# A Method to Assess the Impact of Flooding on Traffic Flows in Hamilton

Nosheen Alamgir • Darren M. Scott

TransLAB / School of Geography & Earth Sciences, McMaster University, Hamilton, ON, Canada L8S 4K1

## INTRODUCTION

Maximizing the robustness of transportation networks has become an important component in city planning and management. Climate change is a driving force behind increased urban flooding, causing transportation systems to be at risk via route closures. The Network Robustness Index (NRI) is a measure that assesses the importance of a network link, if that link becomes disabled (Scott et al., 2006). This system-wide approach measures changes in congested travel time associated with the partial or full closure of a road segment (Scott et al., 2006). The advantage of using a system-wide approach in transportation science is that it identifies critical links while taking the entire network into account. As a result, improvements can be made to the system in order to mitigate damages if a disruptive event were to occur. The objective of this project is to demonstrate the system-wide NRI approach for assessing the traffic flow impacts of flooding events on urban road networks. The study area is the City of Hamilton, Ontario, Canada.

## STUDY AREA

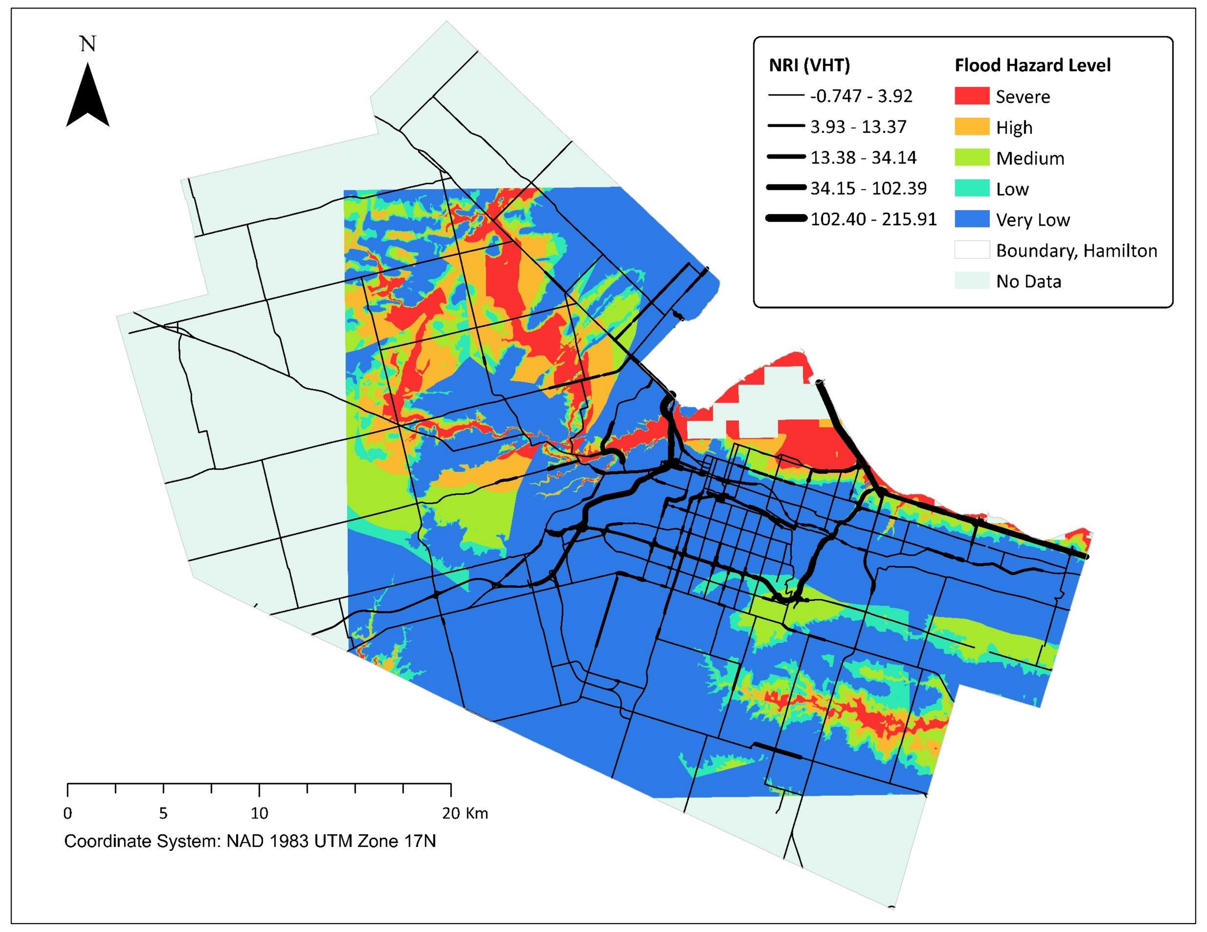


Figure 1: *NRI results for the entire road network, symbolized by graduated symbols, and flood hazard areas in the City of Hamilton. Individual links were disabled.*

## DATA AND METHODS

Flood hazard data was obtained from Elshorbagy et al. (2017) and was developed by combining two parameters: elevation above the nearest drainage (EAND) and distance from nearest drainage (DFND). Hazard levels range from very low with a EAND of >8.0m and DFND of >10,000m, to severe with a EAND of ≤ 2.0m and DFND of ≤ 1000m (Elshorbagy et al., 2017).

TransCad®, a powerful transportation-specific GIS application, was used to compute the measure. The NRI was computed via a toolkit called the "NRI Calculator." A traffic simulation was performed from the following inputs: a road network of Hamilton and an origin-destination (OD) trip matrix. Higher values of the NRI are associated with greater criticality as their removal will have a greater impact to network-wide travel (Sullivan et al., 2010).

## NETWORK ROBUSTNESS INDEX AND FLOOD HAZARD LEVEL

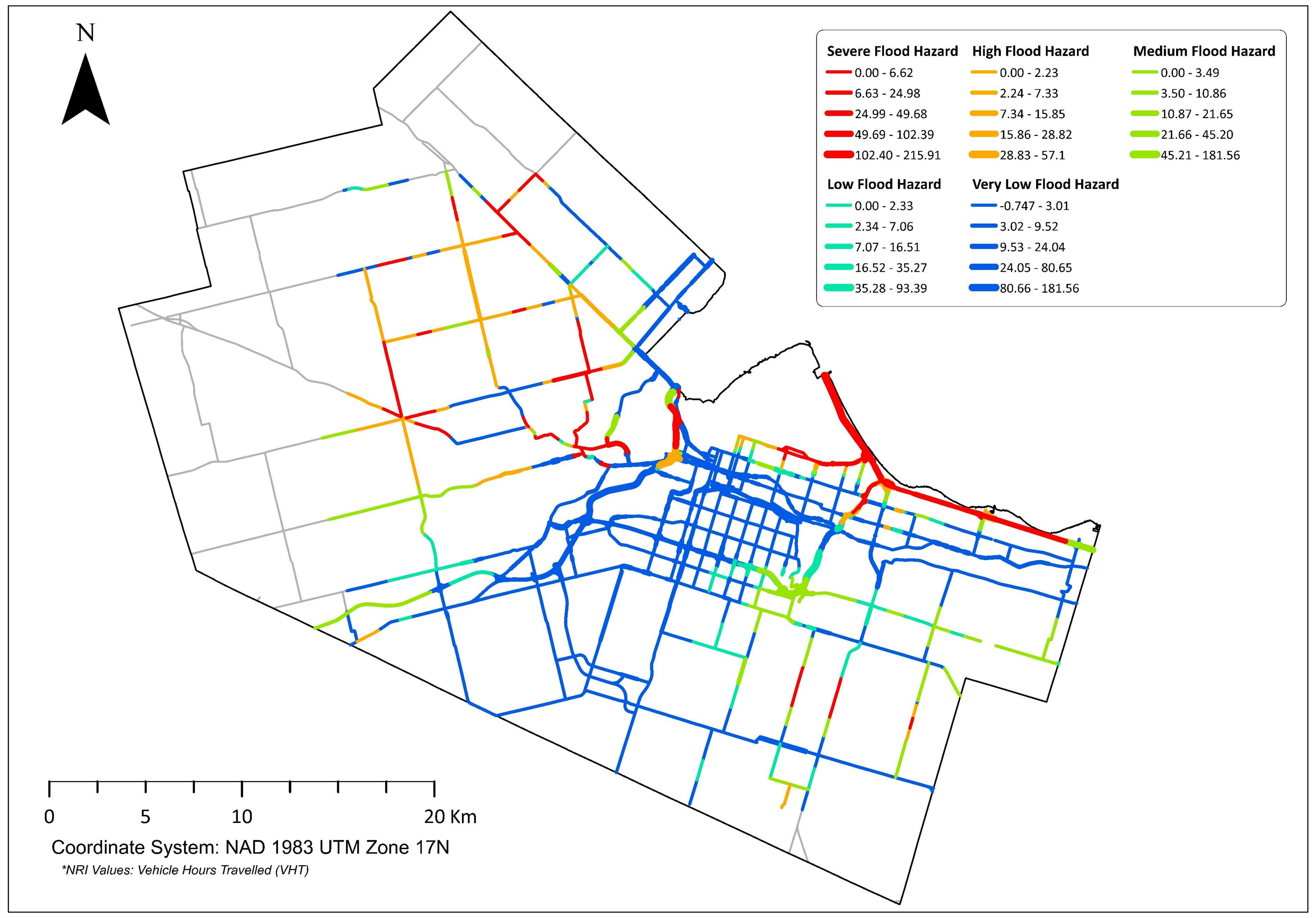


Figure 2: *Road links that intersect with flood hazard areas. NRI values are depicted for each road link, visualized by graduated symbols. Colours indicate which flood hazard level each link intersects. NRI values are in VHT.*

Table 1: *Summary statistics of NRI values (VHT) within each flood hazard level (severe to very low).*

| Flood Hazard Level | Severe | High | Medium | Low | Very Low |
|---|---|---|---|---|---|
| Number of Links | 203 | 186 | 269 | 260 | 2903 |
| Mean | 9.03 | 3.08 | 4.88 | 2.10 | 2.72 |
| Standard Deviation | 23.07 | 7.87 | 15.10 | 6.89 | 6.54 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 | -0.747 |
| Maximum | 215.91 | 57.11 | 181.56 | 93.39 | 181.56 |
| TOTAL NRI | 1833.15 | 573.26 | 1312.70 | 546.97 | 7893.51 |

## RESULTS

The NRI was computed for major roads in Hamilton with a total of 4044 links. An OD matrix of 2011 trips was used to calculate the NRI at a capacity reduction level of 100% with 100 iterations. Through the NRI computation, individual links were disabled and the resulting impacts of system-wide travel time were measured and recorded. Major highways connecting Hamilton to other cities in the Greater Toronto and Hamilton Area (GTHA) are more critical, reflected by higher NRI values for the Queen Elizabeth Way (QEW), Highway 403 and the Red Hill Valley Parkway (RHVP). To better visualize the location of network links in association to a flood hazard level, Figure 2 was developed by intersecting the road network with flood hazard data. The NRI values for each link are depicted alongside the flood hazard level (five levels depicted by different colours) for which that link intersects. The QEW depicts a high NRI value and falls within a severe flood hazard level. Where the Lincoln M. Alexander Parkway (LAP) and RHVP merge, there is a high NRI value which coincides with a medium flood hazard level. The majority of the links in the network are located within a very low flood hazard area, with varying NRI values.

## ANALYSIS AND CONCLUSION

Summary statistics were performed for the NRI links within each flood hazard level in Table 1. The highest number of links were located within a very low flood hazard area. 389 links are within severe and high flood hazard areas, which is 9.6 percent of the entire network.

Links located within a severe and high flood hazard area are identified as the most at risk links in the network. Severe flood hazard areas were characteristic of high mean and standard deviation values of 9.03 VHT and 23.07 VHT respectively, indicating high link criticalities. Within high flood hazard areas, the values for the NRI mean and standard deviation are also high, at 3.08 VHT and 7.87 VHT respectively. These critical links are at risk of flooding as they are within a severe and high hazard zone. Moreover the critical links cause the network to be vulnerable. If links within severe or high flood hazard areas were to be broken, the result will be a network-wide travel time increase. Severe and high flood hazard zones account for 2406.41 vehicle hours travelled, which accounts for 19.72 percent of the increases in travel time for the entire network.

This demonstrates an application for the NRI in identifying at risk links to flooding. From identifying the critical road links within flood hazard areas, city management can implement feasible proactive measures to maximize the robustness of the network in preparation of flooding events. For example, developing flood mitigation road infrastructure and special routes for emergency vehicles. Future research will develop a model to analyze system-wide network impacts to a flooding event.

## DATA SOURCES

- Flood Hazard Map: Elshorbagy A., Bharath R., Lakhanpal A., Ceola S., Montanari A. and Lindenschmidt, K.-E. (2017). Topography- and nightlight-based national flood risk assessment in Canada. *Hydrology Earth System Science*, *21*(4), 2219–2232.
- University of Toronto, Data Management Group, Transportation Tomorrow Survey (TTS), 2011, Greater Toronto and Hamilton Area
- University of Toronto, Data Management Group, Complete road network, Greater Toronto and Hamilton Area (GTHA)
- City of Hamilton Open & Accessible Data, 2017: City Boundary shapefile

## REFERENCES

- Elshorbagy A., Bharath R., Lakhanpal A., Ceola S., Montanari A. and Lindenschmidt, K.-E. (2017). Topography- and nightlight-based national flood risk assessment in Canada. *Hydrology Earth System Science*, *21*(4), 2219–2232.
- Scott D. M., Novak D. C., Aultman-Hall L. and Guo F. (2006). Network Robustness Index: A new method for identifying critical links and evaluating the performance of transportation networks. *Journal of Transport Geography*, *14*(3), 215–227.
- Sullivan J., Aultman-Hall L. and Novak D. (2010). Application of the network robustness index to identifying critical road-network links in Chittenden County, Vermont. *University of Vermont Transportation Research Center*, *10–9*(June), 1–17.