Surface Freight Environmental Footprints in the Ontario-Québec Continental Corridor – Focus on Emissions

The Asia Pacific Gateway and Corridor Initiative:
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Origins

- "Footprint" estimates for US Transportation Research Board project:
  - Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes
  -
  - Project "White Paper": "The Environmental Footprint of Surface Freight Transportation", published 2007

Potential dimensions of “footprint”

- Fuel use
- Greenhouse gas emissions
- Criteria air contaminant emissions
- Area of land occupied
- Water contamination (spills)
- Accidents
- Noise
- Congestion
- Aesthetics
- Introduction of non-indigenous species

Single index for “footprint”?

- WWF designed “ecological footprint”:

  “area of biologically productive land and water needed to provide ecological resources and services – food, fibre and timber, land on which to build and land to absorb CO_2 released by burning fossil fuels”.
- Then WWF compares “footprint” to land area of each country
- Relies on ingenious conversion of each requirement into land
- Can’t handle pollutant emissions, noise, accidents, etc
- Possible conversion of all effects to cost – not attempted here

Propose: multi-dimensional tabulation – standardised to traffic in tonne-km

Effect	Ship	Rail	Truck
Fuel use – tonne-km per litre			
Greenhouse gas emissions – grammes per tonne-km			
NOx – g/tonne-km			
VOCs – g/tonne-km			
CO – g/tonne-km			
PM – g/tonne-km			
Land occupied – hectares			
Accidents – injuries per tonne-km			
Spills			
Noise – noise depreciation cost per tonne-km			
Congestion – delay time or $ per tonne-km			
Aesthetics			
Introduction of non-indigenous species			

Quantification issues

- Need to standardise to traffic
  - compare rates per tonne-kilometre
  - recognise tonne-km doesn't represent all aspects of service, notably speed & reliability; nor value of service
  - recognise also that modal averages include different service trip lengths, commodities, speeds, proportions line-haul vs collection/delivery
- Need therefore to compare competitive traffic - not average impacts for each mode
  - compare only long-distance bulk traffic

Fuel & traffic data issues

- Generic problem with national stats both Canada and US that fuel sales cannot be related to traffic measures
  - Fuel sales stats distinguish types of fuel, but not the vehicles/vessels/traffic for which they are used
  - Traffic tonne-km stats – where available – are for sub-groups of traffic (e.g. Class I rail, domestic shipping, for-hire or inter-state trucking)
  - "Official" NRCan and EPA comparisons of fuel use and GHG per tonne-km appear incorrect – ship worse than train

Erroneous estimates from official data sources

	GHG Mt CO2e	Billion tonne-km	GHG g/tonne-km
Canada - 2007			
Marine	8.3	253	33
Rail	6.6	357	18
Truck	49.6	253	196
US - 2007			
Ships and boats	56.3	807	70
Rail	58.0	2,584	22
Truck*	410.8	1,845	223

** 2003 figures, most recent for ton-km.*

Canadian estimates of fuel use and tonne-km from Natural Resources Canada Energy Use Data 2007;
US data combine EPA fuel use with DOT-BTS tonne-km

Emissions data issues

- Emissions are not measured directly in traffic, but estimated from fuel use.
- Fuel use is usually estimated from assumed distributions of technologies in vehicle/vessels, combined with assumed kilometres travelled and assumed fuel consumptions rates per km.
- Assumptions differ among agencies; and in both US and Can, official GHG inventories are not consistent with CAC inventories
- Rates per tonne-km often use assumed average loadings.

Applicability of research from elsewhere

- Estimates available from research in other countries (notably EU):
  - might be applicable for vessels in similar operations
  - but not for trucks and trains, which differ internationally
- Engine technology and fuel composition is changing rapidly – fuel use and emission rates improving in all modes

Marine emissions

- Comparison of international studies
- EPA study (98) includes estimates of tonne-km
- Levelton study (06) for Transport Canada
  - For Great Lakes/St Lawrence/Canadian eastern waters
  - Uses Coast Guard data on 29,600 movements in 2006
  - Distinguishes vessel type, activity type, sub-region
  - Estimates fuel use for each movement, from engine type and speed
  - Uses emission factors from international research (UK, Sweden, US)
  - No tonne-km data – add est. GHG/tonne-km from Cdn Shipowners Assocn in 2000

Ship emissions estimates

grams per tonne-km

Study	CO_2	CO	HC	NOx	SOx	PM_{10}
OECD (91) EU	40	0.018	0.08	0.05	0.05	0.03
Befahy (93) Belgium		0.2	0.08	0.58		0.04
SN (97) Neths	33	0.11	0.05	0.26	0.04	0.02
ECMT (98) EU	12		0.01	0.32	0.24	
EPA (98) US		0.012	0.006	0.163		0.012
Levelton (06) E^n Can	(10) *#	0.009	0.009	0.285	0.145	0.025
IMO (07) worldwide	15.6 #	0.037	0.012	0.366	0.220	0.026

* Estimate from Canada's national GHG strategy assessment

CO_2e

Rail emissions estimates

grams per tonne-km

Study	CO_2	CO	HC	NOx	SOx	PM_{10}
OECD (91) EU	48	0.15	0.07	0.4	0.18	0.07
Schoemaker/Bouman (91) Neths	102	0.02	0.01	1.01	0.07	0.01
RCEP (94) UK	41	0.05	0.06	0.2		
ECMT (98) EU	69		0.07	1.22	0.08	
RAC (07) Can	18 #	0.03	0.01	0.27	0.005	0.01

CO2e

Truck emissions estimates

grams per tonne-km

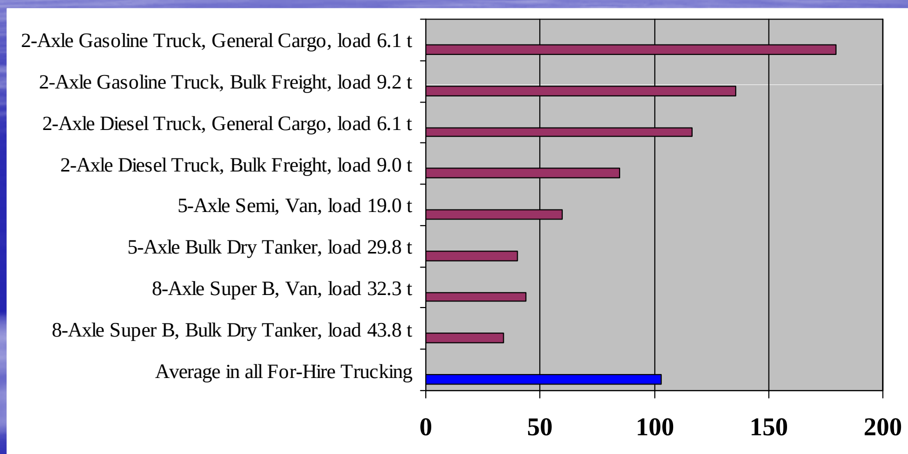
Study	CO_2	CO	HC	NOx	SOx	PM_{10}
OECD (91) EU*	140	0.25	0.32	3.0	0.18	0.17
Schoemaker/Bouman (91) Neths*	127	0.34	0.34	2.3	0.11	0.19
ECMT (98) EU*	100		0.05	1.2	0.03	
Transport Canada (00) Can**	103 #	1.52	0.14	2.6	0.05	0.11
Lawson (07) Canada long-haul	88 #	0.12	0.02	0.53	0.001	0.01
Lawson (07) Canada 8-axle combination	33 #	0.04	0.01	0.20	0.0004	0.005

*large EU trucks/tractor-trailers

** all for-hire trucks

Truck emissions estimates

grams per tonne-km

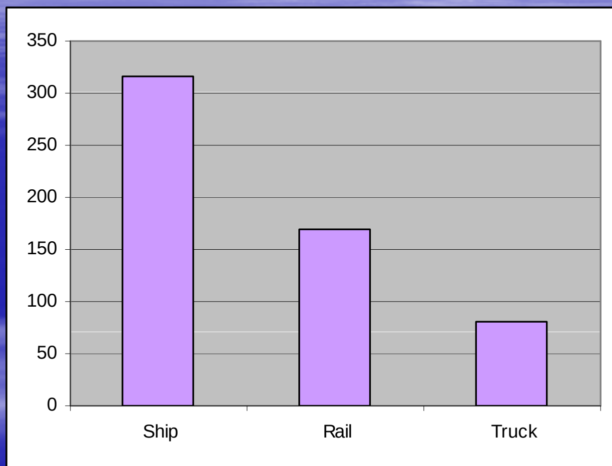


Source: Transport Canada inference from Trimac truck cost data, 1996

Comparison of best estimates fuel use/intensity

Freight mode	Tonne-km per litre
Ship (06)	315
Rail (07)	169
Truck – 8-axle combination (07)	81

Tonne-km per litre



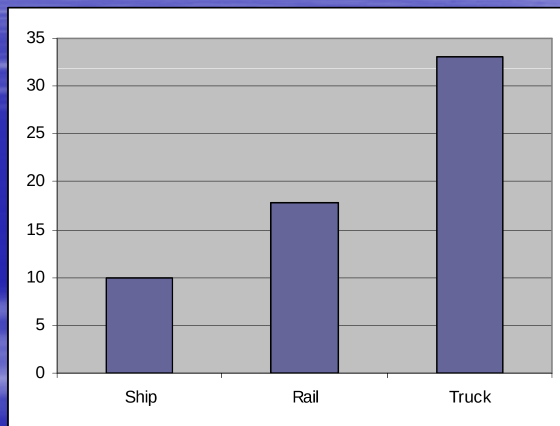
Comparison of best estimates

grams per tonne-km

Freight mode	CO_2e	CO	HC	NOx	SOx	PM_{10}
Ship (06)	10	0.01	0.009	0.29	0.15	0.03
Rail (07)	18	0.03	0.011	0.27	0.005	0.01
Truck – 8-axle combination (07)	33	0.04	0.008	0.20	0.0004	0.005

Comparison of best estimates

CO_2e grams per tonne-km



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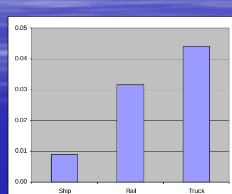
Comparison of best estimates

CAC emissions grams per tonne-km

CO



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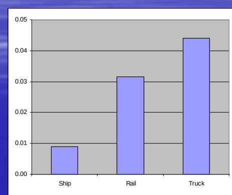
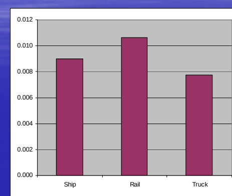
Comparison of best estimates CAC emissions grams per tonne-km

CO



HC



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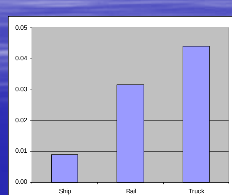
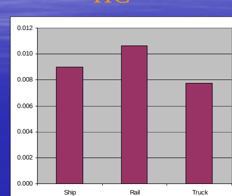
Comparison of best estimates CAC emissions grams per tonne-km

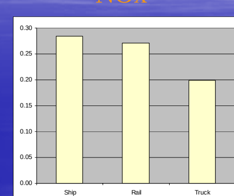
CO



HC



NOx



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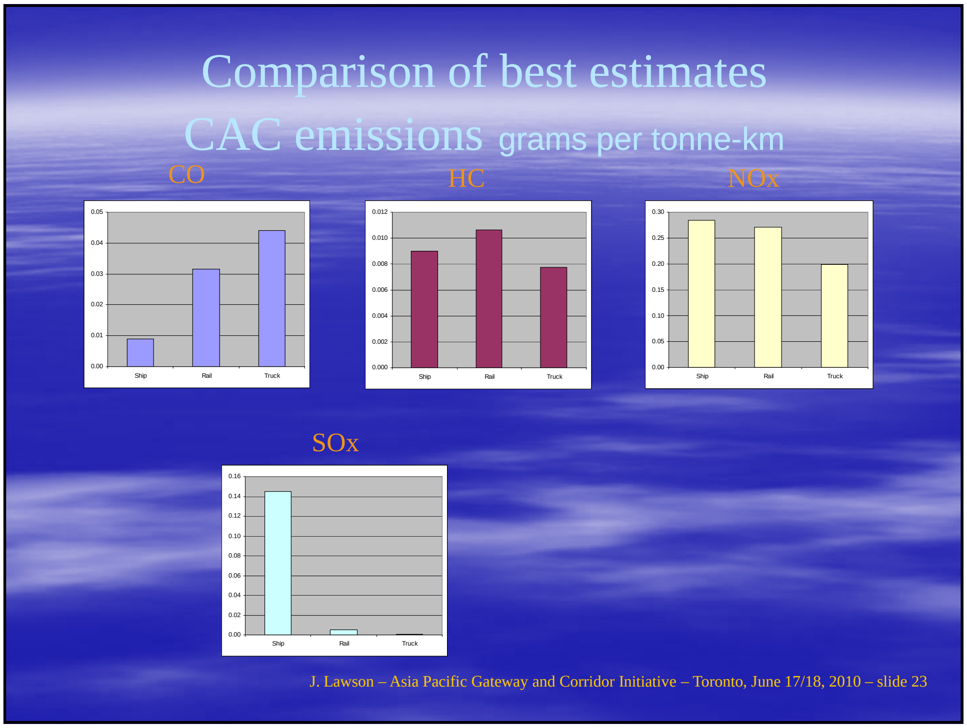
Comparison of best estimates
CAC emissions grams per tonne-km
CO
HC
NOx
SOx
Ship
Rail
Truck
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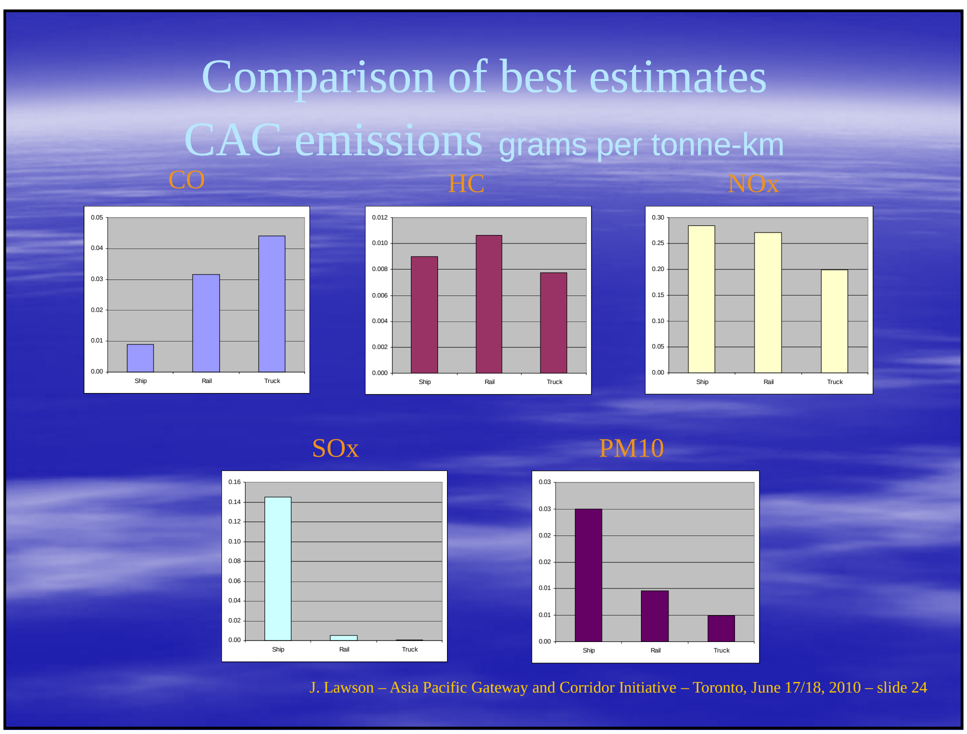
Comparison of best estimates
CAC emissions grams per tonne-km
CO
HC
NOx
SOx
PM10
Ship
Rail
Truck
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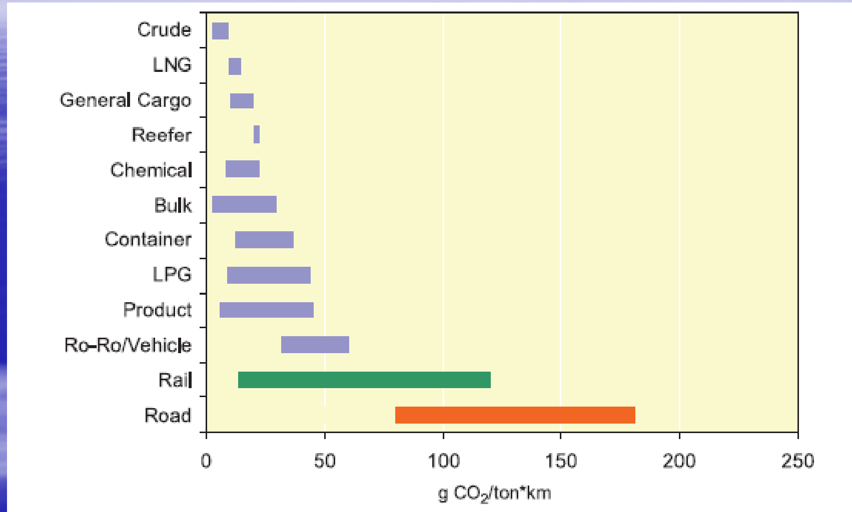
Second IMO GHG Study 2009 comparison by ship type and alternative modes



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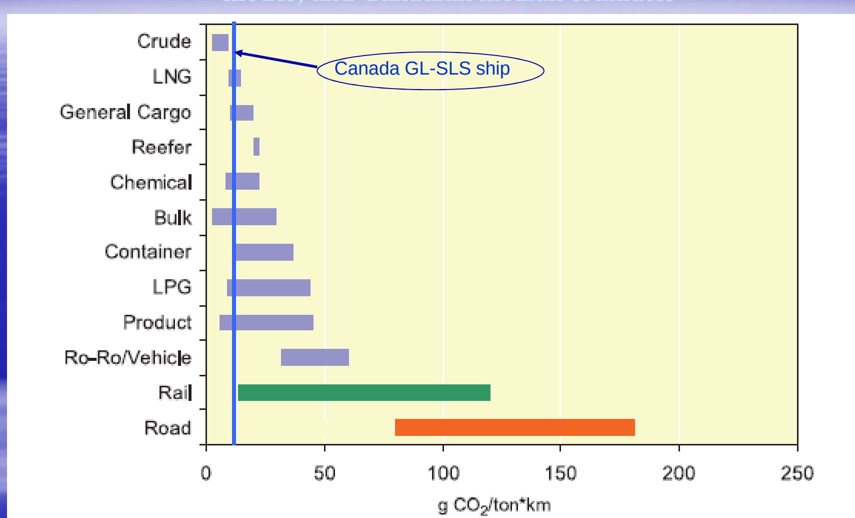
Second IMO GHG Study 2009 comparison by ship type and alternative modes; and Canadian median estimates



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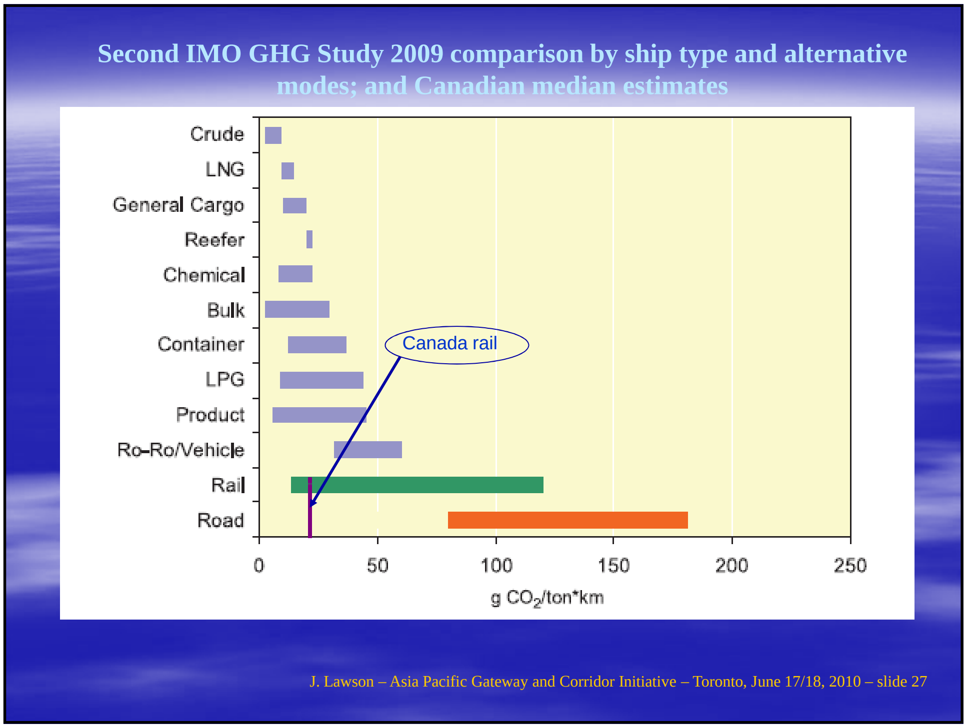
Second IMO GHG Study 2009 comparison by ship type and alternative modes; and Canadian median estimates
Crude
LNG
General Cargo
Reefer
Chemical
Bulk
Container
LPG
Product
Ro-Ro/Vehicle
Rail
Road
Canada rail
0
50
100
150
200
250
g CO_2/ton*km
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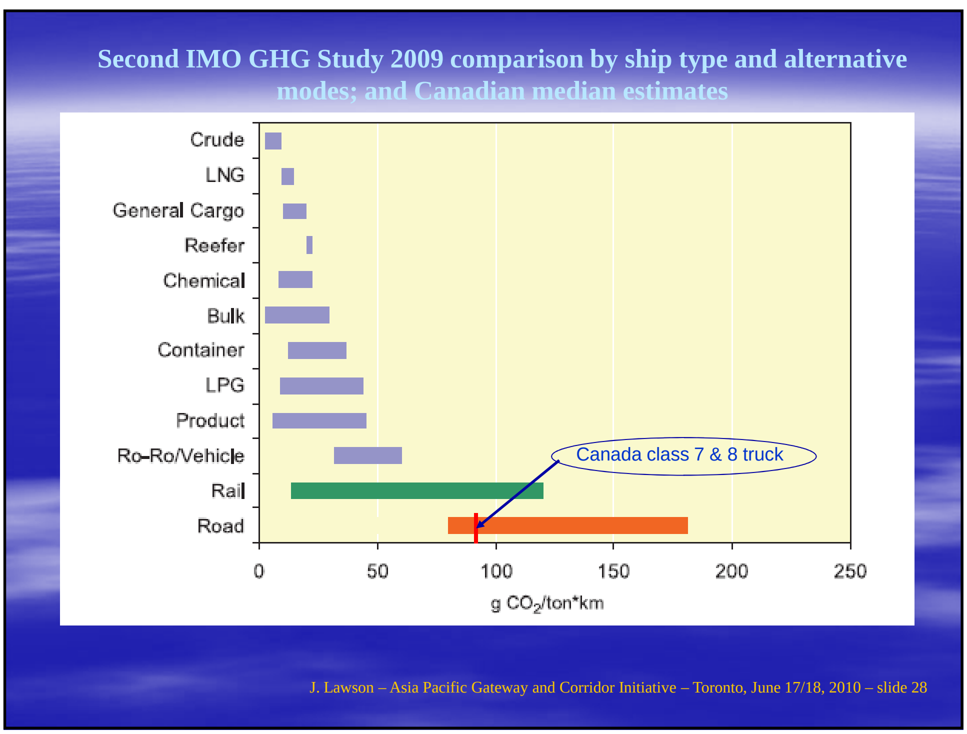
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Crude
LNG
General Cargo
Reefer
Chemical
Bulk
Container
LPG
Product
Ro-Ro/Vehicle
Rail
Road
Canada class 7 & 8 truck
0
50
100
150
200
250
g CO_2/ton*km
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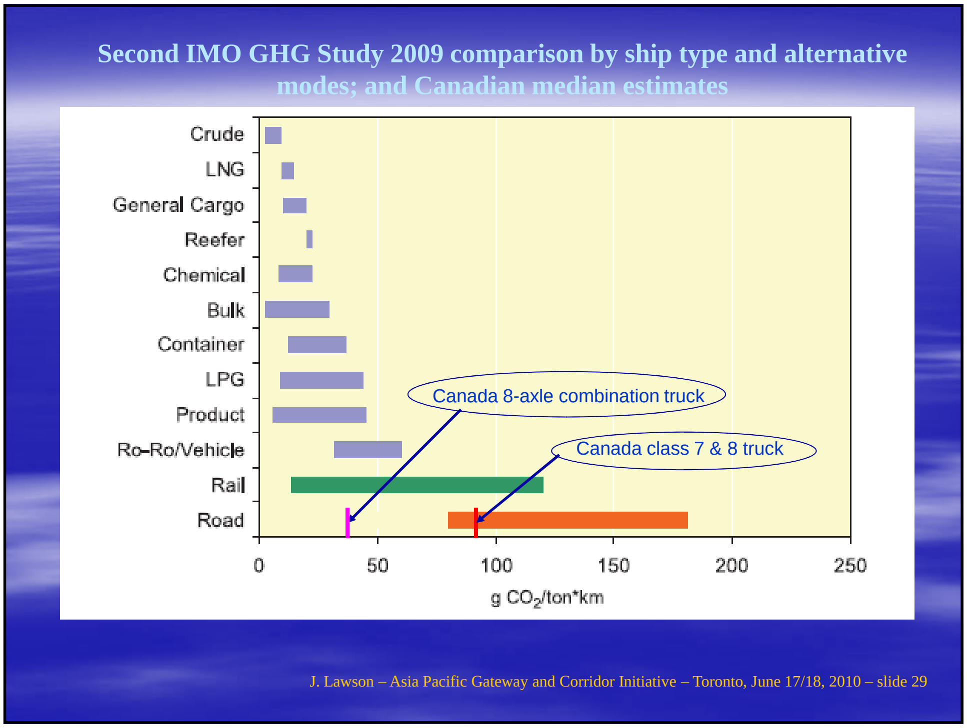
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LNG
General Cargo
Reefer
Chemical
Bulk
Container
LPG
Product
Ro-Ro/Vehicle
Rail
Road
Canada 8-axle combination truck
Canada class 7 & 8 truck
0
50
100
150
200
250
g CO2/ton*km
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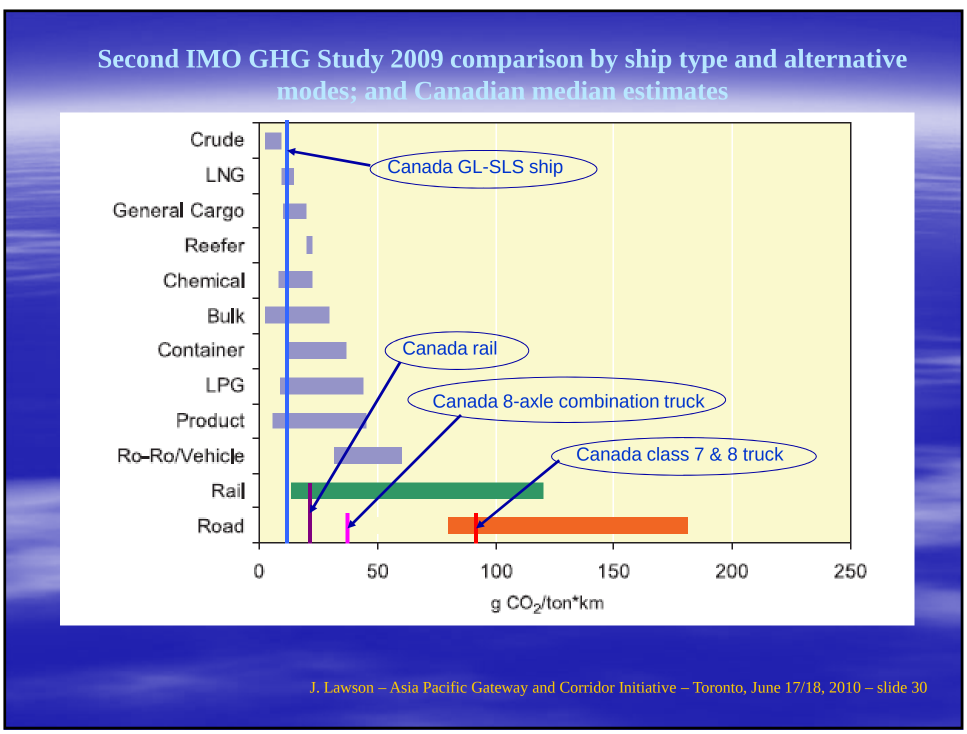
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Road
Canada GL-SLS ship
Canada rail
Canada 8-axle combination truck
Canada class 7 & 8 truck
0
50
100
150
200
250
g CO2/ton*km
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Comparison of land area occupied

Freight mode	Land area hectares
Ship facilities	10,000
Railtrack	10-15,000
Roads	36,000

- Is such comparison useful?
  - Intensities and types of use differ: serving different O-Ds and types of traffic (e.g. roads used more for passengers than freight, etc)
  - Land used differs in value by mode
  - No standardisation by traffic meaningful

Accidents

- Use system-wide statistics for US from DOT
- Reporting is routine
- Comparison to tonne-km is not routine – suffers from problems of reporting tkm
- How to treat rail/hwy grade crossings?
- Truck occupant casualties don’t represent full responsibility of trucks for casualties

Accidents - US estimates 2007

Freight mode	Fatality rate	Injury rate	Accident rate
Ship	0.07	0.17	6*
Rail (exc crossings)	0.20	3.22	1
Rail (inc crossings)	0.33	3.62	2
Truck	0.40	11.3	181*

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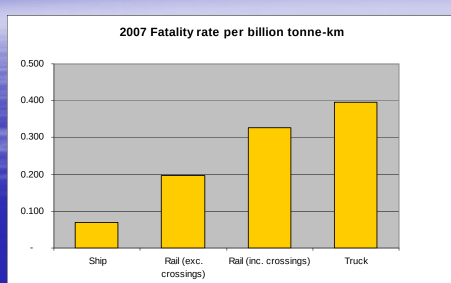
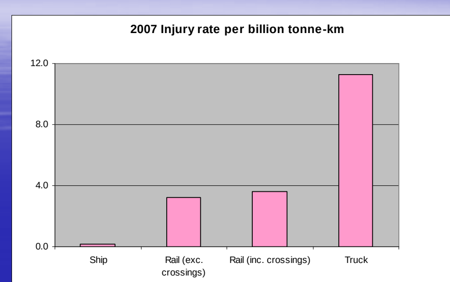
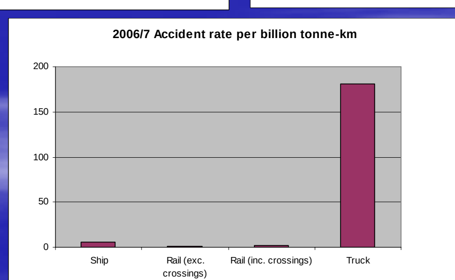
Accident rates







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Non-quantified dimensions

- Spills
- Noise
- Congestion
- Aesthetic degradation
- Introduction of non-indigenous species

Summary Table

Effect	Ship	Rail	Truck
Fuel use – tonne-km per litre	315	169	81
Greenhouse gas emissions – grammes per tonne-km	10	18	33
NOx – g/tonne-km	0.29	0.27	0.20
VOCs – g/tonne-km	0.009	0.011	0.008
CO – g/tonne-km	0.01	0.03	0.04
PM – g/tonne-km	0.025	0.010	0.005
Land occupied – hectares	10,000	10-15,000	36,000
Accidents – injuries per tonne-km	0.17	3.22	11.3
Spills	L	greater than ship	
Noise – noise depreciation cost per tonne-km	L	M	H
Congestion – delay time or $ per tonne-km	L	M	H
Aesthetics	L	M	H
Introduction of non-indigenous species	H	less than ship	