Network-risk toolbox

for ArcGIS

USER MANUAL

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version 0.2

Contents

Introduction

Network-risk toolbox provides capabilities to analyze the direct and indirect implications of natural hazards on transportation networks. Network-risk implements the methodology described in Figure 1. For a better understanding of its characteristics and capabilities, please read our articles:

- Toma-Danila D., Armas I., Tiganescu A. (2020) [Network-risk: an open GIS toolbox for estimating the implications of transportation network damage due to natural hazards, tested for Bucharest, Romania.]() Natural Hazards and Earth System Sciences, 20(5):1421-1439, doi: 10.5194/nhess-20-1421-2020 (please use this as main citation)
- Toma-Danila D. (2018) [A GIS framework for evaluating the implications of urban road network failure due to earthquakes: Bucharest (Romania) case study.]() Natural Hazards, 93, 97-111.

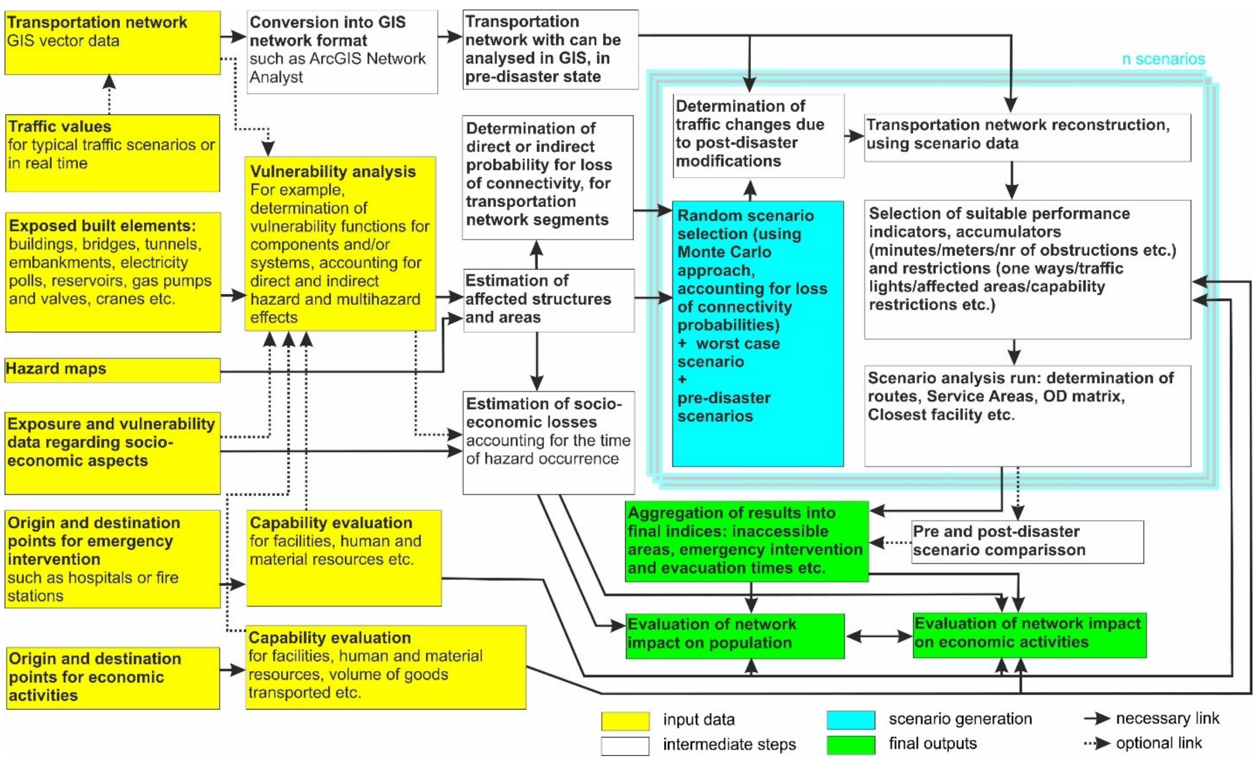

Figure 1 Graphical representation of the proposed methodology for evaluating the implications of transportation network damage due to natural hazards, integrated into the Network-risk toolbox (modified after Toma-Danila et al., 2020)

Requirements

ArcGIS Desktop Advanced 10.2+, with the Network Analyst extension.

Download

Go to www.infp.ro/network-risk

Installation

Currently tested on Windows OS:

1. Download and unzip the files in the “Network_risk”
2. For default settings, copy the “Network_risk” folder in C:
3. Open ArcMap
4. Open the ArcToolbox window
5. Right click on the ArcToolbox icon in the window and click “Add toolbox”
6. Select the “Network-risk” toolbox in C:\Network_risk and click Open
7. The Network-risk toolbox should appear in the toolbox list. You’re all set!

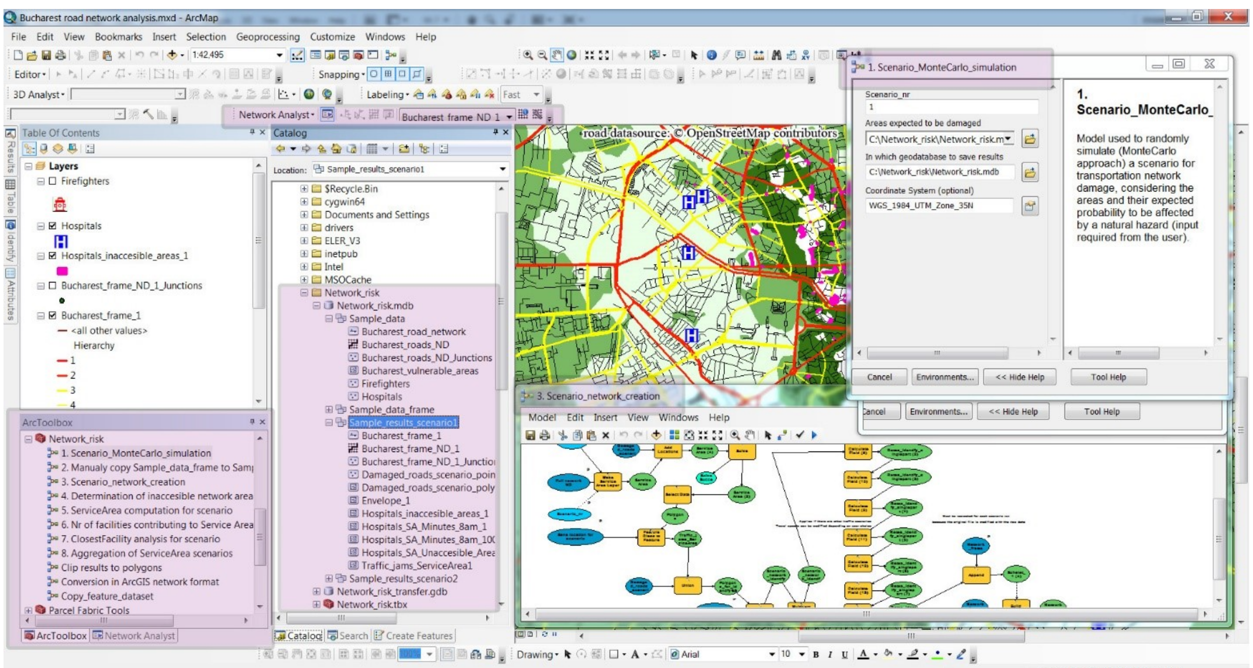

Figure 2 Screen capture of ArcGIS Desktop ArcMap with Network-risk toolbox added, contributing to the analysis of Bucharest's road network risk analysis; the framework of one of the models (3. Scenario_network_creation) can be seen as well as the model run interface (1. Scenario_MonteCarlo_simulation), the Network-risk toolbox modules and the sample data results created using these modules (highlighted in purple) (Toma-Danila et al., 2020)

How to use Network-risk

Network-risk toolbox comprises of different Models built mostly using the ModelBuilder function of ArcMap and bringing together various geoprocessing modules. Models are customizable (just edit them in ModelBuilder), and to facilitate their understanding and applicability are at the moment closely designed for the Bucharest sample data, provided in the download; for a new study area we recommend modifying/replicating the structure of sample data provided. However, new geodatasets with different columns and specifications can be added and used – requiring some knowledge on ModelBuilder and on network datasets (the ArcGIS Help section provides well-structured descriptions and tutorials; it is also our please to help you – feel free to contact us at toma@infp.ro or tomadaniladragos@gmail.com). In order to make it easier to understand the methods and identify errors at different steps we split the toolbox into different Models, described below.

0. The first necessary step: defining a network dataset

In order to analyze a network, you need to create this network; according also to the ArcGIS Network Analyst extension specifications (https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/creating-a-network-dataset.htm). If you do not have vectorial data, you can use road or railway data from free sources, such as OpenStreetMap (https://www.openstreetmap.org/ or http://download.geofabrik.de for data download). In order to assist you in this process we documented how we obtained a road network dataset for Bucharest:

1. **OSM road data download in shapefile format**: from http://download.geofabrik.de/
2. **Archive extraction** -> **shapefile A** (is better that all shapefiles are added to a Personal Geodatabase)
3. **Clip** (in ArcGis) of the road data **to the study area extent** -> **shapefile B**
4. **Query applied to shapefile B** in order to extract only relevant roads (can be modified according to personal needs: for example, for a regional or national scale analysis, low hierarchy roads might not be necessary because they might not influence the analysis and their contribution increase computation time considerably):

   "type" IN ('construction', 'living_street', 'motorway', 'motorway_link', 'primary', 'primary_link', 'raceway', 'residential', 'residential; ped', 'road', 'secondary', 'secondary_link', 'service', 'services', 'tertiary', 'tertiary_link', 'trunk', 'trunk_link') OR ("type" IN ('pedestrian', 'track','unclassified') AND "maxspeed" > 0)

5. Save of the queried result to **shapefile C**, in the Personal Geodatabase.
6. **Reproject shapefile C** to a local preferred projection (preferably projected coordinate system, such as UTM - 35N for Romania) -> **shapefile D.**
7. Manual or topological-rule-based **removing of not connected roads** for **shapefile D, manual validation of roads** (location or hierarchy) with additional data: basemap layers, other road data sources, satellite images etc., **and editing**.
8. **New topology for shapefile D, verification rules used**: *Must not intersect or touch interior*, **corrections applied** and **saving of the new file -> shapefile E**.

9. **For shapefile E: Integrate** (from the Data Management Toolbox), with a recommended small interval (1 meter).
10. **For shapefile E: creation of new columns**:
    - ***F_ZLEV and T_ZLEV*** *(data type **short numeric**)*: for height relation between the roads; F stands for From and T stands for To:
        - Using the ***bridge*** column: if the value is 1, 1 is added to ***F_ZLEV and T_ZLEV;***
        - Segments connected to the bridges are manually checked (the symbology layers "Bucharest road network ZLEV" provided in the downloaded folder can be used for an easier check) and based on the direction the road was drawn, 1 is attributed to the ZLEV column representative to the vertex connected to the bridge (if the first vertex of the segment is connected to the bridge, than ***F_ZLEV*** receives the value 1 and the other end, if it is connected to a segment at ground level, determines value 0 in ***T_ZLEV***).
        - Using the ***tunnel*** column, a similar procedure is done, but with -1 value instead of 1.
        - For the rest of the segments, value 0 is assigned (can be assigned before the previous steps with "Field calculator", or afterwards with a query/codeblock section.
    - ***Oneway*** *(data type **text**, length 2)*, to establish travel direction restrictions:
        - The already available ***oneway*** column can be used: data can be copied to a new column – oneway_orig, the **oneway** column can be erased and the new ***Oneway*** column can be created; next, the following Field Calculator VBScript can be applied on the ***Oneway*** column:

```
if [oneway_orig]=1 then
a = "FT"
end if
```

    - ***Meters*** *(data type **double**)*, to provide the length of the network segment, computed by using "Calculate Geometry".
    - ***FT_Minutes and TF_Minutes*** *(data type **double**)*, showing how many minutes it would take to travel from one network segment end to another.
        - By using the ***max_sp*** (maximum speed) column, the following general formula can be applied: **FT_Minutes (or TF_Minutes)**=([**Meters**]*60)/([**max_sp**]*1000)
        - For pedestrians, the formula can be:
          FT_Minutes (or TF_Minutes)=([**Meters**]*60)/(*3000) (3000 = 3 km/h, medium pedestrian travel time)
        - For other traffic conditions, the formula can be adapted to the congestion level of an area or to know travel times.
    - ***Hierarchy*** *(data type **short numeric**)*, will reflect the rank of a road, with impact on routing preferences; 1 represents the most important road and 5 the least important (local) road. Values in the ***type*** column can be used to assign a hierarchy (highways and national roads = 1 etc.).
    - ***name*** *(data type **text**)*, can be left as it is – it will provide directions if needed when performing route analysis.
11. From the ArcCatalog window, a **Dataset** is created and **shapefile E** is added.
12. With a right mouse click on the **Dataset** it is selected **New/Network Dataset**; in the dialogue, in Connectivity, **Connectivity Policy** it is checked **Any vertex**, and new Attribute **Evaluators** are added

depending on columns (such as Minutes_pedestrians or Minutes_traffic, if different Minutes columns are available).

13. Click on the **Build Network Dataset** button or *yes* if asked.
14. For the Network-risk toolbox analysis it is important to also have a Network Dataset Frame - made from just two not representative segments, but already built with specific Evaluators and columns. This can be achieved after running Module 1: MonteCarlo_simulation and 2. Make the network frame, renaming the shapefile, erasing network segments and repeating step 12, using also the new columns to generate new evaluators such as for inaccessible roads.

1. *MonteCarlo_simulation* module

Model used to randomly simulate (MonteCarlo approach) a scenario for transportation network damage, considering the areas and their expected probability to be affected by a natural hazard (input required from the user).

Dependencies:

- shapefile containing areas expected to be affected by the considered natural hazard (as polygons). The shapefile is expected by default to contain the following columns (modify the Model if your data is different):
    - D_Prob (data type Double): column for probabilities of polygons to be affected
    - MC_result (data type Double): for storing results
    - Damaged (data type Short Number): for checking if it should be damaged or not in the scenario

Main result:

- **Damaged_roads_scenario_polygons%nr%** and **Damaged_roads_scenario_points%nr%** (by default) shapefiles, showing the randomly selected polygons, converted also as points.

2. *Make the network frame* module

This module creates a Network Dataset Frame - made from just two not representative segments, used as a foundation for building a network considering damage scenarios simulated with Module 1.

Dependencies:

- Results from module 1: in order to have the same columns and then use them to build a new network dataset with more Evaluators.

Main result:

- **Network_frame** (default) shapefile, **needed to be built manually as a new network dataset**, with new Evaluators (see Step 0 – 14)

3. Manualy copy the sample_data_frame to sampl_results_scenario%nr%

Currently just an indicator of the following action to perform: copy the Frame Network Dataset (ND) from Sample_data_frame to Sample_results_scenario (sample scenario), renaming it including also the Scenario number. Use preferably the ArcCatalog window for the task. We are working on automating this process, but currently there are some ArcGIS limitations to overcome. This frame is needed because in the next step it will be the base for a new disrupted network, tested against the initial functional network.

4. *Scenario_network_build* module

Used for creating a Network Dataset (ND) for a scenario, considering affected areas and traffic jams generated.

Dependencies:

- Results from module 1, 2 and 3.

Main result:

- **A scenario network dataset**, considering the impact of MonteCarlo simulated segments which led to network blockages.
- **Traffic_Jams_ServiceArea** shapefile polygons, containing Service Areas surrounding affected areas, in order to modify travel times in post-event conditions.

Potential issues:

- Depending on the size of the full network, this model might take a considerable amount of time (more than 10 minutes for network with more than 50000 segments, also depending on PC configuration). If it gets stuck, try again (without doing other parallel tasks on the PC) or work with a network sample/use hierarchy to get rid of not representative segments.
- Make sure that you use a Network_frame ND with just 2 network segments and not one already built using this module.

5. *Determination of inaccessible network areas* module

Used for determining which network areas are inaccessible for certain facilities (hospitals, fire stations etc.)

Dependencies:

- Results from module 1, 2, 3 and 4.

Main result:

- **%Facility_name%_inaccessible_areas** shapefile polygon, containing inaccessible areas.
- **Envelope** shapefile polygon of the study area.

6. *ServiceArea scenario analysis* module

Used to compute Service Areas for a type of facilities (hospitals, fire stations etc.), considering inaccessible areas and traffic scenarios.

Dependencies:

- Results from module 1, 2, 3, 4 and 5.

Main result:

- **%Facility_name%_SA_Minutes** shapefile polygons of Service Areas (according to selected Break Values)

Potential issues:

- If the model run with **Polygon Type *DETAILED POLYS*** produces weird looking results (polygons not surrounding facilities), try to use fewer Break Values (detailed polygons are important especially near affected areas) and then merge polygons, or use a ***SIMPLE POLYS*** analysis.

7. *Nr of facilities contributing to Service Areas* module

Used to assess how many facilities provide the minimum service area time. Currently its implementation is in progress.

Dependencies:

- Results from module 1, 2, 3, 4, 5 and 6.

8. *Aggregation of Service Area scenarios* module

Module for aggregating all Monte Carlo scenarios into a single result. Currently its implementation is in progress.

Dependencies:

- Results from module 1, 2, 3, 4, 5, 6 (optional) and 7.

9. *Closest Facility scenario analysis* module

Model for evaluating the travel times, distance and routes between representative Origin-Destination (OD) Pairs. Currently its implementation is in progress.

Dependencies:

- Results from module 1, 2, 3, 4 and 5.

Troubleshooting

- **When using the Network-risk toolbox, script error messages appear or when opening the modules the window freezes:**
    - On Windows it might help to go to Internet Explorer or the Control Panel, to Internet Options, to the Security tab and set the security level from Medium-High to Medium (http://gisgeek.blogspot.com/2011/01/arcgis-10-script-error-after-clicking.html). Problems could be due to ActiveX controls.
- **To see the outputs created, refresh databases or dataframes in ArcCatalog after running successfully the models.**

Examples of what Network-risk toolbox and ArcGIS Desktop can do

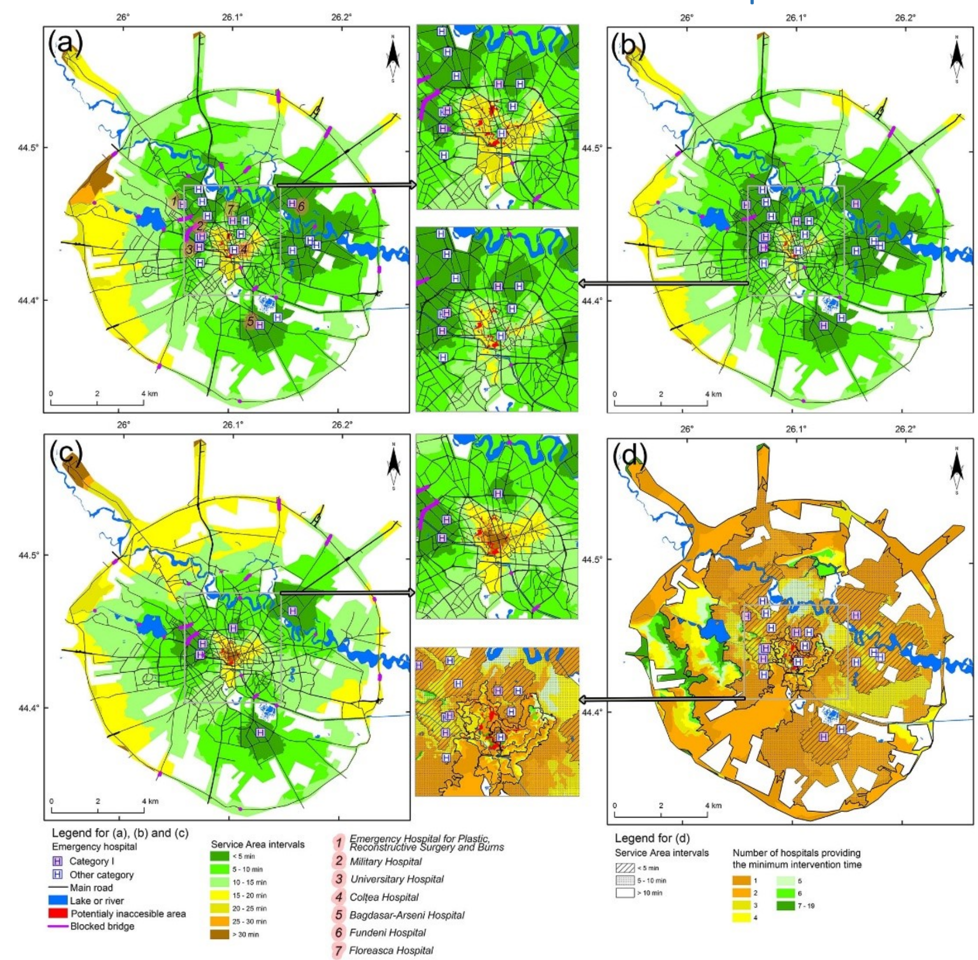

Figure 3 Service Areas for emergency hospitals, for the Monday 8AM typical traffic scenario and for: the worst-case model (A); a MonteCarlo scenario (B); emergency hospitals in category I of importance and the worst-case model (C); the number of emergency hospitals providing the minimum intervention time in the worst-case model (D) (Toma-Danila et al., 2020)

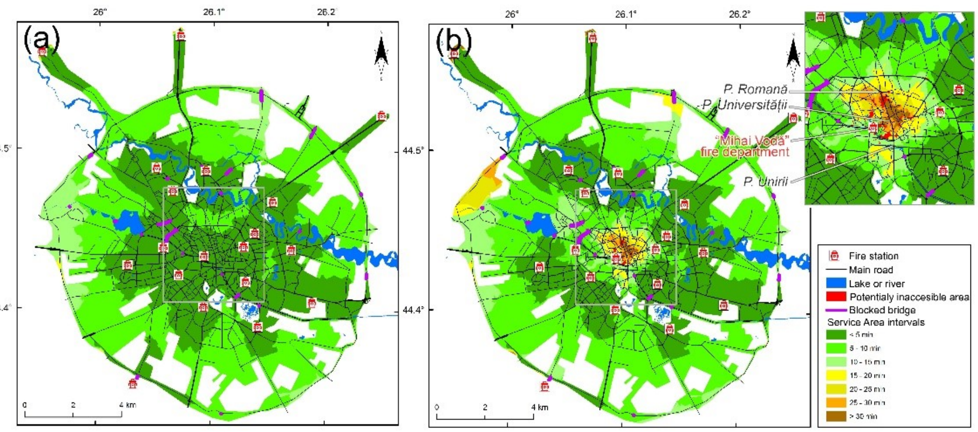

Figure 4 Service Areas for fire stations, pre-earthquake (A) and post-earthquake, considering the worst-case model (B), for the Monday 8AM typical traffic scenario (Toma-Danila et al., 2020)

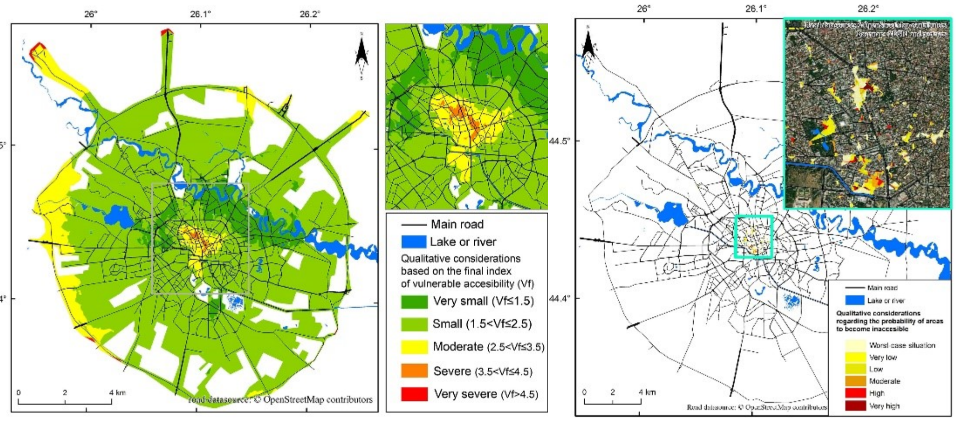

Figure 5 Final map showing qualitative values for the combined final index of vulnerable road network accessibility (Vf) for Bucharest (left) and areas who can become inaccessible immediately after an earthquake (right) (Toma-Danila et al., 2020)

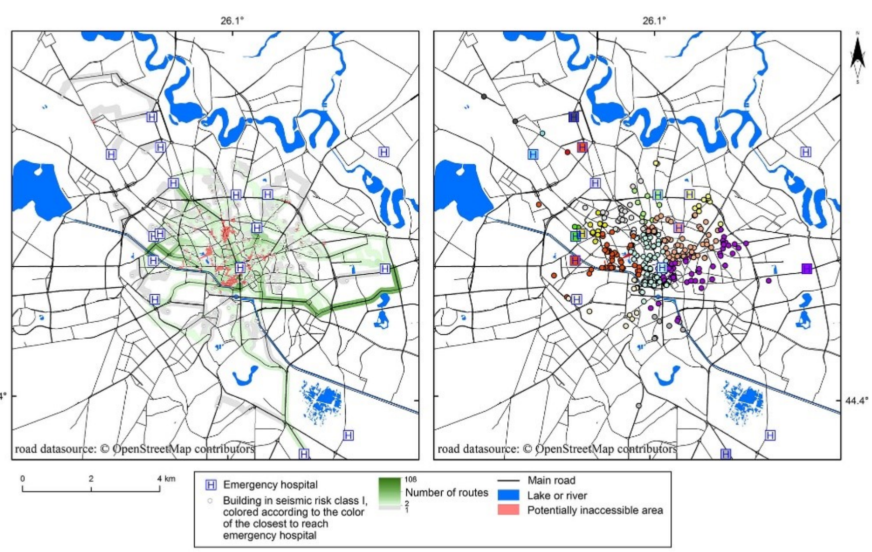

Figure 6 Maps reflecting fastest routes (and the density of these routes) between buildings in seismic risk class I and emergency hospitals (A), and the closest hospital (B), for the Monday 8AM typical traffic scenario (Toma-Danila et al., 2020)

Contact

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