Transportation of Dangerous Goods by Rail, Dynamic Risk Assessment and Emergency Planning by AnyLogic: Case of Toronto

Ali Asgary, Ph.D.

Associate Professor, Disaster & Emergency Management,

York University, Toronto, Canada,

asgary@yorku.ca

YORK U UNIVERSITÉ UNIVERSITY redefine THE POSSIBLE.

AnyLogic® CONFERENCE

12-13 November 2014, San Francisco

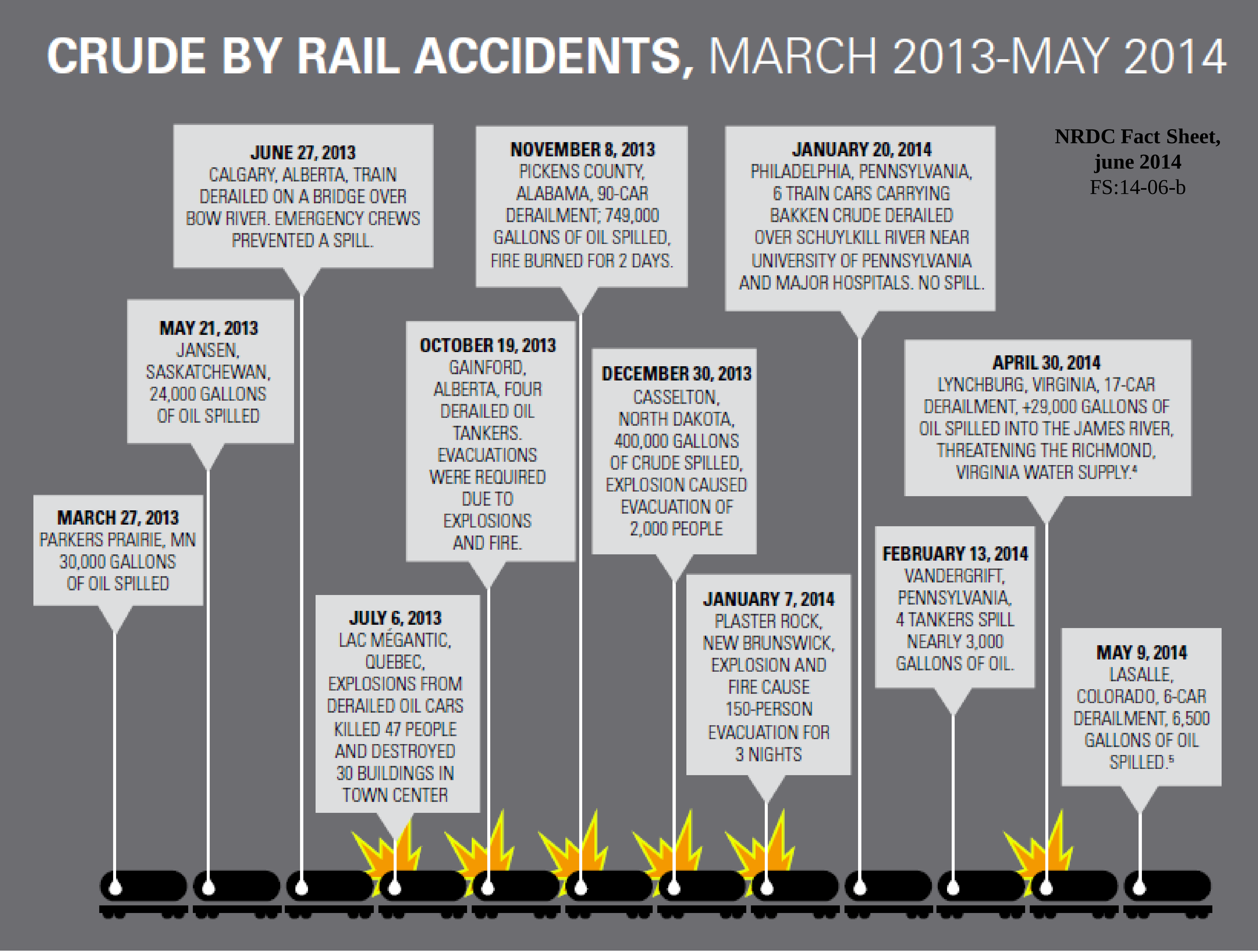
Outline

- Introduction
- Problem
- Dynamic risk modelling
- AnyLogic application
- Application demo
- Future work

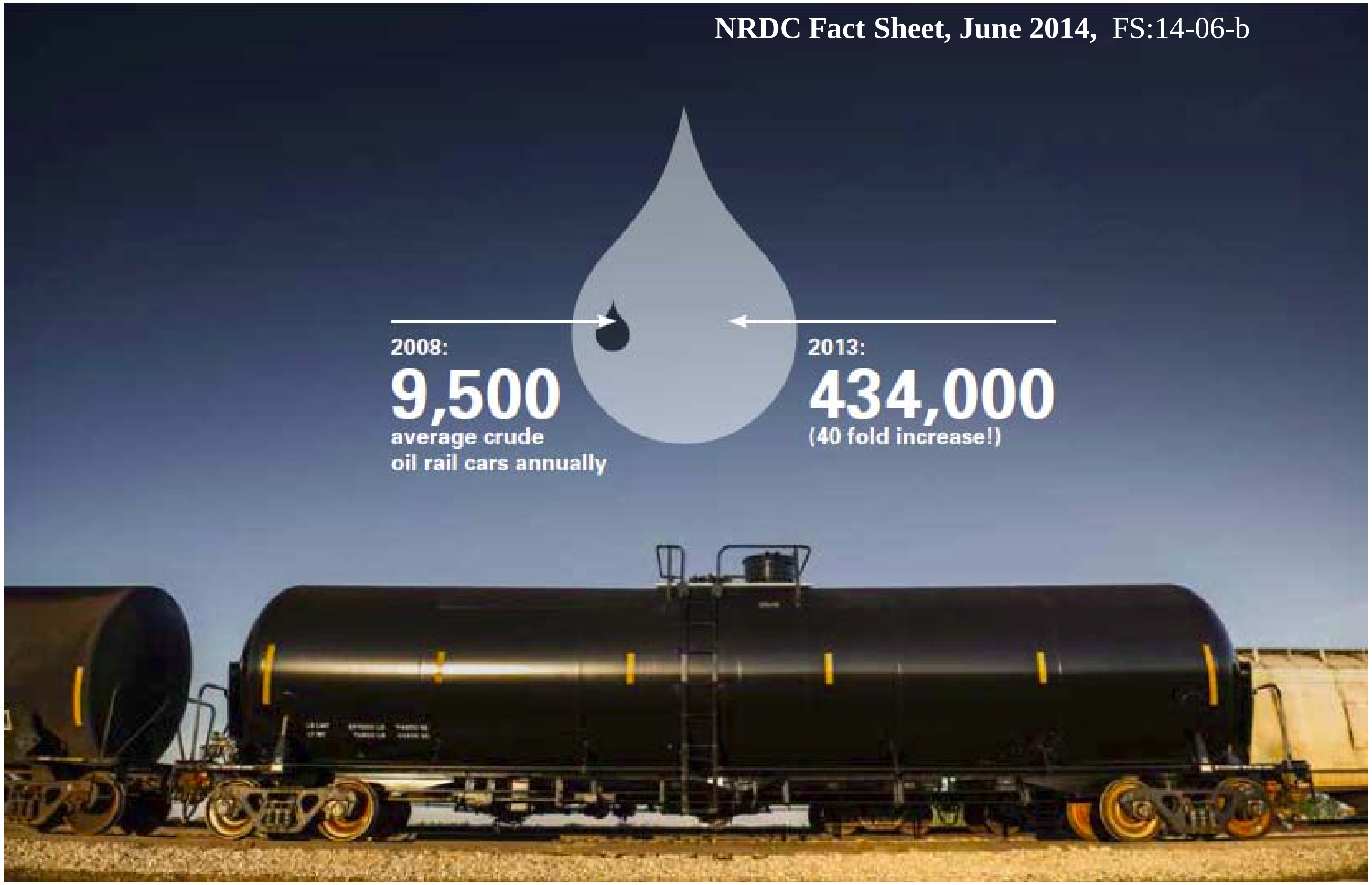
Problem: Risk

Lac Megantic Train Derailment Disaster, July 2013

NRDC Fact Sheet, june 2014
FS:14-06-b



Problem: Opportunities



Risk of Hazmat Train Derailment: Institutional and Regulatory Solution

Railways must give cities annual data on hazardous materials, Ottawa says

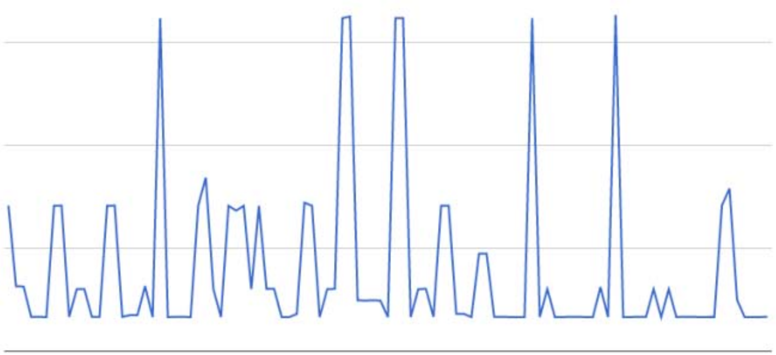
KIM MACKRAEL
Ottawa — The Globe and Mail
Published Wednesday, Nov. 20 2013, 10:48 AM EST
Last updated Wednesday, Nov. 20 2013, 8:29 PM EST

"Canadian municipalities are now demanding better communications about dangerous goods travelling through their territory."

"Rail Recommendations R14-01, R14-02, R14-03"

Solution: Risk Management (through dynamic risk assessment

- The **peak risk spikes** may be 1000 times riskier than the average risk level.
- "Identifying **how** and **when** these risk spikes occur is a fundamental objective of the dynamic risk assessment".



Harrald et al., 1999, Assessing Risk in the Washington State Ferry System

Dynamic risk modelling

Static

- The unchangeable part of risk
- Fixed facts (previous derailments, derailment characteristics)

Stable (Dynamic)

- The changeable part of risk
- How the train transportation functions (transported materials, volumes, standards, regulations, technology)

Acute (Dynamic)

- The variable part of risk
- Seasonal, Monthly, Daily or Hourly fluctuations (derailment potential, exposure, …

D'Orazio, & Thornton, CCOSO 2011

Dynamic risk agents (example)

Class A (Light, Volatile)
Class B Oils are less toxic
Class C (Heavy, Sticky)
Class D (Non-fluid)

temperature drops

Probability of Derailment Model

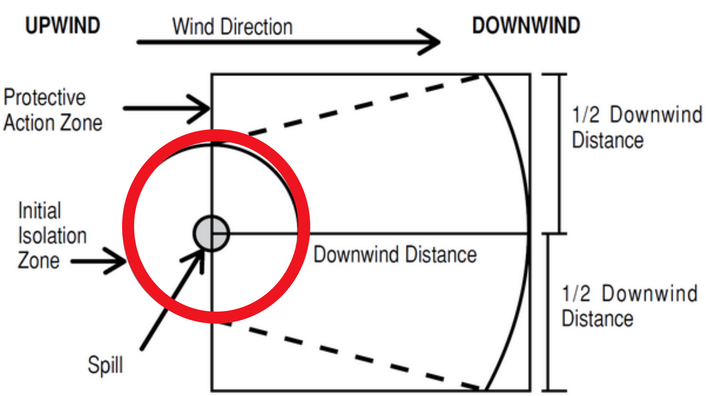
$$\Pr(der) = \sum_{i=1}^{n} R_i m_i$$

R_i is the derailment rate per mile for class i track and m_i is the mileage traversed on class i track.

QUANTITATIVE ANALYSIS OF FACTORS AFFECTING RAILROAD ACCIDENT PROBABILITY AND SEVERITY, 2003

$\Pr(der) = (0.53\text{x}10^{-6}\text{ x } 650) + (0.32\text{x}10^{-6}\text{ x } 350) = 4.6\text{x}10^{-4}$, or a little less than 1 in 2,000.

Potential Impacted Areas



Source: Transport Canada

		Small Spills			Large Spills		
		First ISOLATE in all directions	Then PROTECT persons Downwind during		First ISOLATE in all directions	Then PROTECT persons Downwind during	
			Day	Night		Day	Night
ID	Name of Material	m	km	km	m	km	km
1005 *	Ammonia, anhydrous	30	0.1	0.2	150	0.8	2
1005 *	Anhydrous ammonia	30	0.1	0.2	150	0.8	2
1008	Boron trifluoride	30	0.1	0.5	300	1.7	4.8
1008	Boron trifluoride, compressed	30	0.1	0.5	300	1.7	4.8
1016	Carbon monoxide	30	0.1	0.2	200	1.2	4.8
1016	Carbon monoxide, compressed	30	0.1	0.2	200	1.2	4.8
1017 *	Chlorine	60	0.4	1.5	500	3	7.9
1023	Coal gas	60	0.2	0.2	100	0.4	0.5
1023	Coal gas, compressed	60	0.2	0.2	100	0.4	0.5
1026	Cyanogen	30	0.1	0.5	60	0.4	1.7
1026	Cyanogen gas	30	0.1	0.5	60	0.4	1.7
1040 *	Ethylene oxide	30	0.1	0.2	150	0.9	2
1040 *	Ethylene oxide with Nitrogen	30	0.1	0.2	150	0.9	2
1045	Fluorine	30	0.1	0.2	100	0.5	2.3

Dynamic Risk Model

$$\mathbf{HR}_{\mathbf{h}\boldsymbol{lt}}=\mathbf{Pr}(\mathbf{TD}_{\mathbf{h}\boldsymbol{lt}}) * \mathbf{P}_{\mathbf{h}\boldsymbol{lt}}$$

$\mathbf{HR}_{\mathbf{hlt}}$ = Human risk of hazmat ***h*** at location ***l*** at time ***t***

$\mathbf{Pr}(\mathbf{TD}_{\mathbf{lt}})$= Probability of train derailment at location *l* at time *t*

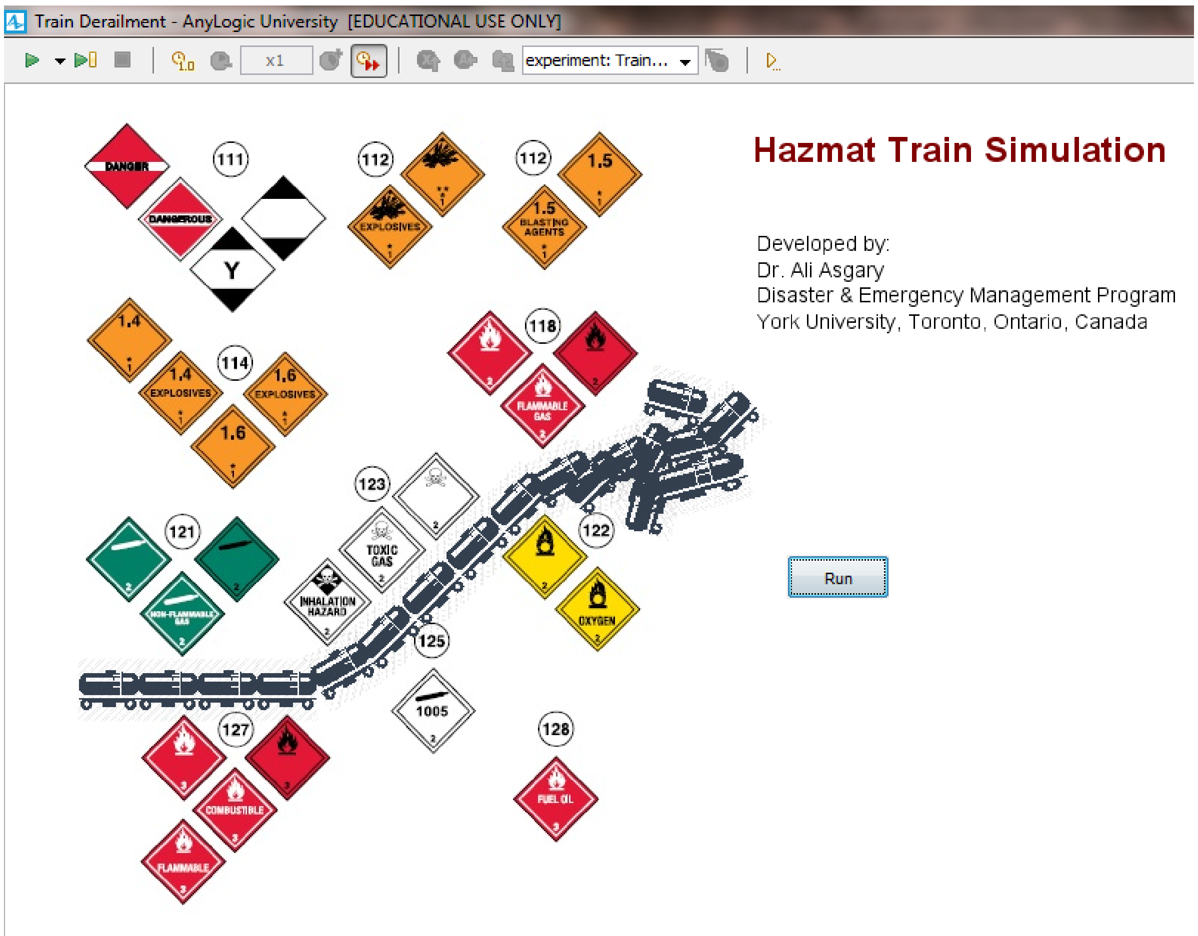
$\boldsymbol{P}_{\boldsymbol{lt}}$ = Population of the ***Initial Isolation*** and ***Protective Actions*** distance of hazmat ***h*** at time ***t***

Why Toronto?

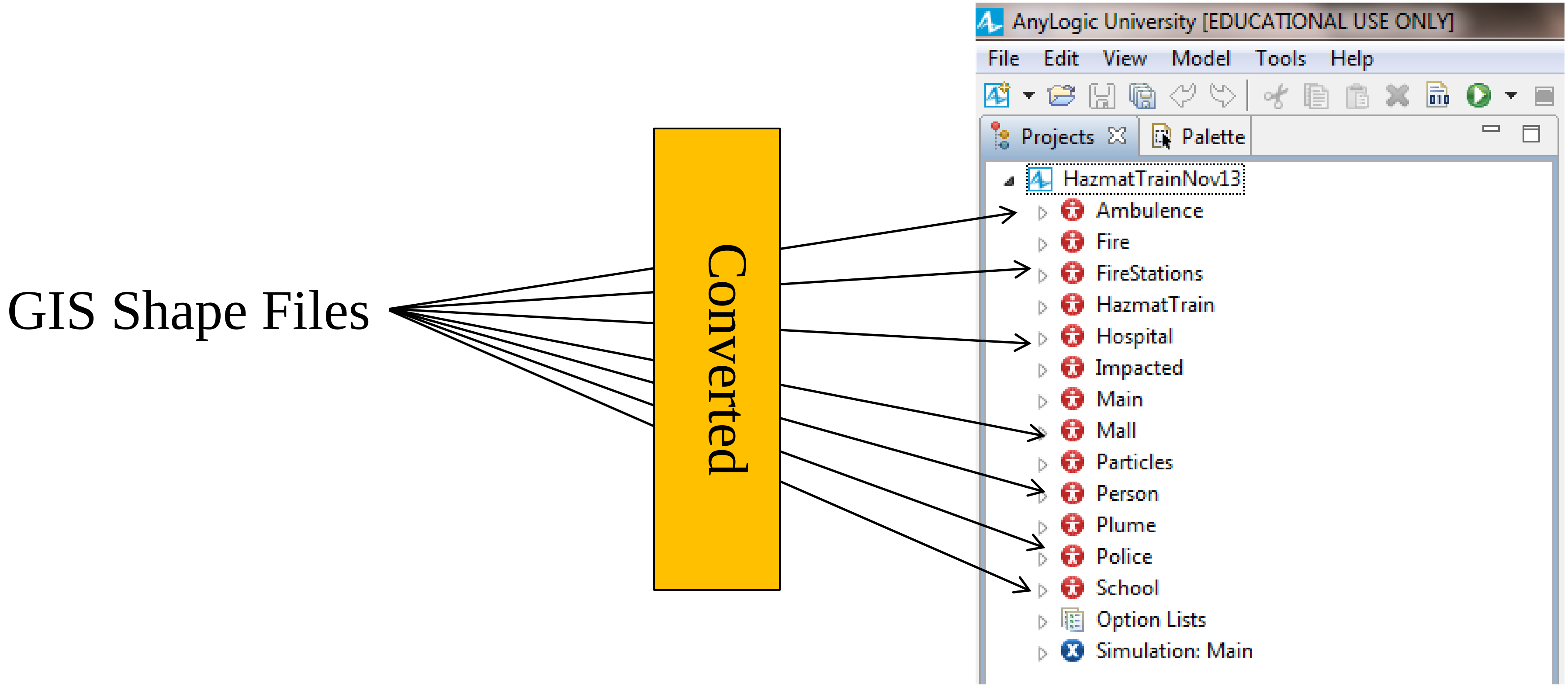
Rail car worries

This rail line, owned by CP Rail, is used to ship crude oil through the centre of Toronto. Councillor Josh Matlow (Ward 22, St. Paul's) wants the tanker cars rerouted to avoid the heavily populated area.

AnyLogic Application

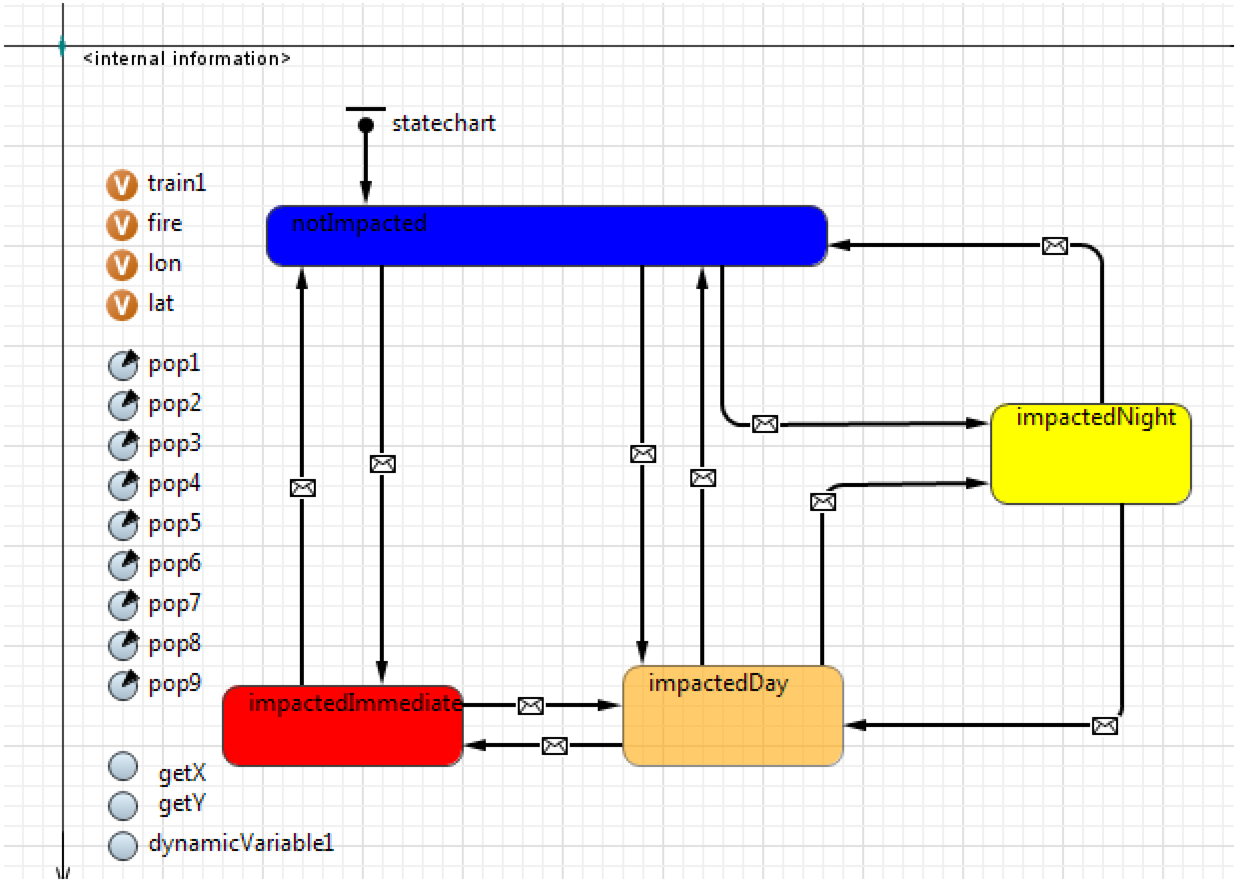


Agents

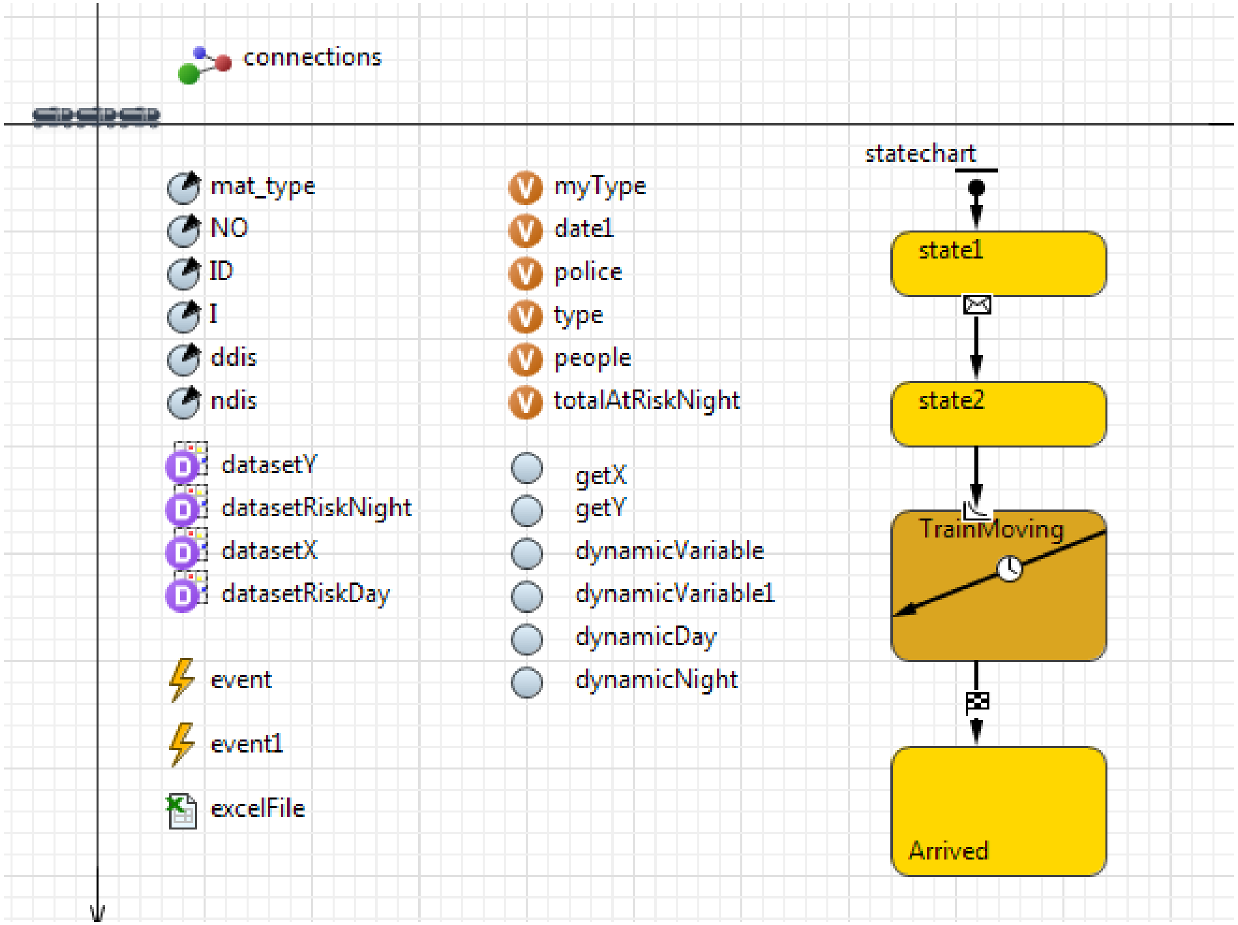


GIS Shape Files
Converted
AnyLogic University [EDUCATIONAL USE ONLY]
File Edit View Model Tools Help
Projects
Palette
HazmatTrainNov13
Ambulence
Fire
FireStations
HazmatTrain
Hospital
Impacted
Main
Mall
Particles
Person
Plume
Police
School
Option Lists
Simulation: Main

Person (Population) Agent

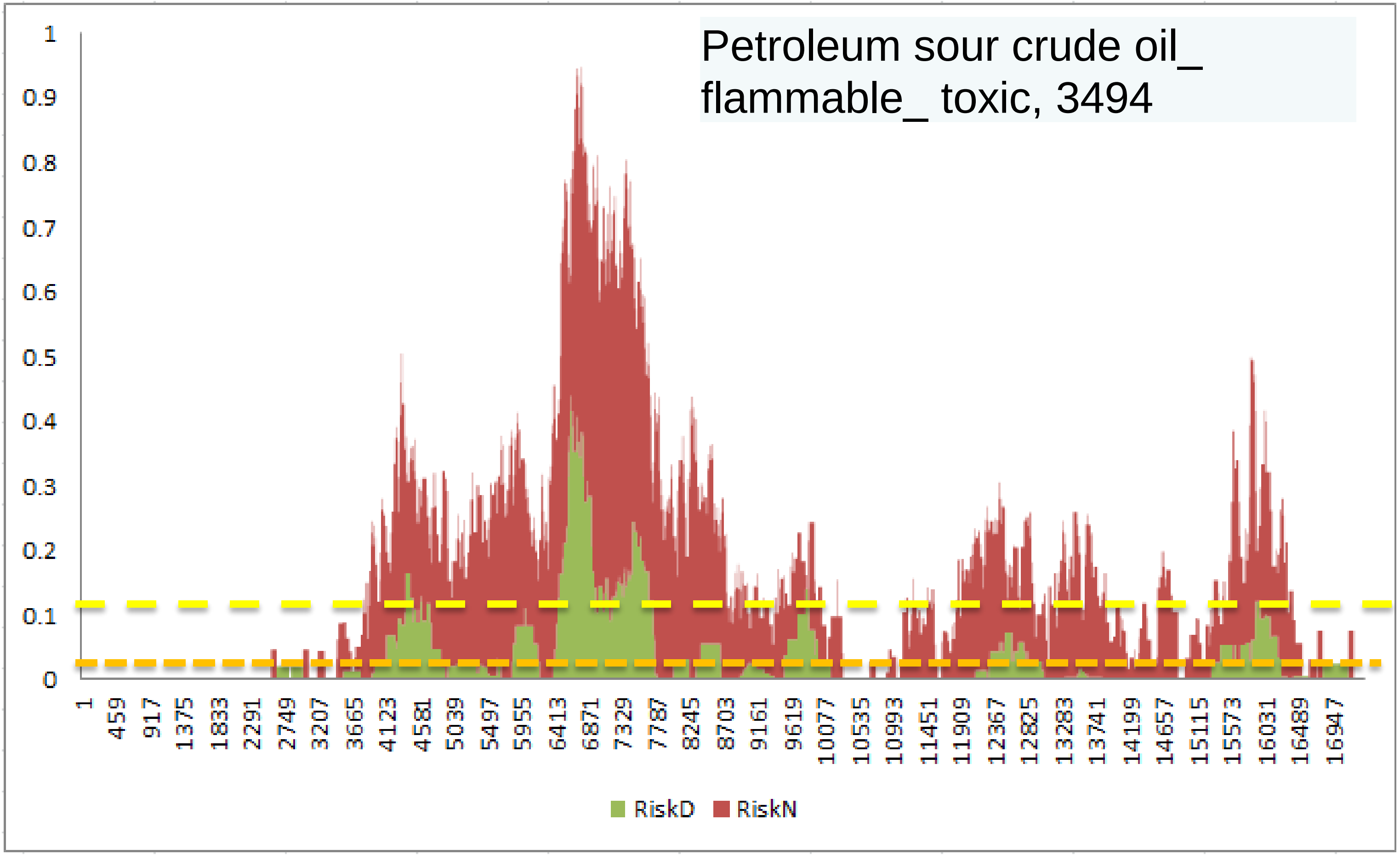


Train Agent

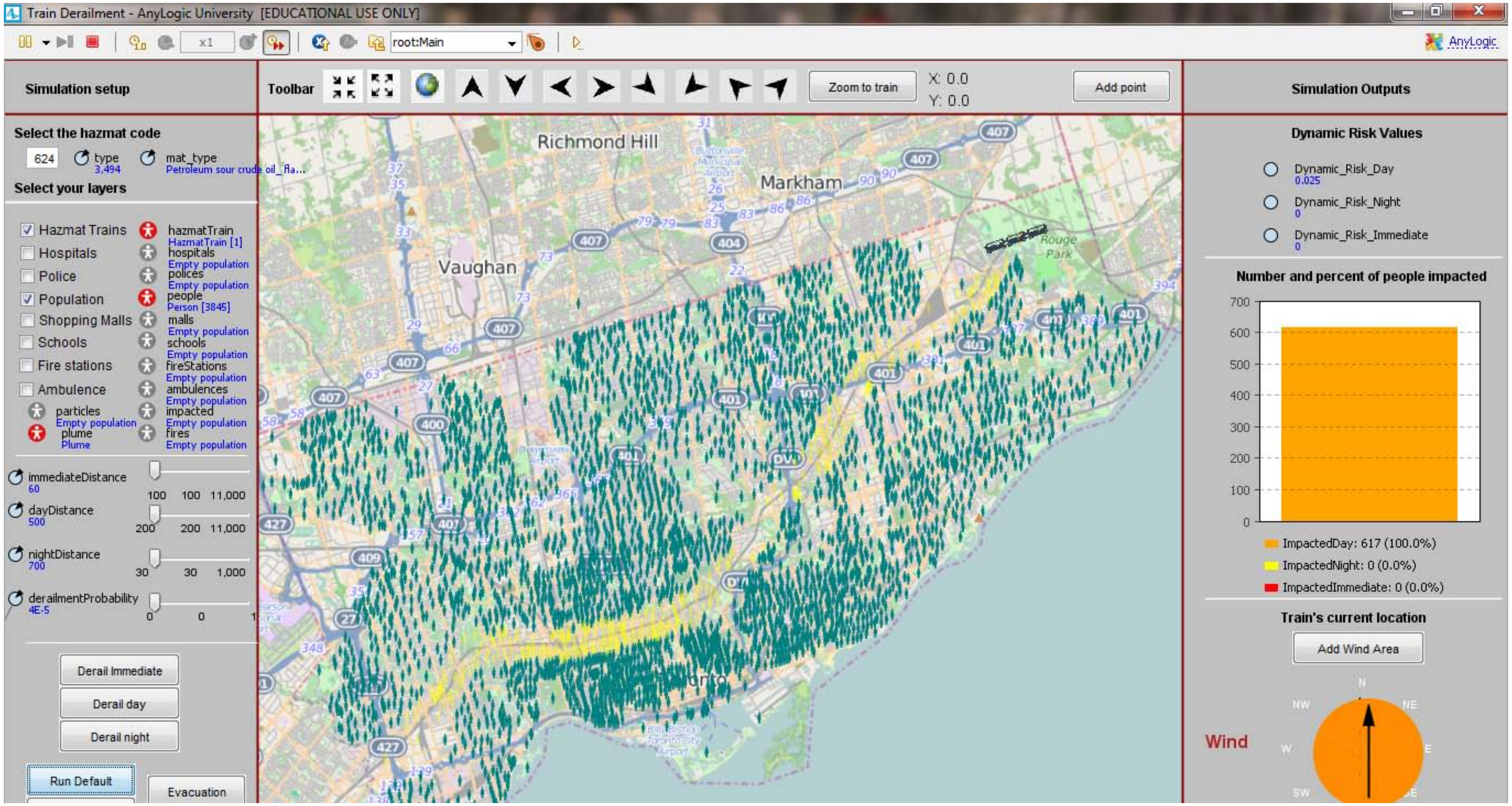


connections
mat_type
NO
ID
I
ddis
ndis
datasetY
datasetRiskNight
datasetX
datasetRiskDay
event
event1
excelFile
myType
date1
police
type
people
totalAtRiskNight
getX
getY
dynamicVariable
dynamicVariable1
dynamicDay
dynamicNight
statechart
state1
state2
TrainMoving
Arrived

Risk Spikes – Sample Output



Sample Demo


Train Derailment - AnyLogic University [EDUCATIONAL USE ONLY]
Simulation setup
Toolbar
Zoom to train
Add point
Simulation Outputs
Select the hazmat code
Select your layers
Hazmat Trains
Hospitals
Police
Population
Shopping Malls
Schools
Fire stations
Ambulence
immediateDistance
dayDistance
nightDistance
derailmentProbability
Derail Immediate
Derail day
Derail night
Run Default
Evacuation
Richmond Hill
Markham
Vaughan
Dynamic Risk Values
Dynamic_Risk_Day
Dynamic_Risk_Night
Dynamic_Risk_Immediate
Number and percent of people impacted
ImpactedDay: 617 (100.0%)
ImpactedNight: 0 (0.0%)
ImpactedImmediate: 0 (0.0%)
Train's current location
Add Wind Area
Wind

Future works

- Dynamic day and night population
- Evacuation and shelter planning
- Risk mitigation scenarios
- More intelligent model
- Train specifications