Simulation-Based Performance Evaluation of the Road Network in the Aftermath of Earthquake: A Case Study of Montreal Island

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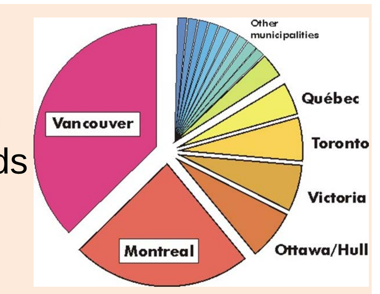
Abstract

The transportation network plays an importation role in case of emergency. The efficiency of the rescue operation in an urban area largely depends on the performance of the transportation network. This paper simulates traffic flows in case of earthquakes and load this additional traffic flows into the network to evaluate the performance of the transportation system. This study also measures the seismic vulnerability of bridges within Montreal regions as per the bridge classes typical to National Building Inventory (NBI) through the development of bridge fragility curves. Based on the damage level estimated using HAZUS software, bridges are prioritized in order to rehabilitate bridges, or deployment of inspection crews for field assessment of bridge damage. This study can provide valuable insights to the first responders of earthquake disaster to take necessary actions for an efficient evacuation in a metropolitan area. Moreover, it can assist residents to plan their evacuation routes based on the prevailing road condition.

Introduction

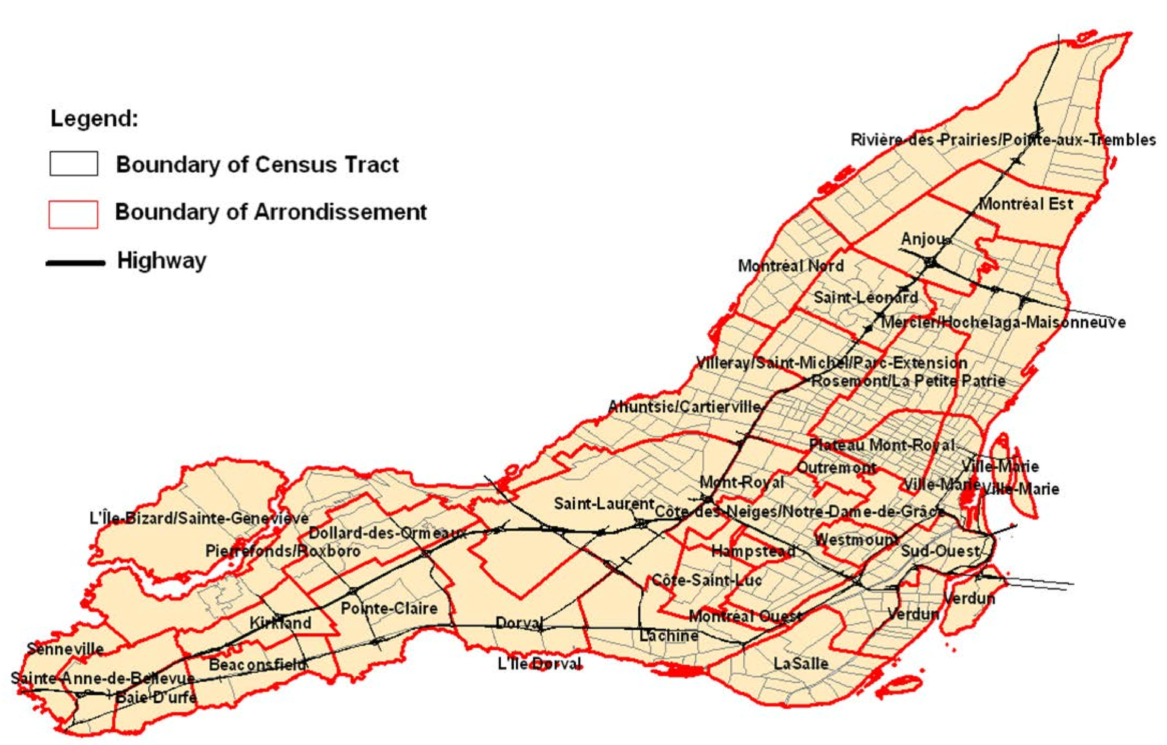
- Montreal is ranked 2nd in Canada for seismic risks after Vancouver due to its large population aging infrastructure and regional seismic hazards



- Prevention or prediction of Earthquakes is not possible
- The adverse effect of disasters can be minimized through various intervention strategies such as evacuation planning
- Emergency response for a no-notice disaster occurring in a metropolitan area is extremely challenging due to the co-existence of multi-priority groups in a network

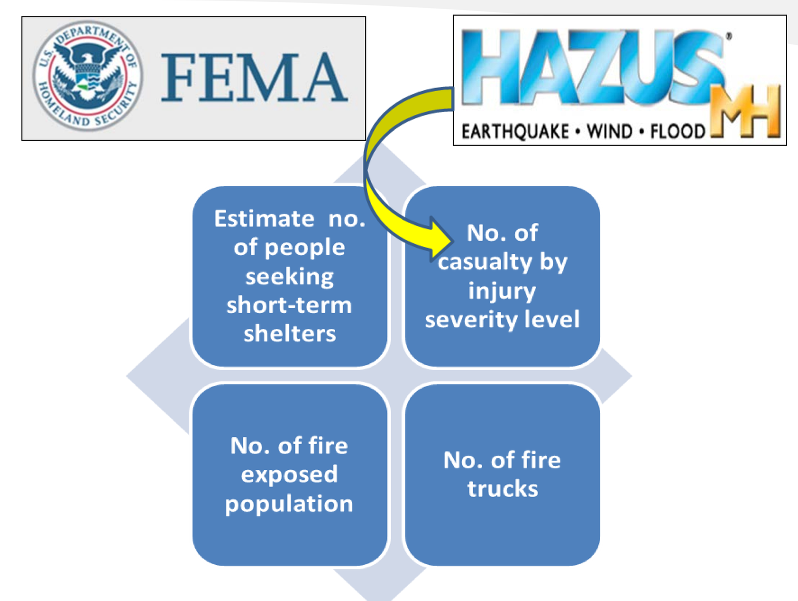
Objective and Study Area

Evacuation time estimation for earthquake disaster in Montreal



Methodology

Step 1: Estimation of the number of evacuees



Step 2: Transportation modeling

$$\min \quad z = \sum_a \int_0^{x_a} t_a(x)\,dx$$

Subject to:	$f_k^{rs} \geq 0$
$X_a = \sum_r \sum_s \sum_k f_k^{rs} \delta_{a,k}^{rs}$	$X_a \geq 0$
$\sum_k f_k^{rs} = q_{rs}$	$t_a(X_a) = t_a^0\left[1 + \alpha\left(\frac{x_a}{C_a}\right)^{\beta}\right]$

Where

$t_a(x)$ = travel time function for link a	c_a = Capacity on link a, veh/hr
t_a^0 = Travel time in link a in free speed, minute	$\delta_a^{rs}, k = 1$ if link a is part of path k connecting O-D pair r-s; = 0 other wise
q_{rs}= trip rate between origin r and destination s	k_{rs}= set of paths connecting origin r and destination s
fk^{rs} = flow on path k connecting O-D pair r-s	α,β = parameters which are to capture the quality of the traffic flow

Step 3: Damage evaluation of the bridges within Montreal region

Step 1: Data collection
Get the bridge location (longitude and latitude), class (HWB1 through HWB28), no. of spans (N), skew angle (α), span width (W), bridge length (L), and maximum span length (Lmax).

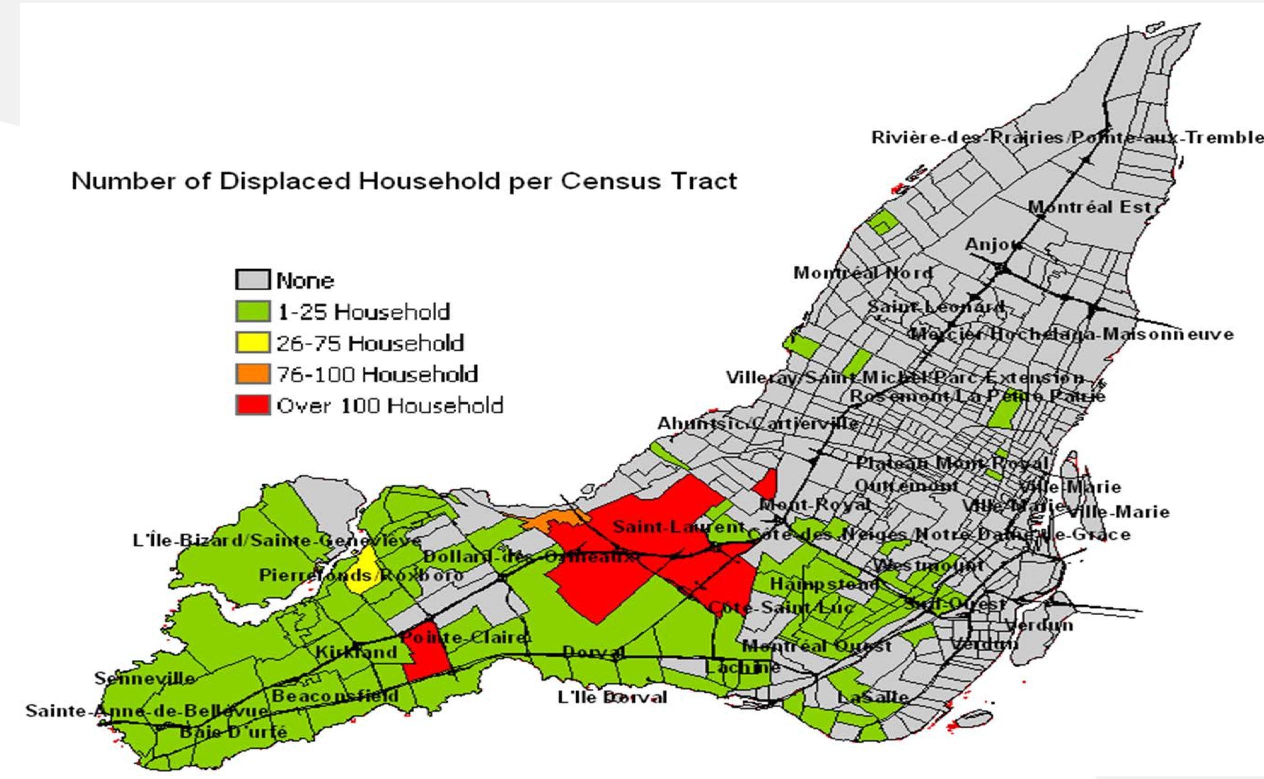
Step 2: Peak Ground Acceleration
Evaluate the soil-amplified shaking at the bridge site. That is, get the peak ground acceleration (PGA), spectral accelerations (Sa[0.3 sec] and Sa[1.0 sec]).

Step 3: Evaluation of the ground shaking related damage state probabilities

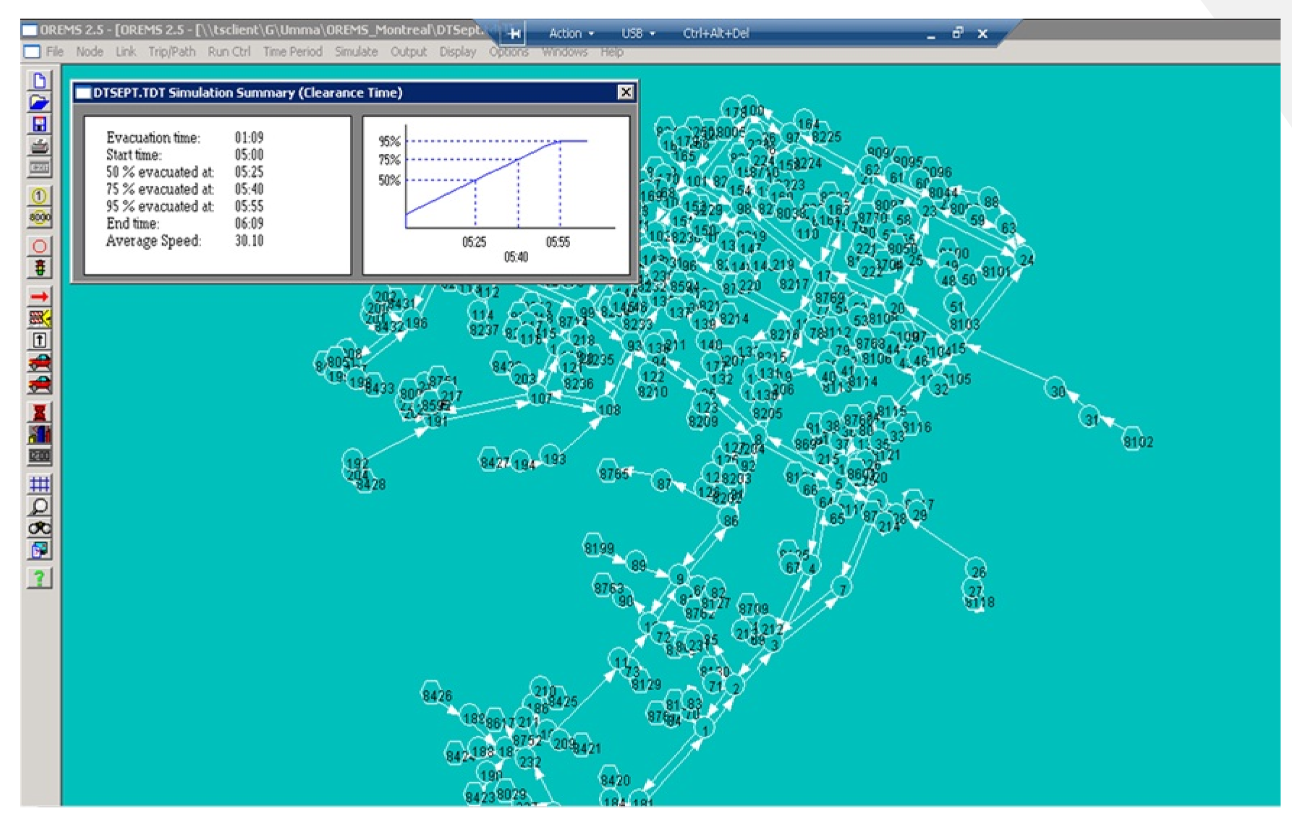
Step 4: Combine the damage state probabilities and evaluate functionality of bridge

Results

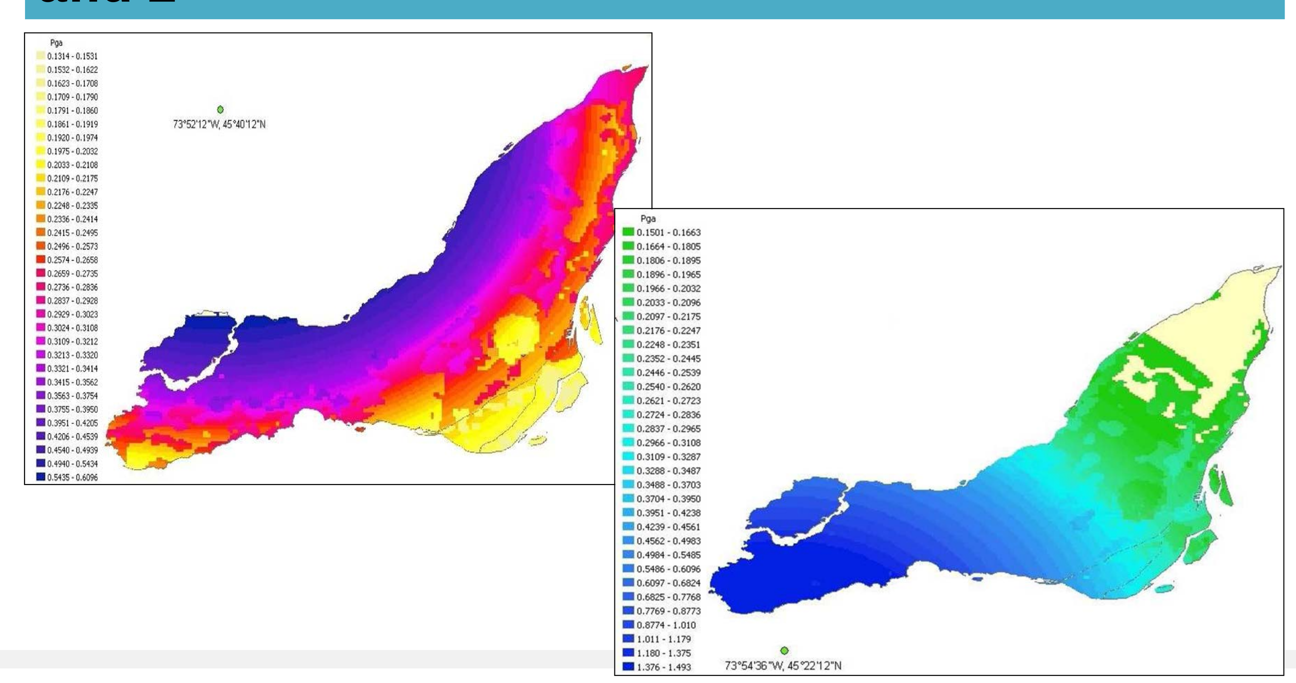
Number of Displaced Household per Census Tract



Evacuation time under emergency condition

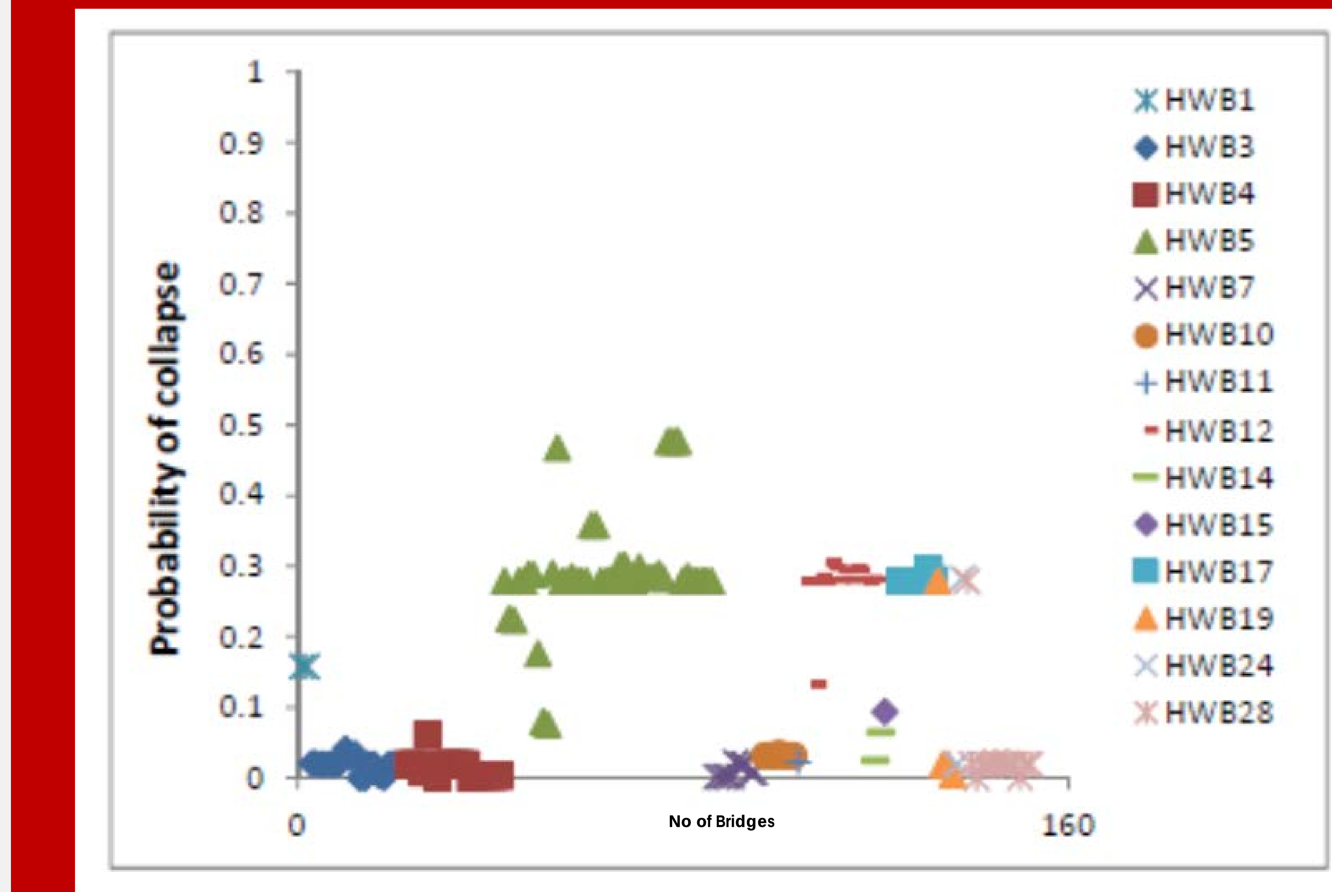


Contour map showing PGA values for scenario 1 and 2



Results

Probability of collapse for bridges, case scenario 1



Conclusion

- Evacuation time for downtown Montreal is 55 min for all evacuation vehicles and major part of Sherbrooke Street has worst speed (<30Km/hr) in the network
- The result shows that the bridge class HWB5 (Concrete, Multi-Column Bent, Simple support -Conventional Design) has the maximum vulnerability with damageability of 3 for scenario 1.
- In case of scenario 2, the HWB12 (Steel, Multi-Column Bent, Simple support -Conventional Design) class of bridges has the highest priority due to its high probability of damage (i.e. damageability as 3.26)
- All the bridges that exhibits high level of damage have been constructed based on conventional (predating modern seismic code) design

Future Works

- Performance evaluation of road networks
- Evacuation time estimation considering the bridge failure

Bibliography

- Chang, L. (2010) "Transportation system modeling and its application in EQ engineering" PhD dissertation" University of Illinois at Urbana-Champaign, USA.
- Yu. K. (2010) "Seismic Vulnerability Assessment for Montreal -An Application of HAZUS-MH4"MSc dissertation. McGill University, Canada
- FEMA (2003). Multi-hazard Loss Estimation Methodology Earthquake Model HAZUS®MH MR4 Technical Manual. Washington, D.C.: National Institute of Building Sciences