Application of pan – European map projections on the territory of Republic of Moldova

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Abstract

Currently in the member countries or candidate of the European Union is recommended to use a single geodetic reference system and a single map projection for pan-European applications. In perspective of the integration of the Republic of Moldova into the European Union, besides the adoption of geodetic reference systems must be taken into consideration map projections compatible with those used for pan-European representations.

This paper represents a study on the main features of maps projections used in European countries and some possibilities on their application on the territory of Republic of Moldova, in terms of geographic position and the level of deformations produced by these projections. Following the study of the European Lambert Azimuthal Equal Area projection (ETRS89-LAEA) for statistical analysis and visualization, it was found that the smallest deformations are when the projection pole is taken in the center of the Republic of Moldova and the relative linear deformations vary up to ± 12 cm/km. In the Lambert Conformal Conic projection (ETRS89-LCC) designed to draw pan-European maps at scales smaller or equal than 1: 500 000, 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 linear deformations range from -15.18 cm/km to 19.17 cm/km. And in the European Transversal Mercator Projection (ETRS89-TMzn) recommended for pan-European compliant maps at scales higher than 1: 500 000, the linear deformations range from -40 cm/km on the axial meridian to +32 cm/km in the eastern part of the country. The results of this study could be used by Land Relation and Cadastre Agency for spatial data infrastructure development.

Keywords

Map projection, reference system, the relative linear deformations, standard parallel, axial meridian.

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1. 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].

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 on the territory of Republic of Moldova [2, 6].

For representation of data in plane coordinates for general applications were proposed the following systems [1]:

- for statistical analysis and visualization – *Pan-European Reference and Coordinate System with ETRS89 Datum in Lambert Azimuthal Equal Area* (ETRS89-LAEA);
- for conformal pan-European mapping at scales smaller or equal to 1:500 000 – *Pan-European Reference and Coordinate System with ETRS89 Datum in Lambert Conformal Conic* (ETRS89-LCC);
- for conformal pan-European mapping 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 area of INSPIRE transformation services in accordance with the standard EN ISO 19111 [3].

Therefore, a study will be made on the main features of map projections used in European countries as well some possibilities of representing the territory of the Republic of Moldova using recommended projections.

2. 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 parameters established for Europe are [4]:

- ellipsoid: GRS80;
- latitude of natural origin: $\varphi_0 = 52°00'00''$N;
- 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 formulas of the above mentioned map projections are published in the proceedings of the “Map Projections for Europe” [4] and for other map projections in working manual [5].

In the oblique LAEA projection we have distortions of distances and angles.

The 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 are presented in Table 1.

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 linear deformations relative at the longitude of the natural origin of the projection 28°30' is shown in the Figures 1-2.

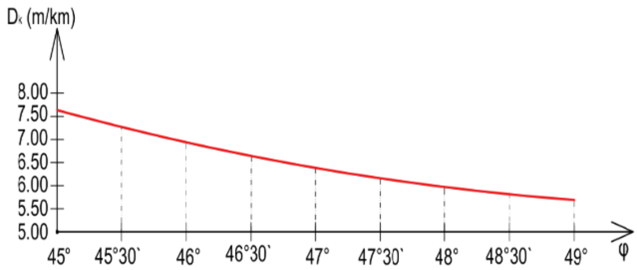

Fig. 1 Relative linear deformations D_k (m/km) in the direction of the parallels (λ = 28°30') in the LAEA projection with the pole in the center of the Europe

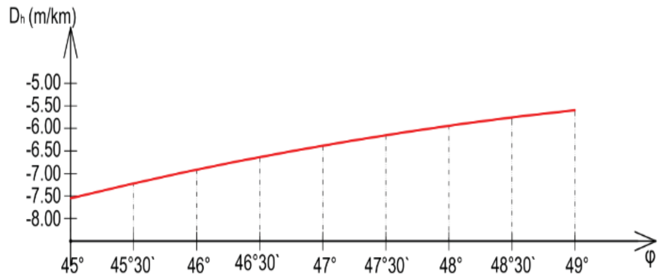

Fig. 2 Relative linear deformations D_h (cm/km) in the direction of the meridians (λ = 28°30') in the LAEA projection with the pole in the center of the Europe

The graphical distribution of maximum angular deformations at the longitude of the natural origin of the projection 28°30' is shown in the Figure 3.

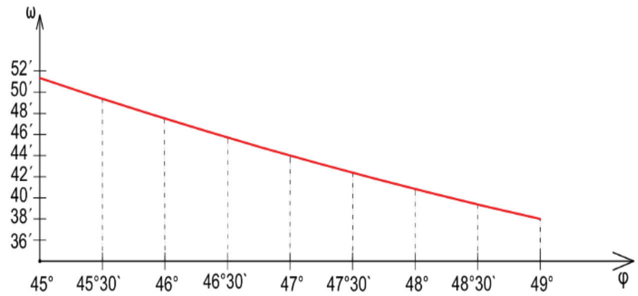

Fig. 3 The maximum angular deformations ω (') (λ = 28°30') in the LAEA projection with the pole in the center of the Europe

If we want to represent the territory of the Republic of Moldova in the Lambert azimuthal equal-area projection, as a pole of projection, the geometric center of our country of latitude 47°15' and longitude 28°30' has been taken.

In this case the 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 will vary according to the data presented in Table 2.

Table 2 The relative linear and angular deformations in the Lambert azimuthal equal-area projection for the Republic of Moldova (φ_0= 47°15' λ_0= 28°30')

φ/λ° ′	27°			28°		
	D_k (m/km)	D_h (m/km)	ω ° ′ ″	D_k (m/km)	D_h (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°**		
	D_k (m/km)	D_h (m/km)	ω ° ′ ″	D_k (m/km)	D_h (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

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 Figures 4-6.

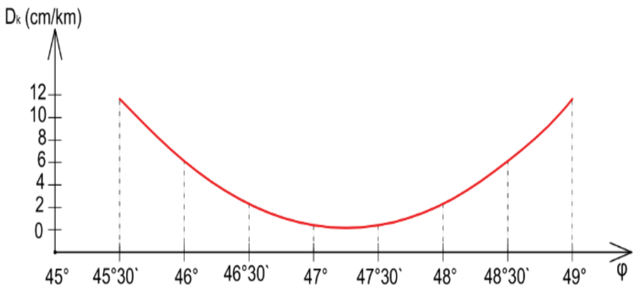

Fig. 4 Relative linear deformations D_k (cm/km) in the parallel direction (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova

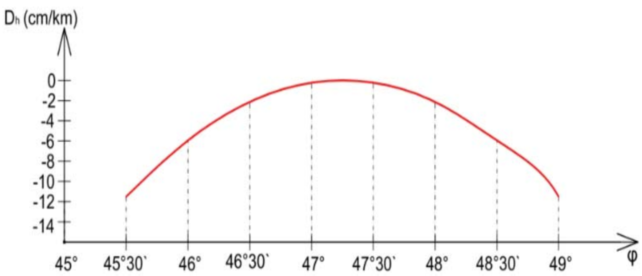

Fig. 5 Relative linear deformations D_h (cm/km) in the meridian direction (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova

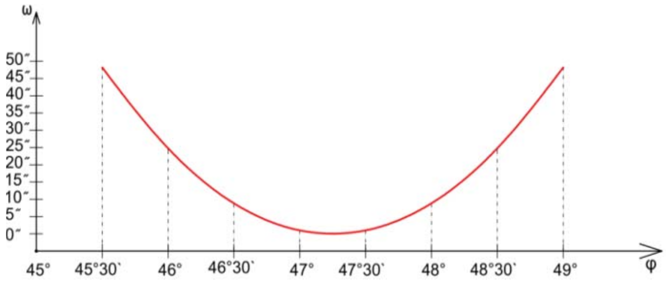

Fig. 6 The maximum angular deformations ω (") (λ = 28°30') in the LAEA projection with the pole in the center of the Republic of Moldova

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

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 φ_{kS} and the north φ_{kN}.

The LCC projection parameters for Europe are [4]:

- ellipsoid: GRS80;
- latitude of natural origin: φ_0 = 52°00′00″N;
- longitude of natural origin: λ_0 = 10°00′00″E;
- latitude of the 1st standard parallel: $\varphi_{kS} = \varphi_1$ = 35°;
- 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.

In the LCC projection, the angular deformations are zero, 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]. The values of these deformations for the geographic boundaries of Europe in the LCC projection will have the following variations shown in Table 3.

Table 3 Relative linear deformations D and relative areolar deformations P for Europe in the LCC projection (φ_{kS} = 35°; φ_{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 European territory, the following values of the deformations presented in Table 4 and Figures 7-8 will be produced.

Table 4 Relative linear deformations D and relative areolar deformations P for the Republic of Moldova in LCC projection (φ_{kS} = 35°; φ_{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

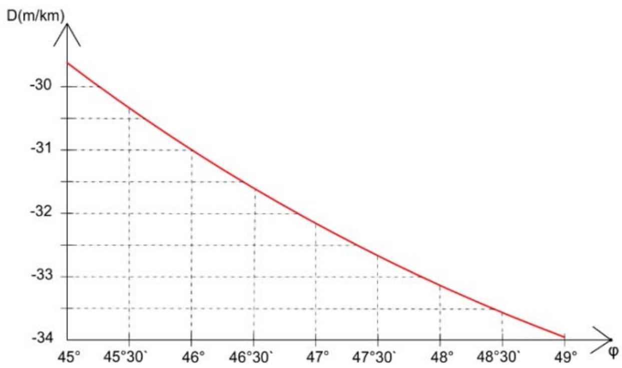

Fig. 7 Relative linear deformations D (m/km) for the Republic of Moldova in the LCC projection (φ_{kS} = 35°; φ_{kN} = 65°)

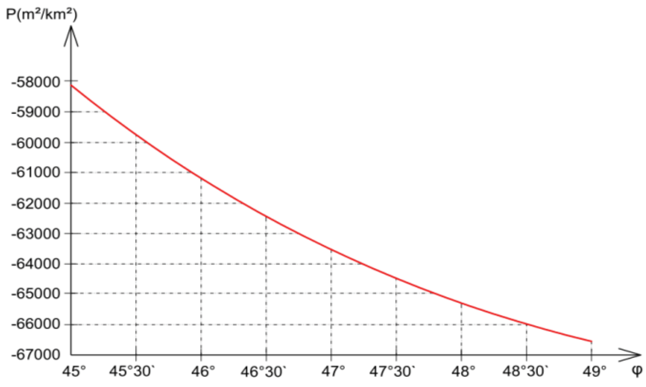

Fig. 8 Relative areolar deformations P (m²/km²) for the Republic of Moldova in the LCC projection (φ_{kS} = 35°; φ_{kN} = 65°)

The representation of the territory of the Republic of Moldova in the LCC projection can be performed by using 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 φ_{kS} = 46° and respectively φ_{kN} = 48° has been taken. Deformations according to these parameters established for the territory of our country we will produce the situation presented in Table 5 and Figures 9-10.

Table 5 Relative linear deformations D and relative areolar deformations P for the Republic of Moldova in LCC projection (φ_{kS} = 46°; φ_{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

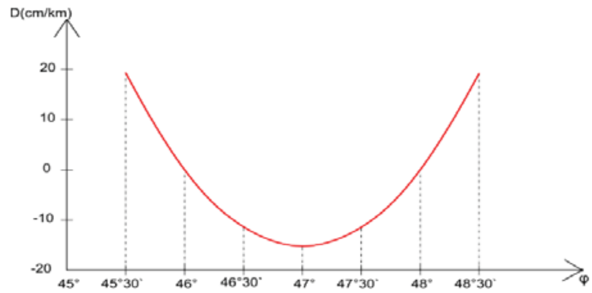

Fig. 9 Relative linear deformations D (m/km) for the Republic of Moldova in the LCC projection (φ_{kS} = 46°; φ_{kN} = 48°)

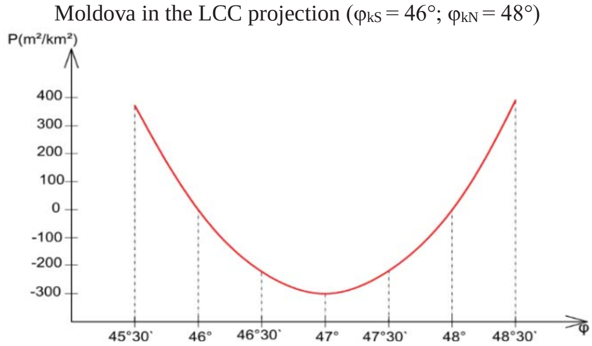

Fig.10 Relative areolar deformations P (m²/ km²) for the Republic of Moldova in the LCC projection (φ_{kS} = 46°; φ_{kN} = 48°)

4. 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 geodetic data recommended by the European Commission for pan-European mapping at scales larger than 1:500 000. 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 zone 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, except for the X band, that has a stretch of more than 4° (figure 11), situated between the parallels of North 72° -84° [6, 11].

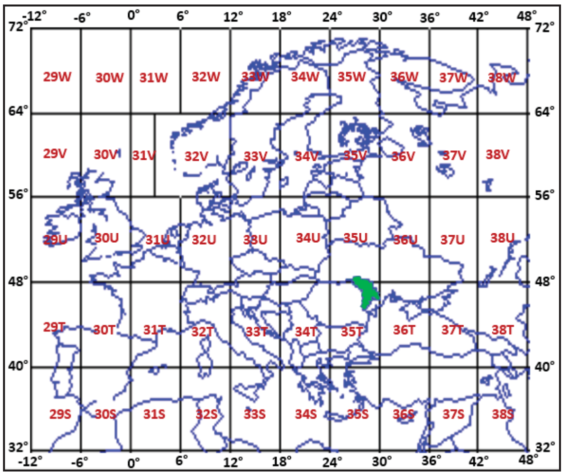

Fig. 11 European zones in the ETRS89-TMzn (UTM) projection

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

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 zero deformations relative to the axial meridian in each zone where negative linear deformations occur and on the outside they are positive.

In Table 5 and Figures 12-13 are presented the variation of deformations in the zone 35 for the territory of the Republic of Moldova in the TMzn projection.

Table 5 Relative linear deformations D and relative areolar deformations P for the Republic of Moldova in TMzn projection, zone 35 (λ_0=27°)

φ/λ	26° 30´		27°		27° 30´		28°	
	D cm/km	P m²/km²	D cm/km	P m²/km²	D cm/km	P m²/km²	D cm/km	P m²/km²
45°	-38,09	-761,66	-40,00	-799,84	-38,09	-761,66	-32,36	-647,13
45° 30´	-38,12	-762,33	-40,00	-799,84	-38,12	-762,33	-32,50	-649,81
46°	-38,16	-763,00	-40,00	-799,84	-38,16	-763,00	-32,63	-652,48
46° 30´	-38,19	-763,67	-40,00	-799,84	-38,19	-763,67	-32,76	-655,15
47°	-38,22	-764,34	-40,00	-799,84	-38,22	-764,34	-32,90	-657,82
47° 30´	-38,26	-765,00	-40,00	-799,84	-38,26	-765,00	-33,03	-660,48
48°	-38,29	-765,67	-40,00	-799,84	-38,29	-765,67	-33,16	-663,15
48° 30´	-38,32	-766,33	-40,00	-799,84	-38,32	-766,33	-33,30	-665,80
49°	-38,36	-766,99	-40,00	-799,84	-38,36	-766,99	-33,43	-668,45

φ/λ	28° 30´		29°		29° 30´		30°	
	D cm/km	P m²/km²	D cm/km	P m²/km²	D cm/km	P m²/km²	D cm/km	P m²/km²
45°	-22,81	-456,24	-9,45	-188,95	7,74	154,76	28,74	574,93
45° 30´	-23,12	-462,25	-9,98	-199,65	6,90	138,04	27,54	550,85
46°	-23,42	-468,27	-10,52	-210,34	6,07	121,33	26,34	526,78
46° 30´	-23,72	-474,28	-11,05	-221,03	5,23	104,63	25,13	502,73
47°	-24,02	-480,28	-11,59	-231,70	4,40	87,95	23,93	478,70
47° 30´	-24,32	-486,28	-12,12	-242,36	3,56	71,29	22,73	454,71
48°	-24,62	-492,26	-12,65	-253,00	2,73	54,66	21,54	430,75
48° 30´	-24,91	-498,24	-13,18	-263,63	1,90	38,06	20,34	406,84
49°	-25,21	-504,20	-13,71	-274,22	1,07	21,49	19,15	382,99

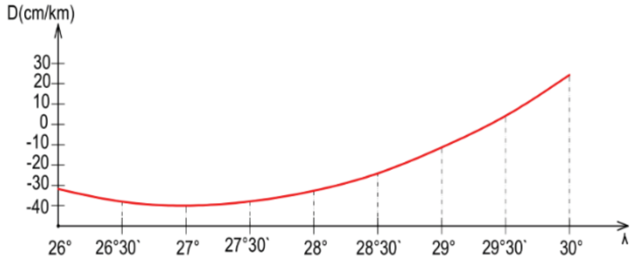

Fig. 12 Relative linear deformations D (cm / km) at country average latitude 47° in the ETRS89-TMzn projection

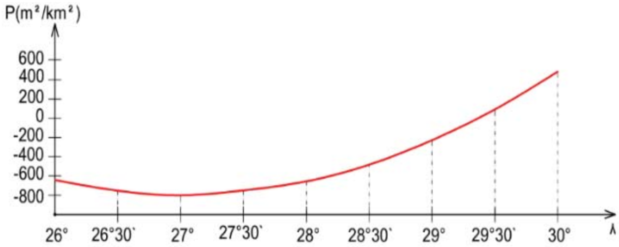

Fig. 13 Relative areolar deformations P (m^2/km^2) at country average latitude 47° in the ETRS89-TMzn projection

5. Conclusions

According to 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, results 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, results that:

- when the projection pole is taken in the center of Europe, and the standard parallels φ_{kS} = 35°; φ_{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 deformation 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 m^2/km^2 on the axial meridian and +650 m^2/km^2 in the eastern part of the country.

The results of this study are proposed to be taken into consideration for spatial data infrastructure development in Republic of Moldova by Land Relation and Cadastre Agency.

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