068	548.7813	548.6767
L-35-32-A-c-4-III	548.6835	548.4799	548.7094	548.7876	548.6829
L-35-32-A-c-4-IV	548.6835	548.4869	548.7122	548.7940	548.6894
L-35-32-C-a-1-II	548.8961	548.7781	548.9194	548.9900	548.8854
L-35-32-C-a-2-I	548.8961	548.7017	548.9219	548.9963	548.8917
L-35-32-C-a-2-II	548.8961	548.6896	548.9248	549.0026	548.8979
L-35-32-C-a-2-III	549.1086	548.9253	549.1346	549.2048	549.1002
L-35-32-C-a-2-IV	549.1086	548.8989	549.1374	549.2114	549.1067

d. Analysis of the total areolar deformations on geodetic trapeziums, scale 1:5000

For the analysis of the *total areolar deformations* on geodetic trapeziums it was used the general relation: **±ΔS=(S-T)** where: **±ΔS -** total areolar deformation on trapeziums; **S** – the area of the trapezium from the projection plan; **T** – the area of the trapezium from the 1940 – Krasovski.

Based on the algorithm used, resulted the total areolar deformations on the geodetic trapeziums from the four map projection systems. From the comparative analysis of the total areolar deformation on geodetic trapeziums, scale 1:5000, and the *undeformed ellipsoidal area* resulted the conformal representation principle.

- *The Local Stereographic Projection of Iasi City* was used for almost 60 years (1950-2009). It recorded the most significant total areolar deformations on the trapeziums.

The extent of these areolar deformations in relation to *the ellipsoidal area* was established during the spatial distribution of trapeziums in relation to the *Golia point*, ranging between a *minimum* of **- 0.1574 ha** (L-35-32-A-c-3-IV) and a *maximum* **– 0.2097 ha** (L-35-32-C-a-2-IV) on the *eight geodetic trapeziums* scale 1:5000 (Table 2).

The actual cartographic representation relied on the principle of the *stereographic perspective azimuthal projection on the local secant plan with the central point at Golia.* The reference plan for normal quota was the *Baltic Sea (1950-1975)* and afterwards, the *Black Sea (1975-2009).*

The topographic plans made first at scale 1:1000 for the incorporated area of Iasi city and afterwards at scale 1:2000 and 1:5000 for the incorporated and unincorporated area relied on a local triangulation with the *central point at Golia*.

For the transfer of the data from the local projection system into the official system of coordinates of the 1970 – Stereographic projection system, the correlation of the data with the ones obtained from the present measurements results necessary. At the same time, the use of modern methods is necessary as they are capable of providing a homogenous accuracy of the data and an accurate record of the surface of real estates on each cadastral sector and on the *control area of the geodetic trapezium,* respectively.

- *The transverse cylindrical projection, conformal, Gauss-Krüger,* used between 1951 – 1973 recorded relatively small total areolar deformations and homogeneous in size on the *eight geodetic trapeziums,* scale 1:5 000.

The territory of Iasi city is situated on the *35^{th} fus geographic*, with the *marginal meridians of 24^0 and 30^0 longitude and the 27^0 axial meridian longitude East Greenwich*. The length and surface deformations are null for all the points situated on the axial meridian. In the other points whose distance increases in relation to the axial meridian there are only positive deformations of lengths and surfaces.The total areolar deformations on the *eight trapeziums,* situated near the *27^0 axial meridian East Greenwich longitude* ranged in the interval [**0.0233 ha**; **0.0288 ha]**, (Table2).

Table 2

Total areolar deformations on geodetic trapeziums scale 1:5 000 (±ΔS=S-T)

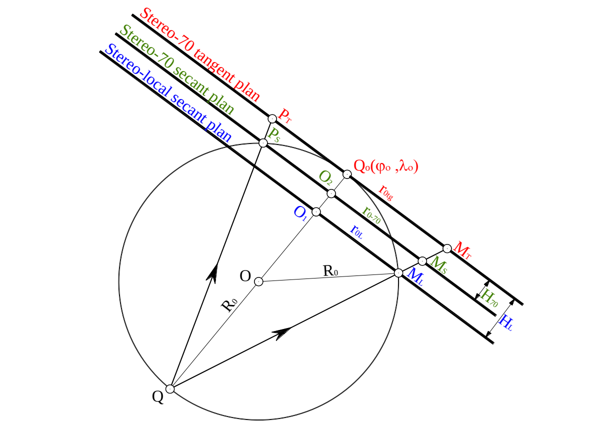
Trapezium nomenclature	Total areolar deformations from the cartographic projection plan			
	Local Golia	Gauss-Krüger	Stereo-1970	Stereo - derived
	ha	ha	ha	ha
L-35-32-A-c-3-IV	-0.1574	0.0233	0.0978	-0.0068
L-35-32-A-c-4-III	-0.2036	0.0259	0.1041	-0.0006
L-35-32-A-c-4-IV	-0.1966	0.0287	0.1105	0.0059
L-35-32-C-a-1-II	-0.1180	0.0233	0.0939	-0.0107
L-35-32-C-a-2-I	-0.1944	0.0258	0.1002	-0.0044
L-35-32-C-a-2-II	-0.2065	0.0287	0.1065	0.0018
L-35-32-C-a-2-III	-0.1833	0.0260	0.0962	-0.0084
L-35-32-C-a-2-IV	-0.2097	0.0288	0.1028	-0.0019

- The stereographic perspective projection, oblique, conformal, on the unique secant plan – 1970 adopted in 1973, answers to the need of accuracy of drawing up the basic topographic plans, scales 1:2000, 1:5000 and 1:10000.

In the case of Iasi city which is situated outside the null distortion circle with the *beam of 201.718 km*, in relation to the centre of the projection $Q_0(\varphi_0 = 46^0$ *and* $\lambda_0 = 25^0)$ situated in the geometrical centre of Romania, there are only positive deformations of lengths and surfaces.

The total areolar deformations identified on the *eight trapeziums*, scale 1:5000 from the central part of the incorporated area of Iasi city also registered relatively similar values that ranged between the minimum limit of **0.0939 ha** and the maximum limit of **0.1105 ha** (Table 2).

- The stereographic projection on the local secant plan of Iasi, parallel to the unique secant plan – 1970 lead to the annulment and/or the significant reduction of linear and areolar deformations (Figure 3).



R_0 = 6378956.681m	H_L = 4405.205 m
H_{70} = 3189.478 m	r_{0-L} =237.025 km
r_{0-70} = 201.718 km	U = 0.99965471264
C = 0.999750	K = 0.999904689

Figure 3. **Geometrical elements of the Stereo – 70 projection and local – derived**

The geometric elements of the local Stereographic projection of Iasi, deriving from the 1970-Stereographic projection were calculated considering the plane 1970-Stereo coordinates of the *Golia point*: (X_G = 632 649.610 m and Y_G = 696 410.698 m). Based on the transformation coefficient (K) and the calculation formulae it is obtained the transcalculation of the coordinates from the official Stereo-70 system into the local system and vice versa.

The total areolar deformations on trapeziums pointed out the significant reduction in relation to the other projections studied but with the disadvantage of using in the cadastral documentation two systems of plane rectangular coordinates (Table 2).

CONCLUSIONS

The territory of Iasi city – 9 366 ha – can be represented on the following trapeziums: *14 plan sheets, scale 1:10 000; 34 plan sheets, scale 1:5 000; 103 plan sheets, scale 1:2 000 and 347 plan sheets, scale 1:1 000.*

The local stereographic projection presented the highest total areolar deformations on trapeziums [**- 0.1574; - 0.2097 ha**] in relation to the undeformed areas from the ellipsoid.

The Gauss projection is characterized by positive and relatively small total areolar deeformations on trapeziums, depending of the distance tot eh axial meridian [**0.0233; 0.0288 ha**].

The 1970 – Stereographci projection pointed out the regional deformations from outside the null deformation circle, with the *beam of 201.718 km*, within the accuracy interval [**0.0939; 0.1105 ha**].

The Stereo projection derived from the 1970-Stereo lead to the diminution of the total areolar deformations [**- 0.0006; - 0.0107 ha**].

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