# Strategic Concept Design of Freight Systems (STRATCODE): An optimization - simulation approach

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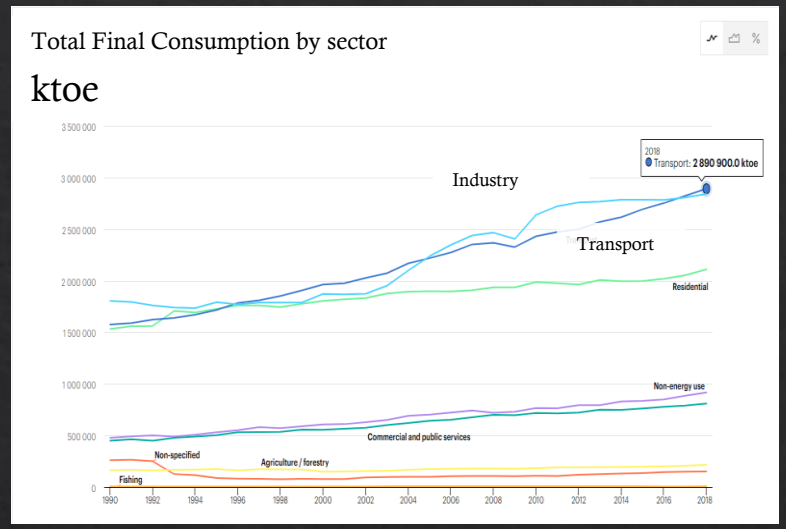
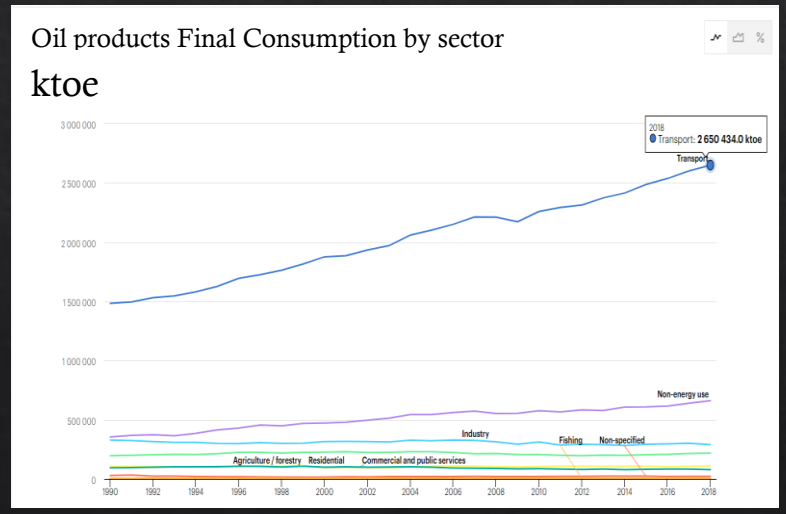
# Motivation


Source: US High Speed Rail Association (2017)




Source: International Energy Agency (2020)
https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource

# Motivation

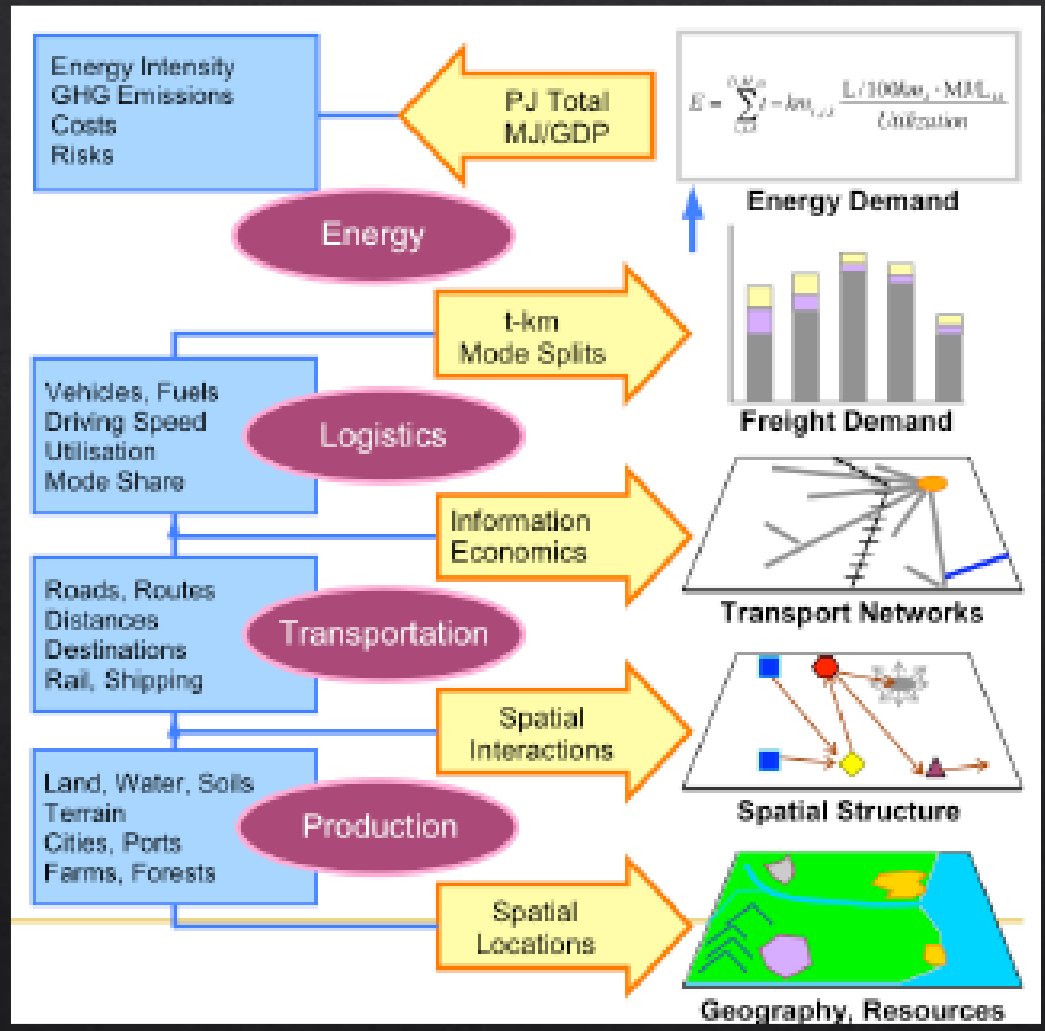
"There is a lack of comprehensive and consistent assessments of the worldwide potential for **GHG emission reduction** and especially costs of mitigation from the transport" (Sims et.al., 2014)

**Research Question:**

How would we know what government infrastructure investment now will provide for the freight supply chain for New Zealand for the next century?

# Limitations of existing modelling methods

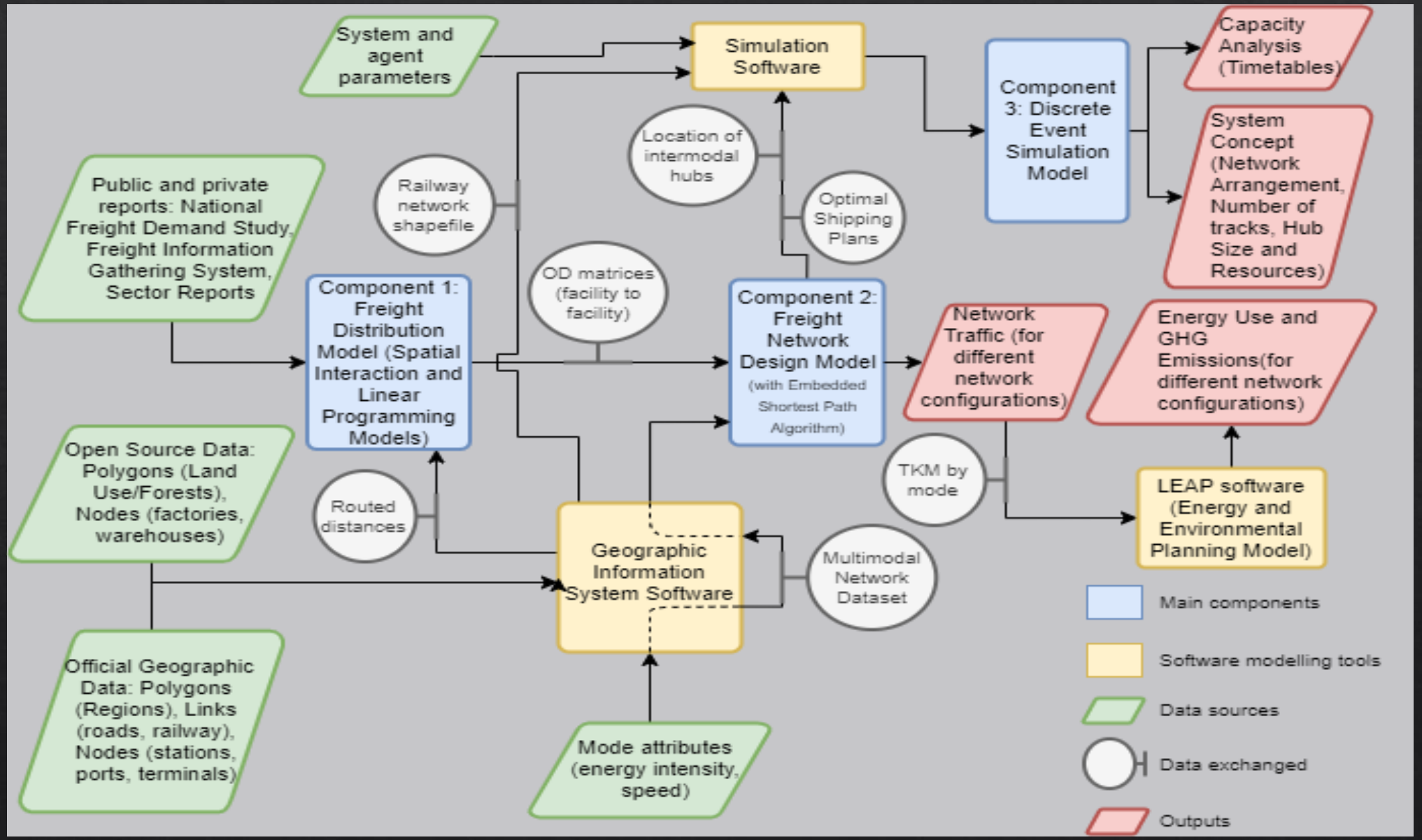
- Status quo tools.
- Overconfidence in unproven technologies and high uncertainty in future projections.
- Data availability.
- Overlook logistics component.






Krumdieck (2017)

# STRATCODE Framework

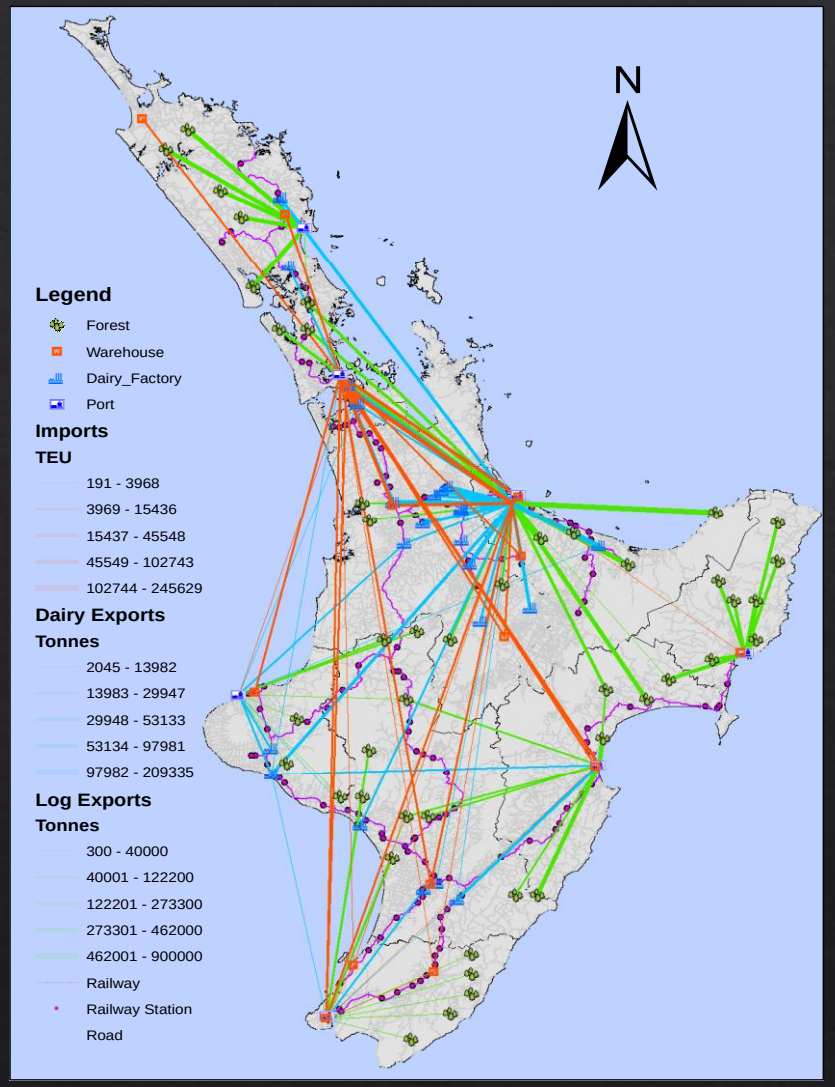


# STRATCODE - Component 1 : Freight Distribution Model

- Preliminary step to allocate regional flows to representative facilities within the area of study.
- Involved iterative proportional fitting, calibration of gravity models, and linear optimization

## CONTRIBUTION

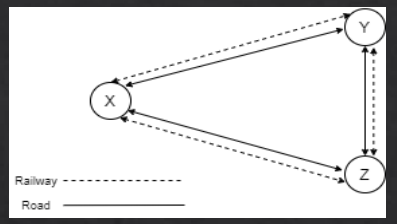
- Allowed to arrange data sources into a format compatible with the subsequent components.
- Replicable on other agriculture based sectors

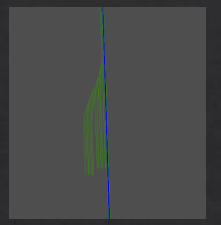


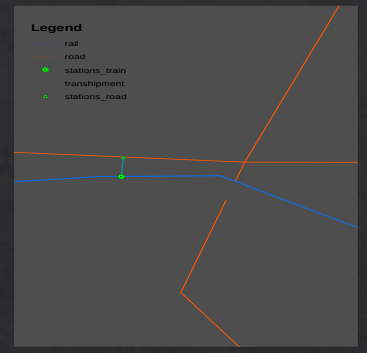

Gallardo et al. (2021)

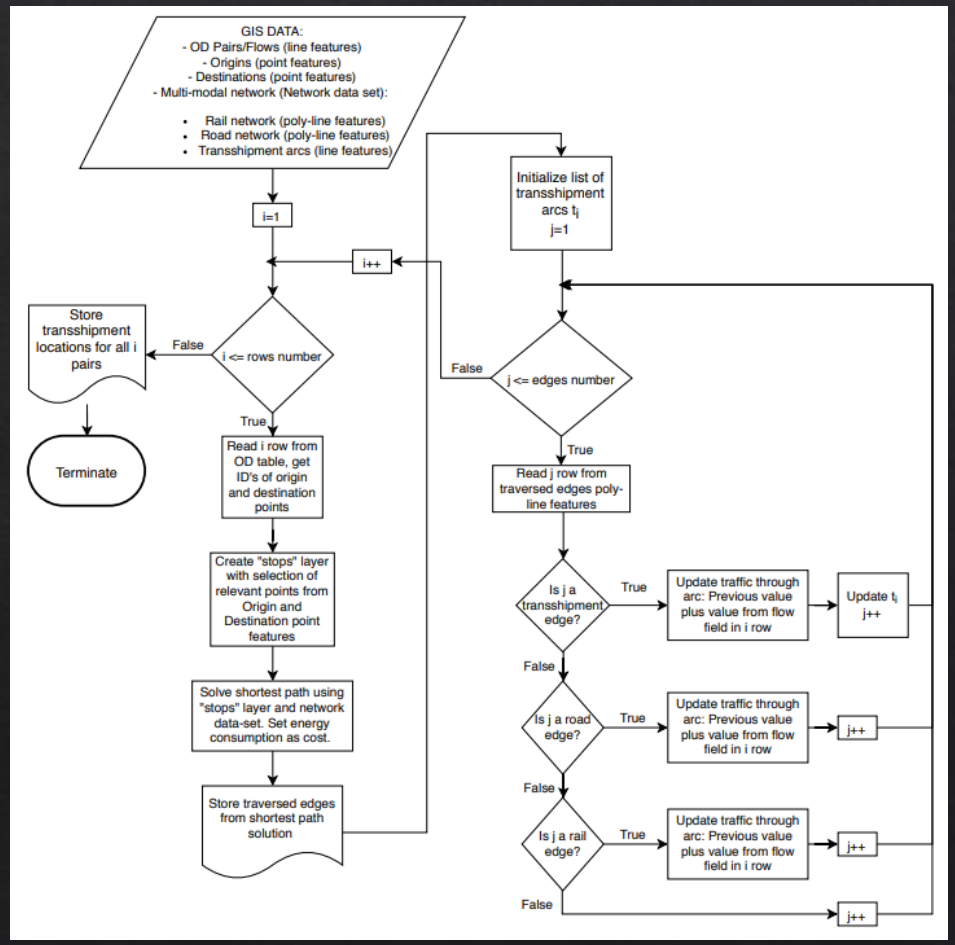
# STRATCODE - Component 2 : GIS based network analysis model

- Inherits elements from the field of multimodal transportation planning.
- GIS technology allowed to detach multimodal operations and assign costs.
- Average trip time, energy demand and GHG emissions were used as key performance indicators.






| O_ID | D_ID | MODE | ACCESS | EXIT |
|---|---|---|---|---|
| f_BP1 | Bay_of_Plenty | intermodal | 97 | 94 |
| f_BP1 | Northland | intermodal | 97 | 109 |
| f_BP1 | Taranaki | intermodal | 97 | 29 |
| f_MW1 | Bay_of_Plenty | intermodal | 40 | 94 |
| f_TK1 | Taranaki | intermodal | 30 | 29 |
| f_WK1 | Bay_of_Plenty | intermodal | 85 | 94 |
| f_NL1 | Northland | intermodal | 2 | 109 |

Gallardo et al. (2021)

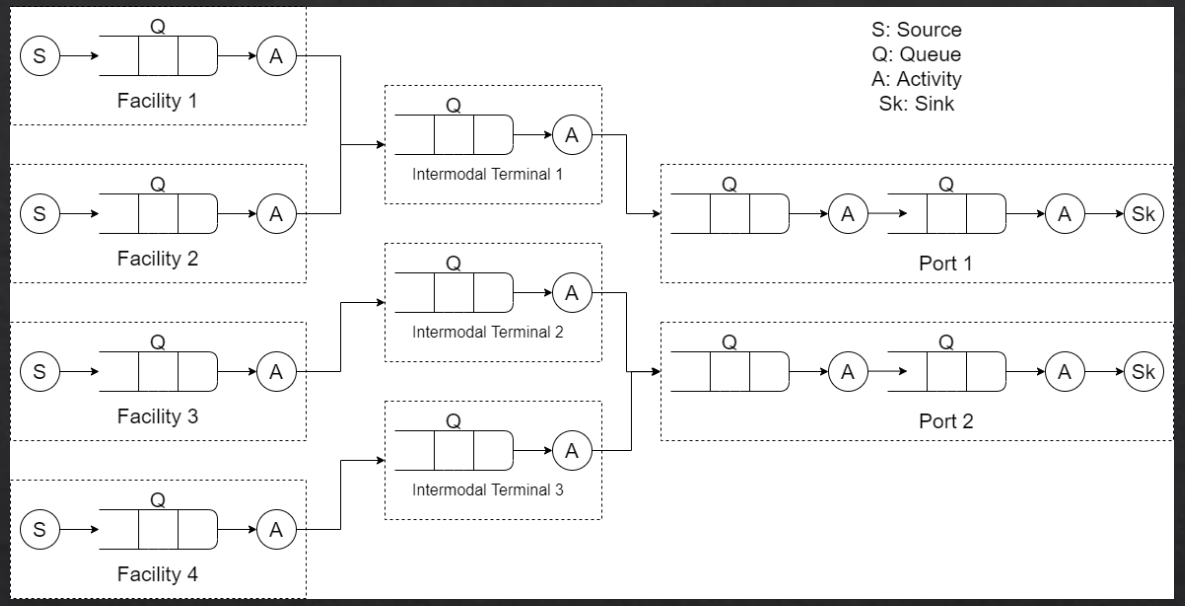
## CONTRIBUTION

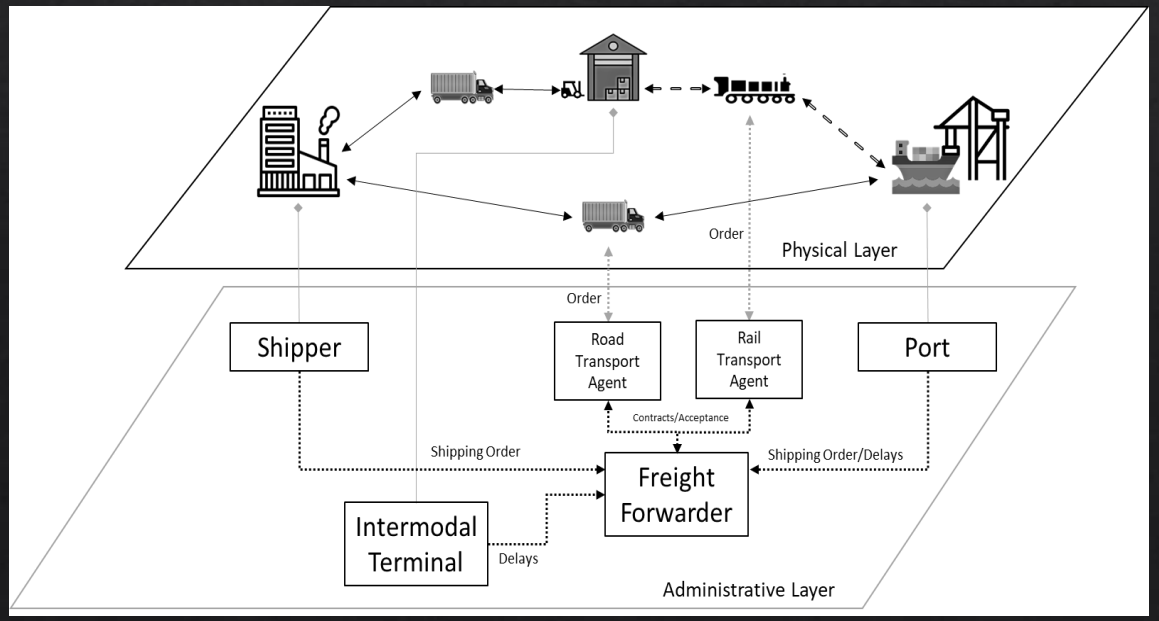
Multifold outputs

- Core of the framework
- Traffic Assessment
- Selection of intermodal locations
- Optimal delivery plans consolidated into a database

# STRATCODE - Component 3 : Discrete event simulation model

- Building upon inherited structural components from multi-server discrete-time queueing systems.
- Every facility represented through a network of service nodes.

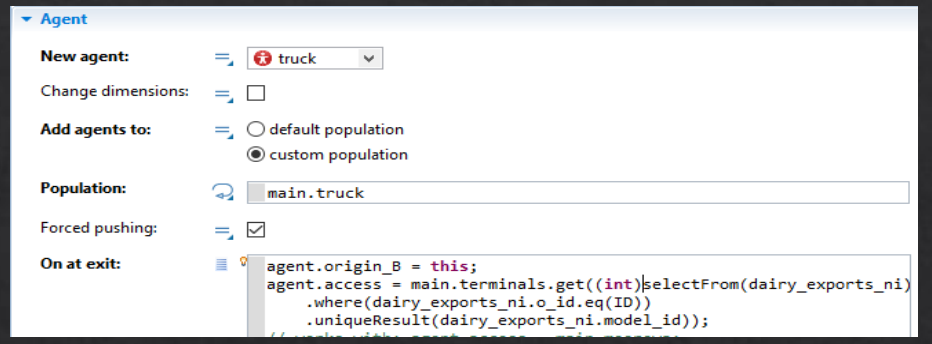


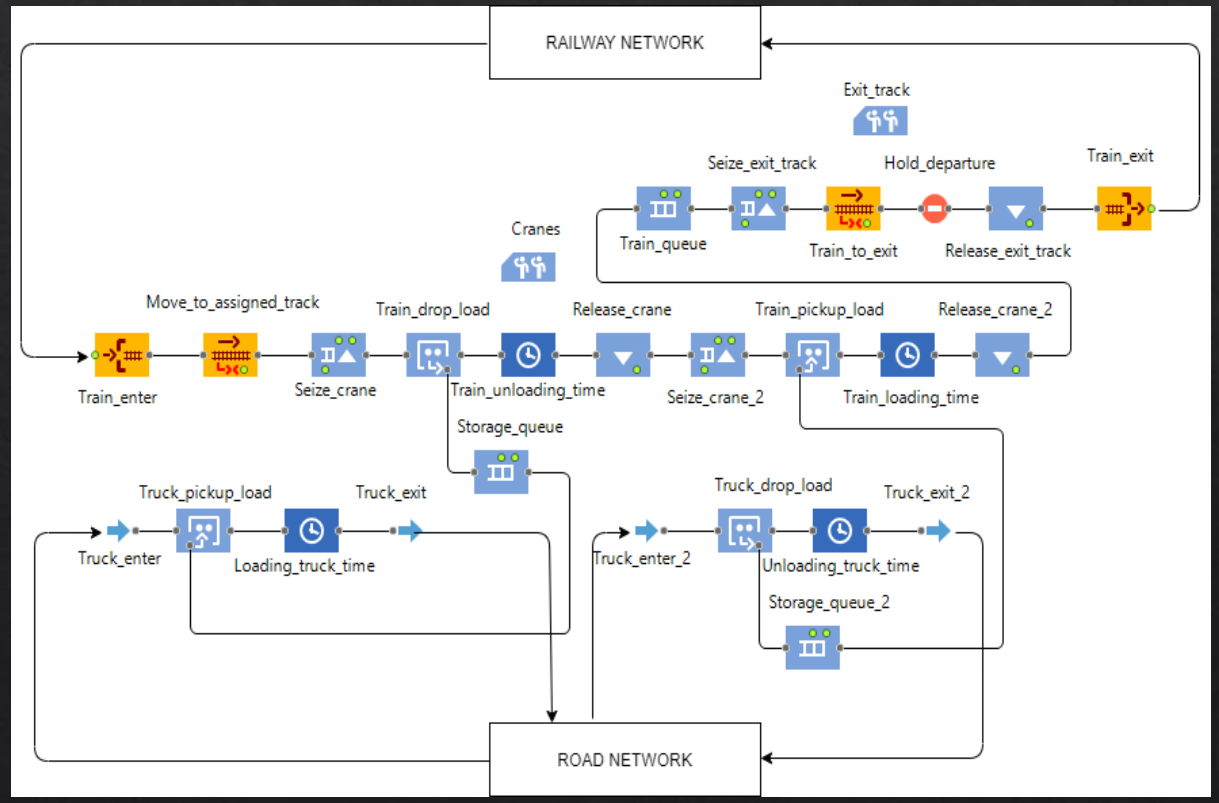




- Captures logistics and behaviour-oriented policies.
- Characterizes the heterogeneity of actors and objects in freight chains.
- Two sets of agent types.

# STRATCODE - Component 3 : Discrete event simulation model

- Enhances the analytical solution from Component 2.
- Modelling tool: Anylogic 8.5.2.
- Agents interact within a GIS space in response to shipping orders.
- Agent parameters retrieved from database.
- Captures the interactions between trucks, trains and loading equipment, and subsequent repercussions on the broad freight system.
- Performance varies with changes in infrastructure and operating conditions.
- Interaction of agents with a central database.



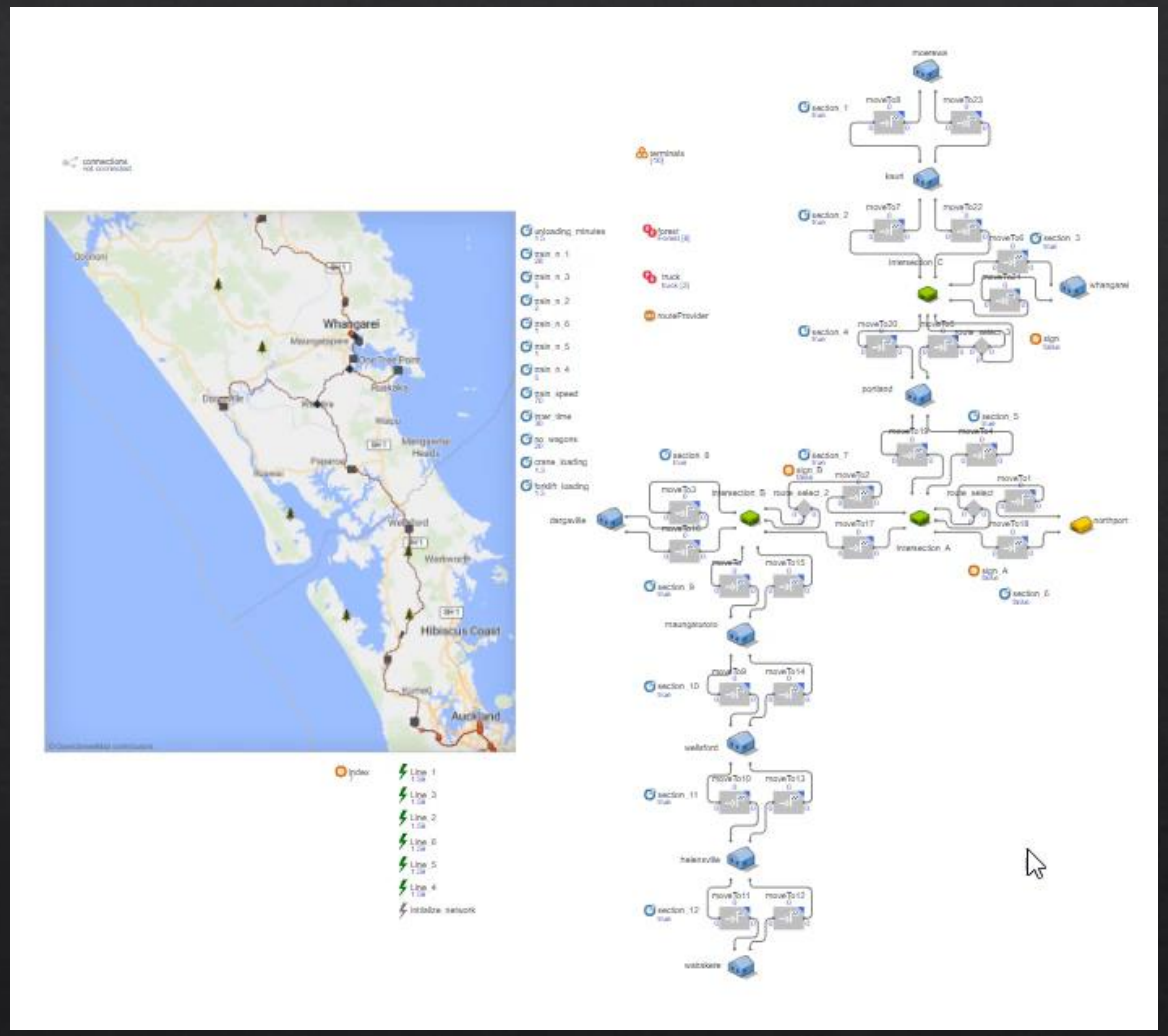

Gallardo et al. (2021)

# STRATCODE - Component 3 : Agent based discrete event simulation model

- Daily train services are simulated.
- Railway capacity (Double tracking, Train speed, Terminal performance )
- Upper part of the North Island.
- Coordinated movement of trains.
- Use of interfaces: Terminals are programmed to allocate distinct workflows depending on the type of load carried by trucks entering their premises.
- Allows to implement customized networks.

CONTRIBUTION

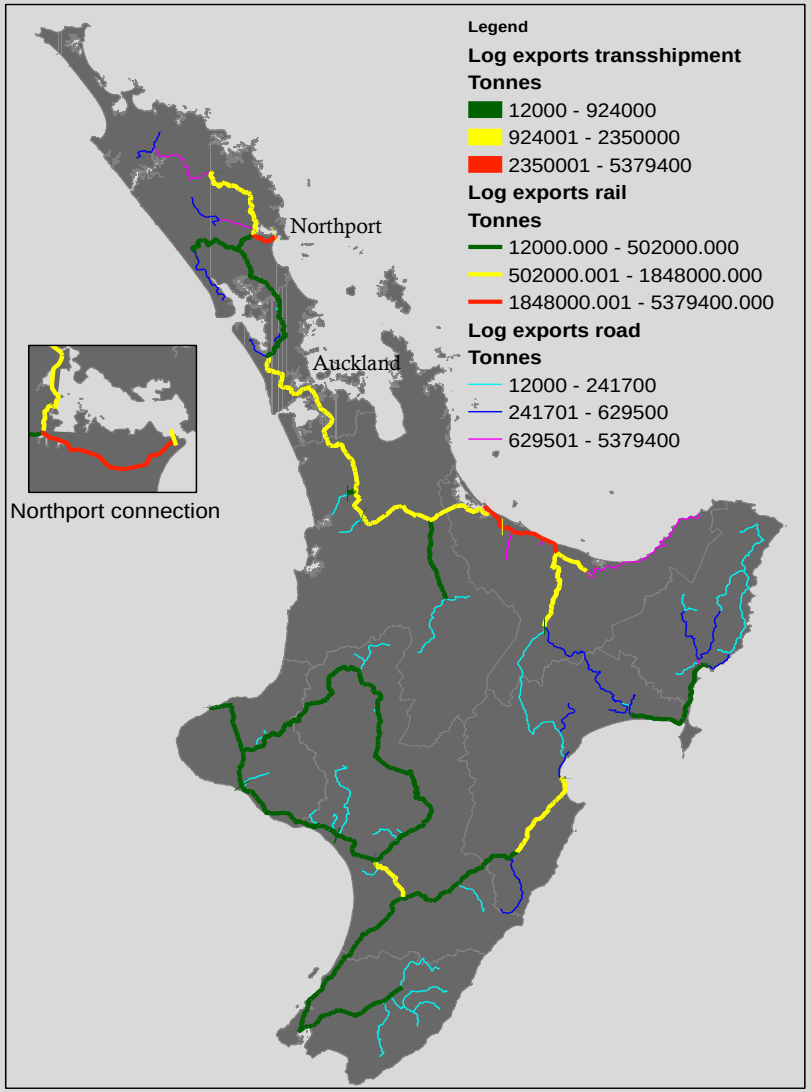
- Connects the perspectives between strategic and operational levels.
- Provides a holistic view of the system's performance derived from the interaction between transportation and terminal operations.
- Conceptual design for a system that can meet the current freight task with half the current fuel demand.



# Results

| Code | Description |
|---|---|
| BAU | Business as Usual |
| FS | Full Shift to Northport |
| WC | With rail connection to Northport |
| NC | No rail connection to Northport |
| E | Energy use optimization |
| T | Travel time optimization |

- Scenarios:
  - Port shift
  - Rail connection
  - E vs T
- Traffic Assessment :
  - Delineate railway services.
  - Obtain strategic terminal locations
  - Identify “hot” road edges

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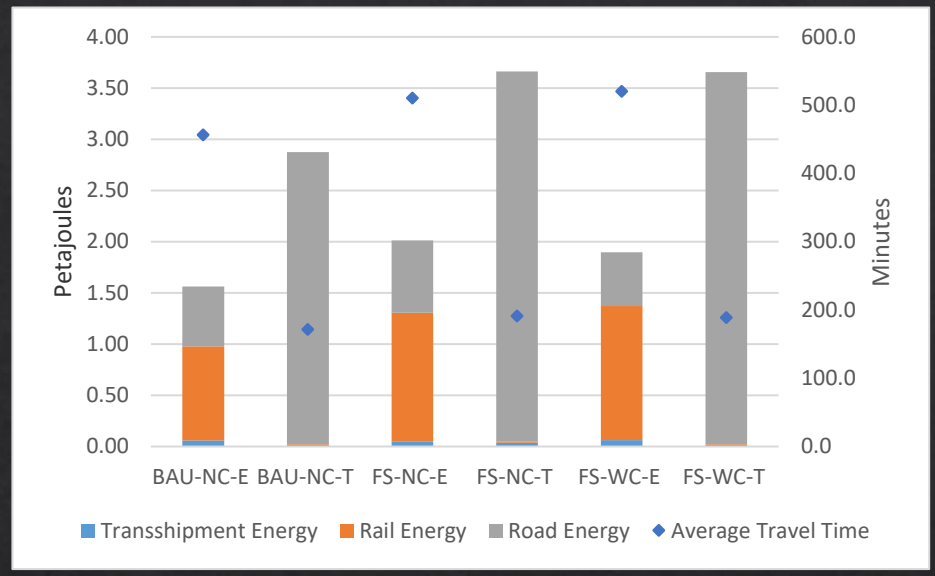
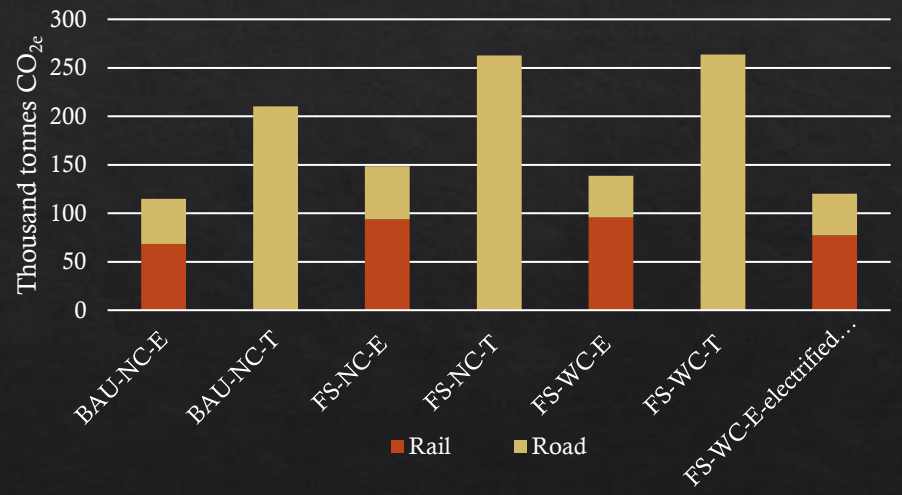
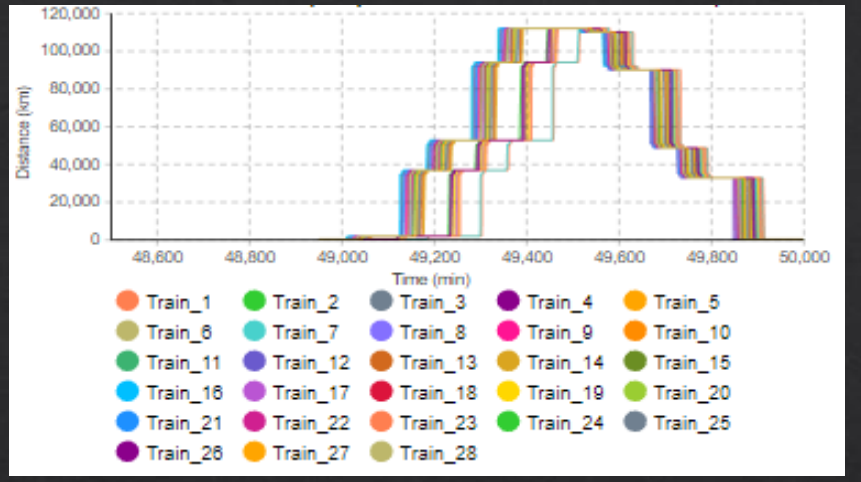


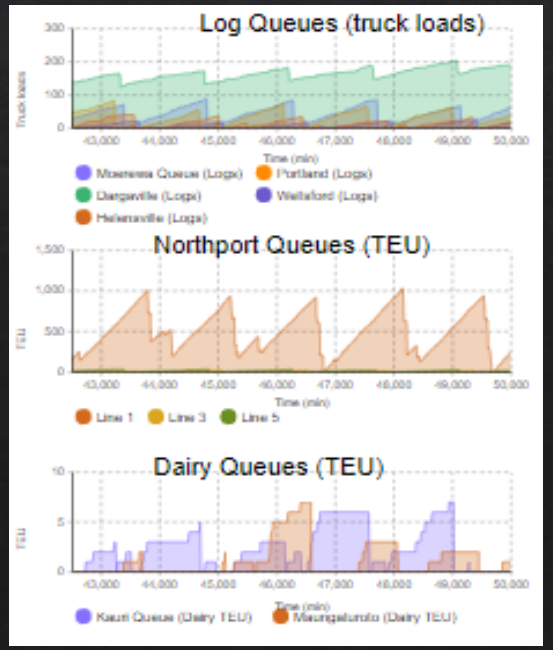

- Energy use optimization represents 170% higher delivery times.
- Time optimization represents 86% more energy demand.

# Results

| Description | Exp. 1 | Exp. 2 | Exp. 3 | Exp. 4 | Exp. 5 | Exp. 6 |
|---|---|---|---|---|---|---|
| Train speed (km/h) | 35 | 35 | 35 | 50 | 35 | 35 |
| Number of forklifts (Utilization %) | | | | | | |
| Moerewa | 5 (2.8%) | 3 (4.5%) | 3 (4.6%) | 3 (4.7%) | 3 (4.9%) | 3 (4.7%) |
| Northport | 10 (3.8%) | 8 (4.7%) | 8 (4.8%) | 8 (4.8%) | 8 (5.1%) | 8 (5.0%) |
| Portland | 10 (1.9%) | 3 (4.6%) | 3 (4.7%) | 3 (4.4%) | 3 (5.5%) | 3 (5.3%) |
| Dargaville | 5 (2.0%) | 3 (3.3%) | 3 (3.3%) | 3 (3.3%) | 3 (3.8%) | 3 (3.7%) |
| Wellsford | 5 (0.01%) | 1 (0.03%) | 1 (0.02%) | 1 (0.05%) | 1 (0.03%) | 1 (0.08%) |
| Helensville | 5 (1.6%) | 4 (2.1%) | 4 (2.1%) | 4 (1.9%) | 4 (1.9%) | 4 (1.9%) |
| Number of Cranes (Utilization %) | | | | | | |
| Moerewa | 5 (1.9%) | 3 (2.5%) | 3 (2.5%) | 3 (2.5%) | 3 (2.3%) | 3 (2.4%) |
| Kauri | 5 (0.09%) | 1 (0.4%) | 1 (0.4%) | 1 (0.6%) | 1 (0.5%) | 1 (0.5%) |
| Whangarei | 5 (0.7%) | 1 (3.6%) | 1 (3.4%) | 1 (3.4%) | 1 (3.8%) | 1 (3.8%) |
| Northport | 10 (12.4%) | 10 (13.0%) | 10 (13.5%) | 10 (13.4%) | 10 (11.5%) | 10 (10.5%) |
| Maungaturoto | 5 (0.04%) | 1 (0.1%) | 1 (0.2%) | 1 (0.2%) | 1 (0.2%) | 1 (0.1%) |
| Waitakere | 10 (10.8%) | 10 (11.3%) | 10 (11.2%) | 10 (11.1%) | 10 (12.3%) | 10 (12.3%) |
| Wagons per train | 20 | 20 | 20 | 20 | 25 | 25 |
| Double track segments | All single track | All single track | Wellsford-Waitakere | Wellsford-Waitakere | Wellsford-Waitakere | All single track |
| Total number of railyard tracks | 90 | 91 | 85 | 101 | 84 | 89 |

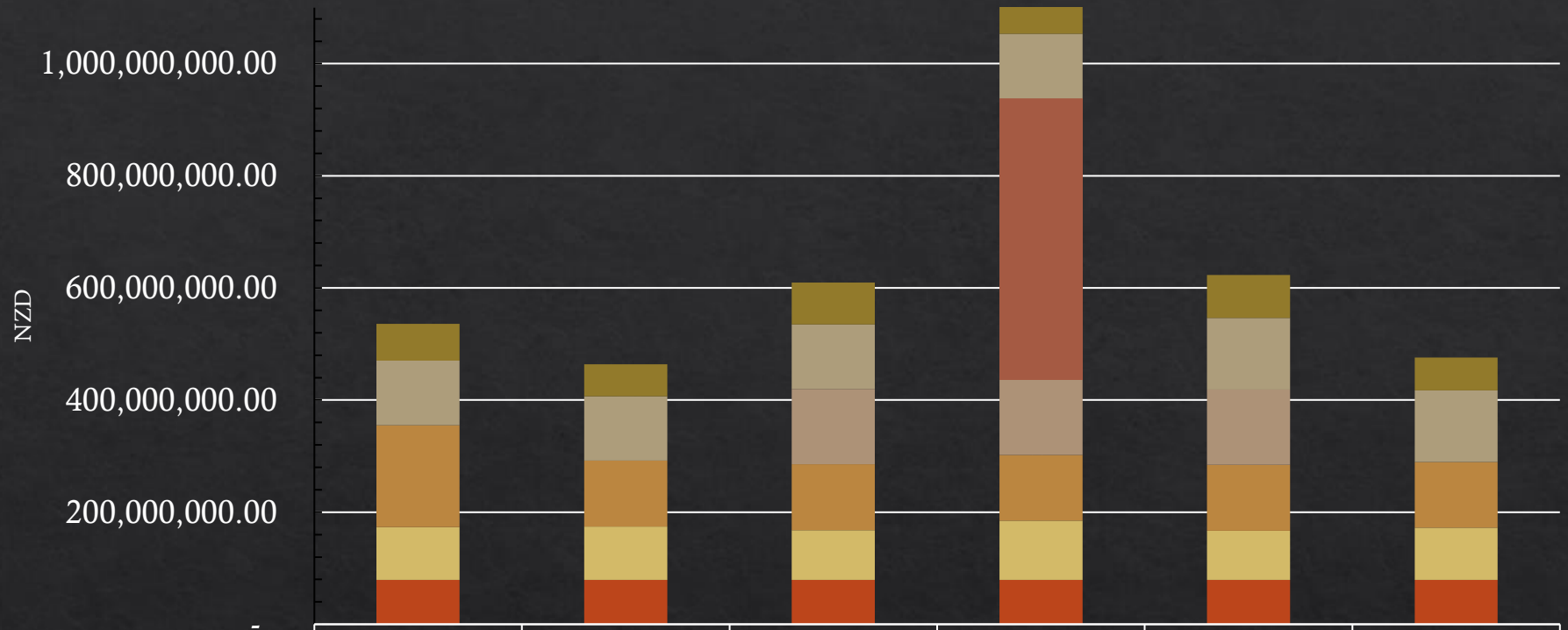



Timetable Experiment 1




Experiment 4

# Results




| | Exp. 1 | Exp. 2 | Exp. 3 | Exp. 4 | Exp. 5 | Exp. 6 |
|---|---|---|---|---|---|---|
| Design and Construction | 65,830,240.00 | 56,946,400.00 | 74,868,258.50 | 147,435,939.00 | 76,509,618.50 | 58,441,600.00 |
| Trains | 114,912,000.00 | 114,912,000.00 | 114,912,000.00 | 114,912,000.00 | 127,680,000.00 | 127,680,000.00 |
| High Speed Upgrade | - | - | - | 501,636,575.00 | - | - |
| Double Tracking | - | - | 134,277,275.00 | 134,277,275.00 | 134,277,275.00 | - |
| Handling equipment | 182,000,000.00 | 117,500,000.00 | 117,500,000.00 | 117,500,000.00 | 117,500,000.00 | 117,500,000.00 |
| Railyard | 93,960,000.00 | 95,004,000.00 | 88,740,000.00 | 105,444,000.00 | 87,696,000.00 | 92,916,000.00 |
| Land | 79,344,000.00 | 79,344,000.00 | 79,344,000.00 | 79,344,000.00 | 79,344,000.00 | 79,344,000.00 |

Gallardo et al. (2021)

…accessibility is the key

# Conclusions

- STRATCODE considers different components enhancing the realization of different objectives
- Distribution Component: key contribution of the approach was the allocation of representative locations.
- GIS-based intermodal planning algorithm enhanced multifold functionality.
- A fully intermodal setup can relieve urban congestion and reduce energy consumption and GHG by approximately 48% and 47%, respectively.
- Discrete Event Simulation allowed to evaluate trade-offs amongst parameters to streamline the arrangement that delivers the best performance.
- Results reveal that future investments should prioritize the development of intermodal hubs over other costly alternatives.

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**A Sequential Optimization-Simulation Approach for Planning the Transition to the Low Carbon Freight System with Case Study in the North Island of New Zealand**

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