# TRANSFORMATION OF THE FORMER AUSTRIAN CADASTRE MAP

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**Summary**

The aim of the present work is to show and compare the process of transforming the map of the former Austrian cadastre from the analogue format to the numerical version, in connection with its still valid application in geodetic-legal, urban design, and planning processes. These include, inter alia, litigation and court cases regarding the extent of ownership of real estate, work related to real estate management (divisions and demarcations), use of maps of former cadastral systems in the process of land consolidation, or modernization of land and building registers and creation of a digital cadastral map, as well as any research studies pertaining to the analysis of spatial changes in the natural environment.

Within the defined scope of research, the following steps were taken: calculation of corner coordinates of the sectional frame, transformation of the obtained coordinates from the KUL system into the "2000" system, followed by calibration and raster vectorization. The calibration process was performed using three different computer software applications, which are used on a daily basis by surveying companies throughout Poland.

Serving as the material for research, a cadastral map of the village of Strzelce Wielkie in the Szczurowa municipality was adopted, that had been acquired from the State Archives in Kraków.

**Keywords**

Geodesy • cadastre • transformation • calibration

## 1. Introduction

A cadastral map is a large-scale study of the Earth's surface in space and time. Being the cadastral map, it contains information such as boundaries defining the scope of ownership, as well as the objects of utility networks and land quality division. This allows us to study and identify changes taking place in space, in selected time periods.

In 1772 Poland lost its independence, and it was divided between the three neighbouring countries: Prussia, Austria and Russia. The southern part of the country was taken over by the Austrian Empire; in this particular area, starting from 1732, work continued on cadastral maps and related land records. The main layout used in southern Poland was the Lviv system, originating at the Wysoki Zamek hill in Lviv. All the

records in this system were created according to a uniform representation by Cassini-Soldner.

After the Second World War, the maps of the former Austrian cadastre, in particular in the area of most of the present-day Małopolska and Podkarpacie regions, constituted the basis for the development of cadastral maps referred to as derivatives of maps of the former Austrian Partition. Therefore, maps of the former Austrian cadastre are still used today as a source or evidence in many geodetic and legal studies. The necessary step enabling the use of these materials is their transformation from the cadastral system to the "2000" system. The result of such a transformation is a numerical (digital) map that facilitates comparison between the two legal statuses, which is why it is an important reference in the regulation of legal status, property divisions, mergers, modernization of land and building registers and taking over real estate for public purposes.

## 2. Description of research methodology

The indirect transformation of the analogue map into digital map was developed by a team of researchers at the Hugo Kołłątaj University of Agriculture in Kraków under the direction of professor Karol Noga, PhD Eng. The method is based on the determination of transformation formulas, while using for this purpose the algorithms of computer software applications, and coordinates of cadastral triangulation points from the Catalogue of the Geographic Survey [Michałowski, Sikorski 1932].

The method is based on the scheme proposed by Kubowicz [2007] and Taszakowski [2011], consisting in:

- performing analogue map scans, using professional high-resolution equipment;
- calculating the coordinates of the corners of the sectional frame in the cadastral system;
- calculating transformation coefficients based on adjustment points;
- transformation of cadastral coordinates to the current system (second degree flat conformal transformation);
- initial raster calibration (pre-calibration), based on the calculated coordinates (affine transformation);
- precise (detailed) raster calibration by identifying points, for instance from the current map (polynomial transformation – affine third degree);
- accurate vectorization.

## 3. Transformation of coordinates

The scanned cadastral maps were graphically processed, by cutting the raster grid to the nominal format of the cadastral map section, and by brightening or darkening certain areas of the raster maps. Then the map sheet identification number was read from the map sheet for each section, after which the coordinates of the corners of the sectional frame in the cadastral layout were calculated, using the following formulas:

$$X = (W - 17) \cdot 7585.935 \text{ m} + g \cdot 1517.19 \text{ m}$$
$$Y = (K - 1) \cdot 7585.936 \text{ m} + (p - 1) \cdot 1896.48 \text{ m}$$

where:

- W – the number of rows given in the map sheet identification number for the particular section
- K – the number of columns given in the map sheet identification number for the particular section
- G – the number of sections, calculated in the southerly direction (e = 1, f = 2, g = 3, h = 4, I = 5)
- p – the number of sections, calculated in the westerly direction ( a = 1, b = 2, c = 3, d = 4)

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TRANSFORMACJA PŁASKA w systemie <GEONET 2006> (c)ALGORES-SOFT
www.geonet.net.pl
---------------------------------------------------------------
DATA:
OBIEKT ROBOCZY: c:\GEONET\Obiekty\TRANSFORMACJA_MAPY_KATASTRALNEJ
WYKONAWCA:


MODEL: TRANSFORMACJA KONFOREMNA stopnia 2
DANE WEJŚCIOWE:
  Liczba danych punktów zbioru pierwotnego (xy1) = 30
  Zweryfikowana liczba punktów zbioru (xy1)      = 30
  Liczba danych punktów zbioru wtórnego (xy2)    = 14
  Zweryfikowana liczba punktów zbioru (xy2)      = 14
  Liczba punktów wspólnych (xy1) i (xy2)         = 14
---------------------------------------------------------------
WYKAZ WSPÓŁRZĘDNYCH PUNKTÓW DOSTOSOWANIA
                       Układ pierwotny            Układ wtórny
         Nr         x1          y1            x2           y2
     48031022   49165.4600  -232626.0160   5567590.5570  7484105.1480
     48031023    4894.3900  -236368.3400   5523210.1940  7482165.0380
     48031024   47440.1430  -233271.0180   5565840.6440  7483530.9430
     48031025   46048.5320  -229712.1080   5564595.2040  7487142.3300
     48031026   43168.5000  -242106.8300   5561213.4590  7474878.6400
     48031027   42748.4200  -234779.1600   5561092.0430  7482215.0500
     48031028   41644.6200  -238032.5700   5559856.8850  7479010.1670
     48031030   38732.5700  -240748.0500   5556837.1000  7476416.0510
     48031033   36380.9800  -246067.6900   5554271.2100  7471197.9890
     48031034   35332.4300  -232060.1400   5553793.8590  7485232.1470
     48031035   35185.7000  -252173.8600   5552828.4600  7465147.3320
     48031036   34168.2800  -247509.3200   5552001.9420  7469847.8870
     48031041   30957.2500  -257470.9900   5548388.3460  7460028.0420
     48031049   23374.1200  -244541.4000   5541339.0740  7473250.8710
PARAMETRY OGÓLNE:
  Srodki ciężkości zbiorów punktów dostosowania:
  Układ pierwotny (1):     36374.3854    -240533.3923 (xo, yo)
  Układ wtórny   (2):   5554489.9269    7476726.2596 (Xo, Yo)
  Skala numeryczna = 3.14907719108037E-0005
WSPÓŁCZYNNIKI WIELOMIANU ZESPOLONEGO I BŁEDY ŚREDNIE
  a[0]:= -1.99606767474649E-0001    blad śr.= 1.60902281235736E-0001
  b[0]:=  2.20652491708516E-0001    blad śr.= 1.60902281235736E-0001
  a[1]:=  3.17229803359633E+0004    blad śr.= 4.17622679137318E-0001
  b[1]:= -1.29288943392732E+0003    blad śr.= 4.17622679137318E-0001
  a[2]:=  5.73100251776155E-0002 ~0 blad śr.= 6.07102795971575E-0001
  b[2]:= -3.87089320921884E+0000    blad śr.= 6.07102795971575E-0001
```

Source: authors' study based on GEONET system

**Fig. 1.** Fragment of a transformation report in the GEONET system

The next step was to determine transformation formulas, which facilitated the transition from the Lviv system to the "2000" system. The determination of transformation formulas between the Lviv system and the "2000" system was made on the basis of the existing grid points, for which coordinates were identified in both systems. To this end, the coordinates of cadastral points from the *Katalog Służby Geograficznej* [Catalogue of the Geographic Survey] were applied [Michałowski J., Sikorski T. 1932], and the coordinates of the points corresponding to them in the current system were found in the *Podgik* resources in Brzesko. The accuracy of the assumed adaptation points was checked using the Helmert distortion-free transformation. Ultimately, 14 adjustment points were adopted for the transformation between the systems. On the basis of these points, the final transformation coefficients were determined using the *Geonet* software application by *Alores-Soft* of Rzeszów. A second-degree conformal plane transformation was used for the purpose. The mean transformation error was 0.576 m.

In order to minimize errors, the transformation model should be selected appropriately. When choosing the Helmert transformation, the accuracy of the location of the adjustment points is an important issue, whereas their distribution is of low importance. With affine transformation, it is the distribution of points that plays the key role, whereas the accuracy of their location is not very important. [Hanus P. 2006].

When choosing the type of transformation, it is always necessary to pay attention to its particular characteristics. It is essential to take into account the limitations to the permissible image distortions with respect to the original system, that is the conformity, affinity and the degree of the polynomial of the transformation function. [Kadaj R. 2002].

Based on the adjustment points presented in Figure 1, the coordinates of the corners of the detailed raster section frames from the Lviv system to the "2000" system were transformed, and the results were summarized in Table 1.

**Table 1.** Calculated coordinates of the corners of the section frame in the Austrian cadastre maps, in the KUL and 2000 systems

| Markings in the map sheet identification number | Section frame corner coordinates | | | |
|---|---|---|---|---|
| | KUL | | 2000 | |
| | X | Y | X | Y |
| W.C. XXXIII 12 de | 36407.58 | −248407.94 | 5554202.36 | 7468859.13 |
| W.C. XXXIII 12 df | 34890.39 | −248407.94 | 5552686.73 | 7468920.87 |
| W.C. XXXIII 12 cf | 34890.39 | −246511.46 | 5552763.98 | 7470815.32 |
| W.C. XXXIII 12 ce | 36407.58 | −246511.46 | 5554279.70 | 7470753.61 |
| W.C. XXXIII 12 bf | 34890.39 | −244614.98 | 5552841.25 | 7472709.77 |
| W.C. XXXIII 12 dg | 33373.20 | −248407.94 | 5551171.16 | 7468982.61 |
| W.C. XXXIII 12 cg | 33373.20 | −246511.46 | 5551248.35 | 7470877.04 |

| | | | | |
|---|---|---|---|---|
| W.C. XXXIII 12 bg | 33373.20 | −244614.98 | 5551325.59 | 7472771.48 |
| W.C. XXXIII 12 dh | 31856.01 | −248407.94 | 5549655.60 | 7469044.32 |
| W.C. XXXIII 12 ch | 31856.01 | −246511.46 | 5549732.77 | 7470938.74 |
| W.C. XXXIII 12 bh | 31856.01 | −244614.98 | 5549809.94 | 7472833.16 |
| W.C. XXXIII 12 ci | 30338.82 | −246511.46 | 5548217.14 | 7471000.39 |
| W.C. XXXIII 12 bi | 30338.82 | −244614.98 | 5548294.28 | 7472894.81 |
| W.C. XXXIII 12 be | 28822.62 | −244614.98 | 5546779.55 | 7472956.38 |
| W.C. XXXIII 12 ai | 30338.82 | −242718.50 | 5548371.42 | 7474789.25 |
| W.C. XXXIII 12 ae | 28822.62 | −242718.50 | 5546856.68 | 7474850.83 |

Source: authors' study

## 4. Raster calibration using the *EwMapa* software application

The raster calibration process can be divided into two stages. The first one is *pre-calibration*, based on affine transformation, which consists in fitting the raster to the nominal frame, created from the previously calculated coordinates (Figure 2). The second stage is a *precise (detailed) calibration*, in which the third degree polynomial transformation is applied. In this latter case, pairs of points at the break of the boundaries between plots and parcels on the raster maps are identified, along with their corresponding points on the cadastral map, for instance. The most characteristic points should be chosen, such as the angles of the original plots of land.
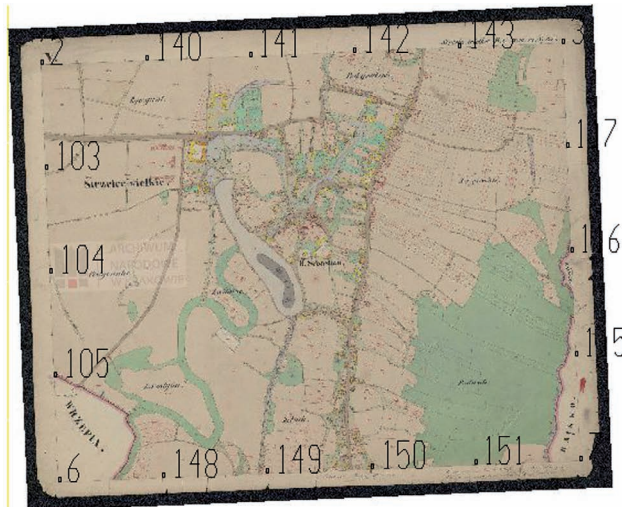


Source: authors' study

**Fig. 2.** Raster fitted into the frame, after the affine transformation

In the *EwMapa* software application, the raster calibration is performed in a very simple and fast way. First, the raster needs to be imported into the software, and placed in the appropriate, previously prepared field.

In the next step, the previously calculated and transformed coordinates of the section frame corners need to be applied. After selecting the appropriate (affine) transformation, the points from the scan must be identified with the imported coordinates. First, the point of the sectional frame must be marked with an inch division, which will be highlighted in green, and then its equivalent must be marked on the map base, whereupon the point on the grid will be highlighted in blue. After doing this, the raster map needs to be placed in the appropriate location, in the "2000" system.

In addition to visual control, mathematical control is performed in the *EwMapa* software application. This particular software provides the mean error as well as the position error at every adjustment point. As a result, the user learns which point should be corrected immediately; is able to quickly capture gross errors; and also knows if the final calibration is correct.

**Table 2.** Mean error of pre-calibration in the frame of a detailed section

| Section frame No. | Scan No. | Mean error [m] |
|---|---|---|
| I | 1 | 0.37 |
| II | 2 | 0.37 |
| II.ad | 3 | 0.28 |
| III | 4 | 0.60 |
| IV | 5 | 0.72 |
| V | 6 | 0.30 |
| VI | 7 | 0.41 |
| VII | 8 | 0.85 |
| VIII | 9 | 0.50 |
| IX | 10 | 0.42 |
| X | 11 | 0.81 |
| XI | 12 | 0.31 |
| IX.ad | 13 | 0.51 |
| XII | 14 | 0.77 |
| XIII | 15 | 0.63 |
| **Mean error** | | **0.52** |

Source: authors' study

The mean error was 0.52 m, whereas the maximum permissible error amounted to 1.50 m. The biggest mean error was obtained on the scan number 8 and amounted to 0.85 m, while the smallest mean error was 0.28 m for the scan number 3 (Figure 3).
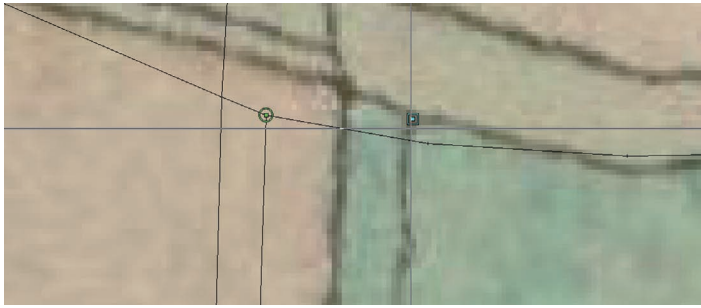
Source: authors' study

**Fig. 3.** Detailed calibration using the EwMapa software

The second stage of the calibration was performed on the foundation of the current cadastral map base. The process consisted in choosing pairs of points on the raster map and on the cadastral map, coupled with their identification. Over the years, the layout of plots and roads has changed significantly, which caused numerous problems when selecting characteristic points.

**Table 3.** Mean error of precise calibration

| Section frame no. | Scan no. | Mean error [m] |
|---|---|---|
| I | 1 | 1.61 |
| II | 2 | 2.69 |
| II.ad | 3 | 1.95 |
| III | 4 | 1.49 |
| IV | 5 | 1.37 |
| V | 6 | 2.77 |
| VI | 7 | 1.60 |
| VII | 8 | 1.83 |
| VIII | 9 | 1.96 |
| IX | 10 | 1.75 |
| X | 11 | 2.39 |
| XI | 12 | 2.92 |
| IX.ad | 13 | 2.14 |
| XII | 14 | 2.07 |
| XIII | 15 | 2.24 |
| **Mean error** | | **2.05** |

Source: authors' study

Despite the fact that most of the raster maps had numerous mechanical damages, the mean error was 2.05 m, therefore the accuracy was satisfactory as this falls within the maximum permissible error (Mt < 3.00 m) for rural areas when switching from analogue to digital map. From the table provided, it is evident that the raster maps number 6, 9, 11, 12, 13, 14 and 15 were the most damaged (torn, covered, dirty and/or creased from folding).

## 5. Calibration in other computer software applications

Further research was conducted based on the calibration of one section frame, and performed in two other software applications.

The raster calibration in the *MicroStation V8i* software application without the use of thematic overlays is similar to the one discussed earlier in the *EwMapa* software. The main difference is that with the *MicroStation V8i* software we do not get any reports or information about the mean error. The only way for the user to control the result is visually, which basically excludes this software from calibration applications in surveying work. The software performs pre-calibration and detailed calibration by affine transformation.

The first stage of the calibration is to import a raster file using the raster file manager. Then the calculated coordinates are imported, and the points are identified (Figure 4).
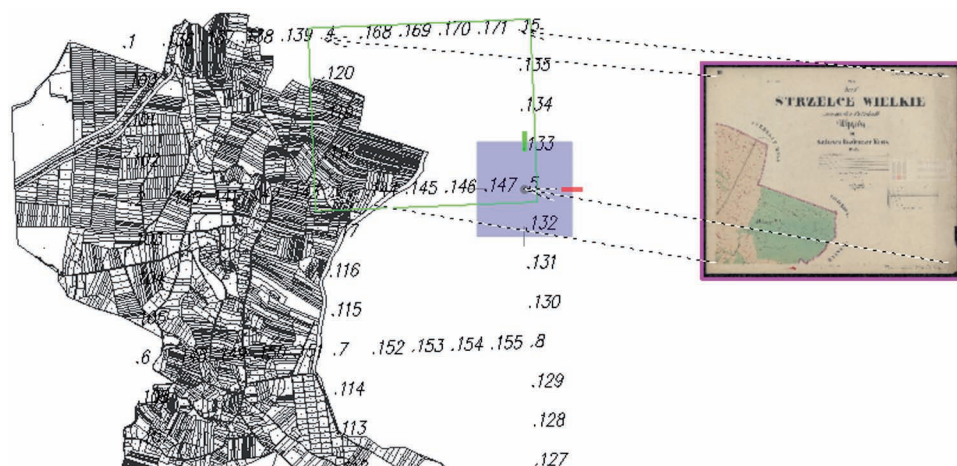


Source: authors' study

**Fig. 4**. Calibration using the Microstation V8i software

For the same section frame, the calibration was performed using the third software application. This time, the *GeoX* tool was used, under the name of *KaliBronek*, which is an overlay for CAD-type software, such as *AutoCAD* or *MicroStation*. Due to the fact

that the calibration had already been performed in the *Bentley* application, this time the *AUTODESK AutoCAD 2015* software was used.

The scheme of operation of this software overlay is the same as in the previously used applications. It consists in connecting the calculated and the imported coordinates, with a line, to the corresponding points on the raster map.

After connecting all the necessary points, the affine calibration begins in a separate dialog box, and you get a modified foundation (map base) in the file with the .jpg extension, as well as the transformation report, such as the one presented in Figure 5.



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RAPORT Z KALIBRACJI RASTRA
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Raster źródłowy:
C:\Users\Arek\Desktop\4afiniczna.jpg
Raster skalibrowany:
C:\Users\Arek\Desktop\4Wielomianowa.jpg

Metoda transformacji:
 wielomianowa 3 stopnia (bicubic)
 Zastosowano poprawki Hausbrandta

Parametry transformacji
a0=5553341.130, a1=1.0066056, a2=0.0042224, a3=0.0000093, a4=0.0000037, a5=-0.0000088,
a6=0.0000000, a7=0.0000000, a8=0.0000000, a9=0.0000000
b0=7471385.679, b1=0.0254854, b2=1.0135027, b3=0.0000146, b4=0.0000597, b5=0.0000185,
b6=0.0000000, b7=0.0000000, b8=0.0000000, b9=0.0000000
mx=0.892, my=1.993, mt=2.183
```
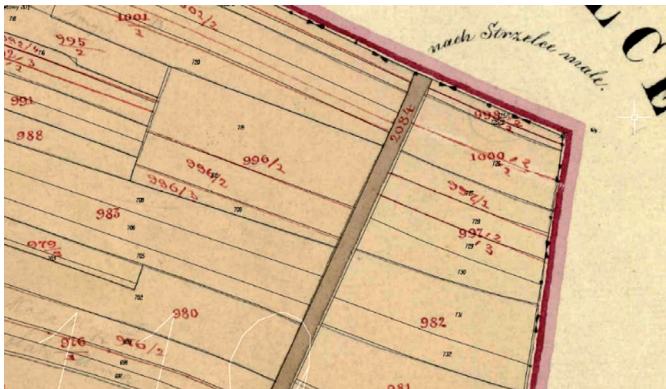
Source: authors' study based on KaliBronek software

**Fig. 5.** Fragment of the calibration report using the KaliBronek software



Source: authors' study

**Fig. 6.** End result of the calibration performed using KaliBronek and AutoCAD software applications

In the case of the section frame III, the mean error was 1.20 m, which means that it falls within the permissible limits of error, and the pre-calibration can be considered correct.

Points at the second stage of the calibration were spread evenly over the entire area. As a result of the third degree polynomial transformation, a calibrated raster map was obtained. The mean transformation error was 2.18 m, therefore remaining within the permissible limits of error also in this case (Figure 6).

## 6. Results and conclusions

In Table 4 below, the mean errors of calibration for the raster of the section frame III were listed and compared.

**Table 4.** Comparison of mean errors from the pre-calibration and detailed calibration

| Software application | Mean error [m] | |
|---|---|---|
| | Pre-calibration | Detailed calibration |
| *EwMapa* | 0.52 | 2.05 |
| *Microstation V8i* | Not reported | Not reported |
| *KaliBronek* | 1.2 | 2.18 |

Source: authors' study

As demonstrated in the comparison presented above, two of the three software applications generate reports after the work is completed. The data presented in the table clearly states that in the case of *EwMapa* and *Kali Bronek*, the calibration was performed correctly with due diligence, accuracy and precision. The calibrated raster maps in both software applications, despite numerous mechanical damages, are suitable for vectorization, and for possible application in various types of geodetic and legal matters. Performing the fitting procedure in these software applications is very simple and fast, and it produces very good results. The errors, both after pre-calibration and after the detailed calibration, are acceptable, and they do not differ from those that are produced in much more expensive applications. These software applications generate reports, and they show errors at individual points. This facilitates the improvement, correction, or removal of the errors during the process. It is a very helpful feature, which allows the user to save a lot of effort and time during geodetic and cartographic work. When it comes to calibration in *MicroStation V8i* software application, without the use of thematic overlays, the lack of reports and polynomial transformation does not provide information on the quality level of the work performed (Figure 7).

In order to show the differences between the examined software applications, subjective assessments for individual criteria were compiled, such as would be relevant to the work. All features have been assessed and presented on a scale from 0.0 points to 5.0 points.

Source: authors' study

**Fig. 7.** Calibrated raster map with the superimposed cadastral map of land and buildings

**Table 5.** Comparison of various software applications in terms of their accuracy and usability

| Criterion | EwMapa | MicroStation | KaliBronek |
|---|---|---|---|
| Clarity of the interface | 3.0 | 3.5 | 4.5 |
| Ease of loading the raster | 4.5 | 4.5 | 4.5 |
| Editing of multiple raster maps simultaneously | 5.0 | 5.0 | 5.0 |
| Speed of task execution | 4.0 | 4.5 | 4.5 |
| The possibility of undoing the last editing change | 5.0 | 5.0 | 5.0 |
| Own graphic environment | 5.0 | 5.0 | 0.0 |
| Generating calibration reports | 5.0 | 0.0 | 5.0 |
| Choice of transformation | 5.0 | 2.5 | 3.5 |
| Price | 4.0 | 3.0 | 5.0 |
| **Average** | **4.5** | **3.7** | **4.1** |

Source: authors' study

In Table 5, we have presented the evaluation of software applications with respect to nine features that are of great importance in carrying out this type of work. The following criteria were selected:

a) clarity of the interface, that is the ease in finding necessary functions, and simplicity of their use;

b) easy loading of the raster;

c) editing multiple raster maps at the same time;

d) speed of task execution, that is the time needed by the application to execute the command;

e) the possibility of undoing the last editing change;

f) own graphic environment;

g) generating calibration reports;

h) choice of transformation, that is the number of transformations that the user can operate;

i) price, based on data from the producers.

The following conclusions can be drawn from the table above:

*EWMAPA*:

- Generates reports, and continuously displays mean errors from the calibration performed to the user;
- Allows the user to select from several types of transformations;
- Has its own graphic environment, and therefore it does not generate additional costs;
- Has a slightly more difficult-to-use interface than other software applications, but it is not a major problem to learn how to operate it.

*KaliBronek*:

- Generates reports, and continuously displays mean errors from the calibration performed to the user;
- Allows the user to edit several raster maps at the same time;
- Has a very easy-to-use interface, and the ability to import data;
- Does not have its own graphic environment, therefore the user must have a CAD software or similar.

*Microstation V8i* (without overlays):

- Does not generate reports;
- Provides a more intuitive transformation, and only visual control;
- Without any additional software, it can perform transformation, calibration, vectorization and printing;
- Has a very easy-to-use interface, and the ability to import data.

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https://www.bentley.com

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