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The carbon footprint of freight traffic and pavement treatments for interprovincial trade flows of Atlantic Canada

Abstract

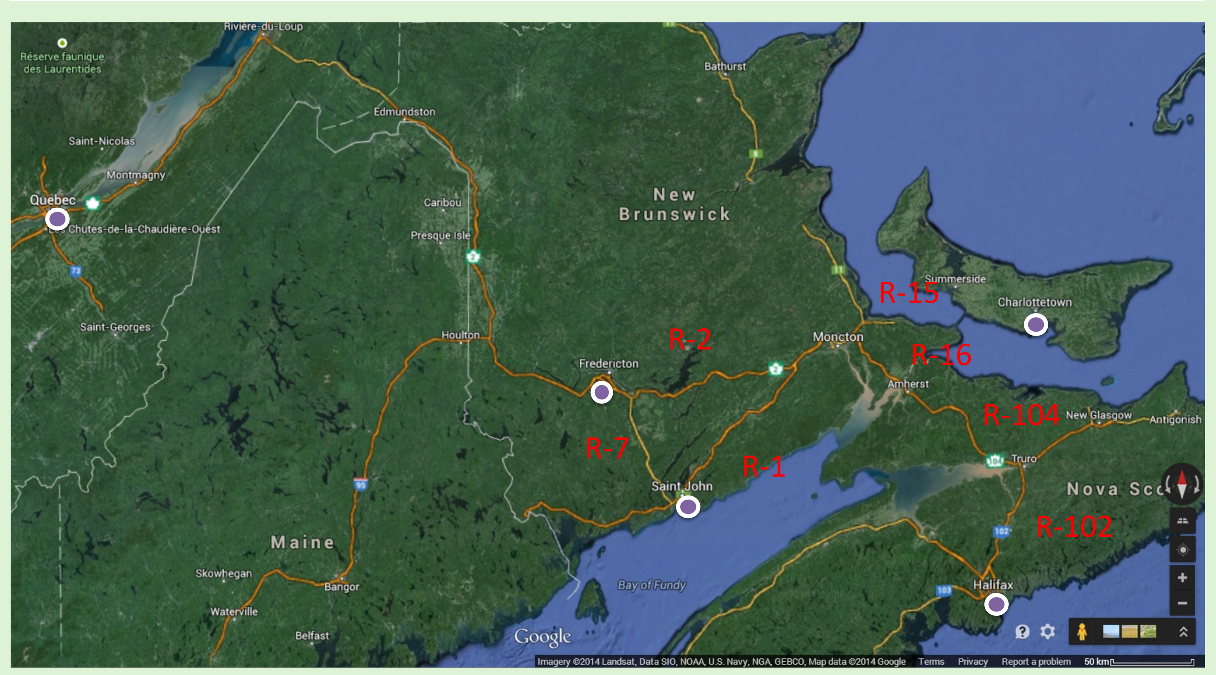
Freight movement emits GHGs and undermines pavement - adding additional emissions from pavement maintenance & rehabilitation (M&R) treatments. This study predicts the carbon footprint of freight movement and pavement maintenance on regional highways of Atlantic provinces of Canada. Integration of environmental analysis within a spatial input-output model estimates equivalent single axle loads (ESALs) and CO2 emissions on regional highways for a 30 years period. ESALs combined with observed pavement strength, result in the generation of pavement deterioration curves. The curves are used for performance-based optimization to estimate necessary pavement maintenance operations. A total 1.279 million tons of CO2 and 1.403 – 1.755 million tons of carbon dioxide equivalent GHGs will emit from predicted fuel consumption and pavement surface treatments during 2012-2041.

Introduction

- Road infrastructure has significant impact on trade flow.
- Road freight transport is the major contributor to trade flow in Canada (Statistics Canada 2009).
- GHG emissions from transport infrastructure and highway expansion strategies cause environment burdens to climate change (Newman and Kenworthy 1999).
- Sustainable development and transportation can be achieved by integrating all impacts into the planning system.
- 'Carbon footprint' concept helps to estimate and visualize the magnitude of environmental effects into a meaningful context.
- Chevoits and Galehouse (2010) revealed that pavement M&R operations significantly reduced energy use and GHG emissions compared to traditional strategies.
- Canadian Construction Association (2005) develops a "Road Rehabilitation Energy Reduction Guide for Canadian Road Builders" to provide information on methods to reduce energy usage during road construction and maintenance operations.

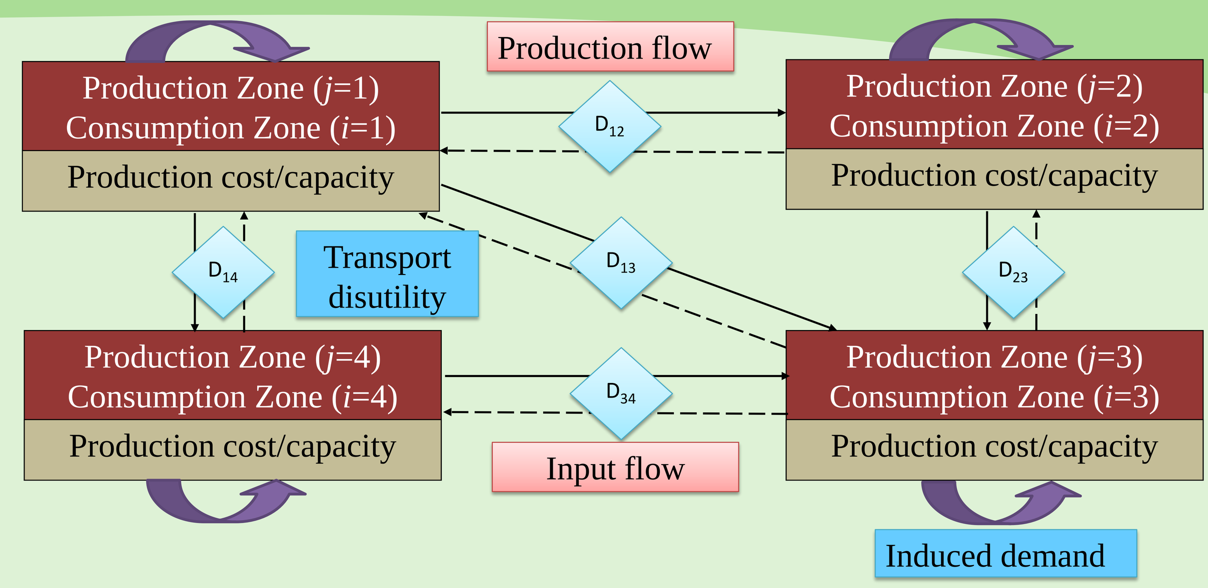
Objective and Study Area

- This study integrates freight movement for inter-provincial trade-flow, pavement maintenance as a consequence of deterioration imposed by such predicted freight movements, and the carbon footprint.
- Case Study -- regional road network between New Brunswick, Prince Edward Island, Newfoundland and Labrador, Nova Scotia and Quebec



Methodology

Step 1: Spatial input-output modeling



Step 2: Transportation modeling

$$C_{op} = C_F + C_T + C_D + C_c + C_e$$

- C_{op} = Operating Cost
- C_F =Fixed operating cost of a truck once for every trip made, usually refers to administrative costs and loading/unloading cost
- C_T = Operating cost per hour, usually includes drivers' salaries and capital payments
- C_D = Operating cost per km of a truck, usually including tires, spares, maintenance, lubricants, and others. This cost varies by link type
- C_c = Charges paid by driver for tolls, parking, duties, etc.
- C_e = Energy cost

Components	Value (CAD)	Data sources
C_F	1.93	Levinson *et al*., 2005
C_T	21.60	(126000/8/270/10) + 15.77
C_D	1.4	Levinson *et al*., 2005
C_c	0	
C_e	$C_e = \left[ed_o^{min} + (ed_o^{max} - ed_o^{min}) * \exp(-\delta^o V_o)\right] pe_o$	West *et al.* 2008

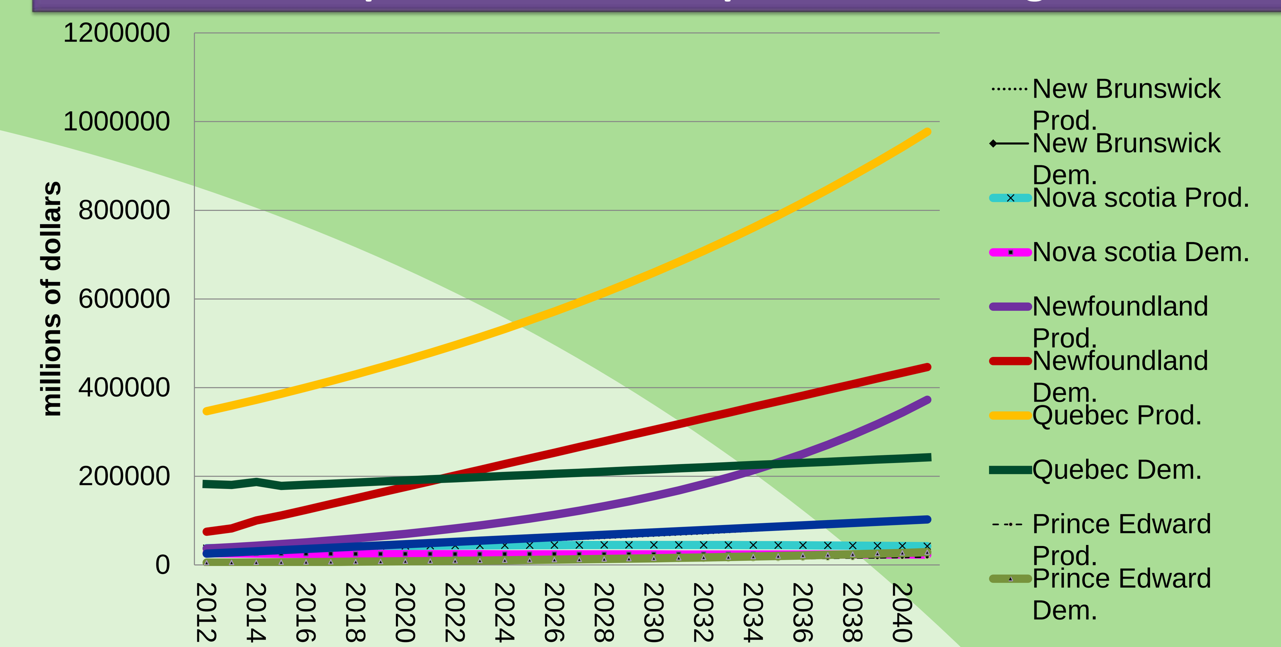
Step 3: Pavement performance modeling

$$IRI_t = e^{mt}[IRI_0 + a(1+SNC)^{-5} \cdot ESAL_t]$$

- IRI_t = International Roughness Index at period *t*
- IRI_0 = As-built quality is set between 0.7 and 1 m/km depending on the route
- *SNC* = Structural number coefficient (SNC) followed the formula given by Watanatada *et al*. (1987)
- *m* = Mean environmental exposure (Thornthwaite's moisture coefficients) and identified as 0.07, 0.074 and 0.08 for the three environmental zones with moisture index of 60, 80 and 100.

Results

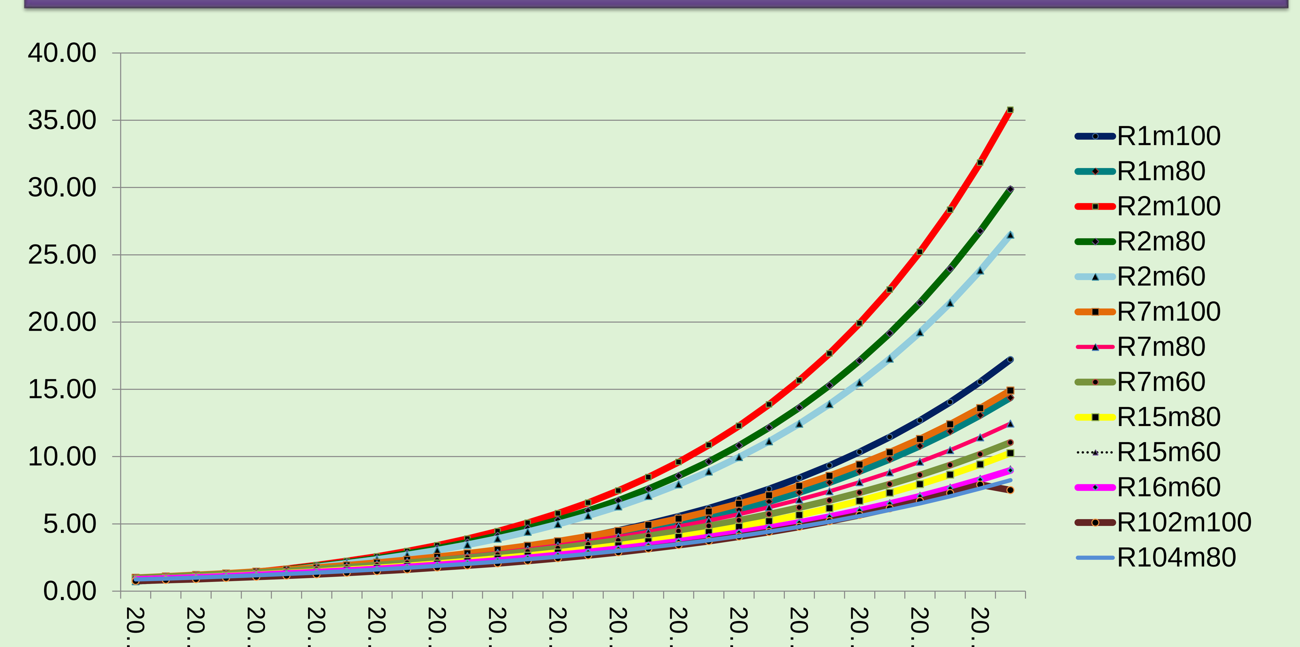
Total demand & production of five provinces during 2012-2041



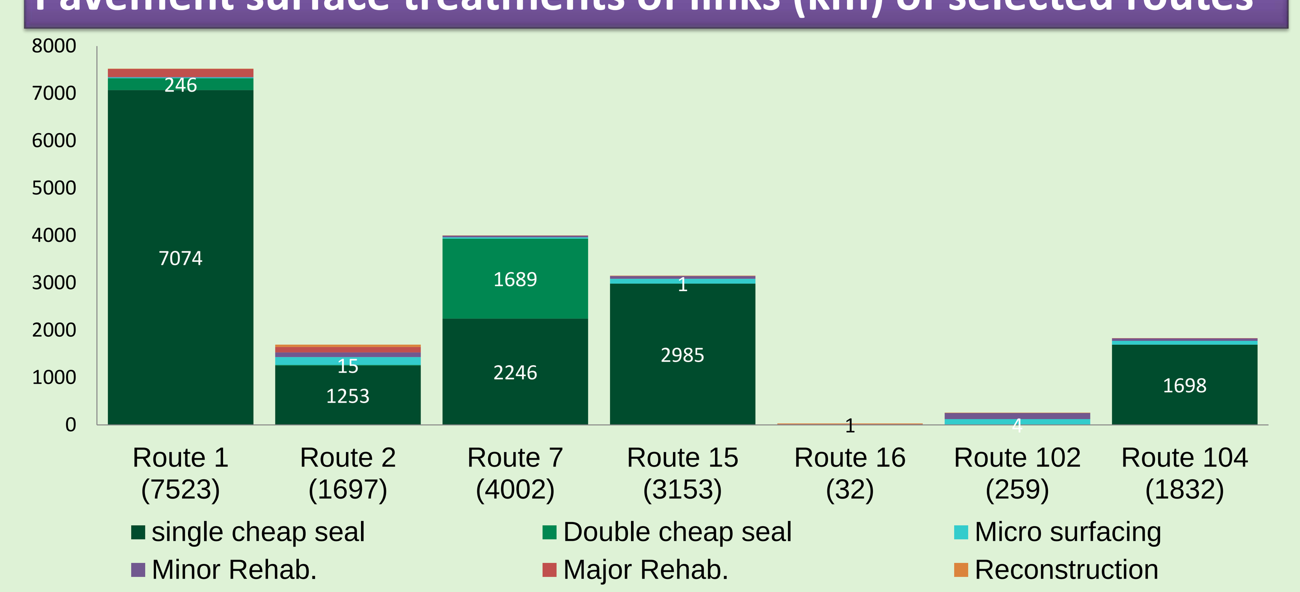
Predicted ESALs per year for regional highways

Truck category (FHWA)	% trucks	Truck Factor	Route 1	Route 2	Route 7	Route 15	Route 16	Route 102	Route 104
5	8.2	0.45	12385	41370	4825	3092	2940	1169	943
6	5.7	1.18	22574	75409	8794	5637	5359	2132	1719
7	0.4	3.25	4363	14575	1700	1089	1036	412	332
8	2.7	0.99	8971	29968	3495	2240	2130	847	683
9	52.6	2.33	411341	1374059	160247	102710	97644	38843	31331
10	28.6	5.91	567302	1895035	221005	141653	134666	53571	43210
13	1.8	4.7	28394	94849	11062	7090	6740	2681	2163
ESALs per year			1055331	3525266	411129	263511	250514	99656	80382

Cumulative IRI for moisture index of 60, 80 and 100



Pavement surface treatments of links (km) of selected routes



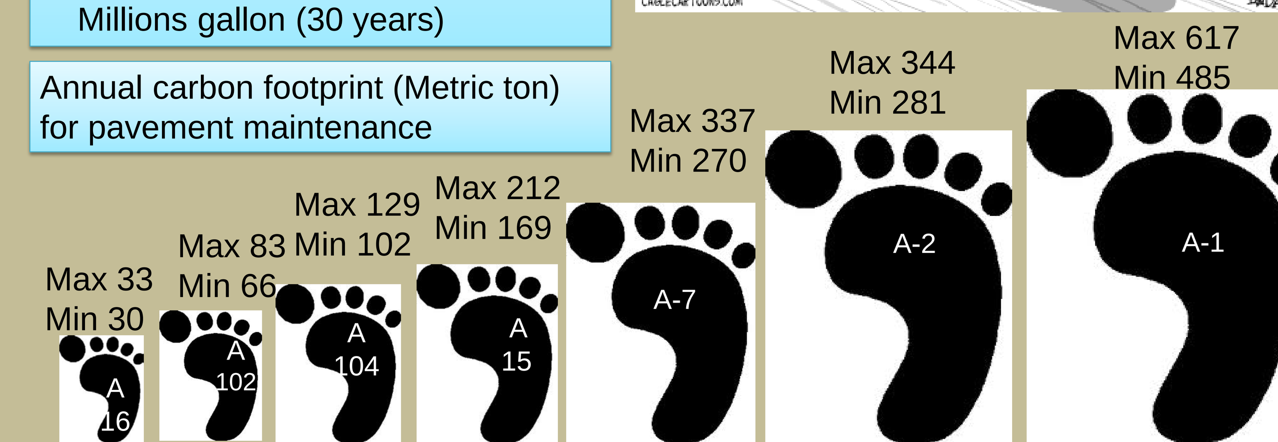
Results

Carbon footprint of forecasted freight traffic and traffic induced pavement maintenance operations

- Per year carbon footprint for fuel consumption 42625.28 Metric Tons
- Total carbon footprint for fuel consumption 1.279 Million Metric Tons (30 years)

- Per year fuel cost $91.70 Millions
- Total fuel cost $2750.96 Millions (30 years)
- Per year fuel consumption 4.19 Millions gallon
- Total fuel consumption 125.61 Millions gallon (30 years)

Annual carbon footprint (Metric ton) for pavement maintenance



Conclusions

- Trucks would travel 334.722 million truck-km per year on the regional highways during 2012–2041.
- Predicted AADTT → 2397, 8008, 934, 599, 569, 226, and 183 for highway 1, 2, 7, 15, 16, 102 and 104 in the year 2012.
- During 2012–2041, 15,261 km, 515.24 km, 1952 km, 383.3 km, 304.1 km, and 84.28 km of pavement will require chip sealing, micro-surfacing, double chip sealing, hot in-place recycling, major rehabilitation (hot mix asphalt), and reconstruction.
- Fuel consumption for truck movement and pavement surface treatments will cause 2.682–3.034 million metric tons of CO2e GHG emissions.
- Predicted environmental impacts will encourage the incorporation of environmental costs within trade flows and transport infrastructure development to ensure sustainable regional economy and transportation.

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