# A Direct Approach for Modelling Transportation Networks Before and After Earthquakes

Professor Terje Haukaas

PhD Student Rodrigo Costa

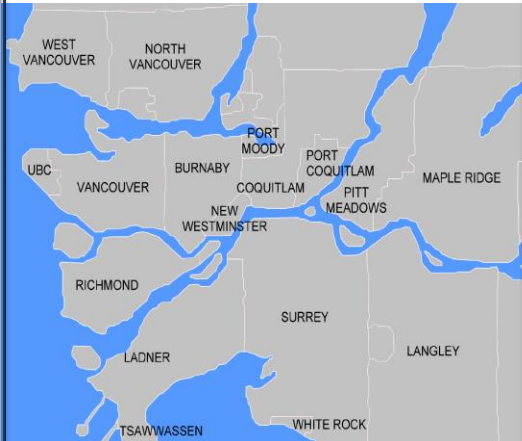University of British Columbia, Vancouver

# Workshop or Symposium?

- **Workshop**
  - Work = No thanks
  - Shop = No thanks

- **Symposium**
  - Συμπόσιον (symposion) stems from Συμπίνειν (sympinein)
  - Συμπίνειν = "To drink together"
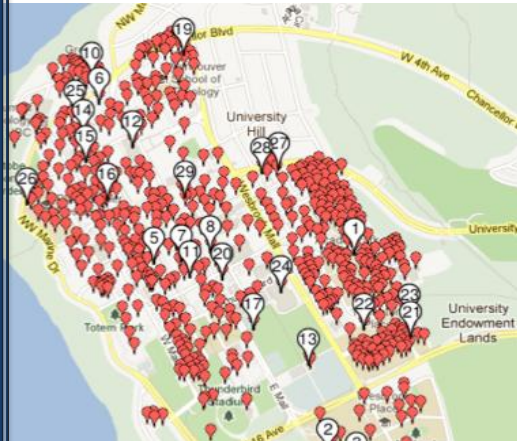  - Symposium = Drinking party

- **Conclusion**
  - Symposium

# ICOSSAR 2013

## Regional Level

Lower Mainland, British Columbia



2,887km$^2$
23 municipalities

## Building Level

UBC Campus, Vancouver



622 buildings

## Component Level
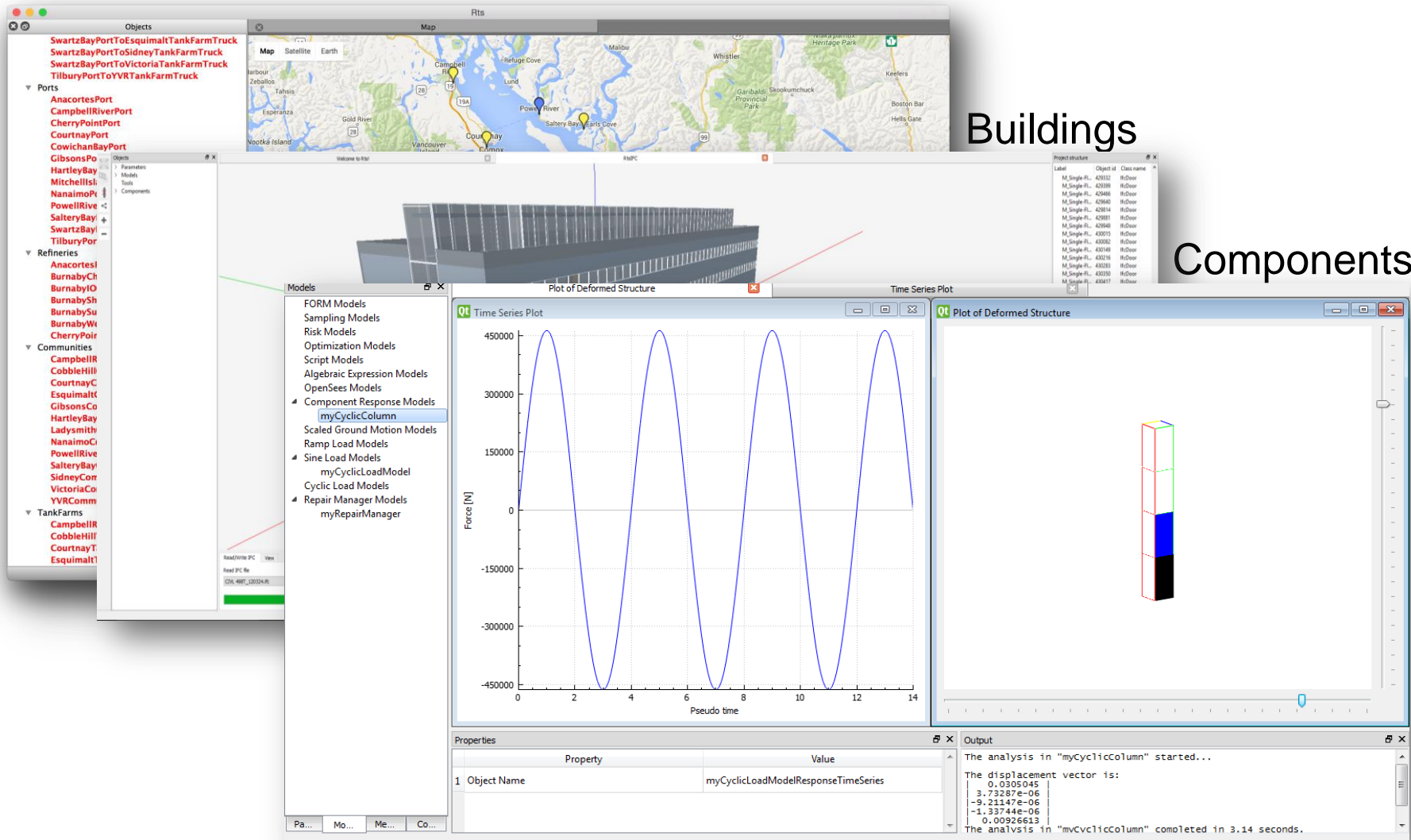
Heritage Court Tower, Vancouver



15 storeys
reinforced concrete

# Research Direction

Networks

Buildings

Components

# Computer Simulations

## Elon Musk believes we are probably characters in some advanced civilization's video game

*Updated by Ezra Klein on June 2, 2016, 2:03 a.m. ET* 🐦 *@ezraklein*

🐦 TWEET    f SHARE (69K)    +



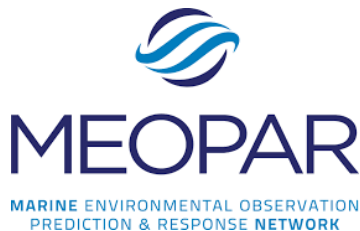1/9   Is life a video game? | Elon Musk | Code Conference 2016   VOX MEDIA

# Project

Resilience of the Coastal Communities in British Columbia

www.resilientcoasts.ubc.ca

**Professor Stephanie Chang**
School of Community and Regional Planning

**Professor Hadi Dowlatabadi**
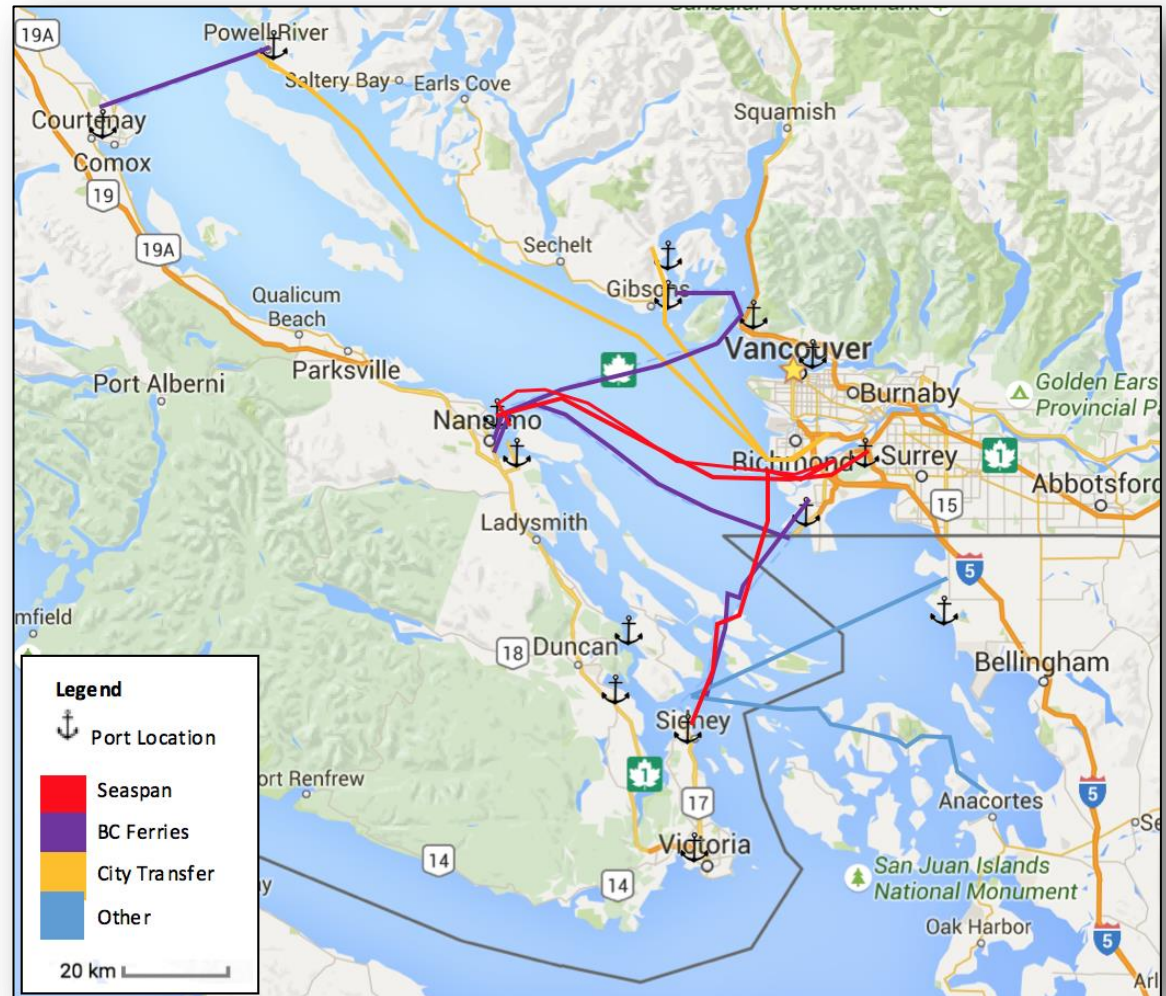Institute for Resources, Environment and Sustainability

**Professor Terje Haukaas**
Department of Civil Engineering

# Objectives

1.  Network model
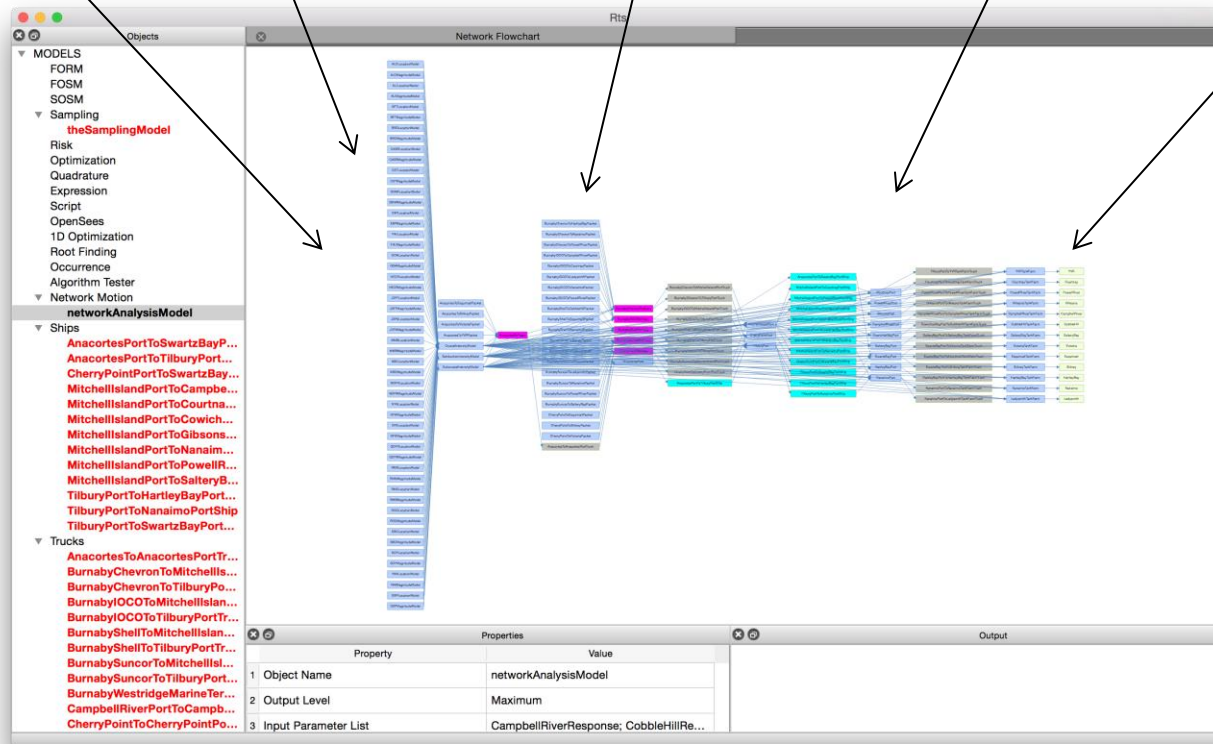
2.  Hazards

3.  Resiliency

# Network Model in Rts

Geological survey of Canada

Communities

Emergency managers

Port authorities

Private sector



*Chang, Brown, Costa, Dobson, Dowlatabadi, Haukaas (2017) "A Community Resilience Approach to Assessing Transportation Risk in Disasters" 16th World Conference on Earthquake Engineering, January 9-13, Chile*

# Simulation in Rts

# How to Present a Model?

```
RTruckModel  |ObjectName: BurnabyShellToTilburyPortTruck |TravelTime: 14.56 |InputPacketList: BurnabyShellRefineryResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: BurnabySuncorToMitchellIslandPortTruck |TravelTime: 23.99 |InputPacketList: BurnabySuncorRefineryResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: BurnabySuncorToTilburyPortTruck |TravelTime: 19.63 |InputPacketList: BurnabySuncorRefineryResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: BurnabyWestridgeMarineTerminalToYVRTankFarmTruck |TravelTime: 26.08 |InputPacketList: BurnabyWestridgeMarineTerminalRefineryResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: CherryPointToCherryPointPortTruck |TravelTime: 1.00 |InputPacketList: CherryPointRefineryResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: CherryPointToYVRTankFarmTruck |TravelTime: 52.16 |InputPacketList: CherryPointRefineryResponse |OutputLevel: Maximum


// -------------------------------------------------------------------
// PORTS ON THIS SIDE
RPortModel |ObjectName: AnacortesPort     |Location: AnacortesPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelRespon
RPortModel |ObjectName: BurnabyChevronPort     |Location: BurnabyChevronPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityM
RPortModel |ObjectName: CherryPointPort    |Location: CherryPointPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelRe
RPortModel |ObjectName: HorseshoeBayPort     |Location: HorseshoeBayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityMod
RPortModel |ObjectName: MitchellIslandPort     |Location: MitchellIslandPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityM
RPortModel |ObjectName: TilburyPort    |Location: TilburyPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse;
RPortModel |ObjectName: TsswassenPort     |Location: TsswassenPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelRespon
RPortModel |ObjectName: VancouverPort    |Location: VancouverPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelRespon


// -------------------------------------------------------------------
// SHIPS
RShipModel |ObjectName: AnacortesPortToSwartzBayPortShip |InputPacketList: AnacortesPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: AnacortesPortToTilburyPortShip |InputPacketList: AnacortesPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: CherryPointPortToSwartzBayPortShip |InputPacketList: CherryPointPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToCampbellRiverPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToCourtnayPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToCowichanBayPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToGibsonsPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToNanaimoPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToPowellRiverPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: MitchellIslandPortToSalteryBayPortShip |InputPacketList: MitchellIslandPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: TilburyPortToHartleyBayPortShip |InputPacketList: TilburyPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: TilburyPortToNanaimoPortShip |InputPacketList: TilburyPortResponse |OutputLevel: Maximum
RShipModel |ObjectName: TilburyPortToSwartzBayPortShip |InputPacketList: TilburyPortResponse |OutputLevel: Maximum


// -------------------------------------------------------------------
// PORTS ON THE OTHER SIDE
RPortModel |ObjectName: CowichanBayPort    |Location: CowichanBayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResp
RPortModel |ObjectName: EsquimaltPort    |Location: EsquimaltPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse
RPortModel |ObjectName: HartleyBayPort    |Location: HartleyBayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelRespon
RPortModel |ObjectName: NanaimoPort   |Location: NanaimoPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse; |I
RPortModel |ObjectName: PowellRiverPort    |Location: PowellRiverPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResp
RPortModel |ObjectName: SwartzBayPort    |Location: SwartzBayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse
RPortModel |ObjectName: CampbellRiverPort   |Location: CampbellRiverPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModel
RPortModel |ObjectName: CourtnayPort   |Location: CourtnayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse;
RPortModel |ObjectName: GibsonsPort   |Location: GibsonsPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelResponse; |I
RPortModel |ObjectName: SalteryBayPort    |Location: SalteryBayPortLocation |IntensityList: CrustalIntensityModelResponse; SubcrustalIntensityModelResponse; SubductionIntensityModelRespon


// -------------------------------------------------------------------
// TRUCKS ON THE OTHER SIDE
RTruckModel  |ObjectName: CampbellRiverPortToCampbellRiverTankFarmTruck |TravelTime: 1.000 |InputPacketList: CampbellRiverPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: CourtnayPortToCourtnayTankFarmTruck |TravelTime: 1.000 |InputPacketList: CourtnayPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: CowichanBayPortToCobbleHillTankFarmTruck |TravelTime: 6.667 |InputPacketList: CowichanBayPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: GibsonsPortToGibsonsTankFarmTruck |TravelTime: 1.000 |InputPacketList: GibsonsPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: HartleyBayPortToHartleyBayTankFarmTruck |TravelTime: 3.853 |InputPacketList: HartleyBayPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: NanaimoPortToLadysmithTankFarmTruck |TravelTime: 11.039 |InputPacketList: NanaimoPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: NanaimoPortToNanaimoTankFarmTruck |TravelTime: 2.652 |InputPacketList: NanaimoPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: PowellRiverPortToPowellRiverTankFarmTruck |TravelTime: 0.398 |InputPacketList: PowellRiverPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: SalteryBayPortToSalteryBayTankFarmTruck |TravelTime: 1.000 |InputPacketList: SalteryBayPortResponse |OutputLevel: Maximum
RTruckModel  |ObjectName: SwartzBayPortToEsquimaltTankFarmTruck |TravelTime: 83.040 |InputPacketList: SwartzBayPortResponse |OutputLevel: Maximum
```
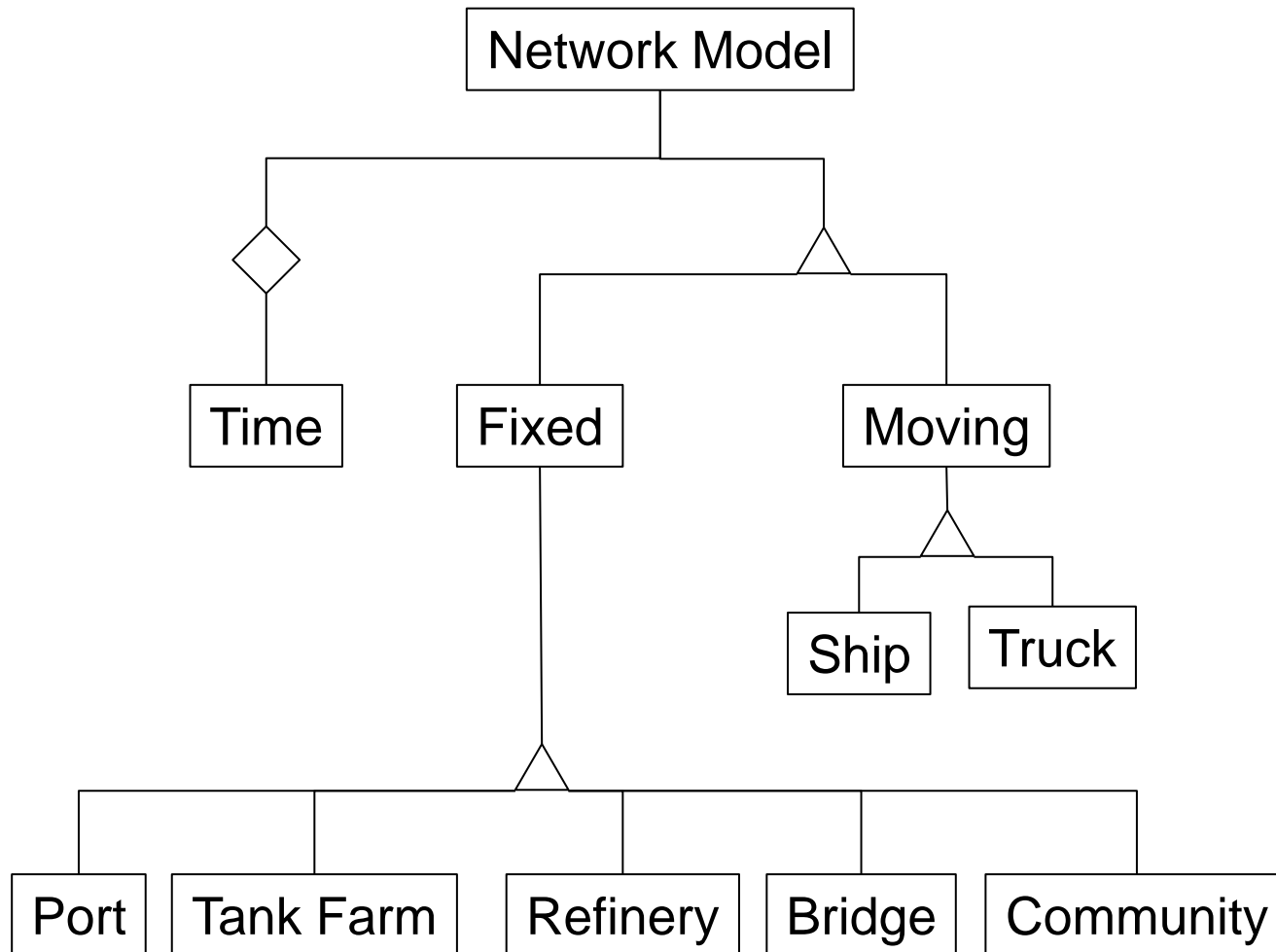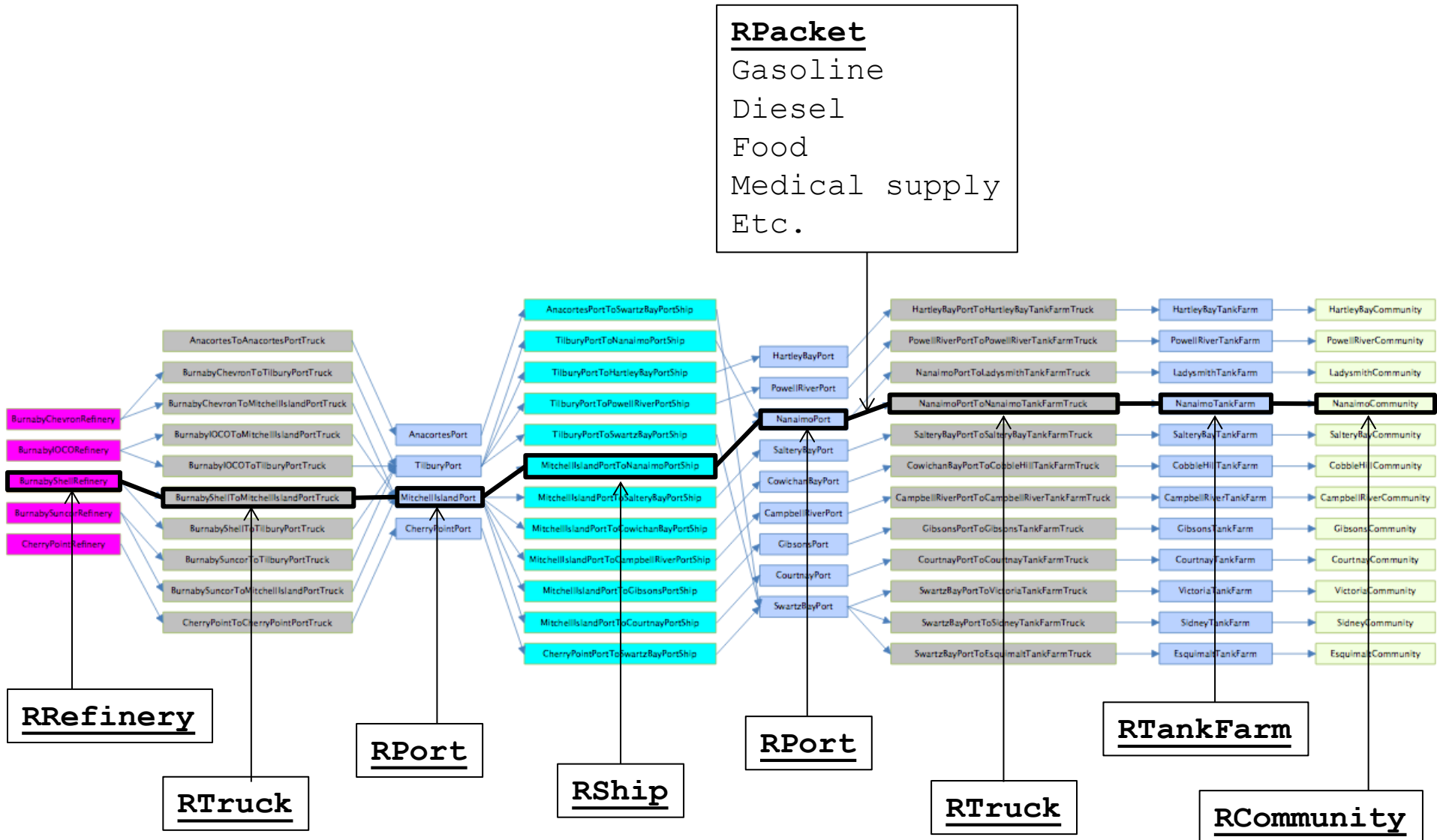
# Class Map

# Object Attributes

- **Port**
  - Type, depth, structures, …

- **Refinery**
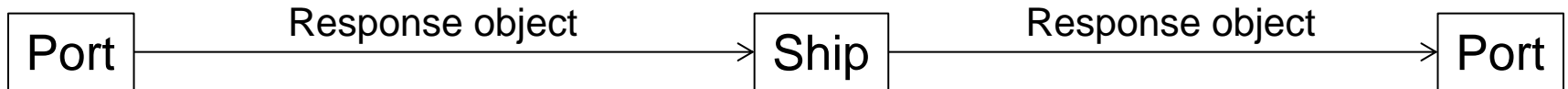  - Capacity, generators, …

- **Tank farm**
  - Capacity, tank type, …

- **Ship**
  - Type, depth, crew, …

- **Truck**
  - Type, capacity, …

- **Community**
  - Population, demand, …

# Flow of Packets



RPacket
Gasoline
Diesel
Food
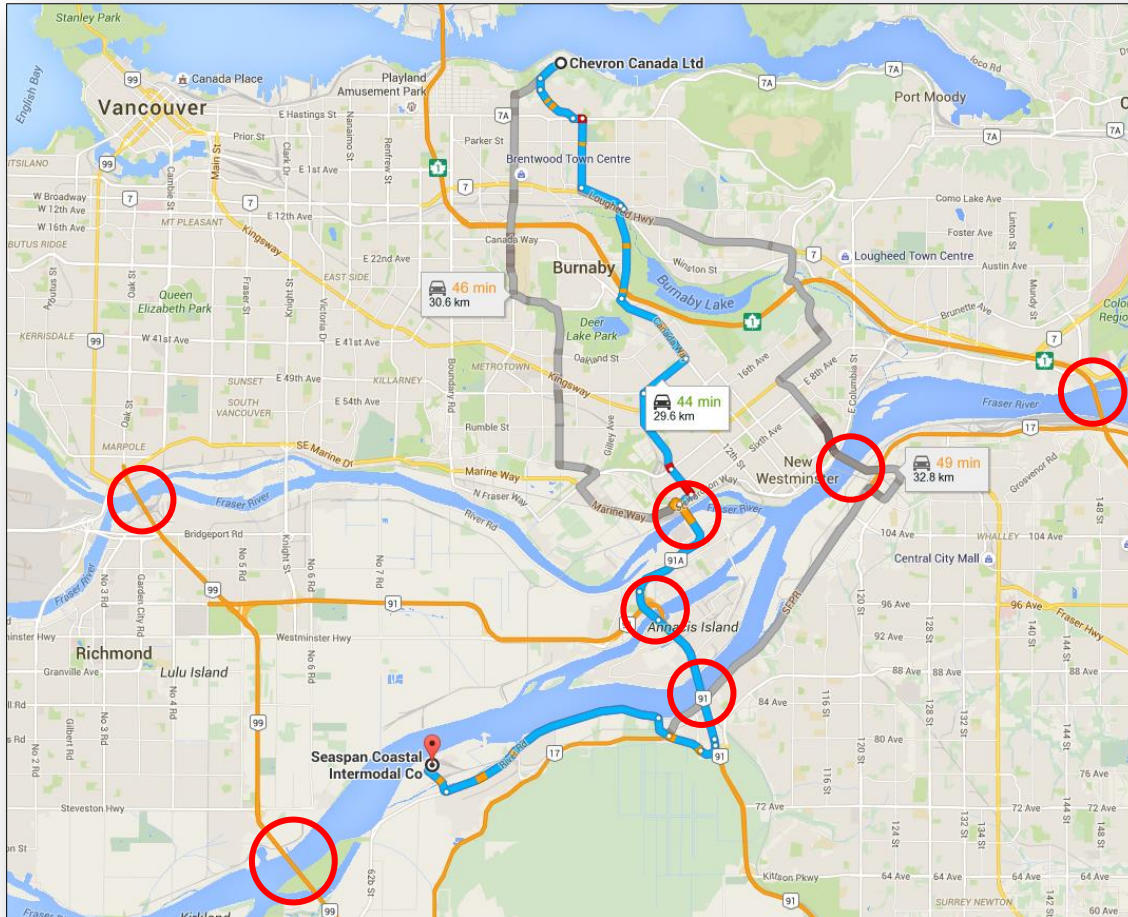Medical supply
Etc.

# Code



```
int RShipModel::evaluateModel(RGradientType theGradientType) {


    // DEPARTURES
    if (thisIsADepartureTime()) {
        loadPackets(theInputPacketList);
    }



    // ARRIVALS
    if (thisIsAnArrivalTime()) {
        unloadPackets(qobject_cast<RPacketResponse *>(thePacketResponse));
    }

    return 1;
}
```
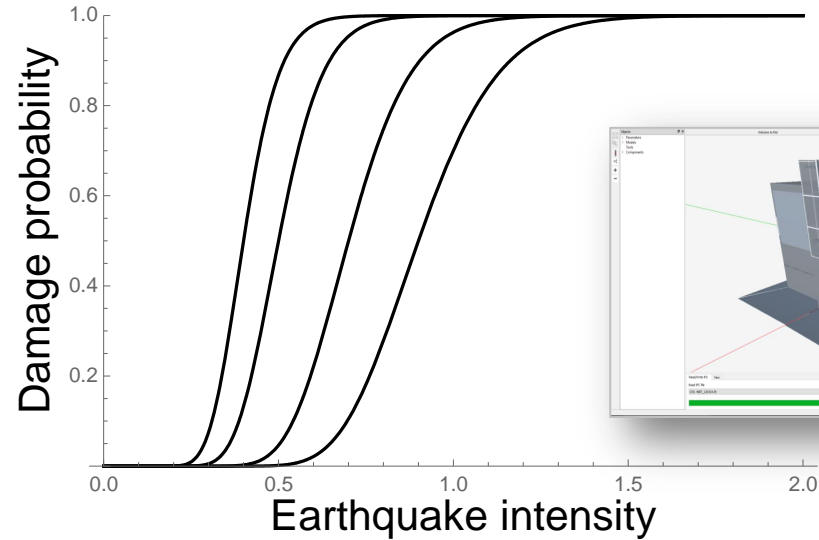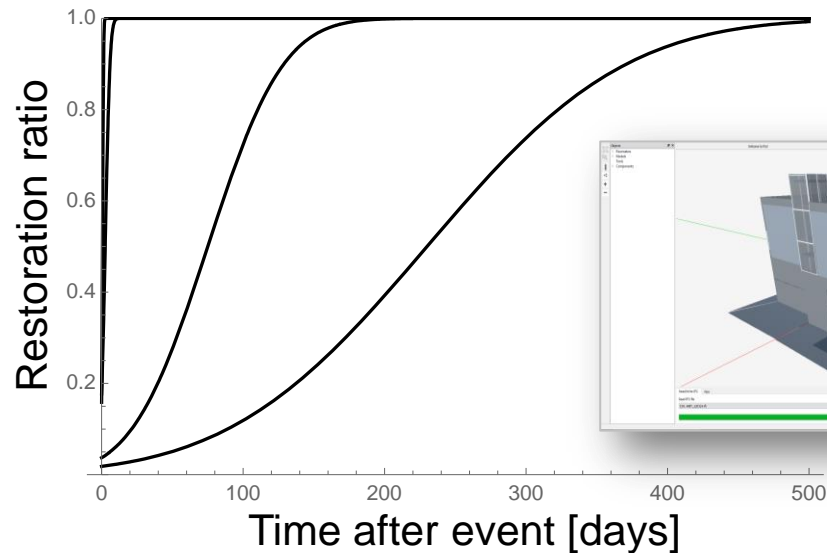
Using the "destination list"

# Routes

# Bridges, Ports, Refineries, Tanks

Damage ⟶



Restoration ⟶

# Earthquake Hazard
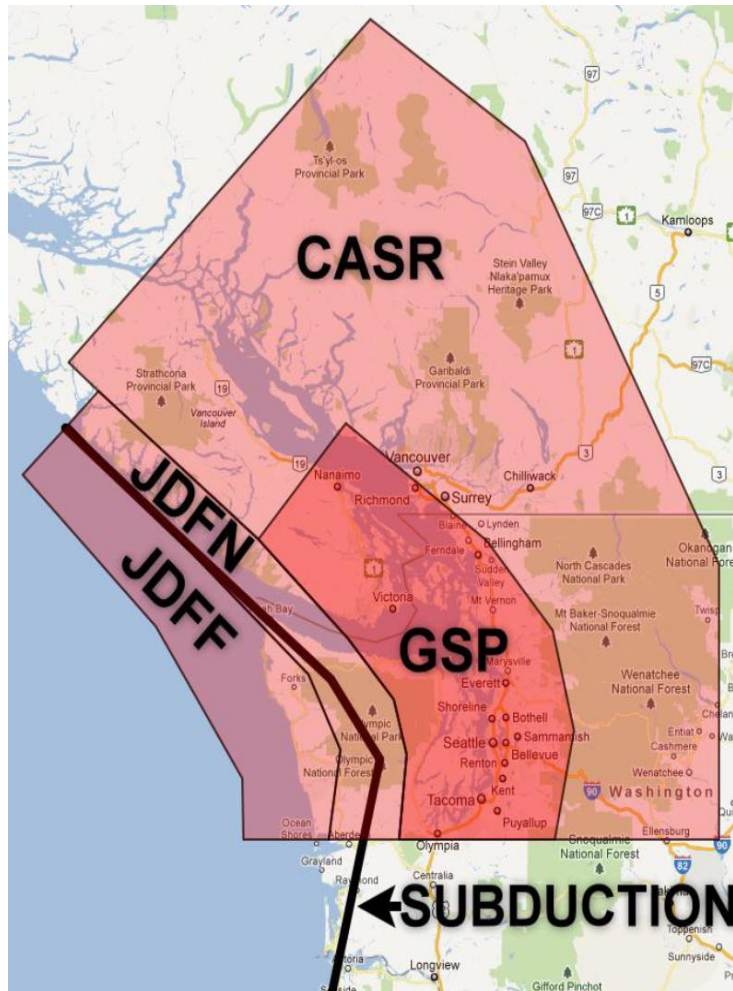


### Occurrence:

| Source | Return Period |
|---|---|
| CASR (shallow) | 5.3 years |
| JDFF (shallow) | 126.6 years |
| JDFN (shallow) | 285.7 years |
| GSP (deep) | 10.7 years |
| SUBDUCTION (megathrust) | 270.3 years |

Magnitude: 
$$f(m) = \frac{b\,\exp\left[-b\left(m - M_{min}\right)\right]}{1 - \exp\left[-b\left(M_{max} - M_{min}\right)\right]} \qquad M_{min} \le m \le M_{max}$$

| | $b' \sim \mathrm{LN}$ | | $M_{max} \sim \mathrm{LN}$ | | $M_{min}$ |
|---|---|---|---|---|---|
| | Mean | Stdv | Mean | Stdv | Deterministic |
| CASR | 1.01 | 0.38 | 7.7 | 0 | 5.0 |
| JDFF | 1.87 | 0.52 | 6.94 | 0.19 | 5.0 |
| JDFN | 2.07 | 0.66 | 7.00 | 0.22 | 5.0 |
| GSP | 1.13 | 0.11 | 7.06 | 0.16 | 5.0 |

*Geological Survey of Canada*

# Analysis Options



**Steady-state simulation**

**Scenario sampling**

**Spatial sampling & system reliability**
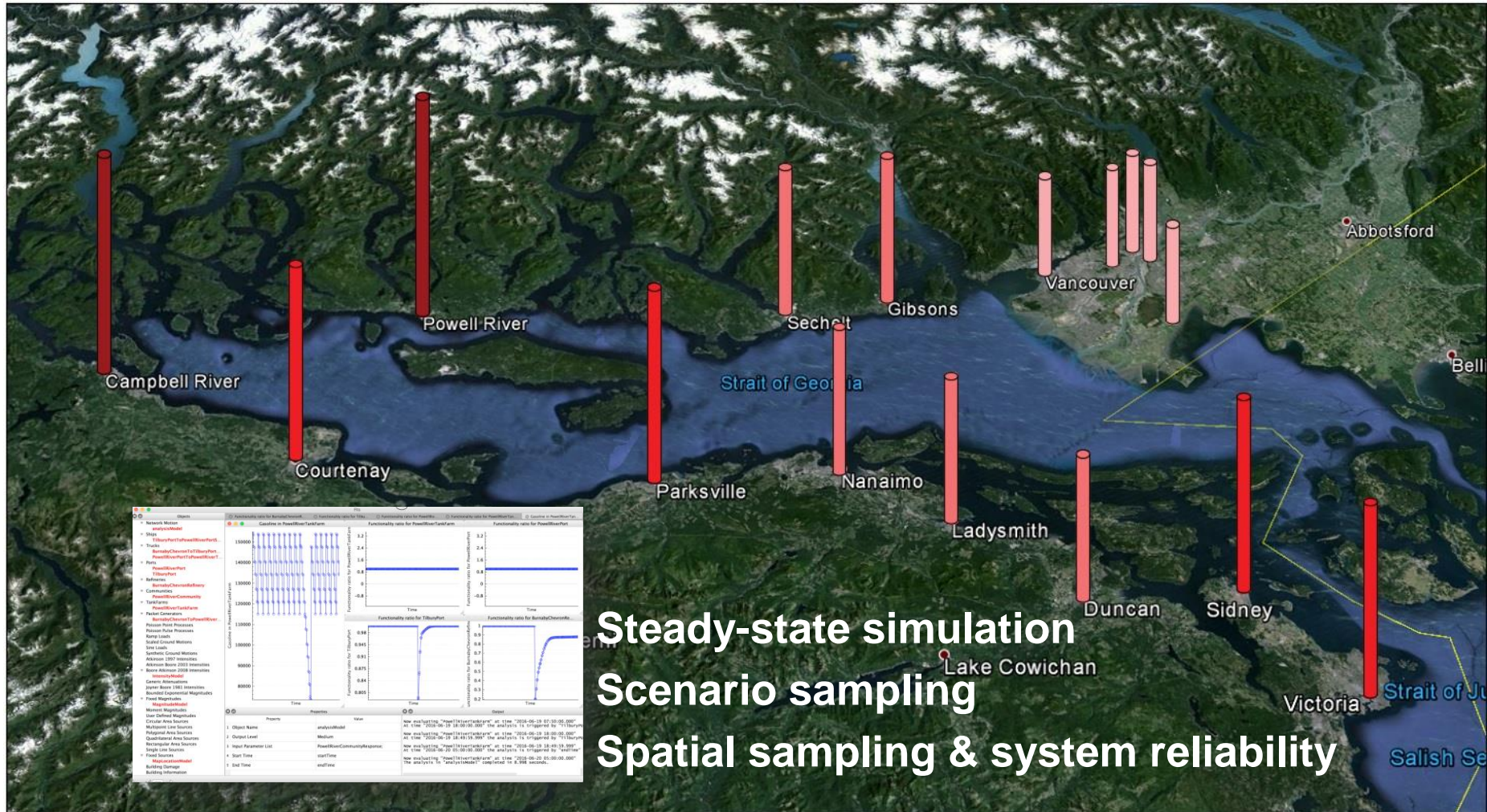
# Hartley Bay

- **Population: 200**

- Tank farm with 3 tanks
  - 98,000L diesel
  - 168,000L gasoline
  - 168,000L spare

- Monthly delivery of 40,000-50,000L

- Reserves can reach the low 15,000L

- **Reserves last minimum 10 days but will the demand change after an earthquake?**
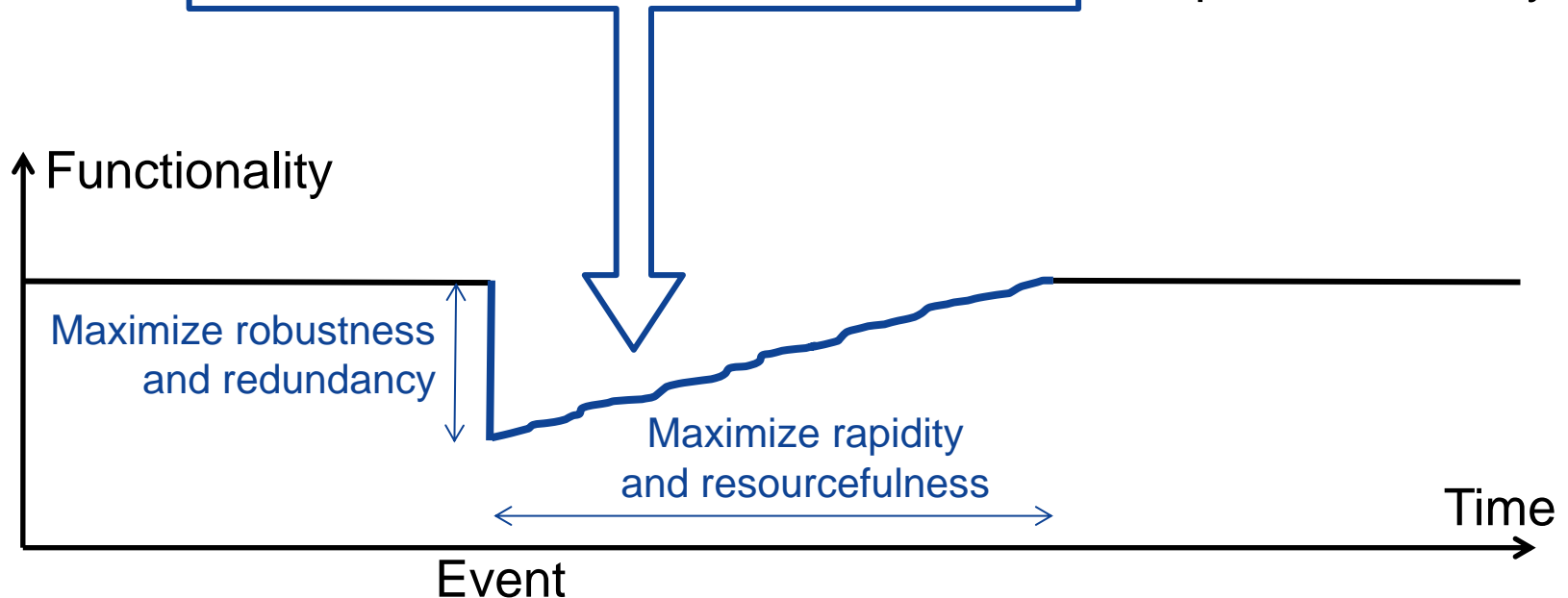
# Powell River

- **Population: 20,000**

- Tank farm with 2 tanks
  - 170,000 diesel
  - 155,000 gasoline

- Deliveries every 3 days
  - 50,000L diesel
  - 40,000L gasoline

- **Reserves could last 10 days but are full tanks more vulnerable to earthquakes?**

# Conclusions

- A **detailed object-oriented** modelling approach

- Integrates **hazard and structural models** of any granularity

- Provides **modelling flexibility** but require lots of information

- Allows **simulation of the effect of decisions** to improve resiliency

# Thank You for Your Attention!