BSB + Partner
Ingenieure und Planer

Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

Dr. Alexander Kohli
BSB + Partner, Consulting Engineers

FIG Working Week 2008, Stockholm, Sweden
TS 2A – Geodetic Networks, Reference Frames and Systems I

Agenda

- **Introduction and Motivation**
- **General Approach**
- **Application in Kosova**
- **Results**
- **Experiences and Conclusions**

Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

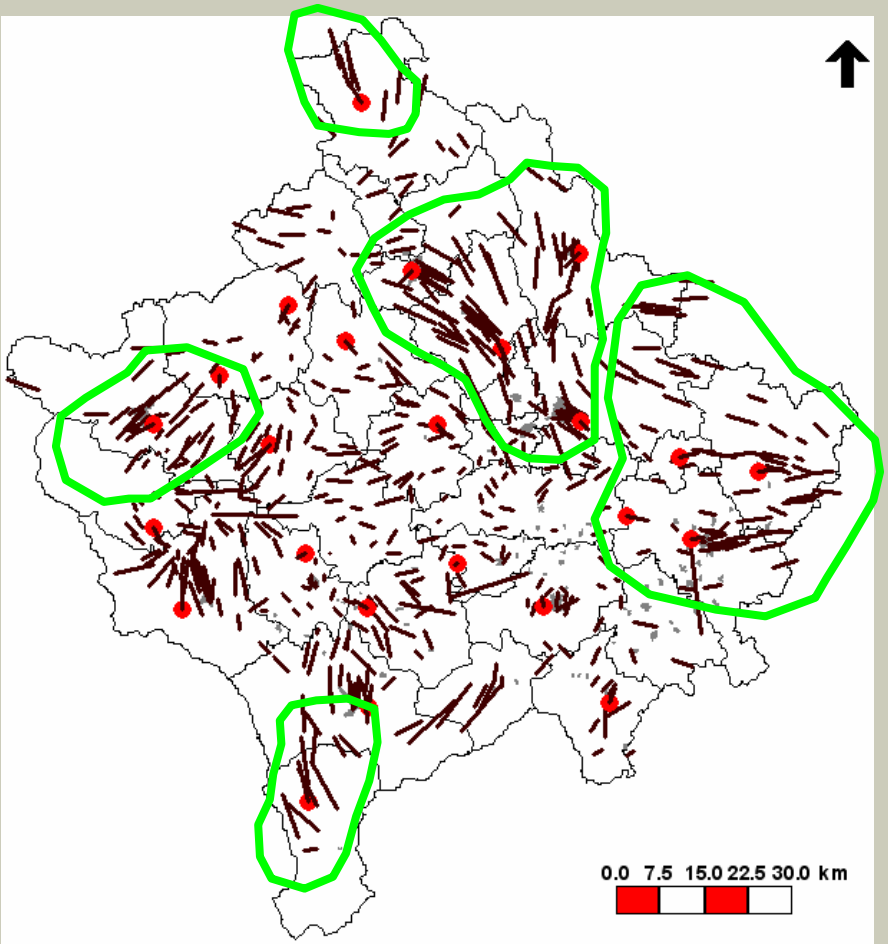
BSB + Partner
Ingenieure und Planer

Introduction and Motivation

- **Inhomogeneous networks regional distortions and deformations**
- **Cadastral data must not have gaps on plot plans**

- **Overall Helmert transformation – bad fit**
- **Local Helmert transformations – gaps**

➔ **New Frame definition (KOSOVAREF01 – ETRS89, ETRF)**



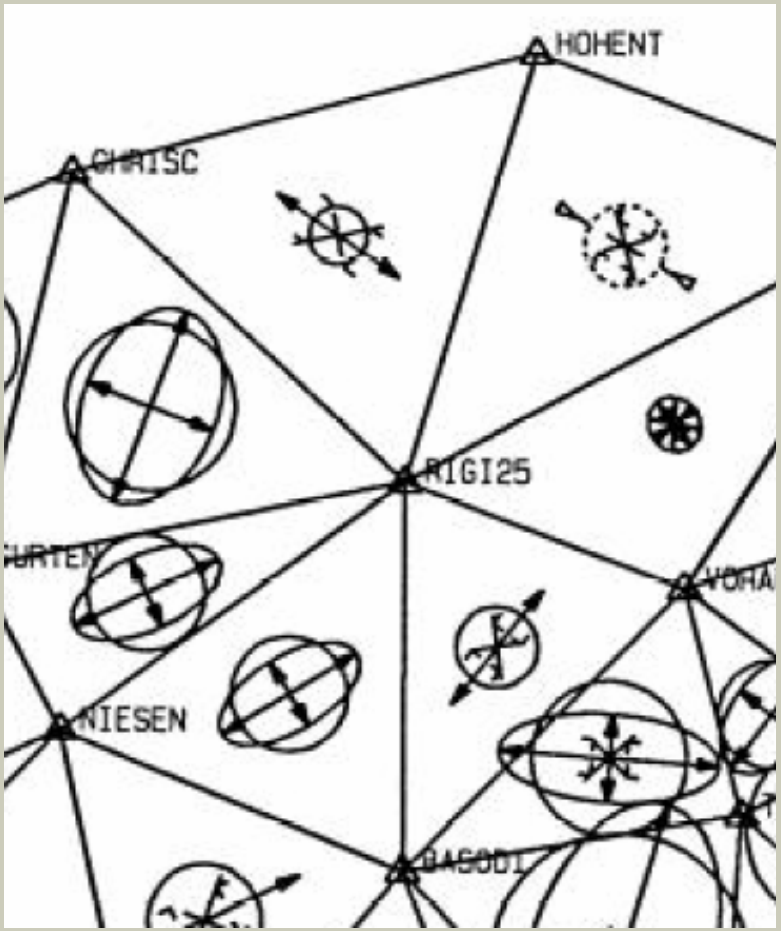
Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

BSB + Partner
Ingenieure und Planer

Finite Element Method

- **Linear affine transformation with finite elements (triangles)**
- **Node points (TBS) become exactly the values in the new system – transformation of data within the triangle depending of the coordinates of the TBS**
- **Local improvements and densification possible**

➔ **Continous and reversible trans-formation, no gaps between triangles**



Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

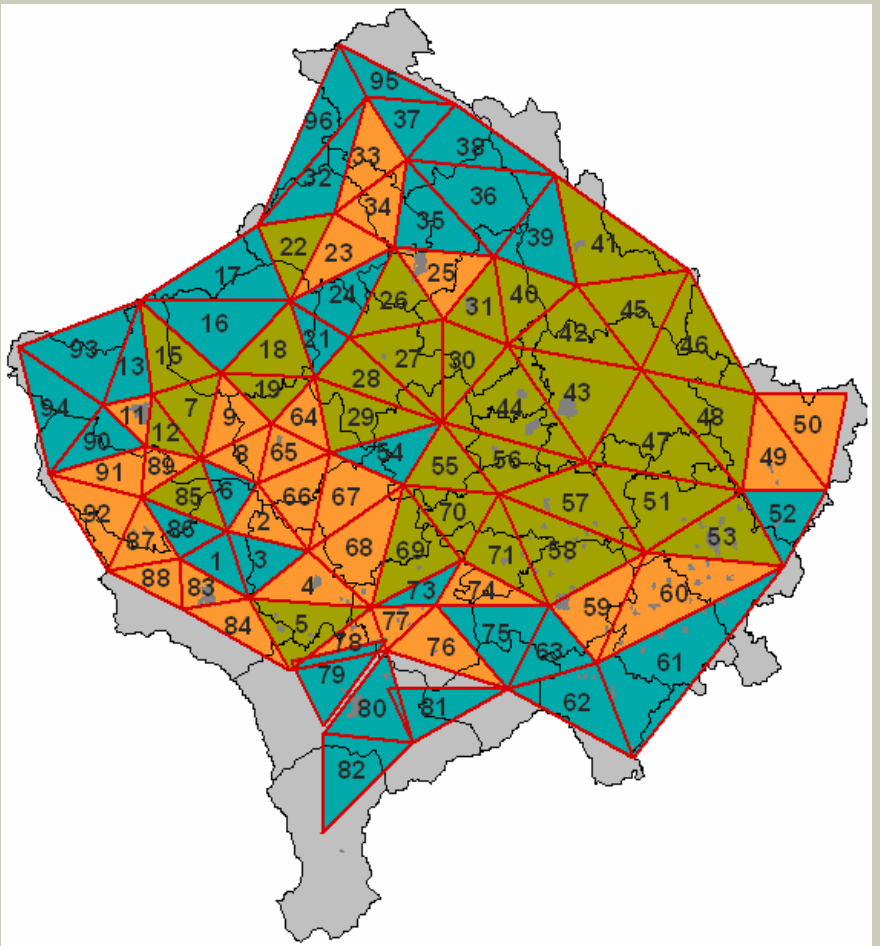
BSB + Partner
Ingenieure und Planer

General Approach

1. Provisional Triangle Network	Triangle network out of former triangulation and traverse points
2. Determination Distortion Vectors	New determination of the points by measurements in the new reference frame → distortion vectors
3. Improvement of Transformation Base	Design the pre-definite triangle network, transformation of the checkpoints and assessment of the transformation base, iterative improvement
4. Transformation of Cadastral Data	Transformation of vectorized cadastral data by finite element method
5. Quality Checks	Quality tests by area comparison of parcels and reporting of results

Application in Kosova (I) – Definition of provisional triangle network

- Stable node points, re-measured in new frame
- Triangles must contain 3-4 checkpoints known in the former system/re-measured
- Consideration of city networks

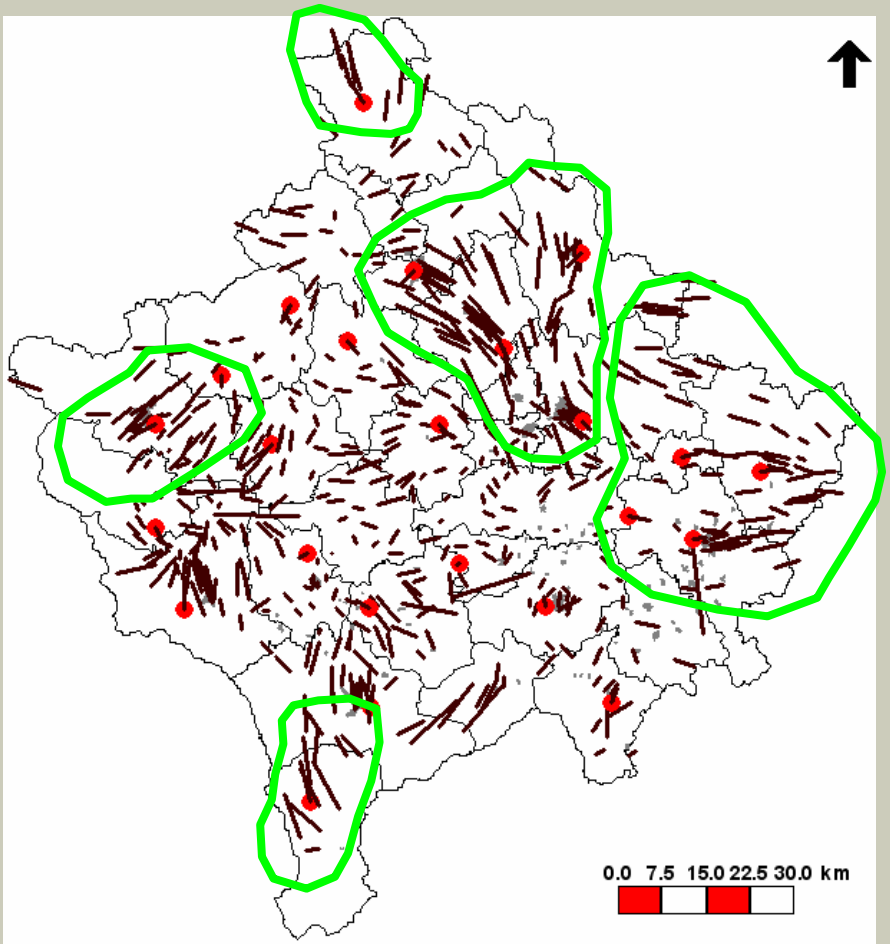


Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

BSB + Partner
Ingenieure und Planer

Application in Kosova (II)

- **Improvement of the Transformation Base by iterative elimination of gross errors**
- **Reduction of distortions by selection of relevant node points (TBS)**
- **Minimization of borderline effects by fictitious TBS**



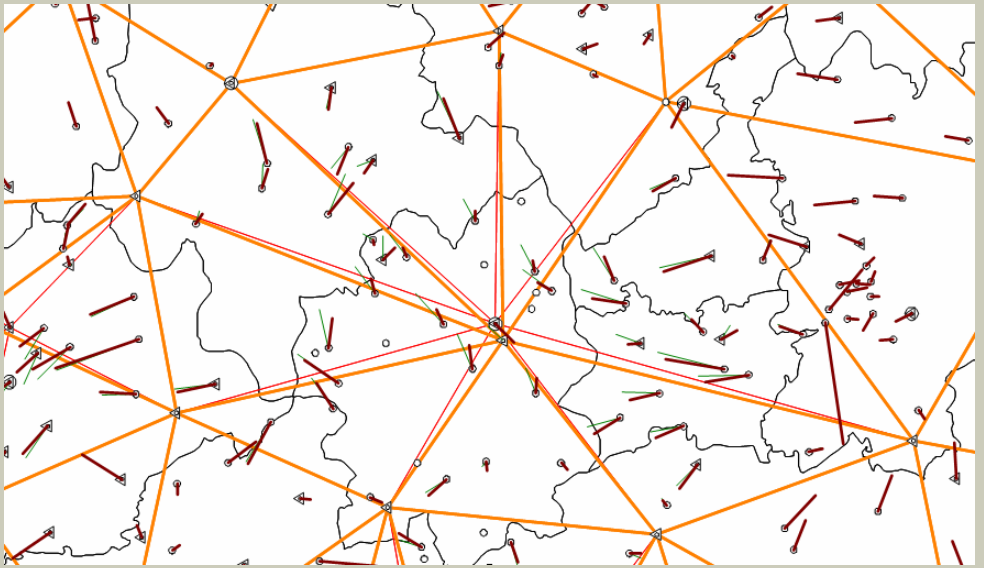
Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

BSB + Partner
Ingenieure und Planer

Application in Kosova (III)

- **Assessment of the TBS by finite element method transformation of the checkpoints within the triangles**
- **Detection of distortion vectors for checkpoints**

- **Goal: reduction of residuals of distortion vectors:**
  - **Modification of TBS by visual approach**
  - **Change of nodes of a not representative vector quality**

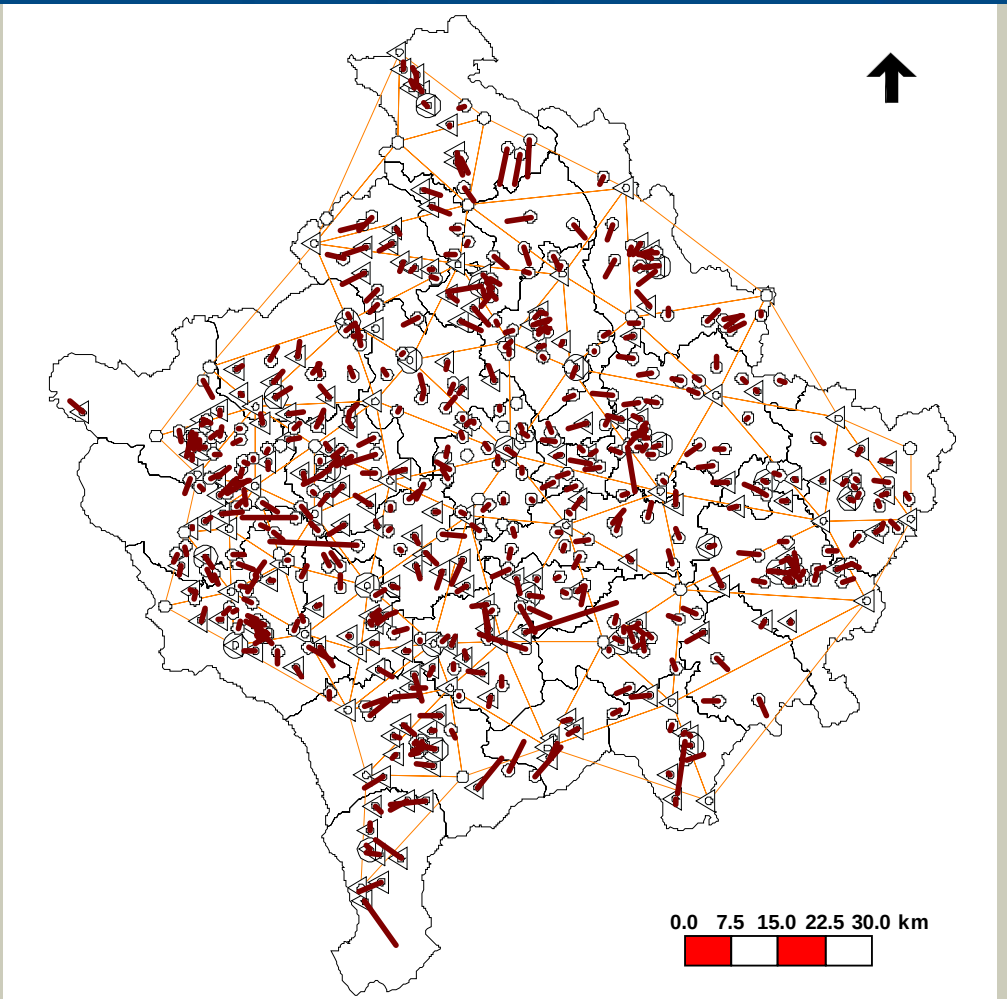


	Average Vector length [m]	Average Deviation [m]	Checkpoints out of Tolerance
Helmert	0.36	0.15	84
Pre-definite Triangles	0.19	0.10	14
Definite Triangles	0.18	0.10	12

Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

BSB + Partner
Ingenieure und Planer

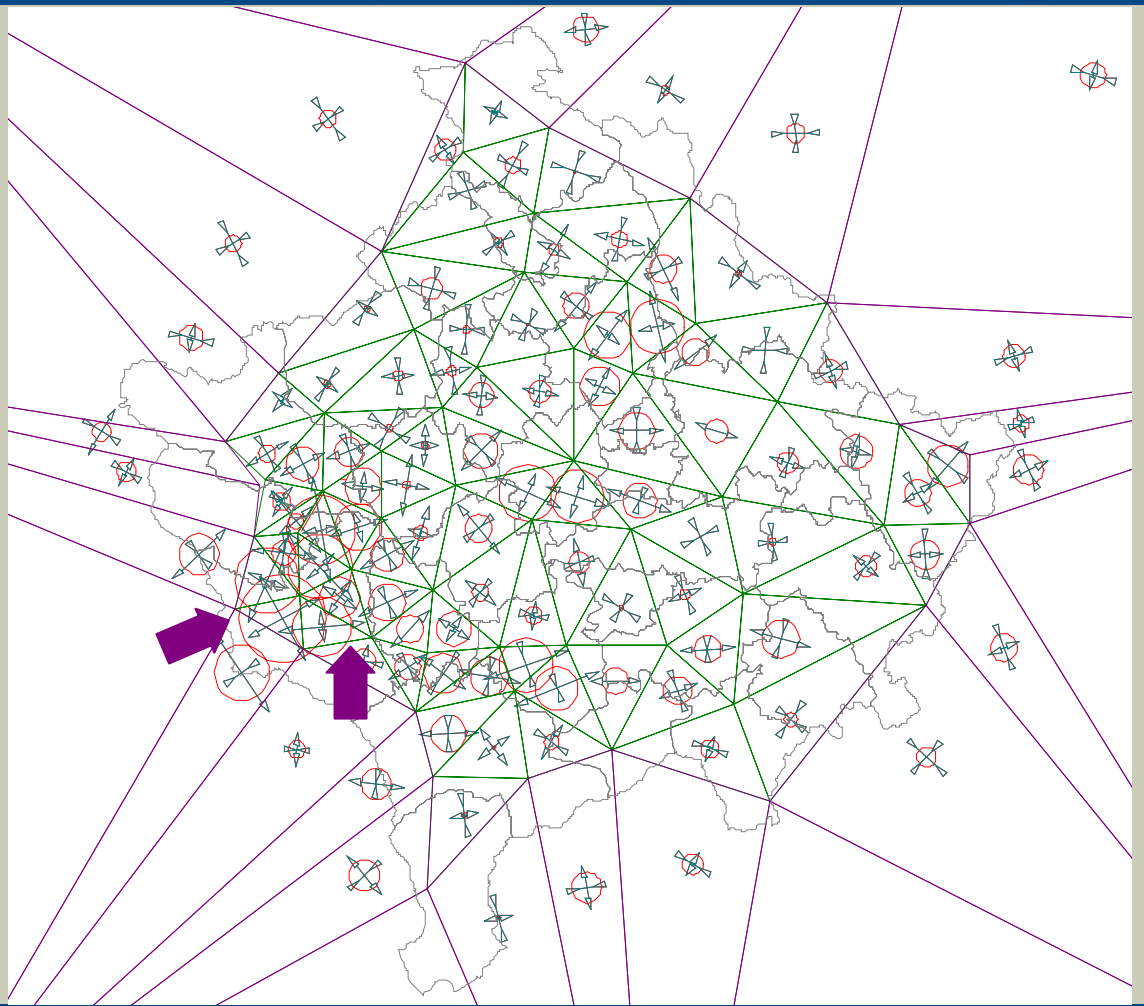
Application in Kosova (IV)



Transformation of Cadastral Data between Geodetic Reference Frames Using Finite Elements Method

BSB + Partner
Ingenieure und Planer

Application in Kosova (V)



Results (I) – A-priori Error Estimation

- **Existing Error on points ?**
  - **Graphical surveying**
  - **Digitalization**

Error Sources of Basic Cadastral Data	Values for Map Scale 1:500
Quality of Basic Surveying (Photogrammetry or Conventional)	+/- 0.30m
Drawing of Plans	+/- 0.05 – 0.25m
Printings from the Original Plans	+/- 0.10m
Vectorization of Scanned Plans after Georeferencing	+/- 0.05 – 0.20m

$$\sigma_{\max} = \sqrt{\sigma_{surveying}^{2} + \sigma_{drawing}^{2} + \sigma_{printing}^{2} + \sigma_{vectorization}^{2}} = \underline{\sim \pm 0.50\text{m}}$$

- **Influence of transformation to parcel areas ?**

Results (II) – Parcel Area after Transformation

Tolerance Level 1:500

$$\sigma_{\max} = 0.2\sqrt{F}$$

3-4 orders of magnitude smaller!

→ Influence negligible

Cadastral Zone - Municipality	No. Triangles	Parcel Area [km²]	Avg. Δ / Parcel [m²]	Max. Δ / Parcel [m²]	σ_{area} [m²]
Berkove - Klina	1	0.025	0.015	-0.23	0.011
Shaptej - Gjakova	2	0.200	0.412	25.07	0.397
Shajnovc - Dragash	1	0.900	0.012	7.92	0.008
Strpce - Strpce	4	9.900	0.176	320.61	0.221

Experiences and Conclusions (I) – General

- **Method leads to cadastral data:**
  - **Homogenous**
  - **Gapless**
  - **No loss of accuracy**
  - **Reduction of local distortions**

- **Needs some efforts – causes some expenditures**

Experiences/Conclusions (II) – Transformation Base

- **Piece de resistance**
- **Produces high expenditures if applied in exaggerated manner**
- **Use of common sense for node selection – reduction of residuals**
- **Design follows the local geographic and topographic characteristics**
- **Iterative process**

Experiences/Conclusions (II) – Limitations

- **Need for TBS densification in case of**
  - later detected local distortion areas
  - Implementation of city networks

- **Need of experience for maintenance of the transformation base**
- **Need of a solid single institution for a sustainable application and service to the public**
- **Need of application and cooperation with private sector for data transformation as well as for TBS improvement**

Thank you, for your Attention!

Dr. Alexander Kohli
alexander.kohli@bsb-partner.ch
BSB + Partner, Consulting Engineers