MOST COMMON STATE MAP PROJECTIONS FOR THE REPUBLIC OF KOSOVA

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ABSTRACT

In our efforts for defining of most relevant state map projection for the Republic of Kosova with the maximum nearness of distances between the referent ellipsoid (GRS 80) and map, firstly the quality of KOSOVAREF01 has been researched, followed by analyzes of the same coordinate system with three other variants with different scale factors. Due to eligibility of the Lambert conform conic and Stereographic projections to the form and dimensions of the territory of the Republic of Kosova, with several scale factors, they have been used for our analyses also, as well as the value of the linear deformations in UTM projection. In total, ten different results have been obtained from our analyses.

Analyses for research of most relevant state map projections have been done in a test model created as a grid with 10km distances between points. In a case of Gauss-Krűger and UTM projections, the meridian 21ºE was used as a central meridian, and in a case of Lambert conform conic and Stereographic projections the cross point between meridian with longitude 20º54'30"E and parallel with latitude 42º33'30"N has been used as the center of coordinate systems. Basic criteria's for choosing of most relevant state map projection are: the value of the largest linear deformation (as a main criteria), right dispersion of the linear deformations, adopting of the mathematical module for geodetic calculations, the value of mean linear deformations, sum of squares of linear deformations, mean value of linear deformations in 1km length, and the percent coverage with defined deformation.

From analyses of the official state coordinate system of Kosova (named as KOSOVAREF01), the linear deformations resulted in interval from -2.1 to -10cm/km, in which the mean linear deformation (MLD) is 8.7cm/km. In other hand in a second researched (tangential) variant, linear deformations are from 0 to 7.9cm/km, with the MLD 1.3cm/km. In first alternative case by defining of -4cm/km linear deformation along the central meridian (scale factor 0.99996), linear deformations are in interval from -4cm/km to 3.9cm/km, where 2.93cm/km is the MLD, and the second alternative

option with scale factor 0.999967 (-3.3cm/km) provides the linear deformations in interval from -3.3cm/km to 4.6cm/km, with the MLD from 2.46cm/km.

In a Lambert conform conic tangential projection the linear deformations are all with the positive prefix and they are in interval between 0 to 7.69cm/km, in which the MLD is 1.15cm/km. With aim to reduce the deformations in half value, -3.8cm/km (scale factor 0.999962) was used as extended option of Lambert conform conic projection, in which the linear deformations are from -3.8 to 3.89cm/km with the MLD 1.08cm/km.

During projecting of the territory of Kosova in Stereographic projection, in tangential case the linear deformations are from 0 to 4.18cm/km, in which MLD for the whole territory is 1.17cm/km. Utilization of negative linear deformation from -2.1cm/km (scale factor 0.999979) and -1.9cm/km (scale factor 0.999981), gives the interval of deformations from -2.1 to 2.08cm/km with 1.08cm/km MLD (for 0.999979), i.e. -1.9 to 2.28cm/km with 0.94cm/km MLD (for 0.999981).

Because of the small area of Kosova, utilization of UTM projection provides very large linear deformations, which are in interval between -32.11 and -40dm/km, where the MLD is 38.7cm/km.

Based on the results from analyses, most common state map projections of the Republic of Kosova for local use is the Stereographic projection with scale factor 0.99998, but utilization of UTM projection for international use is irreplaceable.

1. INTRODUCTION

The territory of the Republic of Kosova is located in a central part of the western Balkan, with 10908km^2 area and 744km border line, lengthened along the parallels, as well as along the meridians. Due to similar distances from the central to extreme points it has approximately a circle form, flattered in southeastern, southwestern, northeastern and northwestern places. Its central and extreme geographic coordinates (represented in ellipsoid GRS80) are given in next table (table 1). Dimensions of the trapeze, defined from the extreme points are: 144.1km the length of the northern parallel, 147.5km the length of the southern parallel, as well 186.6km length of the meridian.

Table 1. Geographic coordinates of the central and extreme points of Kosova

Point	Geographic coordinates (GRS 80)	
	φ	λ
North	43^0 16’07.5’’ N	20^0 49’01.9’’ E
South	41^0 50’50.1’’ N	20^0 37’36.8’’ E
East	42^0 38’48.0’’ N	21^0 47’42.7’’ E
West	42^0 44’10.4’’ N	20^0 01’10.9’’ E

Center	42^0 33’28.8’’ N	20^0 54’26.8’’ E

All official geodetic, cartographic and cadastral data of Kosova bases in own state coordinate system “KOSOVAREF01” (Meha, 2006), defined on year 2001 by the Kosova Cadastral Agency. Compared the new with old coordinate system, the differences are in utilized datum and ellipsoid, which can be seen in next table (table 2).

Table 2. Coordinate systems of the Republic of Kosova from year 1924 up to day

Name:	FryRef 30	KOSOVAREF01
Year of defining:	1924	2001
Period of utilization:	1924-2001	2001-ongoing
Datum:	Harmannsögel	ETRS89
Ellipsoid:	Bessel 1841	GRS 80
Map projection	Gauss–Krüger	Gauss–Krüger
Projecting zone:	7^{th}	7^{th}
Width of the zone:	3^0	3^0
Prime meridian:	Greenwich	Greenwich
Central meridian:	21^0	21^0
Origin of latitude:	Equator	Equator
False easting:	500000m	7500000m
False northing:	0m	0m
Scale factor:	0.9999	0.9999
Length units:	Meter	Meter
Origin of elevations:	Mareograph “Molo Sartorio” – Trieste, Italy	Mareograph “Molo Sartorio” – Trieste, Italy

Based on the theory of map projections (Idrizi, 2006), most common used state map projections in relation with the form of territory are: Gauss-Krüger projection for countries lengthened along the meridians, Lambert conform conic projection for countries lengthened along the parallels, stereographic projection for countries with the form nearness to circle, and the Mercator projection for the countries along the equator. From this criteria’s for selection and above data for the form and dimensions of the Kosova, it is so clear that probably the Gauss-Krüger, Lambert conform conic and stereographic projections can give most common projecting of the territory with the minimum differences between object dimensions in ellipsoid and projection.

Analyses for research of most appropriate state map projections have been done in test model with 108 points in 10km distances between them, defined with their geographic coordinates in ellipsoid GRS 80.

Basic criteria’s for choosing of the most appropriate state map projection according to all standards from the mathematical cartography are (Shehu, 1971):

- the value of the largest linear deformation (main criteria),
- right dispersion of the linear deformations, and
- adopting of the mathematical module for geodetic calculations.

Beside above criteria's, the value of mean linear deformations (Θ), sum of squares of linear deformations ($\Sigma\Delta d\Delta d$), mean value of linear deformations in 1km length (m_0), and the percent coverage with defined deformation (Shehu, 1982), based on grid test model have been obtained as extended criteria's for research also.

2. PROJECTING OF TERRITORY OF KOSOVA IN GAUSS-KRÜGER PROJECTION WITH SEVERAL SCALE FACTORS

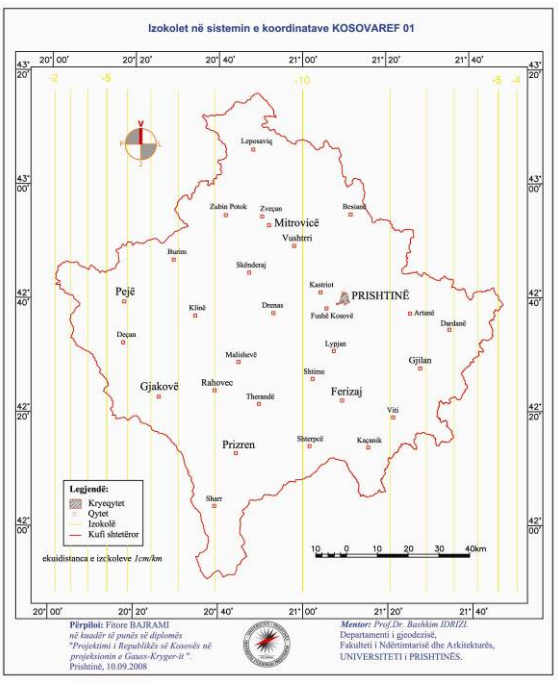
The Gauss-Kruger projection as official for projecting of all objects from ellipsoid to the projection has been in use for the territory of Kosova more than 90 years. During this period, nobody has analyzed the level of adaptability to form and dimensions of Kosova. In a period before year 1999, due to fact that Kosova was a part of former Yugoslavia, it was impossible to make this kind of analyses only for territory of Kosova. After its independence, during defining of new state coordinate system, KCA have obtained map projection with all parameters from older one, without any scientific research for most common state map projection.

With target to find out the most common map projection with minimum values of linear deformations, i.e. nearness length of distances between ellipsoid and projection, firstly the state map projection, as well as the tangential chase has been analyzed. In figure 1 are given the isocholes of state map projection of Kosova in interval 1cm/km, where can be seen so clear that all deformations have the negative prefix.

With aim to dimidiate the maximum linear deformation calculated in tangential case, as a third variant have been used the -4cm/km negative linear deformation along the central meridian (21ºE). Isocholes of this third variant are shown in figure 2.

Because of the difference between linear deformation at eastern and western extreme points, which is the result of difference distances between central meridian (21ºE) and those points, the average value of deformations on extreme eastern and western points (3.3cm/km) has obtained as fourth researched variant.

Results from above four researched variants are given in table 4, where it is so clear that the variant with smaller mean linear deformation is tangential variant, and Gauss-Krűger projection with scale factor 0.99996 gives the smaller value of largest linear deformations.



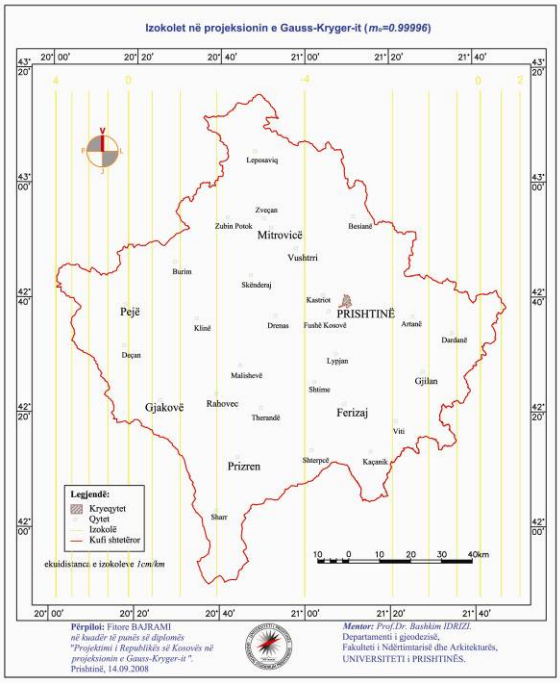


Figure 1. Isocholes in KOSOVAREF01 (Bajrami, 2008)
Figure 2. Isocholes in Gauss-Krűger projection with scale factor 0.99996 (Bajrami, 2008)

3. PROJECTING OF TERRITORY OF KOSOVA IN LAMBERT CONFORM CONIC PROJECTION WITH SEVERAL SCALE FACTORS

In a case of using of Lambert conform conic projection, Kosovas modified center point represents the beginning of coordinate system. With aim to eliminate negative orthogonal coordinates, its false easting and northing values followed by geographic coordinates are given in next table 3.

Table 3. Geographic and orthogonal coordinates of central point in all variants of Lambert conform conic and stereographic projection

φ_0	λ_0	*Y (m)*	*X (m)*
42º 33’30” N	20º 54’30” E	7500000	4500000

With target to calculate the largest linear deformation in a case of Lambert projection, tangential variant with central parallel (42º 33’30”N) was analyzed. In a same way as in previous step, with target to dimidiate linear deformations by implementing of negative linear deformation along the central parallel with value equal to halve of maximum linear deformation from the tangential case, as well as to have the right dispersion of deformations in all territory of Kosova, negative linear deformation of -3.8cm/km (scale

factor 0.999962) along the central parallel have been utilized. Dispersion of isocholes for this variant is given in next figure 3.

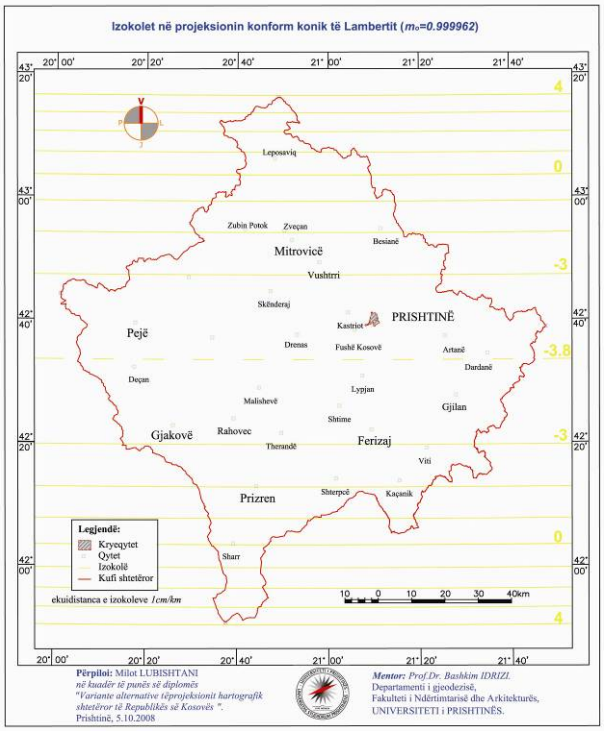


Figure 3. Isocholes in Lambert projection with scale factor "0.999962" (Lubishtani, 2008)

Results from above two researched variants of Lambert conform conic projection are given in table 4, where can be seen so clear that the variant with smaller MLD is tangential variant with scale factor 1, and the Lambert projection with scale factor 0.999962 gives the smaller value of linear deformations.

4. PROJECTING OF TERRITORY OF KOSOVA IN STEREOGRAPHIC PROJECTION WITH SEVERAL SCALE FACTORS

The same way of research has been used in a case of utilization of Stereographic projection as Kosovas map projection also. Beginning of coordinate system in this case was defined at cross point between the parallel with the value of latitude *42º 33'30"N* and meridian with longitude *20º 54'30"E,* which defines the central point of Kosova. Values of false easting and northing are the same as in a previous used projection, i.e. table 3.

Stereographic projection as third utilized map projection for finding of most common state map projection, according to characteristics of this projection and the dimensions and form of Kosova, gives the possibilities for right dispersion of linear dimensions

from central to extreme points. Because of the need to define the largest linear deformation, firstly the tangential variant, i.e. without negative linear deformations, has been used. Due to tangential touch between ellipsoid and projections flat, all deformations are with positive prefix, except very small area without deformations.

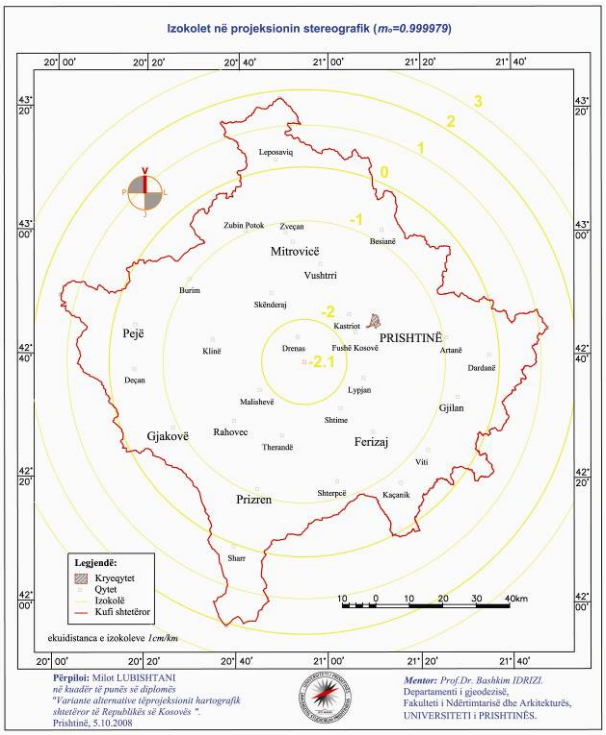


Figure 4. Isocholes in Stereographic projection - scale factor "0.999979" (Lubishtani, 2008)

With the similar methodology of dimidiating of linear deformations with implementing of negative linear deformation with value equal to halve of maximum linear deformation from the tangential case, firstly negative linear deformation of -2.1cm/km, i.e. scale factor 0.999979 have been utilized. Dispersion of isocholes for this variant are given in figure 4.

Due to differences between linear deformations on extreme points of Kosova, the scale factor of the third variant of this kind of projection was calculated as average value from four deformations on extreme points calculated in first (tangential) variant. After calculation, third variant has a scale factor 0.999981, which means that linear deformation in central point is -1.9cm/km.

Results from above three researched variants of stereographic projection are given in table 4 also, where it is so clear that the variant with smaller mean linear deformation is the variant with scale factor 0.999981, and stereographic projection with scale factor 0.999979 gives the smaller value of linear deformations.

5. PROJECTING OF TERRITORY OF KOSOVA IN UTM PROJECTION

At the end of research, an analysis of the level of utilization of UTM projection is inalienable. It descends from the international importance of UTM projection. According to tile reference, all territory of Kosova belongs to 34th zone of UTM projection, with central meridian 21ºE.

Six degrees width of projecting zones, directly have an impact to largest deformations in comparison with previous options. Because of the big difference between the width of UTM projection zone (6º longitude) and width of the territory of Kosova (1º46'31.8" longitude), utilization of UTM projection provides so large linear deformations, which can be seen in table 4. Dispersion of isocholes is given in next figure 5.

In this case there aren't possibilities to use other values of scale factor, because the UTM projection has forward defined parameters, which can't be modified.

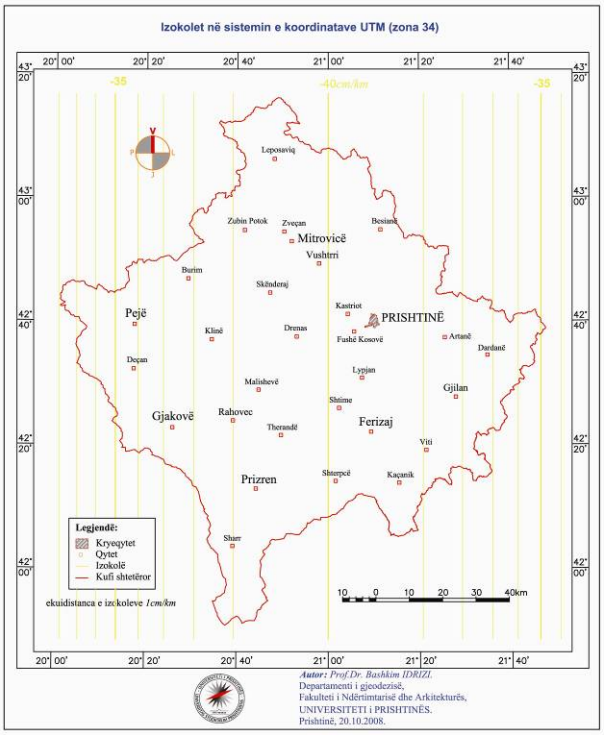


Figure 5. Isocholes in UTM projection – zone 34 (Idrizi, et al., 2009)

Table 5 Results from researched map projections

	Gauss-Krűger				UTM
	KOSOVARE F01	mo=1	mo=0.99996	mo=0.999967	mo=0.9996
Θ	8.7cm/km	1.3cm/km	2.93cm/km	2.46cm/km	38.7cm/km
ΣΔdΔd	8440.26 (cm/km)2	452 (cm/km)2	1055 (cm/km)2	746 (cm/km)2	161988 (cm/km)2
m₀	8.84cm/km	2.05cm/km	3.13cm/km	2.63cm/km	38.73cm/km
dmax	-10cm/km	7.9cm/km	-4cm/km	4.6cm/km	-40cm/km
of deformatio	-2.1 to -10 cm/km	0 to 7.9cm/km	-4 to 3.9 cm/km	-3.3 to 4.6 cm/km	-32.11 to -40 cm/km
d positive	-	87.30%	7.04%	10.85%	-
d negative	100%	-	92.45%	88.48%	100%
d without deformatio	-	12.70%	0.51%	0.67%	-
	Lambert conform conic		Stereographic projection		
	mo=1	mo=0.999962	mo=1	mo=0.999979	mo=0.999981
Θ	1.14cm/km	2.85cm/km	1.17cm/km	1.08cm/km	0.94cm/km
ΣΔdΔd	374 (cm/km)2	993 (cm/km)2	219 (cm/km)2	164 (cm/km)2	128 (cm/km)2
m₀	1.86cm/km	3.03cm/km	1.42cm/km	1.23cm/km	1.09cm/km
dmax	7.69cm/km	-3.8cm/km	4.18cm/km	-2.1cm/km	2.28cm/km
of deformatio	0 to 7.69 cm/km	-3.8 to 3.79 cm/km	0 to 4.18 cm/km	-2.1 to 2.08 cm/km	-1.9 to 2.28 cm/km
d positive	84.34%	92.51%	97.67%	12.04%	16.46%
d negative	-	7.11%	-	85.89%	80.91%
d without deformatio	15.66%	0.38%	2.33%	2.07%	2.63%

Table 6. Area and border line length of the Republic of Kosova projected in analyzed map projections

Map projection	Area	Border line
KOSOVAREF 01 (Gauss-Krüger, m_o=0.9999)	10906.05 km^2	744.042 km
Gauss-Krüger (m_o=1)	10908.23 km^2	744.117 km
Gauss-Krüger (m_o=0.99996)	10907.36 km^2	744.087 km
Gauss-Krüger (m_o=0.999967)	10907.51 km^2	744.092 km
Stereographic (m_o=1)	10908.23 km^2	744.118 km

Stereographic (m_o=0.999979)	10907.77 km^2	744.103 km
Stereographic (m_o=0.999981)	10907.81 km^2	744.104 km
Lambert conform conic (m_o=1)	10908.20 km^2	744.118 km
Lambert conform conic (m_o=0.999962)	10907.38 km^2	744.090 km
UTM	10899.50 km^2	743.819 km

6. CONCLUSIONS

The state coordinate system of the Republic of Kosova (KOSOVAREF01) bases to ETRS89 datum (ellipsoid GRS80) and Gauss-Krüger projection with 1dm/km negative linear deformation (scale factor 0.9999) along the central meridian (21°E). Interval of linear deformations is from -1dm/km to -2.1cm/km, in which the mean linear deformation for all territory is 8.7cm/km, and 9.04cm/km in Kosova cities.

In efforts for defining of new coordinate system with the maximum nearness of distances, Gauss-Krüger projection with scale factors 0.99996, 0.999967 and 1, Stereographic projections with scale factors 1, 0.999979 and 0.999981, Lambert conformal conic projection with scale factors 1 and 0.999962, and the UTM projection were researched also.

From all above researched options, most common values gives the Gauss-Krűger projection in tangential variant (with scale factor 1), Stereographic projection with scale factor 0.999979 and Lambert conform conic projection with scale factor 0.999962.

Based on results from research, most common state map projection of the Republic of Kosova for internal use is Stereographic projection with scale factor 0.999979, however utilization of UTM projection for international use is irreplaceable.

In the case of stereographic projection with scale factor 0.999979, linear deformations are in interval from -2.1 to 2.08cm/km, in which the mean value of deformations is 1.08cm/km.

Due to small area of Kosova, utilization of UTM projection provides very large linear deformations, i.e. in interval between -32.11 to -40dm/km, with mean deformation in all territory is 38.7cm/km.

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