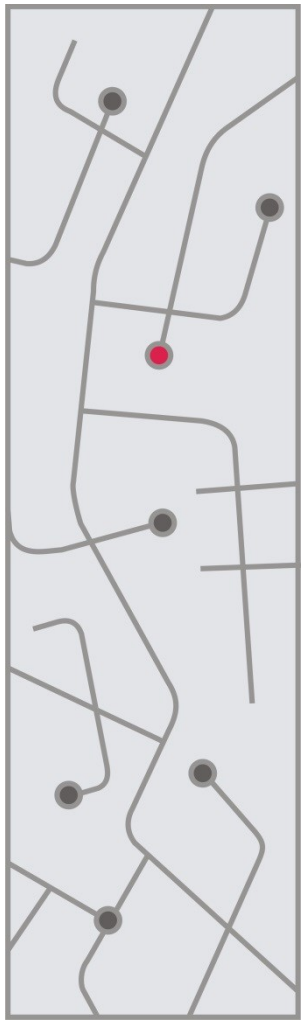

RISKGIS

3.2
CONGESTIONS AND INTERSECTIONS OF CRITICAL INFRASTRUCTURE

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CONCEPT OF GEOGRAPHIC INTERDEPENDENCIES OF CRITICAL INFRASTRUCTURES

- CI = networks of infrastructures from various sectors
- Consequences of malfunctions /disruptions of particular infrastructure affect other infrastructures = concept of interdependency
- **GEOGRAPHIC INTERDEPENDENCIES**: negative events can due to the geo. proximity of infrastructural objects simultaneously create damage on multiple infrastructures or it can be instantly transferred from one infrastructure to another
- **Common cause failures**: natural disaster, human-made disaster, intentional act: terrorism, sabotage…
- GIS has the potential for displaying the geographic interdependencies of critical infrastructures

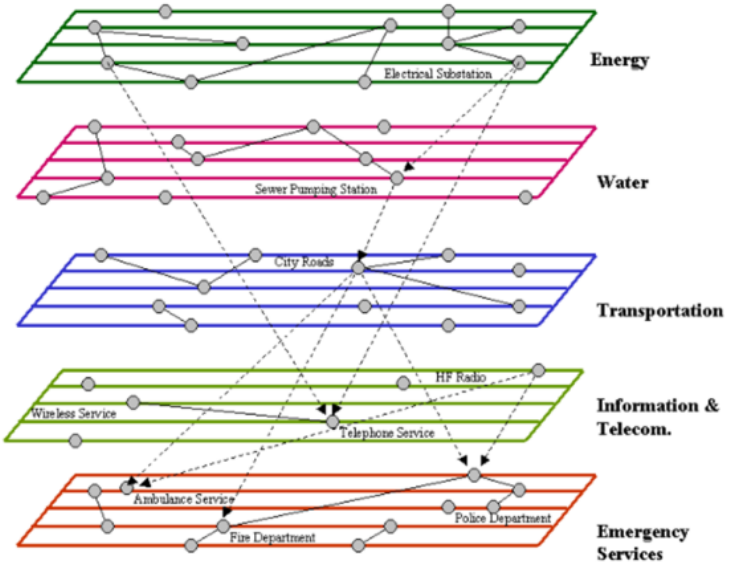
CASE FROM THE USA, BALTIMORE, 2001

- COMMON CAUSE EVENT: DERAILED TRAIN carrying hazardous chemicals

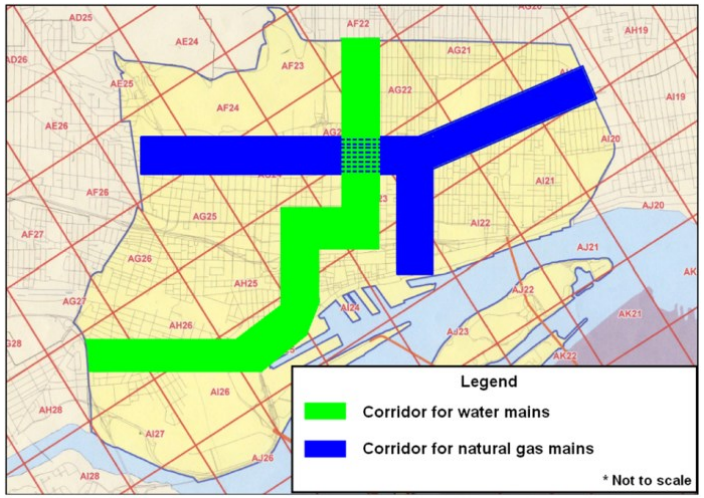
- Consequence 1: disruption of the **rail traffic**
- Consequence 2: fire in the tunnel caused a **water main to break** above the tunnel shooting geysers 20 ft into the air. The break caused localized **flooding** which exceeded a depth of three feet in some areas; flooding knocked out **the electricity and fiber opical cables**, affecting all telephone, cell phone and internet communications in the area

SOME PRACTICAL APPROACHES TO ANALYSE GEOGRAPHIC INTERDEPENDENCIES IN THE FIELD OF CI

1. Colocation and integration of different GIS:



2. Determination of locations that are most likely to generate geographic interdependencies and their ranking in the assessment zone



- SOME PRACTICAL APPROACHES TO ANALYSE GEOGRAPHIC INTERDEPENDENCIES IN THE FIELD OF CI

3. LID GIS approach (University of Glasgow): geographical proximity of CI (colocations) used to identify and rank the areas

4. Quantitative prioritization of critical infrastructural crossings (MIT): number of infrastructural crossings in particular geographic area affects its rank / weight

5. Netherlands: a list of intersectoral junctions for the whole country

THE CONCEPT OF VULNERABILITY THROUGH THE PRISM OF INFRASTRUCTURAL INTERSECTIONS AND COLOCATIONS

- Vulnerability of CI in geographic space = „structural weakness, susceptibility and defenselessness“ in the network of CIs
- **Structural vulnerability** = highest on the points / intersections where one negative event causes simultaneously damage on more infrastructures **„Achilles approach“**

- **Project goals in this phase:**
- IDENTIFY THE MOST VULNERABLE INTERSECTIONS OF DIFFERENT INFRASTRUCTURES IN THE WHOLE SLOVENIA:
  - Identify all intersections
  - Weight individual infrastructures according to their sectoral importance
  - Identify intersections with the highest factor of vulnerability
  - Display locations of intersections in GIS environment

INTRODUCTION - INTERSECTIONS AND CONGESTIONS IN RISKGIS PROJECT

- Addressed infrastructure - transport, energy, the state level, the possibility of extending
- The data used in the project
  - Public infrastructure cadaster GJI (GURS), DRSC
  - missing data - prepared directly for this project
- Intersections of major infrastructure (the result is vector data)
- Congestions of major infrastructure (the result is raster data)

PREPARATION OF INPUT DATA FOR DETERMINATION OF INTERSECTIONS AND AREAS OF CONGESTIONS

- Database of the major infrastructure in the Republic of Slovenia

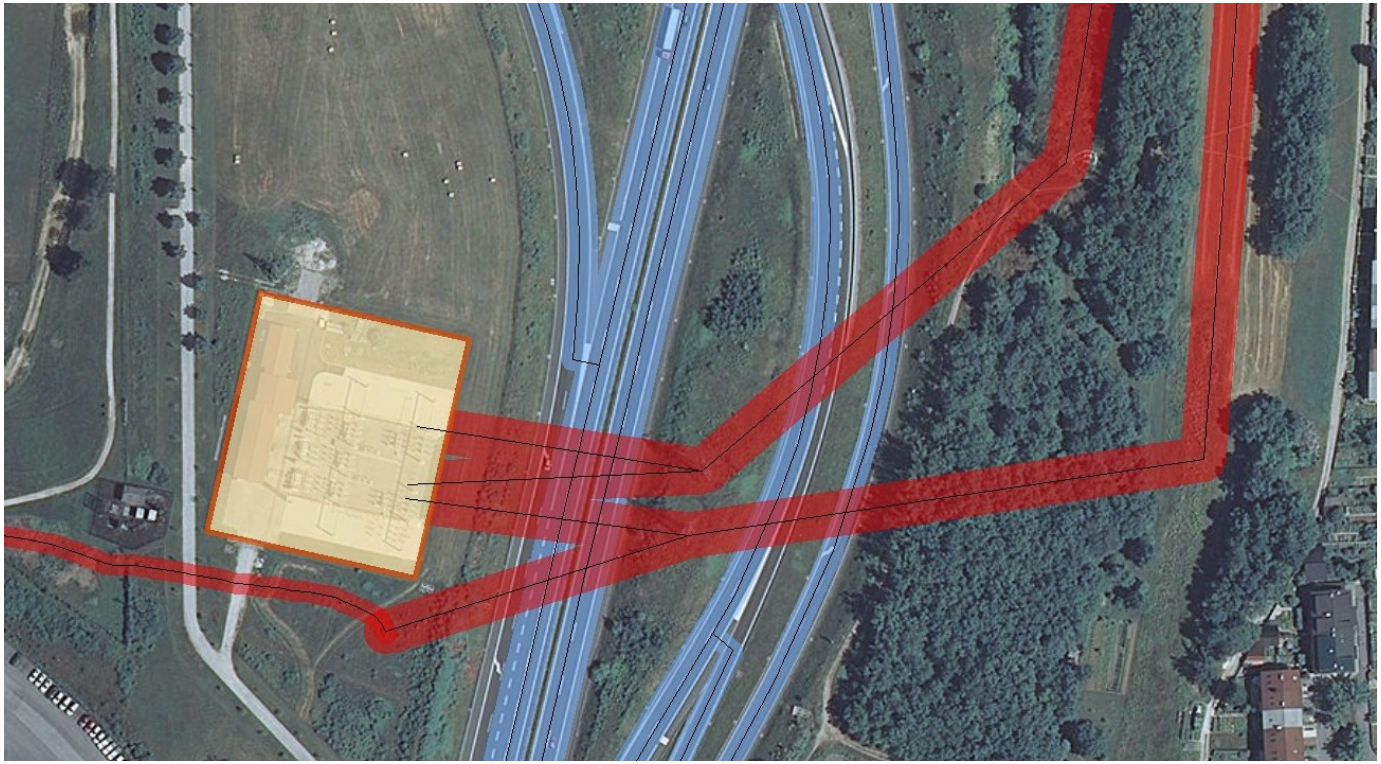
  The database was formed by selecting data from Public infrastructure cadaster (selection criteria: capacity; length - for roads and railway facilities)

Sector	Sub-sector	Major infrastructure pipelines and facilities
ENERGETICS	Electricity	**Production (over 10 MW)**: - **thermal power plant** (resource: coal, natural gas, fuel oil) Šoštanj, Trbovlje, Brestanica, TE-TOL; within thermal power plan are also local storages of oil and petroleum products for starting thermal power plants - **nuclear power plant** (resource: nuclear fuel) NEK Krško; within NEK Krško is also storage of nuclear materials in Krško - **hydro power plant** (resource: water); Holding Slovenske elektrarne, Dravske elektrarne Maribor, Savske elektrarne Ljubljana, Soške elektrarne Nova Gorica; within hydro power plants are also dams and barriers
		Transmission and distribution: - **power lines and cable lines** 400, 220, 110 kV - **transmission and distribution substations** 400, 220, 110 kV
		control centers
	Natural gas	- **transportation gas pipelines** 16 bar and more - **distribution gas pipelines** over 10 bar - **facilities on the gas pipeline network** (border gas measuring and regulating station, compressor station, gas measuring and regulating station), - **control centre** - **storage of liquefied petroleum gas** (Celje, Maribor, Račje selo, Ljubljana, Kozina) - **gas field pumping**
	Oil	- **oil field pumping** - **oil pipeline** - **storage of oil and petroleum products** (Smin, Zalog, Ortnek, Rače, Lendava)
TRAFFIC	Roads	- **national roads** (motorways, expressways, main roads, regional roads) - **facilities on national roads** (bridge, viaduct, tunnel, cut-and-cover) longer than 50 m - **control centers**
	Railways	- **railway** (main railway, regional railway) - **facilities on railways** (bridge, tunnel, facilities for protection) longer than 50 m - **control centers** (Ljubljana, Pragersko, Zidani most, Divača)
	Airports	- **airport area** (Ljubljana, Maribor, Cerklje, Portorož) - **control centers**
	Ports	- **port area** (Luka Koper)
ADDITIONAL FACILITIES		Central Storage for Radioactive Waste in Brinje

DETERMINATION OF THE MAJOR INFRASTRUCTURE INTERSECTIONS

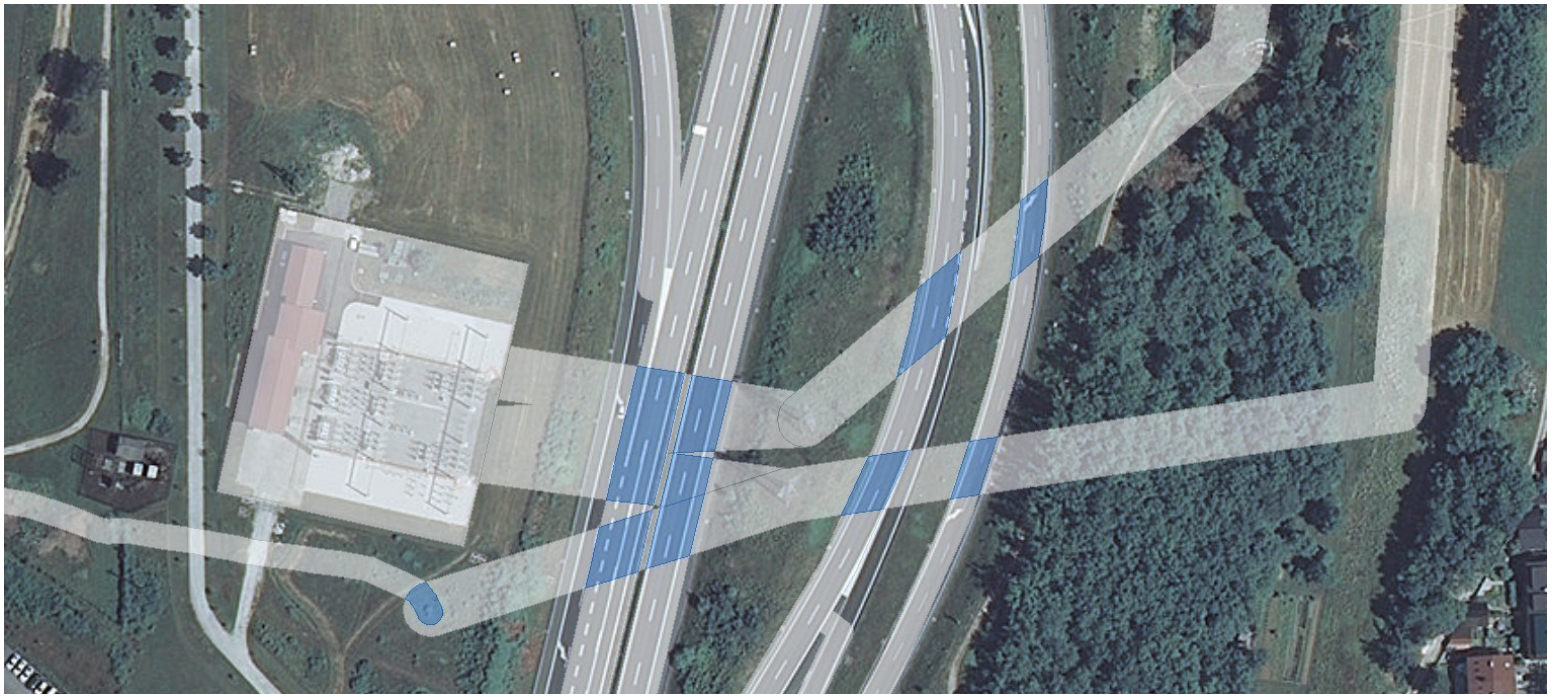
- Drawing of linear and point objects

Determination of intersections: all linear and point objects are drawn as planar (polyline) entities regarding determined width of linear corridors; point objects are drawn as planar (polyline) entities originating from digital aerial photos.



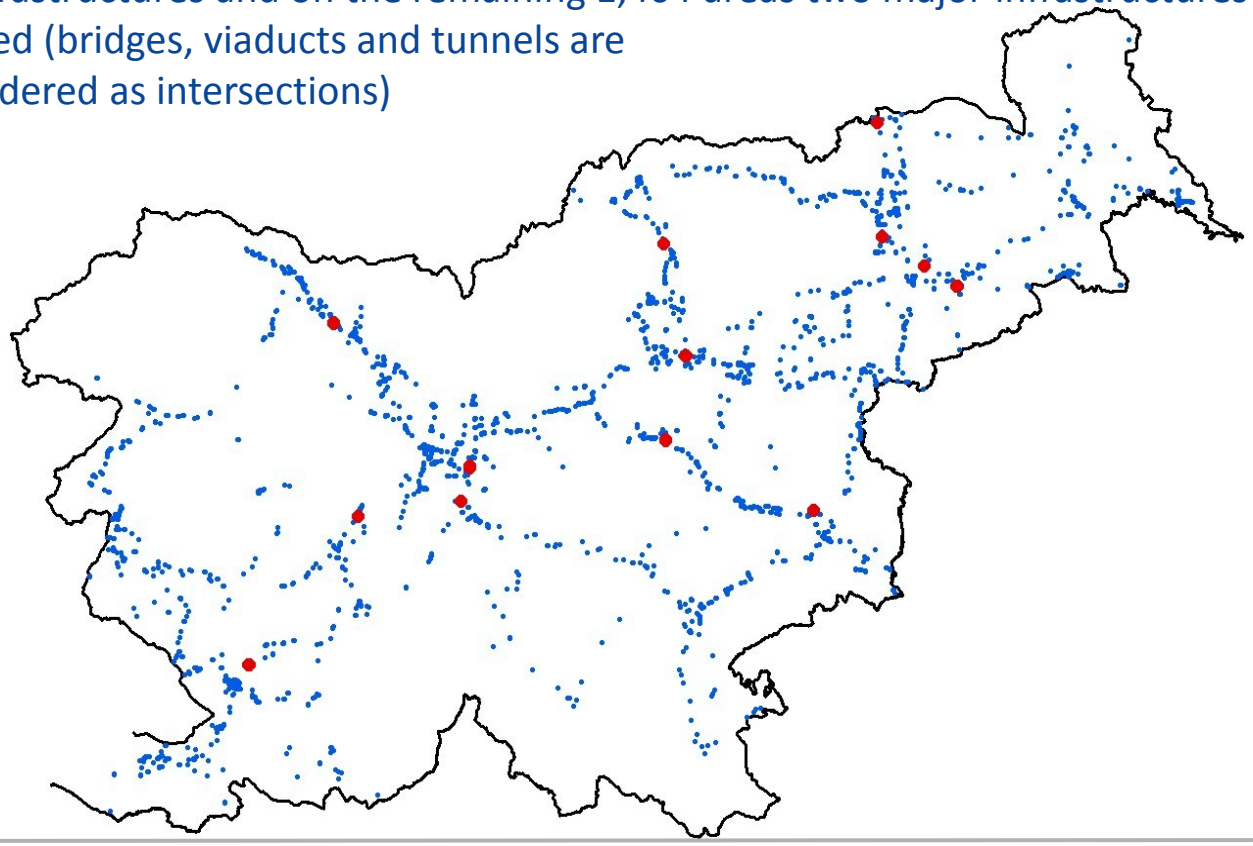
DETERMINATION OF THE MAJOR INFRASTRUCTURE INTERSECTIONS

- Intersections are determined on the basis of intersection of corridors of all infrastructure lines and point objects



RESULTS – MAJOR INFRASTRUCTURE INTERSECTIONS IN THE REPUBLIC OF SLOVENIA

- On the territory of the Republic of Slovenia is the total 2,477 intersections of major infrastructure, which appear in 94 different combinations. In 13 intersection areas three major infrastructures and on the remaining 1,464 areas two major infrastructures are intersected (bridges, viaducts and tunnels are not considered as intersections)

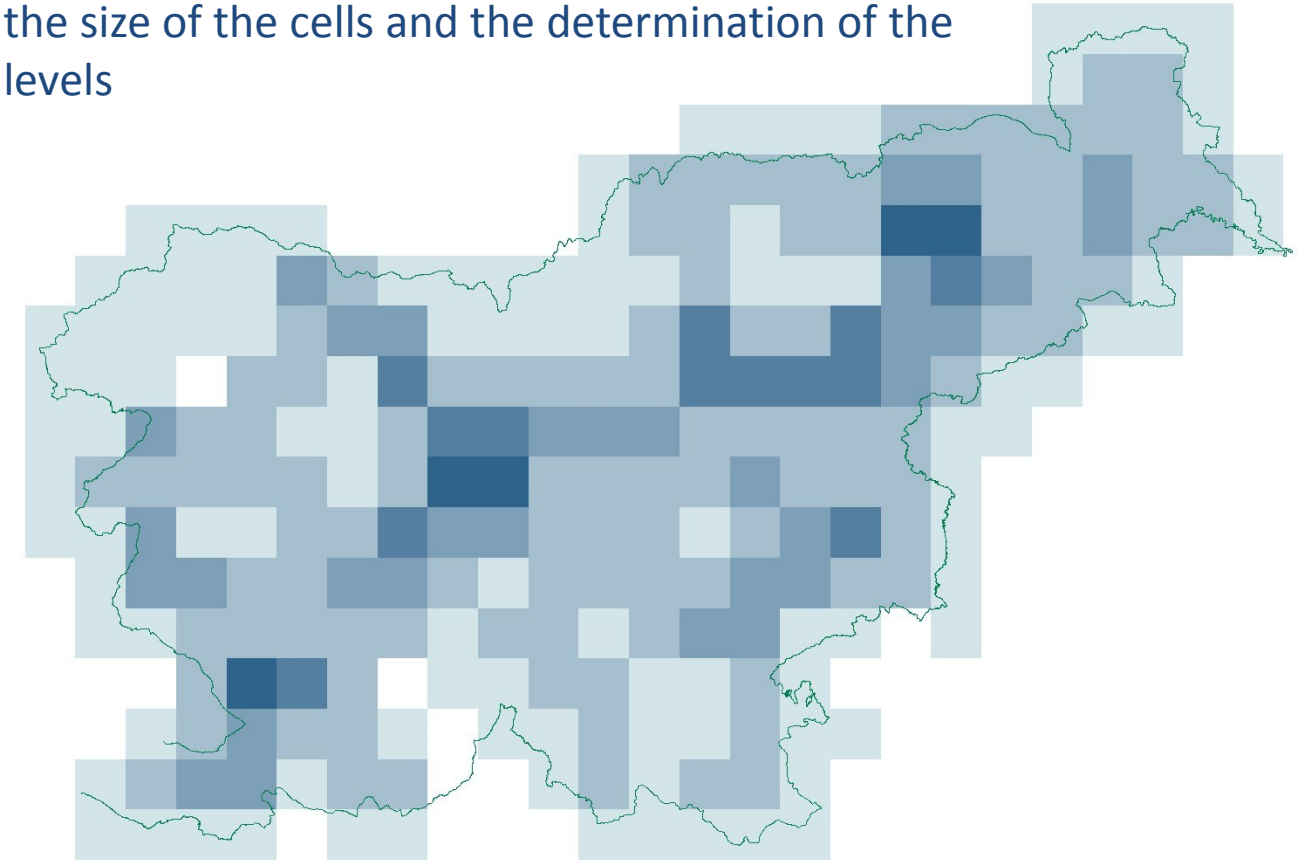


RESULTS – MAJOR INFRASTRUCTURE CONGESTIONS IN THE REPUBLIC OF SLOVENIA

- areas of higher congestions of infrastructure
- congestion of infrastructure (proximity - not only the direct intersections, parallel linear infrastructure courses)
- the same input data as for intersections
- vulnerability of the infrastructure increases with the density - higher density generates increased attractiveness for the generation of an event
- areas of greater density of the infrastructure are more vulnerable (not just the facility / micro location, but also the area)
- appropriate for the analysis of the linear infrastructure lines (surface infrastructure facilities - exclusive use)

RESULTS - MAJOR INFRASTRUCTURE CONGESTIONS IN THE REPUBLIC OF SLOVENIA

- raster data, usability/presentation: depending on the size of the cells and the determination of the levels



RANKING OF THE INTERSECTIONS – DETERMINATION OF VULNERABILITY

- Mutual comparison of the intersections: Intersections with a higher degree of vulnerability are areas more vulnerable to an event (attack, accident ...), which would multiplicative transfer damage to several infrastructures at the same time
- Weight of importance is assigned for each infrastructure
- Determination of weights: between 1 and 100 for all infrastructure lines and facilities according to their functional importance in the system
- Cross-border impact: determination of cross-border weights - 50 to all infrastructure lines and facilities that have cross-border impact (are functionally important for the connection to the neighboring infrastructure systems)
- The basic method: calculation of vulnerability of intersections is the sum of the weights of importance of infrastructure lines and facilities within intersection
- Variation of the method regarding cross-border impact: weights of cross-border impact is added to the basic method

PREPARATION OF INPUT DATA FOR DETERMINING THE VULNERABILITY OF INTERSECTIONS AND AREAS OF CONGESTIONS

- Determination of the weights of importance
- Example: electric infrastructure

- production

Category	Description	Weight
1. category	NE Krško, TE Šoštanj	100
2. category	all other thermal power plants	70
3. category	all hydro power plants	40

- transmission and distribution lines

Category	Description	Weight
1. category	400 kV power line	100
2. category	220 kV power line	90
3. category	110 kV power line and cabel line	60

- transmission and distribution power substations

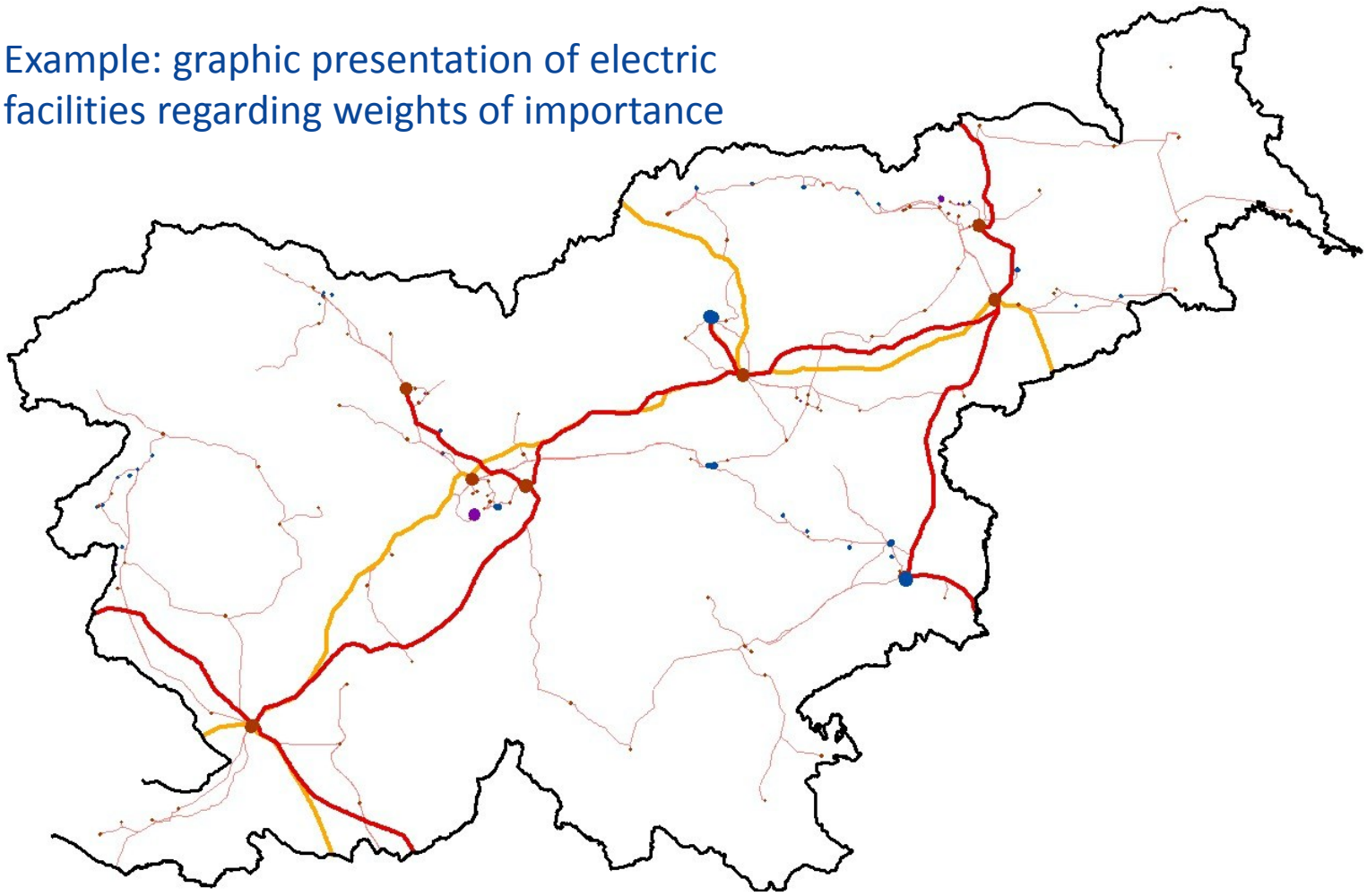
Category	Description	Weight
1. category	RTP Beričevo, RTP Kleče, RTP Okroglo, RTP Divača, RTP Podlog, RTP Cirkovce, RTP Maribor, RTP Krško	100
2. category	all other RTP	60

- control centers

Category	Description	Weight
1. category	Eles	100
2. category	GEN, HSE	80
3. category	all other control centers	40

PREPARATION OF INPUT DATA FOR DETERMINING THE VULNERABILITY OF INTERSECTIONS AND AREAS OF CONGESTIONS

- Example: graphic presentation of electric facilities regarding weights of importance



PREPARATION OF INPUT DATA FOR DETERMINING THE VULNERABILITY OF INTERSECTIONS AND AREAS OF CONGESTIONS

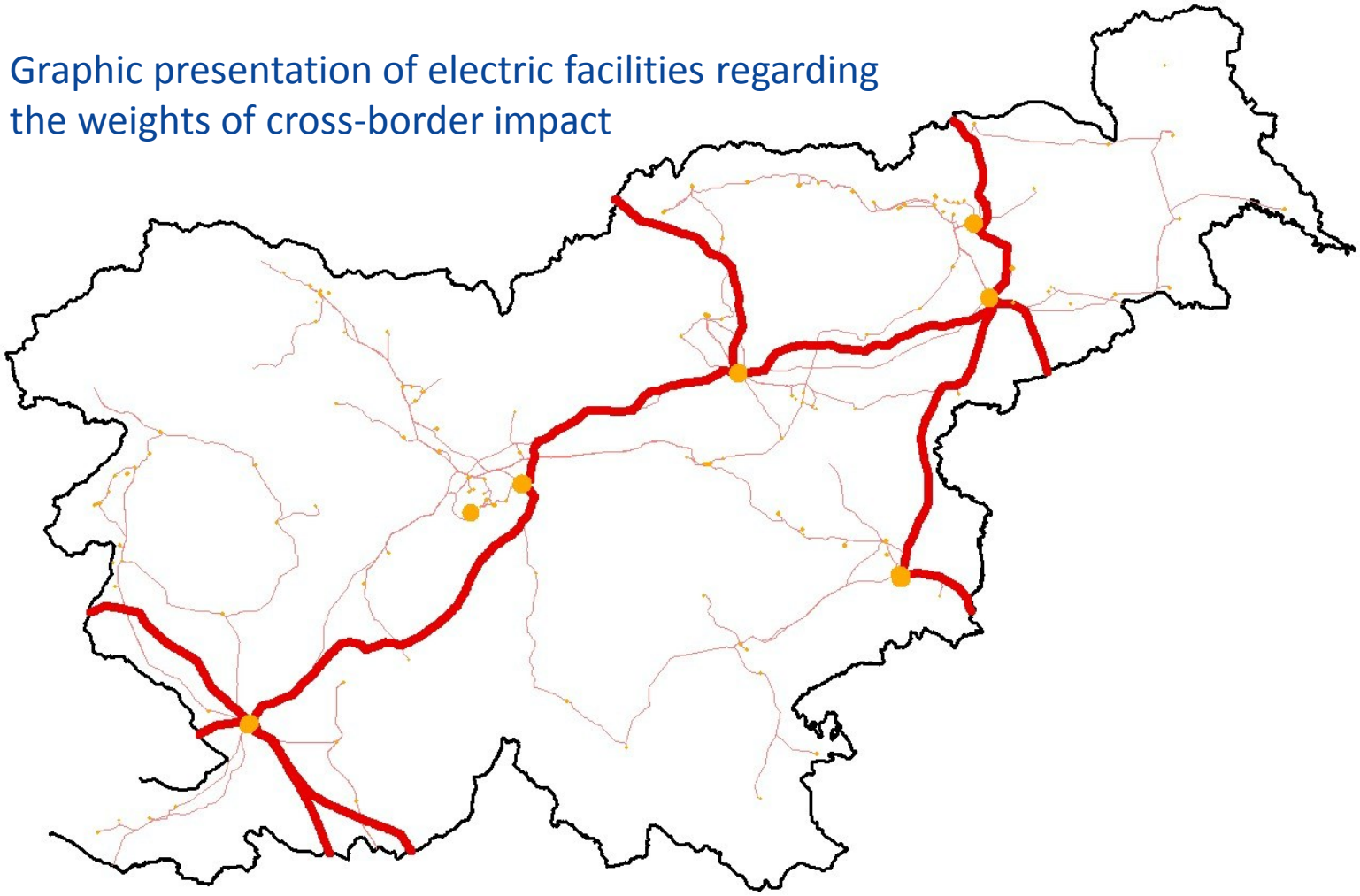
- Determination of the weight of the cross-border impact

Cross-border impact is assigned to all transsmision infrastructure systems of high capacity, which connect to infrastructure systems of neighboring countries.

Sector	Sub-sector	Major infrastructure pipelines and facilities
ENERGETICS	Electricity	**Production (over 10 MW):** - **nuclear power plant** - NEK Krško
		Transmission: - **400 and 220 kV power lines** from the border to the first transmission substation in the Republic of Slovenia, - **400 kV power line** between RTP Maribor and RTP Divača - **400 kV power line** between RTP Maribor and RTP Krško - **transmission substations** in the selected 400 and 220 kV network (RTP Maribor, RTP Cirkovce, RTP Krško, RTP Podlog, RTP Beričevo and RTP Divača)
		control centre - Slovenian National Control Centre Eles
	Natural gas	- **transportation gas pipelines**, which cross the Republic of Slovenia between borders with Austria and Italy (gas pipelines M1 Ceršak - Rogatec, M2 Rogatec - Vodice and M3 Vodice - Miren) - **transportation gas pipelines** from border gas measuring and regulating station Rogatec to the border with Croatia - **facilities on the transportation gas pipelines** - border gas measuring and regulating station Šempeter, Rogatec and Ceršak, distribution and measuring regulation station Vodice and compressor station Kidričevo and Ajdovščina - **control centre** - Dispatching centre Ljubljana
TRAFFIC	Roads	- **national roads** – all motorways and expressways in the Republic of Slovenia and all major roads I. and II. category, which take place from network of motorways and expressways to the border - **control centre** - regional control centre in Ljubljana
	Railways	- **railway** - all major railways - **control centre** – Traffic Management Business Unit, Slovenian Railways
	Airports	- **airport area** – airports in Ljubljana and Maribor - **control centre** – Slovenia Control, Slovenian Air Navigation Services
	Ports	- **port area** - Luka Koper

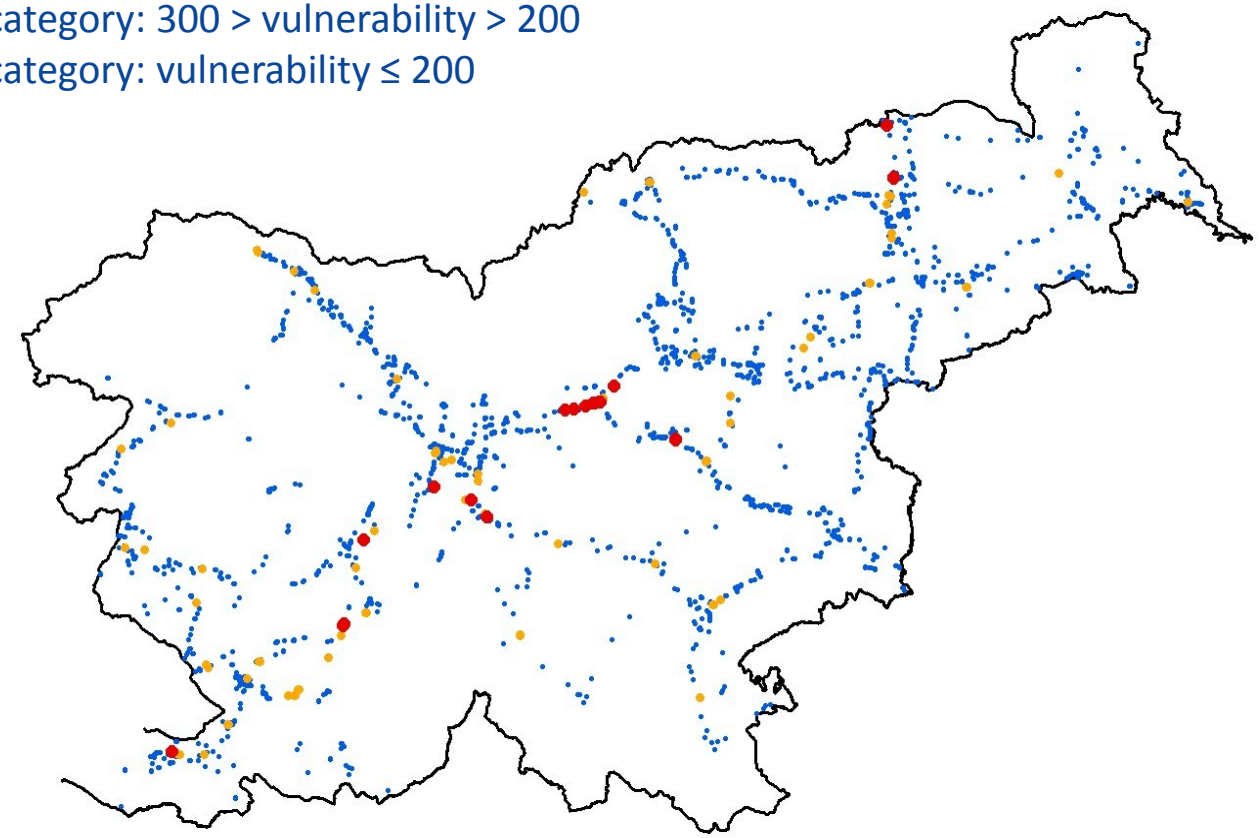
PREPARATION OF INPUT DATA FOR DETERMINING OF INTERSECTIONS AND AREAS OF CONGESTIONS

- Graphic presentation of electric facilities regarding the weights of cross-border impact



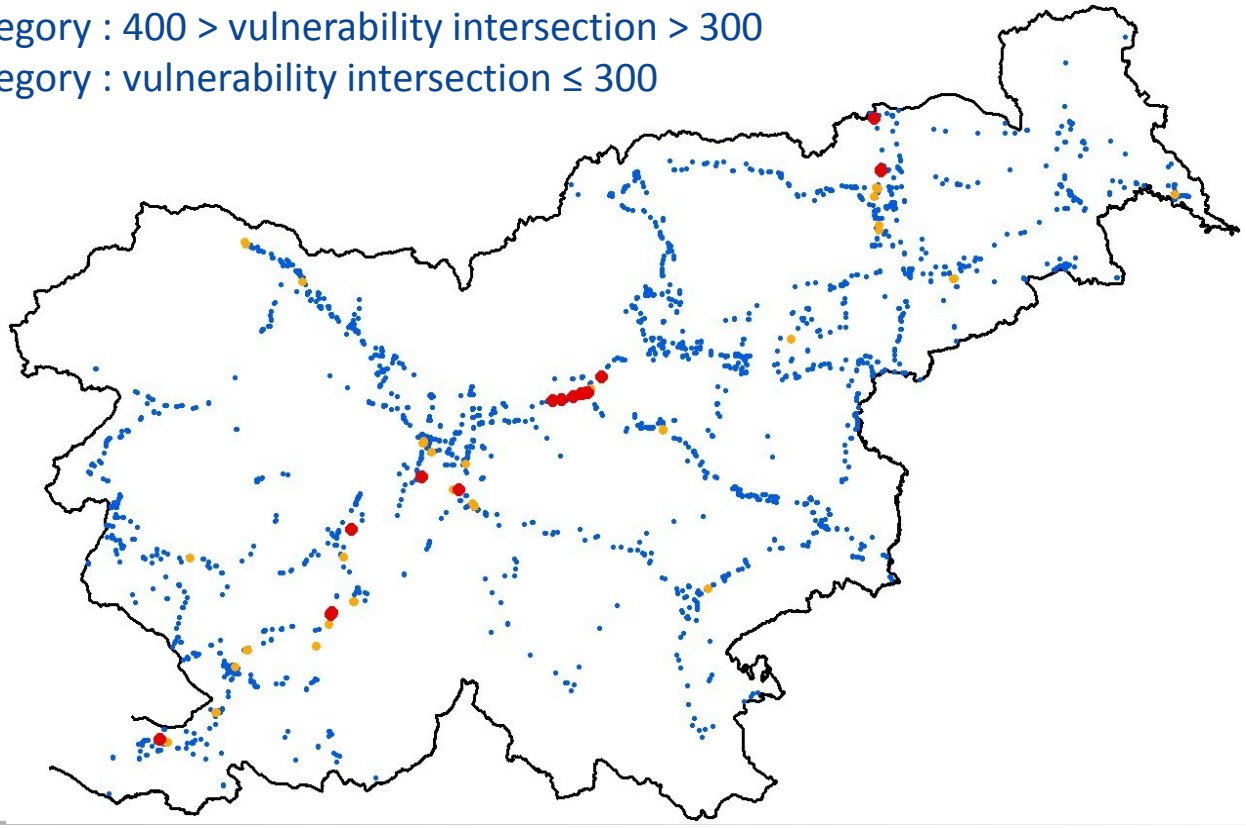
RESULTS - RANKING OF MAJOR INFRASTRUCTURE INTERSECTIONS IN THE REPUBLIC OF SLOVENIA

- All intersections are ranked on the basis of vulnerability of intersection and grouped into three categories (most vulnerable to less vulnerable):
  1. category: vulnerability ≥ 300 (18 intersections)
  2. category: 300 > vulnerability > 200
  3. category: vulnerability ≤ 200



RESULTS – RANKING OF MAJOR INFRASTRUCTURE INTERSECTIONS IN THE REPUBLIC OF SLOVENIA REGARDING CROSS-BORDER IMPACT

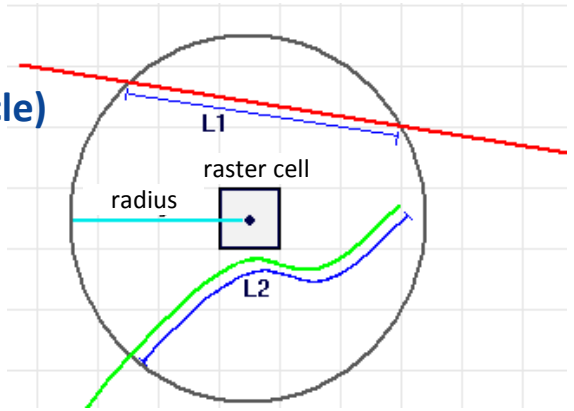
- All intersections are ranked on the basis of vulnerability of intersection and grouped into three categories (most vulnerable to less vulnerable):
  1. category: vulnerability intersection ≥ 400 (16 intersections)
  2. category : 400 > vulnerability intersection > 300
  3. category : vulnerability intersection ≤ 300



AREAS OF INFRASTRUCTURE CONGESTIONS

- Each raster cell (different sizes) is attributed a circle (determined radius) with its center in the center of the cell,
- Calculation of the length of infrastructure linear objects within the circle,
- The length of infrastructure linear objects (in the circle) is multiplied with weight of importance (U1, U2, …) (basic method),
- The length of infrastructure linear objects (in the circle) is multiplied with the sum of weights of importance and cross-border effect (variation),
- sum of multiplications of all infrastructures is divided with the surface area of the circle,
- vulnerability result (density of weighted infrastructure in the circle) is attributed to the cell; unit is expressed in length unit over area unit.

density = ((L1 * U1) + (L2 * U2)) / (surface area of the circle)

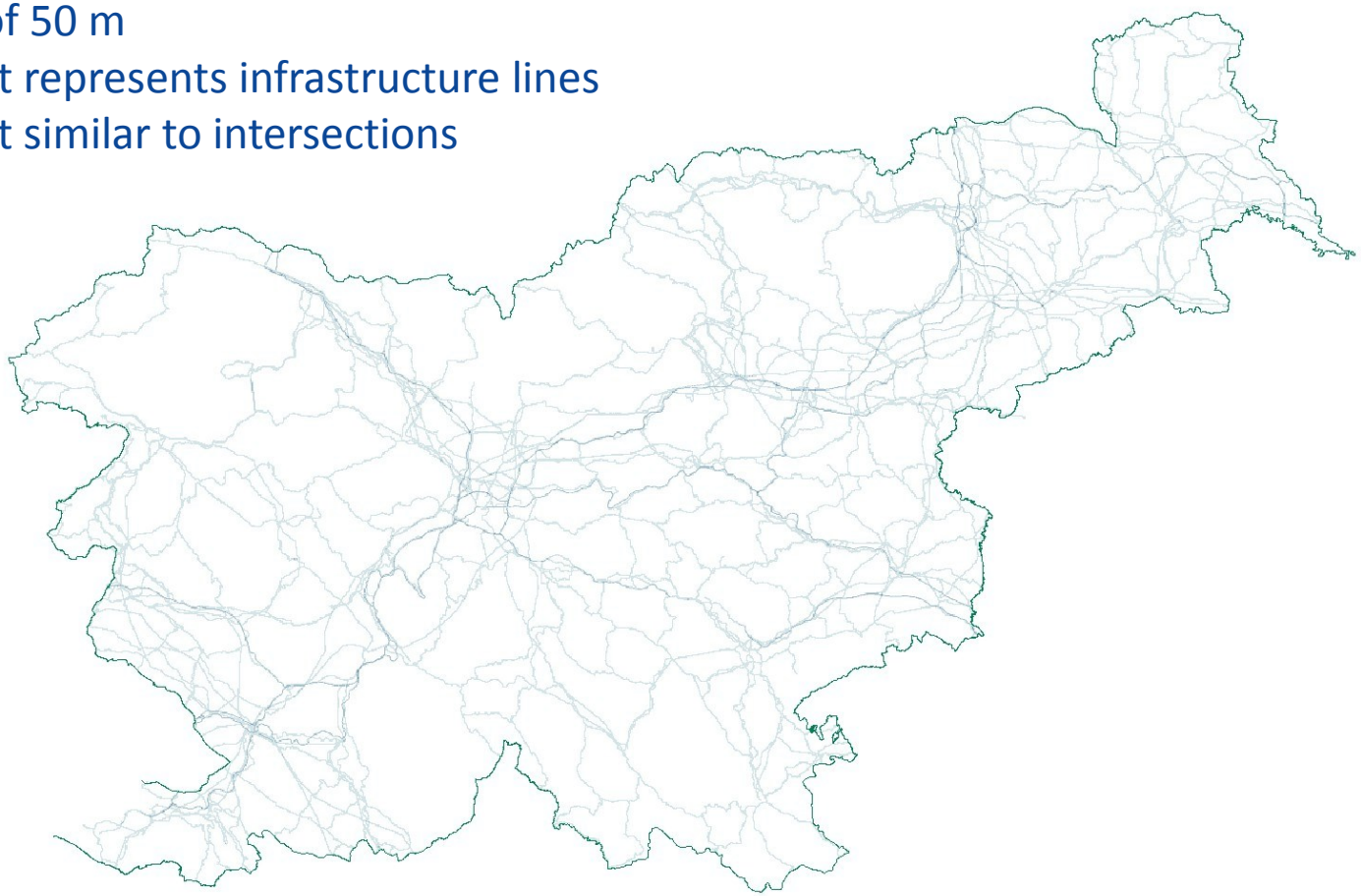


RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- results in raster format
- different sizes of the cells (10 m, 50 m, 200 m, 1 km, 5 km and 10 km): different precision, size of the cell depends on the purpose. Slovenia‘s surface area: max. cell 10 km
- micro (local - 10 m, 50 m, 200 m, 1 km cell) in macro (regional, national - 1 km, 5 km and 10 km cell) level

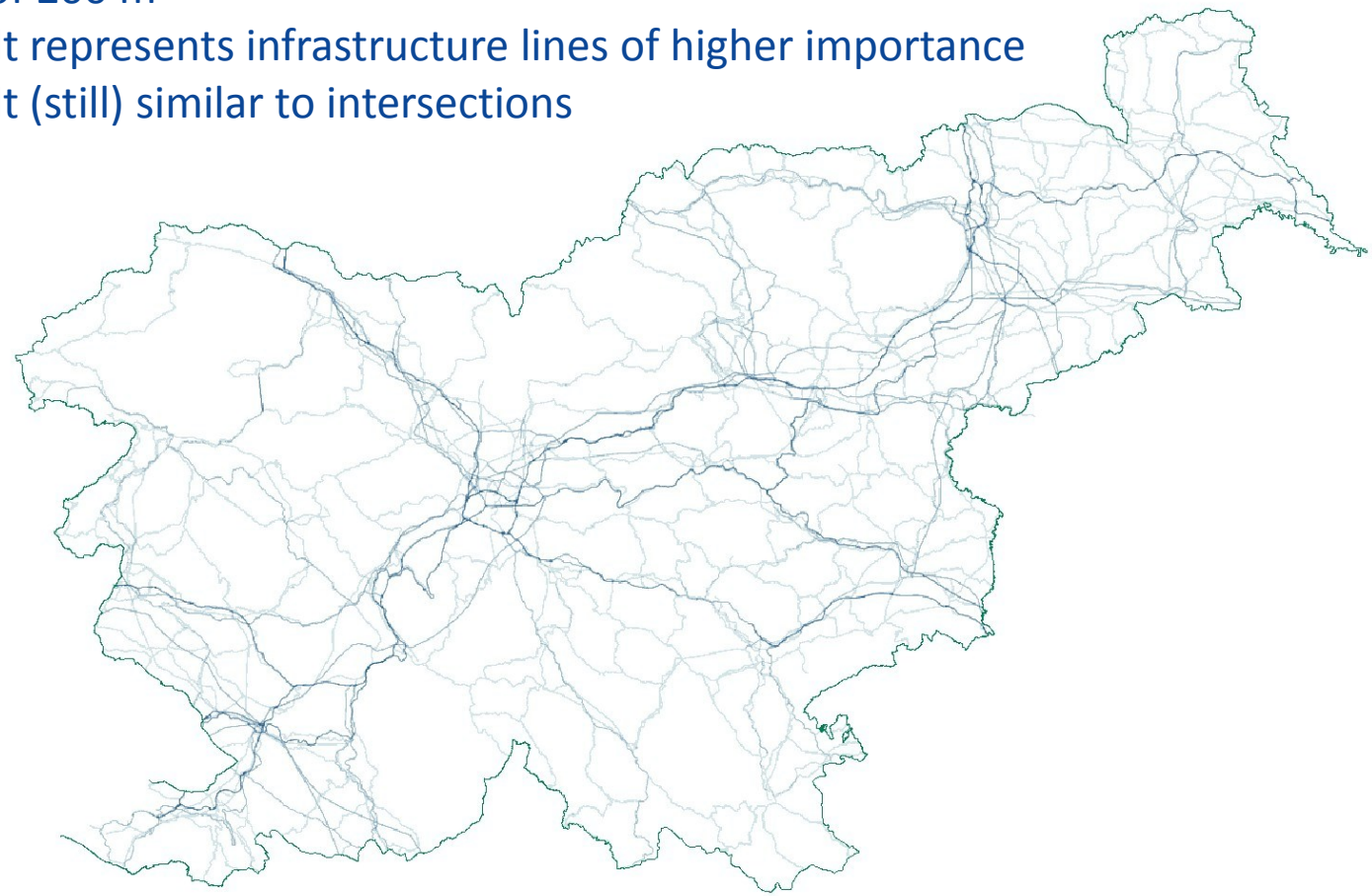
RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- cell of 50 m
- result represents infrastructure lines
- result similar to intersections



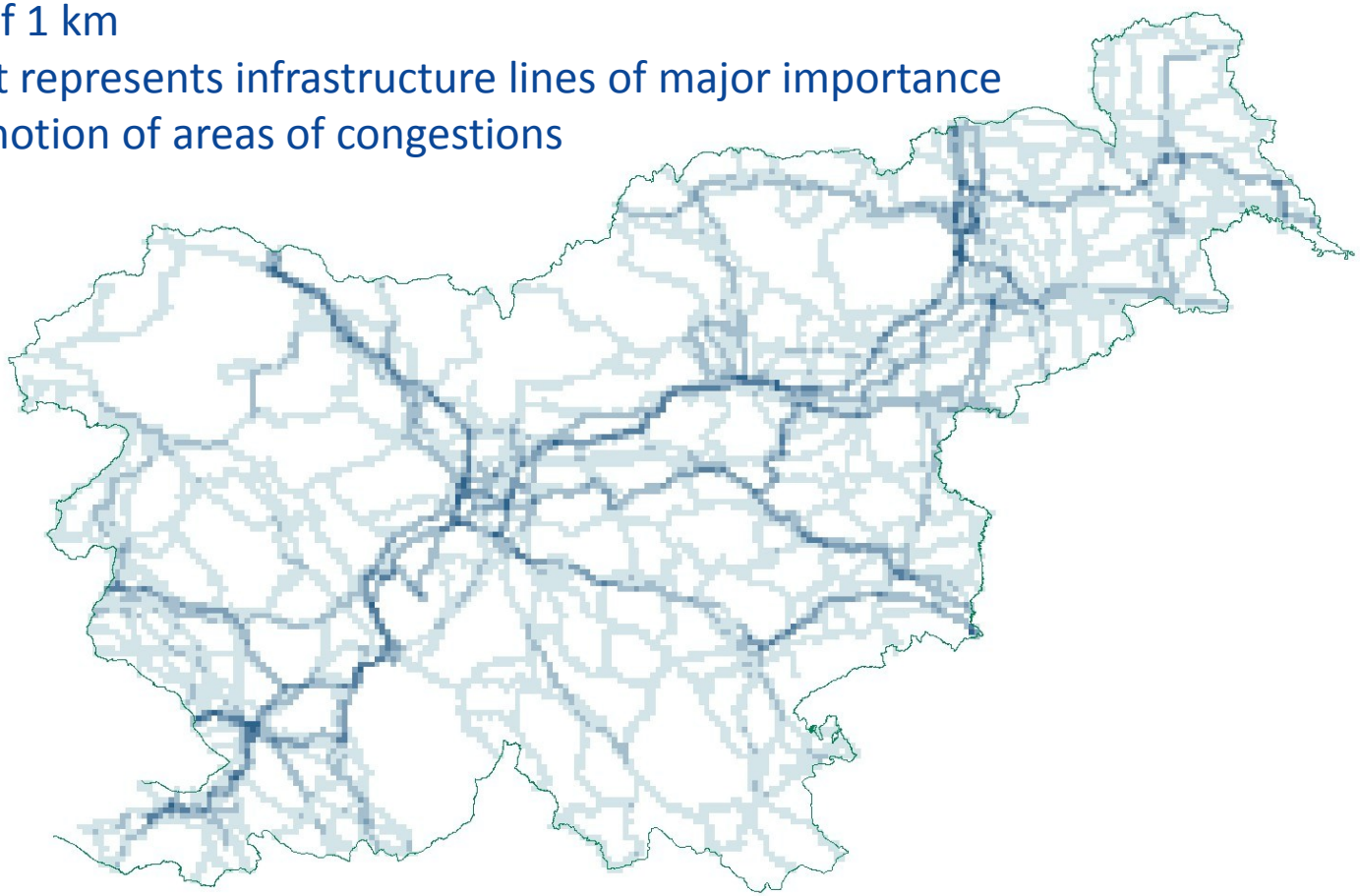
RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- cell of 200 m
- result represents infrastructure lines of higher importance
- result (still) similar to intersections



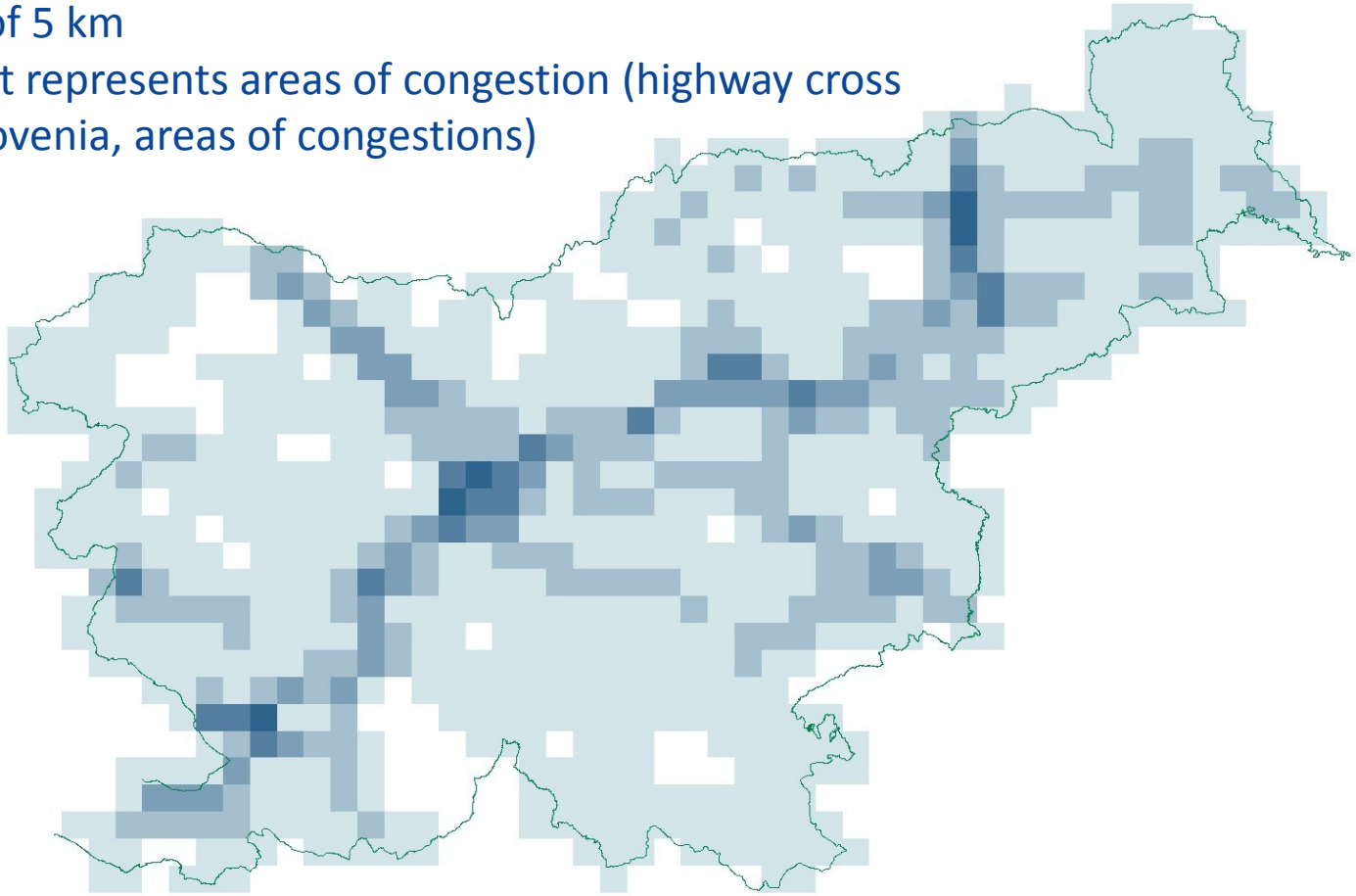
RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- cell of 1 km
- result represents infrastructure lines of major importance
- first notion of areas of congestions



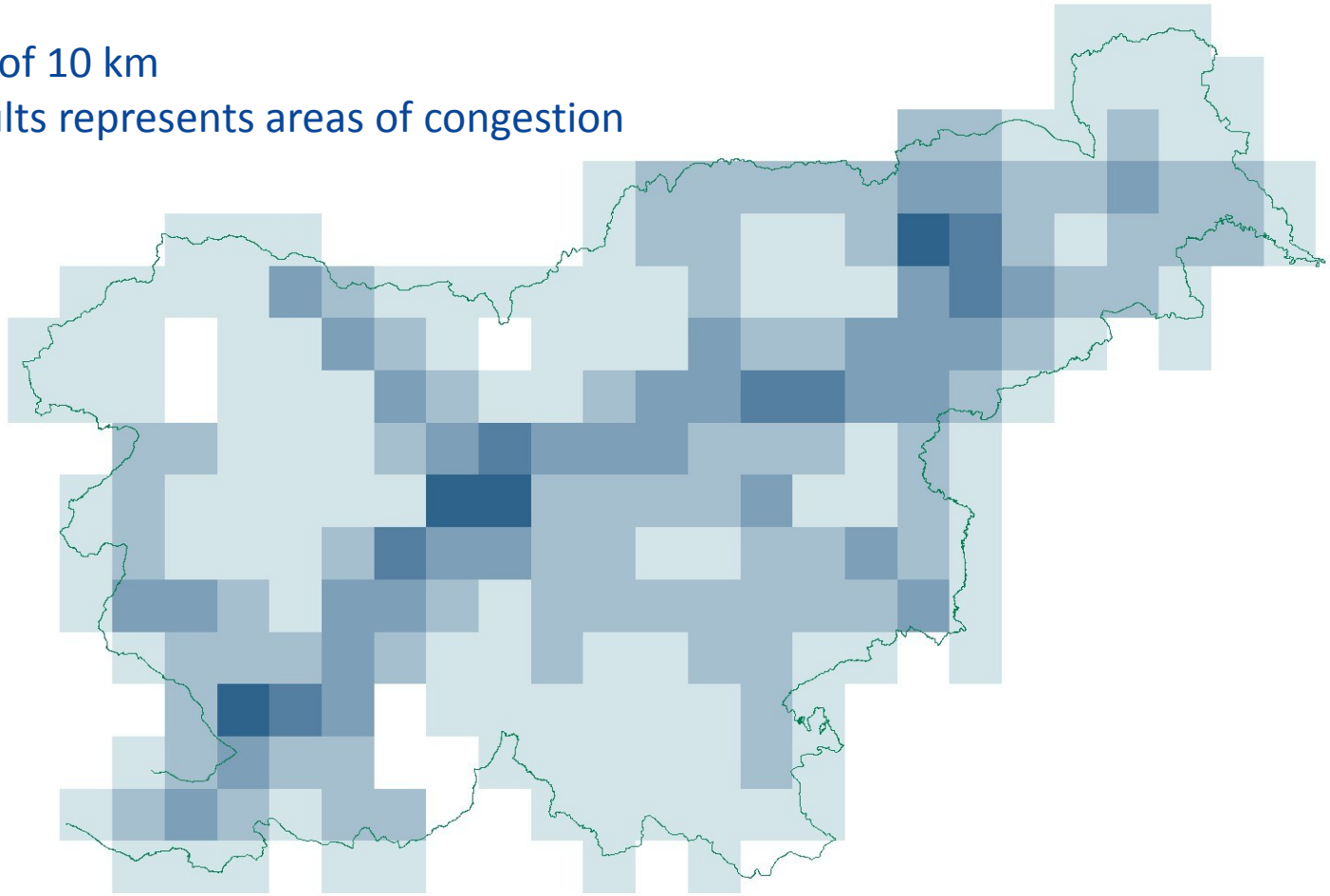
RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- cell of 5 km
- result represents areas of congestion (highway cross of Slovenia, areas of congestions)



RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- cell of 10 km
- results represents areas of congestion



RESULTS – CONGESTIONS OF MAJOR INFRASTRUCTURE IN THE REPUBLIC OF SLOVENIA

- results in smaller cells – up to 1 km (more precise data):
  - representation of infrastructure lines,
  - micro/local level
  - no significant differences in the density of infrastructure
  - similar to intersections
  - parallel course included (small impact to the result)
  - applicability: to determine the vulnerability of infrastructures due to proximity (intersection and congestion) of different infrastructure lines (geographical co-location)

- results in larger cells – over 1 km (more generalized, average):
  - presentation of areas of congestions
  - significant differences in density, infrastructure lines are no longer visible
  - strategic data
  - regional, national and international level
  - applicability: location siting of objects in spatial planning, strategic assessment, regional safety ranks

APPLICABILITY OF THE RESULTS AND GUIDELINES FOR FUTURE WORK

- Determination of intersections allows the implementation of additional criteria in determination of the vulnerability of particular infrastructure facility
- It is necessary to upgrade Public infrastructure cadaster (database) into functional GIS – all infrastructure data must have attributes and topology to perform functional analyses and simulations
- Operators of Public infrastructure: special attention to intersections as particular risk elements (security, surveillance, technical measures and organizational measures)
- Analysis of congestions (density of the infrastructure) - input data for location siting of infrastructure objects (spatial planning) and for determination of safety ranks of broader areas
- In order to achieve the integrity of the project results it is necessary to involve other (infrastructural) sectors
- Possible upgrading of the model: corridors of impact areas (instead of physical infrastructure corridor)
- Inclusion of electronic communications (databases must be updated and accurate, hierarchically organized)