Moving towards a sustainable transportation system for New Zealand

A summary of recent research

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IAEE 2020

Dual Plenary 4: Energy Transition in Transport
Background

• Transport sector:
  ▪ a main component of economic development

• Critical long-term challenge worldwide:
  ▪ 20% of global energy
  ▪ One-quarter of the overall energy-related CO2
  ▪ Road transport: three quarters of total transport emissions

• New Zealand’s unique emissions profile:
  ▪ NZ’s gross GHGs were 80.9 Mt CO2-e in 2017 = 2.2% increase from 2016 emissions, mainly caused by an increase of emissions from road transport
  ▪ Two largest emitters in 2017: Agriculture (48.1%) & Energy (40.7%)
  ▪ Road Transportation - 44% of total emissions from energy sector

Fig. 1 NZ’s gross and net emissions from 1990 to 2017, 23%+ (MfE, 2019) Fig. 2 International comparisons for per capita emissions in 2016 (MfE, 2019)
Sustainability and sustainable transportation

Sustainability criteria have significant implications for transport planning:

- Efficient use of fuel
- Optimal control of traffic

A sustainable transport system should provide the inhabitants:

- Mobility
- Accessibility

What are the current barriers that hinder us from developing a sustainable transport system?
What policies should our government adapt in order to make our transport system sustainable?

Figure 3. The Three Spheres of Sustainability
Source: Rodriguez et al. (2002).
Car ownership in New Zealand

Figure 4. Motor Vehicle Ownership among OECD members in 2010

Source: OECD, 2013.
Note: 2009 data for Canada and Ireland; 2011 data for Australia, Iceland, Japan, Mexico, New Zealand and Switzerland. 2010 data for the other countries. The OECD totals are based on OECD Secretariat's estimates.
Transport choice in New Zealand

Figure 5. Commuting to work in New Zealand (2009 – 2014)
Source: MoT, 2015
Fuels we use

Figure 6. Energy Greenhouse Gas Emissions by Fuel Type (kt CO₂-e)

Source: MBIE, 2015
Fuel consumption in Auckland

Figure 7. Annual fuel consumption ($NZD) in the Auckland region, average

Source: Constructive Thinking, 2014
Transport is the dominant sector, accounting for 43.6% of gross GHG emissions. CO₂ contributed 83.1%, CH₄ 10.5%, N₂O 1.7% and other GHGs 4.7%.
Congestion is a flipside of a city’s success.
Congestion in Auckland is well above comparable cities (i.e. Perth, Brisbane, Adelaide)
The economic cost of congestion is between $0.9 - $1.3 billion – equivalent to 1% and 1.4% of Auckland’s GDP (NZIER, 2017).
- hinders job matching
- reduces labour force participation
Environmental cost in New Zealand

<table>
<thead>
<tr>
<th>Unit Cost of Carbon (NZD$25)</th>
<th>Public Transport</th>
<th>Private Transport</th>
</tr>
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<tbody>
<tr>
<td>Per passenger and km</td>
<td>$0.001</td>
<td>$0.0067</td>
</tr>
<tr>
<td>To Society</td>
<td>$0.67 million</td>
<td>$57.76 million</td>
</tr>
</tbody>
</table>

Source: Jakob et al. (2006)

What happens if we increase the unit cost to **NZD$157**?
Road transport externalities -3

Figure 10. Share of total social cost of fatal and injury crashes in 2017 by cost component

Source: MoT, 2019

This is an increase of $0.6 billion (15%) compared to the previous year ($4.2 billion in 2016).
Objective: Maximise Net Benefits/Minimise Costs

Households Travel Demand and Mode Choice

- Public Transport: \{Bus, Train, Ferry\}
- Private Transport: \{ICEs, PEVs, wireless EVs\}
- Active Transport: \{Walk, Bike\}

Transport Supply

- Public Transport Network
  - Conventional
  - Static
  - Semi-Dynamic
  - Dynamic
- Roadway Infrastructure: \{IPT Options for wireless EVs\}
- Associated Infrastructure: \{Local network, Home, Work, Carpark\}
- Electricity Supply
- Solar/Battery

Road transport externalities \{Congestion, CO₂ emissions, Health issues\}

Exogenous Factors: Road Pricing \{Realtime, Fixed\}
Transport mode choice and social networks effect -1

• What factors are important when people make their travel decisions (which transport mode to use)?

• What is the probability that a transport user will choose to use public transport to go to work, given the transport mode preference of his/her neighbours and the characteristics of the regions where he/she lives?

Social Network Effects
Transit patronage: infrastructure service & accessibility; do not vary across neighbourhood

Positive Social Network Effects
When people prefer to use public transport together with other people as a result of social spillover

1) A utility gain through complementarity – not alone;
2) Avoiding a utility loss by not following others: meet & communicate, feel safer
3) A rise in utility level which stems from sending signals – feasible & reliable transport mode

Neighborhood effects/peer effects/social interactions/social spillovers
Transport mode choice and social networks effect -2

• Transport mode choice decision-making is dependent on social network effects.
• People’s transport mode choice decisions DO influence each other, positively.
  ▪ As the % of commuters taking public transport to work increases, we expect to see a spillover effect that changes some non-public transport users travel behaviour
• The social network effects = the 2nd largest impact (approx. 20%) on commuter’s transport mode choice (in Auckland, after household vehicles, approx. 30%).
  ▪ Shifting road user’s travel behaviour - a more economical way?
• For urban/transportation planners:
  ▪ Improving infrastructure
  ▪ Strengthening the city’s ‘greener’ transport mode culture
Future transport infrastructure for EVs

• Electrification of road transport: benefit of reducing emissions.
• The overall % is still miniscule compared to the large body of other types of vehicles in the fleet i.e. 1% of the entire vehicle fleet in NZ
• Barriers: *Range anxiety factor*, high price of EVs, the cost of batteries etc.
• Inductive Power Transfer (IPT) system (Zaheer and Covic, 2016): EVs can be energised wirelessly by embedding a roadway charging network while travelling in-motion.
  1. Stationary Inductive Power Transfer (SIPT)
  2. Semi-dynamic Inductive Power Transfer (SDIPT)
  3. Dynamic Inductive Power Transfer (DIPT)
• Economic Viability of IPT (Sheng et al., 2019)
  ▪ DIPT under PPP scheme
  ▪ More details will be delivered in the afternoon transport session
Transport emissions, road energy consumption and economic growth -1

• Reducing Methane emissions from agriculture? Nah...
• Reducing Energy demand (CO₂ emissions) from transport? Yes!
• This study:
  ▪ Investigates the impact of energy consumption from road transport and economic growth on CO₂ emissions from transport sectors;

A double-log quadratic equation is specified:

\[
\ln TCO2_t = \beta_0 + \beta_1 \ln REC_t + \beta_2 \ln GDP_t + \beta_3 \ln GDP^2_t + \epsilon_t \quad (1)
\]

- \( TCO2_t \) = the per capita carbon emissions from transport at time \( t \);
- \( REC_t \) is the per capita fossil fuel consumption at time \( t \) (road energy consumption);
- \( GDP_t \) is the per capita real GDP at time \( t \) (economic growth);
- \( GDP^2_t \) is the quadratic term of \( GDP_t \);
- \( \beta_1, \beta_2 \) and \( \beta_3 \) = impacts of \( REC_t, GDP_t \) and \( GDP^2_t \) on \( TCO2_t \), respectively;
- \( \beta_0 \) is the intercept;
- \( \epsilon_t \) is the disturbance term at time \( t \), \( i.i.d, \ mean = 0 \ & \ constant \ variance \).

▪ \( \beta_1 > 0 \): ↑ energy consumption ↑ economic activity ↑ CO₂ emissions.
▪ \( \beta_2 > 0 \) while \( \beta_3 < 0 \), EKC theory suggests:
  ▪ At the initial stages of economic growth, environmental pressure will tend to intensify,
  ▪ After reaching certain turning point in income per capita, environmental quality improves.
Transport emissions, road energy consumption and economic growth -2

1) Bidirectional causality (transport CO₂ emissions & road energy consumption):
   - The carbon abatement policy initiatives should be directed at energy use from fossil fuels and incentivise the adoption of alternative renewable energy sources.

   - 85%+ of NZ’s electricity: renewable sources, rapid adoption of EVs as replacements for ICE based passenger transport should be an obvious goal.

2) One-way causality (from economic growth to environmental pollutant emissions growth):
   - Transport policies addressing carbon emissions abatement, will not hurt economic growth.

   - Any investment in emission reduction strategies could serve as a practicable policy instrument for NZ govt. to achieve its net-zero emission target by 2050.
Traffic congestion issues -1

• Congestion
  ▪ Most prominent negative externality with economic cost: NZD$0.9 billion to NZD$1.3 billion ≈ 1% and 1.4% of Auckland’s GDP (NZIER, 2017)

• The Congestion Question in Auckland
  ▪ Auckland Council’s pilot study: how to reduce congestion on Auckland roads?
  ▪ No further progress as to date
  ▪ Congestion as a result of a binary choice problem between a ‘safe’ route and a ‘risky’ route
  ▪ Solutions? 1) Increase the road capacity 2) Charging toll fees 3) Justify the public transport price scheme

• A complementary method for achieving the “ideal” economically efficient vehicular diverging
  ▪ The combination of charging toll fee on the highway and applying an average pricing structure for public transportation

• We conduct a laboratory experiment to simulate transportation route-choice games
  ▪ Set the route-choice model of commuters as a coordination game
    - a set of \( I = \{1, 2, \cdots, n\} \) commuters
    - an action set: \( D_i = \{R, M\} \)
    - a binary choice: \( d_i \in D_i \)
    - identical ex-ante preferences
Traffic congestion issues -2

• Theoretical background
  • Constant vs Average pricing schemes; Equal Pay-off Equilibria V.S. Socially Optimal Equilibria; Definition of The Route-choice Games; Equilibrium Strategies; Parameters, Equilibria and Testable Hypotheses

• Experimental Interface: Example

![Experimental Interface Example]

• We obtained a panel dataset made by 240 subjects (i.e. 40 periods across 12 sessions)

• We conducted a session-level random effects regression analysis to examine reverse order effects

\[ \sigma^S_r - \sigma^* = \alpha + \beta r + \gamma d + \theta(rd) + \epsilon^S_r \]

• The reserve order effects ought to be captured by the sequence dummy \( d \)

• In total, is insignificant in all six regressions, therefore, we can conclude that reverse order effects do not exist in our sample.
The observations exhibit substantial variations: Choice behaviour might include an inherent error component.

Quantal Response Equilibrium (QRE) justification: with a game dependent logit specification (McKelvey and Palfrey, 1995).

Variations of the fitted QR are much lower than the raw data, we no longer observe the behaviour of over-use or under-use of the road.

Preliminary results:
- If we increase road capacity then congestion will increase
- Different policy mixes contribute to lowering congestion to a socially optimal level
- E.g. A combination of congestion tolls with price differentiation in public transport reduces congestion
A selection of our work


Takeaway messages

• Transport system is not a perfect system by any manner or means.

• We have learned a lot along the way, we made some mistakes, we corrected some mistakes.

• Climate-related targets can play an important role in legitimating transport practices that advance sustainable energy transition.

• A widespread transition to e-mobility and introduction of congestion tax is economically feasible – but socially and politically desirable?

• Flows of funding from the national Govt. to major cities and regions – urban policy-making.

Thank you 😊