# STUDY OF CARTOGRAPHIC PROJECTS FOR PAN-EUROPEAN REPRESENTATIONS

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## INTRODUCTION

With the development of the European integration programs for the spatial information infrastructure INSPIRE (Infrastructure for Spatial Information in Europe) used in various fields, it has become necessary to use a unique and homogeneous reference system for the whole Europe. The International Association of Geodesy (IAG) constituted the EUREF Subcommittee which since 1987 has carried out a series of activities to develop the European Terrestrial Reference System 1989 (ETRS89) based on the International Terrestrial Reference System (ITRS) [13] and the European Vertical Reference System 2000 (EVRS2000). These systems have been recommended for their adoption by the European Commission for spatial planning of the integration and evaluation policy of the candidate and integrated countries of the European Union [1, 9].

In perspective of the integration of the Republic of Moldova into the European Union, besides the adoption of reference systems must be taken into consideration cartographic projections compatible with those used for pan-European applications. For this purpose, the directions of the Directive 2007/2 / EC of the European Parliament and of the Council on the interoperability of spatial data sets and services for implementation will be followed [2, 6].

In this article a study will be made on the main features of cartographic projections used in European countries as well some possibilities of representing the territory of the Republic of Moldova in the recommended projections.

## 1. PROJECTIONS RECOMMENDED BY THE EUROPEAN COMMISSION

In order to unify a European Geographic Information System (GIS) so that domestic products to be compatible with this system, some studies and possibilities have been carried out by the European Commission that recommending the following systems [1]:

- for statistical analysis and display on the display - *Pan-European Reference and Coordinate System with ETRS89 Datum in Lambert Azimuthal Equal Area coordinate reference system of 2001* (ETRS89-LAEA);
- For the preparation of pan-European compliant maps at scales smaller than or equal to 1: 500 000 - *Pan-European Reference and Coordinating System with ETRS89 Datum in Lambert Conic Conformal coordinate reference system of 2001* (ETRS89-LCC);
- For the preparation of the maps at scales larger than 1: 500 000 - *Pan-European Reference and Coordinate System with ETRS89 Datum in the Transversal Mercator coordinate reference systems* (ETRS89-TMzn).

These projections are available in the field of INSPIRE transformation services in accordance with EN ISO 19111 [3].

## 2. EUROPEAN LAMBERT AZIMUTHAL EQUAL-AREA PROJECTION

Azimuthal equal-area projections are usually used to represent regions with round surfaces where the condition of representation is to maintain undeformed areas. Following the position of the projection pole, the straight azimuthal equal-area projections are used for the representation of the polar zones, transversal ones for the equatorial zones, and the oblique ones for the regions at medium latitudes [8].

For the preparation of pan-European maps for statistical analysis and visualization it was proposed to use the Lambert oblique azimuthal equal-area (LAEA).

The LAEA projection parameters established for Europe are [4]:

- the ellipsoid: GRS80;

– the latitude of natural origin: $\varphi_0 = 52°00'00''$N;
– the longitude of natural origin: $\lambda_0 = 10°00'00''$E;
– False Northing of natural origin: $X_0$ = 4 321 000 m;
– False Easting of natural origin: $Y_0$ = 3 210 000 m.

The geographical limits for Europe are: on the longitude 25W-45E, and on the latitude 32N-72N. The LAEA projection pole is chosen at latitude 52 ° N and longitude 10 ° E (Figure 1).

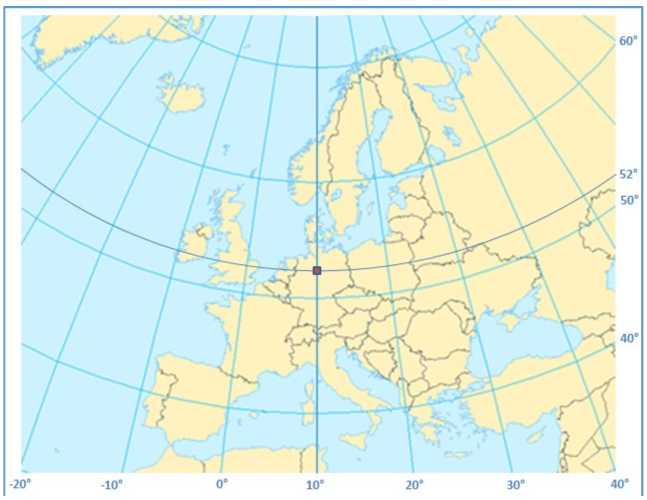


***Figure 1.*** Europe in the Lambert azimuthal equal-area projection.

In the LAEA projection we have distortions of distances and angles that can be determined based on relations [5]:

$$k = \{2/[1+\sin\varphi_0 \sin\varphi + \cos\varphi_0 \cos\varphi \cos(\lambda - \lambda_0)]\}^{1/2};$$
$$h = 1/k; \qquad (1)$$
$$\omega = 2\arcsin[(k^2-1)/(1+k^2)],$$

where k - the scale factor in the direction of the parallels, h - the scale factor in the meridian direction, ω - the angular deformation.

After calculations we will obtain the following values of the relative linear deformations (in the direction of the meridians and the parallels) and the angular deformations for the Republic of Moldova area, which are presented in Table 1.

The graphical distribution of linear deformations relative to the longitude of the natural origin of the projection 28° 30 ' is shown in the following figures.

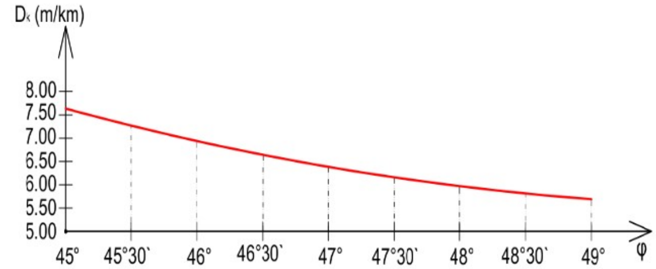


***Figure 2.*** Relative linear deformations $D_k$ (m/km) in the direction of the parallels (λ = 28°30') in the LAEA projection with the pole in the center of the Europe.

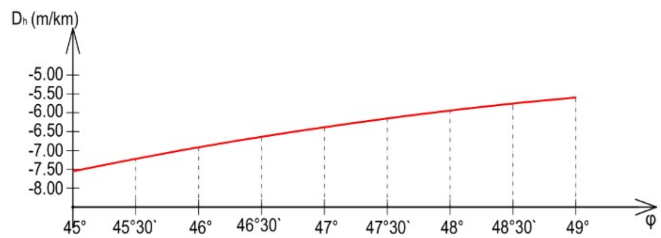


***Figure 3.*** Relative linear deformations $D_h$ (cm/km) in the direction of the meridians (λ = 28°30') in the LAEA projection with the pole in centre of the Europe.

***Table 1.*** Relative linear and angular deformations in the Lambert azimuthal equal-area projection for the Republic of Moldova zone ($\varphi_0$ = 52° $\lambda_0$ = 10°).

| φ/λ ° ' | 27° | | | 28° | | |
|---|---|---|---|---|---|---|
| | $D_k$ (cm/km) | $D_h$ (cm/km) | ω ° ' '' | $D_k$ (cm/km) | $D_h$ (cm/km) | ω ° ' '' |
| **45** | 6.685 | -6.641 | 0.4548 | 7.269 | -7.216 | 0.4947 |
| **45. 30** | 6.381 | -6.341 | 0.4344 | 6.959 | -6.911 | 0.4740 |
| **46** | 6.097 | -6.060 | 0.4147 | 6.669 | -6.624 | 0.4541 |
| **46. 30** | 5.831 | -5.797 | 0.3958 | 6.393 | -6.357 | 0.4350 |
| **47** | 5.584 | -5.553 | 0.3817 | 6.145 | -6.107 | 0.4207 |
| **47. 30** | 5.537 | -5.328 | 0.3644 | 5.912 | -5.877 | 0.4031 |
| **48** | 5.149 | -5.122 | 0.3518 | 5.698 | -5.666 | 0.3903 |
| **48. 30** | 4.959 | -4.935 | 0.3400 | 5.503 | -5.473 | 0.3743 |
| **49** | 4.789 | -4.766 | 0.3250 | 5.327 | -5.299 | 0.3631 |
| **φ/λ ° '** | **29°** | | | **30°** | | |
| | $D_k$ (cm/km) | $D_h$ (cm/km) | ω ° ' '' | $D_k$ (cm/km) | $D_h$ (cm/km) | ω ° ' '' |
| **45** | 7.885 | -7.823 | 0.5400 | 8.535 | -8.463 | 0.5825 |
| **45. 30** | 7.570 | -7.513 | 0.5150 | 8.213 | -8.146 | 0.5614 |
| **46** | 7.273 | -7.221 | 0.4949 | 7.910 | -7.848 | 0.5410 |
| **46. 30** | 6.996 | -6.947 | 0.4755 | 7.627 | -7.569 | 0.5214 |
| **47** | 6.738 | -6.693 | 0.4610 | 7.362 | -7.308 | 0.5026 |
| **47. 30** | 6.499 | -6.457 | 0.4432 | 7.117 | -7.067 | 0.4845 |
| **48** | 6.279 | -6.239 | 0.4302 | 6.891 | -6.843 | 0.4712 |
| **48. 30** | 6.078 | -6.041 | 0.4139 | 6.683 | -6.639 | 0.4547 |
| **49** | 5.896 | -5.861 | 0.4025 | 6.495 | -6.453 | 0.4430 |

The graphical distribution of maximum angular deformations at the longitude of the natural origin of the projection 28°30' is shown in the following figure.

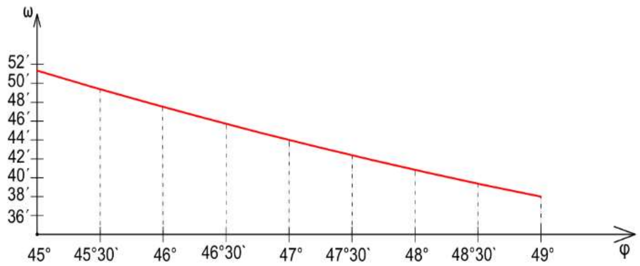


***Figure 4.*** Maximum angular deformations ω (') (λ = 28°30') in the LAEA projection with the pole in the center of the Europe.

If we want to represent the territory of the Republic of Moldova in the Lambert azimuthal equal-area projection, we can use the following parameters:

- the ellipsoid: GRS80;
- the latitude of natural origin: $\varphi_0 = 47°15'00''$N;
- the longitude of natural origin: $\lambda_0 = 28°30'00''$E;
- False Northing of natural origin: $X_0$ = 500 000 m;
- False Easting of natural origin: $Y_0$ = 500 000 m.

***Table 2.*** The relative linear and angular deformations in the Lambert azimuthal equal-area projection for the Republic of Moldova ($\varphi_0$= 47°15' $\lambda_0$= 28°30').

| ϕ/λ° ′ | 27° | | | 28° | | |
|---|---|---|---|---|---|---|
| | Dk (m/km) | Dh (m/km) | ω ° ′ ″ | Dk (m/km) | Dh (m/km) | ω ° ′ ″ |
| **45** | 0.233 | -0.233 | 0.0136 | 0.197 | -0.197 | 0.0122 |
| **45. 30** | 0.157 | -0.157 | 0.0105 | 0.121 | -0.121 | 0.0049 |
| **46** | 0.100 | -0.100 | 0.0041 | 0.064 | -0.064 | 0.0026 |
| **46. 30** | 0.061 | -0.061 | 0.0028 | 0.026 | -0.026 | 0.0011 |
| **47** | 0.042 | -0.042 | 0.0017 | 0.007 | -0.007 | 0.0003 |
| **47. 30** | 0.042 | -0.042 | 0.0017 | 0.007 | -0.007 | 0.0003 |
| **48** | 0.060 | -0.060 | 0.0025 | 0.026 | -0.026 | 0.0011 |
| **48. 30** | 0.098 | -0.098 | 0.0041 | 0.064 | -0.064 | 0.0026 |
| **49** | 0.155 | -0.155 | 0.0104 | 0.121 | -0.121 | 0.0049 |
| **ϕ/λ° ′** | **29°** | | | **30°** | | |
| | Dk (m/km) | Dh (m/km) | ω ° ′ ″ | Dk (m/km) | Dh (m/km) | ω ° ′ ″ |
| **45** | 0.197 | -0.197 | 0.0122 | 0.234 | -0.234 | 0.0136 |
| **45. 30** | 0.121 | -0.121 | 0.0049 | 0.157 | -0.157 | 0.0105 |
| **46** | 0.064 | -0.064 | 0.0026 | 0.100 | -0.100 | 0.0041 |
| **46. 30** | 0.026 | -0.026 | 0.0011 | 0.061 | -0.061 | 0.0028 |
| **47** | 0.007 | -0.007 | 0.0003 | 0.042 | -0.042 | 0.0017 |
| **47. 30** | 0.007 | -0.007 | 0.0003 | 0.042 | -0.042 | 0.0017 |
| **48** | 0.026 | -0.026 | 0.0011 | 0.060 | -0.060 | 0.0025 |
| **48. 30** | 0.064 | -0.064 | 0.0026 | 0.098 | -0.098 | 0.0041 |
| **49** | 0.121 | -0.121 | 0.0049 | 0.155 | -0.155 | 0.0104 |

As a pole of projection, the geometric center of our country of latitude 47°15' and longitude 28°30' has been taken.

The graphical distribution of relative linear deformations and angular deformations at the longitude of the natural origin of the projection 28°30' are shown in the following figures.

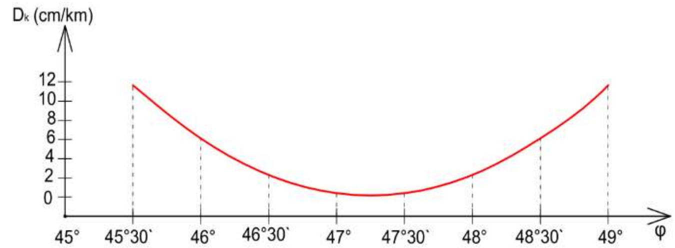


***Figure 5.*** Relative linear deformations $D_k$ (cm/km) in the direction of the parallel (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova.

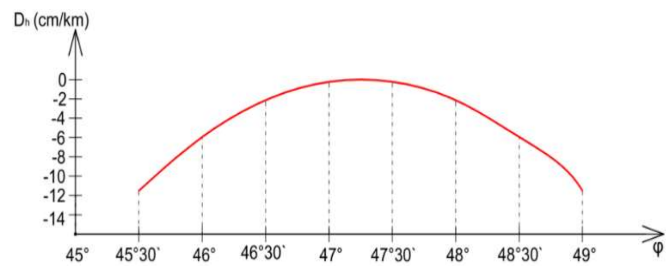


***Figure 6.*** Relative linear deformations $D_h$ (cm/km) in the meridian direction (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova.

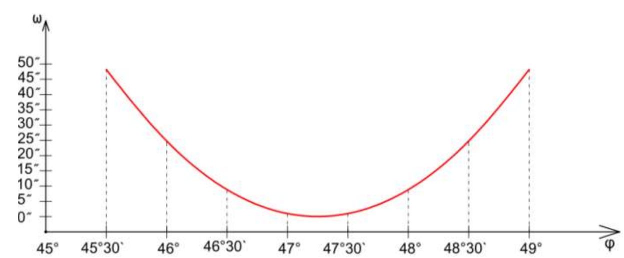


***Figure 7.*** The maximum angular deformations ω (") (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova.

Expressing the degree of deformation of the azimuthal equal-area projection through the ellipse of deformation (indicative of Tissot) on the territory of the Republic of Moldova will have the following form presented in figure 8.

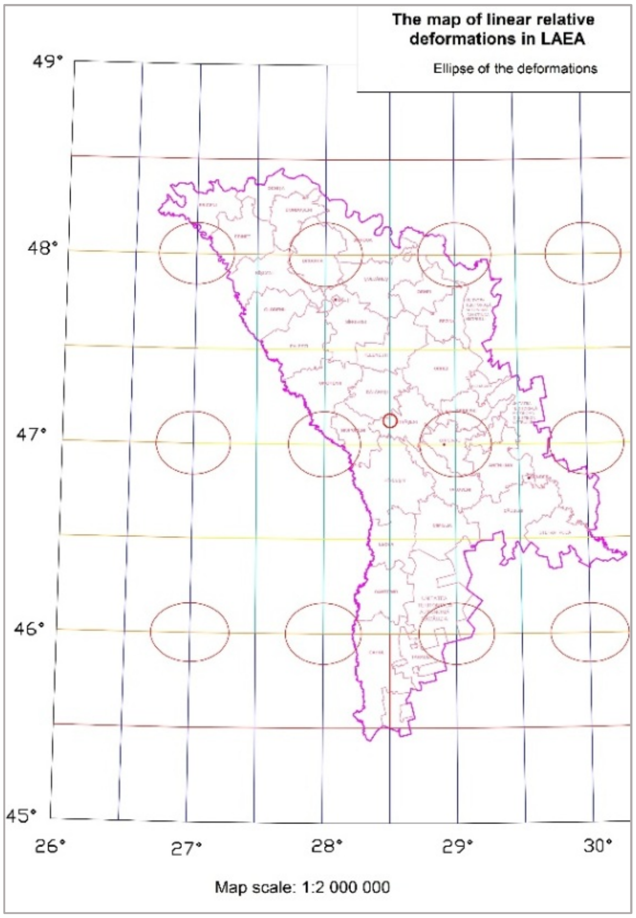


***Figure 8.*** Ellipse of the deformations in the LAEA projection with the pole in the center of the Republic of Moldova.

This projection is advantageous in terms of deformations for the central area of the Republic of Moldova, since relative linear deformations are approximately ± 2 cm/km [15].

## 3. LAMBERT CONFORMAL CONIC PROJECTION

Straight conformal conic projections are typically used to represent territories at medium latitudes and where the largest axis is in the direction of the parallel. From the point of view of the deformations, in the plane of this projection we do not have angular deformations, but the linear and areolar distortions depend only on the latitude [8].

The object of study refers to the representation of the ellipsoid on a secant cone after the secant parallel with known latitudes on the south $\varphi_{kS}$ and the north $\varphi_{kN}$.

Lambert Conformal Conic Projection parameters for the Europe are [4]:

- the ellipsoid: GRS80;
- the latitude of natural origin: $\varphi_0 = 52°00'00''$N;
- the longitude of natural origin: $\lambda_0 = 10°00'00''$E;
- the latitude of the 1st standard parallel: $\varphi_{kS} = \varphi_1 = 35°$;
- the latitude of the 2nd standard parallel: $\varphi_{kN} = \varphi_2 = 65°$;
- False Northing of natural origin: $N_0$= 2 800 000 m;
- False Easting of natural origin: $E_0$ = 4 000 000 m.

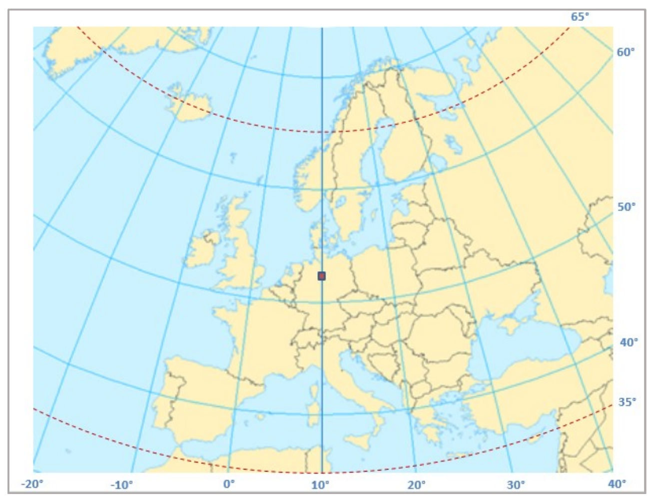


***Figure 9.*** The Europe in Lambert Conformal Conic Projection

In the LCC projection, the angular deformations are null, as well as the deformations on the two secant parallels, and the linear and areolar ones are negative on the area located between the secant parallels and positive outside this zone [7].

A deformation study will be performed in this projection based on the linear deformation module (scale factor) [5,17]:

$$k = \frac{rn}{am} = m_1 t^n / (m t_1^n), \quad (2)$$

where:

$$m = cos\varphi \;/\; (1 - e^2 sin^2\varphi)^{0.5}, \quad (3)$$

for $m_1$ is taken $\varphi_1$ and for $m_2$ respectively $\varphi_2$, in which $\varphi_1, \varphi_2$ are the latitudes of the standard parallels, and *a* – semi-major axis of the ellipsoid.

$$t = \frac{\tan(\pi/4-\varphi/2)}{[(1-e\sin\varphi)/(1+e\ \sin\varphi)]^{e/2}} \quad (4)$$

for $t_1$, $t_2$, $t_0$ și $t$ it is used $\varphi_1$, $\varphi_2$, $\varphi_0$, and $\varphi$ respectively.

$$r = aFt^n, \quad (5)$$

in which: $F = m_1 / (nt_1{}^{n})$, (6)

$$n = (\ln\ m_1 - \ln\ m_2)/(\ln\ t_1 - \ln\ t_2), \quad (7)$$

To determine the relative linear deformations, being the same in the direction of the meridians as well as in the direction of the parallels (from the condition of conformity), as well as the relative areolar deformations, the relations [7, 16] will be used:

$$D = (k-1) * 10^5 \text{ cm/km},$$

$$\text{or } D = (k-1) * 10^3 \text{ m/km}, \quad (8)$$

$$P = (k^2-1) * 10^6 \text{ m}^2/\text{km}^2. \quad (9)$$

The values of these deformations for the geographic boundaries of Europe based on the use of the parameters set in the LCC projection will have the following variations shown in table 3.

***Table 3.*** Relative linear deformations D and relative relational deformations P for Europe in the LCC projection ($\varphi_{kS}$ = 35°; $\varphi_{kN}$ = 65°).

| φ | D (m/km) | P (m²/km²) |
|---|---|---|
| 30° | 24.816 | 50248.329 |
| 35° | 0.000 | 0.000 |
| 40° | -18.076 | -35825.421 |
| 45° | -29.549 | -58224.790 |
| 50° | -34.275 | -67374.771 |
| 55° | -31.751 | -62493.897 |
| 60° | -20.954 | -41469.163 |
| 65° | -0.000 | -0.000 |
| 70° | 34.620 | 70438.981 |
| 75° | 90.021 | 188145.879 |

On the territory of the Republic of Moldova with the same parameters of Europe, the following values of the deformations presented in Table 4 will be produced.

***Table 4.*** Relative linear deformations D and relative relational deformations P for the Republic of Moldova in LCC projection ($\varphi_{kS}$ = 35°; $\varphi_{kN}$ = 65°).

| φ | D(m/km) | P(m²/km²) |
|---|---|---|
| 45° | -29,549 | -58224,789 |
| 45°30′ | -30,330 | -59740,640 |
| 46° | -31,044 | -61124,470 |
| 46°30′ | -31,690 | -62375,891 |
| 47° | -32,268 | -63494,422 |
| 47°30′ | -32,777 | -64479,473 |
| 48° | -33,217 | -65330,362 |
| 48°30′ | -33,587 | -66046,295 |
| 49° | -33,887 | -66626,370 |

The graphical distribution of relative linear deformations and relational relative deformations on the territory of the Republic of Moldova at the longitude of the natural origin of the LCC projection for Europe of 10° 00' with the secant parallels at latitudes $\varphi_{kS}$ = 35° and $\varphi_{kN}$ = 65° are presented in the following figures below.

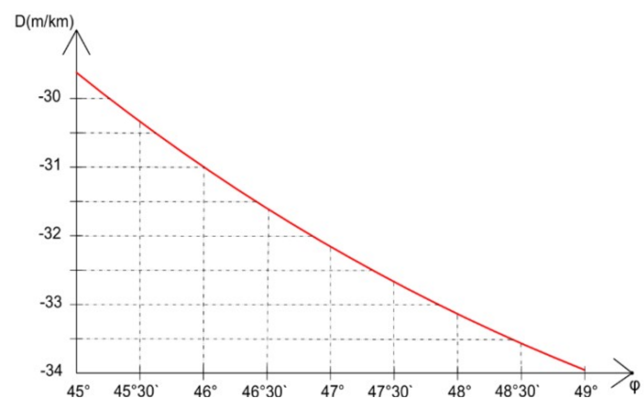


***Figure 10.*** Relative linear deformations D (m/km) for the Republic of Moldova in the LCC projection ($\varphi_{kS}$ = 35°; $\varphi_{kN}$ = 65°)

The representation of the territory of the Republic of Moldova in the Lambert conformal conic projection can be performed by using the following parameters:

- the ellipsoid: GRS80;
- the latitude of natural origin: $\varphi_0$ = 47°15′00″N;
- the longitude of natural origin: $\lambda_0$ = 28°30′00″E;
- the latitude of the 1st standard parallel: $\varphi_{kS} = \varphi_1$ = 46°;
- the latitude of the 2nd standard parallel: $\varphi_{kN} = \varphi_2$ = 48°;

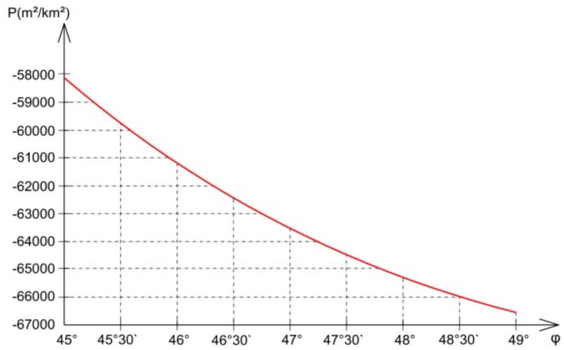


***Figure 11.*** Relative areolar deformations P (m$^2$/km$^2$) for the Republic of Moldova in the LCC projection ($\varphi_{kS}$ = 35°; $\varphi_{kN}$ = 65°)

- False Northing of natural origin: $N_0$=500 000 m;
- False Easting of natural origin: $E_0$ = 500 000 m.

As a pole of projection, the geometric center of our country of latitude 47°15' and 28°30' longitude, and secant parallels with the latitudes $\varphi_{kS}$ = *46°* and respectively $\varphi_{kN}$ = *48°* has been taken.

If we determine the deformations according to these parameters established for the territory of our country we will obtain the situation presented in table 5.

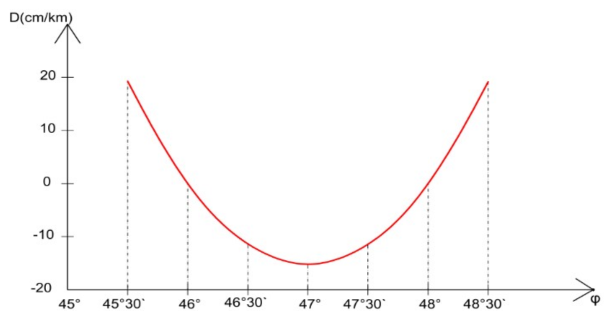


***Figure 12.*** Relative linear deformations D (m/km) for the Republic of Moldova in the LCC projection ($\varphi_{kS}$ = 46°; $\varphi_{kN}$ = 48°).

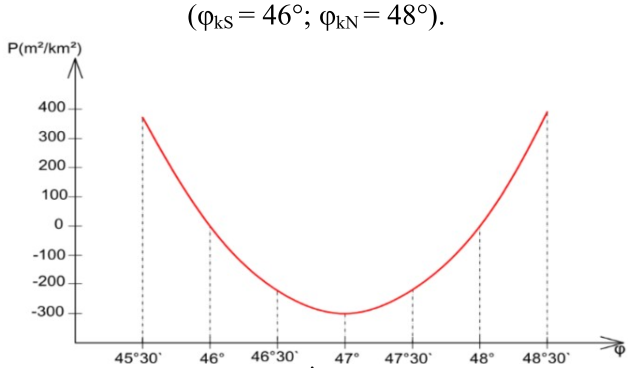


***Figure 13.*** Relative relational deformations P (m$^2$/ km$^2$) for the Republic of Moldova in the LCC projection ($\varphi_{kS}$ = 46°; $\varphi_{kN}$ = 48°).

***Table 5.*** Relative linear deformations D and relative relational deformations P for the Republic of Moldova in LCC projection ($\varphi_{kS}$ = 46°; $\varphi_{kN}$ = 48°).

| φ | D(cm/km) | P(m²/km²) |
|---|---|---|
| 45° | 45,012 | 900,452 |
| 45°30´ | 18,808 | 376,201 |
| 46° | 0,000 | 0,000 |
| 46°30´ | -11,352 | -227,030 |
| 47° | -15,183 | -303,644 |
| 47°30´ | -11,424 | -228,469 |
| 48° | 0,000 | 0,000 |
| 48°30´ | 19,168 | 383,405 |
| 49° | 46,166 | 923,530 |

Since the deformations are independent from the longitude and depend only on latitude, the isolines of the deformations coincide with the images of the parallels (Figure 14).

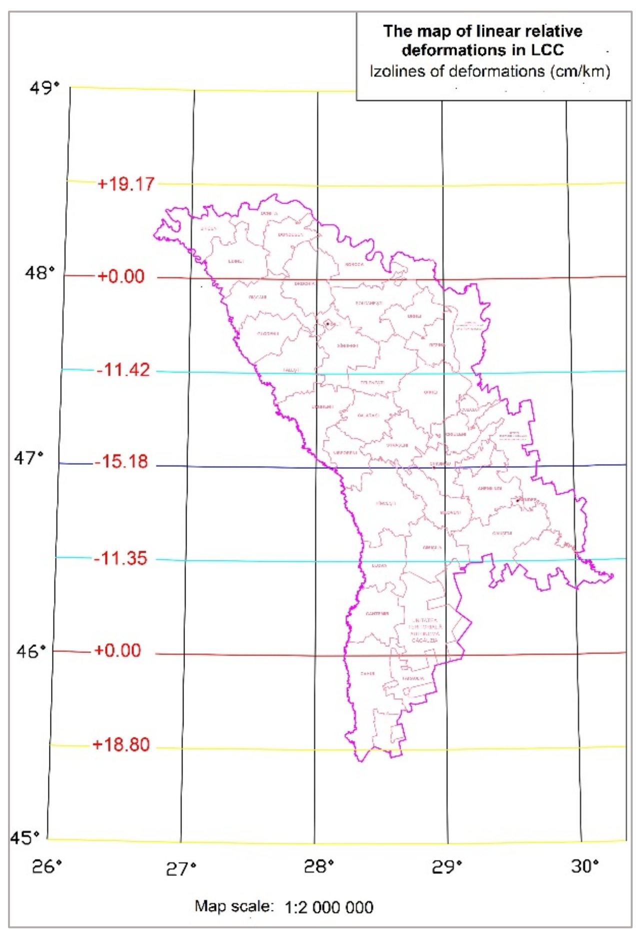


***Figure 14.*** Isolines of the deformations on the territory of the Republic of Moldova in LCC projection ($\varphi_{kS}$ = 46°; $\varphi_{kN}$ = 48°).

## 4. THE EUROPEAN TRANSVERSAL MERCATOR PROJECTION

The European Transversal Mercator Projection (ETRS89-TMzn) is identical to the Universal Transversal Mercator (UTM) projection for the northern hemisphere, using the ESTRS89 (GRS80 ellipsoid) geodetic data recommended by the European Commission for pan-European compliant maps at scales higher than 1:500 000, because for maps that have scales equal to or less than 1:500,000, the projection ETRS89-LCC [1, 4] is recommended.

The UTM projection is currently used in the Republic of Moldova for mapping on scales larger than 1:500,000, based on the WGS84 ellipsoid [10].

For the plane representation in the TMzn projection, the ellipsoid is divided into 60 zones of 6° longitude, numbered with Arabic numerals from 1 to 60, starting with the spindle 1, limited by 180° and -174° Western longitude, and in strips of 8° latitude from -80° S and up to + 84° N, written in letters of the Latin alphabet (Figure 15), except for the X band, that has a stretch of more than 4°, situated between the parallels of North 72° -84° [6, 11].

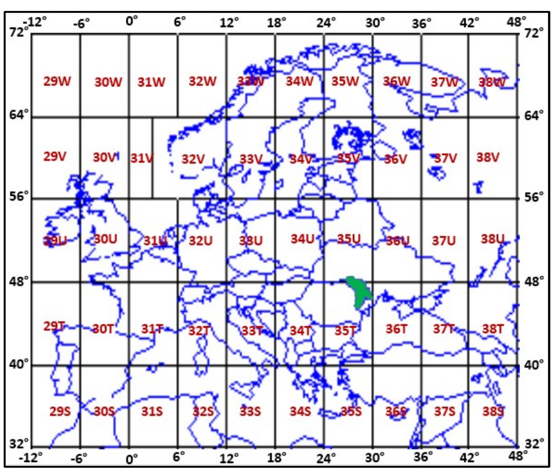


*Figure 15.* European zones in the ETRS89-TMzn (UTM) projection

Each zone has its own coordinate system: the ON axis is the image of the axial meridian with positive northward direction, and the OE axis is the equatorial image with positive eastward direction.

Most of the territory of the Republic of Moldova is located in the 35T and 35U zones with the axial longitudinal meridian 27°E (Figure 16).

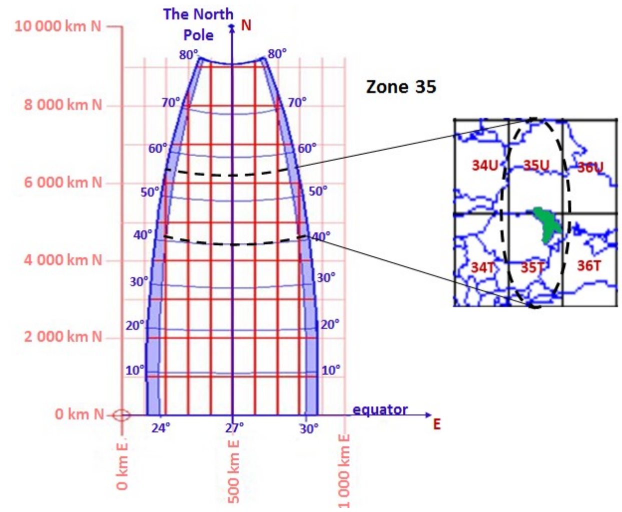


*Figure 16.* Zone 35 in the ETRS89-TMzn projection.

The plane rectangular coordinates N (x), E (y) of any point located in a particular spindle in the TMzn projection are determined based on the parameters of this projection, for example for the 35 zone the parameters are [12]:

- The ellipsoid: GRS80;
- The longitude of the axial meridian: $\lambda_0$=27°;
- Scale factor: $k_0$=0,9996;
- false Easting: $E_0$=500 000 m;
- false Northing: $N_0$= 0 m.

From the point of view of the deformations, the TMzn (UTM) projection is a conformal one, so the angles are represented without deformations. In the projection plane there are two lines of symmetrical null deformations relative to the axial meridian in each zone where negative linear deformations occur and on the outside they are positive.

Next there will be presented the variation of deformations in the spindle 35 for the territory of the Republic of Moldova in the TMzn projection (TUM).

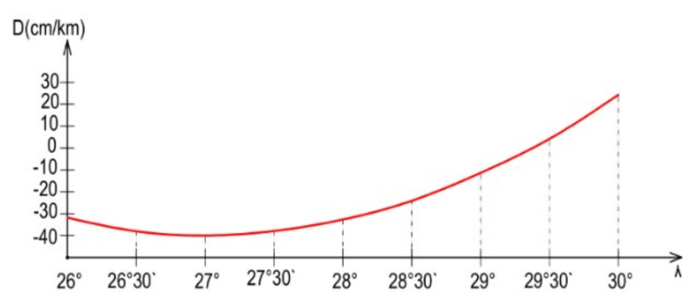


*Figure 17.* Relative linear deformations D (cm / km) at country average latitude = 47° in the ETRS89-TMzn projection (UTM)

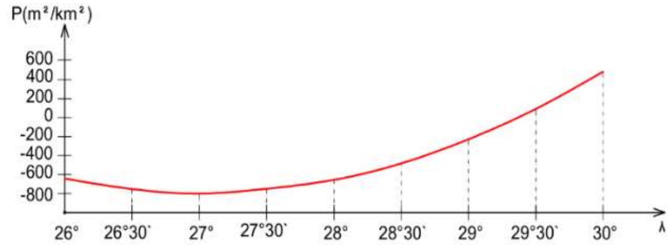


***Figure 18.*** Relative areolar deformations P ($m^2/km^2$) at country average latitude = 47 ° in the ETRS89-TMzn projection (UTM)

With the presented information available, a map of the deformation isolines is presented for the whole territory of the Republic of Moldova in which are represented by means of color scales, the values of the relative linear deformations in the UTM projection.

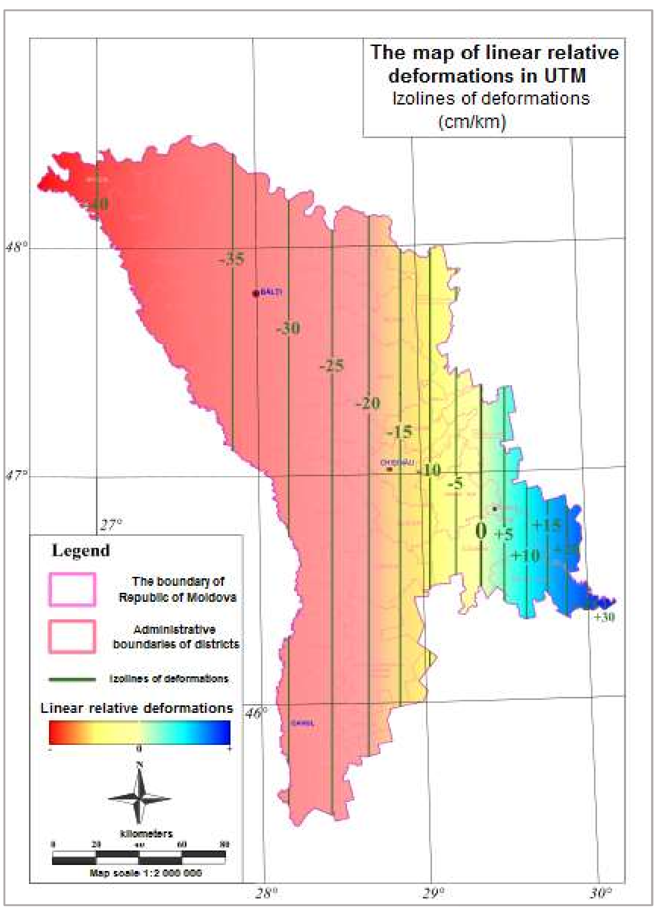


***Figure 19.*** Isolines of deformations on the territory of the Republic of Moldova in the UTM projection.

## 5. CONCLUSIONS

Using the International Association of Geodesy (IAG) recommendations on the use of European projections in view of the accession of the Republic of Moldova to the European Community in this article was studied the real possibilities of their application in our country.

Following the study of the European Lambert Azimuthal Equal Area projection (ETRS89-LAEA) for statistical analysis and visualization, it was found that:

– When the projection pole is taken in the center of Europe, deformations increase with the distance from the pole, and for our country the relative linear deformations to the direction of the parallels range from +4.78 m / km to +8.53 m / km, and in the direction of the meridians from -8.46 m / km to -4.76 m / km. Maximum angular deformations vary between [0°32' ÷ 0°44'];

– When the projection pole is taken in the center of the Republic of Moldova, the deformations increase with the deviation from the pole where the deformations are null and the relative linear deformations vary up to ± 12 cm / km (lower compared to the Transversal Mercator projection for Moldova [14]). Maximum angular deformations are in the range [0°00'00 "÷ 0°00'50"].

Following the study of Lambert Conformal Conic projection (ETRS89-LCC) designed to draw pan-European maps at scales smaller or equal than 1: 500,000, it was found that:

– When the projection pole is taken in the center of Europe, and the standard parallels $\varphi_{kS}$ = 35°; $\varphi_{kN}$ = 65°, on the territory of our country there are negative linear distortions from -33.59 m/km in the north, to - 30.20 m/km in the southern part of the territory. Relative areolar deformations vary from -66046 $m^2/km^2$ to -59488 $m^2/km^2$.

– When the projection pole is taken in the center of the Republic of Moldova, and the secant parallels on the territory of our country $\varphi_{kS}$ = 46°; $\varphi_{kN}$ = 48°, the deformations decrease greatly (approximately 20 times), so the linear deformations range from -15.18 cm/km to 19.17 cm/km and the areolar from -303.64 $m^2/km^2$ to +383.40 $m^2/km^2$.

Following the study of the European Transversal Mercator Projection (ETRS89-TMzn) which is identical to the Universal Transversal Mercator (UTM) projection recommended by the European

Commission for pan-European compliant maps at scales higher than 1: 500,000, it was found that:

– The zero strain lines cross the country's territory approximately at 180 km symmetrically to the axial meridian;

– The relative linear deformations have negative and positive values ranging between -40 cm/km on the axial meridian and +32 cm/km in the eastern part of the country;

– The relative areolar deformations have negative and positive values ranging from -800 m²/km² on the axial meridian and +650 m²/km² in the eastern part of the country.

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