GEOGRAPHIC ECONOMIC ACCESSIBILITY (GEA) FOR FREIGHT TRANSPORT

Patricio Gallardo

Uniuversity of Canterbury

Is the current freight transportation system at risk?

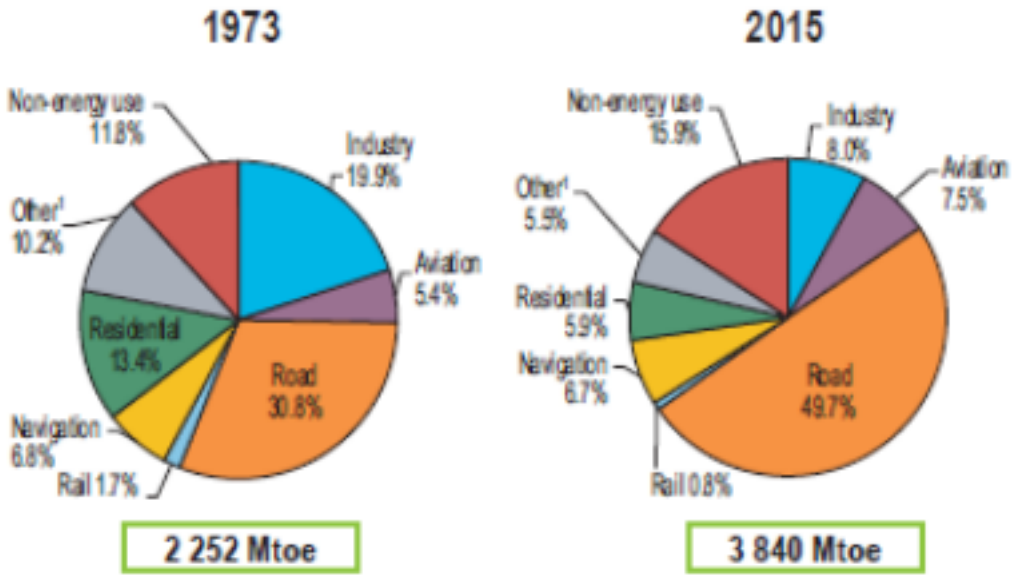
(Sunday Express, 2015)

(Defense Visual Information Distribution Service, 2013)

(stuff, 2016)

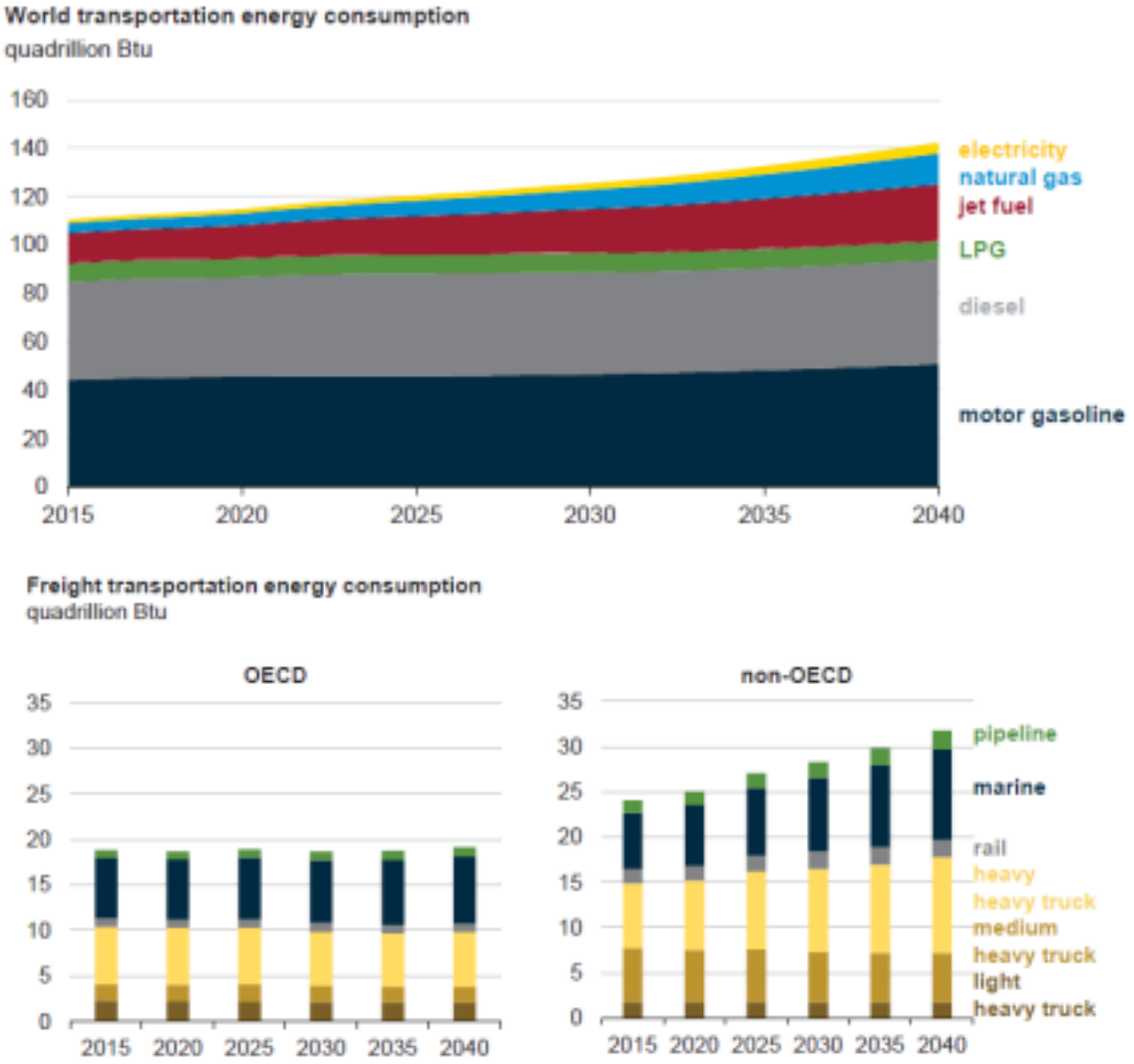
(US High Speed Rail Association, 2017)

Energy and Transportation



1. Includes agriculture, commercial and public services, non-specified other, pipeline and non-specified transport.

(International Energy agency, 2016)



(U.S. Energy Information Administration, 2017)

Aim

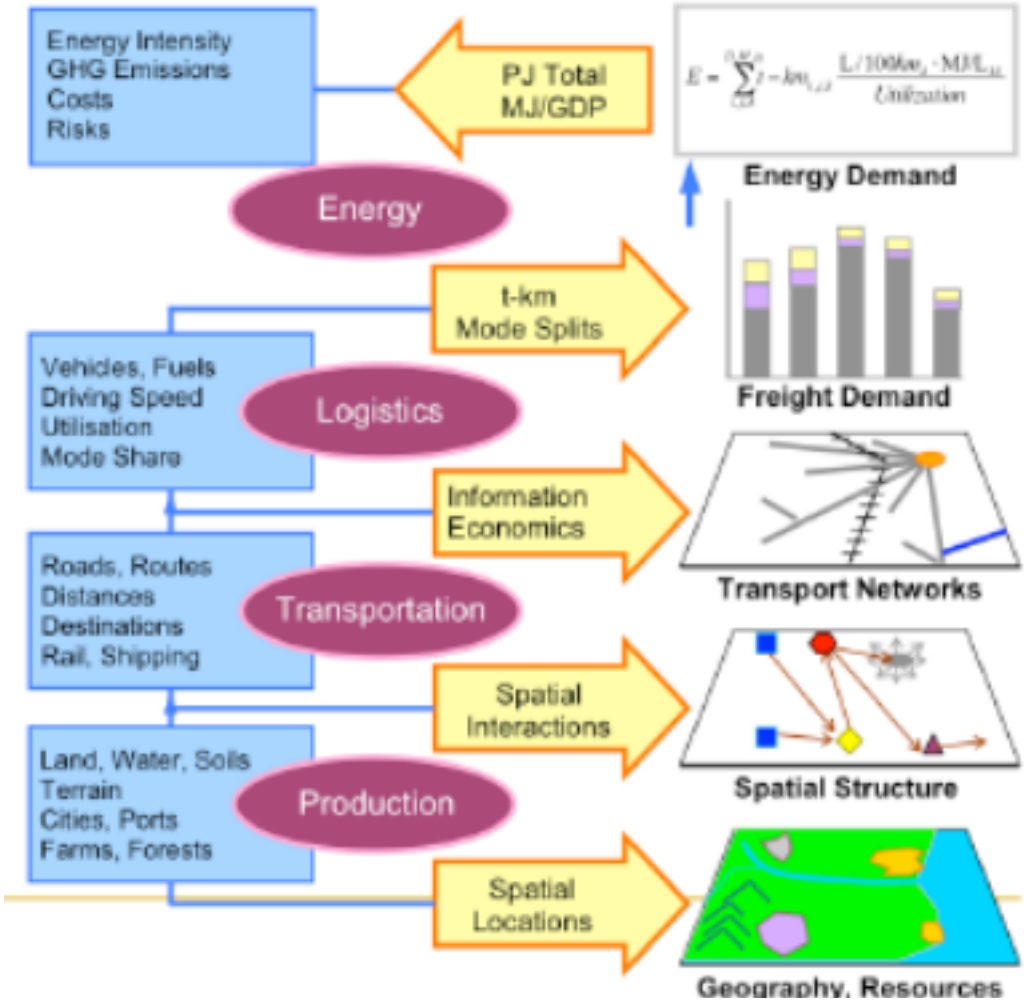
- Assess the response of mode share and freight flow dispersion to changes in transportation costs induced by an escalation in fuel prices.

Objectives

- Estimate freight activity and energy consumption upon the execution of a Random Utility Based Multiregional Input Output Model and the application of mode/commodity specific energy intensities.
- Explore the response of the current configuration to potential scenarios with elevated fuel prices.

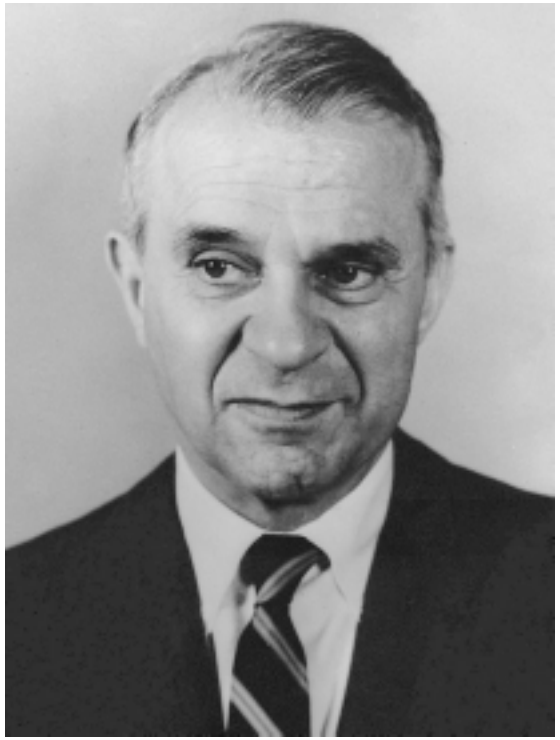
Understanding the freight transportation system

- Complex system that involves a large number of actors, large number of heterogeneous goods and multiple combinations of transportation modes.
- Freight activity is determined by the spatial interaction between production and consumption activities.
- The methodologies behind freight demand models are based on different interpretations on how the economy works.



(Krumdieck, 2017)

Input Output Models



(Wikipedia, 2018)

m, n: sectors from economy
Y: final demand
X: total output
x: intersectoral flow

Example

If final demand for sector 1 increases to 600 and for sector 2 decreases to 1500, How much total output from the two sectors would be necessary in order to fulfil new demand

		To Processing Sectors			
		1	**2**	**Final Demand (*fi*)**	**Total Output (*xi*)**
From Processing Sectors	**1**	150	500	350	1000
	2	200	100	1700	2000
Payments Sector		650	1400	1100	3150
Total Outlays (*xi*)		1000	2000	3150	6150

Solution

	Sector 1 (Agriculture)	Sector 2 (Manufacturing)
Sector 1 (Agriculture)	0.15	0.25
Sector 2 (Manufacturing)	0.20	0.05

		To Processing Sectors			
		1	**2**	**Final Demand (*fi*)**	**Total Output (*xi*)**
From Processing Sectors	**1**	187.13	460.40	600	1247.52
	2	249.50	92.08	1500	1841.58
Payments Sector		810.89	1289.11	1100	3200.00
Total Outlays (*xi*)		1247.52	1841.58	3200	6289.10

(Miller & Blair, 2009)

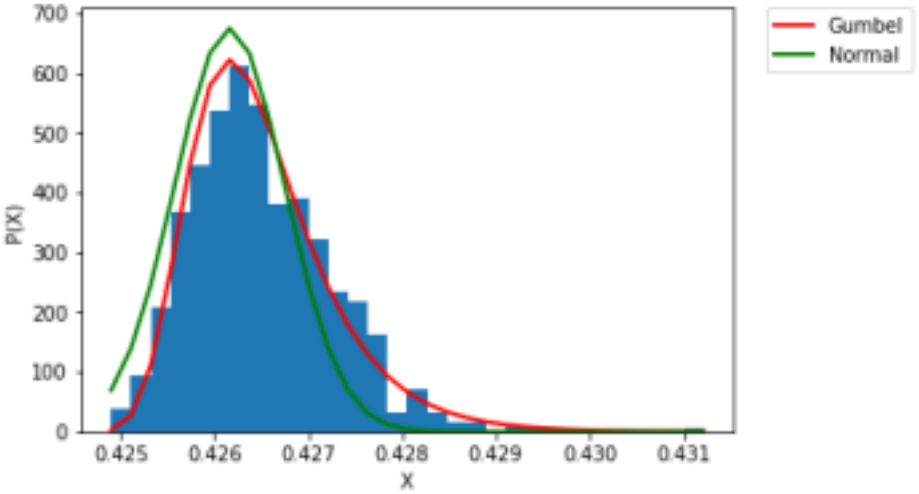
Multiregional Input Output Models

Additional Notation:
i, j, k: regions

Discrete Choice Theory

- Four elements associated with the decision process:
  - Decision maker
  - The alternatives
  - Attributes of alternatives
  - The decision rule
- $U_{it} = V_{it} + \varepsilon_{it}$
  - U is the utility of the alternative i to the decision maker t
  - V is the deterministic or observable portion of the utility estimated bythe analyst
  - ε is the error or the portion of the utility unknown to the analyst (random error)

Cumulative Probability Distributions

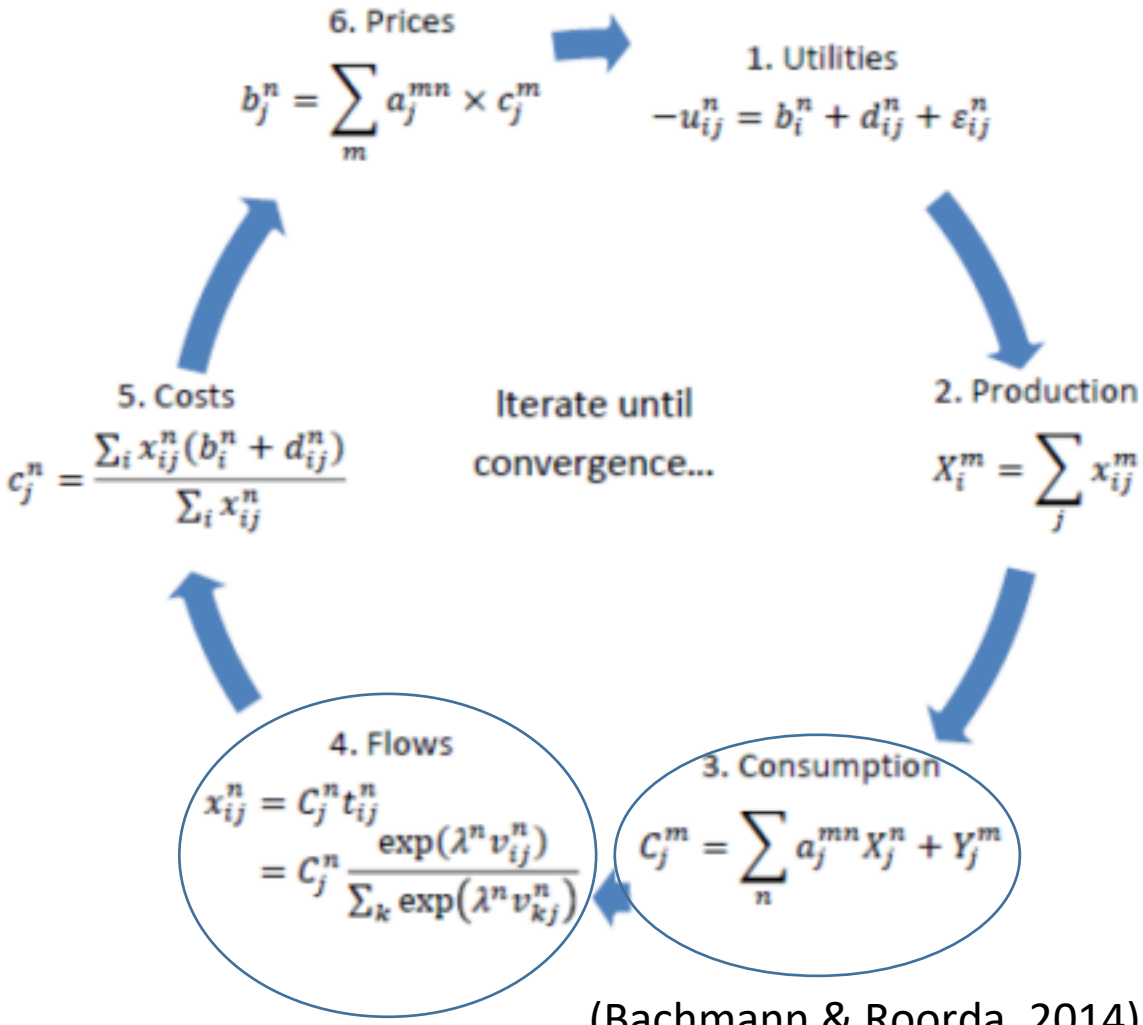


$$\Pr(i) = \frac{\exp(V_i)}{\sum_{j=1}^{J} \exp(V_j)}$$

Pr(i) : Probability of choosing alternative i from a set of J alternatives

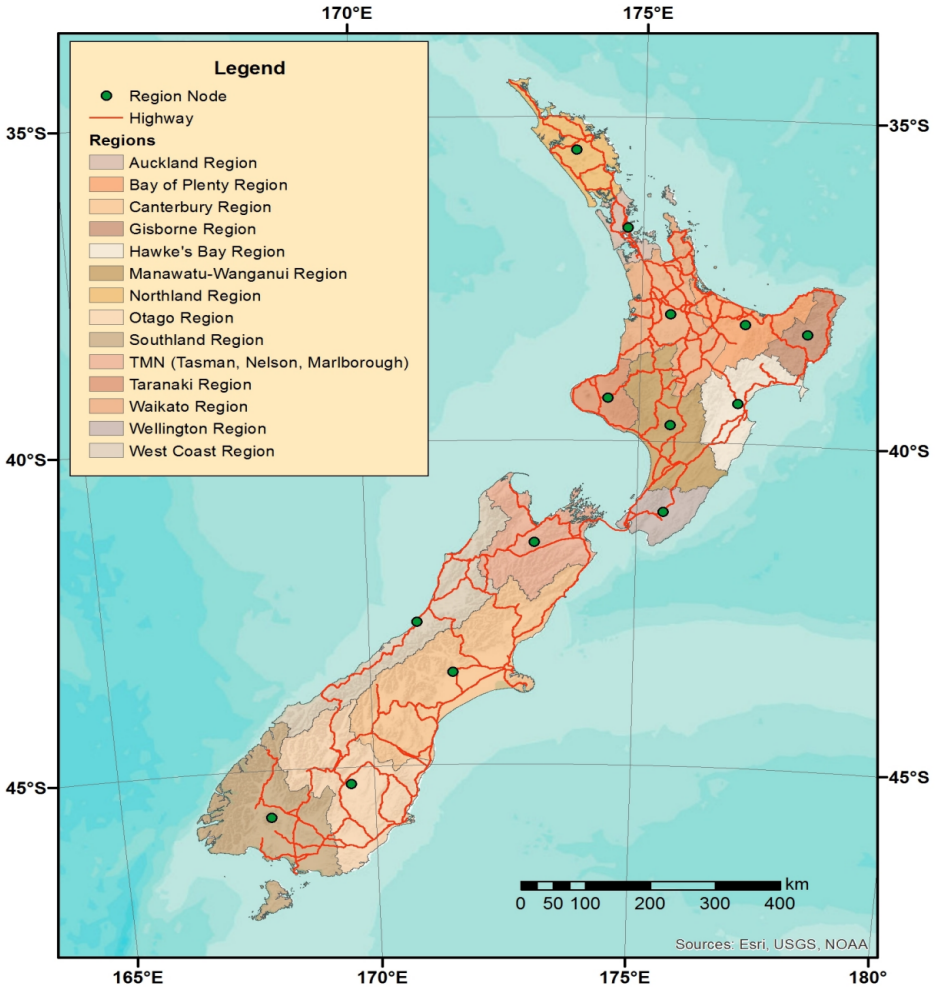
Random Utility Based Multiregional Input Output (RUBMRIO) Models

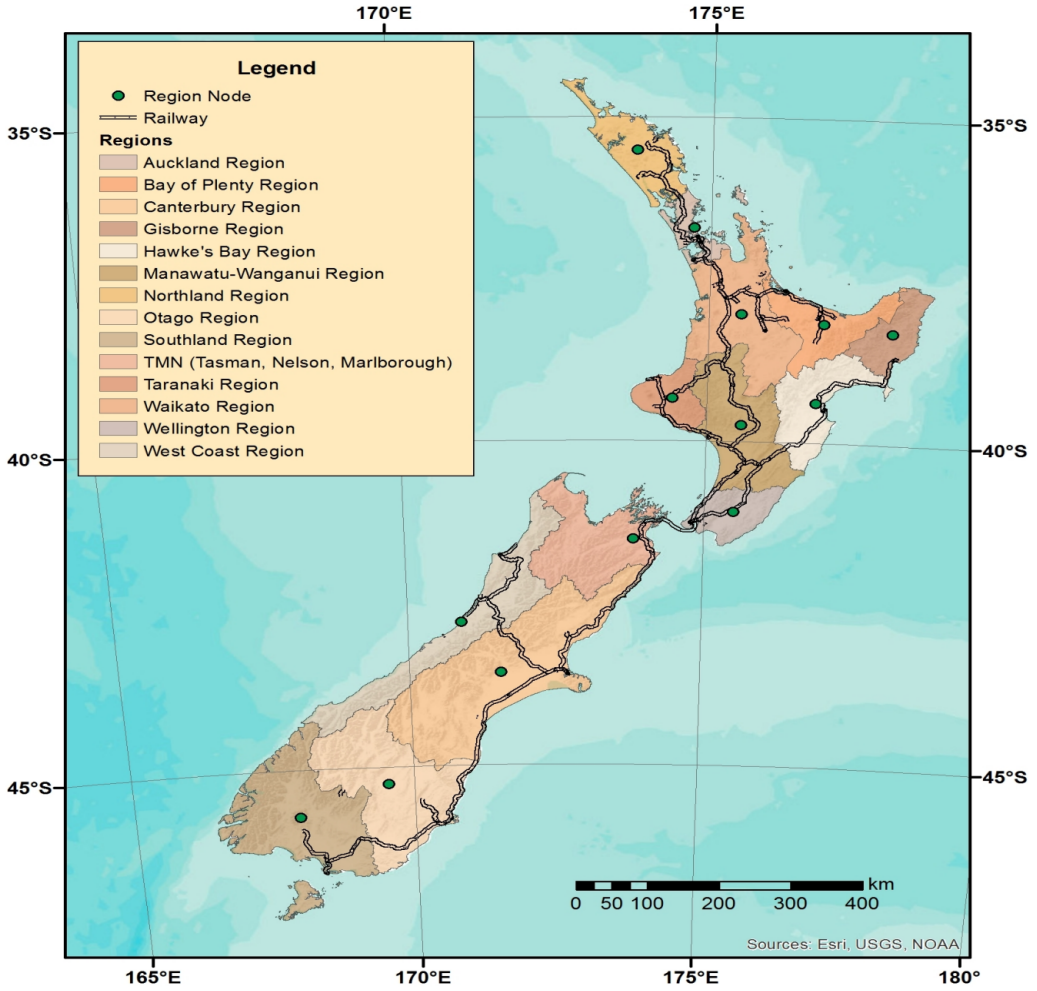
- Trade flows were initially estimated upon gravity type formulations where the impedance for trade was expressed as a function of transportation costs.
- An alternative and more recent multiregional framework contemplates variations in trade coefficients through a discrete choice model; models that have been developed upon this concept are known to belong to the Random Utility Based MRIO (RUBMRIO) category.



(Bachmann & Roorda, 2014)

Geographic Data





Stats NZ
Tatauranga Aotearoa

https://www.stats.govt.nz/

koordinates

https://koordinates.com/

Technical Coefficients

- The methodology contemplated the application of the RAS technique to update the national input output table for New Zealand. Once the updated table was obtained, it was further used to generate regional input output tables through a non-survey method known as Location Quotients (LQ).
- We worked with 14 input output tables and considered 23 economic sectors.

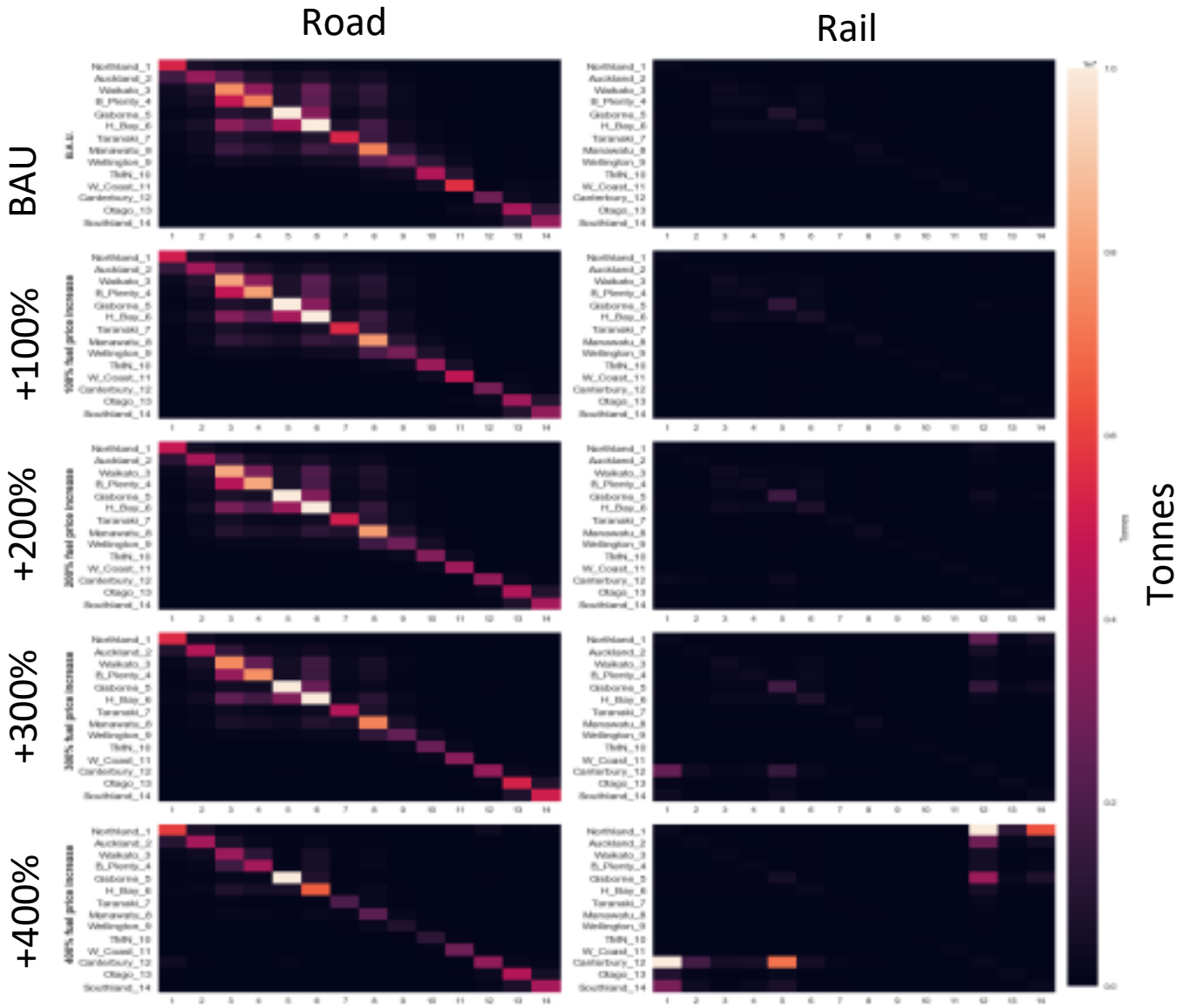
Going back to our example...

		To Processing Sectors			
		1	**2**	**Final Demand (*fi*)**	**Total Output (*xi*)**
From Processing Sectors	**1**	150	500	350	1000
	2	200	100	1700	2000
Payments Sector		650	1400	1100	3150
Total Outlays (*xi*)		1000	2000	3150	6150

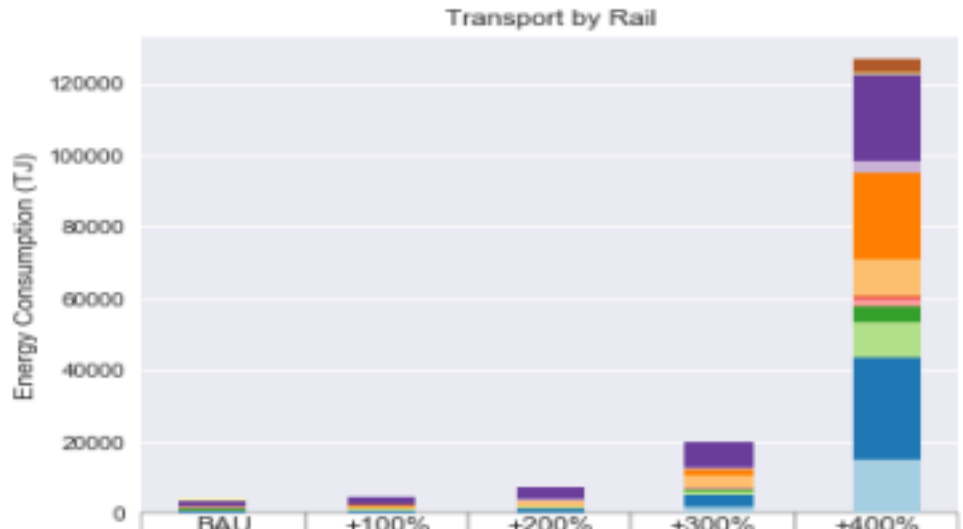
(Miller & Blair, 2009)

Energy Consumption Estimation

Results



Results



	BAU	+100%	+200%	+300%	+400%
milk	70.08	63.05	72.38	913.81	11144.47
manuf_dairy	92.29	113.97	228.56	790.67	4019.14
timber	312.37	280.52	351.83	2138.66	24732.12
wood_paper	324.61	428.19	658.48	1212.04	3448.21
livestock	194.19	210.99	363.64	1347.21	10063.63
meat	5.73	4.93	5.14	57.38	932.52
horticulture	32.16	27.91	30.41	203.67	3502.6
other_agric_grain	98.98	123.65	198.81	458.73	2059.85
wool	45.0	61.17	79.03	95.94	102.99
fish	2.79	2.32	2.33	39.72	636.28
coal	83.97	125.81	310.93	1023.02	3369.4
petroleum	446.58	599.24	988.29	2129.7	6827.67
aggregate	125.83	111.96	124.75	822.91	11499.41
limest_cement_fert_conc	138.77	126.6	162.68	968.9	12805.27
steal_aluminum	117.54	149.19	258.59	688.47	3109.91
manuf_goods	1140.84	1511.67	2393.72	4761.87	15844.07
supermarket	492.73	636.33	1011.85	2122.23	8300.31
post_courier	37.85	49.14	69.38	108.21	232.82
imported_cars	9.89	12.56	22.16	59.58	275.19
other_minerals	12.24	14.68	23.13	56.01	263.55
waste	10.27	9.27	8.81	66.98	3509.11

Discussion

- Commodities from the retail sectors are mainly shipped by trucks. This behaviour may follow the preference for modes that are flexible enough to respond to just on time deliveries while preserving product care features during transportation.
- It can be deduced that when fuel prices exceed the 300% increase threshold, rail starts becoming the driving force behind trade. Even though, rail is a more energy efficient mode of transportation than trucks, the energy consumed by the entire transportation systems rises abruptly after the aforementioned threshold. This peculiarity can be explained by the potential that railways have to develop economies of scale.
- In this particular case, the Canterbury region becomes a major centre for inter-island trade. Given the case that the national rail infrastructure connects the entire country, the **differences for input prices between regions** start dropping and it starts becoming more economically feasible to purchase products from other regions.

Conclusions

- In this paper, we were not focused on the precise estimation of travel demand, but rather on understanding how vulnerable the current system is, taking into account that our freight transportation system is highly dependent on truck transport and on the fossil fuels that are consumed by this mode.
- It is worth noting that, as it is the case with any other model, it is complex to incorporate all the dynamic feedbacks that occur in reality.
- It may be appropriate to consider complementary methods to incorporate essentiality metrics over the products that are being transferred within and outside the country.

References

- Bachmann, C., & Roorda, M. (2014). Applications of Random-Utility-based Multiregion Input Output Models of Transport and the Spatial Economy. *Transport Reviews*. doi:10.1080/01441647.2014.907369
- Defense Visual Information Distribution Service. (2013, 06 13). Retrieved 3 12, 2018, from Container Collapse: https://www.dvidshub.net/image/880628/container-collapse
- Internatiional Energy Agency. (2017). Retrieved 3 12, 2018, from Key World Energy Statistics: https://www.iea.org/publications/freepublications/publication/KeyWorld2017.pdf
- Koppelman, F. S., & Bhat, C. (2006). *A self instructing course in mode choice modeling.*
- Krumdieck, S. (2017). Transportation Energy End-Use. Christchurch.
- Miller, R. E., & Blair, P. D. (2009). *Input-Output Analysis .* Cambridge: Cambridge University Press.
- stuff. (2016, December 7). *stuff.* Retrieved 3 12, 2018, from Earthquake repairs crucial to 'viability of rail in New Zealand': https://www.stuff.co.nz/national/87236596/earthquake-repairs-crucial-to-viability-of-rail-in-new-zealand
- Sunday Express. (2015, July 9). Retrieved 3 12, 2018, from Holiday warning: Britons flocking to sun in Spain at HIGH risk of ISIS attack: https://www.express.co.uk/news/world/589982/Spain-terror-alert-Islamic-State-ISIS-attacks-Britain-warning
- U.S. Energy Information Administration. (2017, 9 14). Retrieved 3 12, 2018, from International Energy outlook 2017: https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf
- US High Speed Rail Association. (2017). Retrieved 3 12, 2018, from Energy security: http://www.ushsr.com/benefits/energysecurity.html
- Wikipedia. (2018). *Wassily Leontief.* Retrieved 3 12, 2018, from 1973 Press Photo Wassily W. Leontief: https://en.wikipedia.org/wiki/File:Wassily_Leontief_1973.jpg