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Earthquake hazard mapping and analysis by integrating GIS, AHP and TOPSIS for Küçükçekmece region in Turkey

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EMBRACING OUR SMART WORLD WHERE THE CONTINENTS CONNECT:
ENHANCING THE GEOSPATIAL MATURITY OF SOCIETIES

Presentation Outline

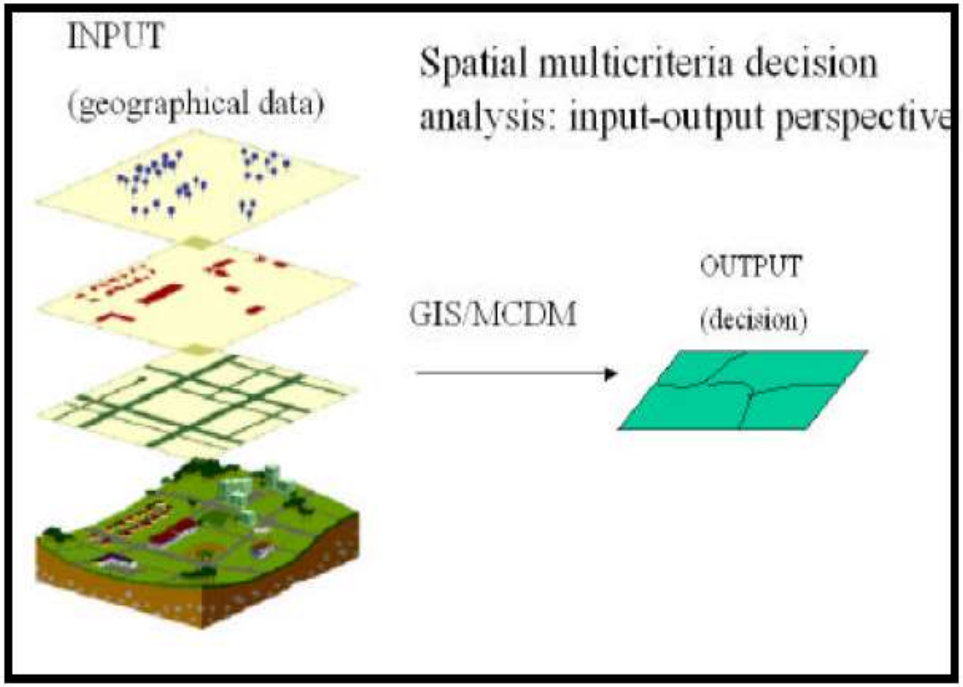
- Introduction
- Motivation and Objectives
- Case Study – AHP and TOPSIS Implementation
- Results and Comparisons
- Discussion and Conclusions

Introduction: Why do we need to produce Hazard maps?

- Tragic earthquake events underscore need for effective disaster and earthquake management (DEM)
- Hazard maps via GIS required across all phases:
  - *risk identification, most hazardous areas*
  - *planning equipment, mobilization, asset removal/retrofit, damage assessment, recovery efforts*
  - *part of disaster mitigation activities*
- Need to minimize *conflicts*, *uncertainties* in *hazard map production*

Introduction: Multi-Criteria Decision Analysis (MCDA)

- Technique introduced in mid-1970s
- For solving complex problems having many conflicting criteria and alternatives
- GIS-based MCDA – integration of GIS, enhancing planning and decision-making



- *Spatial* + *value judgement* decision-making problems e.g. *site selection*

Multi-Criteria Decision Analysis (MCDA) Methods

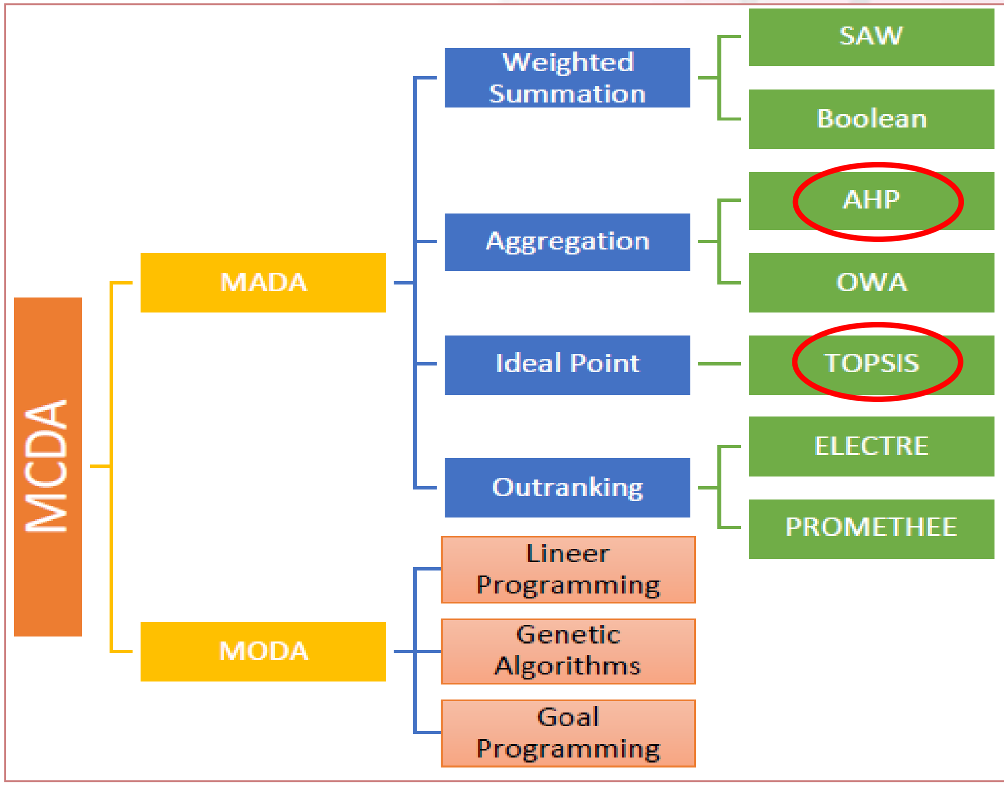
- **MADA** (Multi-Attribute Decision Analysis) ~ evaluating *criteria* into *attributes*

  \- *discrete*: *pre-set, finite alternatives*

  \- *selection process = solution*

- **MODA** (Multi-Objective Decision Analysis) ~ evaluating *criteria* into *objectives*

  \- *continuous*: *infinite alternatives*



TOPSIS Method (Hwang and Yoon, 1981)

- *Concept*:
  - *Best alternative: simultaneously, closest to Positive Ideal Solution (PIS) and farthest away from Negative Ideal Solution (NIS)*
- *final ranking* acquired by *closeness index*

Step 1: Define and construct a performance/decision matrix

Step 2: Normalize the decision matrix

Step 3: Assign a weight vector to attribute set for group and calculate weighted normalized decision matrix

Step 4: Determine the **PIS** and **NIS**

Step 5: Calculate the separation distance from **PIS** and **NIS**

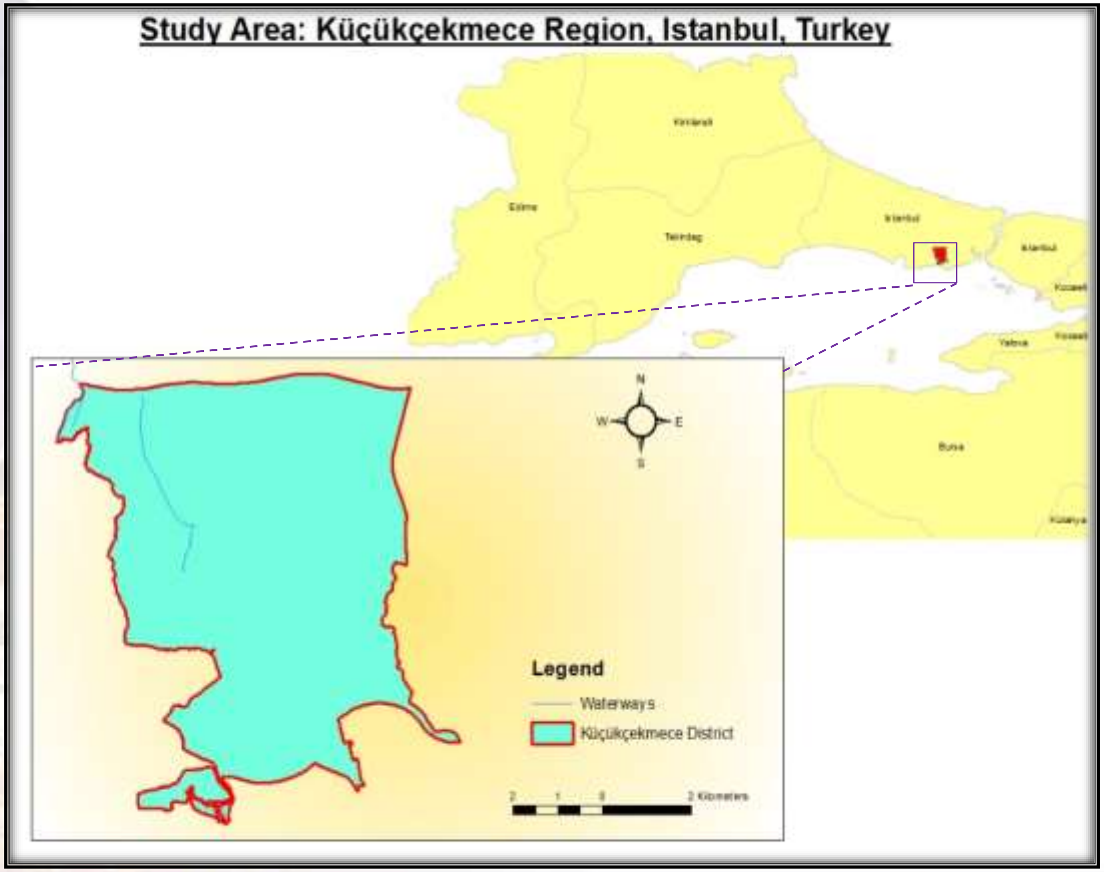
Step 6: Compute relative closeness of each alternative to ideal solution

Step 7: Ranking of alternatives/preference order

Motivation and Objectives: Why use TOPSIS?

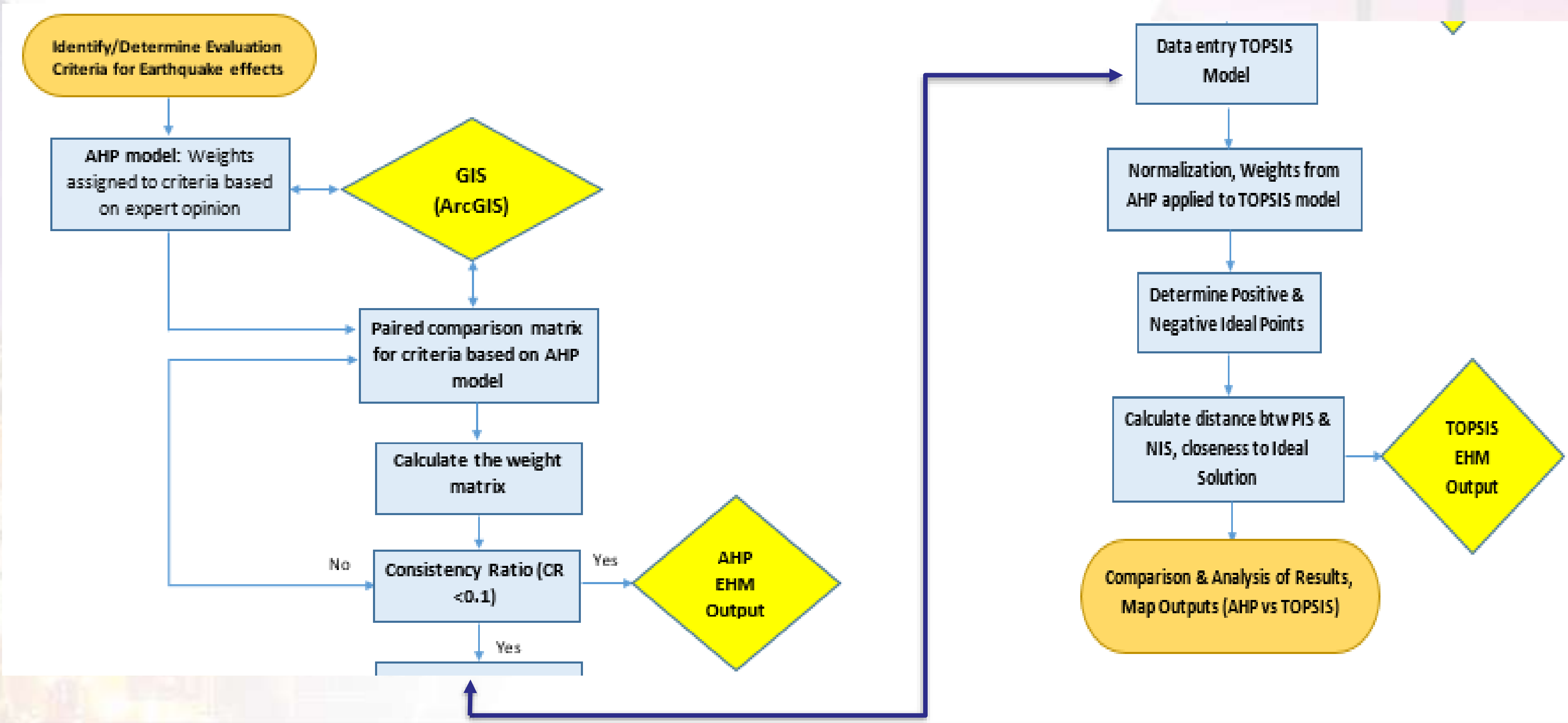
- Among *best* for resolving *rank reversal* issues
- *Intuitive*: easy to *use* and *understand*.
- *Simple computational* process; *easily programmable* and *integrated* in other *DSS* - *GIS*.
- *GIS visualization* of all alternatives on attributes
- *Scaler value* for both *best* and *worst* alternatives
- *Suitable* for *raster data*
- *For comparison and validation of AHP result for suitability assessment for earthquake hazard risk/ loss assessment - map*

Case Study: Study area



- # *Study focus: generation of earthquake hazard maps (EHMs) using GIS integrated with AHP and TOPSIS*
- # *36 km^2 extent over Küçükçekmece region, Istanbul*

Case Study: Framework for the Study



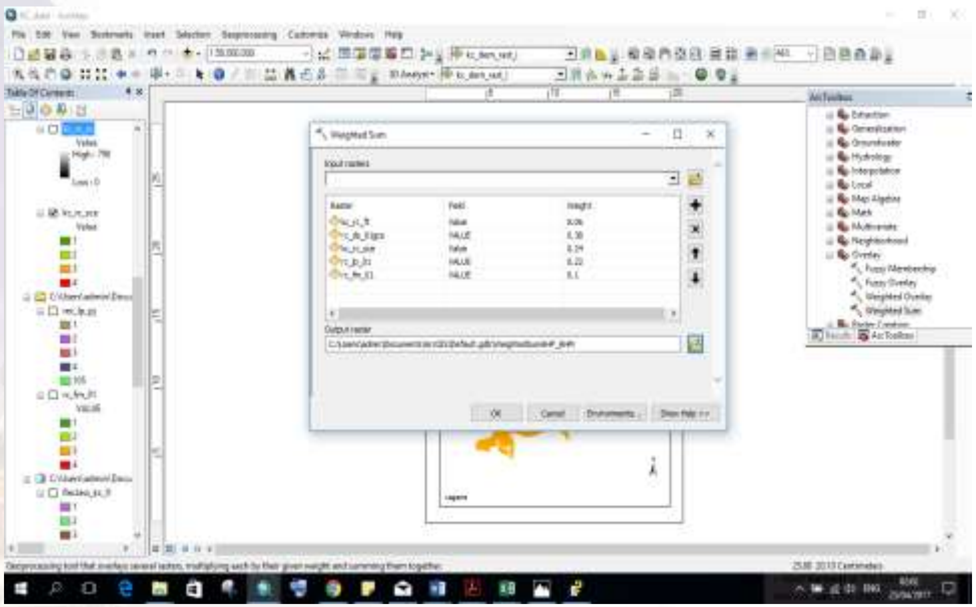
Case Study: Criteria selection

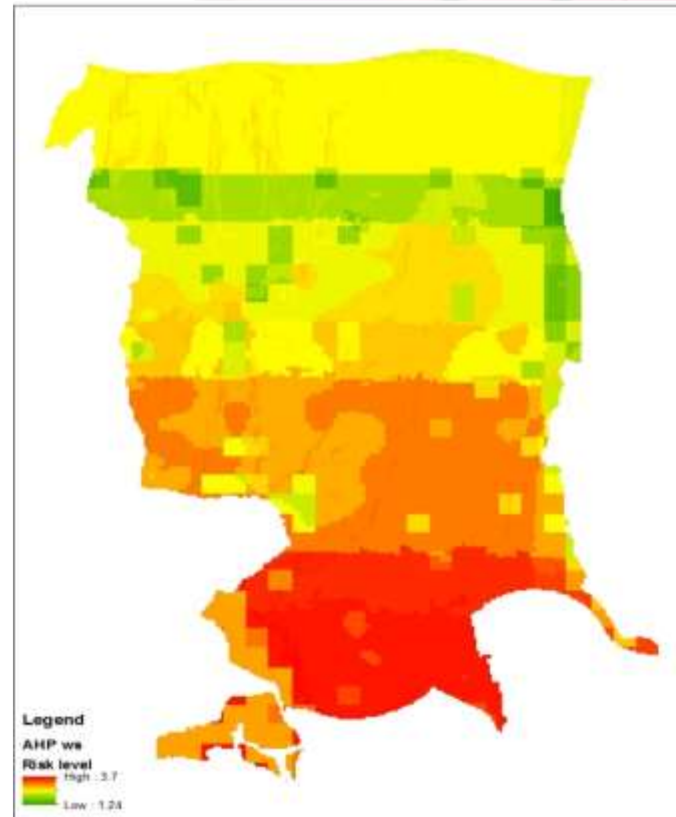
- For *five (5) criterion map layers*, *pairwise comparison analysis*, *data preparation* and *GIS processing* for **AHP** as applied - ***Erden and Karaman*** (***2012***) *study*

	Criteria		Class Values				Weights/ Priorities
			1	2	3	4	
		Risk Level Scale	*No/Low Risk*	---▸--▸	---▸--▸	*Major Risk*	
1	**FT** (field topography) [*degrees*]		0-10	10-15	15-30	>30	0.06 (6%)
2	**DS** (source-to-site distance) [*km*]		22.21-19.80	19.80-17.38	17.38-14.97	14.97-12.55	0.38 (38%)
3	**SC** (soil classification) [*m/s*]		800-760	760-360	360-180	180-50	0.24 (24%)
4	**LP** (liquefaction potential)		104-103	103-102	102-101	101	0.22 (22%)
5	**FM** (fault/focal mechanism)		0.45-0.53	0.53-0.61	0.61-0.68	0.68-0.76	0.10 (10%)

- Input in AHP *and* TOPSIS models *for final hazard map generation*

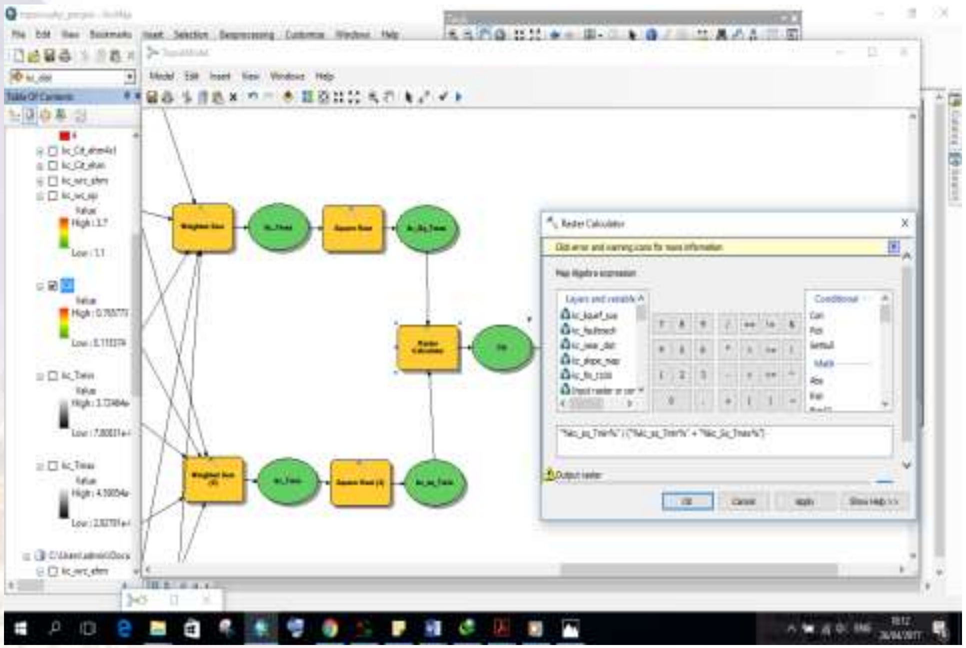
Results and Comparisons: AHP model

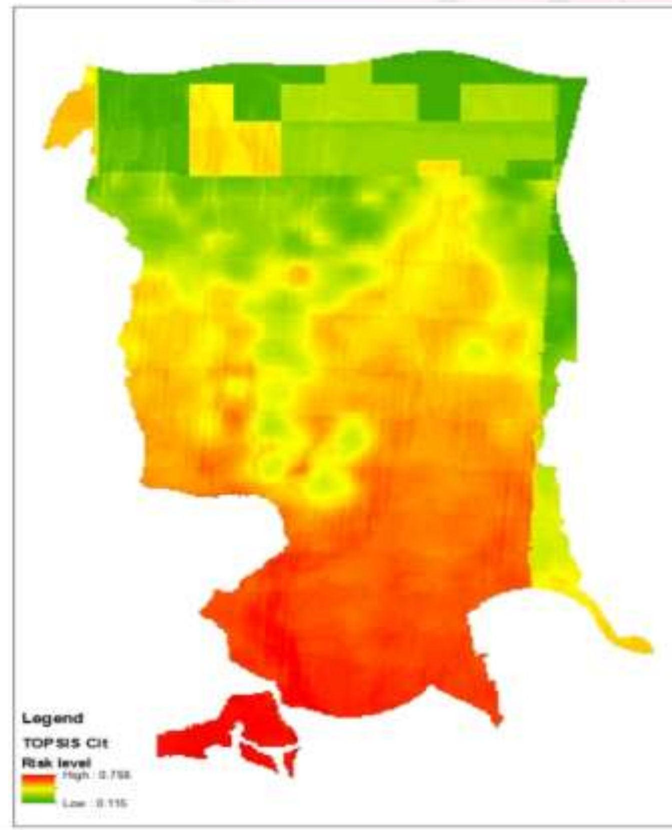




- *After weighted sum analysis process = weighted sum earthquake hazard map (EHM) output raster*

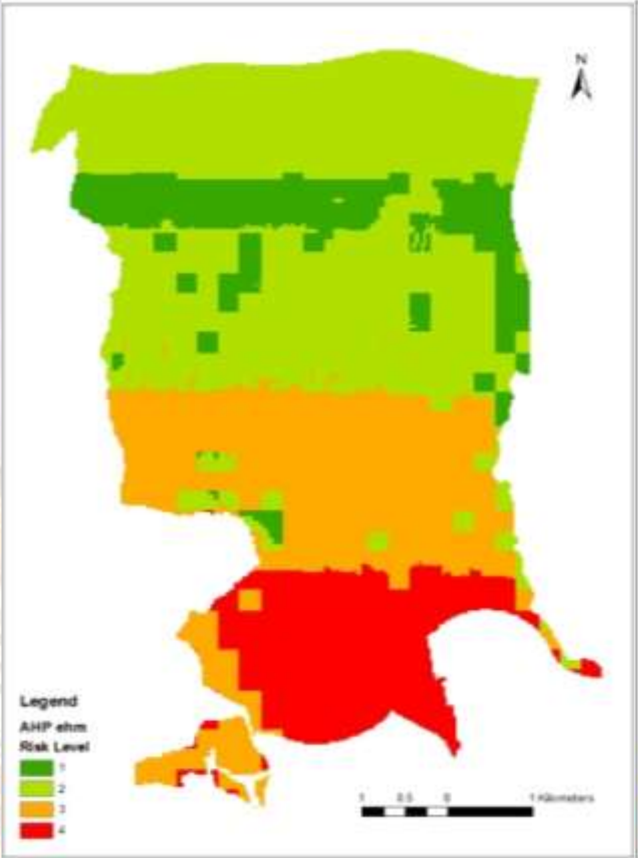
Results and Comparisons: TOPSIS model

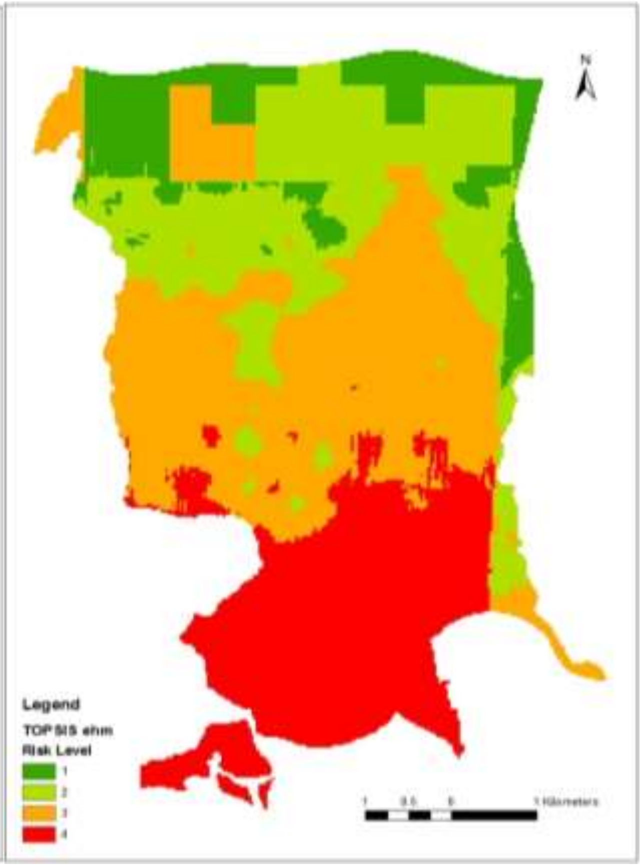




- *After relative closeness to PIS process = weighted sum earthquake hazard map (EHM)*

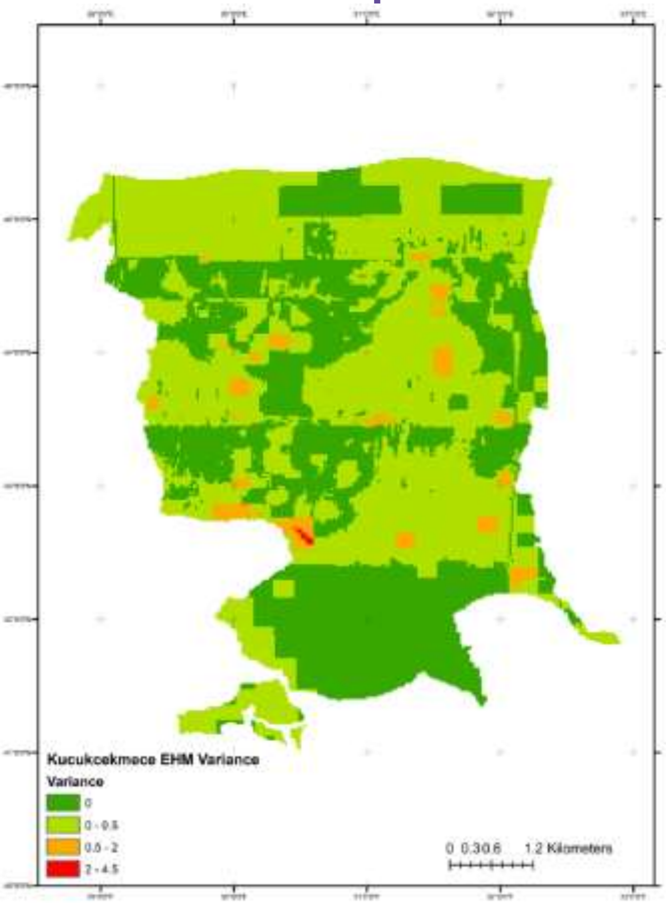
AHP vs TOPSIS hazard maps – *visual comparison*





- *Similar risk level patterns:*
- ⇒ *Areas to south = highest risk (risk level 4)*
- ⇒ *Areas around middle section = medium to high risk (risk level 3)*
- ⇒ *Areas to north = generally, lower risk (risk level 1 and 2)*

Statistical comparison analysis – *Variance map*



- *Compared the difference between the AHP and TOPSIS maps, pixel by pixel by spatial location*

⇒ *the class value ranging from 0 to 0.5 and 2 showed no variance or little difference between the AHP and TOPSIS hazard map*

Discussion

- *Five (5) main criteria* used as input for *earthquake effects simulation* in form of *hazard maps* for both AHP and TOPSIS
- AHP and TOPSIS hazard maps, comparable = *high correlation* and *good compatibility*
- Most hazardous regions in southern parts extending towards middle
- *Weights from AHP* method = *consistent and robust* ~ increasing *reliability* of TOPSIS hazard maps
- Some limitations - *accuracy*, *resolution* and *up-to-datedness* of data could affect reliability of final AHP and TOPSIS hazard maps

Conclusions and future developments

- Other MCDA techniques such as fuzzy AHP/TOPSIS, ELECTRE - for more comprehensive comparisons and validation
- Framework for hazard mapping and analysis established = *other disasters:* floods, landslides, fires, etc. – *ModelBuilder application*
- *Preferences of experts/others* involved in emergency management = reducing critical decision-making time by *minimizing conflicts*
- *Recommend*: *automated* techniques/ software integration of GIS, AHP and TOPSIS process flows - to *reduce time* for analysis and map preparation