Towards a Modeling Toolbox for Multi-modal Coastal Community Supply to Support Disaster Preparedness Risk Management in Canada

Floris Goerlandt, D.Sc., P.Eng.

Assistant Professor, Canada Research Chair

Probabilistic Safety Assessment and Management (PSAM16)
26th June – 1st July 2022, Honolulu, O'ahu, Hawaii, USA

Hello! I am Dr. Floris Goerlandt

- Canada Research Chair in Risk Management for Marine Industries
- Founded the MARS group in 2018, with **Dr. Ronald Pelot**
- Research on
  - Maritime risk analysis methods
  - Arctic Search and Rescue
  - Multi-modal emergency preparedness and response
  - Shipping environmental risks
  - Risk governance

M A
R S

Maritime
Risk and Safety
Research Group

www.maritimeriskandsafety.ca

Thank you, SIREN project team and collaborators!

MARS Maritime Risk and Safety Research Group

www.maritimeriskandsafety.ca



Samsul Islam


Luana Almeida


Lauryne Rodrigues


Pranitha Vattoni

UVIC


Dr. David Bristow

UBC

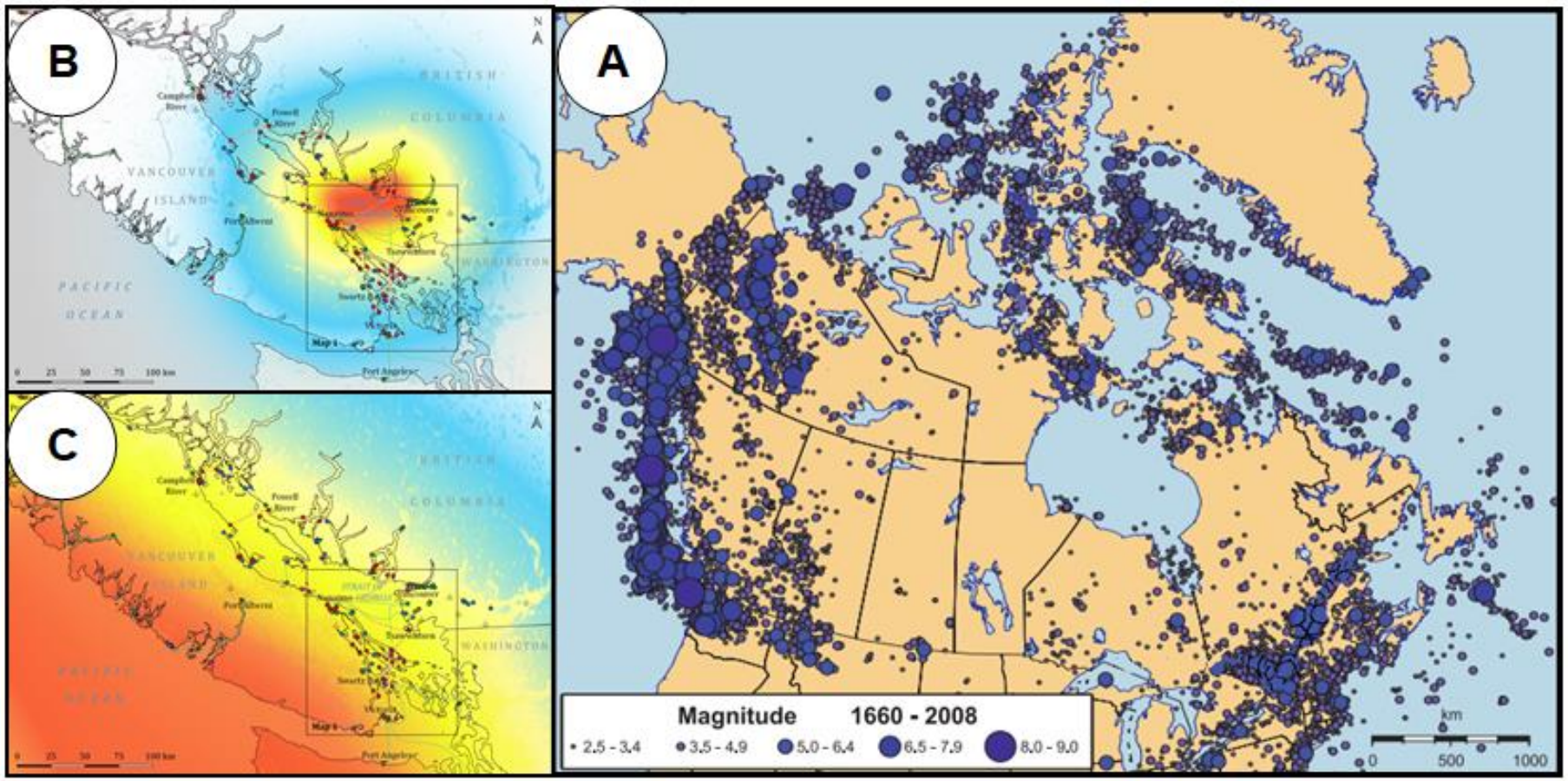

Dr. Stephanie Chang

YORK U


Dr. Jennie Phillips

Natural disasters in Canada: The need for strategic risk management for coastal community supply

Natural disasters in Canada: Earthquakes



A) **Historic earthquakes in Canada**

B) **Shallow Crustal EQ**

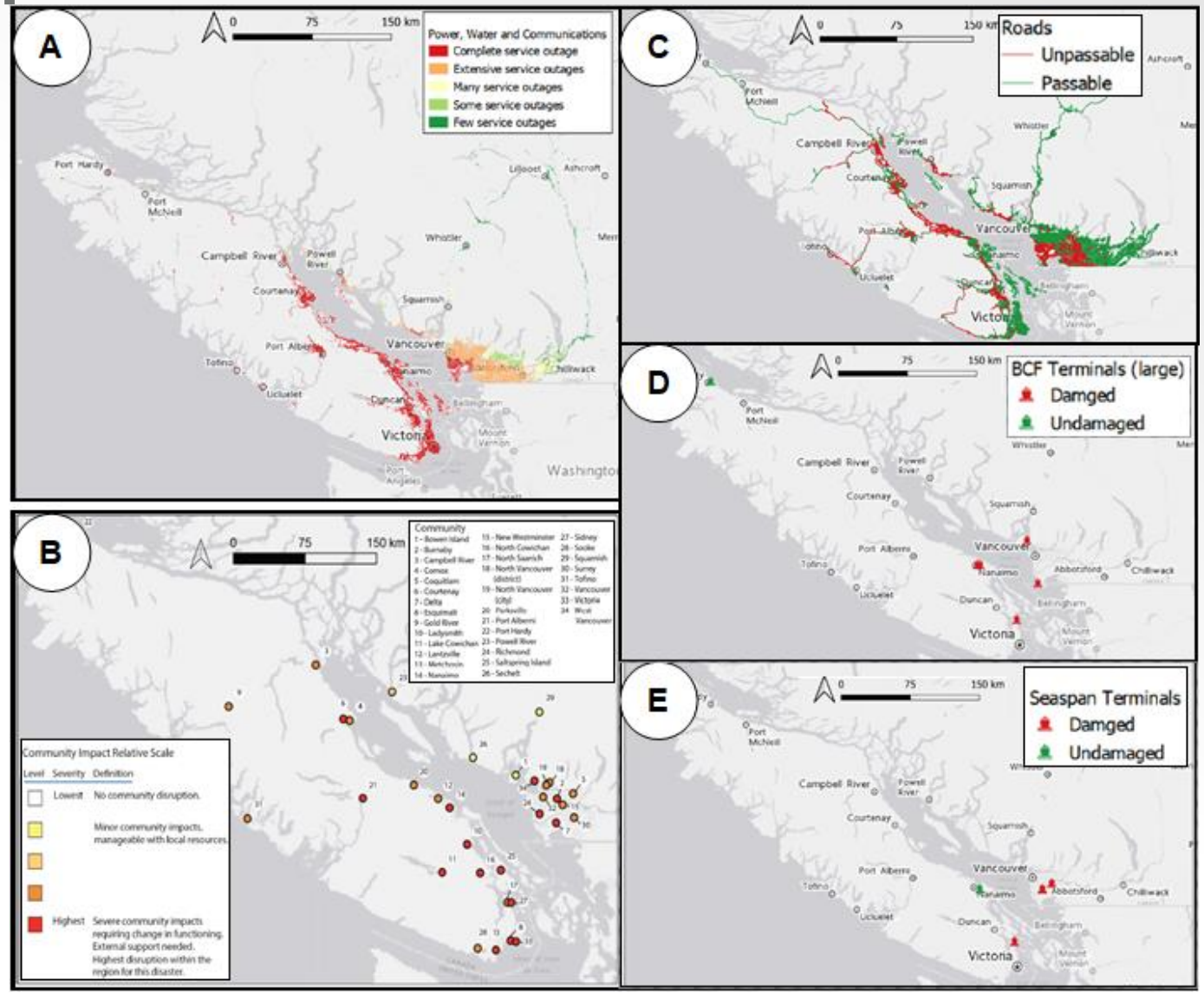
C) **Cascadia M9.0 Subduction Zone EQ**

Source: Cassidy et al. 2014; Chang et al. 2020.

Plausible impacts of a Cascadia M9.0 Subduction Zone EQ

A. **Disruptions to critical infrastructures (power, water, communications)**

B. **Relative impacts to communities**



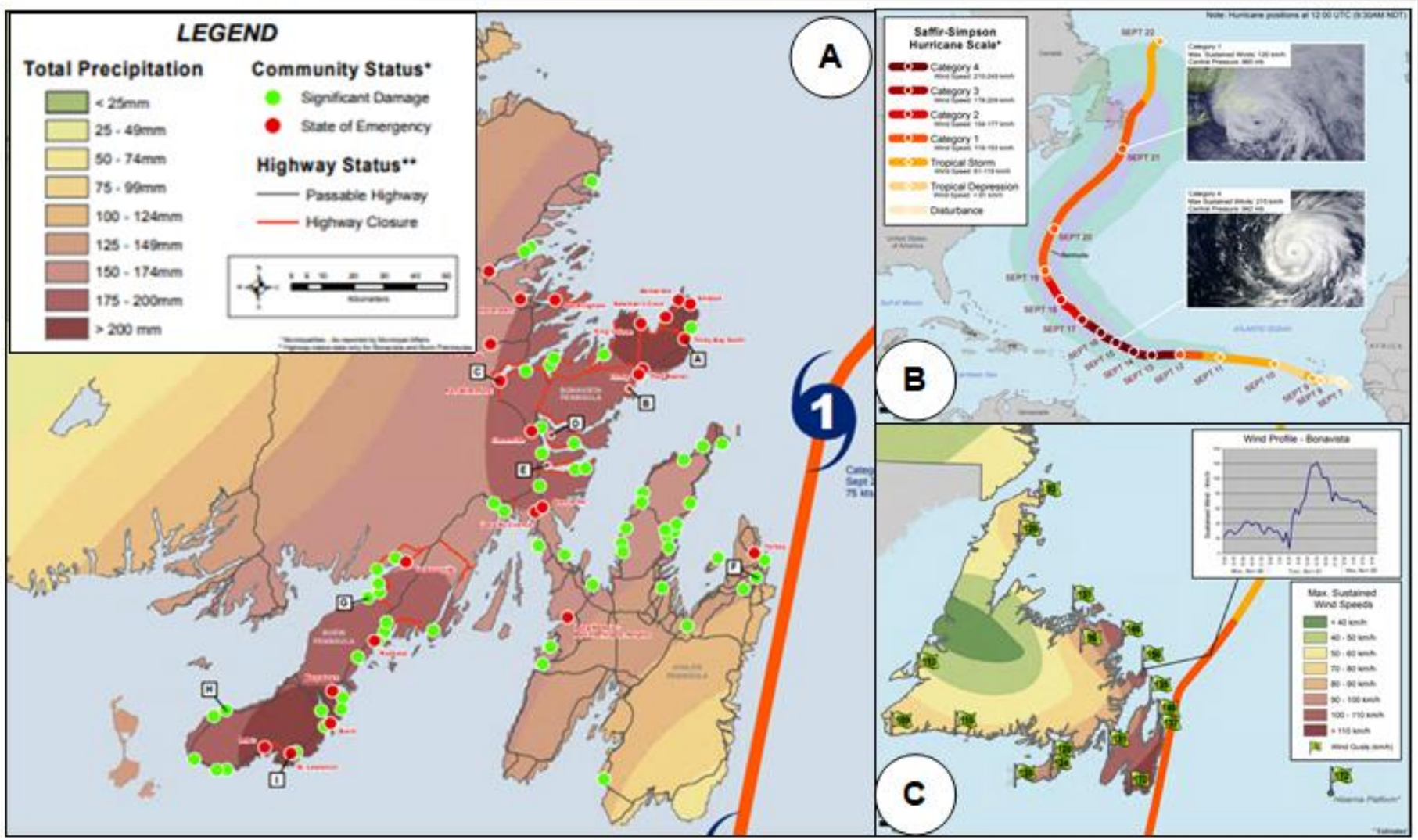
C. **Passability of roads**

D. **Damage to BC Ferries terminals**

E. **Damage to Seaspan terminals**

Source: Chang et al. 2020.

Natural disasters in Canada: Hurricanes



A. **Rain, community impacts, and passability of roads**

B. **Temporal path and intensity evolution**

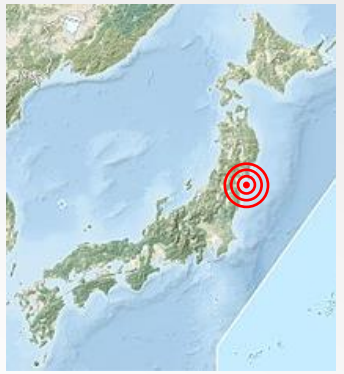
C. **Maximum sustained wind speeds and wind gust**

Source:
Newfoundland and Labrador Statistics Agency 2022

Impacts of natural disasters to maritime transportation

Hurricane Sandy (USA, 2012)

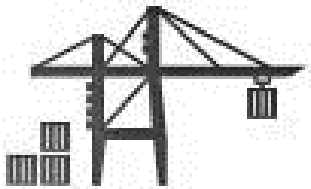
Tohoku Earthquake and Tsunami (Japan, 2011)



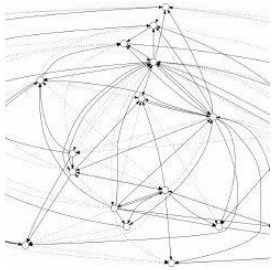
Strategic risk management for coastal community supply in natural disasters: Towards a modeling toolbox

Analyzing disaster impacts on transportation infrastructure and distribution to coastal communities

Port facilities



Transport and infrastructure networks



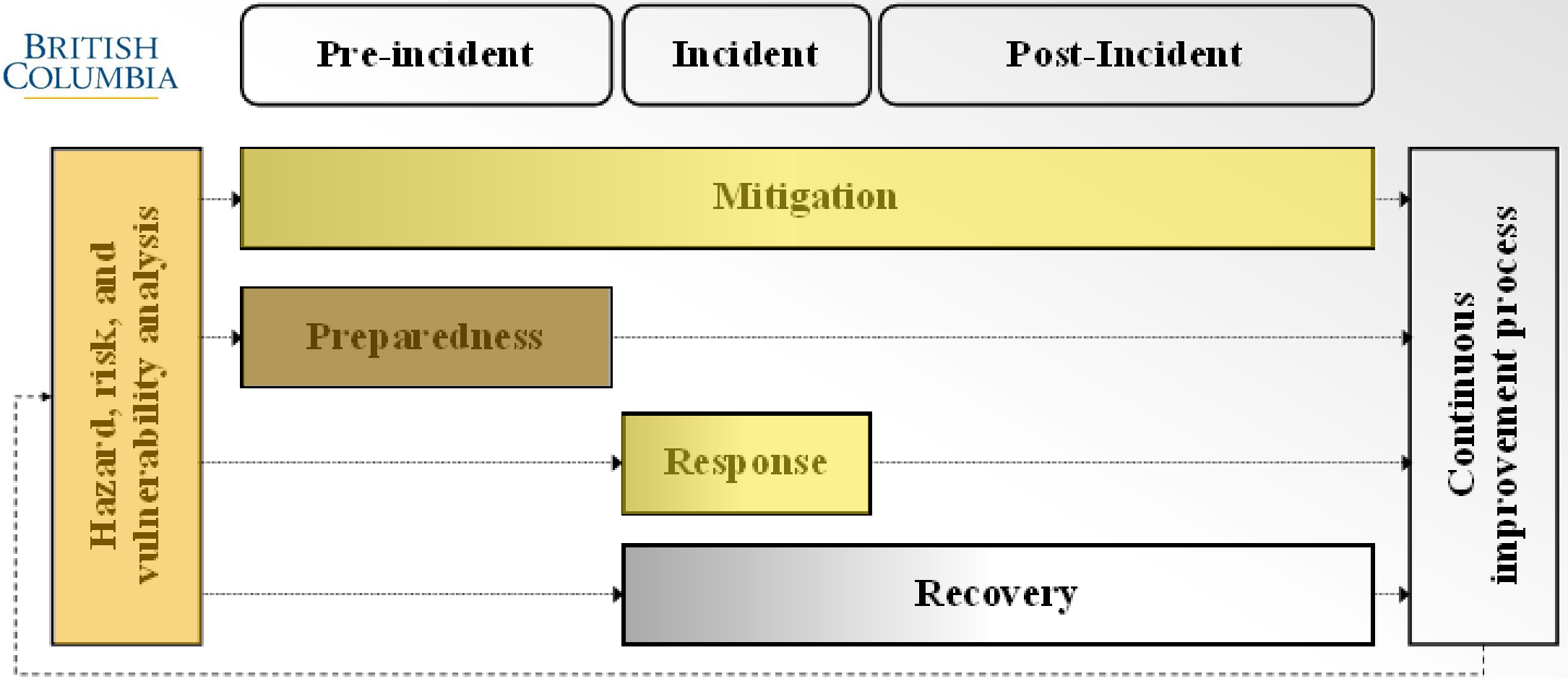
Port operations and maritime supply chain

Other transport modes

Communities

Natural disaster damage — **Transport disruption** — **Community impacts**

Strategic risk management focus: disaster preparedness



Source: Province of British Columbia 2016.

Risk management questions for disaster preparedness

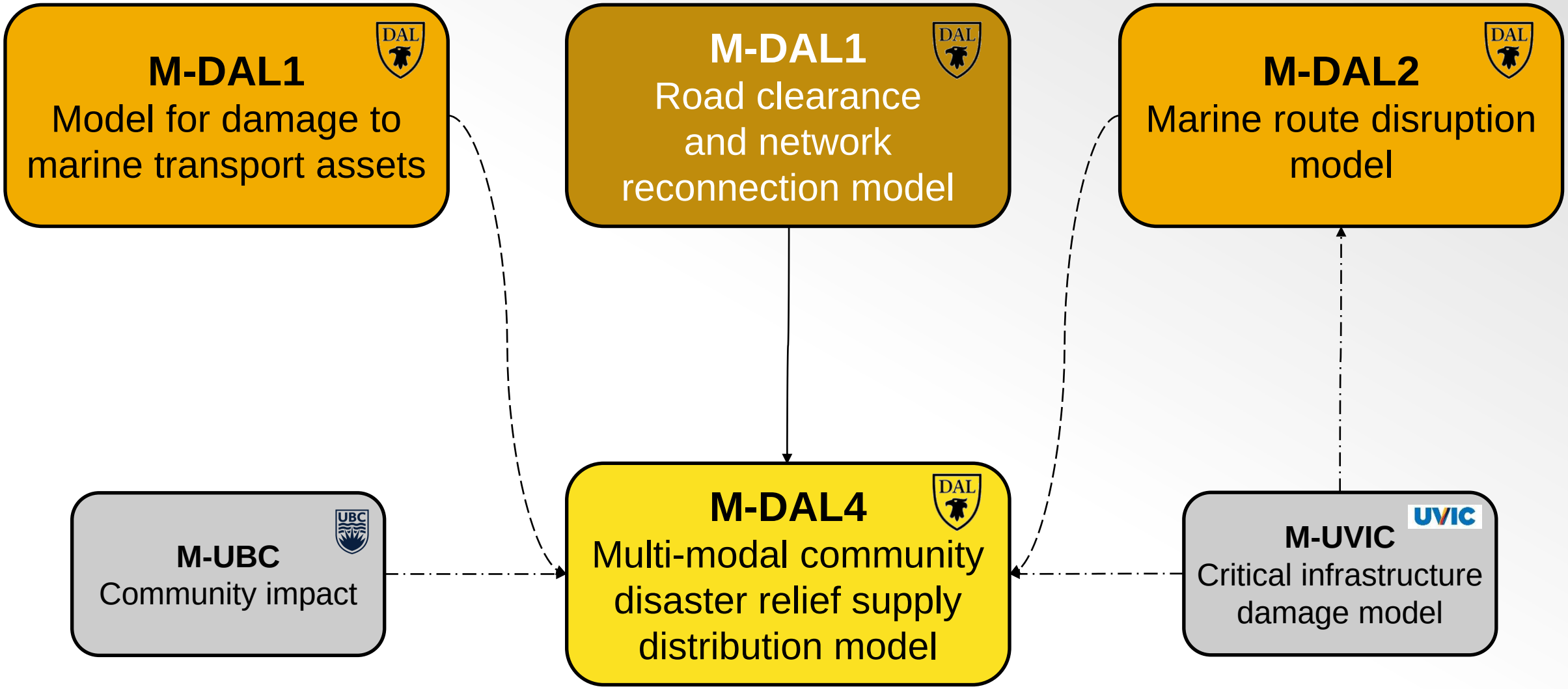
Q1. How are transportation assets (esp. vessels) and their operability affected by disasters?

Q2. How would a disaster affect maritime and multi-modal transportation routes?

Q3. What operational capacity would the disrupted multi-modal transportation system have to ship relief supplies to communities in the response phase?

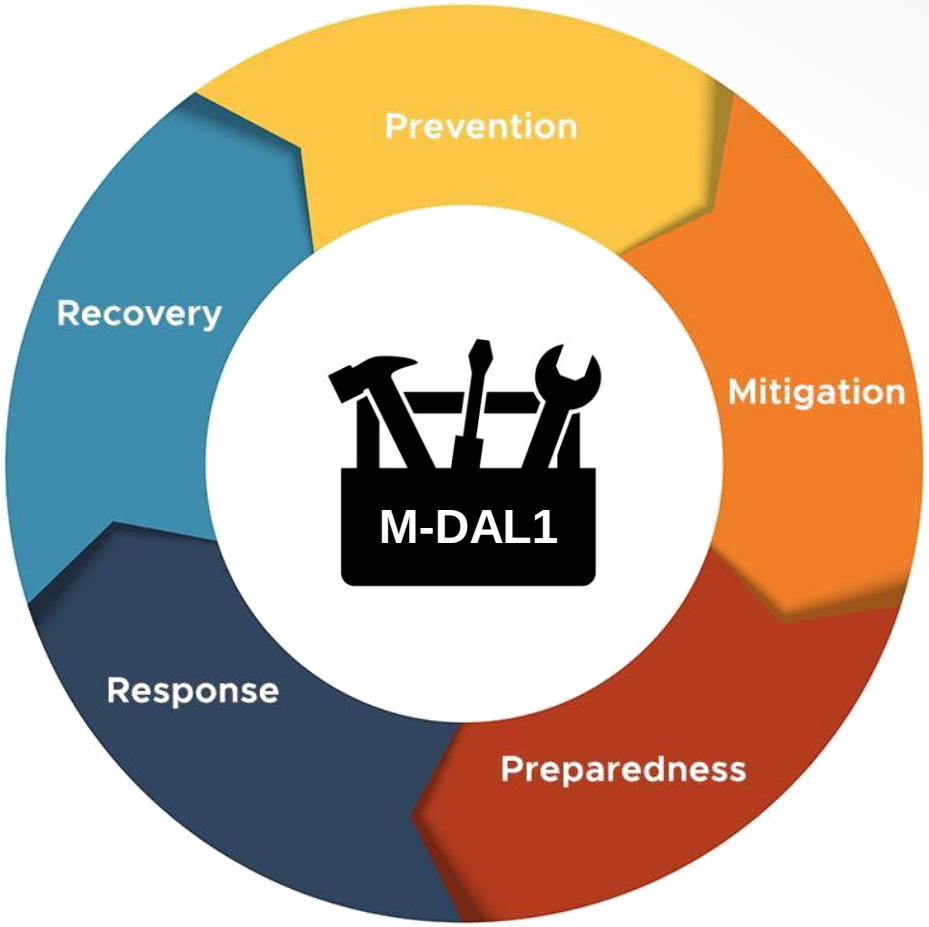
Q4. What ports and other transportation infrastructure should be prioritize for repair and clearance to maximize the effectiveness of supply to the affected communities?

Modeling toolbox: Overview



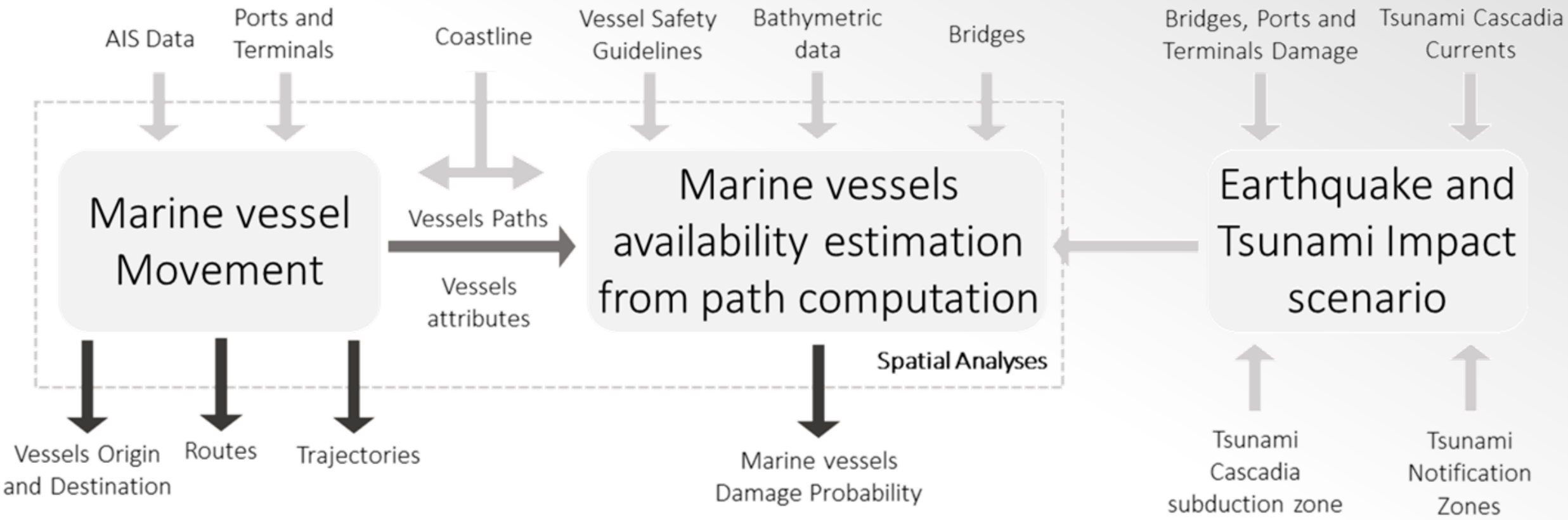
Modeling toolbox: Overview

ID	Model	RMQ	Applied Technique(s)
M-DAL1	Model for damage to marine transport assets	Q1	- Data analysis - Qualitative expert model - GIS analytics
M-DAL2	Marine route disruption model	Q2	- Bayesian Network
M-DAL3	Road clearance and network reconnection model	Q2 Q3 Q4	- Multi-vehicle prize-collecting arc routing for connectivity problem (KPC-ARCP) - Metaheuristics (GRASP, ACO)
M-DAL4	Multi-modal community disaster relief supply distribution model	Q2 Q3 Q4	- 2-echelon Split Delivery Vehicle Routing Problem with Time Windows (2E-SD-VRP-TW) - KPC-ARCP - Metaheuristics (SA)



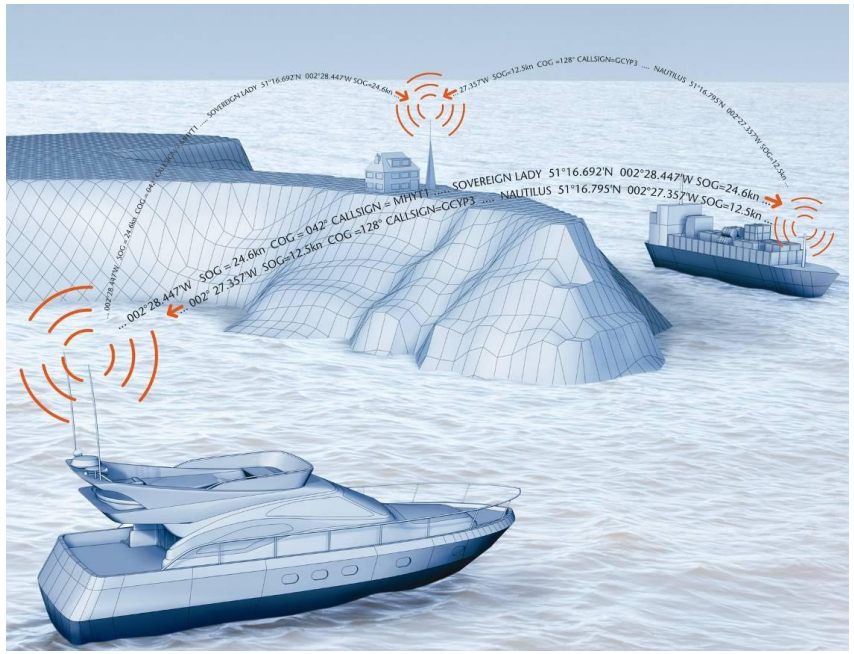
Modeling toolbox: Model for damage to marine transport assets

Ship damage analysis process: Schematic overview

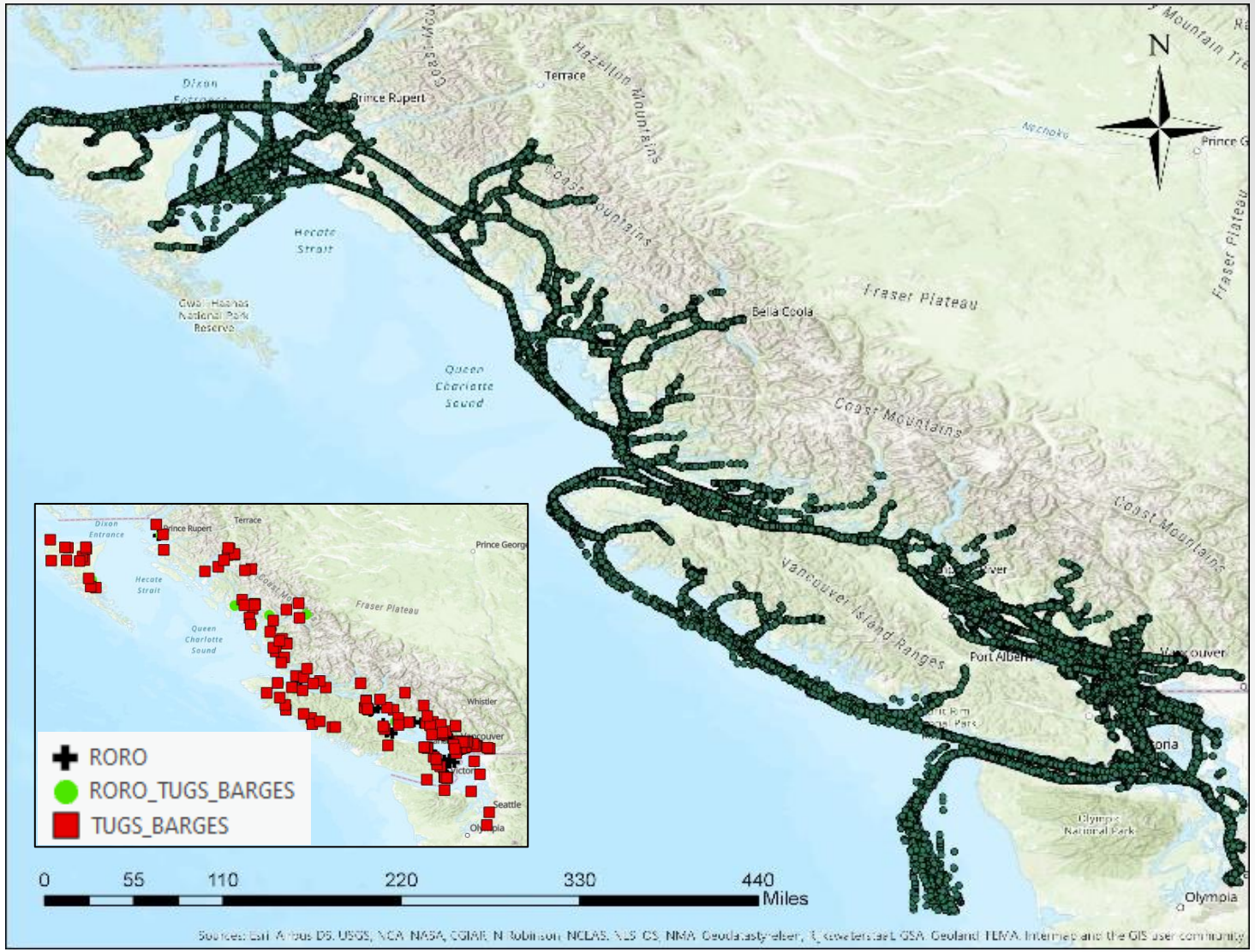


Source: Rodrigues et al. 2022.

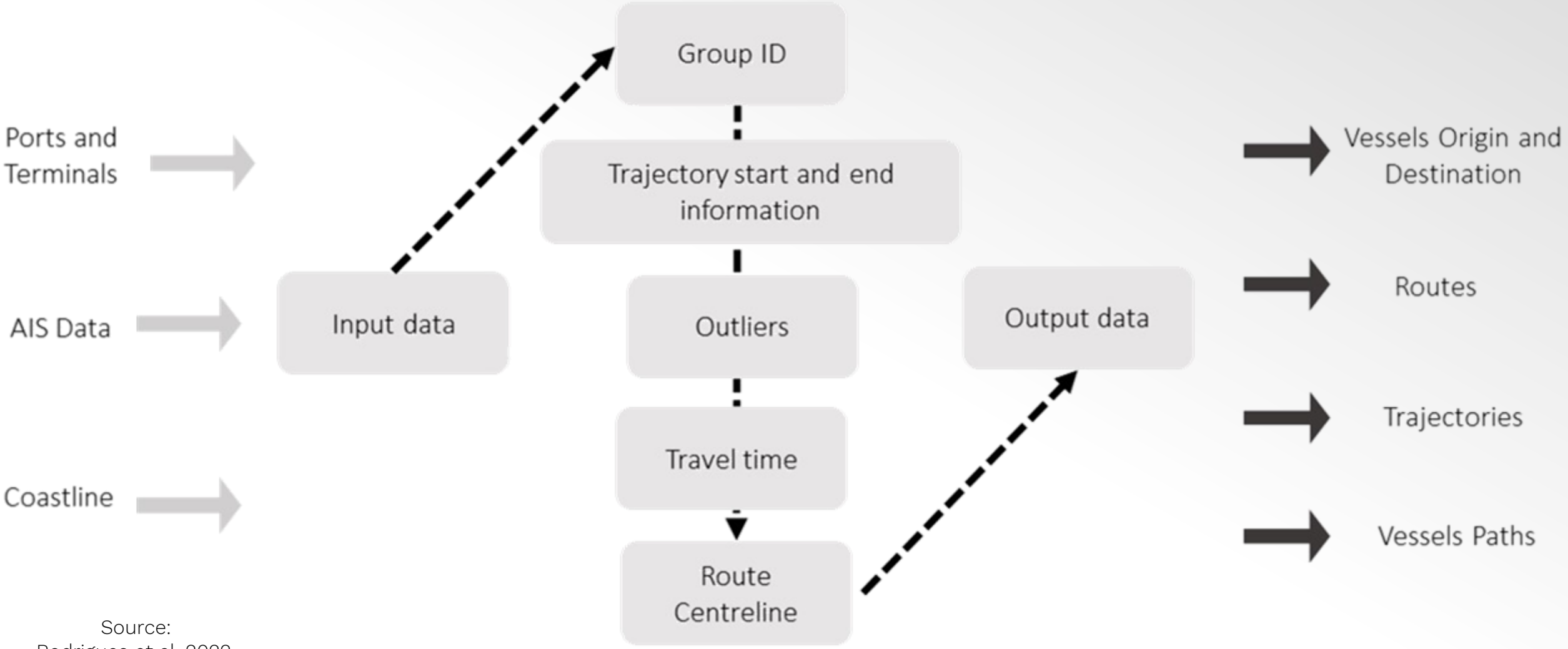
AIS data: Raw data



Source:
Rodrigues et al. 2022.

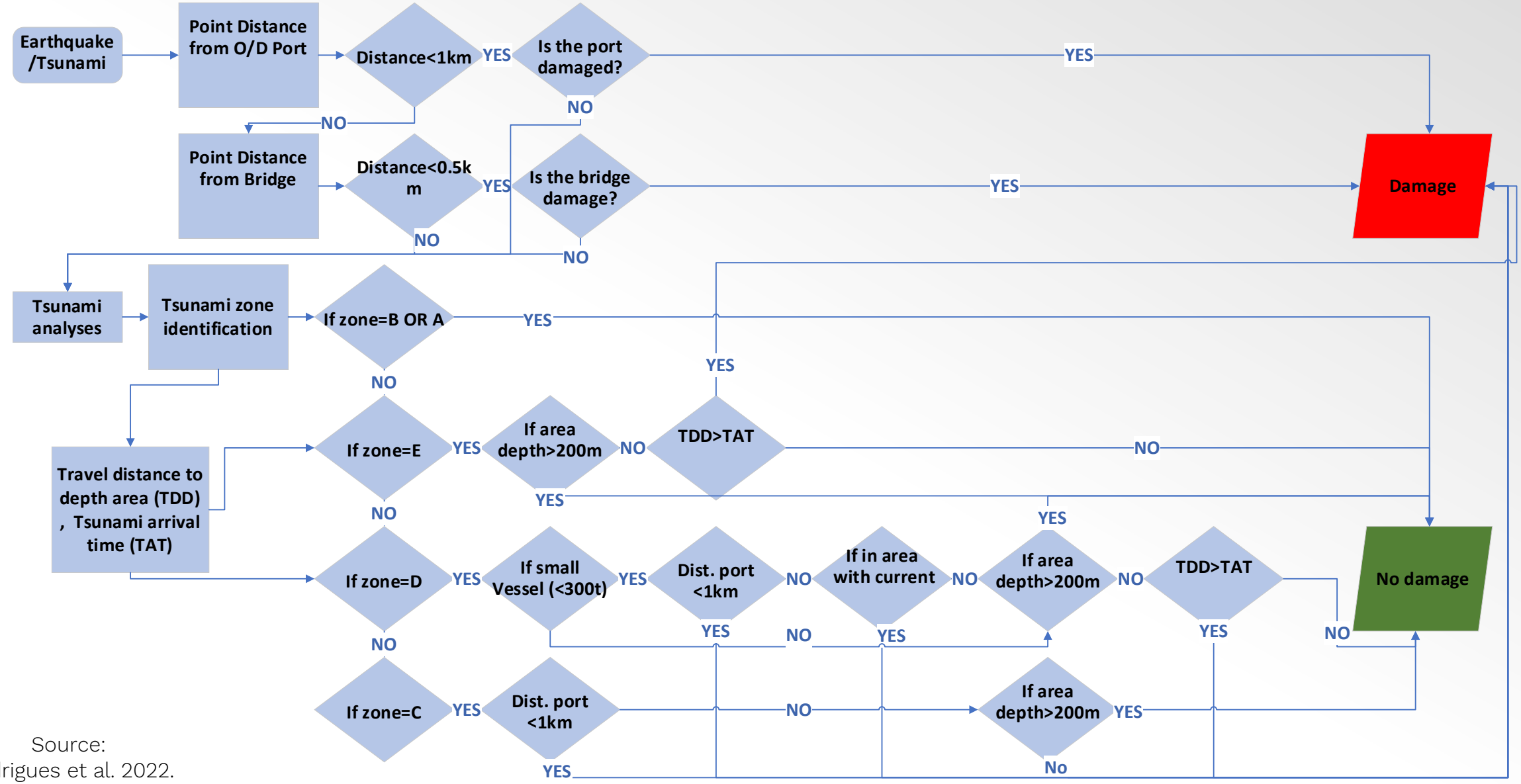


Processing AIS data to trajectories and routes



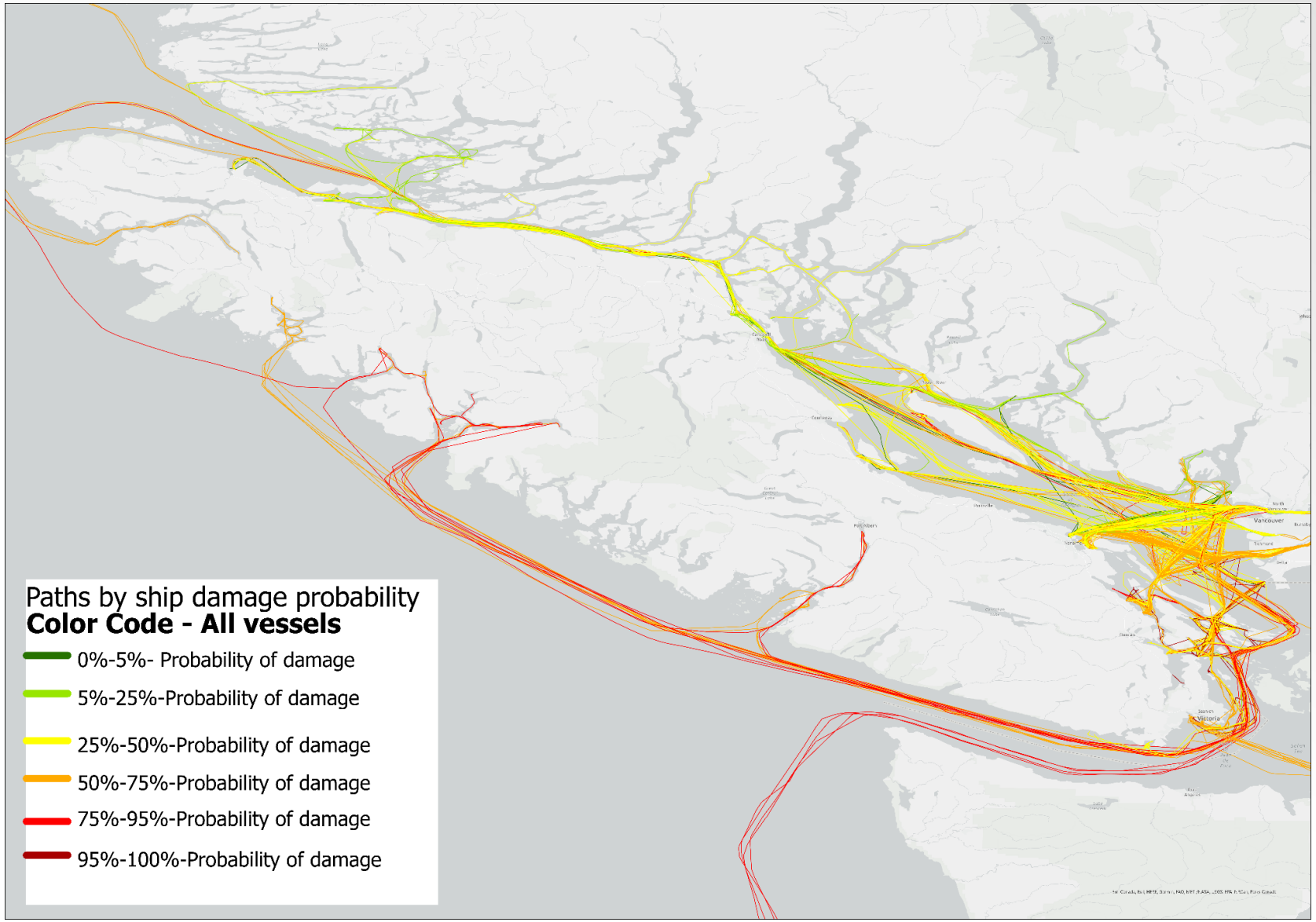
Source:
Rodrigues et al. 2022.

Ship damage estimation model based on vessel path information



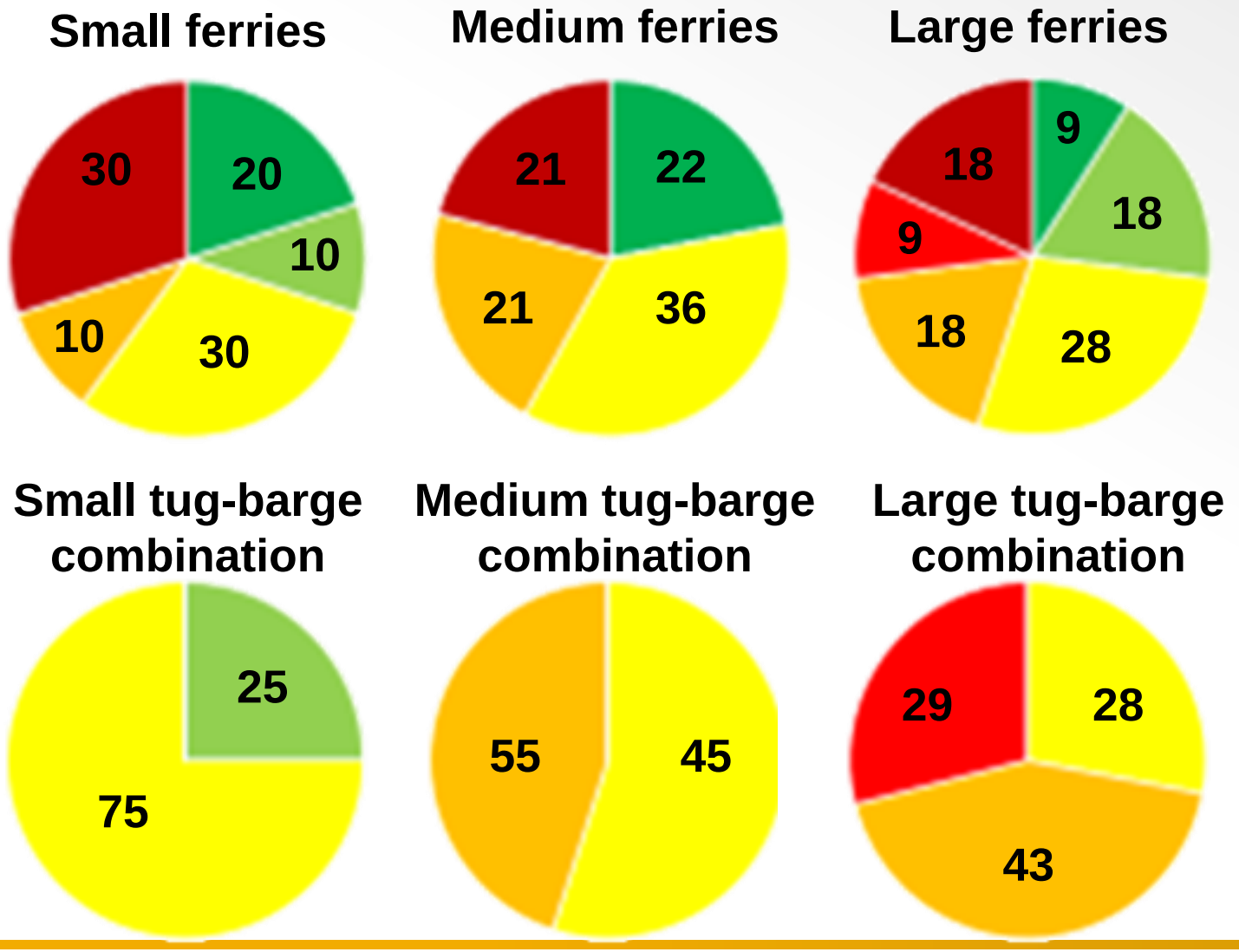
Source:
Rodrigues et al. 2022.

Ship damage probability by shipping routes to Vancouver Island

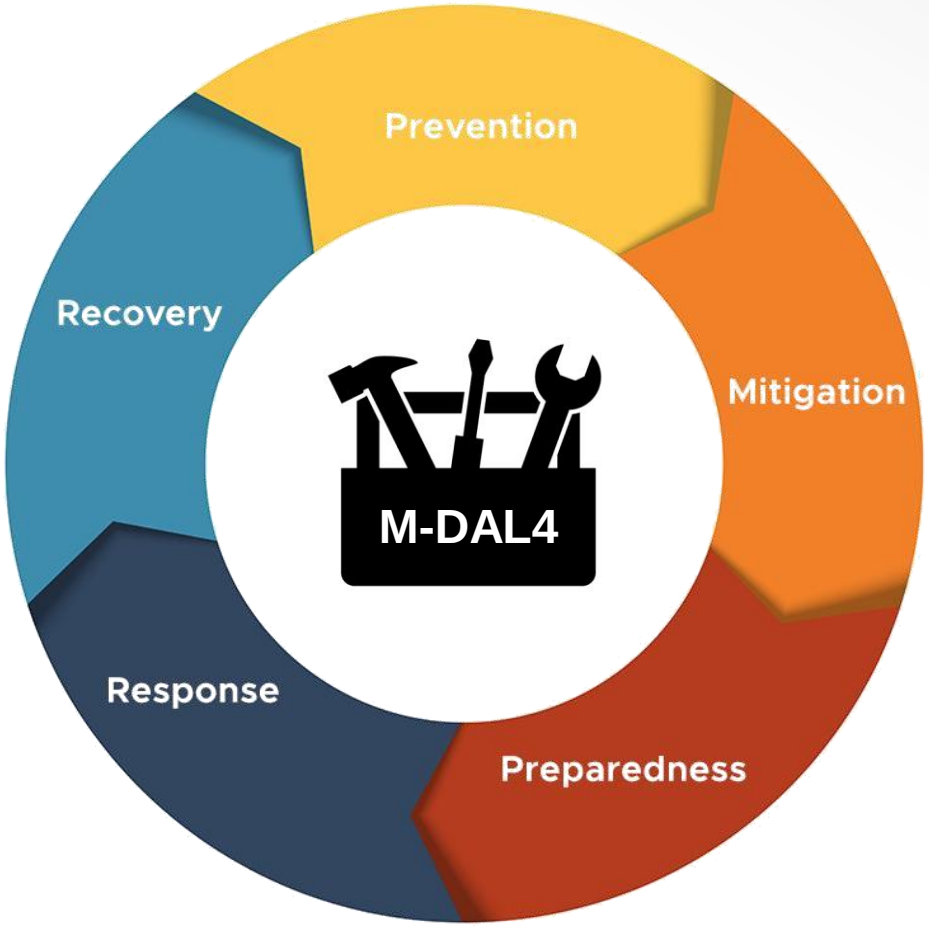


Source:
Rodrigues et al. 2022.

Ship damage probability for ferries and tugs, relative to activity patterns



Source: Rodrigues et al. 2022.



Modeling toolbox: Multi-modal community disaster relief supply distribution model

Multi-modal community disaster relief supply distribution model

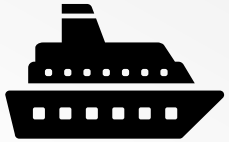
- **Purpose:** give insights about
  - **Critical structures** (roads, ports, and airports)
  - **Resources** availability (trucks, ships, helicopters, and clearing teams)
  - **Isolated areas** after the immediate response phase considering different road clearing/distribution strategies.
  - Communities supported in the immediate response phase considering different **prioritization strategies**
- Integrates multi-vehicle prize collecting arc routing problem (KPC-APRC) with 2-echelon Split Delivery Vehicle Routing Problem with Time Windows (2E-SD-VRP-TW)

Resources and transportation assets considered in the model

Debris management

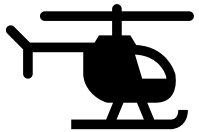
Road clearing teams

Multi-modal Distribution



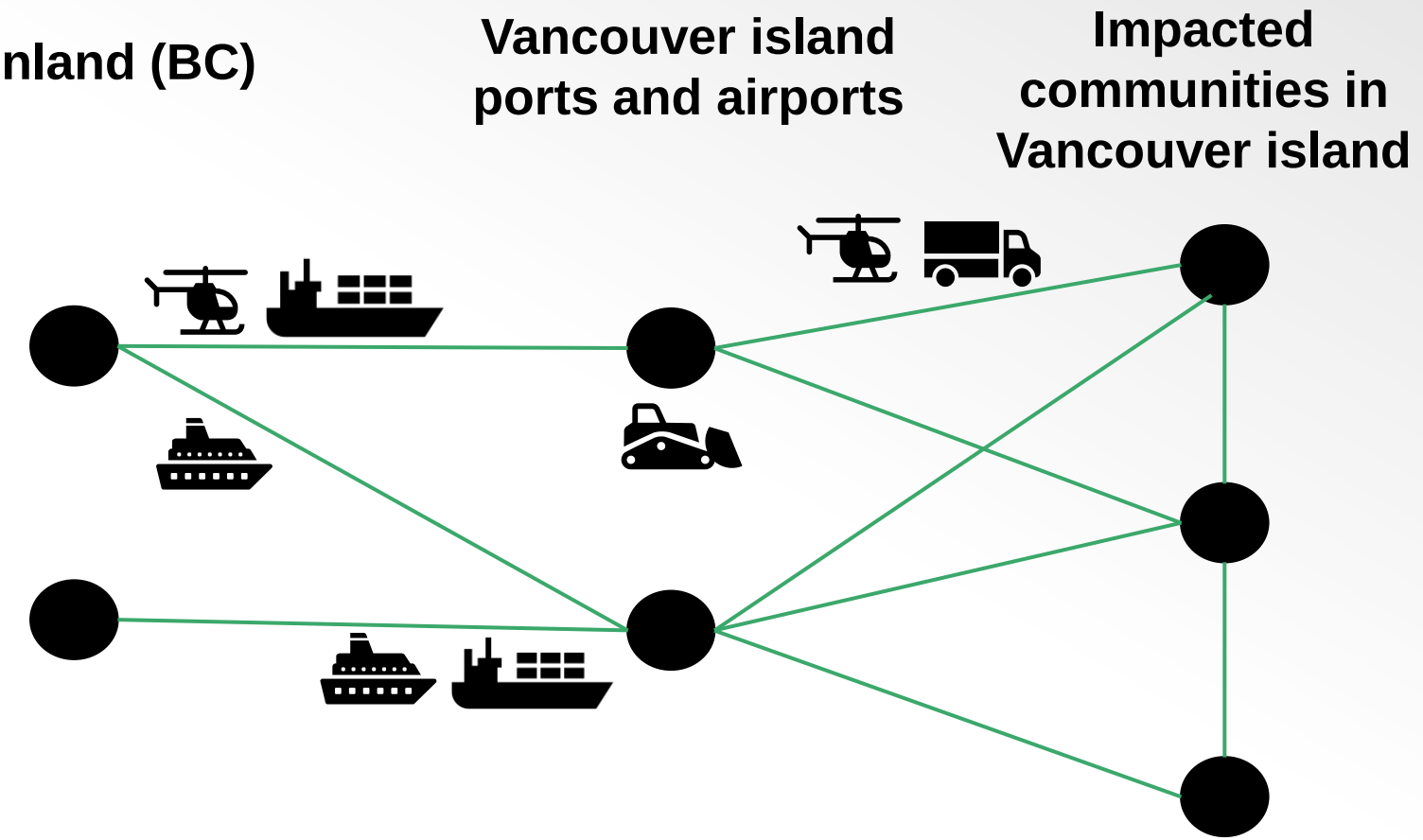
BC Ferries
Seaspan

Trucks

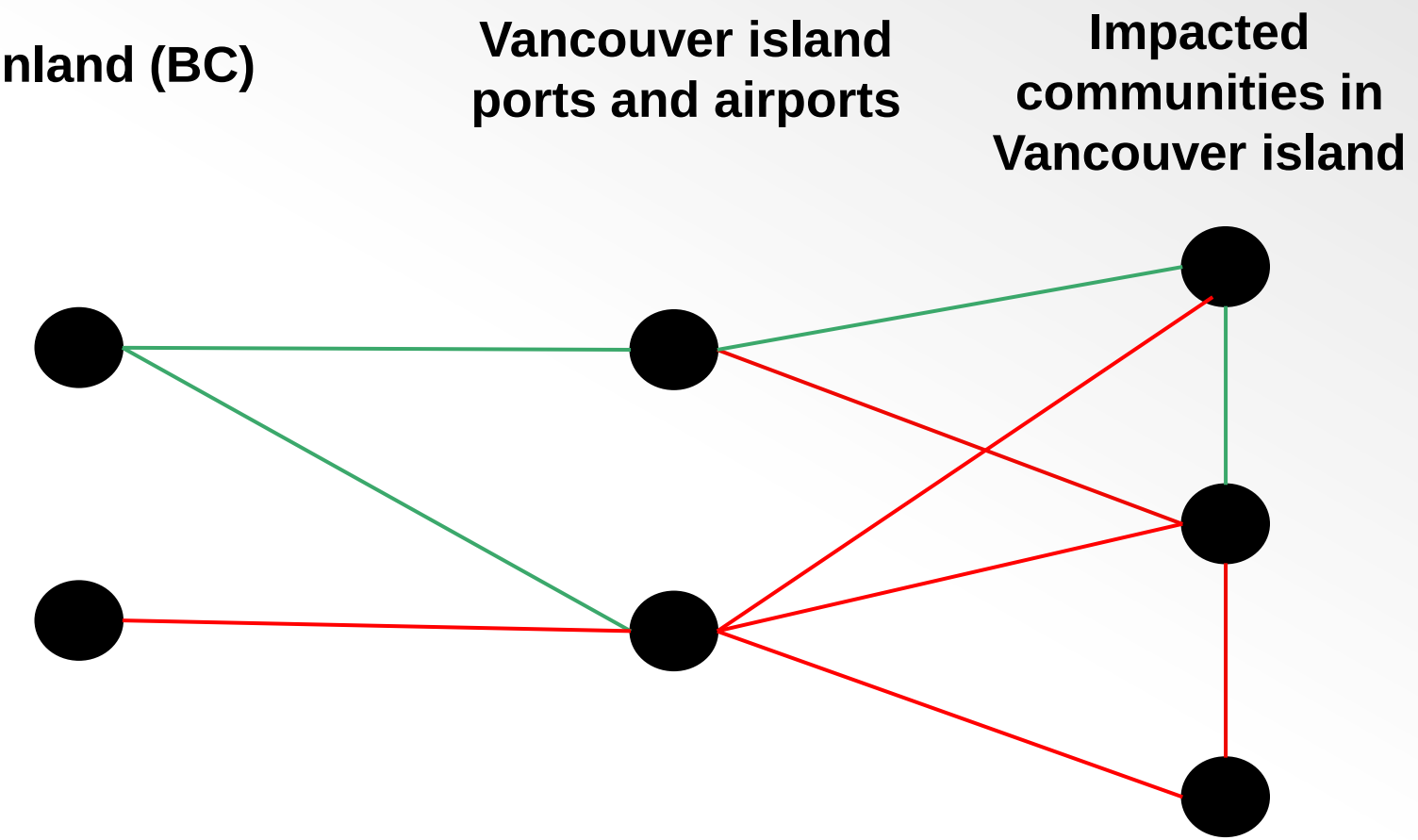


Helicopters

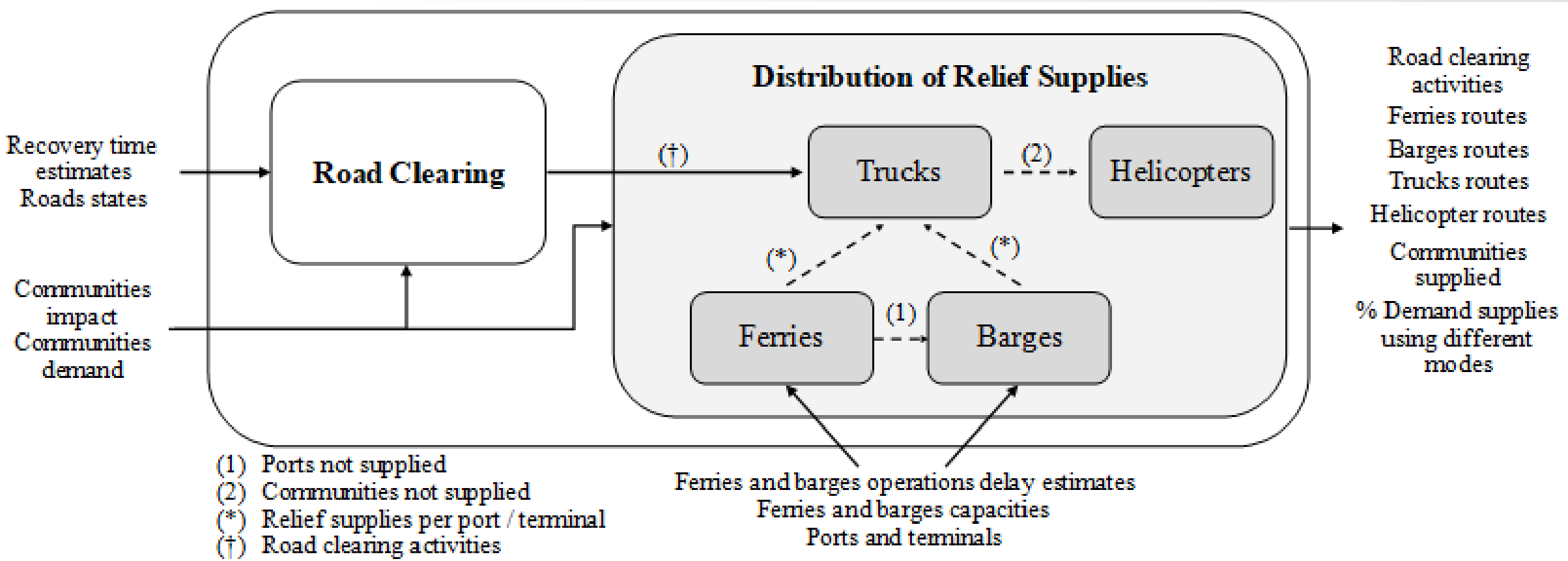
Conceptual model description: Before earthquake



Conceptual model description: After earthquake

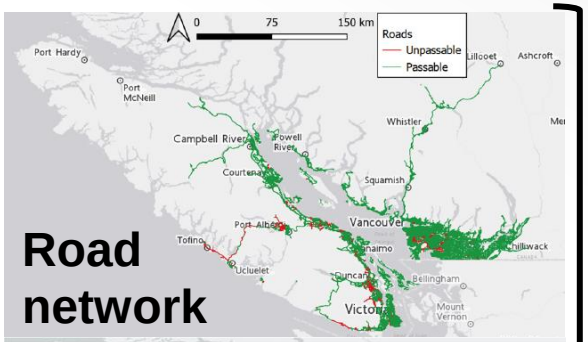


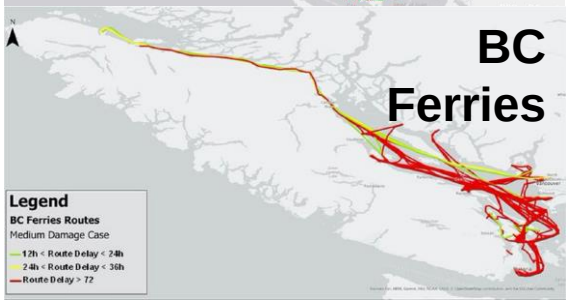
Road clearing and multi-modal disaster supply model: Overview

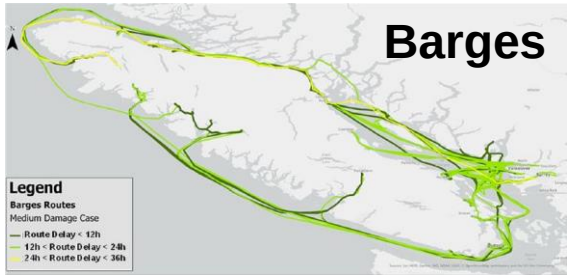


Road clearing and multi-modal disaster supply model: Example

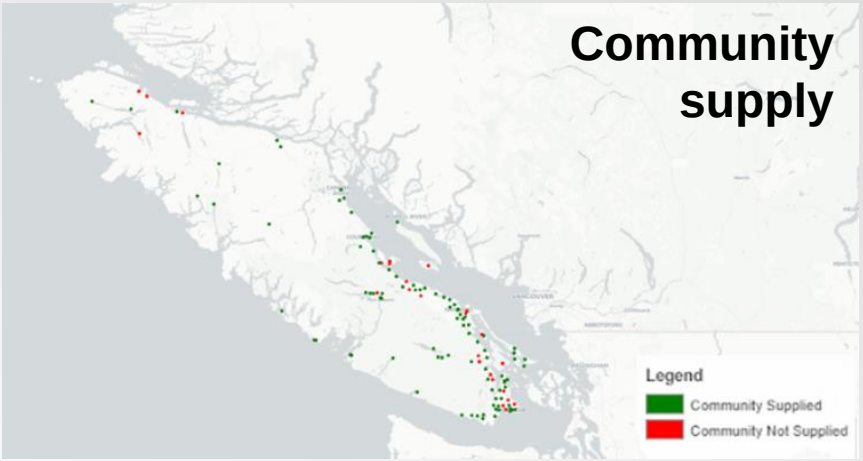
Road clearing and transport routes in Cascadia M9.0 earthquake







Road clearing and multi-modal disaster supply model



Region	Demand delivered				
	Ferries Direct	Barges Direct	Marine + Trucks	Helicopters	Total
North Island	0%	0%	18%	14%	32%
Pacific RIM	0%	19%	20%	3%	42%
Central Island	0%	2%	44%	2%	48%
Sunshine Coast Islands	73%	0%	0%	27%	100%
South Island	0%	0%	7%	2%	9%
Gulf Islands	73%	0%	0%	13%	86%

Ongoing work
Future research

Ongoing work and future research directions

Further developing road clearing and distribution model to multi-depot

Testing and optimizing heuristics algorithms for speeding up model runs

Developing standard model instances for road clearing model

Uncertainty modeling and pattern analysis for range of scenarios

Integrating models with multi-hazard scenario models

Book publishing 2023

Further details

[1] Almeida L.S., Goerlandt F., Pelot R., Sörensen K. 2022. A Greedy Randomized Adaptive Search Procedure (GRASP) for the multi-vehicle price collecting arc routing for connectivity problem. *Computers and Operations Research* 143:105804.

[2] Souza Almeida L., Goerlandt F. 2022. An ant colony optimization approach to the multi-vehicle prize-collecting arc routing for connectivity problem. *Multimodal Transportation*, forthcoming.

[3] Chang S., Bristow D., Goerlandt F., Pelot R., Goodchild A., Lin C., Zhou L. 2020. Planning for a catastrophic earthquake in British Columbia: Marine transportation disruption and coastal community resilience. SIREN Project report, 112p.

[4] Souza Almeida L., Goerlandt F., Pelot R. 2022. Trends and gaps in the literature of road network restoration and recovery in the context of disaster response operations. *Socio-Economic Planning Sciences*, submitted.

[5] Goerlandt F., Islam S. 2021. A Bayesian Network risk model for estimating coastal maritime transportation delays following an earthquake in British Columbia. *Reliability Engineering and System Safety* 214:107708.

[6] Rodrigues L.B., Goerlandt F. 2022. A model for estimating the damage to marine assets by an earthquake-tsunami event. *International Journal of Disaster Risk Reduction*, in progress.

Towards a Modeling Toolbox for Multi-modal Coastal Community Supply to Support Disaster Preparedness Risk Management in Canada

Floris Goerlandt, D.Sc., P.Eng.

Assistant Professor, Canada Research Chair

Probabilistic Safety Assessment and Management (PSAM16)
26th June – 1st July 2022, Honolulu, O'ahu, Hawaii, USA

DALHOUSIE UNIVERSITY

M A R S Maritime Risk and Safety Research Group

BRITISH COLUMBIA

MEOPAR

MITACS