Probabilistic Path Finding Method for Post-Disaster Risk Estimation

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Outline

- Introduction
  - Post-event interventions
  - Fragility curves
- A* search algorithm
  - Deterministic and probabilistic situations
- Case studies
- Conclusions

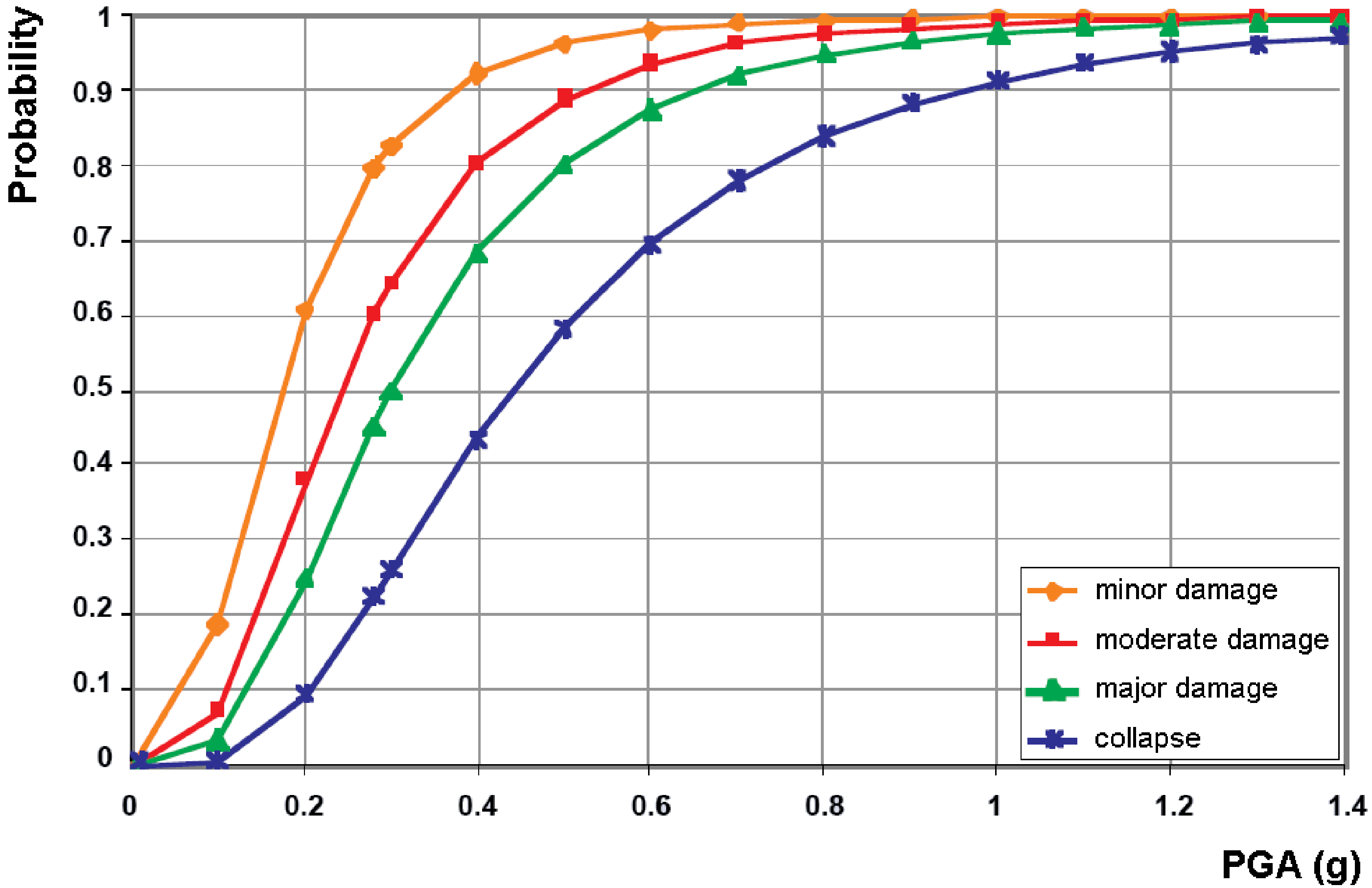
Objectives

- Avoiding further post-event damage because of effects of partial or total collapse of buildings and destruction of lifelines
- Improving the rescue planning in early stages of post-event management
- Reducing the risk for people and infrastructure in the immediate stages after an earthquake

Path Finding

- One of the main problems in post-disaster situations is finding the shortest/quickest paths that link:
  - Command centres: Prefecture, Fire Department headquarters, etc.
  - Affected areas
  - Hospitals and other similar facilities

Fragility Curves: Damage States



A Simplified Analytical Model

$$F_r(x) = P(X \le x)$$

$$F_r(x \mid m_r, \beta_r) = \phi\left(\frac{\ln(x / m_r)}{\beta_r}\right)$$

$$y(x) = \frac{x^e}{\varphi + x^e}$$

Simplified Multiple Multiplicative Factor Model (SMMF)

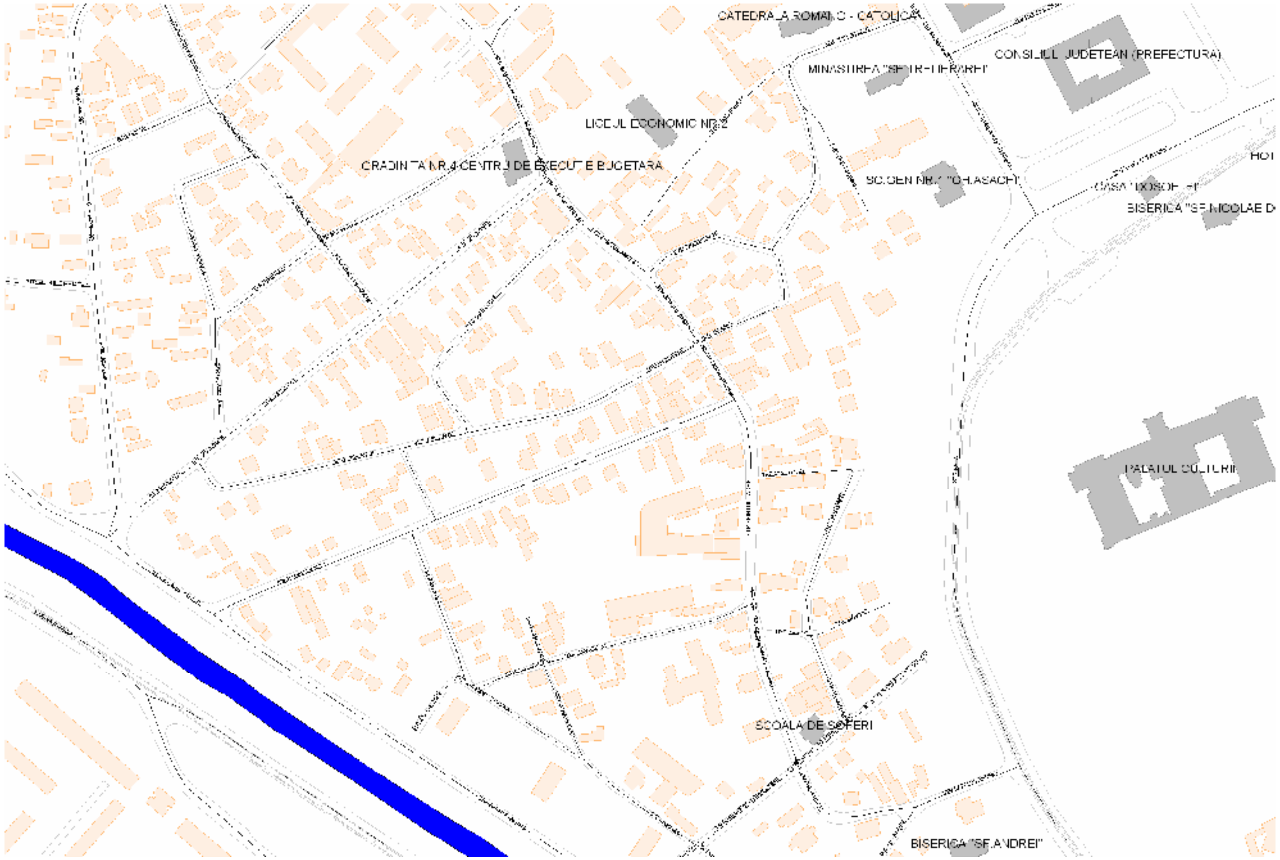
This model can account for changes in vulnerability during the lifecycle of the building

Damage: φ coefficient increases

Repair: φ coefficient decreases

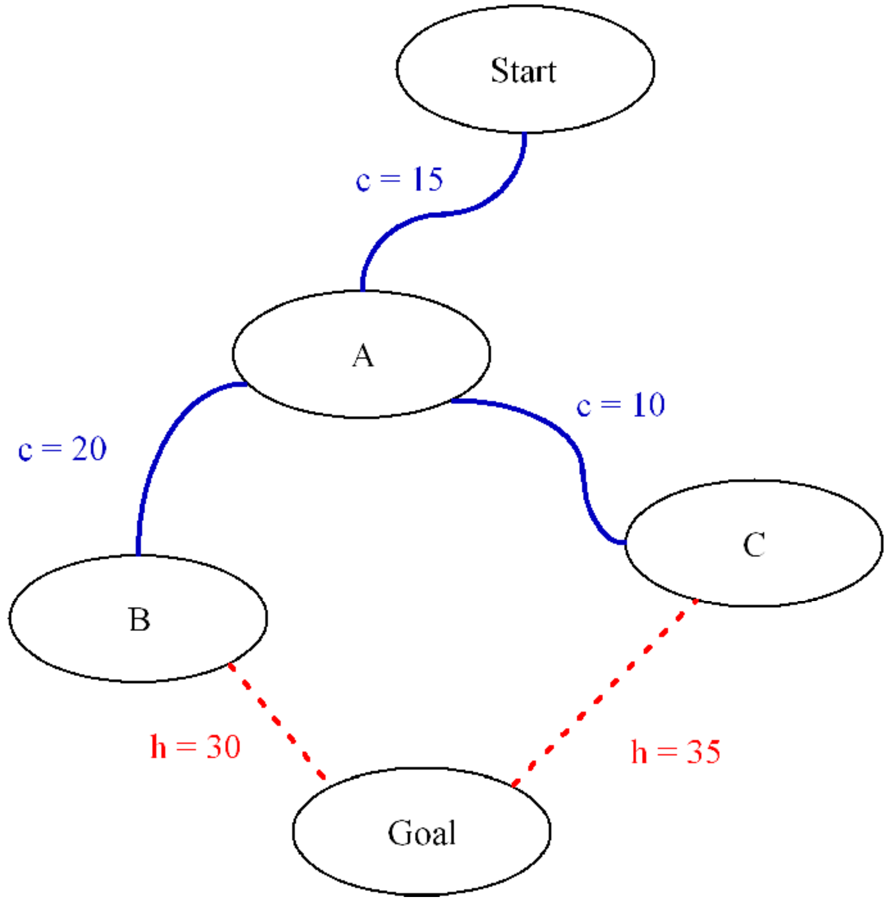
Damage	**Coefficient** φ
Minor	0.007836079
Moderate	0.020117283
Major	0.037445433
Collapse	0.10592203

A Map Sample on NetSET GIS



A* Search. Example

- One of the most popular algorithms in AI
- f(n) = g(n) + h(n), where:
  - g(n) = known best cost so far
  - h(n) = estimated cost to the goal
- Example:
  - f(B) = 15 + 20 + 30 = 65
  - f(C) = 15 +10 + 35 = 60



A* Search

- A* is a general search algorithm
  - Puzzles, Rubik cube, booking flights or train tickets, etc.
- The heuristic function h(n) must be admissible: $0 \le h(n) \le h^*(n)$
  - An admissible heuristic function is always optimistic (never overestimates)
- Path finding on a map:
  - h = straight-line distance

Scenarios

- We considered 3 simulated earthquakes
  - PGA = 0.2 g
  - PGA = 0.35 g
  - PGA = 0.5 g

PGA = 0.2 g, First Scenario

PGA = 0.2 g, Second Scenario

PGA = 0.35 g, First Scenario

PGA = 0.35 g, Second Scenario

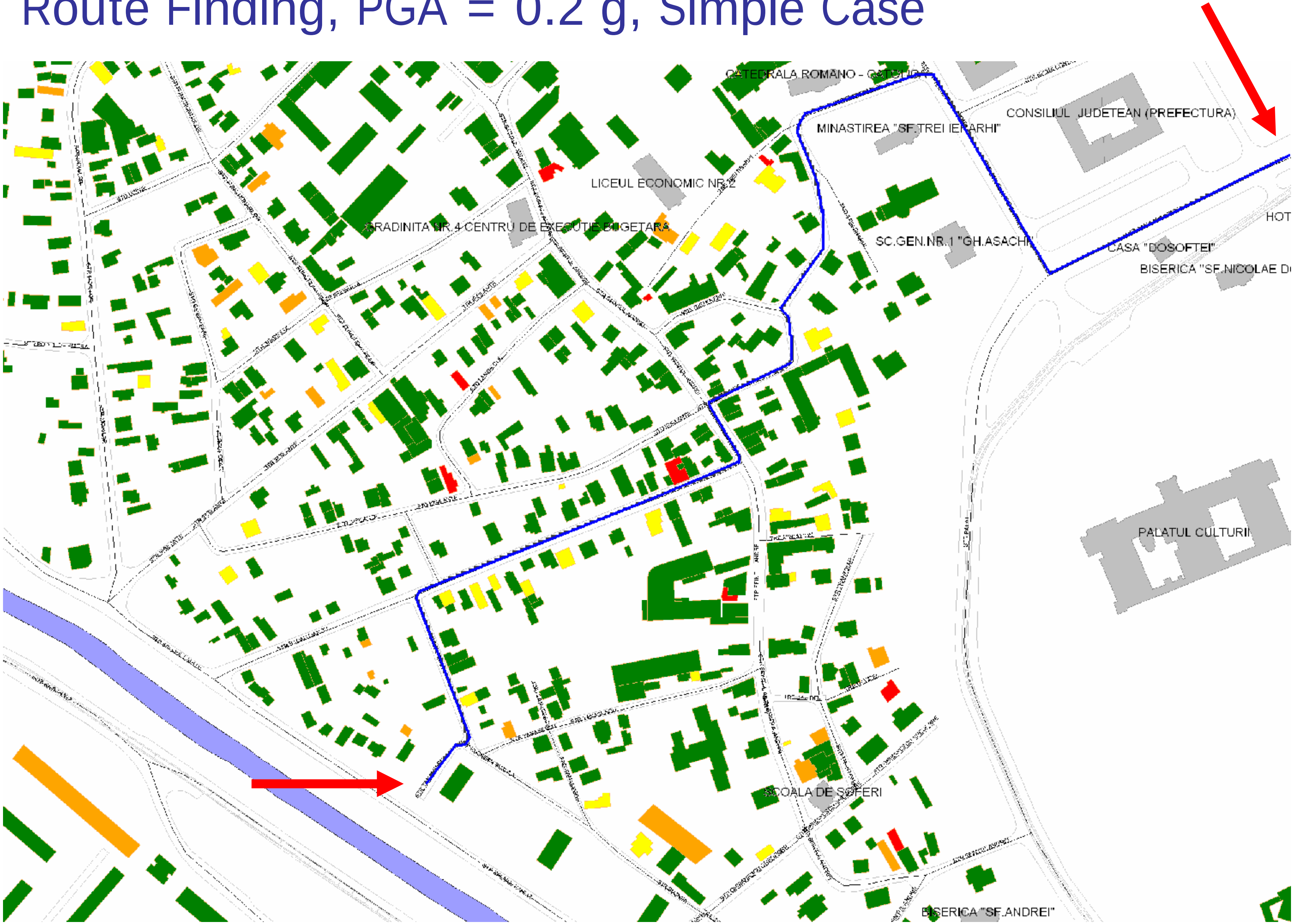
PGA = 0.5 g, First Scenario

PGA = 0.5 g, Second Scenario

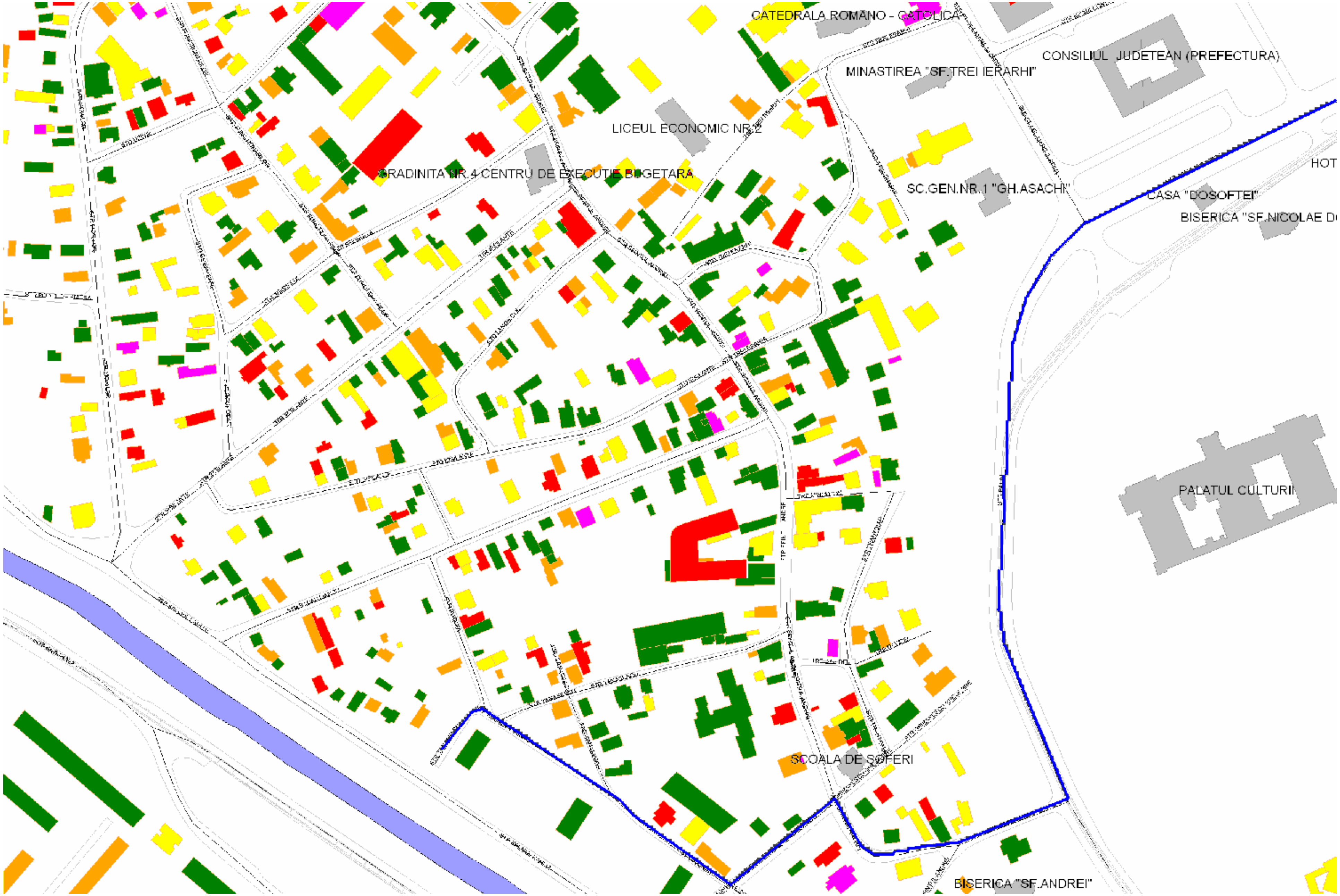
Induced Costs (for A*)

- c = actual cost
- d = distance from the building to the road
- I(c,d) = induced cost
- d = 0 $\Rightarrow$ maximum effect
  - I(c,0) = c * n
- d = d_{max} $\Rightarrow$ no effect
  - I(c,d_{max}) = c
- $I(c,d) = c * \Sigma_i((d_{max} - d_i) * n)$

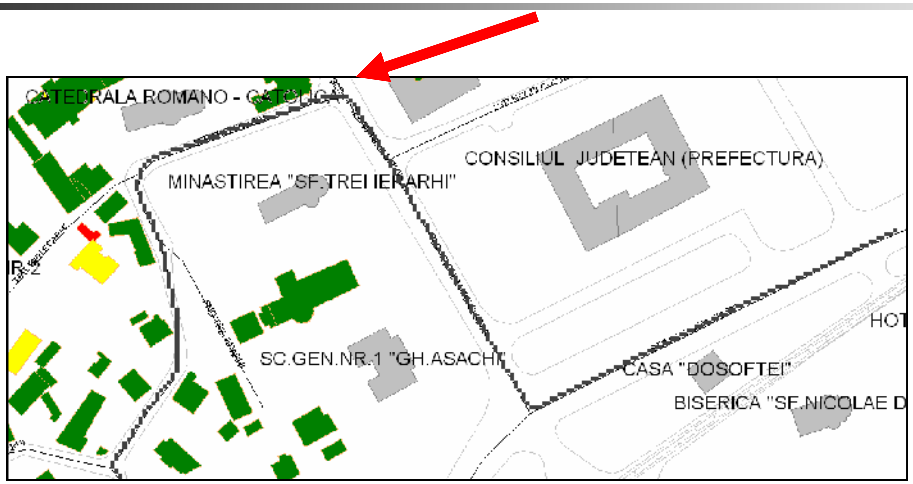
Route Finding, PGA = 0.2 g, Simple Case

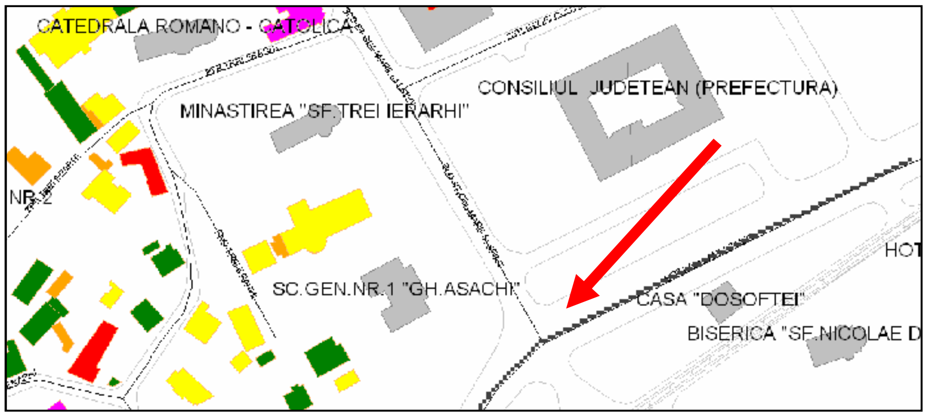


Route Finding, PGA = 0.5 g, Simple Case



Route Change



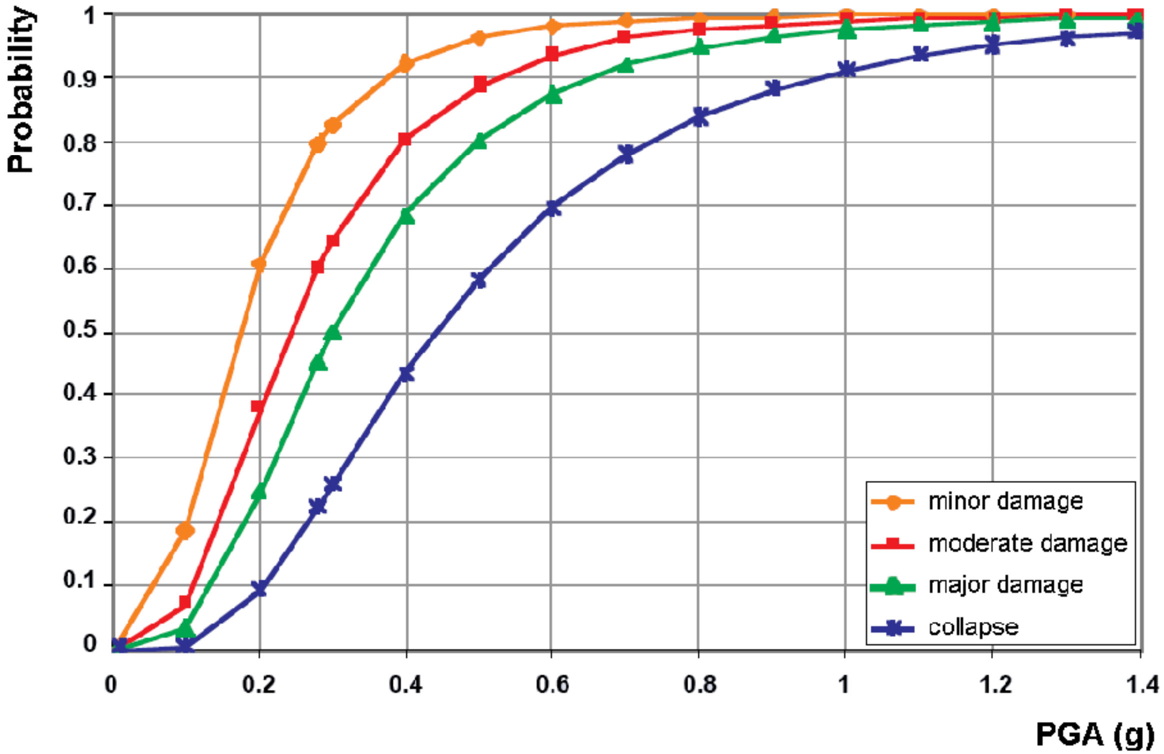


Expected Level of Damage. Expected Costs

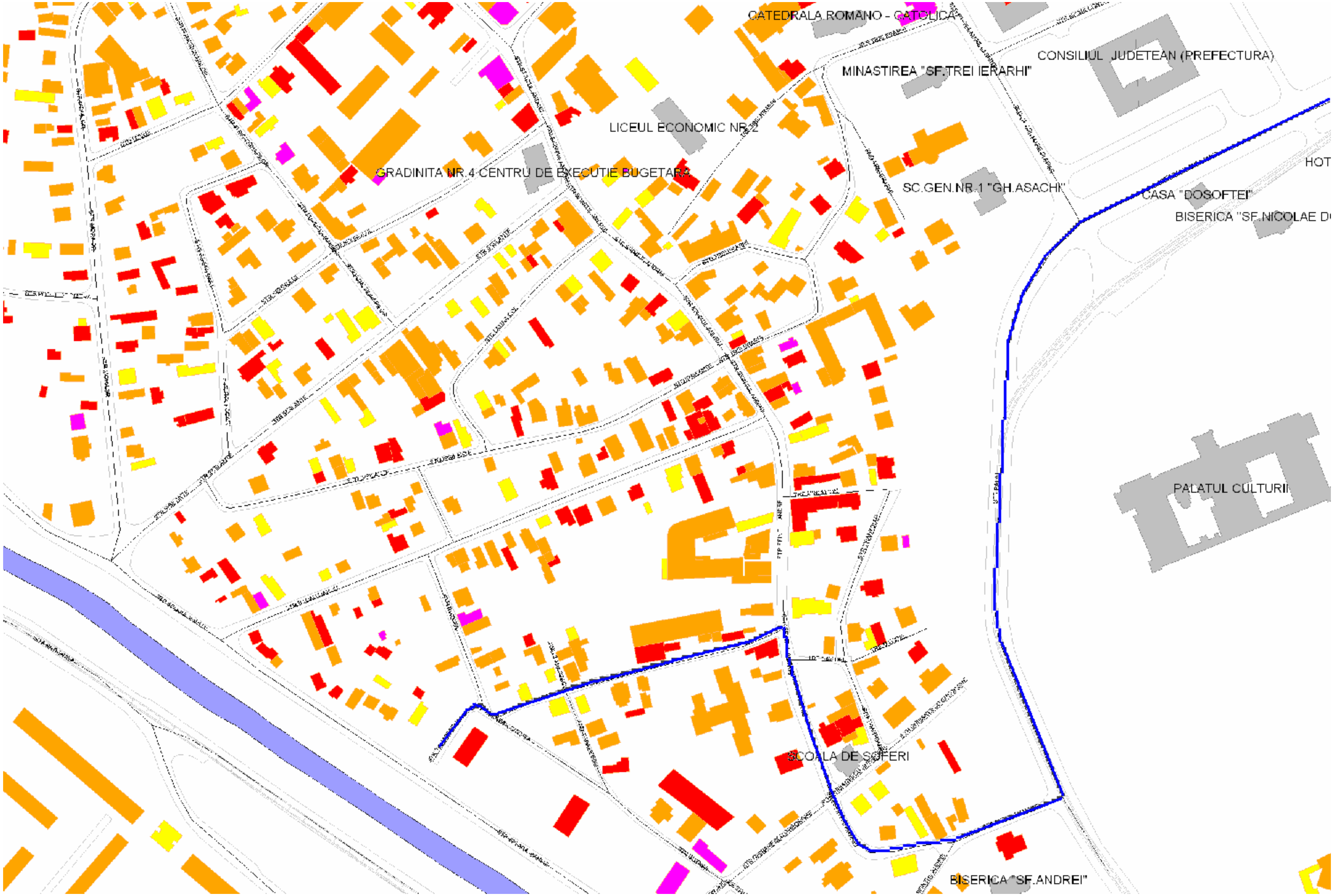
- Expected level of damage
  - $E(P_d) = w_i * (P_i - P_{i+1}),\ \Sigma(P_i) = 1$
  - $w_i = \{ 0, 0.1, 0.2, 0.5, 1 \},\ E(P_d) < 1$
- $d = 0 \Rightarrow$ maximum effect
- $d = d_{max} \Rightarrow$ no effect
- $E(P_d) \approx 0 \Rightarrow$ no effect
- $E(P_d) \approx 1 \Rightarrow$ maximum effect
- $E(c,d,p) = c * \Sigma_i((d_{max} - d_i) * n * E(P_{d;i}) * m)$
  - $E(c,d,p)$ = expected cost

Fragility Curves: Details for ELD

$E(P_d) = w_i * (P_i - P_{i+1})$



Route Finding, PGA = 1.2 g, Probabilistic Case



Further Development

- Extendable upon the needs
  - Possible damage states of the lifelines
  - Possible explosions of oil stations
  - Possible effects of critical infrastructures
    - Bridges
    - Industrial facilities

Conclusions

- The paper presents an application of AI for the mitigation of seismic risk in the early stages of a post-event situation
  - Deterministic evaluation based on scenarios for 3 simulated earthquakes: routes can change depending on the scenario
  - The probabilities given by fragility curves can be weighted to compute the expected level of damage
- The A* algorithm can be modified to find the quickest/safest paths for intervention teams in post-disaster situations
- The results can be displayed on a GIS map to help stakeholders to improve the emergency planning scenarios and making decisions for rehabilitation