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Estimating building inventory for rapid seismic vulnerability assessment in Bishkek, Kyrgyzstan

an integrated approach based on multi-source imaging and GIS

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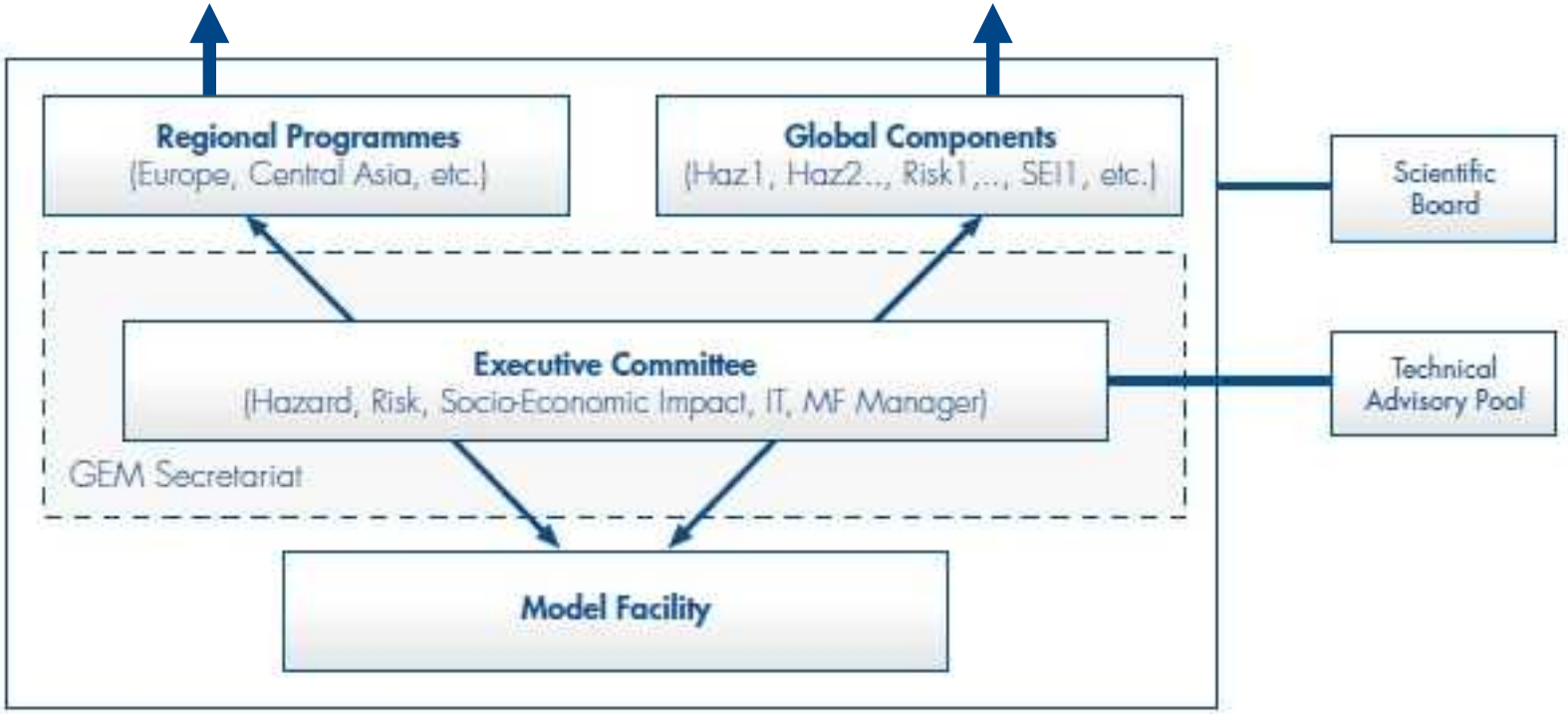
CEDIM GEM EMCA Earthquake Model Central Asia EOS Helmholtz

Earthquake Model Central Asia (EMCA)

Inventory Data Capture Tools (IDCT)



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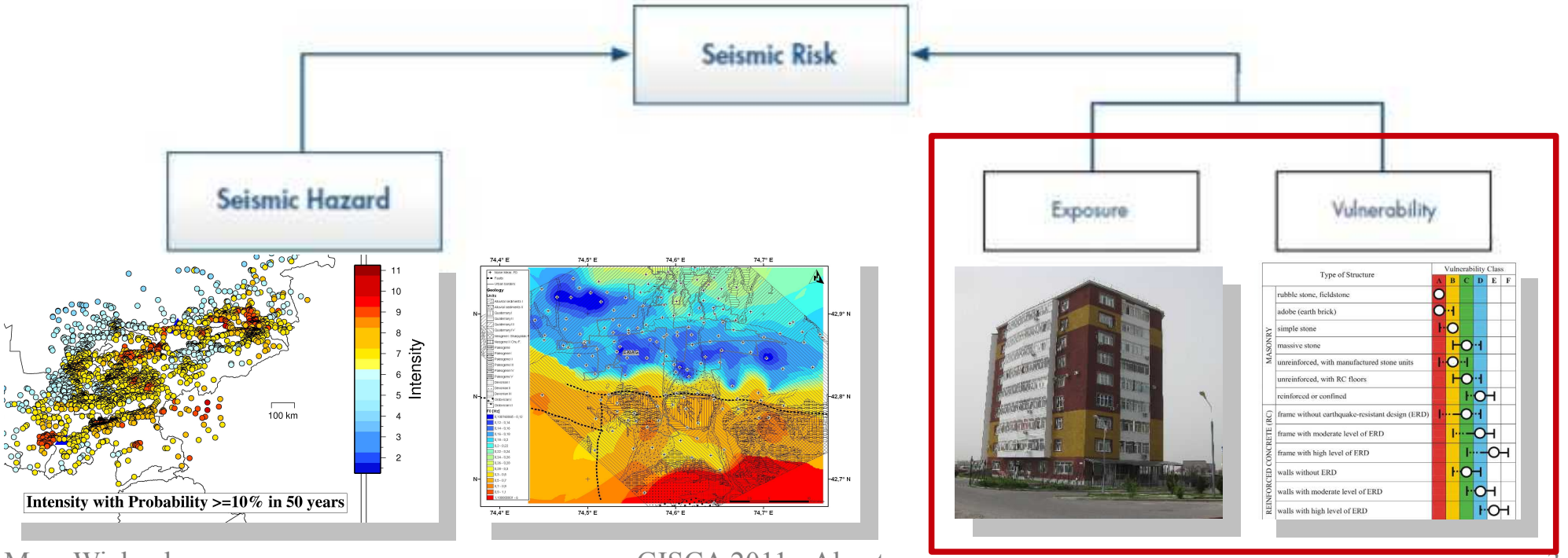
Earthquake Model Central Asia (EMCA)
Coordinated by GFZ



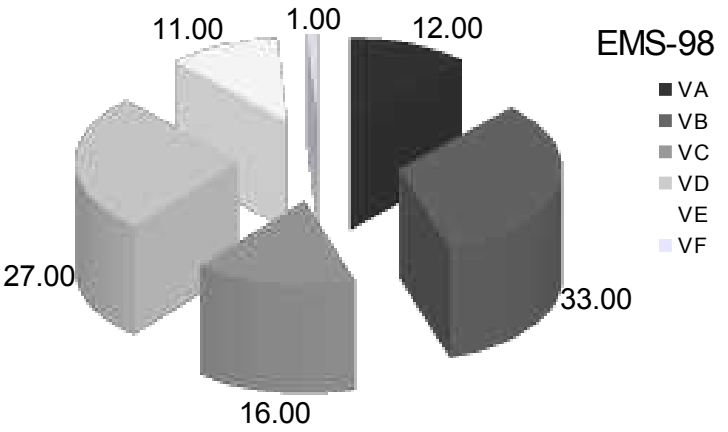
Motivation

Need for new approaches to estimate building inventory and thus vulnerability in a rapid, standardized, comparable and scalable way.

Vulnerability building by building

Building number	Building floor	The constructive decision	Building subgroup on classification EMS-98
1	Three- floor building with a ground floor	Building with bearing brick walls and ferro-concrete overlappings	B
		rete frame with brick lls and ferro-concrete gs	D
		rete frame with brick lls and ferro-concrete gs	C
		...	...

Vulnerability composite



Population: 865.527 people (status 2009)

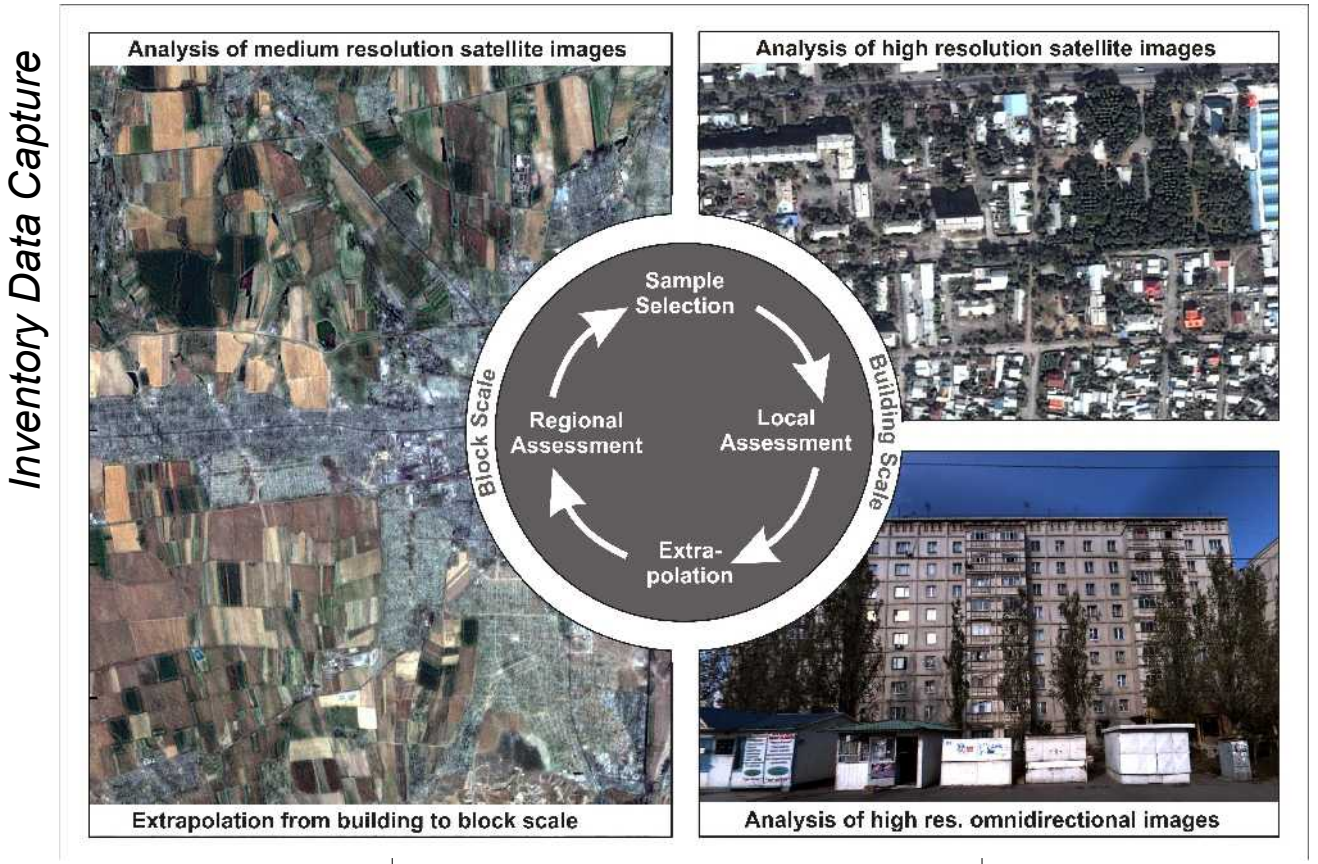
Built-up area 2009: 235 km² (from satellite images)
Built-up area 1994: 152 km² (from satellite images)
Built-up area 1977: 117 km² (from satellite images)

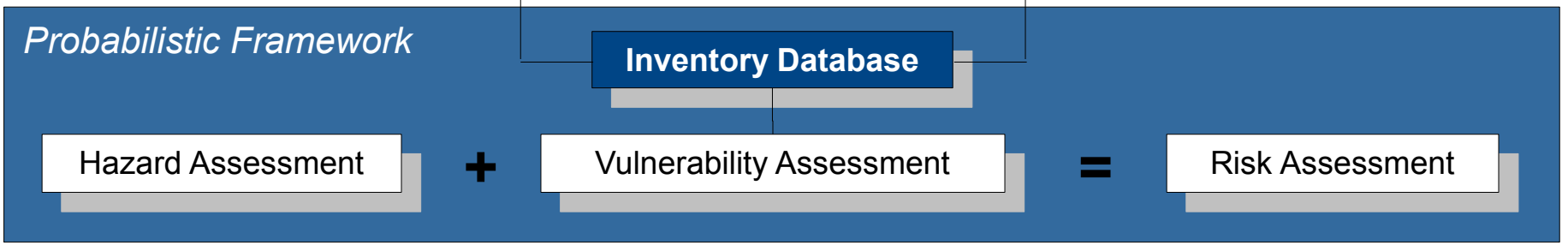
Vision

- A **rapid visual survey** can lead to a reasonable first assessment over broad areas.
- By coupling remote sensing (topview) with omnidirectional imaging (streetview), this could be done in an optimal way (in terms of time and resources).

- **Open-source** tools, **low-cost** data sources.
- **Globally applicable** on regional and local scale.

Overview of the approach

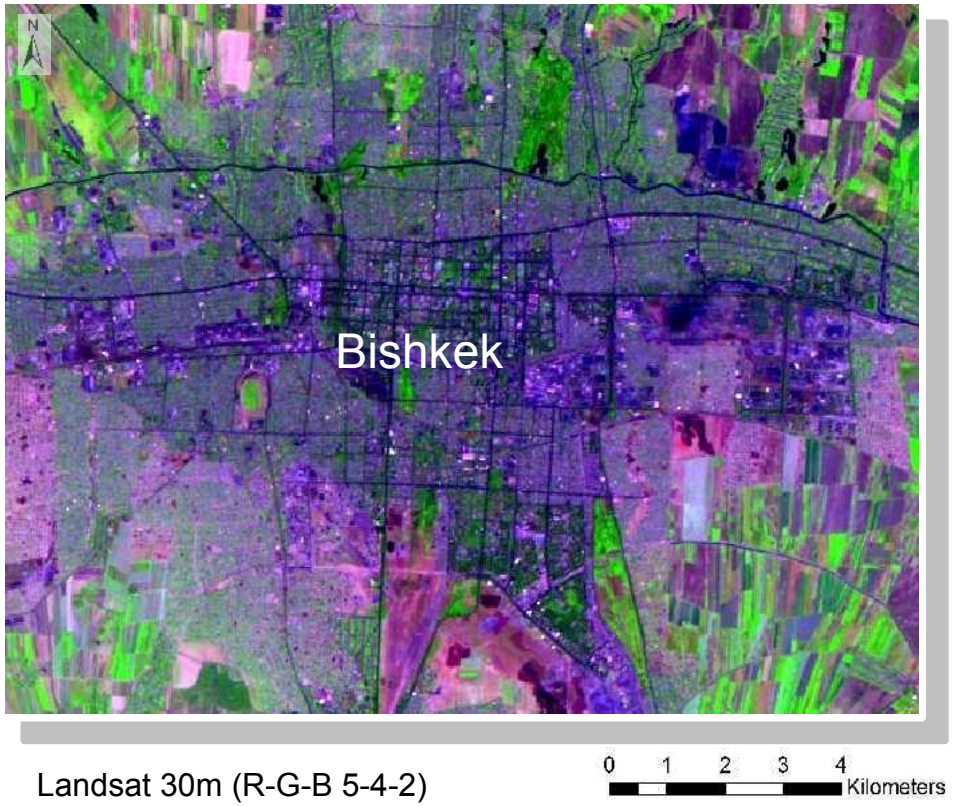




Analysis of medium-resolution satellite images

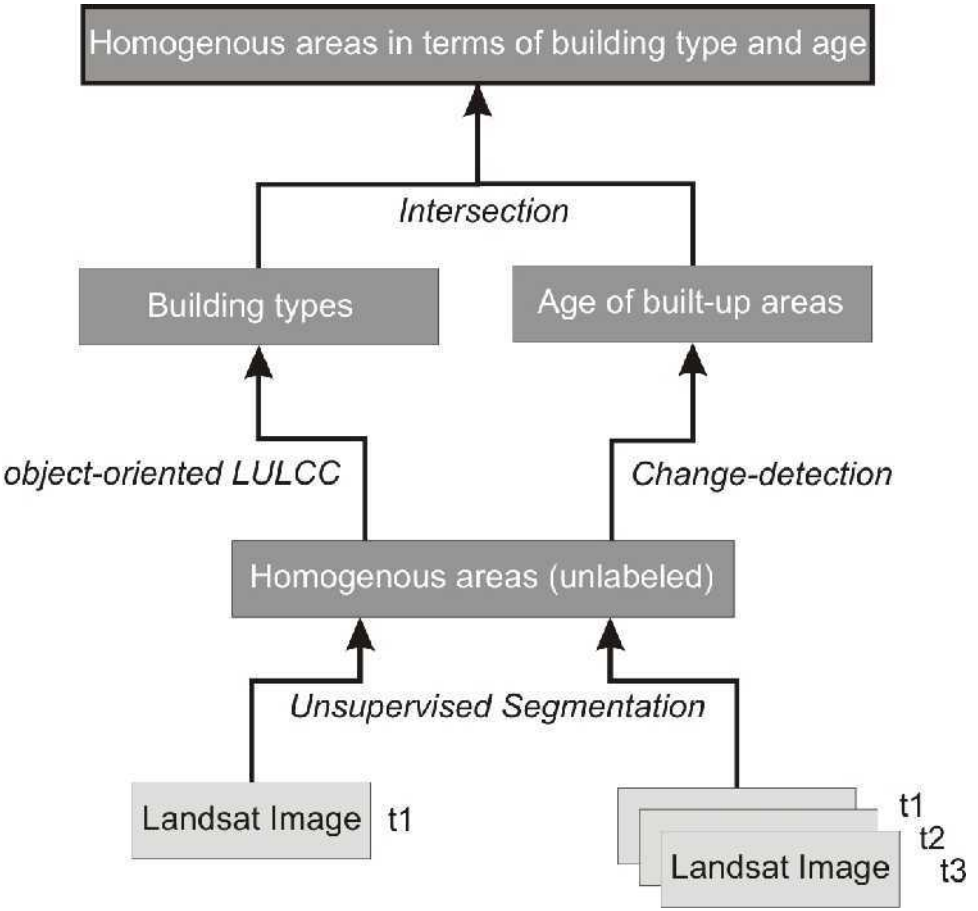
Stage of Stratification

Pixels



Landsat 30m (R-G-B 5-4-2)

Workflow / Results



Pixels → Segments → Thematic Classes → Urban Structure Types

Analysis of medium-resolution satellite images

Stage of Stratification

Workflow / Results

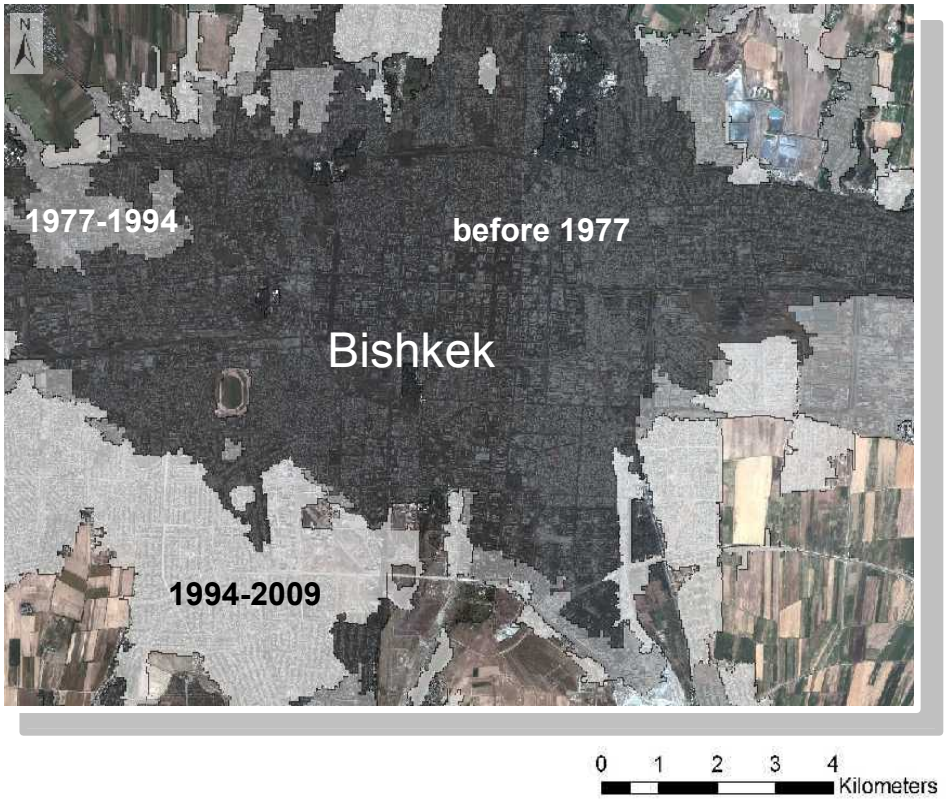
Thematic class (LULC)

L1 (general)	L2 (general)	L3 (Bishkek)
urban	residential	**1-2 storey masonry, brick, clay – type 1**
		1-2 storey masonry, brick, clay – type 2
		1-2 storey masonry, brick, clay – type 3
		3-6 storey masonry, brick, concrete, panel
		7-9 storey concrete, panel, frame, monolithic
	industrial / commercial	
	mixed built-up	
vegetation		
water		
other (rock, soil)		

Analysis of medium-resolution satellite images

Stage of Stratification

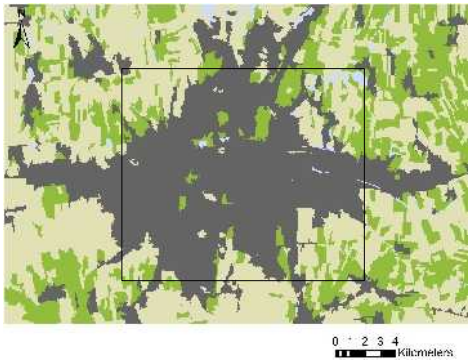
Thematic Class (Age of built-up areas)



Workflow / Results

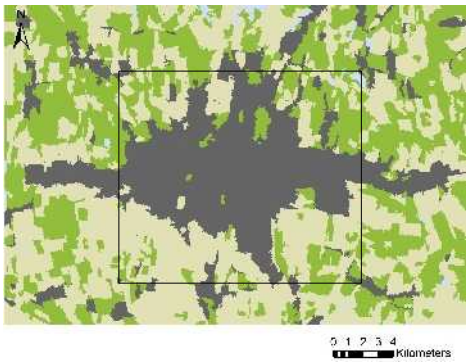
08.07.2009 Landsat TM

built-up area: 235 km²
growth rate (1994-2009): 55 %



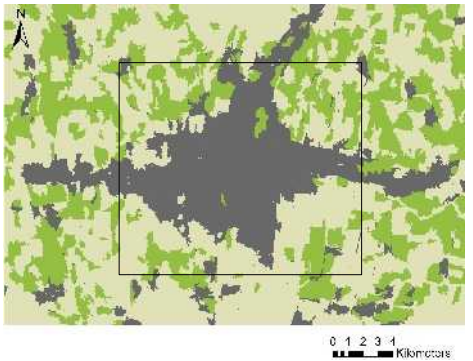
15.07.1994 Landsat TM

built-up area: 152 km²
growth rate (1977-1994): 30 %



22.08.1977 Landsat MSS

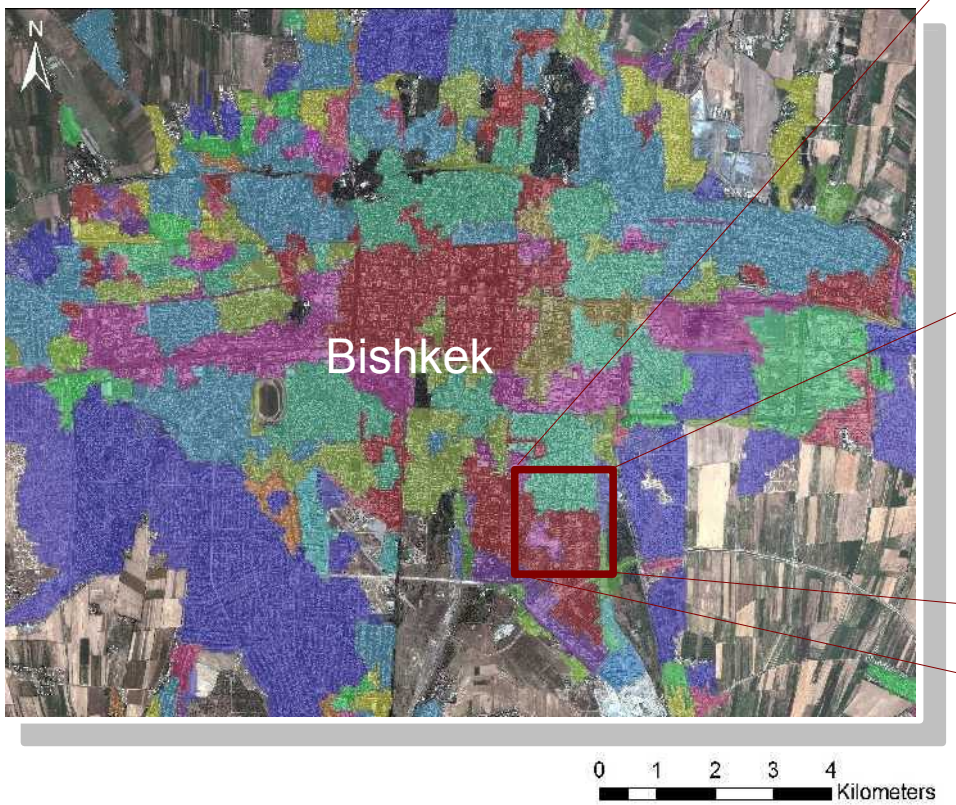
built-up area: 117 km²



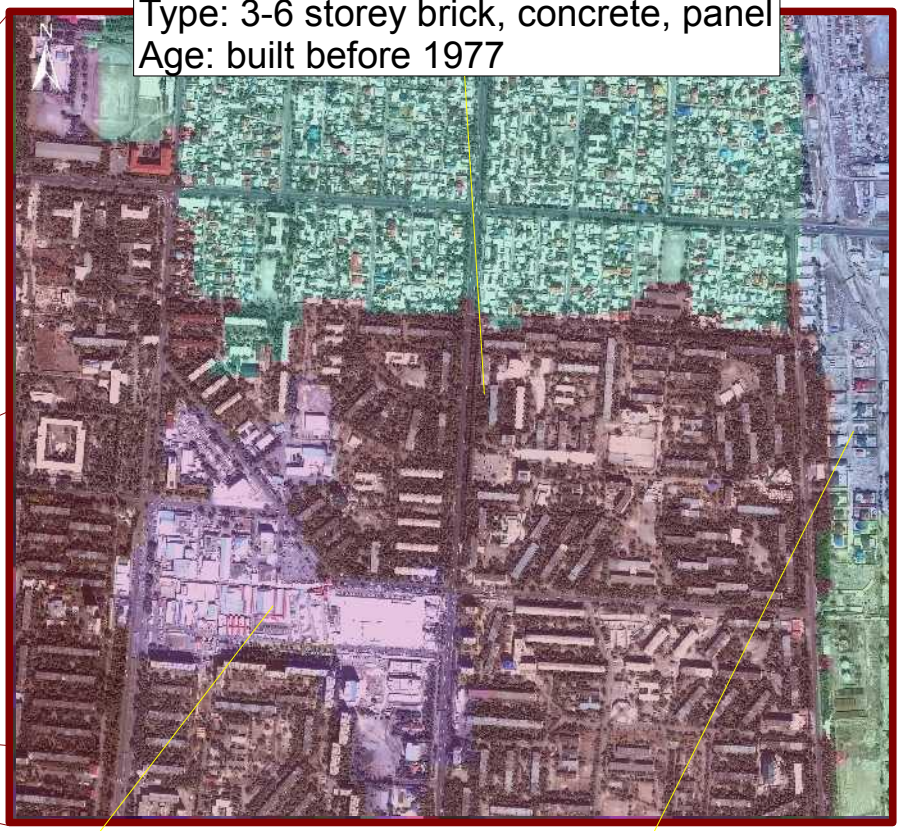
Analysis of medium-resolution satellite images

Stage of Stratification

Urban Structure Types



Urban Structure Type: 10
Type: 3-6 storey brick, concrete, panel
Age: built before 1977



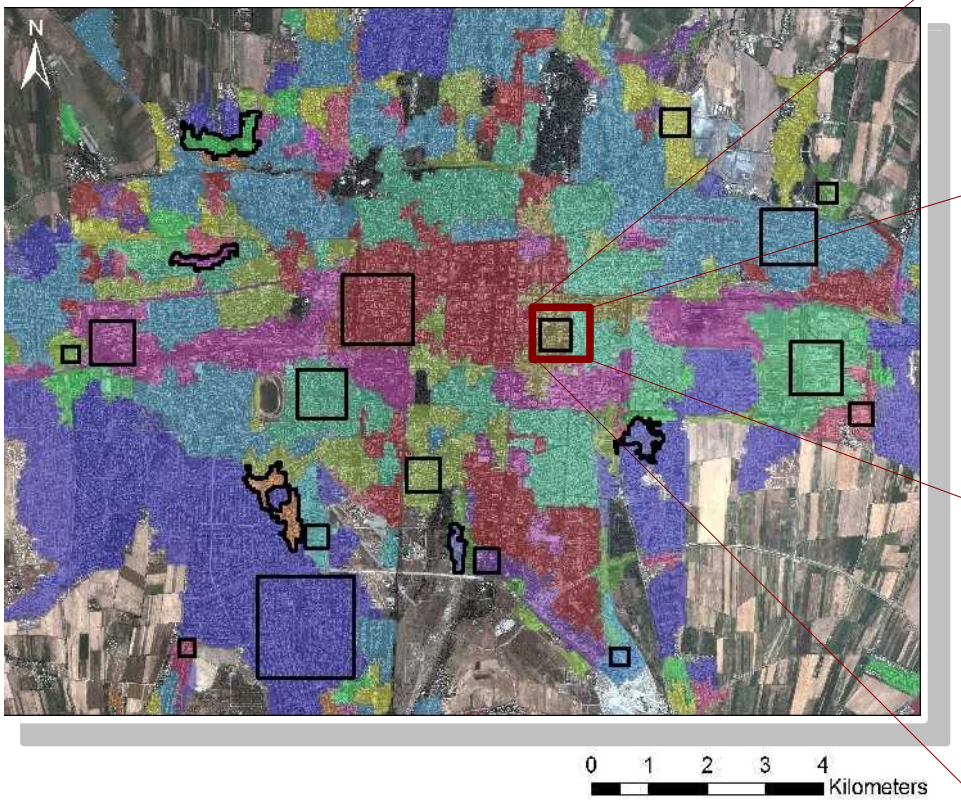
Urban Structure Type: 16
Type: industrial, commercial
Age: built before 1977

Urban Structure Type: 8
Type: 1-2 storey masonry, brick
Age: built between 1994 and 2009

Stratified sampling and analysis of high-resolution satellite images

Extraction of building footprint and location

Sample areas



Quickbird R-G-B (3-2-1)

Building shape, area, roof-type, roof-color/-material, etc.

Acquisition and analysis of high-resolution omnidirectional images

Omnidirectional Image

Acquisition and analysis of high-resolution omnidirectional images

Omnidirectional Camera

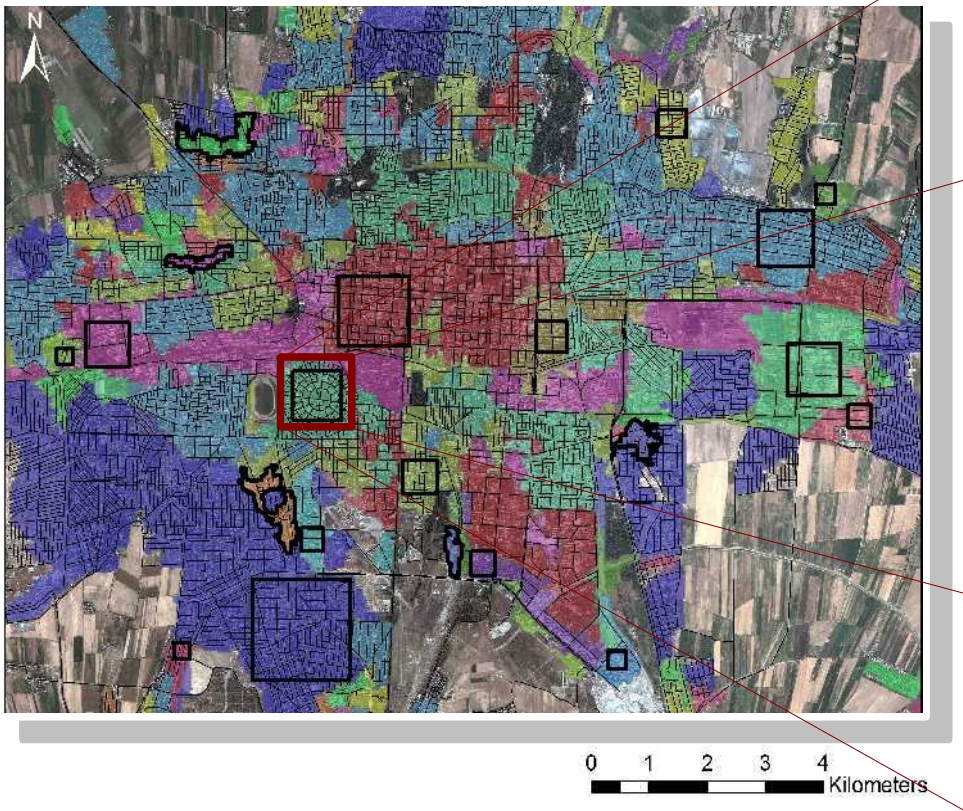
Navigation Unit

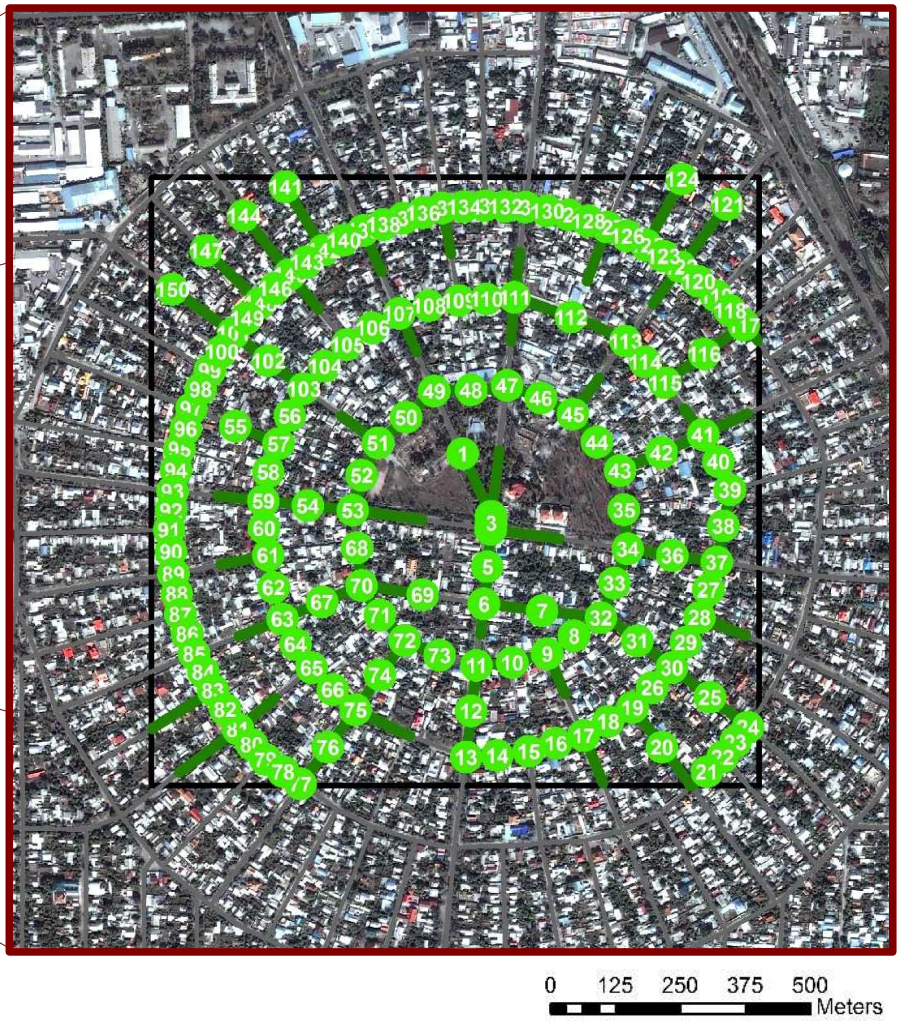
System mounted on car

Acquisition and analysis of high-resolution omnidirectional images

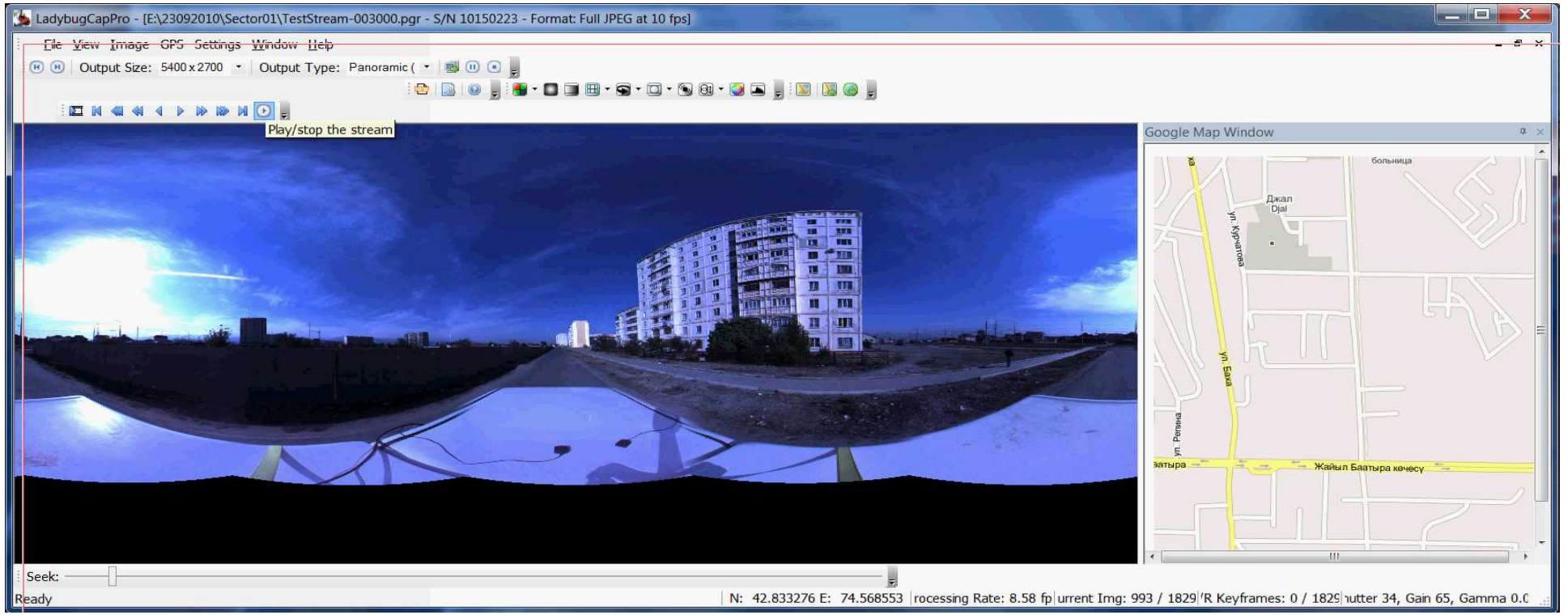
Travelling Salesman Problem (TSP)

Sample areas and OpenStreetMap





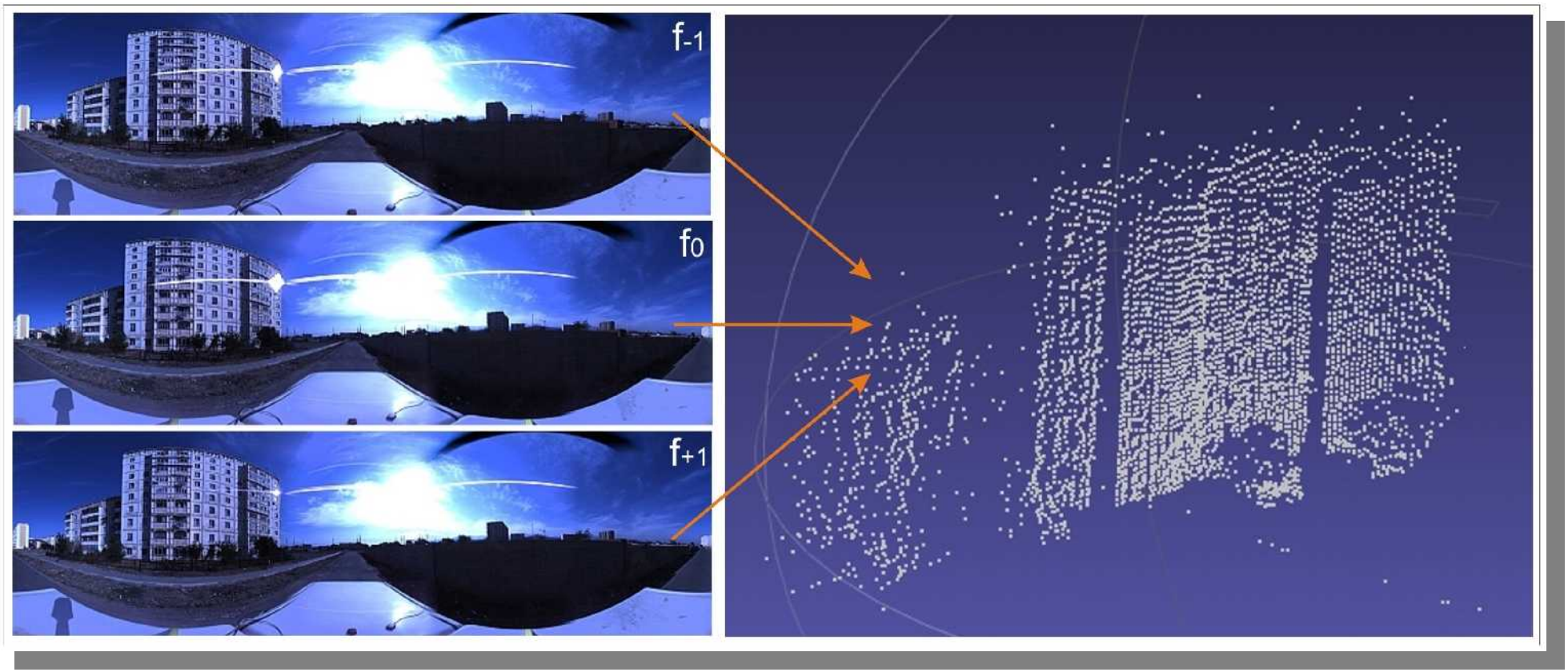
Acquisition and analysis of high-resolution omnidirectional images



Omnidirectional Imagestream

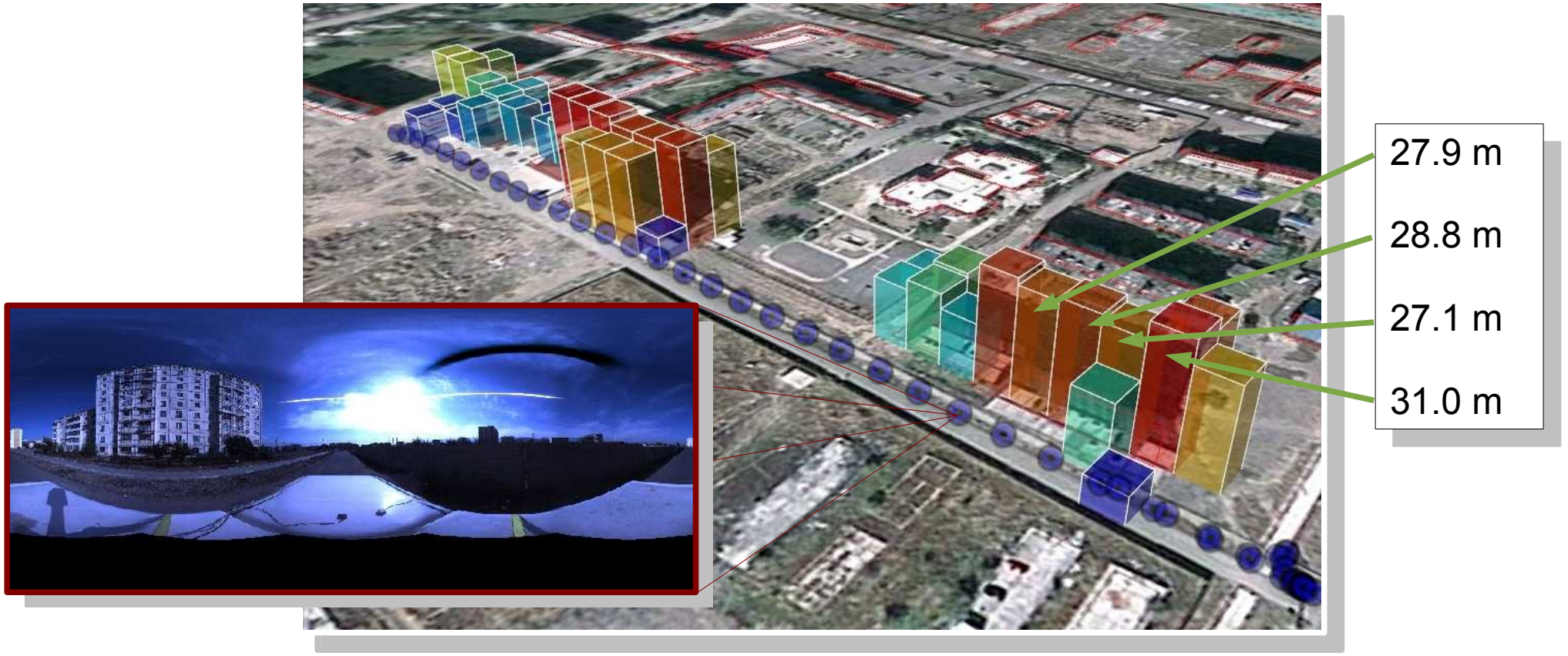
Acquisition and analysis of high-resolution omnidirectional images

Automated height measurement from 3D-points



Acquisition and analysis of high-resolution omnidirectional images

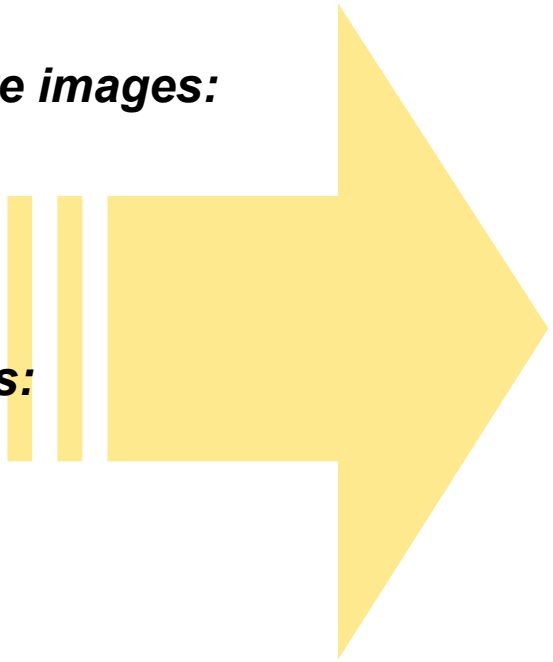
Automated height measurement from 3D-points



Vertical shape, soft-storey detection, nr. of windows, etc.

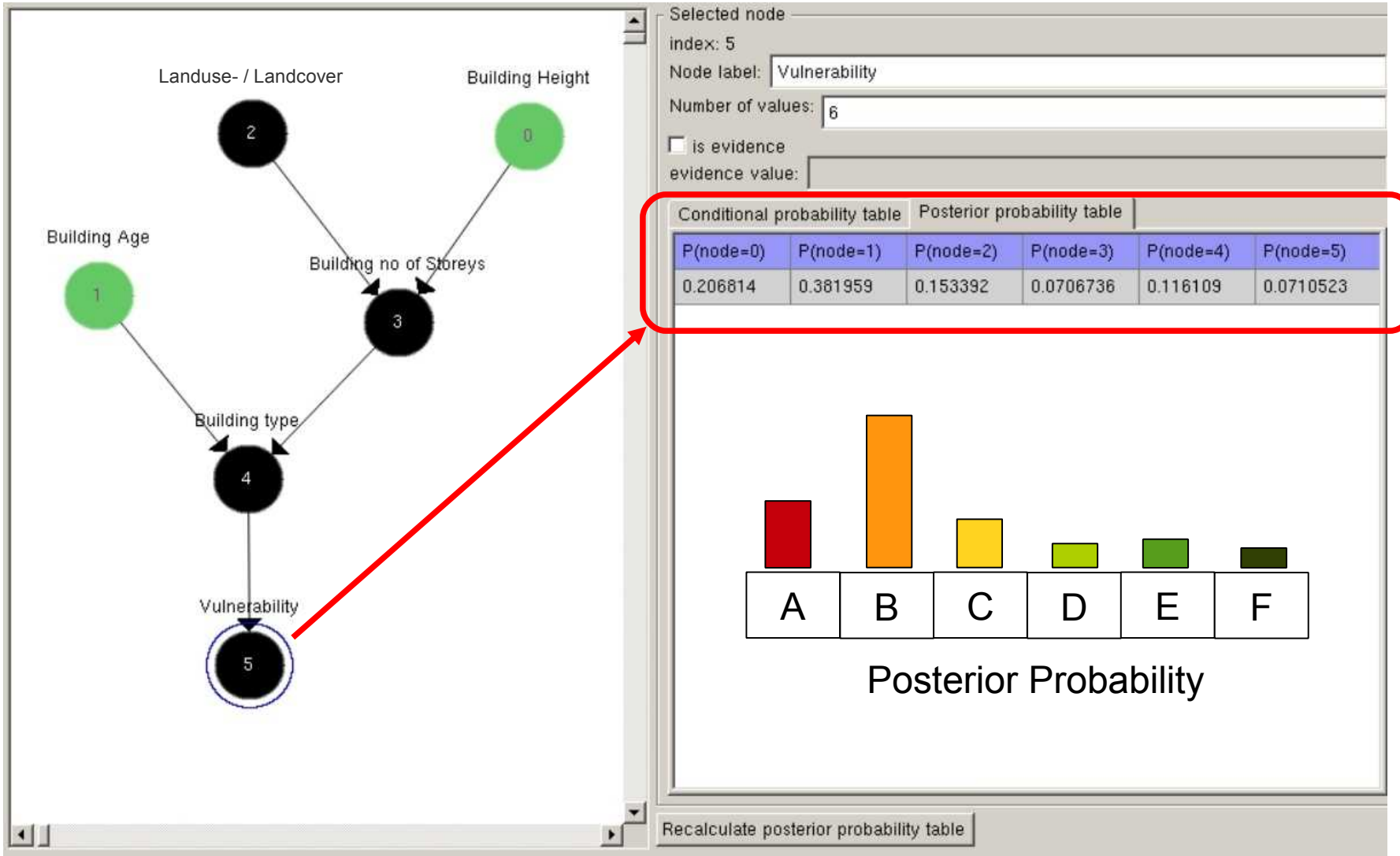
Data integration

- ***Priors* from medium-resolution satellite images**
  - Estimated Age
  - Land-Use / Land-Cover (LULC)
- ***Information from high-resolution satellite images:***
  - *Building footprints*
  - *...*
- ***Information from omnidirectional images:***
  - *Estimated Height of Structures*
  - *...*
- ***Priors* from manual data entry :**
  - Expert knowledge
  - Ancillary data



VULNERABILITY

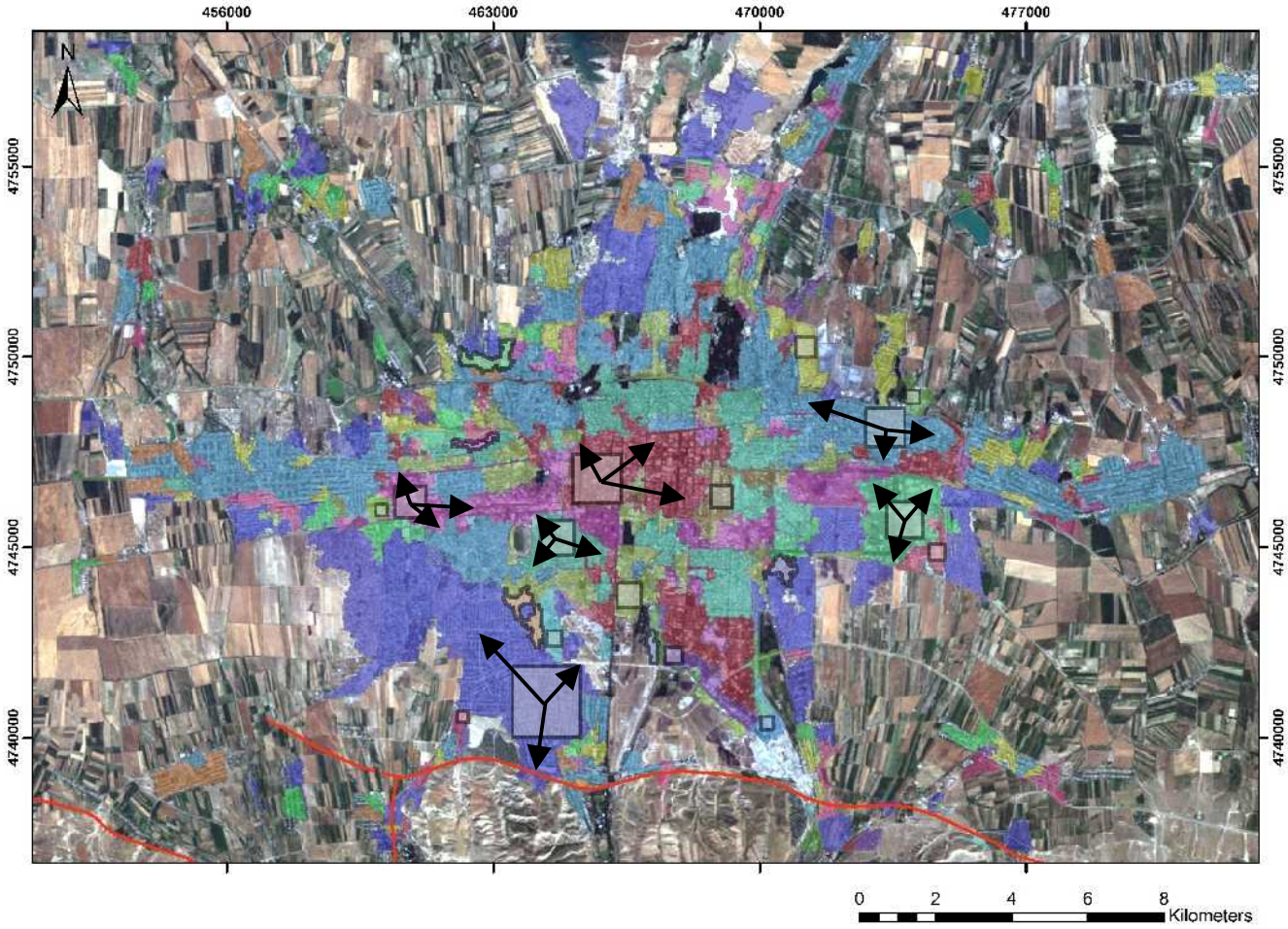
Vulnerability estimation (EMS-98): bayesian network



Vulnerability estimation (EMS-98): building scale

Age: 1994-2009
Nr. of storeys: 9
Type: 5-9 storey, concrete, panel, frame
Vuln: E

Vulnerability estimation (EMS-98): extrapolation to district scale



Work in progress...

Conclusion

- Stratified **sampling** using remote sensing proved **successful**.
- Omnidirectional imaging: **fast** deployed, **easily** operated.

- Feature **extraction** from remote sensing proved **feasible.**
- **Automatic** extraction from omnidirectional images proved **feasible**.

- Bayesian approach to **data fusion** seems promising.

- Approach is **scalable**, flexible and transferable.
- All tools are **open** source and costs for data can be reduced to a minimum.

Thank you for your attention!