27 March 2024

[redacted]

Via email: [redacted]

Dear [redacted]

I write in reply to your Official Information Act request, received on 21 February 2024. You requested:

> "any advice the Infrastructure Commission has given about the City Centre to Māngere/Airport light rail project.
>
> "I am seeking specifically the advice that was given to Auckland Light Rail Ltd from its establishment in October 2022 to present, as well as its predecessor the Auckland Light Rail Establishment Unit (which worked under Waka Kotahi & The Ministry of Transport) from March 2021-October 2022."

Our reply was due to you on 20 March, but we notified you by email on 20 March that we needed a week's extension to properly consult with colleagues at other agencies identified in documents we were proposing to release to you. We have now completed this consultation.

Information being released

Please find enclosed a pdf binder containing 33 documents being released to you. A list of these documents is provided at Annex 1.

I have decided to release the documents listed in Annex 1, subject to information being withheld under the following section of the Official Information Act, as applicable:

- **s9(2)(k):** Direct dial phone numbers of officials have been redacted under section 9(2)(k) in order to reduce the possibility of staff being exposed to phishing and other scams. This is because information released under the OIA may end up in the public domain, for example, on websites including Treasury's website.
- **S9(2)(b)(ii):** to protect information that, if released, would be likely unreasonably to prejudice a person's commercial position.

Information being withheld

I am not withholding any documents within scope of your request.

In making my decision, I have considered the public interest considerations in section 9(1) of the Official Information Act.

Please note that this letter (with your personal details removed) and the enclosed documents may be published on Te Waihanga's website.

This reply addresses the information you requested. You have the right to ask the Ombudsman to investigate and review my decision. You can find information about how to do this on the Ombudsman's website.

Yours sincerely

Barbara Tebbs
General Manager, Policy

Annex 1: Document schedule

Note that Te Waihanga routinely redacts staff phone numbers, under section s9(2)(k). TW = Te Waihanga (NZ Infrastructure Commission); NZTA = NZ Transport Agency (Waka Kotahi); MOT = Ministry of Transport; Tsy = the Treasury

Documents released			
Doc #	**Date**	**Document**	**Section of the Act applied**
1	26 August 2021	Email from TW to NZTA re comments on the delivery entity paper	s9(2)(k)
2	29 October 2021	Teams chat message from TW re heterogeneous effects of transport infrastructure	n/a
3	30 March 2022	Email from TW to MOT re ALR Cabinet paper	s9(2)(k)
4	6 April 2022	Email from TW to ALR re project support agreement	s9(2)(k)
5	27 April 2022	Email from TW to Tsy cc'ing others re TW's role supporting ALR decisions	s9(2)(k)
6 7	25 May 2022 23 March 2022	Email from TW to ALR, attaching: • TW Board paper re TW's position on ALR	s9(2)(k) S9(2)(b)(ii)
8	25 May 2022	Email from TW to ALR re population growth data	s9(2)(k)
9 10	1 June 2022	Email from TW to ALR re information and confidentiality arrangements, attaching: • draft information sharing and confidentiality agreement	s9(2)(k)
11	10 June 2022	Email from TW to Tsy re ALR sponsors' letter	s9(2)(k)
12	20 July 2022	Email from TW to MOT re ALR value capture	s9(2)(k)
13	14 Septem-ber 2022	Email from TW to ALR re need for PT investment post-COVID	s9(2)(k)

Documents released			
Doc #	**Date**	**Document**	**Section of the Act applied**
14	24 September 2022	Email from TW to workshop participants re ALR business case, attaching:	s9(2)(k)
15	2017	• published article by Laird and Venables re transport investment and economic performance	n/a
16		• published report by Nunns re transport investment and housing development	n/a
17	3 October 2022	Email from TW to KPMG cc others re ALR funding principles	s9(2)(k)
18	27 October 2022	Teams chat message from TW re risk reduction	n/a
19	27 October 2022	Teams chat message from TW re risk reduction	n/a
20	27 October 2022	Teams chat message from TW re benefit cost ratios of light rail projects in Europe	n/a
21	13 December 2022	Email from TW to ALR re draft slides, attaching:	s9(2)(k)
22		• draft slides re 'benchmarking NZ's infrastructure costs'	n/a
23	2 March 2023	Teams chat message from TW re cost optimisation and value for money	n/a
24	2 March 2023	Teams chat message from TW re costs of mining out station boxes	n/a
25	3 April 2023	Teams chat message from TW re non-transport enabling infrastructure	n/a
26	3 April 2023	Teams chat message from TW re modelling error as a source of uncertainty	n/a
27	1 June 2023	Teams chat message from TW re costings information	n/a
28	1 June 2023	Teams chat message from TW re option cost	n/a

Documents released			
Doc #	**Date**	**Document**	**Section of the Act applied**
29 30	22 June 2022	Teams chat message from TW re cost of infrastructure over time, attaching: • slide re costs of Trans-Tasman and Hawaiki cables	n/a n/a
31	22 June 2022	Teams chat message from TW re Monte Carlo analysis	n/a
32	22 June 2022	Teams chat message from TW re levers to manage down-side risks	n/a
33	3 July 2022	Email from TW to ALR with TW feedback on draft ALR Notice of Requirement (NoR)	s9(2)(k)

Doc 1

From: Dan Cameron
To: Lucy Riddiford
Cc: Tommy Parker; Brendan Herder; Julie Chuor
Subject: RE: Comments on the delivery entity paper
Date: Thursday, 26 August 2021 11:24:19 am

Hi Lucy,
I have included some comments below.
I would expect that the delivery entity form will probably evolve over time in any event once the ambition of MRT in Auckland and elsewhere in NZ becomes clearer. Certainly that has been my experience internationally with greenfields projects e.g

- Dubai – devolved into a metro separate division within the Transport agency;
- Tel Aviv – separate entity created just doing LRT in Tel Aviv -master planning and delivery;
- Sydney Metro – started as part of a project delivery office within TfNSW but carved off and corporatized.

All of them used international PMC delivery entities, albeit SM uses a mixed model. As they mature as organisations they rely less on the international PMCs . There are a number of very big advantages in this – their international reach in pulling in expertise as required, they take the resourcing risk including finding the PD, swapping out etc and manage the integration risk[for LRT's this is where things often go bad eg Cross Rail]. The CE etc of the delivery entities are never, in my experience, subject matter experts [albeit they obviously learn a lot on the journey] but generally senior officials who rely on the PMC PDs to manage the projects. The type of PD will also inevitably change as the project progresses through business case to procurement, delivery and operations.
The structure you propose is essentially the same as CRL but without an independent assurance layer ie the Sponsors have their own independent assurance provider for CRL. This is common for large scale projects and good practice. There are in our opinion a lot of issues with the CRL experience and I understand that there is draft Audit Office report on their governance. If you could get a copy of that you might find it helpful albeit that might be difficult.
There is also the question of Te Waihanga's role in the structure and indeed the Minister for Infrastructure , which is not addressed and needs to be considered. My personal preference is an observer to the Board proper and advisor to Minister of Infrastructure.
I have included some more specific comments from Julie below:

Delivery Entity Powers
It appears that much of the power sits with Auckland Transport with Waka Kotahi and Kainga Ora holding some powers themselves. If the DE Board is a group of independents, how will those with decision making powers like AT be required to comply with decisions made by the DE Board? Will the partnership model be strong enough to compel AT to do so including where the DE Board makes a decision that may not align with AT's views?

Delivery Entity – Partnering
The DE governance and partner roles were set out in attachment 3 but this wasn't provided. At a high level, the partnership model should form the basis of a framework that ensures the DE is sufficiently empowered with the authority it will required to ensure timely progress etc.

Sponsors Forum
The SF is noted as an oversight group but appears to be governance as well given the input they are expected to have. However, if it is a group of Ministers, this group should not be a

governance group and scope of their role should reflect a more limited involvement that leans more towards oversight.
Further clarity is required on the scope of decision making this group will have – if it is an escalation path, this should be clear. If there are matters that will be reserved solely for the SF then this should also be defined.

Partners Reference Group
We know from New Dunedin Hospital how problematic it becomes when you have such a group and their role is not well defined. This group should be a stakeholder group that inputs into the DE Board and not be allowed to drive direction or decisions.

DE Independent Board
I agree that having independence is key – but that they be appropriately informed, as per the proposed partnership model, by the PRG. However, they need to be empowered to make decisions despite any input from the PRG if they see fit.

Happy to discuss further.

Regards Dan

From: Lucy Riddiford <Lucy.Riddiford@nzta.govt.nz>
Sent: Wednesday, 25 August 2021 3:59 pm
To: Dan Cameron <Dan.Cameron@tewaihanga.govt.nz>
Cc: Tommy Parker <Tommy.parker@arup.com>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Subject: Comments on the delivery entity paper

Hi Dan

I think you mentioned that you might have some more detail on the delivery entity, procurement and funding paper that we discussed at the Board yesterday. Really keen to get those, so we can factor them into our thinking – as you can imagine, we're getting close to the deadline to close out comments, so that we can get things ready to bring through the Board in September. Let me know if it would be easier to have a conversation.

Ngā mihi

Lucy

Lucy Riddiford/ Workstream Lead – Governance & Policy
DDI [redacted] s9(2)(k)
Auckland Light Rail Group

Doc 2

From:	Peter Nunns
To:	Kaitlyn Stringer; Kathleen Wong; Kain Glensor; Gareth Fairweather; Angela Parker; Nick Potter; Alex Voutratzis; Dan Jenkins; Danny Tsai; Shrividya Ravi; Mieke Welvaert; Jade Mackay; Joanne Leung; Simon Kingham; 3QW.01 Ngake (External 14 pax); Dana Danilova; Iain McGlinchy; Matthew Skinner; Andrew de Montalk; Carla Hemmes; Greg Mossong; James McDevitt; Joni Philip; Josh Bullivant; Marian Willberg; Sam Harris; Jackie Van der berg; Sian Thompson; 8:teamsvisitor:3af5c473f7ee4302a3b0a5f42fc89fe3; Stuart Donovan; Eddie Dolan; Richard Deakin; David Hampton; Erana Sitterle [TSY]; Hannah Ouellet [TSY]; 8:orgid:8dccd190-a3f7-470d-83cb-ebfcfe318b6b; Wayne Heerdegen
Date:	Thursday, 28 October 2021 2:18:44 pm

FYI, on the heterogenous effects of transport infrastructure, here's some new research on the impact of Swiss highways, showing that rapid transit projects aren't the only ones that have distributional impacts: https://voxeu.org/article/how-highways-shape-regional-disparities

Doc 3

From: Blake Lepper
To: G.Fairweather@transport.govt.nz
Cc: Brendan Herder; Ross Copland; Sarah McNaught; Ben Wells [TSY]
Subject: RE: Auckland Light Rail Cabinet paper - departmental consultation
Date: Wednesday, 30 March 2022 2:47:47 pm
Attachments: image001.png

HI Gareth

Sorry for the delay in getting back to you and missing the deadline.

At this stage we have no comments on the Cabinet paper or the Terms of Reference.

I note that we have been discussing the project further internally and with our Board. We are particularly interested in providing independent advice to Ministers in advance of any further decisions they are making on:

- the business case parameters and processes, and
- the investment management system and assurance framework.

Would it please be possible to find a time to better understand timeframes for decisions and how we can best work together to ensure Ministers are fully aware of Te Waihanga's advice and views ahead of making any further decisions under the existing delegations.

If you can let Sarah (copied) know some availability I'm sure we can find a time that works for you.

Thanks and please don't hesitate to give me a call if you have any questions.

Regards
Blake

Blake Lepper | GM Infrastructure Delivery - Kaiwhakahaere Whakatū Hanganga
M: [redacted] **| Email:** **blake.lepper@tewaihanga.govt.nz**
https://tewaihanga.govt.nz/

s9(2)(k)

From: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Sent: Monday, 28 March 2022 8:33 am
To: Blake Lepper <Blake.Lepper@tewaihanga.govt.nz>; Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>; Helen Kerr <Helen.Kerr@tewaihanga.govt.nz>
Cc: Ross Copland <Ross.Copland@tewaihanga.govt.nz>
Subject: Fwd: Auckland Light Rail Cabinet paper - departmental consultation

FYI and for collective organisational comment.

Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

s9(2)(k)

From: Gareth Fairweather <G.Fairweather@transport.govt.nz>
Sent: Monday, March 28, 2022 8:16:21 AM
To: McPhail, Leigh <Leigh.McPhail@tearawhiti.govt.nz>; philip.stables@publicservice.govt.nz <philip.stables@publicservice.govt.nz>; Jym Clark <Jym.Clark@mfe.govt.nz>; Jamie.Higgison@mfe.govt.nz <Jamie.Higgison@mfe.govt.nz>; JSheppard@linz.govt.nz <JSheppard@linz.govt.nz>; Hayden Glass <Hayden.Glass@dpmc.govt.nz>; Graham.Nielsen@dia.govt.nz <Graham.Nielsen@dia.govt.nz>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Cc: Ben Wells <Ben.Wells@treasury.govt.nz>; Mary Barton <Mary.Barton@hud.govt.nz>; Chris Gulik <C.Gulik@transport.govt.nz>; Damien Looi <D.Looi@transport.govt.nz>; ALR Queries <ALRqueries@transport.govt.nz>
Subject: Auckland Light Rail Cabinet paper - departmental consultation

Kia ora koutou

Please find attached, for departmental consultation, a draft Cabinet paper which reports back to Cabinet on progress being made with the current phase of the Auckland Light Rail project. The paper is currently due to be considered by DEV on 13 April, and Cabinet on 19 April.

Many apologies for the tight timeframes but we would appreciate feedback by 2pm on Wednesday 30 March.

The primary purpose of the paper is to set out the Heads of Terms of a Sponsors Agreement that we are working up with Auckland Council. Ultimately, the intention is that the Crown, Auckland Council and mana whenua will all sign up as 'Sponsors' to this agreement, although we are still working through the steps to identify mana whenua representation at Sponsor level (and are currently engaging with Te Arawhiti and Ministers directly on this matter). For this reason, and the fact that there are still ongoing matters to resolve with Auckland Council's role as Sponsor, Cabinet will only be approving the Heads of Terms of the Sponsors' Agreement. Delegated authority for the three Sponsoring ministers (Housing, Finance, Transport) is sought from Cabinet to prepare and agree the final Sponsors agreement.

For your reference, an early draft of the Sponsors Agreement Heads of Terms is attached to this paper.

You will see that the paper is still work in progress, which reflects the pace at which officials from the three Sponsor agencies (Ministry of Transport, Treasury and MHUD) have been working with the ALR Unit, Auckland Council and others to progress through a complex process of scoping and initiating workstreams, and confirming and implementing the governance arrangements, alongside reporting back to Cabinet within the timeframes set by Ministers.

It is likely that the Cabinet paper will continue to evolve in the next week (further ministerial directions and input from Auckland Council are expected next week, prior to Ministerial consultation beginning at the end of this week).

We will also be sharing with agencies including Kāinga Ora and Waka Kotahi, although this will be done under separate cover.

Please reach out to myself, Chris, Damien, Ben or Mary if you have any questions or would like to discuss specific aspects of the paper. Apologies again for the tight timeframes.

Ngā mihi

Gareth

Gareth Fairweather (he / his / Mr)
Pou Whakahaere | Director
Te Manatū Waka Ministry of Transport
s9(2)(k) M: [redacted] | E: g.fairweather@transport.govt.nz | transport.govt.nz

Te Manatū Waka is a COVID-19 vaccinated workplace. *To meet our workplace safety requirements you will be asked to provide proof of vaccination when you visit our offices.*

Doc 4

From: Ross Copland
To: Tommy Parker
Cc: Blake Lepper
Subject: PSA
Date: Wednesday, 6 April 2022 11:16:50 am

Hi Tommy,
Here is the link to our project support agreement section.
https://www.tewaihanga.govt.nz/major-projects/project-support-agreements/
Talk soon.

Get Outlook for iOS

Doc 5

From:	Brendan Herder
To:	Ben Wells [TSY]
Cc:	ALR Queries; Gareth Fairweather; Elliot Clayton; c.ballantyne@transport.govt.nz; Jesse Doherty [TSY]; Blake Lepper; Liz Innes; Helen Kerr; Channa Wright
Subject:	RE: Te Waihanga role supporting ALR decisions
Date:	Wednesday, 27 April 2022 5:07:07 pm
Attachments:	image002.jpg image003.png image004.png

Hi Ben

Thank you for the opportunity to comment on the draft Sponsors' letter on DBC expectations.

We can discuss the workstreams and Te Waihanga's role when we meet later in the week but our pressing comments on the DBC expectations are set out below. Liz and I are happy to chat through them in the morning if that would be useful.

Te Waihanga feedback on Sponsors' Expectations letter:

At the completion of the Detailed Business Case Sponsors will be tasked with approving one of the single greatest infrastructure investment decisions for generations of New Zealanders. An exemplary Detailed Business Case process is essential for a project of this scale and ambition and we are committed to setting the project up for success.

We support most aspects of the Sponsors' letter and think it is useful to clearly articulate these expectations. However, in order to ensure that Sponsors can have complete confidence in the final Detailed Business Case recommendation we do not agree that the options analysis should be constrained to the extent signalled in the draft letter. Having robust counterfactuals to compare the preferred option against will significantly de-risk the decision making process, particularly in an environment where over the next 24 months construction costs may continue to escalate, interface and integration issues are yet to be resolved, and quantifiable benefits may remain uncertain.

Business Case Point of Entry and Scope

It is encouraging that the draft Sponsor's letter indicates there are aspects of the preferred tunnelled light rail option to be explored further through the DBC. However, the Treasury and Te Waihanga shared significant concerns in relation to the IBC options assessment and did not believe that Cabinet had sufficient information on which to make the decision to progress with the preferred IBC option. These concerns have not become any less relevant in the months that have followed. If anything, global and local conditions affecting ongoing construction cost escalation have made a complete analysis that captures all integrated costs and benefits even more important. We think that Sponsors should take this opportunity to task the project team with further evidencing the IBC recommendation.

Accordingly, we strongly advise that the ALR unit be empowered to carry out all analysis necessary to confirm that it is progressing with the option that best meets the investment objectives and provides the greatest benefits at lowest relative cost. If material factors such as grade separation are excluded from this analysis then the final DBC recommendation will lack a complete evidence base. The benefits of grade separation and other factors that were integral to Cabinet's decision on the IBC will of course be included in the analysis and reflected in the final DBC recommendation.

This process should be framed as ensuring that the unprecedented investment in the living standards of Aucklanders delivers the solution that best serves the city, rather than a potential unwinding of existing decisions. Sponsors have committed to a once in a generation public transport and urban development project that transforms the corridor, and should not reject robust economic analysis that ensures that this is delivered to their expectations.

ILM, BBC and Benefits Management Frameworks

We agree that established New Zealand guidance should be followed, with any departures to be based on international best practice for integrated transport and urban development projects of this nature. In particular, we note the location/corridor based nature of the project lends itself to consideration of the place-based business case methodologies being advanced in overseas jurisdictions. We also support consideration of staging or phased delivery as a means to de-risk the project, accelerate learning and realise some benefits early.

We welcome the opportunity to be involved in the updated Investment Logic Mapping exercise and are optimistic that an effective workshop with adequate preparation will help illuminate and address some of the concerns raised by the Treasury and Te Waihanga in relation to the IBC.

Investment Appraisal Methodology

We agree it is critical that the DBC improves upon the transport-oriented methodology adopted for the IBC. Robust cost benefit analysis is fundamental to any major investment decision, but for a project of this scale the economic analysis and investment option selection must be beyond reproach. We also acknowledge that integrating transport and urban development investment objectives, costs and benefits in this way is unique and will be challenging. Te Waihanga is willing to assist in the development of a bespoke methodology that can better inform the investment decision and provide precedent for future projects.

Financing Options and Contractual/Commercial/Procurement Model

The preferred contracting model should be determined after the technical solution has been further refined and risks understood. A key driver of the preferred contractual/commercial/procurement model will be the optimum packaging of various works requirements, including the extent to which works packages (e.g. civil works, tunnelling, bulk water and roading infrastructure, tracks, stations, rolling stock, depots, PT operations, maintenance) are aggregated to better manage the interface risk between component parts.

Some private financing tools are integrated into the procurement package to unlock innovative delivery models and potential funding sources (which offer financial and non-financial benefits), while other financing tools 'stand-alone' to merely spread the cash flow impact of the project for funders. The DBC phase should include market sounding activity to assist in identifying the preferred packaging and contracting model, including appropriate private financing options.

Kind regards
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

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From: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>
Sent: Friday, 22 April 2022 4:44 pm

To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>; Blake Lepper <Blake.Lepper@tewaihanga.govt.nz>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>; Channa Wright <Channa.Wright@tewaihanga.govt.nz>; alrqueries@transport.govt.nz; Jesse Doherty [TSY] <Jesse.Doherty@treasury.govt.nz>
Cc: ALR Queries <ALRqueries@transport.govt.nz>; Gareth Fairweather <G.Fairweather@transport.govt.nz>; Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>; Elliot Clayton <E.Clayton@transport.govt.nz>; c.ballantyne@transport.govt.nz
Subject: RE: Te Waihanga role supporting ALR decisions

[UNCLASSIFIED]

Hi all,

A little later than expected but I just wanted to follow up our meeting last week with the actions. I think we universally agreed to include TW on the Policy cross reference group (details TBC), and on the other items:

- **TW involvement in workstreams** – attached is the draft list of workstreams. Great if the TW team could identify which workstreams you would looking to be involved with during the Detailed Business Phase.
- **Potential observer role on the new ALR Board** – we discussed the merits of this, especially as a forum of TW to provide procurement advice to the Board as part of their project advisory function. We also discussed the need to be clear about what channels TW would reporting to out of the Board. I suggest we reflect on this and come back to discuss.
- **TW role in assessing DBC** – we didn't have a chance to discuss this fully, but suggest we do so in the next session also.
- **Draft Sponsor Letter setting out expectations for DBC/IMS –** this is one of the early mechanisms that we are using to set some high-level expectations around the scope of the DBC. Given TW interest in aspects of the IBC/DBC it would great to get (1) any feedback on the content, (2) whether TW want to be referenced in the letter including wanting to be consulted alongside other departments. See attached email to the Unit and Council on this letter. We are seeking feedback by Wednesday if possible, to deliver to Ministers for agreement.

Channa, Jess, Jesse – appreciate if you could set up a 1 hour meeting late next week between us all.

Brendan/Blake – sorry I don't seem to have your colleagues email who joined us last week. Appreciate if you can forward on.

Have a great long weekend.

Cheers,
Ben

Ben Wells | Principal Advisor - National Infrastructure Unit | Auckland Policy Office | **Te Tai Ōhanga – The Treasury**
s9(2)(k) Tel: [redacted] | Ben.Wells@treasury.govt.nz

-----Original Appointment-----
From: ALR Queries <ALRqueries@transport.govt.nz>
Sent: Monday, 11 April 2022 4:21 pm
To: ALR Queries; ALR Queries; Gareth Fairweather; Ben Wells; brendan.herder@infracom.govt.nz; Danni.Thian@tewaihanga.govt.nz; Blake.Lepper@tewaihanga.govt.nz
Cc: Brendan Herder
Subject: Te Waihanga role supporting ALR decisions
When: Thursday, 14 April 2022 11:00 am-12:00 pm (UTC+12:00) Auckland, Wellington.
Where: Microsoft Teams Meeting

Kia ora koutou,

As discussed with Ben Wells, this is good time to have this discussion, and for Te Waihanga team to get an update on how the workstreams scopes and governance arrangements are imbedding – and what role would best suit TW within them.

Please note this is an online meeting.

Ngā mihi nui,

Jessica Ziegler (she/her)
Kairuruku – Ara Tereina ki Tāmaki | Programme Coordinator – Auckland Light Rail
Te Manatū Waka Ministry of Transport
s9(2)(k) M: [redacted] | E: ALRqueries@transport.govt.nz | transport.govt.nz

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Microsoft Teams meeting

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Doc 6

From:	Helen Kerr
To:	Lee Welch
Cc:	Tommy Parker; Jen Scott; Blake Lepper; Brendan Herder
Subject:	RE: ALR & Te Waihanga Session 2 June
Date:	Wednesday, 25 May 2022 8:51:49 am
Attachments:	2.4 Auckland Light Rail - Te Waihanga Position.pdf image001.png image002.jpg

Hi Lee and Tommy,

Thanks again for inviting us up next week. Attached is a copy of an internal board paper regarding Auckland Light Rail. It contains the background thinking of our initial thoughts on the business case and our initial concerns about the project. It's been provided for transparency, please keep its circulation limited. I've summarised the key issues from the paper below, and whilst we know you wont have all the answers now, these are the items we are keen to talk to you about next Thursday.

- **Scope and Cost Control:** How will ALR manage scope and cost control, how will sponsor agencies be held responsible for cost/scope increases (especially those not in the alliance), what will happen if the P90 figure is reached at the end of the next project phase (as at this point the BCR falls below 1) and has the project considered using a maximum value cap (for example $X billion and making the required compromises which deliver the best outcome but for that set figure)?
- **Benefits Realistion**: What work is ALR undertaking with development partners, what will Auckland Council need to deliver on in order for the project to be a success and how will ALR enable this and or manage this and or deliver this on behalf of Auckland Council, what legislation work might need to get started now so that its ready in time for the project?

- **Station locations, route alignment and grade separation** brief overview of options considered, why the current option has been selected (when there was a lower value option which provided a BCR over 1), what options are still being explored and how the current scheme fits within the wider light rail (and ATAP) program
- **People** how will the project attract qualified people, consultants and contractors to successfully deliver the project?
- **Net Zero by 2050:** what is the project doing and/or what can government do to assist in reaching net zero targets (research and development into recycled aggregates on concrete/pavement and use of alternative materials, better use of existing infrastructure through the at grade sections?)
- **Lessons learnt:** how is the project taking on board lessons learnt from other large scale projects in New Zealand especially CRL and similar overseas projects

If you have any thoughts on how we could help the project, any issues you'd like us to advocate on your behalf we would also be keen on hearing those on Thursday.
Any questions, please let me know.

Helen

From: Helen Kerr

Sent: Monday, 23 May 2022 3:54 pm
To: Lee Welch <lee.welch@aucklandlightrail.govt.nz>
Cc: Tommy Parker <tommy.parker@aucklandlightrail.govt.nz>; Jen Scott <jen.scott@aucklandlightrail.govt.nz>; Blake Lepper <Blake.Lepper@tewaihanga.govt.nz>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Subject: RE: ALR & Te Waihanga Session 2 June

Hi Lee,

Thanks for the invite. Thursday the 2nd from 1-4pm suits us and we will send you through a formal list of discussion points within the next few days.

Kind regards,
Helen

From: Lee Welch <lee.welch@aucklandlightrail.govt.nz>
Sent: Friday, 20 May 2022 6:03 pm
To: Helen Kerr <Helen.Kerr@tewaihanga.govt.nz>
Cc: Tommy Parker <tommy.parker@aucklandlightrail.govt.nz>; Jen Scott <jen.scott@aucklandlightrail.govt.nz>
Subject: FW: ALR & Te Waihanga Session 2 June

Good Afternoon Helen,

I hope this email finds you well and apologies for the delay in responding the email below.
Tommy is more than happy to host the workshop in the ALR Project Office on 2 June.
Our preference would be to hold the workshop in the afternoon, between 1-4pm.

Would you like to check in with Blake and Brendan a come back to me on:

- Preferred timing for 2 June
- Formal list of discussion points

I believe that Blake was invited to attended our Site Tour on Tuesday. I hope he enjoyed it if he was able to attend.
Have a nice weekend and I look forward to hearing from you.
Kind regards,

Lee

Lee Welch | PA to Tommy Parker

D. [redacted] | M. [redacted] s9(2)(k)
E. Lee.welch@aucklandlightrail.govt.nz

Bringing us closer

From: Helen Kerr <Helen.Kerr@tewaihanga.govt.nz>
Sent: Tuesday, May 17, 2022 11:21 AM
To: Tommy Parker <tommy.parker@aucklandlightrail.govt.nz>
Subject: ALR / Te Waihanga

Hi Tommy,

It was nice catching up at the conference the other day. Blake and Brendan (and I) would be keen to come up and spend some time with your team discussing the ALR project – I'm not sure if either of them have contacted you about this? Blake is up in Auckland on the 1st June and we wondered if the 2nd June might work, if not perhaps you could suggest some alternates? Te Waihanga have a few questions that would be really great if you could try and answer - I will get an official / formal list to send across to you (if you'll agree to have us – which is totally optional) but my understanding of our feedback to you is mainly around the following four issues:

1. What happens if the $15b ends up at the upper end of the cost range (near the P90) – how will the ALR manage this? If the costs get too large will the team want to revert to a surface option? If reverting to an alternate might still happen how will the team manage parallel work streams? If the tunnel option is to remain preferred how will the team manage cost and scope creep to ensure that the option remains affordable (especially given the uncertainty around scope in regards to urban design and place making and urban planning – it seems there is significant opportunity for the scope of ALR to expand)
2. What happens if the urban outcomes and mode shift aren't delivered on (and therefore benefits not realised) – how will the ALR team manage this aspect of the project considering it is essential to its success but perhaps out of its control? (and is there anything we could do to help)
3. What work is the team doing with private developers to potentially in part fund the project via development contributions or private financing and what legislation or government process is in the way of this occurring (and is there anything we could do to help)
4. Have the team given consideration to embedded carbon, how this can be reduced and how net carbon neutrality can be achieved earlier than the current prediction (which is post 2050)?

This is my own paraphrasing so please don't take this as formal advice - I just thought I'd get in contact to see if it was okay for us to take up your offer, check out what timing might work (again totally optional) and give you a bit of a heads up on what I think the team will be interested in.

Helen

s9(2)(k)

Helen Kerr | Principal Advisor | New Zealand Infrastructure Commission, Te Waihanga|
Mobile: [redacted] | Email: helen.kerr@tewaihanga.govt.nz

2.4 Auckland Light Rail - agree the Commission's position

Author: Brendan Herder, Principal Infrastructure Advisor

Approver: Ross Copland, Chief Executive

Date: 23 March 2022

Purpose

The purpose of this paper is to seek the Board's **agreement** to how Te Waihanga will engage in the continuing development of the Auckland Light Rail project. This involves:

- Agreeing the key issues we will seek to engage on and positions we will advocate for both publicly and within formal advice on the project to decision makers.
- Developing an engagement strategy that will increase our traction on these key issues.
- Learning from experience with City Rail Link and applying the lessons to Auckland Light Rail.

Actions sought

Note that Te Waihanga worked closely with the Treasury on reviewing the indicative business case for Auckland Light Rail and that our combined advice is publicly available.

Note that we consider the current business case process is not aligned with best practice.

Note we have developed a set of key position statements that we think inform important actions for the Government to take to better set the project up for success.

Agree to the proposed key position statements to guide our engagement on this project.

Agree to Management engaging with the Minister for Infrastructure on Terms of Reference for an urgent review of the City Rail Link project.

Report

1. Background and context

The proposal to build a light rail line from Auckland CBD to the Airport was first proposed in 1990. Auckland Transport investigations commenced in 2014 highlighting capacity limits on the bus network along the CBD-Airport route.

On 29 March 2021, the Cabinet Business Committee agreed that an Establishment Unit be tasked with preparing an Indicative Business Case (IBC) considering the options. Cabinet invited the Minister of Transport, in consultation with relevant portfolio Ministers, to report back in November 2021 with recommendations on a preferred way forward for the project, including route, mode, funding and financing, the form of a delivery entity, and decision gateways.

In line with the Cabinet directive, in October 2021 the Establishment Unit provided their Indicative Business Case which included recommendations on route and mode. The short-listed options included surface light rail, tunnelled light rail and tunnelled light metro.

Te Waihanga worked closely with the Treasury on reviewing the indicative business case with a focus on testing the robustness of the case and the strength of the recommendations made.

Through Treasury, the advice provided to the Minister of Finance (T2021/2570 refers), highlighted the following[1]:

- *The economic case shows that only half of the modelled project benefits relate to traditional transport benefits such as travel time savings or reliability benefits. The other half of project benefits relate to wider economic benefits,… Based on the lack of detail provided on how urban development will be achieved, we have low confidence that these benefits will be realised, resulting in poor public value.*
- *To give the project the best chance of success, we recommend that decisions on route and mode are deferred at this point in time given insufficient urban analysis, social licence and robust cost information….Taking the time now to get the design and alignment right, in a process that follows international best practice and includes stakeholders in its development, will ultimately speed up delivery.*
- *On the specific recommended option of tunnelled light rail, … we do not consider the key factors influencing the Establishment Unit's position (urban growth potential, disruption and ability to integrate with the North Shore) sufficiently support the recommended option, over the surface running light rail option.*

Notwithstanding officials' advice, the Cabinet paper "Auckland Light Rail - decision to progress"[2] suggested project success required the Government and its partners "*to make bold decisions and enduring commitments"* including on the scope of the project. Cabinet agreed to a 24km partially-

[1] This advice has been proactively released and is publicly available at: https://www.treasury.govt.nz/sites/default/files/2022-03/alr-4533296.pdf . While framed as Treasury advice it notes: *We have worked closely with Te Waihanga in undertaking this review, and there is alignment on the conclusions we have reached.*

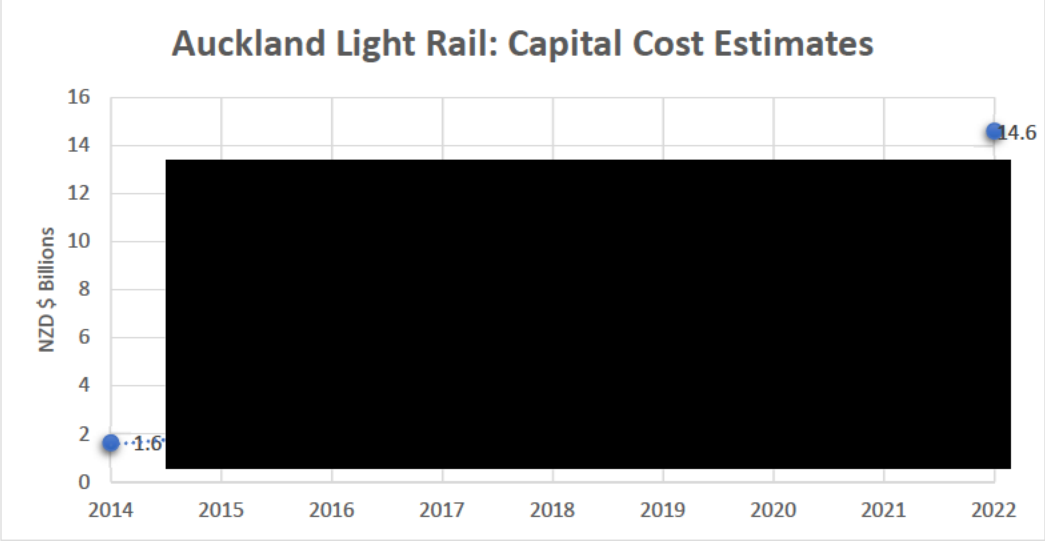
[2] https://www.transport.govt.nz//assets/Uploads/OC210779-Auckland-Light-Rail-decision-to-progress-Cabinet-Paper.pdf

tunnelled light rail solution and instructed further development of the preferred option through technical project design and development, policy implementation and decision-making under the guidance of a skills-based board. This decision was announced on 28 January 2022 and included an unforeseen announcement to proceed with a crossing of the Waitemata harbour (with tunnelled Light Rail the likely transport mode) to provide additional transport capacity for the North Shore.

2. History of Cost Increases

Three separate capital cost estimates were made for a CBD-Airport light rail in 2014 which ranged from $1.63 to $3.31 billion. Over the following 8 years the capital cost estimates evolved as follows:

- 2015 peer review by Ian Wallis: $2.6 billion (adopting WT Partnership estimate)
- 2017 AT Light Rail Transit Update: $2.17 to $2.99 billion
- 2018 Minister of Transport Light Rail recommendation to Cabinet: $4 billion
- [redacted] s9(2)(b)(ii)
- 2021 CC2M Indicative Business Case options: $9 to $14.6 billion (P50)
- 2022 Government Announcement: $14.6 to $23.3 billion (P50 – P95 tunnelled option)



s9(2)(b)(ii)

Figure 1: Auckland Light Rail capital costs are 9x the original cost estimate, yet the BCR remains >1 according to the IBC.

Recent history of major transport projects has demonstrated achieving P50[3] cost estimates is far from certain. The Northern Pathway Bridge proposal was approved by the current Minster of Transport at approximately double its P95 value. The P95 for Auckland Light Rail is $23.3 billion – a figure which recent history would suggest is an entirely possible outcome for the final build cost. **The Benefit Cost Ratio is so slim that at the P95 price the sum of all benefits is considerably less than the costs resulting in a project that would deliver billions of dollars of net cost to New Zealand**.

[3] A P50 cost estimate has an accuracy range of -50% to +100%

There are other significant factors in the capital and operating cost budget worth noting:

- **Over half of the benefits are non-transport related** including from densification along the route. **The IBC does not include the associated costs** of infrastructure required to complete this infill housing (estimated at circa $7 billion for the greenfield sites alone).
- It is not entirely clear how Financing and Insurance costs have been handled in the IBC.
- Operating Cost Concerns
    - The operating cost estimates included in the business case require careful review.
    - A 2015 peer review of the Auckland Transport Light Rail business case by Ian Wallis Associated Ltd highlighted that the opex assumptions had been "very considerably under-estimated" at $36 million per annum versus the peer reviewers estimate of $116 million per annum.
    - City Rail Link 2015 business case estimates the cost of operating its 3.5km twin tunnels will be $35 million to $64 million per annum. 7 years have elapsed since that business case and capital costs have doubled from those projected in the same business case. Without speculating on the operating cost inflation, it would seem prudent to assess the operating costs at up to double these figures – say $70 million to $128 million per annum. The length of tunnel for the preferred option is estimated to be 3-4x the length of the CRL tunnel and the overall line is 24km long suggesting operating costs could be far greater than the P90 value of $119.3million reported in the IBC.
    - Auckland Light Rail IBC states opex of $104.4 million per annum for the surface option and just $14.9 million per annum more for the tunnelled option despite a capital cost increase of $5.6 billion.
        - To put this in context, the insurance cost difference alone would typically add around 1-1.5% of the capital cost, in this case $56-84 million per annum.
        - The incremental financing costs at a WACC rate of 5% would add $280 million per annum.
        - Tunnels are very expensive and complex to operate. In 2018 it was reported that the Waterview tunnel costs approximately $16 million per annum to operate – by comparison to Auckland Light Rail it is short and simple.
    - Despite the possible under-stating of the operating costs in the IBC, the Tunnelled Light Rail option has the highest lifecycle (60 year) operating costs of each of the 3 short-listed options at $17.46 billion.
    - Putting aside the issue of how to finance the initial investment, the funding mix required to operate this rather short 24km's of transport network over its 60-year life is a potentially greater challenge when faced with a National Land Transport Fund that is over capacity and projected farebox recovery (ticket sales) far below the annual direct operating costs.
    - Very little public discourse has yet been had on who will pay for Auckland Light Rail – neither the capital nor operating costs, both of which are very material. Our staff that are close to the project have seen early indications that Central Government (i.e. national taxpayers, the majority of whom will derive no direct benefit from the project) will be expected to fund a large share.
- Transparency
    - The project has and continues to advance in an opaque manner.

- Auckland Light Rail proactively released the 35 appendices supporting the Indicative Business Case, however they are so heavily redacted they reveal too little for the reader to scrutinise the assumptions.
- Both capital and operating cost assumptions and results are almost entirely redacted in appendix 15.
- The ongoing lack of transparency heightens the importance of the role of Te Waihanga on this project given our likely improved access to information beyond what is being made available to the public.

Table 44 Ongoing cost summary (60 years, NZ$m) (nominal)

Cost element	Option 1B Light Rail	Option 2A Light Metro	Option 3 Tunnelled Light Rail
Operations and maintenance	9,165	7,498	10,451
Lifecycle	2,954	5,014	3,757
Rolling stock replacement	1,308	1,372	1,344
Sub-total opex costs	*13,427*	*13,885*	*15,552*
Delivery Entity post-commencement	731	771	729
Total (base)	**14,158**	**14,655**	**16,281**
Total (P50)	**14,568**	**15,092**	**16,745**
Total (P90)	**15,163**	**15,827**	**17,466**

Figure 2: Whole of life operating costs (expressed in nominal terms)

3. Comparison with International Light Rail Projects

A 2019 paper[4] by Neil Douglas and Daryl Cockburn investigated the cost of light rail projects completed recently in Australia and compared them with projected costs for Auckland and Wellington Light Rail proposals.

Douglas found that "Australian Light Rail construction costs have soared to around $125 million per kilometre", while he noted that the current estimate at the time for Auckland Light Rail (2018 figure of $3.7 billion) produced a unit rate of $168million/km. The paper is very worthwhile skimming over – the numbers are quite revealing.

The more concerning comparison comes when you plug in the latest P50 and P95 cost estimates for Auckland Light Rail which Cabinet approved in January 2022. These come to **$608million/km** and **$983million/km** respectively. **The most expensive Light Rail project ever undertaken in Australia**

[4] https://trid.trb.org/view/1693155

was the Sydney CBD project which opened in 2020 and reached a figure of 'just' AUD$250million/km.

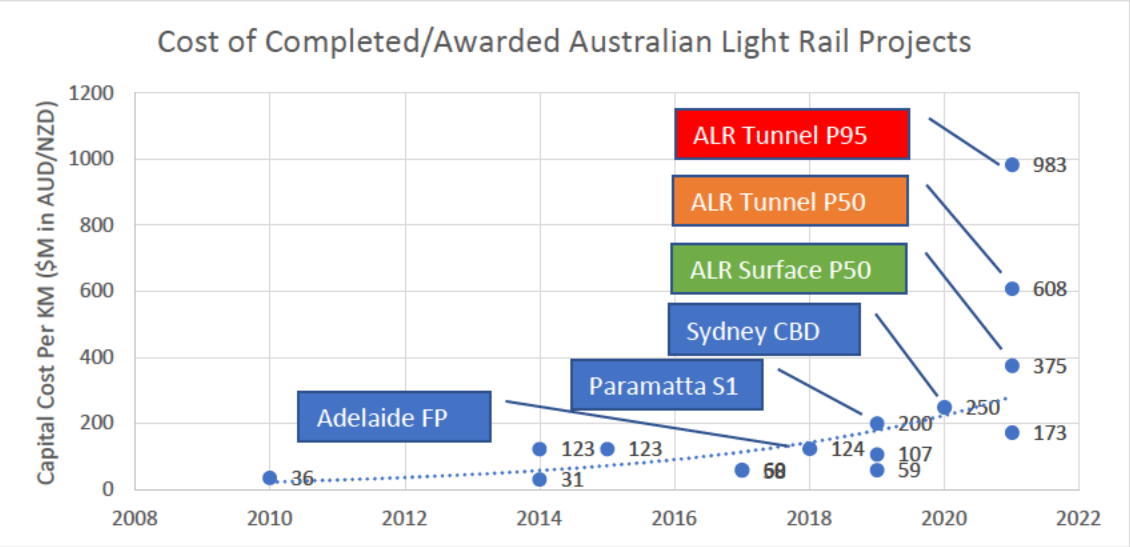


Figure 3: Adapted from Douglas, N. (2019) et al, with latest cost estimates for ALR added.

Peter Nunns, Director Economics at Te Waihanga, undertook further international analysis and noted:

- *The project team expects to buy a single 25km route about half of which is in a tunnel and half of which is at grade.*
- *For the same price, here's what other countries have delivered:*
  - *If we matched Canadian, Australian, or Spanish costs for at-grade light rail, **we could have a 190-200km long network.***
  - *If we matched French or US costs for at-grade light rail, we could have a 140-150km network*
  - *If we matched Spanish or Italian costs for tunnelled light rail, we could have a 50-60km network*
- *Based on the international experience, a realistic aspiration would be that we should be able to build around 100km of light rail for $12 billion, taking into account the fact that Auckland has some topographic challenges and that you'd have to build some structures to address them.*
- *This would be enough to:*
  - *Build a light rail line from the city centre to the airport (roughly 25km)*
  - *Build another line from the city centre to Westgate (roughly 20km)*
  - *Build a third line in south/east Auckland (eg airport to Botany, roughly 18km)*
  - *Build two light rail lines in Christchurch (eg city centre to Rolleston and city centre to Kaiapoi, roughly 43km).*

4. Auckland Transport Alignment Project (ATAP)

The Auckland Transport Alignment Project (ATAP) brings together central government and Auckland Council to strategically align transport objectives and investment priorities for Auckland. An important part of the work is to agree a ten-year investment package that guides the Auckland Regional Land Transport Plan and the National Land Transport Programme. The ATAP 2021-31 programme invests around $31.4 billion into critical transport infrastructure and services across Auckland. It focuses on encouraging the shift from private cars to public transport, walking and cycling and addressing Auckland's longer-term challenges of climate change and housing development.[5]

It is worth noting that Auckland Light Rail is not budgeted for within the $31 billion ATAP.

Together with the commitment to pursue a second harbour crossing, the 28 January announcement commits an additional $30 billion of capital funding to significant transport projects in Auckland over the same period. This assumes of course that the ATAP and ALR programmes are delivered within their budgets.

Already the New Zealand Upgrade Programme (NZUP) component of ATAP was re-baselined in early 2021 after significant concerns about budget costs were raised (including by Te Waihanga) during 2020. The re-baselining resulted in estimates for the programme reaching nearly double the original budget[6] requiring $6 billion in addition to the original $6.8 billion[7] to deliver the scope. Approximately 18 months had elapsed between the original announcement and the announcement that the costs had doubled.

The combined investments of ATAP, Auckland Light Rail City Centre to the Airport, and Light Rail tunnel connection to the North Shore exceed $60 billion of proposed transport investment over the next 10-15 years.

Most notably, the **announcements made on 28 January by the Minister of Finance and Minister of Transport appear to commit Auckland to a city-wide roll out of Light Rail lines to the North and North West**, a programme of investment which is yet to be studied but may represent many tens of billions of dollars in addition to the initial stage.

[5] https://www.transport.govt.nz//assets/Uploads/Report/ATAP20212031.pdf
[6] https://www.beehive.govt.nz/release/nz-upgrade-programme-kept-track
[7] https://www.beehive.govt.nz/release/transport-infrastructure-upgrades-get-nz-moving-and-prepared-future

5. Significance of the Auckland Light Rail project

The Auckland Light Rail (ALR) project is the most material project on the immediate horizon.

The combined costs of ALR and a future additional Waitematā Harbour crossing (which were announced together by the Government) would have a greater capital value than our entire Health or Education portfolios and would be approaching the valuation of the entire state highway network.

The fiscal risks with the preferred option can be measured in percentage points of GDP. Poorly executed this project could have significant consequences for current and future New Zealanders, limiting our financial headroom for investing in other infrastructure or responding to internal or external shocks and stresses.

A rupture on the Alpine Fault (75% probability over 50 years) is likely to cost New Zealand tens of billions. In 2018 a Treasury review of the potential direct and indirect costs of a Wellington earthquake alone was put at $65 billion. It is clear that the opportunity costs of a project of the scale of Auckland Light Rail are felt well beyond the transport sector, and well beyond Auckland.

In this context, it is important that the Infrastructure Commission express clear and coherent views on ALR as a project and the wider implications of pushing ahead.

Key position statements

Te Waihanga staff have several significant concerns about the current direction of the project. Project decisions to date perform poorly when compared against the principles of project decision making set out in the New Zealand Infrastructure Strategy, Rautaki Hanganga o Aotearoa. We have also raised specific concerns around the process to appoint the Governance Board, Project Director, and consultants.

Te Waihanga's strategic response must consider the significant momentum and political commitment towards a particular project solution – tunnelled light rail. To be influential in this context we need to identify our organisational position and then decide how to champion that position carefully and strategically.

It has become evident on this project and the recent Northern Pathway, that the sunk cost fallacy and post-decision rationalisation are very powerful forces influencing the investment decisions of Government. It seems that almost limitless cost increases will remain acceptable provided equally optimistic and wide-reaching benefits can be computed to justify continuation of projects that clearly require radical rethinking or rescoping.

The IBC has many signs of confirmation bias which is on display most visibly in the benefits analysis and in the lifecycle carbon analysis which appears to ignore assumptions that would profoundly change the outcome of the modelling. It was pulled together in a very short period of time with incomplete information and as per the advice from Treasury, simply didn't provide a suitable basis for narrowing of options much less selection of a preferred option.

Management believes that a principle-based position (rather than overtly supporting or opposing the project) will enable us to effectively balance the importance of championing our independent view, whilst remaining a trusted advisor to Government and retaining access to the project team.

We also consider that our external and public messaging must include actionable advice, not just observation or critique. For example – rather than "this is too expensive compared to international benchmarks" we should offer suggestions for better controlling costs such as "staged or modular implementation would de-risk delivery, bring benefits onstream earlier, and offer opportunities for learning and cost efficiencies".

The positions suggested in this paper draw heavily on the principles of the New Zealand Infrastructure Strategy, and the principles for Infrastructure Delivery outlined in an earlier Board paper today.

We propose the following key positions:

Key position 1: A genuine business case process that rigorously examines options is essential.

The Benefit Cost Ratio for this project is razor thin and highly sensitive to changes in assumptions. Cost and benefit assumptions must therefore be rigorously tested and monitored closely. We should keep all options (including surface running light rail) on the table as long as possible by encouraging the project team to observe the discipline of good business casing which requires the consideration of options (including the 'do nothing' case).

A better approach was applied on the NZ Battery Project (Pumped Hydro) business case process which we will advocate for on ALR. The project team was able to pursue the Minister of Energy's preferred option (a huge pumped hydro energy storage facility at Lake Onslow in the South Island) whilst also considering a range of other potential solutions to the problem to ensure the business case will provide decision makers with well-formed choices. Keeping options open de-risks the critical path to project delivery and provides a 'Plan B' or politically acceptable 'offramp' if the high-level costs and benefits that have informed decision making to date prove unrealistic.

Key position 2: This cannot be progressed as a traditional transport project.

Wider economic benefits from increased productivity and urban development are critical to the project and account for roughly half the proposed benefits.

We cannot follow a typical transport project playbook. We need an integrated infrastructure and urban development scheme and to take a deliberate approach to securing wider economic benefits, while also delivering the transport benefits.

New Zealand has a poor track record of delivering on these types of benefits – unlike tangible outputs they require complex interfaces with the private sector, creating trust and confidence and getting regulatory settings right across multiple domains.

The project needs to focus attention on developing a realistic plan to address the urban outcomes, further detail the required urban interventions, and ensure these are driving the built/transport solution (not the other way around). We need to examine the degree to which this project creates additional urban development benefits over what would already occur under a 'do nothing' scenario by virtue of policy interventions such as the NPS Urban Development and ensure the business case is not claiming benefits for development it isn't assigning costs to.

Key position 3: There needs to be absolute transparency about what this will cost and who will pay for it

This is an important time to champion the funding principles of New Zealand Infrastructure Strategy – in particular the "beneficiary pays" principle.

The benefits of ALR are localised to Auckland, and particularly concentrated around the project corridor. **The funding of the project should reflect this**. It is worth noting that City Rail Link was 50/50 funded by Central and Local Government which may have created a precedent. An investment of this scale is also likely to be precedent setting (or reaffirming) so needs to be carefully considered and designed.

Current and future generations of New Zealanders deserve transparency as to how an investment of this scale will be funded, including the extent to which direct beneficiaries will be subsidised by taxpayers. This should be made very clear during the business case process (including the mix of local taxes, fare box recovery, value capture etc) so people understand the contribution they will be asked to make if the project goes ahead.

Key position 4: The investment must be part of a cohesive and deliverable strategy for Auckland's transport and urban development

ALR is positioned as the first step in a wider overhaul of Auckland's public transport system which could cost more than $100 billion. Much of the proposed benefits of ALR rely on effective system and network integration, so we need to have confidence in the deliverability of that wider programme of investment before proceeding with the project. **A full Programme Business Case should be a prerequisite to the final investment sign-off.**

We also support methodologies that make ALR itself more deliverable. This means retaining bundling and staging options that de-risk delivery (and manage delivery capacity). We will continue to promote staging to bring benefits on stream early (i.e. make the project more modular) and allow assumptions to be tested in practice before progressing to subsequent investment stages.

Key position 5: People deliver projects

We need to invest in, listen to and learn from those with credible expertise in delivering integrated, city-shaping projects. (Refer Key Position 2: This is not just a Light Rail project. It's not even just a Transport project).

A project of this scale and complexity requires world-class project leadership with relevant skills and experience. Procurement and personnel decisions need to account for the nature of the project outcomes and must follow good practice.

Processes to date have not always shown appropriate focus on attracting the best in an international market**. We will continue to hold the project to account when not following established best practice.**

Key position 6: We need to agree investment criteria with our Minister

The IBC uses language which suggests the authors foresee further cost increases above the publicly-adopted P50 cost estimate as likely, if not certain. This is a project for which the capital cost has climbed by a factor of between 7 and 11x in just 5 years. It is a project for which the slightest changes in assumptions cause the BCR to drop well below 1. It is a project which generates so much risk and so little public value that it cannot reasonably tolerate any increase in costs or any reduction in benefits. We know from recent history that without strong guard rails this is a likely outcome.

With this in mind, an unambiguous, inflexible definition of the investment hurdle criteria is essential guidance for the project team who have so far explored and promoted transport options which bear no resemblance to the cost envelopes they were commissioned to work within. They clearly didn't rule out the tunnelled light rail option when costs doubled, then doubled again. There is a nationally significant interest in constraining the ability of the project team to operate like this during the next phase of the project.

Acknowledging the strong influence that a range of biases have on politicians, their decision making and their officials – particularly as we approach an election year, and responding with a pre-agreed set of investment criteria will help manage the down-side risks of proceeding for the wrong reasons.

Key position 7: Net Zero by 2050 is a bottom line for Te Waihanga. Are there others?

We have just published a New Zealand Infrastructure Strategy which states unambiguously that infrastructure needs to do a lot of the heavy lifting to meet the Government's commitment to net zero by 2050. The modelling shows this project generates a net increase in emissions by 2050 due to the enormous volumes of concrete and steel in its construction.

This doesn't include the opportunity costs of not undertaking other de-carbonising initiatives with the capital. Unless the project team can demonstrate how this option (tunnelled light rail) makes a contribution to our net-zero targets proportionate to the magnitude of the investment, it should not proceed. The enormity of decarbonising our transport system is such that we cannot afford to make poor investments in this regard – this is a bottom line.

It would be useful to understand if there are other bottom lines the Board would like Management to promote. One example might be insisting that a Programme Business Case be undertaken.

Key position 8: An in-depth review of City Rail Link is essential and urgent

City Rail Link offers tremendous insights into the possible risks and opportunities arising from Auckland Light Rail at almost every level. It also offers a potentially lower cost alternative to provide the urban renewal benefits the Light Rail project purports to target.

A wide ranging review into City Rail Link looking at the costs, benefits, procurement, delivery, governance, risks and its potential to meet part or all of the needs delivered by Auckland Light Rail would offer tremendous value to decision makers and the ALR project team itself as they progress toward a final investment decision in 2023/24.

Te Waihanga is ideally placed as the Governments Lead Advisor to **formally seek commissioning of such a review from the Minister for Infrastructure**.

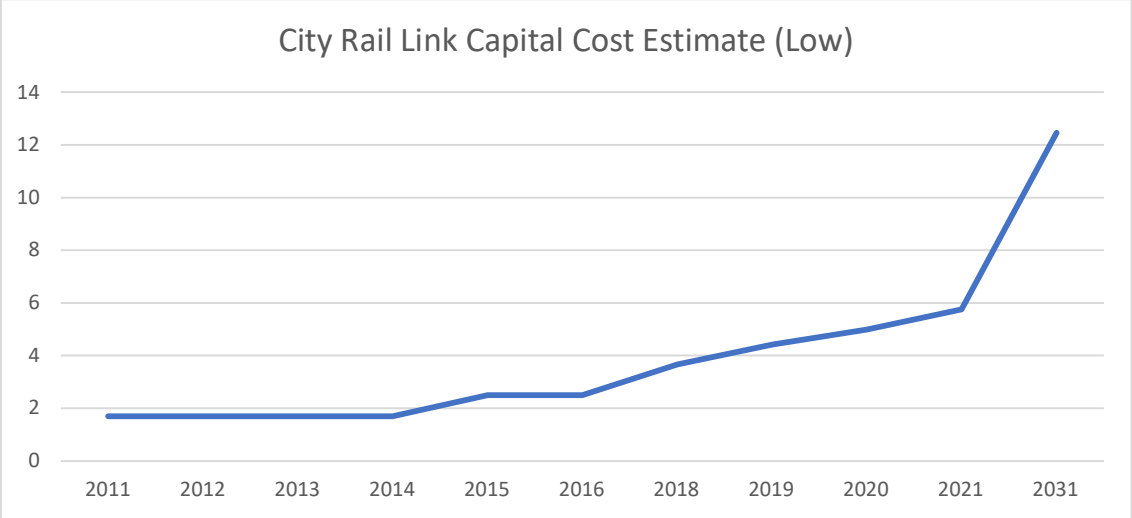


Figure 4: Capital costs for CRL have also increased many times the original estimates. Recently release information indicates that a further $6.7 billion is required to enable 54k per hour network capacity. CRL's rail tunnel project is one of the most expensive ever built, anywhere in the world.

Doc 8

From: Geoff Cooper
To: Peter Clark
Subject: Re: Population Growth 2006 - 2021
Date: Wednesday, 25 May 2022 9:36:54 pm
Attachments: image001.png
image002.png

Inside out cities!

Get Outlook for iOS

From: Peter Clark <peter.clark@aucklandlightrail.govt.nz>
Sent: Wednesday, May 25, 2022 6:06:54 PM
To: Geoff Cooper <Geoff.Cooper@tewaihanga.govt.nz>
Subject: FW: Population Growth 2006 - 2021

From: John Williamson <john@ascaripartners.co.nz>
Sent: Wednesday, 25 May 2022 4:07 pm
To: Peter Clark <peter.clark@aucklandlightrail.govt.nz>
Subject: Re: Population Growth 2006 - 2021

Thanks Pete, the classic combination - good land supply in the greenfield locations and permissive planning framework in the city centre. It's trying to tell us something!

John Williamson

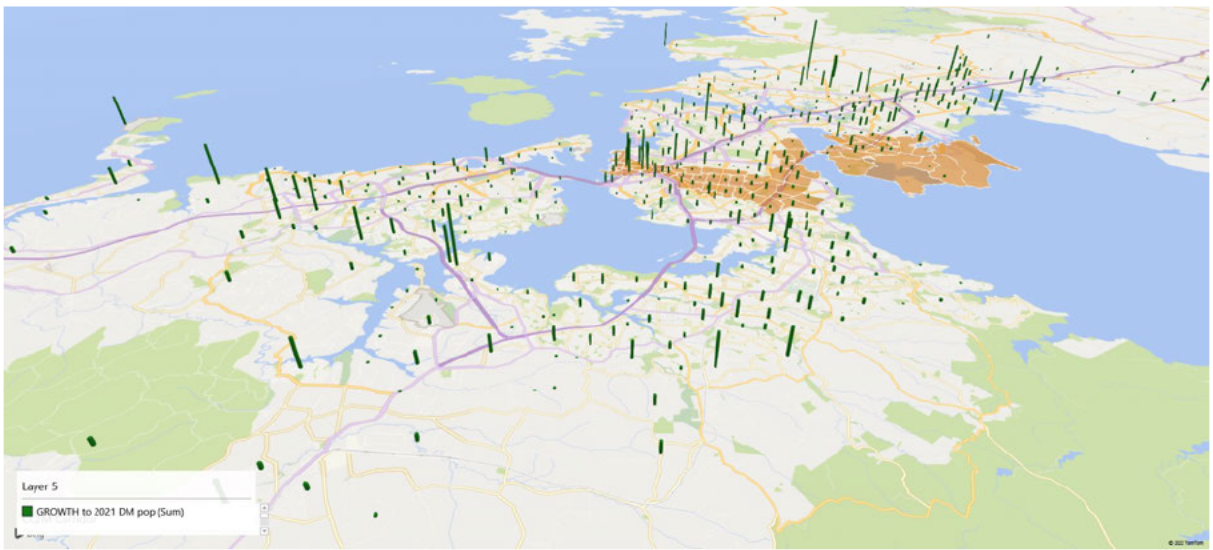
Director

Ascari Partners

s9(2)(k) [redacted]

From: Peter Clark <peter.clark@aucklandlightrail.govt.nz>
Sent: Wednesday, 25 May 2022 12:32 pm
To: John Williamson <john@ascaripartners.co.nz>
Subject: Population Growth 2006 - 2021

John
Thought you'd enjoy this – plot of population growth 2006-2021. Not much in CC2M corridor despite its accessibility! In fact it's a donut! City Centre huge! Most growth in greenfields



Doc 9

From: Brendan Herder
To: Lucy Riddiford
Cc: Tommy Parker; Helen Kerr; Ben Wells [TSY]
Subject: Information Sharing and Confidentiality
Date: Wednesday, 1 June 2022 10:39:53 am
Attachments: image001.jpg
image002.jpg
Te Waihanga - Information Sharing and Confidentiality.docx

Hi Lucy

We are looking forward to our meeting tomorrow afternoon. I know you are keen to share information as freely as possible but as discussed previously need some formal documentation in place in order to do so. We have adapted the attached agreement from our early project support frameworks.

The proposed agreement establishes:

- That we will keep confidential information safe and prevent unauthorised use of the information.
- That we will need to be able to use the information and insights gained from the information to effectively perform our wide range of functions as a centralised Infrastructure Delivery team, that provides a broad range of advice to many stakeholders, and seeks to improve infrastructure delivery for all New Zealanders.
- A 'no-surprises' and consultative approach to sharing insights or information with other projects/agencies and with Ministers.

I've copied Ben Wells for visibility from Treasury as Ministers have also set clear expectations that some of the information that was redacted for public release is to be handled with particular sensitivity.

Kind regards
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

s9(2)(k)

Information Sharing and Confidentiality Agreement

Te Waihanga, New Zealand Infrastructure Commission

and

[*Insert Procuring Entity*]

[*Insert date*]

1 About this Agreement

Parties

1.1 The parties to this Information Sharing and Confidentiality Agreement (**Agreement**) are:

a) Te Waihanga, New Zealand Infrastructure Commission (the **Commission**); and

b) **[*Drafting note: Insert full name of Procuring Entity* (the **Procuring Entity**)]**.

Purpose

1.2 On 25th of September 2019 the New Zealand Infrastructure Commission/Te Waihanga Act 2019 (the **Act**) received Royal asset creating the Commission.

1.3 The main function of the Commission is to co-ordinate, develop, and promote an approach to infrastructure that encourages infrastructure, and services that result from the infrastructure, that improve the well-being of New Zealanders.

1.4 In addition, the Commission has the following support functions:
a) to promote a strategic and co-ordinated approach to the delivery of current and proposed infrastructure projects:

b) to provide and co-ordinate information about current and proposed infrastructure projects:

c) to provide support services to current and proposed infrastructure projects

1.5 To enable the Commission to perform its functions, procuring entities (including the Procuring Entity) will be required to share certain information with the Commission, for instance about planned, active or past procurements. Such information sharing is contemplated by the Commission's establishing legislation, the Act. In doing so, the Commission recognises that the Procuring Entity may be required to protect Confidential Information, including where it has received such information from third parties (e.g. from potential suppliers during market engagement or a procurement process). The purpose of this Agreement is to provide guidance and record the parties' agreement on how the Commission and Procuring Entity will manage any information sharing to ensure that probity and confidentiality requirements are met.

1.6 This Agreement applies to the Commission in the performance of its above functions but does not apply to the wider strategy and planning function of the Commission.

2 Sharing of information with the Commission

This section outlines the types of information the Commission is likely to be privy to in its role working with the Procuring Entity

2.1 The Procuring Entity acknowledges that in order for the Commission to provide support services promote a strategic and co-ordinated approach to the delivery of its infrastructure project, Commission will need to receive information from the Procuring Entity at various stages of the procurement life-cycle. Such information may relate to:

a) the business case for new infrastructure investment;

b) market dynamics and relevant suppliers;

d) procurement plans, associated issues and risks;

e) budget and funding considerations in progressing a procurement;

f) risk allocation in key contracts;

g) assurance of risk management and delivery in the course of a procurement;

h) financial models;

i) executed project agreements; and/or

j) project performance and cost out-turn information.

The Procuring Entity agrees to provide such information to the Commission within such time frame as may be reasonably requested in writing by the Commission.

2.2 The Commission and the Procuring Entity acknowledge and agree that:

a) given the competitive market context for infrastructure procurement and the Crown's interest in protecting its own commercial position, the Procuring Entity may need to share Confidential Information with the Commission for it to fully discharge its functions and provide the requisite support to the Procuring Entity;

b) the Commission may also need to collect historical information that retains elements of Confidential Information to continue to enhance the quality of its advice and published guidance over time; and

c) the following key parameters will apply to the Commission's internal handling of any such information that it receives from the Procuring Entity:

(i) internal security measures (such as secure storage and electronic information barriers) will be implemented and followed by the Commission to keep Confidential Information secure;

(ii) where the Commission is dealing with Confidential Information, the sharing of such information within the Commission will be limited to staff who need to know that information to perform their role; and

(iii) the Commission will have a designated point of contact for communications with the Procuring Entity involving Confidential Information, who will oversee the distribution of information within the Commission.

3 Confidentiality duties of the Commission

This section outlines the duties of the Commission in receiving and handling Confidential Information provided by the Procuring Entity

3.1 The Commission must keep safe, confidential, and prevent unauthorised use and disclosure of, the Confidential Information.

3.2 Authorised use and disclosure of the Confidential Information by the Commission includes any use or disclosure made under the Official Information Act 1982, or otherwise appropriate or required in order for the Commission to carry out is responsibilities under or comply with any law (including the Commission's establishing legislation), convention, Parliamentary or Cabinet Office practice, or necessary for the Commission to fulfil its public accountability obligations.

3.3 The Commission must not discuss with or disclose to any person other than those of its directors, officers, employees (which include, for these purposes, any individuals on secondment at the Commission or individuals contracted by the Commission), or its relevant professional advisors:

a) the Confidential Information; or

b) that particular Confidential Information is to be, or has been, disclosed to the Commission,

except with the prior written consent of the Procuring Entity (not to be unreasonably withheld), or otherwise in accordance with this agreement.

3.4 Subject to clause 3.2, the Commission must not:

a) use the Confidential Information for any purpose other than the purposes outlined in this Agreement;

b) modify or copy the Confidential Information;

c) solicit or receive Confidential Information from any person other than such persons designated by the Procuring Entity for the purposes of liaising with the Commission under this Agreement,

except with the prior written consent of the Procuring Entity (not to be unreasonably withheld).

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3.5 The Commission will use reasonable endeavours to comply with all security measures reasonably required by the Procuring Entity and notified to the Commission in writing to safeguard the Confidential Information.

3.6 On receipt of a written request by the Procuring Entity, the Commission will use reasonable endeavours to notify the Procuring Entity of the location of all copies of the Confidential Information made or held by the Commission.

3.7 The Commission will use reasonable endeavours to notify the Procuring Entity immediately if the Commission becomes aware of any actual or potential unauthorised use or disclosure of Confidential Information.

3.8 The Commission will use reasonable endeavours to co-operate with the Procuring Entity:

a) to prevent potential unauthorised use or disclosure of Confidential Information;

b) to limit loss or damage to the related entities of the Procuring Entity (as applicable) which may result from unauthorised use or disclosure of Confidential Information; and

c) in any investigation, prosecution, or other action taken by the Procuring Entity against another person for unauthorised use or disclosure of Confidential Information.

3.9 Upon the earlier of termination of the project or written request by the Procuring Entity, the Commission will use reasonable endeavours to ensure that all Confidential Information provided to the Commission pursuant to this Agreement is returned to the Procuring Entity or destroyed (at the Commission's sole discretion), except to the extent that any such information may need to be retained to enable the Commission to perform its wider statutory functions.

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4 Tendering of advice to Ministers

The following section outlines how the Commission will handle information relating to advice to Ministers, including the sorts of information that may be included and how the information will be handled to protect confidentiality.

4.1 The Procuring Entity acknowledges that the Commission has a duty to provide independent advice to its Ministers in the performance of its functions, and that such advice may address matters such as:

a) the assessment of high-value infrastructure projects in terms of how or whether such projects achieve economic, environmental, social, cultural and security objectives;

b) the prioritisation of high value infrastructure projects;

c) appropriate delivery mechanisms for infrastructure projects, the management of relevant risks and providing assurance regarding delivery; and

d) matters arising out of the Commission's participation in aspects of procurement processes, including in any relevant project governance and working groups.

4.2 The Procuring Entity further acknowledges that the Commission needs to have sufficient information about New Zealand's infrastructure projects to provide accurate, comprehensive and balanced advice to its Ministers. Accordingly, the Procuring Entity acknowledges and agrees that the Commission's advice may (in its sole discretion) draw on its analysis of relevant information that has been provided by the Procuring Entity about planned or active procurements. In this regard the parties acknowledge that it is not generally expected that underlying Confidential Information would need to be shared with Ministers.

4.3 The Commission acknowledges that the Procuring Entity may owe certain confidentiality obligations to third parties, subject to certain exceptions such as under the Official Information Act 1982 (**OIA**) or the Local Government Official Information and Meetings Act 1987 (**LGOIMA**) (as applicable). The Procuring Entity acknowledges that while Rule 4 of the of the Government Procurement Rules, 4th edition requires the protection of suppliers' confidential information, there is an exception where the disclosure is required by law, convention or Parliamentary or Cabinet Office practice, or where it is a limited disclosure notified in a Notice of Procurement.

4.4 The parties acknowledge that while it is not generally expected that advice tendered to Ministers would include underlying third party Confidential Information, the Commission needs to manage for the possibility of situations arising where such information may need to be shared with Ministers for the Commission to provide full and accurate advice.

4.5 The Commission agrees that if such a situation arises, the Commission will use reasonable endeavours to first inform and discuss with the Procuring Entity the nature of the Confidential Information that is proposed to be shared, so that the Procuring Entity has an opportunity to advise its responsible Minister (or, where the Procuring Entity is a local authority, such other appropriate elected office-holder, governance board member or senior executive, as applicable) and in which case the Infrastructure Delivery team will use reasonable endeavours to ensure that any relevant confidentiality obligations are properly identified and complied with.

5 Promoting a co-ordinated approach to the delivery of current and proposed infrastructure projects

This section considers how the Commission will handle sensitive information in its role promoting a co-ordinated approach to the delivery of current and proposed infrastructure projects and as the point of contact for the infrastructure market. It also includes provision for OIA requests.

5.1 The Commission and the Procuring Entity acknowledge and agree that, as a central repository for infrastructure transaction knowledge and best practice, the Commission may, in its sole discretion (acting reasonably), share information across central and local government agencies, enabling the transfer of lessons learned between different procuring entities and projects, and better enabling coordination across sectors.

5.2 Where the Commission proposes to share Confidential Information about the Procuring Entity's infrastructure procurement with other agencies, it will use reasonable endeavours to first inform and seek the Procuring Entity's views on such proposal, indicating the type of information it wishes to share and providing assurance about what measures will be taken to maintain confidentiality where required. The Procuring Entity acknowledges that the Commission acts as a first point of contact for the market in relation to upcoming infrastructure investment and delivery opportunities, and that the Commission also coordinates and publishes pipeline information. The Commission agrees that in providing information to the market, the Commission will adhere to the following protocols to prevent the disclosure of Confidential Information:

a) Any infrastructure pipeline information that is published to the market will be sourced from publicly available information, or, to the extent such information relates to the Procuring Entity, the Commission will seek confirmation from the Procuring Entity that the proposed pipeline information may be released (such confirmation not to be unreasonably withheld or delayed).

b) Internal guidance will be implemented for the Commission staff outlining the types of early-stage and general information that are approved for publication to the market.

c) The Commission will ensure it has designated and suitably qualified points of contact who are responsible for communicating information to the market and answering queries to ensure that there is consistency of information being provided. The Commission will also ensure that market participants are not receiving information that might give them an unfair advantage over other participants in the market.

d) Confidential Information not intended for release, that the Commission may receive from third parties it engages with, will be handled in accordance with detailed security protocols to ensure that such information is not inadvertently released to the market.

e) The Commission will keep a record of its market engagement and document the general nature of its interactions with market participants.

5.3 The Procuring Entity acknowledges that the Commission is subject to the OIA, and accordingly, where the Commission receives a request for information under the OIA, such a request will be responded to in accordance with the Commission's obligations under that Act. If the Commission receives an information request that another agency has an interest in or that relates to a third party's potentially Confidential Information, the Commission will use its reasonable endeavours to consult with that agency or third party prior to responding to the request. The Commission agrees that where it receives a request for information that is not held by the Commission but that the Commission believes is either held by or more closely connected with the functions of another agency, the Commission will transfer that request to the other agency in accordance with the OIA.

6 Facilitating the implementation of this Agreement

This section includes some practical information about the implementation of this Agreement and definitions.

Implementation of the Agreement

6.1 To achieve the objectives of this Agreement, where the Procuring Entity is releasing a Notice of Procurement or entering into a confidentiality undertaking (or similar), the Procuring Entity will include exceptions in the relevant documentation that are sufficient to enable Confidential Information to be shared with Commission staff and (only to the extent necessary) by the Commission team with the Commission's responsible Ministers. The Commission agrees that it will share such information only in accordance with this Agreement.

Definitions

6.2 In this Agreement, unless the context otherwise requires:

a) **Confidential Information** includes information that:

(i) is by its nature confidential;

(ii) is identified by the Procuring Entity as 'confidential', 'commercially sensitive', 'sensitive', 'in confidence', 'top secret', 'secret', 'classified' and/or 'restricted';

(iii) is provided by the Procuring Entity or a third party in confidence; and/or

(iv) the Commission knows, or ought to know, is confidential,

(v) but excludes information that is in the public domain through no fault of either the Commission or the Procuring Entity.

b) **Procuring Entity** means the public sector agency or local authority referred to in clause 1.1b), being an entity that is considering the procurement of infrastructure with a total cost of ownership of more than $50 million.

Execution

Executed as an Agreement

SIGNED on behalf of **the Commission** by**:**

_____

Authorised Signatory

_____

Print Name

SIGNED on behalf of

Procuring Entity by**:**

_____

Authorised Signatory

_____

Print Name

Doc 11

From:	Brendan Herder
To:	Ben Wells [TSY]
Cc:	chris gulik (C.Gulik@transport.govt.nz); Blake Lepper; Helen Kerr
Subject:	RE: ALR Sponsors' letter
Date:	Friday, 10 June 2022 4:45:30 pm
Attachments:	image003.jpg image004.jpg image006.png image007.png image008.png

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Hi Ben

I think there was a misunderstanding between being consulted on draft versions of the letter and having an opportunity to contribute to the final advice. The weekly catch ups we have set up will help us work more closely together and make it clear when we have firm views to be represented. Nonetheless, it appears we continue to share similar perspectives, concerns and objectives for the project and we want to make sure we are well positioned to provide effective advice to Minister Robertson and support to other officials, particularly in instances where a separate agency comment is required as was the case here.

The Minister has asked very specifically that where possible Te Waihanga inputs into joint advice rather than sending its own advice so it would be helpful to get a Te Waihanga comment section in future reports where necessary. Not being more proactively involved in this case means we missed an opportunity to provide direct and targeted advice before the briefing and final letter were considered, and when combined with the recommendation to note we had been consulted creates potential for Ministers to misunderstand our position on critical issues. We are keen to contribute to any future briefings as early as possible please and will share any independent advice we intend to send directly with you also.

Te Waihanga officials and our Board remain very concerned around the extent that decision making on this project diverges from the best practice principles articulated in *Rautaki Hanganga o Aotearoa, the New Zealand Infrastructure Strategy.* The Strategy highlights the additional risk associated with projects that have scope and budget announced without full business case analysis. The revised wording of the IMS letter that the tunnelled section through the central isthmus to Mt Roskill should not be revisited goes further in determining the extent of grade separation than the wording of the business case that has been quoted in the briefing, which is extremely problematic. While we respect Ministers' views on the decisions that have been made to date, we feel a strong obligation to continue to highlight that any constraint on the options analysis process creates a significant risk to the business case arriving at a robust and defensible recommendation, especially as the understanding of costs and value will evolve significantly as the reference design develops.

In this context, we do really want to work closely with you to mitigate risk as much as possible. Given the IMS letter has been sent we think we can best add value by having a critical focus on some of the stronger elements of the Letter. In particular whether:

- *the business case contains sufficient analysis to confirm that the final recommended route and mode remains the best value investment option for New Zealand;*
- *Sponsors are properly exposed to the trade-offs across critical aspects of the Programme, particularly if there are significant issues or value-for-money benefits in refining decisions;*
- *the final route alignment options, especially the tunnelled sections, are subject to further exploration and refinement to ensure value for money and benefit realisation; and*

- *the cost-benefit assessment enhances previous analysis, integrating both urban development and transport appraisal.*

Early warning to Ministers if this is not occurring should help reduce risks of unpalatable decisions at the end of the process.

In regard to workstreams: the workstream table may have been refined further since the early April version I have referred back to, but to provide the advice outlined above we will have a strong interest in the outputs of many of the delivery and policy workstreams. Given the breadth of the list below perhaps what we should discuss on Tuesday is not so much *what* we are interested in but *how* we go about performing our role as advisor to the Minister and making ourselves available and useful to the new Board.

- Programme Business Case
- Options for Staging
- Costs of the ALR Project
- Technical Assessment and Design
- Procurement
- Reduce Embodied Emissions
- Vision for Corridor
- Funding (including Value Capture) and Financing
- Ownership Model for Transport Infrastructure
- Operating Model for Transport Infrastructure

Kind regards
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

From: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>
Sent: Friday, 10 June 2022 2:37 pm
To: Blake Lepper <Blake.Lepper@tewaihanga.govt.nz>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>; Helen Kerr <Helen.Kerr@tewaihanga.govt.nz>
Cc: chris gulik (C.Gulik@transport.govt.nz) <C.Gulik@transport.govt.nz>
Subject: RE: ALR Sponsors' letter

Hi team,

Just heard from Moffice that TW reported, on the topic of the ILM letter, that:

> *We had been hoping to provide advice in conjunction with Treasury to support the Ministers consideration of the Letter from Ministers. Unfortunately, given timing and the number of agencies already involved in the sign-out process Te Waihanga was not able to be consulted on the joint report nor any summary of our advice included.*

Just to let you know I flagged with the Moffice that this isn't an accurate characterisation of the consultation you received on the letter itself, both meeting and via email, and resulting draft changes. And noting that the letter changes in the joint report were giving effect to decisions made my Ministers/Sponsors at the Sponsors meeting, so did not commission any further advice on the topic.

Look forward to catching up next week - in particular, interested in what worksteams TW will be involved with.

Have a great weekend.

Cheers,
Ben

Ben Wells | Principal Advisor - National Infrastructure Unit | Auckland Policy Office | **Te Tai Ōhanga – The Treasury**
s9(2)(k) Tel: [redacted] | Ben.Wells@treasury.govt.nz

From: Ben Wells [TSY]
Sent: Thursday, 9 June 2022 5:51 pm
To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Cc: blake.lepper@tewaihanga.govt.nz; helen.kerr@tewaihanga.govt.nz
Subject: RE: ALR Sponsors' letter

Hi Brendan,

Thanks for the call earlier. Final IMS letter and Joint report attached.

Interested in hearing about the forthcoming TW advice, and which ALR workstreams you guys are interested in - to form the basis of what advise the team would like to contribute to.

Cheers,
Ben

Ben Wells | Principal Advisor - National Infrastructure Unit | Auckland Policy Office | **Te Tai Ōhanga – The Treasury**
s9(2)(k) Tel: [redacted] | Ben.Wells@treasury.govt.nz

From: Ben Wells [TSY]
Sent: Friday, 27 May 2022 11:50 am
To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Subject: RE: ALR Sponsors' letter

Hi Brendan,

Just gave you a call. Sponsors meeting items from last week attached. Most relevant part for TW catch up with the Ministers on 9am Tuesday is the decision around the observers on the Board – Ministers agreed instead that the Board would be encouraged to seek advice as needed – I've given Blake a heads up on this.

Interested to hear what TW are intending to cover on Tuesday on the ALR item – I'm just briefing the Ministers office for this today. Give me a call if that suits?

On a separate/related note – I don't think we have heard back from TW on what individual ALR work streams you would like to be involved in – keen to hear if you have advanced any thinking here. The Minister will probably be interested in what streams TW will be lending a shoulder to.

Cheers,
Ben

Ben Wells | Principal Advisor - National Infrastructure Unit | Auckland Policy Office | **Te Tai Ōhanga – The Treasury**
s9(2)(k) Tel: [redacted] | Ben.Wells@treasury.govt.nz

From: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Sent: Tuesday, 24 May 2022 10:57 am
To: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>
Subject: RE: ALR Sponsors' letter

Hi Ben

That was me trying to call this morning.

The MoT paper to last week's Board Meeting referred to the content of the sponsors letter and sounded positive but I haven't seen the latest (or final?) version. Do you have a copy or a status update you could share please?

Is Chris the better contact than Gareth going forward?

Cheers
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: + [redacted] | Email: brendan.herder@tewaihanga.govt.nz

From: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>
Sent: Wednesday, 18 May 2022 11:56 am

To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Subject: RE: ALR Sponsors' letter

[UNCLASSIFIED]

Hey mate,

Sorry missed this – did you get an answer from Chris at MoT?

Give me a call this avo if you want a general chat / update.

Cheers,
B

Ben Wells | Principal Advisor - National Infrastructure Unit | Auckland Policy Office | **Te Tai Ōhanga – The Treasury**
s9(2)(k) Tel: [redacted] | Ben.Wells@treasury.govt.nz

From: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Sent: Monday, 16 May 2022 3:18 pm
To: gareth.fairweather@transport.govt.nz
Cc: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>
Subject: ALR Sponsors' letter

Hi Gareth

I am going to be in Auckland tomorrow for the Board alignment tour and Board meeting Wednesday.

What is the current status of the Sponsors' letter. Tommy and Lucy raised it when I last saw them at our Infrastructures Symposium so it will be helpful to have an update before tomorrow afternoon please.

Cheers
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

Doc 12

From:	Helen Kerr
To:	d.looi@transport.govt.nz
Cc:	Nadine Dodge; Geoff Cooper; Blake Lepper; Brendan Herder; Ben Wells [TSY]; benjamin.richards@hud.govt.nz; Mary.Barton@hud.govt.nz
Subject:	RE: ALR Value Capture
Date:	Wednesday, 20 July 2022 10:34:57 am
Attachments:	image001.png image002.jpg

Hi Damien,

Thanks for sending the paper on ALR Value Capture across. The following extract from Treasury's previous paper OC220323 / T2022/987 / BRF21/22051324 ALR Funding and Financing Policy Work Programme cover our key concerns about the financing and funding workstream in general:

"The funding mix for the programme represents an important decision that will have a range of implications, and will need to take account of broader context, including:

- how costs are borne and equity considerations across the various cohorts that might contribute to the project, including local residential and business beneficiaries, road users, and taxpayers,
- fiscal impacts on Sponsors and other contributors,
- potential incentive/disincentive effects for urban development,
- affordability, both directly (i.e. to meet the costs of ALR) and indirectly (e.g. the impact on general rates to meet potential related Council costs),
- political economy and social license trade-offs in the use and mix of tools that generate additional revenue to support the programme,
- the impact of other infrastructure, policy and reform programmes affecting Auckland, and
- precedent effects for future 'mega' projects including rapid transit.

In the agreement of a funding and financing package, Sponsors will need to commit to meeting their respective contributions including the use of any funding tools necessary to generate additional revenue to meet the costs of the project."

The ALR Value Capture paper indicates that beneficiary-pays funding will likely provide between 10% and 20% of the project cost due to other considerations and constraints. We therefore believe it is important that the work you undertake for the value capture paper is undertaken in conjunction with the wider work you are undertaking on financing mega-projects and the Land Transport Revenue Review (as it seems most of the money for ALR will need to be found elsewhere which is especially important given the precedence this sets for the other ALR lines and other mega-projects). Currently this work seems to have quite a long lead time which could result in a scheme proceeding to the consenting phase which is too expensive to fund.

We believe that prior to consents being lodged, Treasury should present a draft report on both this paper, and its other work on financing and funding to the ALR Board and that Project Sponsors should indicatively agree to the amounts they will each need to contribute to the project, and which organisation will be taking the financial responsibility (and risk) of the operation phase (as there has been significant discussion and pressure around discounted fares and/or free public transport and it is important this risk is discussed and understood). What we have seeing across the system at the moment is massive affordability issues with agencies such as Waka Kotahi not being able to deliver previously committed projects due to escalation and

cost pressures. We believe on-going robust discussions around project costs and who will pay, will set up ALR for financial success.

Any issues please call,
Helen

Helen Kerr | Principal Advisor | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: [redacted] | Email: helen.kerr@tewaihanga.govt.nz

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From: Damien Looi <D.Looi@transport.govt.nz>
Sent: Tuesday, 12 July 2022 1:04 pm
To: Geoff Cooper <Geoff.Cooper@tewaihanga.govt.nz>; Helen Kerr <Helen.Kerr@tewaihanga.govt.nz>; Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Cc: Gareth Fairweather <G.Fairweather@transport.govt.nz>; Ben Wells <Ben.Wells@treasury.govt.nz>; Ben Richards <benjamin.richards@hud.govt.nz>; Mary Barton <Mary.Barton@hud.govt.nz>; Ward, Stephanie J <StephanieWard@kpmg.co.nz>; Wade, Andrew J <awade@kpmg.co.nz>
Subject: ALR Value Capture

Hi Geoff, Helen and Brendan,

Thank you for offering to provide comments on the advice that we are looking to send to joint sponsoring ministers on broad-based value capture for ALR.

Please find the latest draft for Te Waihanga's review. Kindly note that this version is also going through consultation internally at Treasury and MHUD, with further changes to the paper expected this week and the next.

If you could provide us any comments by the **21st of July COB** that would be much appreciated.

We could also set up a short session to discuss the paper and your comments next week – please let us know if this would be helpful.

Kind regards,

Kian Siew Looi (Damien)
Kaitohutohu Matua | Senior Adviser – Investment
Auckland Policy Office
Te Manatū Waka - Ministry of Transport

s9(2)(k) M: [redacted] | E: d.looi@transport.govt.nz | transport.govt.nz

Doc 13

From: Geoff Cooper
To: Peter Clark
Subject: Re: Rapid post covid population growth - need for PT investment
Date: Wednesday, 14 September 2022 8:15:15 am
Attachments: image001.png

Quite interesting!

In NZ property markets, it's the satellite towns that are proving resilient, probably because of WFH. Location decisions do appear to be changing. I still subscribe to this idea that we will see secondary employment areas suffer and city centres get more firms occupying lower floor space per person. Covid could well exacerbate city centre access issues.

One other thing - I was at an urban economics conference last Friday, which was well represented with some big names. We had a paper presented to us showing that transport infrastructure improvements in congested cities can end up increasing VKT as the size of the city ends up expanding. This effect can dominate mode shift. The conclusion was to get the environmental and congestion relief benefits of mass rapid transit improvements, you have to implement congestion charging at the same time.
It created a lot of discussion as an application to ALR.

G

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From: Peter Clark <peter.clark@aucklandlightrail.govt.nz>
Sent: Tuesday, September 13, 2022 8:38:57 AM
To: Geoff Cooper <Geoff.Cooper@tewaihanga.govt.nz>
Subject: Rapid post covid population growth - need for PT investment

Hi Geoff
Hope you had a great trip!
Worth a read – key messages for Auckland re rapidly increasing post covid population growth

EXPERT WARNS TRANSPORT ISN'T KEEPING UP WITH BRISBANE'S POPULATION GROWTH

MORE HERE

Peter Clark
T. [redacted] s9(2)(k)
E. peter.clark@aucklandlightrail.govt.nz
Bringing us closer

Doc 14

From:	Peter Nunns
To:	John Williamson; Cameron Law; Amy Kearse; Gareth Fairweather; Elliot Clayton; Ben Wells [TSY]; Geoff Cooper; gary.blick@aucklandcouncil.govt.nz; Coral Aldridge; Nicole Van Heijst; Sam.price@kaingaora.govt.nz; Anna Chau; Cc: Tony Innes; Robert Simpson; chris.parker@treasury.govt.nz; Daniel Newcombe; John Davies
Subject:	RE: Business Case Huihuinga
Date:	Saturday, 24 September 2022 10:58:56 am
Attachments:	image003.jpg image004.jpg image005.png Laird and Venables - 2017 - Transport investment and economic performance A f.pdf Transport-investment-and-housing-development-ENZ-TG-report-Peter-Nunns.docx

Hi folks

Apologies for turning up, opening a can of worms, and then leaving early. I hope that the subsequent discussion was useful. I'd be keen for a follow-up meeting with John and Anna – week after next would be best for me.

As noted, I have some concerns about the overall evaluation approach. My concerns centre around Figure 3, which outlines several parallel assessment processes. It is unclear how these three frameworks relate to each other, and which (if any) will take precedence in the event of overlaps or conflicts. Unless this is addressed, I see significant risk of:

1. A lack of transparency in decision-making – it may be unclear why a specific option is recommended or preferred, or why some options have been ruled out
2. Double-counting (or omission) of benefits that are included in different frameworks (eg some project objectives are also quantified in CBA)
3. Inadequate consideration of costs of design and siting decisions – in my view, this is an area where CBA is useful to identify whether lower-cost options are preferable or whether additional scope is beneficial.

Some clear guidelines for a 'hierarchy' of decision-making tools are needed. Given the intention to lodge a NOR by a set date, I see a risk that key decisions will be driven primarily be consentability rather than best value for money. Anna had some good ideas about how to manage this issue, and I would be keen to see those worked through.

A well-done CBA can be really useful for detailed optioneering on a project of this scale. This could include incremental analysis of costs and benefits of station location and designs, which will have cost implications on the order of hundreds of millions. (It is common to do CBA on projects that cost less than 1% as much as an underground rail station. This is not an area where you want to skimp on analysis.)

In terms of the rest of the document, I have fewer comments. The broad approach to identifying potential benefits seems reasonable, although it would be useful to see additional detail on modelling and valuation approaches. I went through the documentation and (some) spreadsheets for the IBC cost benefit analysis of alternative mode options last year, so that may be a useful place to pick up. However, I'd like to have a clearer understanding of how CBA and other decision-making tools will be used in practice before signing up to that!

That being said, here are a few lower-altitude thoughts:

1. If you are thinking about experimenting with alternative modelling and valuation

approaches, then I would encourage you to focus attention on how you value decision-making under uncertainty. Some potential candidate uncertainties:

   a. Demand uncertainty driven by population and employment growth in the study area
   b. Demand uncertainty driven by other parameters, eg user sensitivity to travel times or journey quality
   c. Cost and scope uncertainty driven by, say, geotechnical conditions.

2. There are a whole bunch of theoretical debates about how to model and value urban development benefits. There is a risk of double-counting of conventional transport benefits+WEBs, which is why people tend to tread carefully. However, if there are theoretical alternative approaches, such as estimation of land value uplift, then it might be a good idea to use these as a 'sense check' on the base approach to ensure that you obtain a similar order of magnitude of benefits and relativity between options. This could help to reveal cases where there are gaps in the conventional assessment framework. For instance, if the incremental transport BCR on an individual station is poor but land value uplift modelling suggests a lot of benefit from the station, it could suggest that the conventional approach is missing some potential urban development benefit streams.
3. Given that the proposed approach is to start with a conventional appraisal and then bolt on additional benefit streams from urban redevelopment, there may be value in thinking about additional WEBs that might arise from a large-scale urban/transport project. I've attached two papers that might be relevant. The Laird and Venables paper identifies the potential for consumer-side agglomeration benefits from increased product variety (eg more types of restaurants). To the extent to which the project will catalyse mixed-use redevelopment, this might be worth considering. The paper that I wrote explores the issue of how to value project-induced changes in housing supply, and sketches out the basics of a model that you could use to quantify this benefit. The key point in the paper is that there ***may*** be a WEB here that arises due to the fact that transport investment can shift constrained and distorted housing supply markets in a more efficient direction.

Have a good weekend
Peter

s9(2)(k)

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From: John Williamson <john@ascaripartners.co.nz>
Sent: Tuesday, 20 September 2022 8:51 am
To: Cameron Law <cameron.law@aucklandlightrail.govt.nz>; Amy Kearse <amy.kearse@lgwm.nz>; Gareth Fairweather <g.fairweather@transport.govt.nz>; Elliot Clayton <E.Clayton@transport.govt.nz>; Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>; Geoff Cooper <Geoff.Cooper@tewaihanga.govt.nz>; Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>; gary.blick@aucklandcouncil.govt.nz; Coral Aldridge <Coral.Aldridge@nzta.govt.nz>; Nicole Van Heijst <Nicole.VanHeijst@hud.govt.nz>; Sam.price@kaingaora.govt.nz; Anna Chau <anna@annachauenterprises.com.au>; Cc: Tony Innes <tony@commute.kiwi>; Robert Simpson <robert.simpson@aucklandcouncil.govt.nz>; chris.parker@treasury.govt.nz; Daniel Newcombe <daniel.newcombe@aucklandlightrail.govt.nz>; John Davies <John.Davies@aucklandlightrail.govt.nz>
Subject: Re: Business Case Huihuinga

Hi all, in advance of Thursday's meeting please find attached a draft paper setting out our initial view of the economic assessment framework for the for the next phase of ALR (CBC and consenting) as well as the overall options assessment framework of which the economic assessment is a key part.

Look forward to discussing this (note that there are comments from the ALR team still pending too). In particular, it would be good to consider whether there are any significant gaps in the economic assessment framework and what methodologies might be available to assist with monetising a number of the urban benefits, noting that there is a tight timeframe for the next stage.

Thanks, John

John Williamson

Director

Ascari Partners

s9(2)(k) [redacted]

From: Cameron Law
Sent: Tuesday, 30 August 2022 4:36 pm
To: Cameron Law <cameron.law@aucklandlightrail.govt.nz>; Amy Kearse <amy.kearse@lgwm.nz>; Gareth Fairweather <g.fairweather@transport.govt.nz>; Elliot Clayton <E.Clayton@transport.govt.nz>; Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>; Geoff.Cooper@tewaihanga.govt.nz <Geoff.Cooper@tewaihanga.govt.nz>; peter.nunns@tewaihanga.govt.nz <peter.nunns@tewaihanga.govt.nz>; gary.blick@aucklandcouncil.govt.nz <gary.blick@aucklandcouncil.govt.nz>; Coral Aldridge

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Subject: Business Case Huihuinga
When: Thursday, 22 September 2022 12:30 pm-4:30 pm.
Where: 5-Waipun-a-Rangi (VC)

Kia ora,

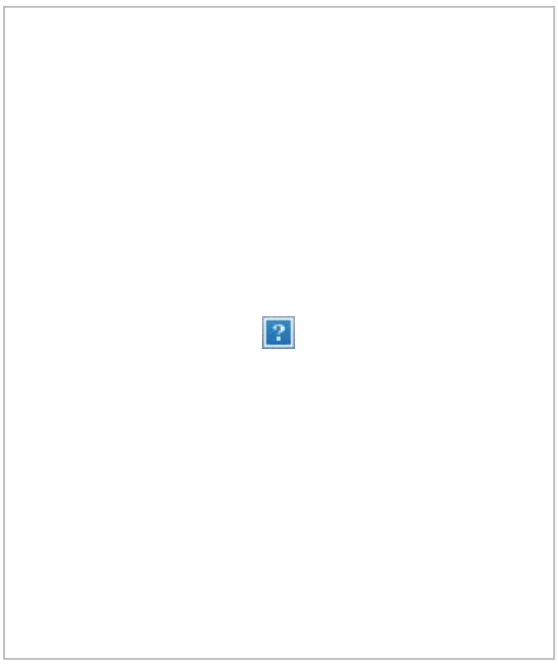
This calendar invite is for future Business Case Huihuinga.

All documents and information related to each event will be provided closer to the time.

If you have any queries, please contact feel free to contact me.

Teams meeting link here:
Click here to join the meeting

The venue is the ALR Office: Level 10, 203 Queen Street.
You do not need an access card to use the elevator and we will meet you in reception on arrival.



Ngā mihi

Sharon Fairbrother

s9(2)(k) [redacted]

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Transport investment and economic performance: A framework for project appraisal

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ABSTRACT

The case for major transport investment is frequently made in terms of impact on economic performance. A recurring difficulty however faced by policy makers is a disjoint between this motivation and the cost benefit analysis, which may be too narrow. Broadening the set of economic mechanisms studied creates the risk that bad arguments are legitimised and effects can be exaggerated. There is a need for an appraisal framework that ensures all relevant impacts are captured, ensures the opportunity cost of drawing more resources into an activity is identified and meets the needs of the different audiences of the appraisal. There is a need for context specific appraisal. Central to the impact on economic performance is how private sector investment responds to changes in accessibility. Investment in one location can improve productivity, create growth, but may also displace output and employment. Thus we group impacts within the framework into four types: user benefits, proximity and productivity effects, investment and land use impacts and employment effects. Within each of these groups there are a series of transport-economy mechanisms which become relevant in different contexts. Some of these mechanisms are well established and are applied in practice. Others still are more challenging and need to be the subject of further research. Throughout improvements in the evidence base are needed.

1. Introduction

The case for investment in major transport improvements is frequently made in terms of impact on economic performance. There is an expectation that they will act as a catalyst for private sector investment, creating jobs, boosting economic activity and growing (or rebalancing) the local (or national) economy. These 'wider economic impacts' typically go beyond a conventional transport cost-benefit appraisal (CBA) which focuses on the user-benefits created by a project. This is an unsatisfactory situation which creates a disjoint between the strategic arguments put forward in support of a project, and the associated economic analysis and CBA.

Unsurprisingly therefore, studies that examine the role of CBA in transport investment decision-making have found that it can have little or no impact on decision-making (Nilsson, 1991; Fridstrom and Elvik, 1997; Odeck, 1996; Eliasson et al., 2013) or that only certain elements of the CBA seem to matter (Nellthorp and Mackie, 2000; Odeck, 2010; Eliasson and Lundberg, 2012). Arguably, even with the most developed appraisal systems a 'good' CBA is at best a hurdle that has to be cleared (Eliasson and Lundberg, 2013; Eliasson et al., 2013; Kelly et al., 2015). This is also seen in England where projects are ascribed value for money criteria which influences the likelihood of a project being funded. Ultimately this marginalisation of CBA can result in politicised decision-making and potentially bad decisions. Decision-making is undertaken by a very heterogeneous group and within that group there exist philosophical differences in the approaches of economists, planners and politicians (Mouter et al., 2013; Eliasson et al., 2013). One solution to bridge the differences between the groups is to extend the CBA to incorporate wider economic impacts, while remaining firmly grounded in careful analysis of the impact of projects on welfare, as is attempted in the UK (see e.g. SACTRA, 1999; DfT, 2005). Then even if the value of wider economic impacts turns out to be small, the appraisal has engaged with the arguments put forward by scheme promoters and local interests and runs less risk of being marginalised.

Internationally, development of transport appraisal guidance in this area remains limited (for surveys see Odgaard et al., 2005; Mackie et al., 2014). Incorporating wider economic impacts in CBA is challenging and has its own risks. Broadening the set of mechanisms that are studied creates the risk that bad arguments may appear to be legitimised, and that effects can be exaggerated. Studies tend to concentrate on areas where a transport improvement expands economic activity, and to ignore areas from which this activity may have

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0967-070X/

been displaced. This, together with reporting of GVA effects, makes it possible that fundamental economic principles – above all that drawing resources into an activity has an opportunity cost – can be overlooked. The challenge is to be ambitious in broadening the scope of appraisal while remaining grounded in rigorous analysis of the social value of transport investments and of any private sector responses that they induce.

How should this be done? One answer is a full economic modelling exercise, in which resource constraints are properly imposed, private sector responses are modelled, market imperfections are made explicit, and real income (utility) benefits accurately calculated. This may be appropriate for some large projects, but is not a general solution. Such models are expensive and it would be disproportionate to use them for the majority of projects. A consequence of their expense is that typically one model is built and then applied to different situations in a somewhat mechanical manner, paying insufficient attention to the characteristics of the scheme and its likely effects. They then fail to capture the quite different impacts of e.g. an urban commuting scheme, an urban by-pass, or an inter-city rail line. These projects have different stated objectives and will trigger different private sector responses. It follows that the appraisals must be designed to be context specific. Some should focus on the consequences of getting more people into a city centre, others on relieving traffic congestion or on better linking remote locations, and so on.

The need, therefore, is to develop a framework of possible channels or mechanisms through which wider economic impacts can occur and to find the evidence needed to quantify these mechanisms and apply them in appraisal. The application of these mechanisms to particular projects needs to be context specific, informed by the strategic narrative that motivates the project; some mechanisms are applicable to some types of transport projects, others to others. For larger projects the mechanisms can be formulated in a complete economic model. For other projects this has to be done by the analyst's linear approximation to the formal model. This means that component parts will be studied separately and then added up. Of course, the relationship between the components must be consistent (so adding up does not double-count), the components must be exhaustive (so if some activity expands others may contract), and the focus should be on identifying the true social value of effects.

The focus in this paper is on wider economic impacts. That is not to say that social, equity and environmental impacts additional to user-benefits do not occur, but they are addressed elsewhere in the literature on appraisal. There are of course inter-relationships between wider economic, social, equity and environmental impacts – an example would be a transport investment that reduces unemployment in a remote region having wider economic, social and equity impacts. We do not delve into these inter-relationships beyond observing that, as with the treatment of wider economic impacts, double counting of the same benefit has to be avoided. Our focus here is on the correct treatment of wider economic impacts in an appraisal including avoiding double counting both between wider economic impacts and user benefits and between different wider economic impacts.

This paper sets out and discusses the key components of this approach. The next section, Section 2, presents the mechanisms that comprise the framework grouped into: user-benefits: proximity and productivity due to agglomeration: induced investment and land use change: and employment. It discusses the concept of a context specific appraisal in which the analyst focuses on the mechanisms of relevance in the analysis. Section 3 of the paper then sets out three key challenges to the implementation of the framework, whilst the final section, Section 4, presents some concluding remarks.

2. The framework

2.1. The effects of a transport improvement

A transport improvement brings time and cost savings to users of the transport network.[1] The users are individuals and households in their work and leisure activity, and firms which need to move goods, services, and employees. Time and cost savings change traffic flows, leading to increased flows in some parts of the network and possibly less traffic elsewhere. They are illustrated in the left hand column of Fig. 1. We follow practice in the transport literature and refer to the social value of these change as the ***user-benefits*** of a project.[2]

Wider economic impacts are illustrated in the right hand part of Fig. 1, and arise as a consequence of transport's impact on economic geography. Better transport increases proximity, making economic agents closer together, and may also trigger relocation of economic activity as firms and households respond to new opportunities. Together, these changes create potential sources of 'wider economic benefit' through three main mechanisms.

The first is that proximity and relocation shape the effective density of economic activity and thereby productivity. This is over and above the direct productivity effects of faster journeys, and arises because of the intense economic interaction that occurs in economically large and dense places. This is why cities and other agglomerations exist. This observation is backed-up by a substantial research literature that quantifies the positive relationship between economic density and productivity.

Second, a transport improvement, other things equal, will make affected locations more attractive destinations for investment. User-benefits are experienced by residents, workers, and firms, and this may induce investment to occur, changing land use. Investments include residential development of land, the development of office centres or retail parks, or the redevelopment and regeneration of city centres. They may in turn generate agglomeration and productivity effects, and also have further value by changing the 'attractiveness' of affected places.

Third, there may be impacts in the labour market, on both the supply and demand side. On the supply side, transport may enable labour force participation. On the demand side, jobs will be created in some places and some activities, and possibly lost in others.

Of course, there are links between all these mechanisms. A transport improvement might induce private investment, raising employment, creating agglomeration effects and feeding back into traffic flows. Distinguishing between the different mechanisms that may create welfare gain is conceptually important, while in practice care must be taken not to double-count effects.

To include these impacts in transport appraisal two economic questions must be addressed. First, is there a sound reason to think that they create a *social value*, over and above user-benefits? This requires understanding the mechanisms at work and, essentially, identifying a market failure. Absent such failures (small) quantity changes are of zero social value, as the price system equates the marginal value of changing an activity to its marginal cost. But if transport induces a change that interacts in some way with a market failure then it will create additional benefit or cost. Notice that these valuations are in terms of social welfare (ultimate household benefit), not of GVA. The distinction between the two is well known, and the focus throughout this paper is social welfare.

Second, local changes have to be set in the context of the national aggregate. In practice, this means thinking hard about displacement.

[1] Throughout we focus on the effects of the completed project. We do not investigate the construction costs of projects, nor include the temporary economic activity created by construction.

[2] Of course, they do not necessarily accrue to the user as e.g. they may be shifted to rents and captured in land value appreciation.

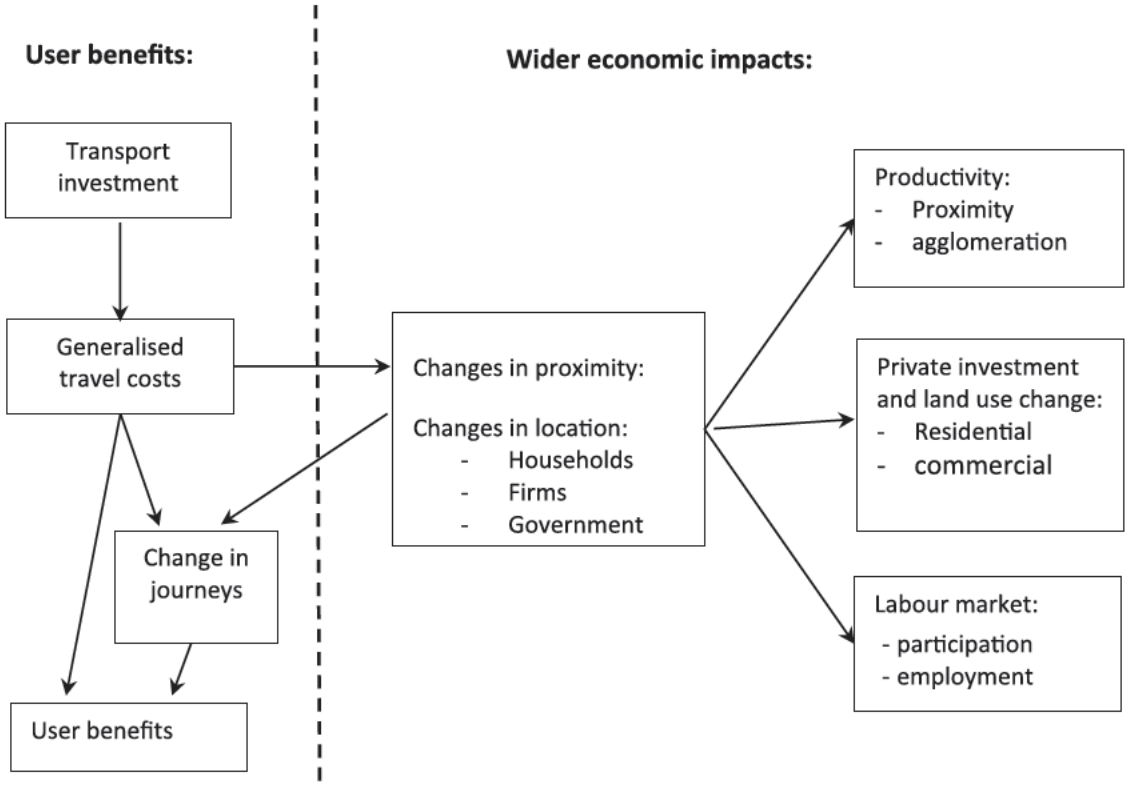

Fig. 1. The effects of a transport improvement. Note: Feedback effects are excluded for clarity.

For example, job creation in one region may be at the expense of job losses in another. Each change may be of interest to local stakeholders, and it may therefore be appropriate to report them in project appraisal. However, national appraisal has to report national aggregates and provide the complete view, which may be missing due to concentration on effects in the neighbourhood of the project.

The remainder of this section looks in turn at each element of this framework starting with user-benefits.

2.2. User-benefits

The core of an evaluation is the benefits and costs accruing to users of the transport system. This is the primary activity in which the policy intervention acts. Evidence to date suggests that these benefits form the largest component of benefit of infrastructure investment. In fact when markets are working perfectly and changes are small the benefits accruing in the transport system are all that need to be considered as marginal costs and benefits equal each other in the inter-related secondary markets.

Accurate measurement of user-benefits can be challenging and considerable effort is often expended in calculating travel demands, travel times and costs. A change in quality and cost of travel leads to substitution between routes, time periods, origins, destinations and mode. Travel demand may also grow in absolute terms – both in terms of number of trips and/or in distance travelled. Underlying these changes are a whole host of behavioural decisions including where to trade, who to trade with, and where to shop, work, or live. Generalised travel costs comprise both the direct user experienced monetary costs of operating private vehicles, road charges and public transport fares, as well as non-market goods such as time, comfort and reliability. Shadow pricing of these non-market effects is therefore critical to the accurate measurement of generalised transport costs and hence user-benefits.

The quantity changes in travel demand, travel time and reliability, etc. in combination with the observed market prices and shadow prices are used to value the real income gain of the transport investment. When the changes are small this can be approximated using the rule of half.

$$User\ Benefit = \frac{1}{2}(T_1+T_0)(GTC_1-GTC_0),$$

where T_0, T_1, GTC_0 and GTC_1 are the travel demands and generalised travel costs before and after the transport investment.

Two further comments are noteworthy. First, elements of generalised travel costs may be shadow priced to incorporate external effects that may go beyond those immediately experienced by transport users. These include costs of local pollution such as noise and particulates, and of C02 emissions and global environmental damage. Second, user-benefits may be associated with productivity increases. This is because physical assets such as rolling stock or road haulage vehicles can be used more efficiently if trips take less time, and similarly the usefulness or productivity of travel time depends on comfort, reliability, service frequency, and so on. These effects are valued in generalised travel costs; a cost saving in road haulage and a productivity increase in vehicles are just two names for the same thing. They are not to be confused with external economies of agglomeration and productivity, as described in the next sub-section.

2.3. Proximity and productivity due to agglomeration

It is widely recognised that economic density – the clustering of activity in towns and cities – has a positive impact on productivity, and that such clustering is dependent on effective transport systems. Some of the productivity effects come from interactions between different economic agents that are not fully internalised, creating market failure and wider economic benefits, as recognised in the appraisal methodology of the UK, Australia, New Zealand, Sweden and different US states (Mackie et al., 2014).

Transport improvements enable savings in transport and communication costs for firms, workers, and consumers, enhancing effective proximity. In turn, cheaper, more reliable and faster transport may allow firms to change the way in which they organise their logistics or production (e.g. just-in-time manufacturing technologies). These gains are user-benefits, and are accounted for in calculation of those benefits. They should not be double-counted as a wider economic impact.

Wider economic impacts arise when economic agents cannot capture the entire benefits (or costs) of their actions, i.e. they create externalities that are of value for other agents.[3] These may be technological (i.e. effects not intermediated through a market, such as knowledge spillovers) or pecuniary (going through an imperfect market). By supporting thicker markets and more intense economic interaction, proximity creates a number of these effects. Probably the most important mechanism is that scale and density together create an environment where firms and workers can develop highly specialised products, services and skills. These are typically inputs to other firms – the specialist components, and engineers, lawyers, finance experts who may be necessary to efficient operation of a firm.[4] A new specialist supplier will set up once the market is big enough, and the presence of the new supplier will make the cluster more attractive as a location for other firms that use the product or service. This grows the market for specialist suppliers, encouraging further entry and hence a cumulative causation process. This is the classic process of cluster formation, such as an auto-industry cluster of assemblers and suppliers or a film industry cluster of directors, actors and technicians. There are spillover effects (externalities) in this process. Indivisibilities or increasing returns to scale mean that a service, skill, facility or product will only be supplied if the market is big enough. The supplier is generally unable to capture all of the benefit, so there is a positive net effect created for others in the cluster.

A further mechanism arises as competition is likely to be intense in a large and dense cluster so monopolistic pockets of inefficiency are less likely to survive. Monopsonistic behaviour, occurring where there are few potential purchasers for a product or skill, can deter investment; this too is less likely to be a problem in a large and dense cluster. There may also be direct knowledge spillovers, as 'mysteries of the trade become no mysteries; but are as it were in the air' (Marshall 1890).

The mechanisms may operate within particular sectors or across a wide range of sectors, the former being referred to as localisation (or Marshallian) economies, and the latter as urbanisation (or Jacob) economies. Within-sector productivity effects create a force for sectorally specialised clusters and possibly specialised cities. This varies across sectors; it is important in some manufacturing sectors, such as automotive clusters in developed countries, and clusters in labour intensive sectors such as textiles and garments in developing countries. Clustering is particularly prevalent in business services such as finance, law, and media. Both the creation and diffusion of knowledge work particularly well in clusters, and a large body of literature points to the spatial concentration of innovative activities.[5]

A substantial econometric literature quantifies the relationship between productivity and economic mass and a reasonable consensus has emerged on the magnitude of the effects. An authoritative (although quite old) survey of the literature finds that 'in sum, doubling city size seems to increase productivity by an amount that ranges from roughly 3–8%' (Rosenthal and Strange, 2004, p2133). This means that the elasticity of productivity with respect to city size is in the range 0.05- 0.11 .[6] This is a large effect in the cross-section, suggesting that productivity in a city of 5 million is between 12% and 26% higher than in a city of ½ million. A meta-study (Melo et al., 2009) suggests that the mean estimate of this elasticity across thirty four studies which provide more than seven hundred elasticity estimates is somewhat lower, at 0.03, although points to considerable variation according to sector, country, and technique employed by researchers. Recent work using individual data (and controlling for individual effects) produces estimates of similar magnitude (see Combes and Gobillon, 2015). At the sectoral level, there is evidence of heterogeneity, with business services and high technology sectors exhibiting the largest localisation economies.

Transport is a necessary ingredient to securing these benefits, in three distinct ways.

i. Economic interactions between firms (and between firms and consumers) are more intense the better the transport system. Firms can reach wider markets, enabling them to expand, gain scale economies and develop specialist skills; markets are more competitive as the natural barrier of distance is reduced and inefficiencies associated with monopoly and monopsony power are eroded.
ii. Transport enables cities to specialise, developing sector specific advantages. Historically this was manifest in cities specialised in textiles, steel or cutlery. While some manufacturing clusters are still important, the phenomenon is now apparent in service sectors, particularly knowledge intensive activities. If better transport or communication enables some of the ancillary activities to be 'outsourced' to another city, it reduces costs and creates space for the high-value activities to further concentrate in the central cluster.
iii. Transport is necessary to get workers into concentrated and productive centres of activity. This is most apparent in commuting into central business districts, but there is also evidence that firms outside these districts benefit from drawing on a wide catchment area of employees.

While there is a single underlying mechanism at work in each of these cases – concentration of economic activities leads to high productivity – the precise role of transport is different in each. Effects vary across transport projects (e.g. commuting versus inter-city links) and across the areas, and sectors likely to be affected.

2.4. Induced investment and land-use change

A transport improvement will generally change the pattern of private investment across locations, and this process of encouraging – or even 'unlocking' – private development is often put forward as one of the major impacts of transport projects. The investment response is driven by the user-benefits experienced by residents, workers, and firms. These benefits feed through into secondary markets stimulating investment by either lowering marginal costs or increasing the return. This response changes traffic flows, changes which should be included in calculation of user-benefits. The investment would also be expected to increase output (GDP). Are there circumstances in which the induced investment creates wider benefits, additional to the user-benefits? We address this in two different contexts, first looking at the conditions necessary for induced changes in quantities (of outputs and inputs) to yield net economic benefit, and then at changes in land use – such as city centre redevelopment – for which transport improvement is the catalyst.

2.4.1. Increased output

In undistorted secondary markets marginal benefits equal marginal costs. For small changes in quantities supplied and demanded in the secondary markets there is no additional benefit to transport user benefits. In distorted markets however marginal benefits of increased output exceed the marginal cost of supplying them and there is an

[3] Duranton and Puga (2004) survey these ideas.

[4] The economics literature often models this as the presence of a large 'variety' of intermediate inputs. Each variety yields consumer surplus that is not captured by the supplier (i.e. the supplier cannot perfectly price discriminate). See the next section for further development of this idea.

[5] See for example, Audretsch and Feldman (2004), Glaeser and Gottlieb (2009).

[6] Elasticities are therefore in the range 0.05–0.08 since $2^{0.05}$=1.03 and $2^{0.11}$=1.08.

additional surplus, which can be relevant in a transport appraisal context (Venables and Gasiorek, 1999). Market power is prevalent in many sectors; studies have shown large variations by sector and by country with the service sector exhibiting higher mark-ups than manufacturing in the EU, whilst the opposite is the case in the US (Badinger, 2007; Christopoulou and Vermeulen, 2012).

This heterogeneity makes clear the importance of context specificity. Mark-ups differ between sectors and there will be net gains only if expanding sectors have larger mark-ups than those from which activity is displaced. This context specificity is likely to be most obvious between transport investments in cities containing high mark-up tradable services, compared to those in remoter regions dominated either by manufacturing or extraction of primary goods (oil and gas). Displacement can occur through different channels. It may arise directly in the product market (particularly for non-traded goods) or through general equilibrium effects and competition for scarce factors of production.

2.4.2. Land-use change

A more complex situation arises if transport acts as the catalyst that induces private investment in a large commercial development – retail, office, and perhaps involving redevelopment of a substantial parcel of city land. It is often suggested that such developments create an additional benefit by making an area 'more attractive' .[7] Under what circumstances do these benefits exceed the user-benefits received by travellers to and from the area?

A conceptualisation of this is offered in Fig.2; the context developed in the figure is that of a retail development, although the arguments put forward are more general.[8] A transport improvement increases spending in a place, as visits respond to lower travel costs. Increased spending raises profitability of shops and hence the landlord is able to charge higher rents. This makes it profitable to develop more space, redeveloping the site – by extension, or perhaps by building taller. This expansion creates more floor space and hence the entry of more shops, in turn making the place a more attractive destination and creating the feedback loop illustrated in the figure.

User-benefits trigger this process, and wider-benefits arise if (and only if) there are interactions with market failure. There are, arguably, two sources of market failure in this process, labelled M and V on Fig. 2. The first, M, arises as there may be barriers preventing the level of development reaching an efficient level and hence creating gaps between marginal benefits and costs. The second is at point V, and captures the idea that places become more attractive as they attract more stores. We look first at the attractiveness argument, V, and then turn to barriers to development, M.

The attractiveness argument has foundation if entry of new stores creates some consumer surplus, i.e. consumer utility over and above the value of their spending. This will arise if stores are differentiated from each other, and is formalised in many sub-fields of economics as a variety effect. For example, in international trade it is argued that much of gains from trade (at least, intra-industry trade between similar countries) arises from countries being able to access a wider range of products (for quantification of these effects see Broda and Weinstein, 2006). By analogy, introducing new stores in a retail development creates consumer surplus since it increases the range of choice (number of varieties) available to consumers. The standard methodology for quantifying the gain assumes that demand for the products under study is iso-elastic. Denoting this elasticity σ, the ratio of consumer surplus to expenditure on a new variety is $1/(\sigma - 1)$.[9] Hence, the value of any variety effect is equal to the change in expenditure divided by $(\sigma - 1)$. If products are perfect substitutes – the retail development just means more identical stores – then σ is infinite, there is no increase in 'attractiveness' and no welfare effect.[10] Typical estimates of σ from other contexts suggest values in the range 6 – 10, suggesting a wider benefit mark up of 10–20% of expenditure in the development.

Three further remarks need to be made about the variety effect. First, following the approach above, it can be calculated as a mark-up factor on the change in consumer expenditure in the development. This is project specific data that is observable ex post and likely to be part of development plans at the appraisal or planning stage. Thus, estimates of possible wider-benefit created can be tested against the commercial proposition put forward by developers. This avoids having to resort to ad hoc shifts in demand curves in order to capture these effects.

Second, the discussion above is in terms of retail development. An exactly analogous argument applies to an office development scheme, but with the variety effect restated as an agglomeration effect. In both cases entry of a new firm (shop or office) creates a positive spillover, as the entrant is unable to capture the entire benefit created. This analysis is therefore a restatement of the agglomeration and productivity arguments of the previous section. Of course, only one of the two approaches should be followed for any particular project.

Third, these arguments (and those of the preceding section) have to be placed in the context of product market displacement effects. Would the activity – manufacturing, commercial or residential – take place somewhere else, absent the transport improvement? If so, is it subject to the same market failures? Effects across all geographical areas then have to be combined – some of them positive, and others negative.

We now turn to the other possible source of market failure, the presence of barriers to development, M. This is applicable to both commercial and residential developments. A number of sources of market failure may be possible. There may be monopoly power as a developer perceives that building extra space reduces rents, or the planning system may over-restrict development, particularly if it is looking only at the interests of local residents in the development of a scheme that could bring benefits to a more spatially dispersed group of shoppers of workers. In both situations an increase in quantity supplied brings wider benefit proportional to the gap between marginal social benefit and cost.

Additional barriers may be present in large scale commercial developments as they involve investments by many distinct decision takers – property developers and retailers in the conceptualisation of Fig. 2, or perhaps multiple developers in a large scheme. If the profitability of the project for one decision taker depends on investment by others (as illustrated by the feedback mechanism of Fig. 2), then there is potential for coordination failure. It is not in the interest of any single investor to invest, but each would invest if they knew that others were. This positive interdependence of profitability could arise in starting a new cluster of economic activity (i.e. the productivity arguments of Section 2.4) or in launching new retail or urban redevelopment schemes. Coordination failures thus lead to low level traps and require some policy mechanism to coordinate individual actions and break out of the trap. Transport investment can be such a mechanism. Transport infrastructure may act as a catalyst in a growing city as signal that a location will develop or in a regeneration environment[11] by for example increasing property prices

[7] A statement of the issue is given by Simmonds (2012): "if a transport change improves access to a town centre and causes an increase in demand for shopping and services there, this is likely to lead to an improvement in the retail offer of that centre, which will be an externality benefit to residents with easy access to that centre". See also Martinez and Araya (2000), Geurs et al. (2006, 2010).

[8] This is based on Venables (2016) and adds some micro-economic detail to the model of Harris and Wilson (1978).

[9] For an iso-elastic demand curve, $x = p^{-\sigma}$, expenditure is $px = p^{1-\sigma}$ and consumer surplus (CS) is the integral of the area below the demand curve and above price, $CS = p^{1-\sigma}/(1-\sigma)$, from which the ratio of consumer surplus to expenditure is $1/(1\text{-}\sigma)$. For fuller treatment, with many varieties and a spatial structure see Fujita et al. (1999).

[10] See Mankiw and Whinston (1986) for the possibility of welfare loss when products are perfect substitutes.

[11] Subject to other conditions of growth being met – primarily the availability of appropriately skilled labour.

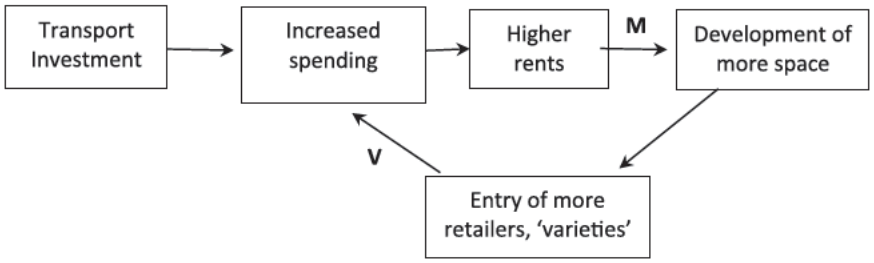

Fig. 2. Land use change in a commercial development.

and thereby increasing the return to property improvement.

2.5. Employment

Job creation is often held up as a major impact of transport investment, with two distinct mechanisms being suggested. One is on the supply side: better transport may make it easier for people to get to work, and may reduce discouraged worker effects. The other is on the demand side, with induced investment creating new employment opportunities. We discuss each in turn noting that, as usual, the benchmark is a situation where a change in quantities – of jobs or other variables – is of zero social value.

2.5.1. Labour supply: participation and tax wedges

On the supply side, individuals' labour force participation decisions are based on comparing the costs of working (including commuting costs), against the wages earned from a job. By reducing the cost (in time and money) of getting to work, a transport investment is likely to increase the returns to working; some people, for whom the net returns to entering the labour market were initially not worthwhile, may decide to enter. Such an increase in labour supply and employment raises GVA but, in the simplest circumstances, does not increase welfare. Initially, the individual was not working because the utility from leisure exceeded that from working, net of commuting costs. If a transport improvement triggers work, the benefit to the individual cannot be greater than the user-benefit received (if it were, the individual would have chosen to work in the first place). However, this conclusion changes if there is an income tax wedge (or loss of state benefits). The individual does not receive the full value of work undertaken because a fraction of it accrues to government. The full gain from entering employment is then the user-benefit plus tax revenue paid (or benefits not received). This distortion has received little attention in appraisal practice – for example Mackie et al. (2014)'s survey finds that only the UK appraisal practice includes this tax wedge effect in guidance.

Similar principles apply if transport triggers a densification of commercial land use - for example around city centre train stations. Workers may now prefer to commute to a higher paid city centre job than have a lower paid job in the suburbs. However, their calculation of the net private gain from switching jobs is based on post-tax income, not the pre-tax wage. The exchequer captures the tax wedge in this decision.

2.5.2. Labour demand and unemployment

Turning to the demand side, if new jobs are created in one place then the value of output produced by each new job is the wage, and this is set against the value of what workers would have done in the absence of the jobs created. For long-run transport projects in reasonably well functioning market economies it is likely that the labour market will adjust to some 'natural rate' of employment which is independent of transport investment. If this is the case then an increase in labour demand is met either by increased labour force participation or by drawing workers out of other employment. If demand is met by increased labour force participation then its value is, as above, the tax wedge on income. If it is met by withdrawing labour from other activities, then the value is the alternative wage. There is no net benefit if wages are the same in both jobs. Displacement is 100%, so demand induced employment effects should, from the national perspective, be ignored.

The argument differs if some market failure leads to persistent involuntary unemployment and transport induced job creation reduces this level of unemployment. The value of output (and of 'leisure') foregone is then less than the value of output in jobs created, and there may be additional social benefits from lowering unemployment. These effects are important in developing economies, as well as in regions of developed economies that have significant structural un- (or under-) employment.

One further point is conceptually important, although perhaps not quantitatively large for any single transport project. To draw labour from other activities there may have to be an increase in wage rates in the area affected or more broadly. Given the level of productivity, an increase in wages must be financed either by a reduction in profits (or more generally, payments to other inputs), or by an increase in prices. The increase in wages is therefore just a transfer, of no value to aggregate income, unless the people paying for it (consumers and recipients of profits) are, for some reason, people that we do not value. A standard approach would be to suggest that benefit arises to the extent that the increase in price is paid by foreigners, i.e. represents a terms of trade improvement, so the country is able to sell its exports at higher price. This is an additional source of benefit, although one that is unlikely to be quantitatively significant for any single transport project.

2.6. Context specific appraisal

Transport appraisal needs to be proportionate. It would clearly be highly resource intensive and unnecessary to research the impacts of all the economy mechanisms discussed as part of every transport appraisal. Context specific appraisals that focus in on the relevant economy mechanisms are therefore necessary (see Table 1). A significant expansion of city centre rail connectivity serving a major urban centre with strong growth (e.g. Crossrail and Canary Wharf, London) would for example focus on the economy mechanisms: user-benefits, dynamic productivity growth through employment changes and the tax wedge from the move to more productive jobs. This is because the strategic narrative underlying the project is one about facilitating employment growth and productivity in Central London by increasing rail capacity and commuting opportunities which are currently constraining growth.

Contrastingly the strategic narrative behind inter-city connectivity such as a high speed rail line is often one of increasing business efficiency and initiating land use change around the stations. This points towards a context specific appraisal that would focus on user-benefits (including productivity increases due to increased specialisation), barriers to development and the benefits of land use change. The strategic narrative for step changes in inter-urban connectivity between rural/peripheral regions and core regions is often one associated with promoting economic growth in core industrial sectors typically primary sector (e.g. oil and gas industry, fishing, etc.) and related manufacturing (e.g. in food and drink). A context specific appraisal would therefore focus on user-benefits, productivity benefits through increased specia-

Table 1
Economic impact and transport-economy mechanism.

Economic impact	Mechanism		Valuing	
			Welfare	National GVA
User-benefits	Firms[1]	ΔGTC leads to Δcost / price	✓	✓[5]
	Households	ΔGTC leads to Δtime/quality/cost	✓	–
Productivity due to agglomeration	Static (larger markets)	ΔEconomic mass (with fixed land uses and ΔGTC) changes productivity	✓	✓
	Dynamic: clustering and increased specialisation	ΔLocation/ activity levels of sectors. Cluster formation raises productivity	✓	✓
Induced Investment and land use change	Increased output[2]	ΔQ x Displacement (0–100%)	–	✓[5]
		ΔQ and imperfect competition x Displacement (0–100%)	✓	✓
	Land use change	Increased varieties/attractiveness (land use externality) x Displacement (0–100%)	✓/–[3]	✓/–[3]
	Barriers to development	Market failure in the planning regime x Displacement (0–100%)	✓	✓
		Coordination failure	✓	✓
	Multi-sectoral investment	Complementary policies reinforcing each other. Partial equilibrium analysis is inappropriate – examine land value uplift or use multi-market methods x Displacement (0–100%)	✓	✓
Employment	Labour supply	Δlabour supply function due to lowering barriers to work (market failure is tax on income)	✓	✓[5]
	Labour demand	Move to more productive jobs (market failure is tax on income)	✓	–[6]
		Reducing unemployment in areas of high unemployment (structural employment, market failure in the labour or housing markets) [4]	✓	–

Notes: (1) ΔGTC – generalised transport costs; (2) ΔQ – change in output; (3) land use externality can be related to the agglomeration externality and the analysis must be structured to avoid double-counting; (4) If labour is displaced from an area experiencing similar market failures, as may be obvious from similar levels of unemployment, then displacement effects also need to be taken into account. (5) Care needs to be taken to avoid double-counting GVA impacts; (6) GVA impact included in dynamic productivity effects due to changes in employment.

lisation, increased output in imperfect markets (should the sectors in the regions affected exhibit imperfect competition) and benefits from increased/displaced employment (should the regions affected exhibit imperfect labour markets).

3. Three challenges

The economic framework set out in the previous section focuses on the mechanisms by which a transport investment delivers economic performance and how that performance can be valued within the context of an appraisal proportionate to the scale of the investment. In implementing an appraisal there remain a number of challenges of which three stand out: the practicalities of using the agglomeration elasticity evidence base in an appraisal, the measurement of user-benefits with land use change and multi-sectoral investments, and the challenge of estimating the quantity effects on output and employment. The rest of this section takes each of these challenges in turn, setting out the issues and in places presenting tractable solutions until further research becomes available.

3.1. Productivity due to agglomeration

The underlying economic theory and empirical evidence on the relationship between productivity, agglomeration and transport is persuasive and its inclusion in transport appraisal practice is becoming standard in certain countries. Challenges, however, remain. There is a degree of consensus regarding how productivity varies with economic mass. Accessibility, as part of the economic mass 'equation', is part of that relationship– both empirically and theoretically. This is however subtly distinct from saying that if we increase accessibility and therefore economic mass we will get an increase in productivity. Ex ante transport appraisal methods employed in the UK, New Zealand, Australia and elsewhere simply assume that we will. Improved statistical methods that account for heterogeneity in labour and that use micro-level firm data increasingly produce lower estimates of agglomeration elasticities, and some advanced methods have not been able to distinguish the role of transport accessibility from other drivers of agglomeration "implying that the use of conventional point elasticity methods may be highly misleading" (Graham and van Dender, 2011). The issue is exacerbated by the lack of robust ex post data. The limited studies there have been have identified a positive change in productivity following transport interventions (What Works, 2015 pp26) – albeit these studies do not distinguish between productivity improvements due to user-benefits and those arising due to increased agglomeration. Better evidence of the ability of transport to deliver gains in productivity due to agglomeration is needed.

The transport market is heterogeneous. Different modes serve different destinations; travel conditions vary by mode and by time of day; and travel is made for a variety of different reasons (e.g. freight, business, commuting, leisure). The key questions then from a productivity and agglomeration perspective are whether some of these market segments are more important than others and if so by how much? Rail and public transport in general serve city centres which are a key driver to agglomeration related productivity gains, peak hour journey times are important for commuting and labour market connectivity, inter-peak journey times are important for freight and business trips and the associated business to business connectivity, whilst non-work-other journey times are important in terms of market access and for education. The implication is that they are all important at some degree, but empirically they are unlikely to be of equal value – unless by coincidence. D'Costa et al. (2012) find some evidence of this variation by mode, but aside from that the literature is silent on the issue. Primarily this is due to empirical difficulties in separating out the contribution of different accessibility measures.[12] Given this void transport appraisal practitioners have been reduced to combining generalised travel costs across modes and time periods on grounds of

[12] Typically locations that are well connected by one mode or in one time period are also well connected in other modes and time periods, leading to a lack of variation in observed data and difficulties separating out effects by mode and time period.

reasonableness, rather than evidence, when formulating the change in economic mass.[13] Unfortunately subtle changes in the assumptions that underpin these calculations can give very different predictions of productivity gains. There is therefore an evidence gap regarding which transport market segments drive the productivity gains from agglomeration and how to aggregate generalised transport costs across these segments.

The empirical literature on agglomeration externalities points increasingly to the use of firm level microdata as the preferred data for estimating agglomeration elasticities. Furthermore methods used to control for endogeneity between accessibility and productivity have also led to the use of distance measures in the economic mass metric (see e.g. Graham, 2007; Graham et al., 2010). This creates a tension in a transport appraisal context at two levels. Firstly firm level data typically excludes the public sector – which in developed country economies can form a third of the workforce; whether or not this sector benefits from agglomeration economies is a moot point. Secondly a distance based economic mass metric is not sensitive to transport policy – aside from the obvious but rare estuarial crossing or mountain pass/tunnel type investments. In application appraisal practice has had to accommodate these difficulties. Guidance such as that in the UK does this by excluding productivity gains to the public sector and extrapolating the distance based agglomeration elasticities to generalised cost (Department for Transport (DfT), 2014a), but clearly this is not ideal.

The increased interest in cluster formation and increased specialisation as a consequence of inter-city effects exposes further empirical gaps when attempting to translate theory into transport appraisal practice. We associate both localisation and urbanisation agglomeration economies with increased city specialisation arising from inter-city effects, but once again empirically we find that these effects are correlated making it empirically difficult to separately identify the urbanisation and localisation effects. The choice of different accessibility metrics in the economic mass variable is one approach that has been adopted Graham (2009) and as expected leads to lower estimates of agglomeration elasticities vis a vis studies that only identify either localisation or urbanisation productivity elasticities (Melo et al., 2009). The other part of the story is the ability to model how industrial composition will alter as a consequence of inter-city connectivity. Land Use Transport Interaction models (see Wegener, 2011 for a review) can be used to model how industry location changes giving rise to industrial clusters, but the recent research effort focused on identifying task specialisation within the service sector (Michaels et al., 2013) has not as yet been subject to any significant modelling effort.

3.2. Land use change and user-benefits

Behaviourally we associate transport investment with private investment decisions of business and households – as in Fig. 1. This leads to land use change. We have also seen that land use change can generate an externality by changing the attractiveness of an area. In the political landscape transport infrastructure typically forms part of a co-ordinated development strategy that has many facets – improving the urban fabric of a city, increasing the supply of business premises, improving broadband connectivity, increasing housing availability and increasing work force skills as well as transport. Changing the attractiveness of an area is usually an expectation of such a co-ordinated strategy. Furthermore a co-ordinated strategy is necessary to maximise the economic growth potential of new transport investment (Bannister and Berechman, 2001; Vickerman, 2015). This combination poses a number of practical and empirical challenges for transport appraisal.

Conceptually a cost benefit analysis focuses on the primary market and surpluses in secondary markets are only considered if prices diverge from marginal costs in these markets. For investments that are co-ordinated across multiple sectors this approach becomes intractable due to the presence of multiple primary markets. Basing the appraisal on only one primary market (e.g. using changes in transport costs and quantities) is clearly inappropriate and can lead to significant errors including of the wrong sign (Neuberger, 1971; Simmonds and Bates, 2001; Geurs et al., 2010). A multi-market analysis with changes in welfare measured at the household level is one solution to this problem – for instance using spatial computable general equilibrium (S-CGE) models (Bröcker, 2010) or land use transport interaction (LUTI) models (Martinez and Araya, 2000; Simmonds, 2012). The modelling techniques needed though remain on the research frontier. This is unfortunate given that most major infrastructure projects are associated with significant changes in land use plans. An alternative to a multi-market approach is to look at the land market and measure the changes in surpluses that occur there. However, the land market is an imperfect place to measure investments (see Arnott and Stiglitz, 1981 and Mohring, 1993 for a discussion vis a vis transport investments) and the use of land value uplift is fraught with difficulties associated with addressing displacement effects and netting out the land value uplift from construction costs and the effects of speculation. There also remains the question as to how accurate changes in land value are at reflecting transport investment benefits.

Transport induced land use change discussed in Section 2.4 is distinct from multi-sectoral investments by the public sector. Changes in the land market induced by the transport shock are indirect effects. The primary market for the appraisal therefore remains the transport market, and price and quantity changes in the land market are general equilibrium effects which can be excluded from the appraisal aside from in the circumstances set out in Section 2.4. With a well functioning land market user-benefits calculated under conditions of variable land use[14] give an accurate measure of economic value. If land use change is associated with a change in attractiveness due to increasing varieties becoming available then an externality may be present. A number of methods have been proposed to measure these benefits/costs: the measurement of a land use externality in spatial interaction model within a maximum entropy framework (Martinez and Araya, 2000); the use of hierarchial logit models and the logsum within a Land-Use Transport Interaction (LUTI) model framework (Geurs et al., 2006); the disaggregation of the transport utility function between a transport cost term and an attractiveness term (Bates et al., 2006); and the calculation of economic benefit at the household level in a LUTI model (Simmonds, 2012).

From a practical perspective unfortunately these methods are relatively untested and remain on the research frontier. There therefore exists a question regarding the size of the error associated with excluding changes in varieties/attractiveness from the transport appraisal analysis. As discussed in Section 2.4 drawing from evidence in other contexts suggests a wider benefit mark-up of 10–20%. There are limited transport examples that shed light on this. Drawing from Borjesson et al. (2015 table 4) we can also see that attractiveness benefits are context specific. The attractiveness benefit brought about by a road scheme whose impacts are quite dispersed is low at 0.5% of consumer surplus, but for a commuter rail link where attractiveness changes around stations are high the benefit is higher at 6%. An alternative to excluding changes in attractiveness/varieties from the appraisal is to hold land uses fixed. This approach has been adopted by the UK Department for Transport for example (Department for Transport (DfT), 2014b). The problem with this approach is that the

[13] The UK Department for Transport for example excludes non-work other and freight travel times from the calculation, gives travel times by each mode and time period an equal weight (DfT, 2014a).

[14] Fixed land use is when land uses in the Do Minimum and Do Something do not vary, whilst variable land use is when land use varies between the Do Minimum and Do Something.

congestion and other external costs associated with the traffic associated with the induced land use change are not included in the appraisal. Borjesson et al.'s analysis indicates that these costs are an order of magnitude bigger than the attractiveness benefits/costs at between 1% for the road scheme and 19% of user-benefits for the rail scheme. The implication is that whilst there is a need to develop analytical methods to capture the benefits from induced land use change it is better to base an appraisal on variable land uses (and exclude benefits from changes in attractiveness/varieties) than to calculate user-benefits based on fixed land uses. This does not however remove the need for further research on this matter.

3.3. Predicting quantity effects

Preceding sections of this paper have concentrated on the sources of wider benefits and the way in which they can be valued. To apply this in appraisal requires that forecasts can be made of the quantity changes (changes in investment, output and employment, as well as changes in traffic) that are likely to follow from a transport improvement, and which drive the wider economic impacts. These predicted changes have always formed part of the political debate that surrounds transport infrastructure but they are inevitably subject to considerable uncertainty. The larger the project and the longer the time-scale over which it is expected to have effects, the more variables need to be treated as endogenous and hence, inevitably, the greater the degree of uncertainty.

A range of modelling approaches is now available,[15] making different assumptions about the economy – primarily in the treatment of the supply side. Many LUTI models are highly constrained and redistribute existing employment to new locations. On the other hand, Multi- Regional Input – Output (MRIO) methods have an unconstrained supply side and output and employment can expand without any constraints on labour supply. Another important difference is the treatment of capital both human and physical. D'Costa et al. (2012) distinguish between people based productivity effects and place based productivity effects. The difference between the two is that people based productivity effects account for structural change in the economy – that is human capital (education, skills) and the industrial mix change in response to the transport scheme. Modelling people based productivity effects clearly treats the supply side in a more relaxed way than modelling only place based productivity effects. Some transport economy modelling captures people based effects without explicitly modelling the causal channels (e.g. using people based agglomeration elasticities – for an application see KPMG, 2014), whilst others model the causal channels more explicitly such as recursive or quasi-dynamic LUTI models and systems dynamic models.[16] A similar relaxation of supply side constraints on physical capital can occur in a model with for example capital flowing from one region to another, or alternatively shifts in physical capital and land uses that permit cities or regions to specialise in response to reductions in transport costs. Even within a model genre it is possible to take adopt different approaches to the supply side – for example the treatment of labour supply within a Spatial Computable General Equilibrium model may vary with the application. These human and physical capital changes that generate structural change are long run effects taking 10 s if not more than 100 years to occur in full (Barro and Sala-i-Martin, 2004 p59) and Bröcker et al. (2004 p175) argue the difference between whether the model is predicting short run effects (with factors fixed) or long run effects can be a major source of difference between models. It is therefore important to not only distinguish between how constrained the supply side is within the modelling exercise but also the time interval over which the expected economy impacts will occur – the two things are obviously interrelated.

Having a family of models is valuable providing there is clarity about the differences between them and appropriate models are chosen for appraising particular types of project. Transparency is needed, particularly in two respects. First, the assumptions that drive predicted quantity changes need to be laid out clearly. And second, assumptions underpinning the valuation of these changes – and hence the impacts of the project on measures of economic performance (be it welfare or GDP) – need to be made clear. Lack of understanding of why different models are likely to produce different predictions means that inappropriate techniques may be used to appraise particular projects. Project promoters will systematically prefer some techniques to others, and lack of transparency means that effective challenge from the transport planning sector is difficult. Informed debate is then very difficult, as is evident for example from the debates surrounding the modelling of the economy impacts of the high speed rail line from London to the north (HS2) and the economic impacts of Heathrow and Gatwick Airports (Overman, 2013; Laird and Stroombergen, 2015).

Transparency in model structure needs to be accompanied by better benchmarking and auditing of transport-economy modelling studies. The aggregate studies of the role of transport infrastructure on economic performance in the tradition of Aschauer, (1989, 1990) and summarised in a meta-study of Melo et al. (2013), whilst lacking the context specificity to be used in a modelling environment are useful as a reality check. They can be used to set bounds against which estimates of effects of particular projects should be compared. The econometric literature on ex post evaluation of the effects of transport improvements faces many methodological challenges, but is another source of reality check for modelling studies.[17]

The uncertainty in the economy modelling means there is a role for sensitivity and scenario testing. One aspect of this is with respect to the way in which the supply side of the economy has been modelled and the possible private sector response to a transport project. Another is with respect to the inter-dependency between transport and other public projects and policies. Synergies extend not just across transport projects and associated private development, but also across government policies, including land-use policy and wider urban and regional development measures. Policy making needs to recognise the potential synergies arising from interaction between policies, and techniques developed for assessing the full impact of transport projects need to be applied to complete policy packages. Thus, a series of small interventions may collectively – if not individually – create a wider economic impact. Scenarios can be produced of the effects of different combinations of policy and other changes, and each scenario can be value. Fundamentally, if each element of a policy package is necessary for change, and no one of them independently sufficient, then the package has to be evaluated as a whole.

4. Concluding remarks

Transport investments are likely to have impacts (positive and negative) over and above conventionally measured user-benefits. These impacts may be social, environmental, or economic. They need to be taken into account in decision-taking and this requires rigorous techniques for establishing effects and for estimating their full value to society. The focus in this paper is on economic impacts. In particular, transport can raise productivity by fostering intense economic interaction; this can occur in clusters within narrowly defined areas or more widely by linking areas; transport shapes the level and location of private investment, unlocking development and triggering large scale redevelopment of urban and other areas; and transport impacts the labour market, potentially enabling more workers to access jobs. These impacts can yield real income gains, particularly where

[15] See Wegener (2011) for an overview of transport-economy modelling approaches.
[16] See Wegener (2014) for a review of LUTI models.
[17] For a survey see Redding and Turner (2016).

transport induced investments interact with market failures associated with increasing returns to scale, obstacles to efficient land use, and labour market imperfections.

Appraisal of transport projects has to combine relevance with rigour. Relevance requires context specificity. There should be a clear narrative of what each project is expected to achieve, and appraisal should capture the causal channels through which the project is expected to have impact. This suggests a modular approach. To maintain rigour, and comparability across projects, modules need to be based on a consistent set of principles. These should be grounded in economics and directed at identifying changes in real income (welfare). This means being careful to identify quantity changes throughout the economy, so taking into account the possibility of relocation and displacement of economic activity. The value of such changes turns on market failures of some type, and need to be referenced against a benchmark of the 'perfect' economy in which small changes are of zero social value.

Some mechanisms and associated appraisal modules are quite well developed and have a large evidence base, notably those to do with proximity and productivity, and with labour force participation and employment. Others, to do with land-use change, dependent development and coordination failure are still in need of further refinement. Notwithstanding that there remains a need to refine the evidence that exists so that it is more useful for transport appraisal. Such research is relevant not just for appraising transport projects, but for appraisal of policy change more broadly.

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References

Arnott, R.J., Stiglitz, J.E., 1981. Aggregate land rents and aggregate transport costs. Econ. J. 91, 331–347.
Aschauer, D.A., 1989. Is public expenditure productive. J. Monet. Econ. 23, 177–200.
Aschauer, D.A., 1990. Highway capacity and economic growth. Econ. Perspect. 14, 14–24.
Audretsch, D.B., Feldman, M.P., 2004. Knowledge spillovers and the geography of innovation. Handb. Reg. Urban Econ. 4, 2713–2739.
Badinger, H., 2007. Has the EU's single market programme fostered competition? Testing for a decrease in mark-up ratios in EU industries. Oxf. Bull. Econ. Stat. 69 (4), 497–519.
Banister, D., Berechman, Y., 2001. Transport investment and the promotion of economic growth. J. Transp. Geogr. 9 (3), 209–218.
Barro, R.J., Sala-i-Martin, X., 2004. Economic growth theory. McGraw-Hill, Boston.
Bates, J., 2006. Economic evaluation and transport modelling: theory and practice. Mov. nets: Phys. Soc. Dimens. Travel, 279–351.
Bröcker, J., Meyer, R., Schneekloth, N., Schürmann, C., Spiekermann, K., Wegener, M., 2004. Modelling the Socio-economic and Spatial Impacts of EU Transport Policy. IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies) Deliverable 6. Funded by 5th Framework RTD Programme. Kiel/Dortmund: Christian-Albrechts-Universität Kiel/Institut für Raumplanung, Universität Dortmund.
Broda, C., Weinstein, D.E., 2006. Globalization and the gains from variety. Q. J. Econ. 121 (2), 541–585.
Christopoulou, R., Vermeulen, P., 2012. Markups in the Euro area and the US over the period 1981–2004: a comparison of 50 sectors. Empir. Econ. 42 (1), 53–77.
Combes, P.-P., Gobillon, L., 2015. The empirics of agglomeration economies. In: Duranton, G., Henderson, V., Strange, W. (Eds.), Handbook of Urban and Regional Economics 5. Elsevier.
D'Costa, S., Gibbons, S., Overman, H.G., Pelkonen, P., 2012. Agglomeration and labour markets: the impact of transport investments on labour market outcomes. In: Riccardo, Crescenzi, Marco, Percoco (Eds.), Geography, Institutions and Regional Economic Performance. Advances in spatial science.. Springer Verlag, Berlin, Germany, 263–280.
Department for Transport (DfT), 2005. Transport, Wider Economic Benefits, and Impacts on GDP. Discussion Paper. July 2005.
Department for Transport (DfT), 2014a. TAG Unit A2-1 Wider Impacts. Department for Transport, London.
Department for Transport (DfT), 2014b. TAG Unit A1-3 User and Provider Impacts. Department for Transport, London.
Duranton, G., Puga, D., 2004. Micro-foundations of urban agglomeration economies. (chapter 48)In: Henderson, J.V., Thisse, J.F. (Eds.), Handbook of Regional and Urban Economics 4. Elsevier, 2063–2117.
Eliasson, J., Lundberg, M., 2012. Do cost–benefit analyses influence transport investment decisions? Experiences from the swedish transport investment plan 2010–21. Transp. Rev. 32 (1), 29–48.
Eliasson, J., Börjesson, M., Odeck, J., Welde, M., 2013. The impact of cost-benefit analyses on transport investment decisions. Presented at the International Transport Economics Association.
Fridstrøm, L., Elvik, R., 1997. The barely revealed preference behind road investment priorities. Public Choice 92 (1/2), 145–168.
Fujita, M., Krugman, P., Venables, A.J., 1999. The Spatial Economy: Cities, Regions and International Trade. MIT press.
Geurs, K., Zondag, B., De Jong, G., De Bok, M., 2010. Accessibility appraisal of landuse/transport policy strategies: more than just adding up travel-time savings. Transp. Res. Part D: Transp. Environ. 15 (7), 382–393.
Geurs, K.T., Van Wee, B., Rietveld, P., 2006. Accessibility appraisal of integrated landuse-transport strategies: methodology and case study for the Netherlands Randstad area. Environ. Plan. B: Plan. Des. 33 (5), 639–660.
Glaeser, E.L., Gottlieb, J.D., 2009. The wealth of cities: Agglomeration economies and spatial equilibrium in the United States. J. Econ. Lit. 47 (4), 983–1028.
Graham D., Gibbons, S., Martin, R., 2010. The spatial decay of agglomeration economies: estimates for use in transport appraisal. Report for Department of Transport, October 2010.
Graham, D.J., 2007. Agglomeration, productivity and transport investment. J. Transp. Econ. Policy 41 (3), 317–343.
Graham, D.J., 2009. Identifying urbanisation and localisation externalities in manufacturing and service industries*. Pap. Reg. Sci. 88 (1), 63–84.
Graham, D.J., Van Dender, K., 2011. Estimating the agglomeration benefits of transport investments: some tests for stability. Transportation 38 (3), 409–426.
Harris, B., Wilson, A.G., 1978. Equilibrium values and dynamics of attractiveness terms in production-constrained spatial-interaction models. Environ. Plan. A 10, 371–388.
Kelly, C., Laird, J., Costantini, S., Richards, P., Carbajo, J., Nellthorp, J., 2015. Ex post appraisal: what lessons can be learnt from EU cohesion funded transport projects? Transp. Policy 37, 83–91.
Laird, J.J., Stroombergen, A., 2015. Airports Commission.2. Economy: Wider Impacts Assessment - Peer review. Report to Gatwick Airport. Dated March 2015. Available at: ⟨https://www.gatwickairport.com/globalassets/publicationfiles/business_and_community/all_public_publications/second_runway/airports_commission_july15/ac-lgw-203—laird-and-stroombergen-2015-peer-review—airports-economic-impact-study—march-2015.pdf⟩.
Mankiw, N.G., Whinston, M.D., 1986. Free entry and social inefficiency. TRAND J. Econ., 48–58.
Mackie, P., Worsley, T., Eliasson, J., 2014. Transport appraisal revisited. Res. Transp. Econ. 47, 3–18.
Martinez, F., Araya, C., 2000. Transport and land-use benefits under location externalities. Environ. Plan. A 32 (9), 1611–1624.
Melo, P.C., Graham, D.J., Noland, R.B., 2009. A meta-analysis of estimates of urban agglomeration economies. Reg. Sci. Urban Econ. 39, 332–342.
Melo, P.C., Graham, D.J., Brage-Ardao, R., 2013. The productivity of transport infrastructure investment: a meta-analysis of empirical evidence. Reg. Sci. Urban Econ. 43, 695–706.
Michaels, G., Rauch, F., Redding, S.J., 2013. Task Specialization in US Cities from 1880–2000 (No. w18715). National Bureau of Economic Research, 2013.
Mohring, Herbert, 1993. Land rents and transport improvements: some urban parables. Transportation 20 (3), 267–283.
Mouter, N., Annema, J.A., van Wee, B., 2013. Attitudes towards the role of cost–benefit analysis in the decision-making process for spatial-infrastructure projects: a Dutch case study. Transp. Res. Part A: Policy Pract. 58, 1–14.
Nellthorp, J., Mackie, P., 2000. The UK roads review—a hedonic model of decision making. Transp. Policy 7 (2), 127–138.
Neuberger, H., 1971. User-benefits in the evaluation of transport and land use plans. J. Transp. Econ. Policy Vol V (1), 52–75.
Nilsson, J.-E., 1991. Investment decisions in a public bureaucracy: a case study of Swedish road planning practices. J. Transp. Econ. Policy 25 (2), 163–175.
Odeck, J., 1996. Ranking of regional road investment in Norway. Transportation 23 (2), 123–140.
Odeck, J., 2010. What determines decision-makers' preferences for road investments? Evidence from the norwegian road sector. Transp. Rev. 30 (4), 473–494.
Odgaard, T., Kelly, C.E., Laird, J.J., 2005. Current practice in project appraisal in Europe. European Transport Conference 3-5 October 2005, Strasbourg. London, AET Transport.
Overman, H.G. (2013) The Regional Economic Impacts of HS2. Spatial Economics Research Centre (SERC) Blog. Post dated 13 Sept 2013. Available at: ⟨http://spatial-economics.blogspot.co.uk/2013/09/the-regional-economic-impacts-of-hs2.html⟩.
Redding, S.J., Turner, M., 2016. Transportation costs and the spatial organisation of economic activity. In: Duranton, G., Henderson, J.V., Strange, W.C. (Eds.), Handbook of Regional and Urban Economics 5. North-Holland.
Rosenthal, S.S., Strange, W.C., 2004. In: Henderson, J.V., Thisse, J.F. (Eds.), Evidence on the Nature and Sources of Agglomeration Economies. Handbook of Urban and Regional Economics 4. North-Holland, New York.
Simmonds, D.C., 2012. Developing land-use/transport economic efficiency appraisal ⟨www.davidsimmonds.com/files/LUTEE-paper-for-ETC-v3-111012-1.pdf⟩.

Simmonds, D.S., Bates, J., 2001. Appraisal in land-use/transport interaction: design. Report to Government Office for the North-West. January 2001.
SACTRA (Standing Advisory Committee on Trunk Road Assessment), 1999. Transport and the Economy. TSO, Norwich.
Venables, A.J., 2016. Transport appraisal with land-use change. Processed, Oxford.
Venables, A.J., Gasiorek, M., 1999. The welfare implications of transport improvements in the presence of market failure. In: SACTRA (Ed.), The welfare implications of transport improvements in the presence of market failure and the incidence of imperfect competition in UK sectors and regions.. Department for the Environment, Transport and the Regions, London, 3–58.
Vickerman, R., 2015. High-speed rail and regional development: the case of intermediate stations. J. Transp. Geogr. 42, 157–165.
Wegener, 2014. Land use transport interaction models. (Chapter 39)In: Fischer, Nijkamp (Eds.), Handbook of Regional Science. Springer, London, 741–758.
Wegener, M., 2011. Transport in spatial models of economic development. A Handb. Transp. Econ., 46–66.
What Works, 2015. Evidence Review 7 Transport. July 2015 London, LSE.

Transport investment and housing development: Modelling and valuing impacts

Final report

Prepared for: Engineering New Zealand – Transportation Group

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1 Executive summary

Transport policy and investments shape how cities and regions grow. Major projects like the London Underground, the US interstate highway system, and, locally, the Auckland Harbour Bridge have shaped urban growth.

Transport improvements also influence opportunities for housing development and, in doing so, can influence the price and availability of housing in growing cities. These effects are widely discussed but they are seldom fully considered when developing projects and programmes.

This paper investigates how to analyse and value the impact of transport investment on housing development, taking into account the price and quantity of housing that is supplied.

Housing and land markets are characterised by various constraints that make it difficult to supply new housing in response to increased demand, such as the differentiated nature of land, persistence in development patterns, and barriers arising from land use regulations and a lack of infrastructure servicing. This drives up prices for housing and urban land above the 'fundamentals'.

Transport investments (or technology changes) that reduce transport costs can improve the functioning of housing development markets by increasing the substitutability between different sites and thus increasing the competitive pressure that landowners experience. Transport improvements can therefore indirectly affect housing prices as well as the shape and size of cities.

Although this creates the potential for wider benefits related to unlocking housing development, existing land use-transport interaction models are poorly suited to capturing these effects. A survey of these models reveals that they typically neglect competitive dynamics in housing development.

This paper therefore outlines an approach for modelling and valuing the impacts of transport investment on housing development. This approach builds upon a well-understood conceptual framework and can be applied in conjunction with existing strategic transport models. Model parameters are estimated using data for the Wellington region.

Application of the proposed model to a simple hypothetical case study suggests that housing development benefits could be significant in magnitude – potentially comparable in magnitude to existing wider economic benefits that arise in labour markets, such as agglomeration benefits.

This research suggests that transport investment can help to overcome housing supply and affordability issues. Improving accessibility between areas tends to increase the competitive pressure facing landowners by making it easier to buy or rent in more locations. This principle applies throughout urban areas. A new rapid transit route or walking and cycling link that improves access to the city centre will allow medium- and high-density development to occur in more places, just as a new link road allows subdivision to extend into greenfield areas.

To achieve optimal results, land use policies must change in line with transport investment. Improved transport access tends to increase local housing demand. If land use policies do not allow or enable more homes to be built in the area, the result will be rising housing prices that benefit existing landowners at the expense of people who may want to move into the area. If land use policies are changed to allow more housing development, then rising demand will flow through into more new homes, more new residents, and lower price increases.

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2 Introduction

Transport policy and investments shape how cities and regions grow. Major projects like the London Underground, the US interstate highway system, and, locally, the Auckland Harbour Bridge have shaped urban growth (Heblich, Redding, and Sturm, 2018; Duranton and Turner, 2012; Grimes, 2011). The effects can last decades or even millennia, as shown by the impact of Roman roads on present-day regional development in Europe (Dalgaard et al, 2018).

Today, policymakers are increasingly concerned about New Zealand's challenges with housing affordability and looking for evidence on how transport investment can help to address this problem. However, we lack methods for predicting impacts on housing development or valuing the resulting benefits (or disbenefits).[1]

There are several reasons why it is desirable to assess these impacts. First, doing so may help inform strategic planning and investment prioritisation. For instance, a project that is expected to have large benefits for housing development may be preferred over a similar project that does not deliver those benefits. Second, assessing these impacts may assist in designing complementary land use policies, such as rezoning of areas to enable housing development.

In this research paper, I examine how to model and value the impacts of transport investment on housing development. I argue that:

- Housing development markets are characterised by imperfect competition due to various factors that constrain the supply of new housing to meet demand (Section 3)
- Transport investments can affect local housing demand, as increased accessibility makes areas more attractive for residents, and local supply dynamics, as increased accessibility can place landowners under greater competitive pressure (Section 4)
- As a result, major transport investments can generate wider economic benefits in housing development (Section 5)
- Existing land use-transport interaction models are ill-suited to capture these benefits, as they typically assume that housing development is perfectly competitive or that transport improvements cannot affect housing supply dynamics (Section 6).

To conclude the research, I:

- Describe a modelling approach that could be used to capture and value the wider benefits of transport investment for housing development and estimate the key parameters of this model for the Wellington urban area (Section 7).
- Apply this model to a hypothetical case study to understand its properties (Section 8).
- Discuss policy implications and areas for further research (Section 9).

[1] These impacts are alluded to in the NZ Transport Agency's interim guidance on valuing the dynamic / transformative benefits of transport investments (NZTA, 2019).

3 Characteristics of housing development markets

To begin, I discuss some important characteristics of housing development markets. I argue that housing development in New Zealand is characterised by market imperfections that make it difficult to supply new homes to meet demand. This results in scarcity-driven price increases that push the price of housing above the underlying cost to supply it.

Market imperfections in housing development play an important role in understanding how transport investment can affect housing markets and how wider economic benefits may arise as a result.

3.1 Market imperfections in housing development

'Housing development' is the process of constructing new residential buildings, either by infilling or redeveloping existing sites or by building on new sites created by subdivision of large greenfield or brownfield sites.[2] In New Zealand, most new housing is developed by private companies and sold to individual buyers or rental property investors.

Housing developers use a mix of inputs, including land, infrastructure services (eg water, wastewater, and roads), construction materials and services, and financing. They also must interact with land use and building regulations, which are governed by national legislation (the Resource Management Act and Building Act) and implemented by local governments.

Housing development is characterised by a number of market imperfections that constrain the supply of new homes to meet demand and in doing so drive up the price of housing. The following table summarises five underlying reasons why housing development markets are not perfectly competitive.[3] These exacerbate the impact of demand 'shocks' such as rapid migration inflows.[4]

Table 1: Reasons why housing development markets are imperfectly competitive

Cause	Explanation
Market power in land markets	Land in each location is only available in a fixed quantity and different locations are imperfect substitutes for each other.[5] Different sites have different underlying geology and different levels of access to amenities, employment opportunities, and so on and so forth. Landowners in any given location can exercise market power over people seeking to buy and use land. Land prices tend to be higher near localised amenities like beaches and closer to employment opportunities.
Persistence in subdivision patterns	After land is initially subdivided for urban use, it tends to be very costly and difficult to amalgamate or re-subdivide it to serve changing demands. Subdivision is a 'putty-clay' problem – lot sizes and shapes are highly malleable at the outset, but rigid and hard to change at later dates. Amalgamating or re-subdividing sites is difficult due to the costs associated with negotiating with multiple neighbouring landowners and the risk of hold-ups if some neighbours are unwilling to sell. As a result, it is rare in practice, even after major disasters

[2] 'Greenfield' sites are large sites, often although not always in rural use, that must be serviced and subdivided before being urbanised. 'Brownfield' sites are large sites with previous uses, such as closed-down industries, that are being re-used for other urban uses.
[3] A 'perfectly competitive' market is one that lacks any significant market imperfections, such as externalities, market power, or information problems (Boardman et al, 2011). In the absence of market imperfections, voluntary transactions between willing buyers and willing sellers will lead to an optimal outcome for society. However, if there are market imperfections, then this may not be the case.
[4] For instance, Nunns (2018) finds that New Zealand regions with greater evidence of supply constraints experienced larger increases in house prices and rents than less-constrained regions in response to similarly-sized migration inflows.
[5] It is possible to create new land by filling or draining water bodies, but this is costly and hence infrequent in New Zealand.

	that clear away existing buildings (Fredrickson, Fergusson and Wildish, 2016; Hornbeck and Keniston, 2017).
Durable housing	Buildings are durable. While different parts of buildings wear out at different rates, the underlying structures may have a usable life of decades or even centuries if they are well maintained (Brand, 1995). This can slow redevelopment of sites, as landowners may be reluctant to scrap existing assets with remaining value. However, existing buildings can also serve changing demands through renovation or redesign. The durable nature of buildings affects the functioning of declining housing markets (Glaeser and Gyourko, 2018). A city with a falling population does not experience an immediate drop in its stock of housing, leading to high vacancy rates and prices that fall significantly below replacement costs.
Monopoly provision of development infrastructure	Housing development must be served by infrastructure, including water, wastewater, road access, and electricity and power. While developers provide on-site infrastructure, they depend on network infrastructure providers for connections. Monopolistic behaviour or inefficient pricing of infrastructure services can therefore constrain housing development or push up its cost. Effective competition regulation can prevent monopoly infrastructure providers from charging prices significantly higher than the cost of providing services or restricting access to networks.
Land use regulations	Housing development is regulated by local and central government through building codes (which set standards for new construction), zoning codes / district plans (which define what land can be used for and how intensely it can be developed), and environmental regulations (such as restrictions on wastewater outflows into sensitive marine areas). In New Zealand, district plans commonly limit how intensively sites can be developed or redeveloped, via building height limits, minimum lot sizes, and requirements to provide land-intensive features like carparking. They also limit the extent of new subdivision, often to manage the costs that councils bear to provide new development infrastructure. There is evidence that the costs of some rules outweigh the benefits they provide (Nunns and Denne, 2016) and that overly restrictive land use regulations can reduce the responsiveness of new housing development to increased demand (Gyourko and Molloy, 2015). There is also significant evidence that the impact of these restrictions varies between locations, including in New Zealand (Glaeser, Gyourko and Saks, 2005; Nunns, 2020).

3.2 Empirical estimates of housing development market imperfections

Economists commonly use price-cost margins (PCMs) to measure the degree of imperfect competition in markets (Stevens, 2011). The intuition behind this measure is that businesses should not be able to charge prices that are significantly higher than their underlying costs of production unless they benefit from market power or barriers to competitors entering the market (Cheshire and Hilber, 2008). PCMs can reflect the aggregate impact of multiple constraints and hence may not provide specific evidence on what specific features of markets limit competition.

A number of recent studies have measured PCMs in housing and land markets in New Zealand (Grimes and Liang, 2009; MBIE, 2017; Lees, 2019; Nunns, 2020). Table 2 summarises price-cost margins for urban residential land in New Zealand cities, based on measured discontinuities in land values at rural-urban zoning boundaries (MBIE, 2017). These reflect the aggregate impact of regulatory and non-regulatory constraints to infill and redevelopment of existing sites and to new subdivision at the edge of cities.

PCMs in residential land markets are large relative to PCMs observed in other areas of the New Zealand economy. Residential land prices at the edge of Auckland and Queenstown appear to be roughly three times as high as the underlying cost to develop new land. In other cities markups range from 30% to 140%.[6]

By comparison, Stevens (2011) uses firm-level data for 2000-2007 to estimate that PCMs in most ANZSIC industries are less than 15%. PCMs only rise above 30% in capital-intensive sectors like water transport and air transport. This indicates that urban housing development is much less competitive than the rest of the New Zealand economy.

Table 2: Land value discontinuities at selected rural-urban zoning boundaries (2017)

Urban area	Price-cost margin	Difference ($/m2)	Difference ($/600m2 section)
Auckland	215%	$345	$206,700
Christchurch	123%	$150	$90,100
Dunedin	29%	$38	$22,500
Hamilton	142%	$227	$136,200
New Plymouth	61%	$92	$55,100
Palmerston North	57%	$73	$43,900
Queenstown	212%	$337	$202,500
Tauranga	102%	$232	$139,100
Wellington	130%	$201	$120,400
Whangarei	100%	$80	$48,100

Source: http://urban-development-capacity.mbie.govt.nz/. Price-cost margins calculated as the ratio of land prices inside and outside boundaries, minus 1.

PCMs in urban housing markets can reduce overall wellbeing. Because housing prices are high, some people consume less housing than would be optimal for them or live in less desirable places. This in turn leads to various other social and economic costs, such as the health impacts of living in overcrowded or substandard housing, the economic costs of discouraging people from living in productive cities with high housing costs, and traffic congestion caused by excess urban sprawl.

[6] PCMs are slightly lower but still significant for house prices and apartment prices, as opposed to residential land prices. Nunns' (2018) estimates of house price distortions imply a PCM of 93% for standalone homes in Auckland, 66% in Wellington, and 38% in Christchurch. PCMs are lower for house prices as they include the cost to physically build structures.

4 Transport and housing markets

I now consider how transport improvements, such as new infrastructure or services, policy changes, or technology, changes can affect housing markets. I argue that it is necessary to distinguish between demand-side effects (such as more people wanting to live in newly accessible locations) and supply-side effects (such as land prices being competed down due to the fact that alternative sites are more substitutable). Complementary policy changes, such as rezoning to increase housing development capacity in areas served by new transport infrastructure or services, can also have supply-side effects.

4.1 Local housing supply and demand dynamics

Transport investments can have two different effects on housing and land markets.

First, they can affect *demand* for housing in particular places. This can be due to improved transport access that makes areas more attractive (Heblich, Redding, and Sturm, 2018; Garcia-López, 2012; Baum-Snow, 2007, 2010; Duranton and Turner, 2012; Grimes, 2011), or noise and severance that makes them less attractive (Brinkman and Lin, 2017). In New Zealand cities, better transport access by both car and public transport increases the density of development and the volume of commuting flows between locations (Nunns, 2019).

Second, transport investments can also affect the conditions under which housing is *supplied* in different places. Improving access can increase the substitutability between alternative sites, thereby reducing the market power held by landowners in a particular location and causing land prices to be competed down (Homans and Marshall, 2008).

As a hypothetical example, consider a case where there are only a handful of vacant/redevelopable sites in an existing city centre. Owners of these sites would be able to name their price. A transport project that significantly reduced travel times to a nearby transitioning industrial area with many redevelopable sites would increase competition in the local land market and reduce prices in the city centre.

The impact of supply-side effects will generally be to *flatten* the land-price gradient around desirable amenities.

The following supply and demand diagrams show the impact of considering one or both of these dynamics. Panel A shows the impact of transport improvements that shift local demand for housing by making some places relatively more accessible and hence desirable. In the context of an upwards-sloping local supply curve for housing, an increase in local housing demand translates into higher house prices as well as greater density.

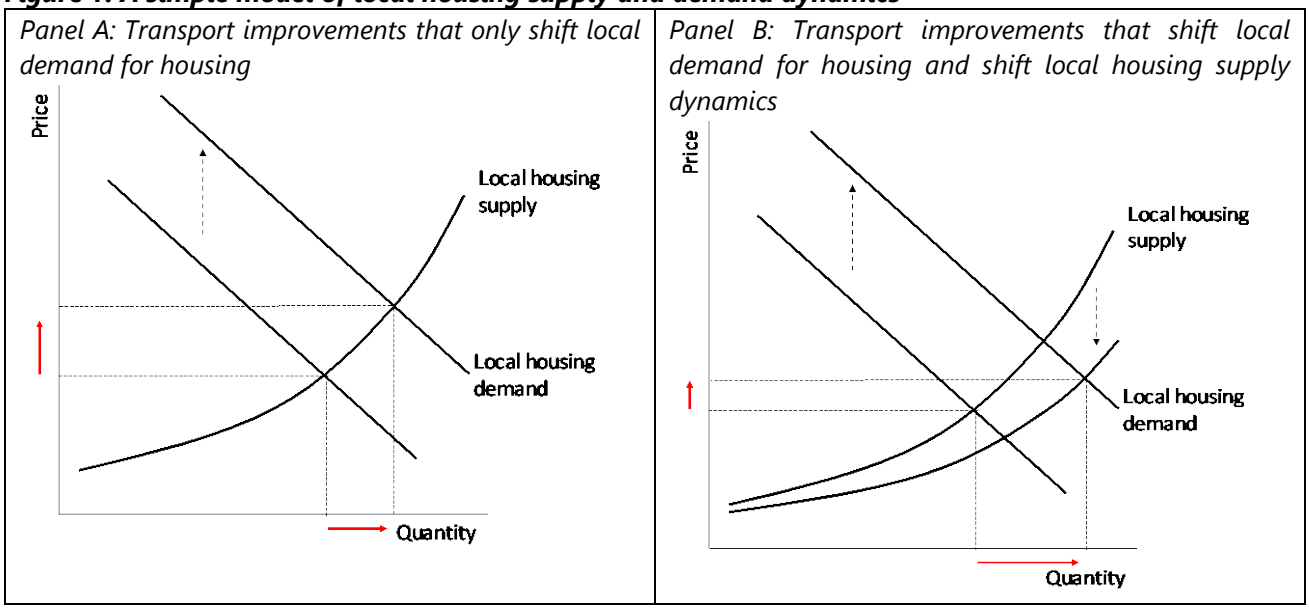
In Panel A, transport improvements can only reduce regional average house prices by shifting housing demand away from densely-developed areas with high prices towards less dense areas with lower prices. This could mean shifting demand away from redevelopment areas into greenfield areas, or shifting demand away from dense city centre areas to less-developed areas around suburban train stations.

Panel B illustrates a case in which transport improvements simultaneously shift local demand for housing, by making some places relatively more accessible, and shift local housing supply dynamics, by making alternative development locations more substitutable and hence increasing competition between them. Supply-side effects are represented as an outward shift or flattening of the housing supply curve.

In Panel B, an increase in local housing demand can be satisfied without increasing prices as much. Furthermore, transport improvements can reduce regional average house prices by increasing competition between alternative locations. Complementary measures such as rezoning to enable greater density can strengthen this

effect. Reductions in prices can coincide with a variety of different patterns of land use relocation. For instance, stronger competition in land / housing development could reduce inner-city housing prices and hence attract people to relocate to formerly-expensive neighbourhoods.

Figure 1: A simple model of local housing supply and demand dynamics



4.1.1 Potential mechanisms for supply-side effects

There are two potential mechanisms for supply-side effects.

First, as noted above, improved transport access may make alternative sites more substitutable, reducing the market power enjoyed by landowners in desirable locations. In a multi-location model, as opposed to the simple single-location example above, this effect might be partly or fully captured by shifts in relative demand to previously inaccessible locations.

Second, transport projects might be bundled with rezoning or land amalgamation projects that increase housing development capacity in newly accessible areas. These could include:

- Upzoning of existing urbanised areas to allow redevelopment of existing sites to provide more dwellings
- Greenfield rezoning to allow new subdivision in non-urban areas
- Projects to amalgamate small sites to create development-ready parcels or to remediate environmental hazards on brownfield sites that were previously used for industrial purposes.

In some cases, transport projects can be a necessary condition for rezoning. For example, existing transport infrastructure may not be perceived to be sufficient to accommodate new development without undesirable congestion issues. In other cases, transport projects may not be a necessary condition for rezoning, but the two projects may be bundled together for institutional or political reasons. Regardless of why they are bundled together, if they coincide it would be desirable to assess them jointly.

4.2 Transport access is necessary but not sufficient for new development

While transport access is important for housing development, other factors also influence whether housing will actually be developed.

First, there must be some underlying, unmet demand for new housing, either overall or in a specific sub-market. Building new transport infrastructure in cities (or neighbourhoods) that are declining economically or losing population is unlikely to encourage more housing development, as these housing markets are already 'slack'.

Second, the rate of new housing development in a newly accessible area will also depend upon pre-existing constraints to housing development. The market imperfections identified in the previous section may slow new development.[7] If these constraints are totally binding, transport improvements may have little impact on housing development as no further development *can* occur.

4.3 City size may change as a result of improvements to housing supply

All else equal, increasing the supply of housing and reducing its price will affect the spatial equilibrium of population distribution between urban and rural areas, between different cities, and potentially between New Zealand and other countries (Glaeser, 2008).

A number of recent papers use spatial equilibrium models to simulate the impact of loosening restrictions on development, mainly in the US (Hsieh and Moretti, 2019; Glaeser and Gyourko, 2018; Ganong and Shoag, 2017; de Groot, Marlet, Teulings, and Vermuelen, 2015). Nunns (2020) recently undertook a similar exercise for New Zealand regions.

The general finding from this literature is that increasing housing supply in highly-productive cities with high house prices will increase national economic output and increase aggregate wellbeing. This reflects the fact that more people can access and take advantage of larger labour markets, which tend to be more productive and thus support higher incomes.[8]

If transport investments result in large reductions in citywide housing prices, they may in turn attract additional residents to those cities. This may have additional economic impacts, depending upon where additional people are moving from.

[7] Poor geography can also play a role. For instance, holding all else equal a new train station next to the coast will do less to enable housing development than an inland train station, as half of the area around the station is underwater and hence undevelopable.
[8] A potential objection to this is that these economic gains will be offset by other social and environmental costs, such as increased congestion, crowding, and environmental damage. The empirical evidence is mixed on the net direction of these effects but in general it does not seem to be the case that the 'bads' outweigh the 'goods' (Nunns and Denne, 2016; MRCagney, 2019; Ahlfeldt and Pietrostefani, 2019).

5 Housing development impacts as a wider economic benefit

In this section, I argue that transport projects can generate wider economic benefits (WEBs) in housing development markets. These benefits are additional to conventional transport benefits, such as benefits from faster or more comfortable journeys, and to agglomeration benefits and other WEBs that principally arise in labour markets.

5.1 Theory of WEBs

Conventional transport appraisal focuses on assessing the impact of transport improvements on the user costs of transport, meaning the time, money, and inconvenience that people must incur to travel. Reducing transport user costs increases the consumer surplus that people enjoy from travelling, as they are able to achieve the benefit of reaching their destination at a lower cost.[9]

If all related markets, such as labour markets that people access by commuting, are functioning efficiently, then transport user cost savings are equivalent to total social benefits (Boardman et al, 2011). However, transport markets and related markets are rife with externalities and other market imperfections, ranging from unpriced traffic congestion impacts to air quality impacts to taxes on labour income to agglomeration externalities in production. This creates the potential for additional (positive or negative) effects to arise from changes in transport behaviours. In transport appraisal, these impacts are described as wider economic benefits, or WEBs.

New Zealand's transport appraisal procedures address three WEBs that arise in the labour market.[10] Following UK WebTAG guidance, Kernohan and Rognlien (2011) describe the theory and evidence underpinning these benefits. They also note the potential for WEBs resulting from transport improvements that increase the level of competition in the economy:

> *Increasing the levels of competition in an economy therefore produces an additional economic benefit by pushing the economy toward its optimum position and reducing the overall deadweight loss to society by increasing output and reducing price, and eroding market power from monopoly, oligopoly and other forms of market failure.*
> *If a price cost margin exists [...] there is also potential for a project to improve the level of competition in the economy by reducing the magnitude of the price cost margin and directly increase welfare.*

Kernohan and Rognlien disregard the potential for increased competition benefits due to the fact that most New Zealand industries have low price-cost markups, indicating a reasonable level of competition (Stevens, 2011). However, their conclusion does *not* apply in housing development markets, as:

1. We observe large price-cost markups for urban land and housing that indicate the presence of various barriers to development and redevelopment of land
2. Transport projects and complementary rezoning projects can affect the level of competition in housing development markets by strengthening competition between landowners in different locations and unlocking additional development opportunities.

[9] Lower transport costs will cause some people to make additional trips. Conventional transport appraisal captures the benefits of these trips using a 'rule of half' calculation.
[10] These are agglomeration benefits, imperfect competition benefits, and labour supply benefits.

5.2 Valuing increased competition WEBs

Kernohan and Rognlien (2011) outline a conceptual approach for valuing increased competition WEBs. The basis for this approach is the observation that price-cost margins result in deadweight losses for society, because some people avoid consuming goods produced in uncompetitive markets. In highly distorted urban housing markets, some people may choose to live in overcrowded or substandard accommodation, or simply move to another location with cheaper housing. Reducing PCMs can therefore generate WEBs by reducing deadweight losses.

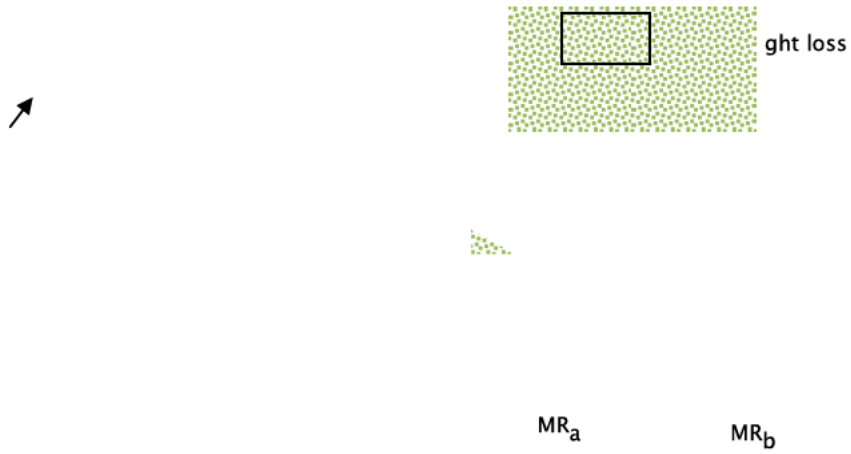
Figure 2 illustrates how to value increased competition benefits based on changes in PCMs in the affected market. Prior to an investment or policy change, low levels of competition produce a price-cost margin of A (ie prices P_a are higher than marginal costs of production MC). After the investment, increased competition reduces the PCM to B (prices drop from P_a to P_b while marginal costs are unchanged).

As a result of lower prices, more buyers enter the market, and the quantity of goods produced increases from Q_a to Q_b. The net social benefits of increased competition are given by the blue-shaded area, and the remaining unmitigated deadweight loss by the green-shaded area.[11] Assuming that the demand curve is linear, increased competition WEBs can be calculated as:

Equation 1: Calculating the value of increased competition WEBs

$$Increased\ competition\ WEBs = (A + B) * (Q_b - Q_a)/2$$

Figure 2: Conceptual approach for valuing increased competition benefits (Kernohan and Rognlien, 2011)



Kernohan and Rognlien's approach is to value additional benefits in imperfectly-functioning secondary markets as an adjustment to benefits that accrue directly in transport markets. This approach is common due to the fact that transport models that are used to value many project benefits are incomplete – that is, they model equilibrium outcomes in transport markets but do not model firm and worker relocation and other land use

[11] There is also a transfer of wealth between existing buyers and sellers. For instance, a general reduction in housing prices will benefit existing renters, who can pay less for their accommodation, while reducing the income of their landlords. This transfer has important distributional consequences but does not affect the net social benefits of a scheme.

responses. However, as Martinez and Araya (2000) observe, a more theoretically sound approach would be to value benefits using a general equilibrium model of transport and land use outcomes that directly accounts for the imperfect functioning of land and labour markets. This research paper focuses on Kernohan and Rognlien's approach, but the models outlined in it could also be applied to a general equilibrium approach.

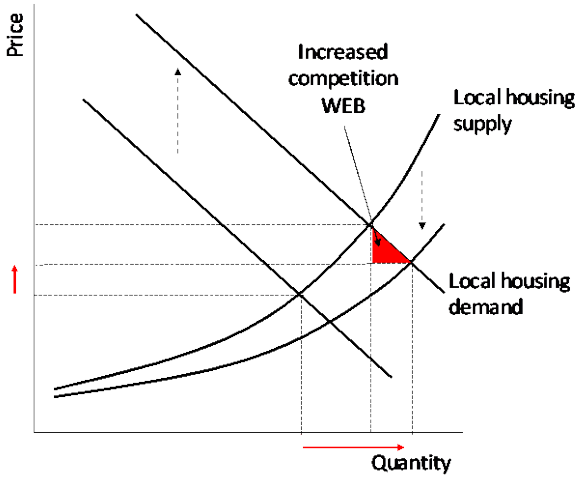
5.2.1 Implementing this calculation

Implementing this calculation requires three pieces of information:

- First, an estimate or forecast of existing housing (or land) prices (or price-cost markups) in affected locations.
- Second, a prediction of how a transport project (or a joint transport and rezoning project) will affect housing prices in affected locations and other competing locations.
- Third, an estimate or forecast of the degree to which reduced housing prices will attract more residents to a given location, relative to alternative competing locations.

Figure 3 illustrates how this calculation could be undertaken if a project affects both local housing supply and demand. The red-shaded area illustrates the magnitude of housing development WEBs that might arise as a result. In effect, this compares the predicted outcome of a local housing demand shift with and without a simultaneous shift in housing supply.

Figure 3: Valuation of housing development WEBs



5.3 Wider economic benefits of changes to inter-regional population distribution

A significant reduction in citywide housing prices may also generate additional wider economic benefits in urban labour markets. These arise when lower prices enable more people to move to relatively productive locations. The benefits that arise as a result may include:

- Dynamic agglomeration benefits that arise as a result of increased economic mass that enables sharing, matching, and learning effects (Duranton and Puga, 2004)
- Economic benefits from reallocation of workers to cities where they can earn higher incomes and be more productive, which are often called 'move to more productive jobs' effects in transport appraisal guidance (NZTA, 2019).

While increased competition WEBs in housing development are universally positive, the above economic impacts can be either positive or negative. If a drop in housing prices in low-productivity cities attracts people from high-productivity cities, then it may *reduce* overall economic productivity and hence offset increased competition WEBs.

An implication of this is that the benefits of transport projects that enable housing development are likely to be larger in cities (or locations within cities) that are more productive than the national average, relative to less productive cities.

Improved competition benefits in housing development are likely to be positive in most growing cities in New Zealand due to economically significant PCMs in housing and land markets. However, M2MPJ WEBs are only likely to be positive in Auckland and Wellington, as these cities have higher productivity and wage levels than the national average (Maré, 2016; Nunns, 2020).

6 Review of existing land use-transport interaction models

In this section, I review a range of existing land use-transport interaction models. This review focuses on how they address competitive dynamics in housing development and land markets and how they address redistribution of growth between cities/regions as well as within them. I consider four broad categories of models: urban economics models, spatial equilibrium models, LUTI models built on four-step transport models, and spatial computable general equilibrium models.

6.1 Urban economics models

The Alonso-Muth-Mills (AMM) model is a standard urban economics model that describes equilibrium location of households within a city. It shows that the house price gradient can be described as a function of transport costs to jobs (and/or consumption amenities). Reduced transport costs therefore affect average housing costs and the location of residents.

Glaeser (2008) describes the basic AMM model and several permutations. In its simplest version, the city is assumed to consist of a population of homogenous workers that all commute to a single central business district (CBD) and earn wage W. Commuting costs t(d) are an increasing function of distance d to the CBD (ie $t'(d) > 0$). Workers rent L units of land from an absentee landlord, paying rents r(d) that vary by distance to the CBD. Workers choose a location d that maximises the utility that they derive from consuming land L and other consumption goods, ie U(W-t(d)-r(d)L, L).

In equilibrium, all workers must be indifferent between staying in their current location and moving to another location instead. Rents adjust to satisfy this condition. The first order condition for utility maximisation is therefore that the rent gradient is a function of the transport cost gradient, ie $r'(d) = -t'(d)/L$. This implies in turn that rents fall with distance to the CBD. A corollary is that a reduction in transport costs will reduce the rate at which rents fall with distance. The spatial extent of the city is determined by the point at which r(d) is equal to agricultural land rents r_a. This also means that a reduction in transport costs will increase the spatial extent of the city.

Two variants of this model address interactions with the rest of the world differently. In the 'closed city' variant, city size is fixed, meaning that reduced transport costs flow through into lower housing costs and higher levels of utility for city population. In the 'open city' variant, city size is not fixed, and reduced transport costs attract more people to live in the city, which in turn increases rents and leaves utility levels unchanged.

The basic AMM model can be extended in various ways. Glaeser (2008) includes a housing development sector into the model, which allows population density to vary between locations. Kulish, Richards, and Gillitzer (2011) and Lees (2014) use this model to assess the impact of different planning policies, such as restrictions on building height or urban growth boundaries that limit city size. Venables (2017) expands the AMM model to account for trade between multiple cities and local production sectors that enjoy local agglomeration economies and which can specialise in specific tasks. He uses this model to understand potential wider economic benefits of transport improvements that reduce commuting costs within cities or reduce transport costs between cities. Hazledine, Donovan and Mak (2017) use a variant of Venables' approach to analyse wider economic benefits from reductions in commuting costs to central business districts.

Anas and Xu (1999) and Lucas and Rossi-Hansberg (2002) generalise the AMM model to account for the fact that jobs can locate outside of the CBD. They make different assumptions about the production sector and

household utility. Anas and Xu assume that firms located in different places each produce a unique good, and that consumers live in one location and travel to all other locations a non-zero number of times to sample the goods in all locations. Consumers have idiosyncratic tastes, meaning that different people will exhibit different travel patterns. By contrast, Lucas and Rossi-Hansberg model a production sector that produces a single undifferentiated product but which enjoys agglomeration economies, ie firms are more productive when they locate near larger concentrations of other firms.

6.2 Spatial equilibrium models

Spatial equilibrium models are calibrated off observed data on people's choice of home and work location, in particular commuting flow data. People are assumed to choose home and work locations to maximise their utility, taking into account job opportunities (and other amenities) available at destinations, housing options (and other amenities) at home locations, and the cost of travelling between these locations. Observed commuting flows are assumed to represent a spatial equilibrium outcome, in which everybody has chosen the location that works best for them.

These models can be used to analyse how changes to transport costs or the availability of transport infrastructure can affect the equilibrium distribution of population and employment. They can also be used to estimate the net welfare impacts of transport improvements, taking into account the potential for land use changes. However, it is necessary to run them iteratively with transport models to capture feedback between increased commuting flows and traffic congestion.

Several recent papers illustrate the estimation and application of spatial equilibrium models. Mulalic, Pilegaard and Rouwendal (2015) estimate a discrete choice model of working households' choice of residential location and car ownership using Danish administrative data. This model accounts for the impact of access to jobs by car and public transport on households' choice of residential location and car ownership. They use it to estimate the impact of the Copenhagen metro expansion on land use and car ownership outcomes.

Mulalic et al observe that the net outcomes for residential population changes depend upon the elasticity of housing supply, and model two alternative scenarios. In the first, an arbitrarily large quantity of new housing can be supplied at the same cost as existing housing, and hence everyone can relocate freely. In the second, housing supply is totally inelastic, and hence relative house prices must adjust to fully offset any increases in the attractiveness of some areas. They find that welfare gains tend to be lower in the latter scenario.

Brinkman (2016) calibrates a spatial equilibrium model of Columbus, Ohio using land price data and Census employment, population and commuting data. This model is closely related to Lucas and Rossi-Hansberg (2002), but includes both congestion and agglomeration externalities. Brinkman simulates the impact of a congestion toll on equilibrium land use, land prices, and net economic outcomes, finding that foregone agglomeration benefits offsets decongestion benefits.

Donovan (2017) estimates a spatial equilibrium model using commuting flow data between suburbs in Brisbane, Australia, focusing on the impact of walking and cycling time on people's location choices. He finds that a one-minute saving on a 15-minute journey causes a 3-6 percent increase in commuting flows between affected locations. Nunns (2019) undertakes a similar analysis using commuting flow data for Auckland and Wellington, focusing on the impact of public transport journey times. Both papers account for amenities at home and work locations using suburb- or area-specific fixed effects that capture the impact of local amenities, wages, and house prices and which do not change if people's location choices change. This is equivalent to the assumption, stated explicitly by Mulalic et al (2015), that housing supply is infinitely elastic.

Teulings, Ossokina and de Groot (2018) estimate a system of equations that defines equilibrium outcomes residential and work location and commuting mode, using household travel survey data, worker microdata, and house sales data for Amsterdam, Netherlands. They use the model to estimate the impact of rail tunnels that connect Amsterdam and its northern suburbs on location choices and welfare for workers with different education levels. They find that the rail tunnels have the largest benefits for high skilled individuals, as they have the highest preference for commuting by train and the most to gain from being able to commute to jobs in central Amsterdam.

Land rents and housing supply also adjust. There is a fixed supply of land in each location, but it can be (re)developed flexibly at any density to meet demand. Housing developers are perfectly competitive and can build additional housing under constant returns to scale, while competition among landowners results in a price that equates demand for land in each location with the available supply. The result is that the price of housing is equal to the cost of production.

Severn (2019) estimates a spatial equilibrium model of residential and employment location using 1990 and 2000 commuting flow data between Census tracts for Los Angeles, California. He then calculates the annual consumer welfare benefits of the Los Angeles Metro, taking into account changes in location choices. He estimates welfare impacts under either a 'closed city' or 'open city' assumption, as in the Alonso-Muth-Mills model. In the former scenario, Los Angeles residents' welfare increases, and in the latter, utility levels are equalised but city population increases.

In Severn's model, housing developers are perfectly competitive, ie selling new housing at marginal cost, but the price of land at each location is affected by frictions due to topography and regulation that push up costs. This results in increased prices in response to increased demand, which in turn dissuades some people from moving into those areas. However, the model does not analyse the nature of housing supply constraints, model the impact of relaxing these constraints, or allow transport improvements to affect the dynamics of housing supply.

6.3 Land use-transport interaction models

Land use-transport interaction (LUTI) models extend existing strategic transport forecasting models. Strategic transport models involve four iterative steps (trip generation, distribution, mode choice, route choice) that sequentially converge to equilibrium. The future location of residential population and employment within the city is treated as exogenous. LUTI models extend this by iteratively allowing population and employment to respond to changing transport access and then re-running the transport model (Department for Transport, 2014).

Lopes et al (2018) review the workings of eight LUTI models.[12] They observe that although models often represent land use as one single system, land use actually covers two distinct aspects: location choices of households, firms, and other actors (ie how local housing demand is affected by improved access) and changing intensity of development in different places (ie housing supply).

Some models do not explicitly address housing development, but others formally model housing development and may capture constraints arising from durable buildings or land use regulations. Where land use regulations are addressed, they are typically treated as exogenous constraints that limit the amount of housing that can be supplied in a given location by perfectly competitive developers. In this setting, changing transport access therefore affects demand for housing in different locations, but not developers' ability to respond to demand.

LUTI models often to make simplifying assumptions about housing development and land markets. For instance, Safirova et al (2006) develop a LUTI model to simulate the impacts of congestion pricing in Washington DC,

12 See also Wegener (2004) for an earlier review.

including impacts on the location of population and employment growth and rents in different locations. Safirova et al's model treats housing development similarly to Anas and Xu (1999). Developers choose whether or not to build new housing based on expected future rents relative to costs. They are assumed to operate under perfect competition, without barriers to redeveloping sites, and hence there is no potential for price-cost markups.

Kim (2019) outlines a LUTI model that was developed for Munich, Germany. This is based on a modelling process developed by Moeckel (2011) in which households balance expenditures on housing and transport against a fixed budget, and also balance travel time. Housing developers respond to the resulting demands. Kim describes the application of this model to new housing development and transport infrastructure to the north of Munich, which is intended to help alleviate a housing shortage. However, the outcomes described by the model appear to largely focus on the location of households, rather than the price of housing.

6.4 Spatial computable general equilibrium models

Spatial computable general equilibrium (SCGE) models simulate the economic impacts of transport improvements. To do so, they extend economic models of interactions between different industries, the household sector (which supplies labour and consumes goods), and international trade, adding a spatial dimension to firm activity and incorporating transport costs for freight and commuting.

SCGE models allow economic activity to redistribute throughout space and allow the overall size of the economy to increase. Depending upon the model, this may reflect agglomeration benefits that arise in larger, denser cities or the impacts of changes to firms' investment decisions. These models focus on predicting overall impacts for economic output (Simmonds and Feldman, 2013).

Byett et al (2017) develop an SCGE model for New Zealand and apply it to a hypothetical case study of a major transport improvement in the Auckland-Hamilton-Tauranga area. This model is aggregated to the city level: it includes four large residential and work zones (Auckland, Hamilton, Tauranga and the rest of Waikato) and four port zones (Auckland Airport, Port of Auckland, Port of Tauranga and Other New Zealand). Firms and households can relocate between zones, but the total regional population is fixed. The overall quantity of land within each zone is fixed, and land and housing prices within each zone can adjust in response to changing demands. Like other economic sectors, housing development is assumed to function competitively.

6.5 How these models address competition in housing development

When these models address housing development, they typically assume that development markets are perfectly competitive, meaning that housing is sold or rented at a price equal to the marginal cost of production. Similarly, landowners are modelled as price-takers – they accept whatever rents are on offer, as long as they are above some 'reservation' level set by agricultural land rents.

As a result, these models do not address the possibility for PCMs for housing or urban land. Land prices are higher in some locations, but this simply reflects the capitalised value of better transport access, or other localised factors that affect prices such as local geography and climate.

Market imperfections arising from land use regulation can be incorporated as an exogenous 'cap' on development (Kulish, Richards and Gillitzer, 2011; Lees, 2014), or as land costs or development costs that rise with density of development (Severn, 2019). These reflect ad hoc treatments of market imperfections, rather than formal modelling of deviations from perfect competition. These models may not be able to capture the

impact of transport investment on PCMs for housing or land without additional exogenous adjustments, such as relaxing land use policies.

6.6 How these models address inter-regional redistribution of population

Some models can account for inter-regional impacts of local transport improvements. For instance, the 'open city' variant of the AMM model allows city size to increase in response to a transport improvement. Severn (2019) builds upon the same approach, considering an 'open city' scenario following the AMM spatial equilibrium concept. The same approach could be implemented in the context of other spatial equilibrium models or LUTI models, with some adjustment.

A limitation of the AMM 'open city' approach is that city residents' utility is equalised relative to an outside 'reservation' location. In the model, transport improvements or reduced house prices can increase city size but only if they do not affect overall levels of wellbeing. For major projects in large cities, this is likely to be unrealistic. It could be addressed by modelling a full system of cities, as in Hsieh and Moretti (2019) or related models, and allowing average utility levels across all cities to change in response to changes in a single location.

SCGE models adopt a different approach. In this model, the size of cities' population and economic output changes in response to better inter-regional or within-city connectivity as well as flow-on impacts on business investment decisions.

7 Proposed modelling approach

In this section, I propose an approach to modelling the impacts of transport investments on:

- People's choice of residential and work location – which in turn provides information about changes to the distribution of population and employment within a city
- Equilibrium outcomes for local housing markets, ie the quantity of housing that is supplied and the price at which it is supplied.

I also present estimates of the key parameters of this model for the Wellington urban area – full details of parameter estimation are provided in appendices.

The proposed model is related to several existing spatial equilibrium models of the land use impacts of transport investments (Mulalic, Pilegaard and Rouwendal, 2015; Teulings, Ossokina and de Groot, 2018; Severen, 2019). The household location choice element of this model builds upon my previous work (Nunns, 2019) as well as the wider literature. Modelling of local housing supply dynamics is related to Severen's (2019) model of the impacts of the Los Angeles Metro. However, I extend the housing supply model to better capture the dynamics explored in Sections 3 and 4.

In an Appendix, I discuss several alternative modelling approaches that I considered but ultimately rejected for a variety of reasons.

7.1 Model setup

The model includes two key actors:

- Households, which are assumed to be represented by individuals that choose where to live and where to work in order to maximise their utility
- Housing developers, who purchase land and develop housing that is then sold to households

Firms, which hire workers to maximise profits, are implicit in the model but not formally modelled. It is assumed that firms are 'labour takers' – that is, they congregate in places that are accessible to workers, rather than choosing locations that workers must then travel to. In principle, the model could be extended to formally capture the role of firms and agglomeration economies that encourage firm clustering.

7.1.1 Household location choice

Each individual i is assumed to choose home location j and work location k to maximise their utility, as in the following equation. U_j and W_k denote the utility derived from living in location j and working in location k, respectively, and GC_{jk} represents the average generalised cost (ie time, money, and perceived inconvenience) of commuting from j to k, summing across all transport modes. ϵ_{ijk} is an error term. β is a coefficient to be estimated that reflects the disutility associated with increased commuting costs.

Equation 2: Utility maximisation via location and transport mode choice

$$\max_{j,k,m} U_{ijkm} = U_j + W_k + \beta GC_{jk} + \epsilon_{ijk}$$

Assuming that ϵ_{ijk} is independent and identically distributed and that it follows an extreme value distribution, the probability that individual i chooses locations j and k can be written as follows.

Equation 3: Probability of travelling between origin and destination by a given mode

$$p_{ijk} = \frac{\exp\left(U_j + W_k + \beta GC_{jk}\right)}{\sum_j \sum_k \exp\left(U_j + W_k + \beta GC_{jk}\right)}$$

By extension, the following formula estimates the number of people who are travelling between home location j and work location k (N_{jk}).

Equation 4: Number of people travelling between origin and destination

$$N_{jk} = \exp\left(U_j + W_k + \beta GC_{jk} + \varepsilon_{jk}\right)$$

Equation 4 can be estimated using a Poisson regression model. An important note is that U_j and W_k, which measure the utility that people derive from given home and work locations, are treated as fixed effects in this equation – that is, a series of home and work location constants are estimated. Explaining why some locations deliver higher (or lower) levels of utility can be addressed through extensions to this model.

7.1.2 Local housing demand

Local housing demand is a function of local house prices (or rents) as well as transport accessibility. It is also likely to reflect the availability of other localised amenities, such as parks, schools, or beaches. To capture this effect, U_j is parameterised as a function of local house prices (P_j) and a vector of other measurable amenities (X_j). γ and ϑ are coefficients to be estimated, and e_j is an error term.

Equation 5: Modelling the utility of living in zone j

$$U_j = \gamma \ln(P_j) + \vartheta' X_j + e_j$$

For current purposes, the X_j term can be disregarded as including it does not influence the main model results. While it is possible to measure P_j using data on average rents or average house prices, it is preferable to construct a quality-adjusted measure of house prices in each zone to avoid the need to include controls for housing quality. This can be done using results from a hedonic model of house prices.

Equation 5 can be substituted back into ***Equation 4*** to obtain a household location choice function that depends upon both local house prices and transport access. This serves as a model of local housing demand.

Equation 6: Expanded household location choice function

$$N_{jk} = \exp\left(\gamma \ln(P_j) + W_k + \beta GC_{jk} + e_j + \varepsilon_{jk}\right)$$

Summing up ***Equation 6*** across all work destinations (ie $N_j = \sum_k N_{jk}$) and partially differentiating with respect to house prices and transport costs gives the following elasticities of housing demand. As coefficients β and γ are both expected to be negative, this implies that higher prices or higher transport costs reduce the number of people who would choose to live in a given location.

Equation 7: Elasticity of local housing demand with respect to house prices

$$\frac{\partial N_j}{\partial P_j}\frac{P_j}{N_j} = \gamma$$

Equation 8: Semi-elasticity of local housing demand with respect to a one-minute change in travel times

$$\frac{\partial N_j}{\partial GC_{jk}}\frac{1}{N_j} = \beta * \frac{N_{jk}}{N_j}$$

7.1.3 Local housing supply

I build upon the housing supply model described by Severn (2019) to consider how transport and land use policy may affect competitive dynamics in development markets. In doing so, I assume that housing supply involves both housing developers, who face a perfectly competitive environment, and landowners, who operate in an imperfectly competitive environment that enables them to set prices (Martinez and Roy, 2004).

I consider two permutations of this model: First, a baseline model that extends Severn's model to incorporate the impact of land use regulations that affect housing development capacity; and second, an extended model that addresses the potential for improved transport access between development sites to reduce land prices in both locations.

Housing developers produce housing in model zone j (quantity of housing produced = H_j) using land (L_j) and construction inputs (M) according to a Cobb-Douglas production technology, where Φ is the land share in housing production and $\widetilde{C_j}$ is a zone-specific productivity factor.

Equation 9: Housing production function

$$H_j = {L_j}^{\Phi} M^{1-\Phi} \widetilde{C_j}$$

Developers sell housing at price P_j to maximise profit π_j, taking into account the zone-specific price of land (P_j^L) and the price of construction inputs (P^M), which is assumed to be equal across locations. Due to competition in housing development, economic profits for developers are driven down to zero.

Equation 10: Housing developer profit / zero profit condition

$$\pi_j = P_j H_j - P_j^L L_j - P^M M = 0$$

It is possible to use the zero profit condition and the first order condition for profit maximisation with respect to construction inputs ($\frac{\partial \pi_j}{\partial M} = 0$) to simplify the above formulae to the following expression for housing prices as a function of local land prices.[13] Details of this derivation are given in Severn (2019).

Equation 11: Housing developer cost function

$$P_j = C_j (P_j^L)^{\Phi}$$

Equation 11 relates prices for housing supplied by developers to local land prices. To close the model, it is necessary to specify competitive dynamics in land markets. As noted above, I consider two alternative land pricing functions that result in the baseline housing supply model and the extended model.

Baseline housing supply model

Equation 12 outlines the baseline land pricing function. K_j is the quantity of development capacity in zone j, ie the total amount of dwellings that are allowed to be constructed under zoning rules, and other variables are as previously defined.

Equation 12: Land pricing function (baseline)

$$P_j^L = \frac{{H_j}^{\tilde{\psi}}}{K_j}$$

[13] $C_j = \frac{(P^M)^{1-\Phi}}{(1-\Phi)^{1-\Phi} * \Phi^{\Phi} * \widetilde{C_j}}$, which means that costs are higher in zones with lower construction productivity.

The term $\frac{H_j}{K_j}^{\tilde{\psi}}$ is a 'congestion factor' that results in increased land prices in areas with higher local densities. This reflects the fact that, as densities rise, landowners can command higher prices due to the scarcity of development sites. $\tilde{\psi}$ is an elasticity that measures the impact of local density and access to nearby development opportunities on land prices.

Equation 12 is substituted into ***Equation 11*** to derive the baseline local housing supply function, shown in ***Equation 13***. This function allows zoning policies to affect local housing supply dynamics. Increases in K_j also place downward pressure on local prices, which I interpret as an increase in the availability of development sites increasing the competitive pressure on landowners.

Equation 13: Local housing supply function (baseline)

$$P_j = C_j \frac{H_j}{K_j}^{\psi}$$

Extended housing supply model

Equation 14 outlines an extended land pricing function. K_j is the quantity of development capacity in zone j, ie the total amount of dwellings that are allowed to be constructed under zoning rules, and other variables are as previously defined.

Equation 14: Land pricing function (extended)

$$P_j^L = \frac{H_j}{K_j}^{\tilde{\psi}} \left(\sum_{k \neq j} \frac{K_k}{GC_{jk}^{\theta}}\right)^{\tilde{\delta}}$$

As above, the first term $(\frac{H_j}{K_j}^{\tilde{\psi}})$ is a 'congestion factor' that results in increased land prices in areas with higher local densities. The second term $((\sum_{k \neq j} \frac{K_k}{GC_{jk}^{\theta}})^{\tilde{\delta}})$ is a 'competition factor' that results in lower land prices when there is a greater supply of development opportunities in nearby areas that are accessible via transport networks. This is defined as the sum of development capacity in other model zones, weighted according to the inverse of travel costs between zones.[14]

$\tilde{\psi}$ and $\tilde{\delta}$ are elasticities that measure the impact of local density and access to nearby development opportunities on land prices, and θ is a distance decay parameter that defines how much weight is placed on near vs far model zones.

Equation 14 is substituted into ***Equation 11*** to derive the extended local housing supply function, shown in ***Equation 15***. This function is more complex than Severn (2019) but has several key advantages:

- First, it allows transport improvements to affect local housing supply dynamics by changing the degree of competitive pressure that local landowners operate under. Reductions in GC_{jk} increase access to development opportunities in nearby zones, thereby placing downward pressure on local prices.
- Second, it allows zoning policies to affect local housing supply dynamics. Increases in K_j also place downward pressure on local prices.

Equation 15: Local housing supply function (extended)

[14] This term is similar to the effective job density measure that is commonly used to calculate agglomeration potential.

$$P_j = C_j \frac{H_j}{K_j}^{\psi} \left(\sum_{k \neq j} \frac{K_k}{GC_{jk}^{\theta}}\right)^{\delta}$$

Empirical research provides some support for this modelling approach. In an analysis of price and zoning data from Montgomery County, Maryland, Pollakowski and Wachter (1990) show that more restrictive zoning raises land prices in adjacent parcels. Byun, Waldorf and Esparza (2005) show that development restrictions in California local governments increase home-building in adjacent areas. Turner, Haughwout, and van der Klaauw (2014) investigate various impacts of land use regulation differentials near municipal boundaries, finding evidence that tighter land use regulations raise land values and the share of land that is developed in neighbouring areas, relative to more restrictively regulated areas.

7.1.4 Summary and model closure

Equation 6 and ***Equation 13*** / ***Equation 15*** constitute a system of equations that defines housing demand and housing supply as a function of transport costs (GC_{jk}), fixed effects for the attractiveness of home and work locations (e_j and W_k), development capacity in each model zone (K_j), and model parameters γ, β, ψ, and δ, which can be estimated econometrically. The endogenous variables of this model are local housing prices (P_j), number of people commuting between each pair of home and work locations (N_{jk}), and total quantity of housing supplied in each zone (H_j).

The following assumptions close the model. First, local housing markets are assumed to clear, meaning that the quantity of housing supplied is equal to the number of people living in the zone (***Equation 16***).[15] Second, I assume that total city size is fixed (***Equation 17***). This is achieved by scaling up or down overall utility levels until city size returns to its fixed level.[16]

Equation 16: Local housing market clearance condition

$$N_j = \sum_k N_{jk} = H_j$$

Equation 17: Fixed city size assumption

$$\sum_{j,k} N_{jk} = \bar{N}$$

Finally, numerical methods are needed to solve this model. This entails running a strategic transport model to predict the impact of a project on travel costs, and then updating ***Equation 6*** and ***Equation 15*** in iterative fashion until they converge on a single solution. Ideally, this would also involve iteration between the above land use change model and the strategic transport model.

7.2 Estimated model parameters for Wellington

To conclude this section, I summarise estimated model parameters for the Wellington urban area. These parameters are estimated using data on the observed variables of the model (commuting flows, travel times, house prices, and development capacity). Details of the underlying data and econometric estimation are provided in the Appendix.

A key challenge to estimating model parameters is that several parameters are likely to be endogenous. There is a potential 'chicken and egg' relationship between commuting flows and travel costs, and between local density and house prices. I address this using an instrumental variables approach that employs additional

[15] This entails normalising housing supply to a per-worker basis. This normalisation has no impact on the interpretation of the model.
[16] An alternative approach (drawing upon the open-city Alonso-Muth-Mills model) would be to hold utility levels fixed at their starting level and allow city size to adjust accordingly.

variables that are (a) correlated with the endogenous explanatory variable of interest but (b) not correlated with other unobserved factors that might influence the outcome variable. I define instruments based on geography (ie the role of hills and harbours in determining transport costs) and history (ie the role of pre-1890 port location in determining historical population density, which in turn influences present-day density). These instruments are plausibly exogenous and pass key statistical tests of instrument validity, but it is difficult to conclusively prove that they are truly exogenous.[17]

The following table summarises estimates of key model parameters and provides notes on estimation and uncertainty. Some key findings from this initial analysis are as follows:

- First, reduced AM peak travel times (averaged across both car or public transport) between two locations leads to an increase in the number of people choosing to live in one location and work in the other.
- Second, higher house prices reduce the number of people choosing to live in a given home location. The elasticity of local housing demand with respect to housing demand is large – well above one in absolute value. This is consistent with the idea that people are mobile within cities in response to housing prices, even if they may be less mobile between cities.
- Third, the coefficient on dwelling density relative to plan-enabled development capacity in the housing supply function is positive but smaller than one. This indicates that increasing demand to live in a given location cannot be met without increases in prices, unless rezoning is pursued to increase the local supply of development opportunities.
- Fourth, the coefficient on nearby development capacity in the housing supply function generally has a positive sign rather than a negative sign as hypothesised, and is statistically insignificant in the preferred model. This suggests that the baseline housing supply model is the preferred specification, and that improved access to development capacity in other locations does not reduce land prices. This in turn suggests that transport projects are most likely to place downward pressure on land prices by shifting the location of housing demand.

Table 3: Preferred estimates of model parameters

Parameter	Estimate	Std err	Interpretation
β (location choice model coefficient on travel time)	-0.101***	0.004	A one minute reduction in AM peak travel time between two locations will lead to a 10% increase in commuting flows. A one minute reduction in travel time from a home location to all other locations will lead to a 10% increase in local housing demand. *Reference: IV Poisson model 1 in Table 5.*
γ (location choice model coefficient on house price)	-4.495***	0.369	Holding transport access constant, a 10% increase in house prices in a single suburb will lead to a ~35% reduction in local housing demand. *Reference: IV Poisson model 1 in Table 7*
ψ (housing supply function coefficient on local dwelling density	0.289***	0.083	House prices must rise by roughly 2.9% in order to accommodate a 10% increase in dwelling density, unless zoning is relaxed to increase development capacity.

[17] While instruments based on the location of historical infrastructure or historical infrastructure plans are widely used in the empirical literature (eg Duranton and Turner, 2012; Dalgaard et al, 2018), they are subject to theoretical and practical critique. For instance, Kelly (2019) argues that the presence of spatial autocorrelation – when outcomes in one place are correlated with outcomes in other nearby places – can invalidate these types of instruments.

relative to development capacity)			*Reference: IV model 1b in Table 9*
δ (housing supply function coefficient on inverse travel time-weighted development capacity in nearby zones)	Not estimated		Coefficient estimates did not have the hypothesised sign (positive rather than negative) and were statistically insignificant in the preferred specification of this model. As a result I conclude that the baseline housing supply model specification is preferred. *Reference: IV models 2a/2b in Table 9*

*Statistical significance indicators: . p<0.1 * p<0.05; ** p<0.01; *** p<0.01*

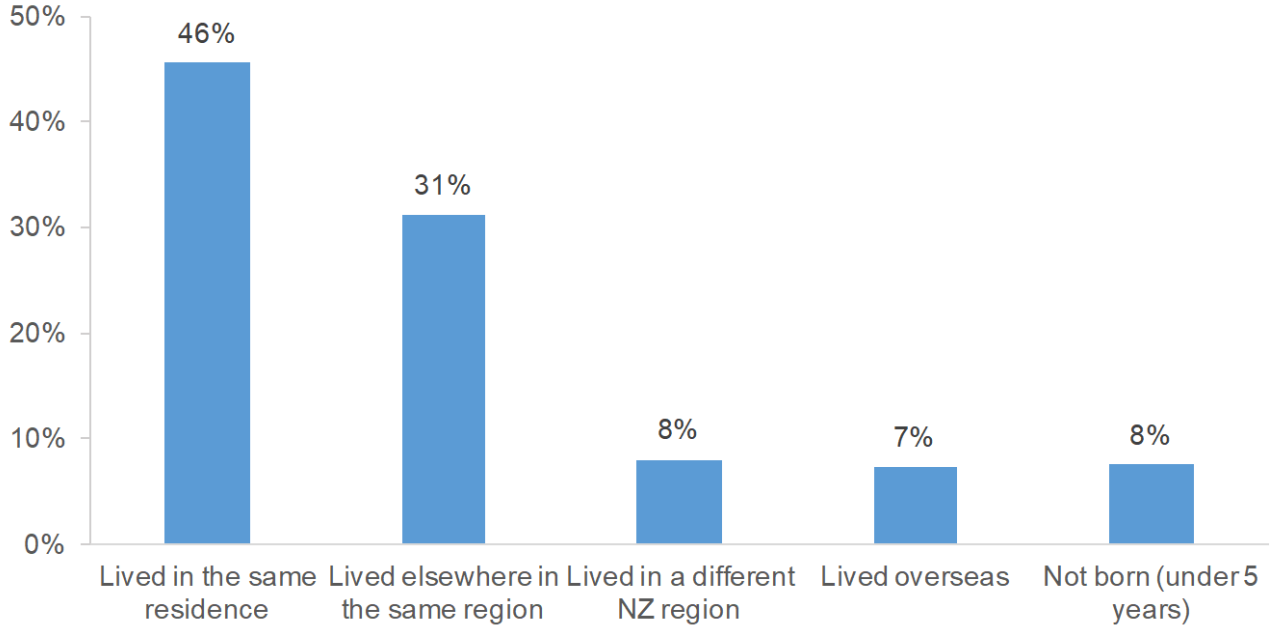
7.2.1 Commentary on price elasticity of local housing demand

The estimated price elasticity of local housing demand is very high (-4.495), implying that people are very sensitive to differences in house prices between suburbs with comparable levels of transport access.

By contrast, previous research suggests that city/regional population is less sensitive to variations in inter-regional house prices. Based on data from the 1986-2013 New Zealand Censuses, Hyslop et al (2019) estimate that the price elasticity of regional housing demand lies between -0.3 and -0.5. The calibrated spatial equilibrium model used by Nunns (2020) also implies a price elasticity of regional housing demand of around -0.35 to -0.5.[18]

In short, people appear to be around ten times as sensitive to local house price variations as they are to inter-regional house price variations. This finding is consistent with evidence on mobility from the Census. Figure 4 shows that roughly one in three New Zealanders moved homes within the same region over the 2008-2013 period, while only one in twelve moved between regions.

Figure 4: Usual residence five years ago (2013 New Zealand Census)



[18] This estimate assumes the presence of idiosyncratic preferences for specific locations or frictions to inter-regional mobility. If idiosyncratic preferences / frictions are disregarded, the model implies a higher demand elasticity in the range of -0.85 to -1.2.

7.2.2 Commentary on housing supply parameter

As detailed in the appendix, the housing supply parameter proved to the most difficult parameter to estimate. My preferred estimate of the housing supply parameter is 0.289, which implies that local house prices must rise by roughly 2.9% in order to accommodate a 10% increase in dwelling density. Alternative model specifications result in different parameter estimates ranging from 0.1 to 1.0.

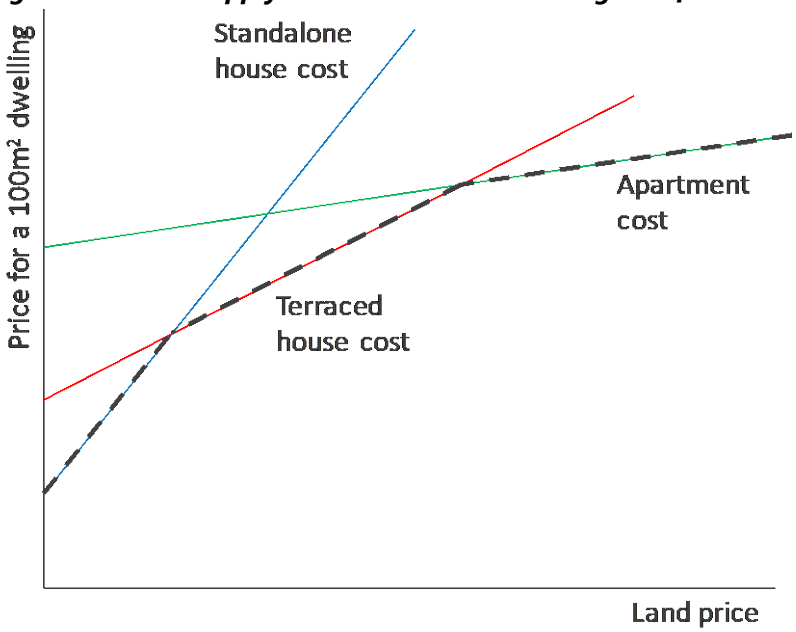
Outside information is therefore helpful to understand what this parameter 'should' be. This indicates that the housing supply parameter should be less than one but considerably higher than 0.1.

The following diagram illustrates the relationship between land prices (horizontal axis) and the cost to build a standard-sized dwelling (vertical axis). Different curves are plotted for standalone homes, terraced homes, and apartments. Terraced homes and apartments incur higher construction costs and planning and financing costs, but require less land per dwelling. As a result:

- When land prices are low, standalone homes are cheaper to build than terraced homes or apartments
- As land prices rise, eg due to increased density leading to more competition for development sites, the cost to build standalone homes escalates more rapidly than the cost to build terraced homes or apartment.
- When land prices reach a certain level, it becomes cheaper to build terraced homes than standalone homes, and then cheaper to build apartments than either.

The dashed line indicates the overall cost envelope for building additional dwellings. Provided that land use regulations allow the construction of terraced houses and apartments, this implies that there should be a less than one-to-one relationship between density and housing prices. However, if land use regulations are extremely restrictive, then we may expect a housing supply parameter greater than one. Severn (2019) estimates a housing supply parameter of around 1.4 for Los Angeles, which may be due to extremely restrictive land use regulation.

Figure 5: Cost to supply a standard-sized dwelling as a function of land prices



However, previous evidence on housing supply responsiveness in New Zealand, the United States, and other OECD countries suggests that the housing supply parameter should be significantly higher than 0.1 at the regional or national level (Saiz, 2010; Caldera and Johansson, 2013; Hyslop et al, 2019).[19]

For purposes of comparing with previous research, I note that ψ is an inverse housing supply elasticity, and hence $1/\psi$ can be interpreted as the elasticity of housing supply with respect to price. My estimate of 0.289 implies that Wellington has a housing supply elasticity of around 3.5.

By comparison, Hyslop et al (2019) estimate a housing supply parameter (comparable to ψ) in the range of 0.4 to 0.65 at the territorial authority / Auckland ward level. This is slightly higher than my parameter estimate and implies that housing supply is slightly less responsive than I have found.

Saiz (2010) estimates housing supply elasticities for US cities that generally fall within the range of 1.5 to 5. My estimate for Wellington (3.5) is within this range, albeit higher than we would expect for a comparably geographically constrained US city with around 0.5 million residents. By contrast, my lower-end estimate of 0.1 would imply a housing supply elasticity of 10, which would be roughly twice as responsive as lightly-regulated American cities with abundant flat land for subdivision.

In short, a higher estimate of the housing supply parameter is more consistent with previous research.

Lastly, I note that the housing supply parameter can be decomposed as follows: $\psi = \Phi * \tilde{\psi}$, where Φ is the land share of expenditure in a Cobb-Douglas housing production function and $\tilde{\psi}$ is the elasticity of land prices with respect to the local density of dwellings relative to development capacity. Previous estimates of the Cobb-Douglas land share fall in the range of 0.2 to 0.3 (Combes, Duranton, and Gobillon, 2017; Albouy and Erhlich, 2018), and a ratio of 0.3 has been used in analysis of housing supply costs in New Zealand (Ministry of Business, Innovation, and Employment, 2017).

A Cobb-Douglas land share parameter of 0.3 implies that the elasticity of land prices with respect to density is near one. This is consistent with previous estimates from the literature. Ahlfeldt and McMillen (2014) estimate that the elasticity of land prices with respect to density is near one using data from Berlin, Chicago, and Pittsburgh. This provides further support for my preferred housing supply parameter estimate.

[19] We would expect supply constraints to be more binding at the local level than at the regional level, due to the fact that there are fewer alternative development opportunities at a local level.

8 Application to a case study

In this section, I apply the model developed in the previous section to a simple hypothetical case study. The aim of this analysis is to understand the qualitative and quantitative predictions arising from the model and to identify potential policy implications arising from the model. I also considered extension to a more complex case study but have left this as an area for further work.

8.1 Description of simple case study

In this example, average travel times from one suburb to the rest of the city reduce by two minutes, while travel times between other locations remain unchanged. This could occur if, for instance, a dead-end road leading to a residential suburb at the edge of the city was straightened to reduce travel times from that suburb to all other locations. However, it is a somewhat unrealistic scenario as most transport projects typically affect travel times between many locations.

The following table summarises key characteristics of the modelled suburb. Model parameters summarised in ***Table 4*** are used in this analysis.

Table 4: Hypothetical suburb characteristics

Suburb characteristic	**Value**
Reduction in average travel time to all other locations	-2 minutes / trip
Starting number of commuters / dwellings *Note: for ease of exposition one commuter per dwelling is assumed*	1000
Average dwelling price	$400,000

I used the model to calculate the underlying increase in local housing demand, defined as the uplift in commuters / dwellings that would occur if local house prices remained constant, as well as the impact of three scenarios:

- A scenario in which local zoning did not change – ie no additional development capacity was provided to serve additional demand
- A scenario in which zoning was changed to allow a 10% increase in development capacity
- A scenario in which zoning was changed to allow a 20% increase in development capacity

8.1.1 Key model results

Key outcomes from these scenarios are presented in the following table. This shows that:

- The transport improvement would lead to a 22% in underlying demand to live in this location
- Under fixed zoning, only 41% of this underlying increase in demand would flow through into increased construction, with the remainder flowing into higher house prices
- Under fixed zoning, local house prices would rise by 2.6%. Due to the fact that local housing demand is found to be very price-sensitive, this is sufficient to ration out the remaining increase in demand to other locations.

- If zoning capacity is increased, an increasing share of the demand uplift is captured as new construction, and house price increases are even smaller.

The predicted increases in house prices are small. Due to the way that the housing supply parameter is estimated, these increases should be interpreted as the increase in prices due to a shift along the housing supply curve. The positive slope of the supply curve in turn reflects the degree to which prices for development sites are bid up as an area becomes more densely developed.

This is because the housing supply regression model includes a control variable for access to jobs via the transport network. That term captures the capitalisation of travel time benefits into house prices, while the housing supply parameter identifies the underlying slope of the housing supply curve. The total impact in house prices, including capitalisation effects, may be higher than indicated in this table.

Table 5: Modelled outcomes of a two minute reduction in average travel times for a single zone

Scenario	**Percentage increase in zone population**	**Percentage increase in house price (housing supply cost)**	**Share of underlying demand captured as increased construction**
Underlying increase in local housing demand	+22%	-	
Outcomes with fixed zoning	+9%	+2.6%	41%
Outcomes with a 10% increase in development capacity	+15%	+1.4%	68%
Outcomes with a 20% increase in development capacity	+21%	+0.2%	94%

8.1.2 Conventional transport benefits and housing development WEBs

I use the above results to calculate conventional transport benefits (ie travel time savings) and housing development WEBs. This is a partial equilibrium analysis – it focuses on outcomes for a single location, ignoring changes in housing demand in other locations.

The following table calculates conventional transport benefits from the hypothetical project. Based on an average two minute travel time saving and a value of travel time parameter of $12/hour (based on the value of travel time savings for commuting purposes in NZ Transport Agency's 2020 *Monetised Benefits and Costs Manual*, updated to 2019 NZ dollars), this will lead to slightly over $400 in benefits per day. This translates to over $5 million in benefits in present value terms, based on a 4% discount rate (again, drawn from NZTA, 2020).

I benchmark outcomes against a scenario in which no land use change occurs and the number of commuters who experience travel time savings stays fixed. Transport user benefits are between 4.6% and 10.5% higher with land use change, depending upon the degree to which the suburb is rezoned to allow more people to move in.

Table 6: Conventional transport benefits of a simple example project

Scenario	Base case commuters	Scenario commuters	Daily travel time savings benefits based on 2 minute time saving and $12/hr value of travel time (incl rule of half for induced commuters)	Present value travel time benefits (bidirectional commutes, 250 working days/year, 4% discount rate)
Outcomes with no land use change	1000	1000	$400	$5,000,000
Outcomes with land use change				
With fixed zoning	1000	1092	$418	$5,230,000 (+4.6%)
With a 10% increase in development capacity	1000	1152	$430	$5,381,000 (+7.6%)
With a 20% increase in development capacity	1000	1210	$442	$5,526,000 (+10.5%)

The following table summarises the additional increased competition WEBs that would arise in housing development markets under the second and third scenarios, which involve rezoning to increase development capacity. No increased competition WEBs are calculated for the first scenario, because the lack of rezoning under that scenario means that local housing supply dynamics do not change. These benefits are calculated using the procedure outlined in Section 5.2, and in particular Equation 1.

The third scenario (a 20% increase in development capacity) would result in housing development WEBs equal to over $0.5 million, or around 10% of the conventional transport benefits generated by the project. These benefits are similar in magnitude to WEBs that arise in labour markets, which typically range from 10 to 30% of conventional benefits (NZTA, 2019).

Table 7: Housing development WEBs of a simple example project

Scenario	Additional dwellings relative to fixed zoning	Average house price reduction relative to fixed zoning	Housing development WEBs	As share of conventional benefits
Outcomes with a 10% increase in development capacity	60	-$4,886	$148,000	2.7%
Outcomes with a 20% increase in development capacity	118	-$9,296	$551,000	10.0%

The impacts of changes in housing demand in other modelled locations are not calculated and valued in this simple example. Assuming that regional population stays (approximately) fixed, then a shift of population growth towards this area will reduce housing demand pressures and hence moderate price increases in other

areas. This will lead to wider housing price impacts and (provided that the region suffers from price-cost markups in housing) broader benefits from reduced price pressures.

8.1.3 Sensitivity tests

Lastly, I sensitivity test alternative model parameters drawn from alternative model specifications. In addition to my preferred parameter estimates, I sensitivity test the lowest estimate of the transport cost parameter and housing price parameter (-0.083 and -3.237, respectively, based on Poisson model 3 results in Table 8 and Table 10), the lowest estimate of the housing supply parameter (0.103, based on OLS model 1b in Table 11), and the highest estimate of the housing supply parameter (1.096, based on IV model 1a in Table 12).

Sensitivity tests show that varying the transport cost and housing price parameters does not have a large impact on modelled outcomes. However, varying the housing supply parameter does have a large impact on modelled outcomes. My lowest estimate of the housing supply parameter implies that two-thirds of the underlying increase in local housing demand would be accommodated without rezoning. My highest estimate implies that only 14% of the increase in local housing demand could be accommodated without rezoning, which is closer to Severn's (2019) findings for Los Angeles. In short, if housing supply is less responsive due to local constraints, fewer people will be able to change location to take advantage of transport improvements.

Table 8: Sensitivity tests on simple example

β (transport cost param)	γ (housing price param)	ψ (housing supply param)	Underlying increase in local housing demand	Increase in zone population under fixed zoning
-0.101	-4.495	0.289	22%	9%
-0.083	-3.237	0.289	18%	9%
-0.101	-4.495	0.103	22%	15%
-0.101	-4.495	1.096	22%	3%
-0.083	-3.237	0.103	18%	13%
-0.083	-3.237	1.096	18%	4%

9 Conclusion

To conclude, I briefly discuss some key lessons from this research, and outline areas for further research.

9.1 Lessons for transport modelling and project appraisal

The key finding from this research is that it is conceptually defensible and technically viable to assess housing development benefits as a wider economic benefit of transport projects and (especially) integrated transport and land use planning projects.

Application of the proposed model to a simple hypothetical case study suggests that these benefits could be significant in magnitude. In some cases, they are likely to be comparable in magnitude to existing WEBs that arise in labour markets, such as agglomeration benefits. Failing to account for these benefits could result in inefficient project selection or project planning and design that does not deliver the appropriate mix of benefits.

However, existing transport models available in New Zealand are not well suited to assessing these benefits. This is because they fail to account for land use changes in response to transport projects, and do not model housing supply and demand dynamics. One approach to addressing this issue is to loosely couple existing transport models with land use models that explicitly address the functioning of the housing market. This paper demonstrates how such a model could be specified and how its key parameters could be estimated.

9.2 Lessons for policymakers

New Zealand is currently suffering from severe and rising levels of housing unaffordability. Rising house prices have a variety of causes but a long-run driver is a lack of housing supply. In light of this, policymakers are asking whether and how transport infrastructure investment can contribute to unlocking housing development.

This research offers three recommendations to policymakers seeking to leverage transport investment for housing development outcomes.

First, transport investment can help to overcome housing supply and affordability issues. Improving accessibility between areas tends to increase the competitive pressure facing landowners by making it easier to buy or rent in more locations. This principle applies throughout urban areas. A new rapid transit route or walking and cycling link that improves access to the city centre will allow medium- and high-density development to occur in more places, just as a new link road allows subdivision to extend into greenfield areas. There is some tentative evidence that public transport improvements may have a larger impact than road improvements, relative to their current share of travel demand.

Second, to achieve optimal results, land use policies must change in line with transport investment. Improved transport access tends to increase local housing demand. If land use policies do not allow or enable more homes to be built in the area, the result will be rising housing prices that benefit existing landowners at the expense of people who may want to move into the area. If land use policies are changed to allow more housing development, then rising demand will flow through into more new homes, more new residents, and lower price increases.

Third, these effects are not particularly controversial, in the empirical literature, and nor are they particularly challenging to model and value. However, they are seldom assessed for major projects. Given the urgency of New Zealand's housing affordability challenges, policymakers should expect better analysis of these impacts from transport agencies.

9.3 Areas for further work

This research project has opened up several areas for further work, which I briefly discuss here.

First, there is a need to complete implementation of the model and loose coupling with an existing transport model. This is conceptually straightforward, as the key elements of the model are specified and key parameters are estimated, but is likely to involve some technical challenges related to finding an equilibrium solution.

Second, the model could be extended to incorporate more detail about other aspects of location choice. This could include a more realistic model of the labour market that addresses issues like agglomeration economies and labour taxation, both of which give rise to WEBs, and further analysis and modelling of other drivers of home location amenity, such as local public goods and negative impacts of traffic noise and emissions. This would move in the direction of a full general equilibrium model that accounts for all aspects of location and transport mode choice.

As Martinez and Araya (2000) observe, directly incorporating these dynamics into the model would allow all welfare impacts to be calculated within the model rather than as an adjustment to transport user benefits.

Third, and following on the above point, if a full general equilibrium model of location and transport mode choice was available, it would be possible to calculate and compare different approaches to valuing the direct and wider benefits of transport projects. In particular, it would be useful to know whether partial equilibrium analysis of WEBs mis-estimates total benefits relative to a general equilibrium analysis.

10 Appendix: Other modelling approaches that were considered

In the course of preparing this research report, I ended up going down a number of modelling dead ends. In this appendix I briefly summarise the approaches that I investigated and briefly explain why they did not work.

In summary, these modelling approaches fall down for one or more of the following reasons:

- It is not possible to link housing supply models with existing transport and land use models without considerable ad-hockery
- Models are tractable for a small number of housing zones but cannot easily be expanded to include many zones (a requirement for modelling complex urban areas)
- Models do not capture the key effect of interest, ie the role of transport access in shaping competition in housing development.

10.1 Dead end 1: Alonso-Muth-Mills

First, I considered whether it would be possible to loosely couple the Alonso-Muth-Mills (AMM) model with a conventional strategic transport model to predict housing development impacts. The AMM model shows that the house price gradient can be described as a function of transport costs to jobs (and sometimes consumption amenities). As a result, changing transport costs can affect average housing costs and the distribution of households throughout the city.

Glaeser (2008) describes the basic AMM model and several permutations. In its simplest version, the city is assumed to consist of a population of homogenous workers that all commute to a single central business district (CBD) and earn wage W. Commuting costs t(d) are an increasing function of distance d to the CBD (ie $t'(d) > 0$). Workers rent L units of land from an absentee landlord, paying rents r(d) that vary by distance to the CBD. Workers choose a location d that maximises the utility that they derive from consuming land L and other consumption goods, ie U(W-t(d)-r(d)L, L).

In equilibrium, all workers must be indifferent between staying in their current location and moving to another location instead. Rents adjust to satisfy this condition. The first order condition for utility maximisation is therefore that the rent gradient is a function of the transport cost gradient, ie $r'(d) = -t'(d)/L$. This implies in turn that rents fall with distance to the CBD. A corollary is that a reduction in transport costs will reduce the rate at which rents fall with distance. The spatial extent of the city is determined by the point at which r(d) is equal to agricultural land rents r_a. This also means that a reduction in transport costs will increase the spatial extent of the city.

The AMM model can be used to simulate the impacts of zoning policies that constrain housing density (eg building height limits and minimum lot sizes) or limit the extent of housing development (eg urban growth boundaries). In the model, these policies shift growth between areas, driving up total housing plus transport costs for residents in the process. If an urban growth boundary is applied, then the model can also estimate price-cost markups between agricultural land and urban land at the edge of the city

I considered the following model process and tested a simple implementation of the model:

- Step 1: Run strategic transport model to estimate transport cost gradient with respect to the CBD.

- Step 2: Source estimates of price discontinuities between urban and agricultural land at the edge of the city.[20]
- Step 3: Use estimated transport cost gradient, plus other economic inputs, to calibrate the AMM model. Use urban land price discontinuities, plus other information on zoning policies, to calibrate the restrictiveness of existing zoning policies.
- Step 4: Re-run transport model to estimate the impact of a transport improvement on the transport cost gradient.
- Step 5: Input the new transport cost gradient into the calibrated AMM model to estimate population redistribution and changes in average house prices.[21]
- Step 6: If transport improvements are paired with relaxation of zoning policies, simulate the joint effect of both policies.

This approach has several fatal flaws.

First, loosely coupling the AMM model with a strategic transport model would require considerable – and probably excessive – simplification of urban space. Strategic transport models contain a large number of zones, with the potential for travel in many directions, while the AMM model assumes that all commuters travel to the CBD and that urban space outside the CBD is homogenous in all other respects.

Second, model testing indicates that housing price-cost markups only reduced in the case where transport improvements were paired with zoning relaxation. If transport access improves but existing building height limits and urban growth boundaries remain unchanged, population will disperse somewhat but land price differentials at the edge of the city will *rise*. This in turn suggests that this modelling approach is not capable of capturing the main effect of interest, ie the impact of transport improvements on housing supply competition.

10.2 Dead end 2: Vertical differentiation models

Second, I considered models of imperfect competition drawn from the industrial organisation (IO) literature. Different IO models incorporate various barriers to competitive market functioning, such as limited numbers of firms (oligopoly), barriers to entry for new firms, or product differentiation that gives firms a degree of market power.

The vertical differentiation model of oligopolistic competition provides one seemingly promising approach. An extension to this model that also captures shifting demand over time and developers' choice of development timing has been used for theoretical analysis of housing market dynamics (Guthrie, 2019).

To demonstrate the basic features of this model, I outline a simple example. Assume that a city has two residential locations separated by a harbour. Location 1 is on the same side of the harbour as the main business district, but there are also small-scale employment locations scattered around both locations. Residents of Location 2 must use a ferry to cross the harbour, which increases the amount of time they must spend commuting. This means that access to jobs via the transport network is higher in Location 1, ie $a_1 > a_2$.

Land in each location is owned by a single firm, which develops rental housing at per-unit cost c. There are N households in the city, who each earn the same average income Y but differ in terms of preference for better transport access. Preference for access θ is distributed continuously on the interval $[\theta_{min}, \theta_{max}]$. For notational convenience, assume that $\theta_{max} = \theta_{min} + 1$. Households derive the following utility from choosing location i:

$$U(\theta, i) = Y - p_i + \theta a_i$$

[20] See MBIE estimates published online at https://mbienz.shinyapps.io/urban-development-capacity/.
[21] The 'open city' version of the model can be used to estimate changes in city size. Under this case, average housing plus transport costs return to their original level as the city 'fills up' again.

Households with high preference for transport access therefore sort themselves into Location 1, and households with low preference sort into Location 2. In equilibrium, the utility of choosing either location must be equalised for the marginal household, which is the household with $\theta = \hat{\theta}$:

$$Y - p_1 + \hat{\theta} a_1 = Y - p_2 + \hat{\theta} a_2$$

We can rearrange this (and cancel out the Y's) to show that the marginal household is located at:

$$\hat{\theta} = \frac{p_1 - p_2}{a_1 - a_2} = \frac{p_1 - p_2}{\Delta a}$$

Turning now to the land owners/developers, we can write the expected profits in each location as a function of market share, prices, and costs:

$$\pi_1 = N * \left(\theta_{max} - \hat{\theta}\right) * (p_1 - c)$$
$$\pi_2 = N * \left(\theta - \widehat{\theta_{min}}\right) * (p_2 - c)$$

If we assume that firms are in Bertrand competition (ie competing on price, rather than quantity), then we can substitute the expression for $\hat{\theta}$ into each profit function, calculating first order conditions for profit maximisation (ie $\partial \pi_i / \partial p_i = 0$), and using the resulting system of equations to solve for equilibrium prices and market shares. This results in the following outcomes:

$$p_1 = c + \frac{\Delta a}{3}(2\theta_{max} - \theta_{min})$$
$$p_2 = c + \frac{\Delta a}{3}(\theta_{max} - 2\theta_{min})$$
$$\hat{\theta} = \frac{1}{3}(\theta_{max} - \theta_{min})$$

Aggregate profits (a measure of price-cost markups) are given by:

$$\pi = \pi_1 + \pi_2 = \frac{\Delta a}{9}(2\theta_{min}^2 + 2\theta_{min} + 5)$$

Rents in both locations are an increasing function of Δa, which means that *reducing* differences in access to jobs between locations, eg by building a bridge across the harbour, will reduce overall housing prices. Intuitively, this reflects the fact that the land owner in the more accessible location is less able to charge a premium for better access. $\partial \pi / \partial \Delta a > 0$, which means that building a bridge is also expected to reduce price-cost markups (ie firms' excess profits). This is a desirable feature of the model.

However, $\hat{\theta}$ is *not* a function of Δa in this model, which means that the share of households living in each location is not expected to change if a bridge is constructed. Moreover, because this model assumes that firms provide enough housing to serve all households, the total quantity of housing produced does not change. These are both unrealistic outcomes that highlight the limitations of this model.

This approach has several fatal flaws.

First, while many alternative housing locations can be differentiated based on a transport accessibility measure, it it is not straightforward to extend the vertical differentiation model to include many model zones. A brief review of the theoretical literature related to this model did not find any clear examples of how this could be done. Experimentation with discrete increases to the number of model zones (eg going from two to three zones)

suggests that the computational complexity of the model would rapidly increase due to the need to solve for a large number of potential 'corner solutions' in which some zones experience no development.

Second, the treatment of housing demand in the vertical differentiation model is inconsistent with how strategic transport models (and other land use models) treat households. The vertical differentiation model assumes that households are homogenous in terms of income, household size, etc, but that they differ on preference for accessibility. Strategic transport models typically segment households based on observable characteristics and assume that households in each segment have the same preferences for travel. This would make it difficult to couple this model to a transport forecasting model.

10.3 Dead end 3: Regional model of transport investment and house price distortions

Third, I investigated whether it was possible to estimate a simple regional model of the relationship between transport investment and house price distortions. This approach would build upon previous work by Nunns (2020) that (a) derived estimates of regional house price distortions using microdata on housing sales and (b) calibrated a spatial equilibrium model of inter-regional location choice that allowed people to relocate between cities in response to changes in house prices.

This model would 'bypass' detailed modelling of the impact of transport investments on land use and local housing supply dynamics. Instead of simulating changes that take place within cities, it would focus on estimating aggregate effects.

I therefore considered the following model process:

- Step 1: Source data on transport investment and house price distortions at the territorial authority level over a multi-year period.
- Step 2: Undertake an econometric analysis of the relationship between transport investment (ie spending on new / improved transport infrastructure) and land price distortions.
- Step 3: Using the coefficients from this econometric model, predict how much house prices would change in response to a given dollar amount of investment in new / improved transport infrastructure.
- Step 4: Plug in estimated changes to house prices Nunns's (2020) inter-regional spatial equilibrium model to predict changes to regional population.
- Step 5: Use results from steps 3 and 4 to calculate increased competition WEBs for housing development, using the procedure set out in the scoping report.

I attempted to implement this approach using data on regional land price distortions from Nunns (2020) and territorial authority-level transport funding data for the 2008-2018 period. In previous research, I showed that three measurable constraints to housing supply have a positive impact on land price distortions.[22] I hypothesised that greater per-capita transport investment would tend to reduce land price distortions by overcoming barriers to housing development and strengthening competition between landowners.

I therefore estimated the following equation, where p_i = land price distortion in region i in the 2015-2017 period; t_i = per-capita spending on new and improved transport infrastructure over the 2008-2018 period; X_i is a vector of other housing supply constraints measured in the early/mid 2000s; e_i is a random error term; and Greek letters are coefficients to be estimated.

[22] These factors were: a smaller supply of developable land that has not yet been built on, larger delays in processing resource consents, and higher development contributions, which indicate greater challenges funding development infrastructure.

Equation 18: Transport investment and regional land price distortions

$$p_i = \beta t_i + \gamma' X_i + e_i$$

The problem with this approach is that t_i is potentially endogenous. That is, if planners expect a region to grow strongly, they may choose to invest more in it. As faster growth tends to push up housing prices, especially in the presence of supply constraints, this can lead to bias in estimates of the impact of t_i on p_i. To correct for this, I searched for instrumental variables that could provide plausibly exogenous variation in t_i. I posit that historical infrastructure provision (proxied by the existing stock of roads per capita) and political incentives (which I proxied by the National Party vote share in the 2008 General Election, which is in turn negatively correlated with votes for left-wing parties) may influence present-day infrastructure spending.

However, I found that historical infrastructure provision and voting patterns in general elections were not related to subsequent transport spending patterns, meaning that these measures are not valid instrumental variables. This meant that it was not possible to convincingly address the endogeneity issue described above.

Ordinary least squares estimation of the above equation, which does not control for endogeneity in transport spending patterns, suggests a positive but statistically insignificant relationship between transport spending and land price distortions. This is potentially consistent with several alternative hypotheses:

- Transport investment is endogenous to regional house prices, as both are affected by expected growth rates
- Recent transport investment has been poorly targeted to unlocking housing development, meaning that we can observe no average relationship between spending and house prices
- The sample size (75 territorial authorities) is is too small to precisely estimate the impacts of transport investment on land price distortions.

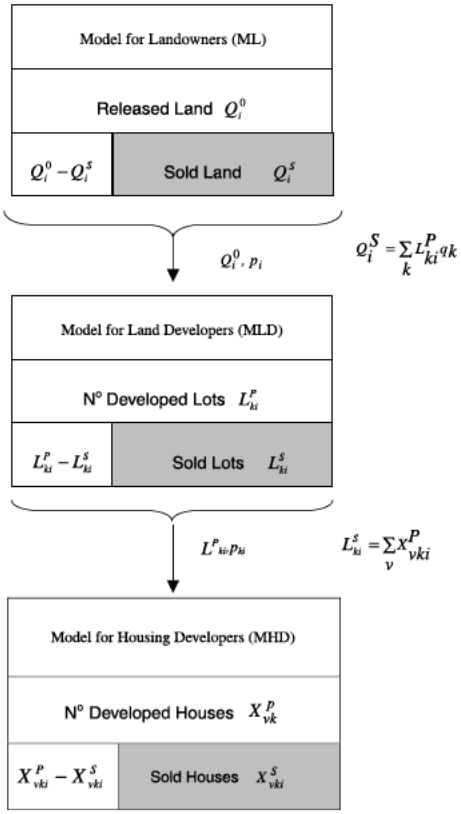
In short, at this stage it is not possible to estimate a parameter that summarises the relationship between transport investment and land price distortions at the regional level. This is a fatal flaw for this modelling approach.

10.4 Dead end 4: Expanded model of the housing supply chains

Fourth, I considered a modelling approach outlined by Martinez and Roy (2004) and Martinez and Henriquez (2007). This model treats housing development as a 'chain' of markets, leading from landowners (who decide whether or not to release land for development) to land developers (who buy undeveloped land and choose how to subdivide it) to housing developers (who buy subdivided sites and choose what type of building to construct on them) to home-buyers or renters.

The following diagram summarises this chain of markets.

Figure 6: Martinez and Roy's model of housing development



Martinez and Roy develop a system of equations to represent this process. At each stage, they implement a probabilistic model for development decisions. Developers are assumed to maximise profits, but a degree of heterogeneity between different developers (or model zones) means that different estimated profit rates will be accepted in different places. This results in a supply model that resembles a multinomial logit model – the share of total development that occurs in each zone is a function of prices and costs in that zone, relative to other zones.

Importantly, Martinez and Roy explicitly address the issue of whether development markets are perfectly competitive or whether they exhibit imperfect competition. They model imperfect competition by assuming that land owners and land developers are 'price-setters' rather than 'price-takers'. That is, developers anticipate buyers' willingness to pay for locations and choose a price and quantity combination that maximises their profit.

The exact behaviour of this housing supply model depends upon whether and how buyers are willing to substitute between living in different model zones. This substitutability in turn depends upon how households' utility functions are defined.

Martinez and Henriquez (2007) provide further detail on the specification of the housing demand function and the housing supply function. They do not explicitly address substitution patterns in households' utility function, but instead suggest that a development cost function could be specified to account for spillovers between alternative model zones, such as development in one zone driving up cost in another zone. However, the version of the model that they solve and apply to an example case does not include spillovers between zones.

This model outlines many of the conceptual issues that are important to this project and proposes a general approach that could be adapted to development of a specific model. However, there are two fatal flaws to this approach.

First, as Martinez and Roy note, it is not clear whether it is possible to calibrate an imperfect competition model of housing development to a real-world city. Nor is it clear that this model would arrive at a unique equilibrium.

Second, while the model can in theory capture spillover between alternative model zones, and hence the potential for investments that improve access to increase competition, there is no straightforward way to implement this. This makes it challenging to implement a realistic model that captures the effects of interest.

11 Appendix: Data sources and data preparation

This appendix summarises the underlying data sources used in model estimation and describes how data was prepared, including data cleaning and matching.

For model estimation, all data was matched to 2013 Census area units. There are 203 Census area units in the Wellington region, most of which fall within the Wellington City, Lower Hutt City, Porirua City, Upper Hutt City, and Kapiti Coast District territorial authorities that include the bulk of urban Wellington.

11.1 Observed commuting flows (N_{jk})

Observed commuting flows between 2013 Census area units were obtained from a custom data request to Statistics New Zealand. This data was used in previous research on transport improvements and land use change (Nunns, 2019). Because there are 203 Census area units in the Wellington region, this results in 41,209 origin-destination pairs.

Statistics NZ confidentialises data like commuting flows by randomly rounding to multiples of three. This results in some inaccuracy for small commuting flows, but previous analysis has showed that this is not material for coefficient estimation.

11.2 Average travel times (GC_{jk})

Average travel times by car and public transport were estimated using outputs from the Wellington Transport Strategy Model (WTSM), which is a four-step transport forecasting model used for transport forecasting and project analysis.[23] Outputs from the 2013 base year of the model were used.

WTSM models travel flows and travel times between 225 model zones. These zones do not exactly align with 2013 Census area units and as a result it was necessary to resample them to Census area units based on the share of land area in each model zone that falls within each Census area unit. For instance, if a WTSM zone overlapped two area units, travel demands would be proportionately allocated to the area units.

As a measure of travel cost, I used demand-weighted average travel time across both car and public transport modes. If car users accounted for 80% of total people travelling between two locations, car travel times would be assigned an 80% weight and public transport travel times a 20% weight.

Generalised cost is a potential alternative measure of travel cost. This includes both travel time and the financial cost of travel, weighted according to the estimated value of travel time.

11.3 House prices (P_j)

I undertook an econometric analysis of residential property sales microdata to construct quality-adjusted house price estimates for each suburb. The derivation of these values is explained in the following appendix.

House sale data was sourced from Wellington region territorial authorities, who gather this data as an input to three-yearly rating revaluations. This data is coded to Census area units.

[23] Model documentation available online at https://www.gw.govt.nz/wellington-transport-models-technical-reports/.

House price data was cleaned according to the following rules:

- Only sales within the Wellington region were included, and sales that could not be matched to a Census area unit were excluded
- Non-residential property sales, sales of vacant lots, and sales of residential lots with extremely small (<30m2) or large (>500m2) buildings were excluded
- Residential sales with large (>1ha) sections were excluded as these are lifestyle blocks or farm properties rather than urban residential properties
- Sales with missing data on key variables (land area, floor area, etc) were excluded, as were sites with zero or negative sale prices
- Sales of dwellings with land (ie not apartments) were excluded if the dwelling site coverage exceeded total site area
- The top and bottom 0.5% of the house price / capital value distribution were excluded
- Indicator variables were constructed to identify sales with missing data on building / roof construction or condition or views
- Sale prices were adjusted to 2017Q1 prices using Statistics New Zealand's Consumer Price Index.

11.4 Number of dwellings (H_j)

The total number of occupied and unoccupied dwellings in each Census area unit was obtained from published Census tables.[24]

11.5 Development capacity (K_j)

Wellington's five urban territorial authorities recently undertook a major planning exercise that included an assessment of how much capacity for new dwellings is enabled by existing district plans. This assessment included both greenfield housing capacity (ie new subdivisions) and capacity for infill and redevelopment in existing urbanised areas. Wellington City Council's (2019) *Wellington Housing and Business Assessment* report published estimates of housing development capacity at a suburb level for these five councils, based on 2018 data on property boundaries, location of existing buildings, and zoning codes.[25]

The following table summarises total dwelling capacity by council area, broken down between infill/redevelopment capacity and greenfield subdivision capacity. Note that the measure used here is plan-enabled capacity – ie what district plans allow to be built – rather than commercially feasible or realisable capacity – ie what developers may currently see as profitable to build.

Table 9: Plan-enabled capacity for additional dwellings in Wellington urban area

Council area	Infill / redevelopment capacity	Greenfield subdivision capacity	Total plan-enabled capacity
Wellington City	103,783	2,628	106,411
Lower Hutt City	39030	2,210	41,240
Upper Hutt City	15,488	2,818	18,306
Kapiti Coast District	19,785	3,350	23,135
Porirua City	36,084	6,629	42,713

[24] Available online at http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE8080

[25] There were not any major changes to district plans between 2013 and 2017/18, and thus these figures are unlikely to materially under- or over-state development capacity in 2013. They are less valid for earlier Census years as there were several significant district plan changes in the 2000s.

Total urban area	**214,170**	**17,635**	**231,805**

Source: Table 1.9 in Wellington Housing and Business Assessment (2019)

For several councils, the suburb definitions used in the report differed from 2013 Census area units. As a result, it was necessary to resample capacity data to Census area units based on the share of land area in each council-defined suburb that falls within each area unit. For instance, if a suburb overlapped two area units, capacity would be proportionately allocated to the area units.

Dwelling capacity estimates were available for 176 Census area units. Capacity data was not available for all Census area units within the region, as the focus of the assessment was on urban and future urban areas. Rural areas typically have some dwelling development capacity, eg from large-lot subdivisions that are allowed by rural zoning, but this was not assessed in the report. If proportional allocation rules only allocated a small amount of development capacity to a given area unit (<10 dwellings), then that area unit was discarded.

To obtain an estimate of total development capacity in each area unit, including both existing and new dwellings, I added together capacity for new dwellings with Census data on the number of total dwellings in 2013.

12 Appendix: Model estimation and robustness checks

This section provides further detail on model estimation, including statistical methods and robustness checks. All model estimation has been conducted in R, an open-source statistics package. The following packages were used for econometric analysis and model estimation: 'AER', 'car', 'fixest', and 'lmtest'.

12.1 Estimating location choice model

I estimate the household location choice model in two stages. First, I estimate the commuting flow model described in ***Equation 4***. Second, I estimate a supplementary model of the impact of higher quality-adjusted house prices on the underlying attractiveness of home locations, as described in ***Equation 5***. Finally, I combine the results from these models into a single location choice model.

Extensions to this basic model are possible. This could include:

- Extending the model of home location attractiveness to include other amenities, such as parks, schools, or other local public goods
- Estimating a model of work location attractiveness that accounts for the impact of wages and other amenities and/or incorporates an agglomeration function.

12.1.1 Commuting flow model

I begin by estimating a Poisson regression model that corresponds to ***Equation 4***. I use a Poisson regression model due to the fact that the dependent variable, the number of people observed to commute between home location j and work location k (N_{jk}), is a 'count' variable that is not normally distributed.[26]

This regression model includes fixed effects for both home and work locations. These fixed effects capture the underlying desirability of living or working in a given place, controlling for transport access to that place. For instance, people may have a preference for living by the beach or living in 'desirable' school zones, or a preference for working in places that offer high wages or diversity of economic opportunities. These factors will be reflected in more positive fixed effects for those locations. Due to the large number of fixed effects in this model, I estimate it using the 'fixest' package in R.

The major challenge in credibly estimating the coefficient on the travel time variable is that average travel times are endogenous to commuting flows. This can happen through several mechanisms. On the one hand, larger car commuting flows result in traffic congestion, which may cause downward bias in the coefficient estimate. On the other hand, transport agencies may respond to high demand for commuting between locations by improving transport infrastructure or services to reduce travel times, which may cause upward bias in the coefficient estimate.

To address this issue, I estimate this model using a control function approach with instruments for the endogenous variable (Train, 2009). This entails estimating the following first stage regression via ordinary least squares, saving the fitted residuals ($\widehat{u_{jk}}$), and including these residuals as control variables in the second stage

[26] Alternatively, both sides of this equation could be log-transformed and the model could be estimated using linear regression. This is not possible due to the fact that zero commuters are observed for some origin-destination pairs, as the logarithm of zero is undefined.

equation. The idea behind this approach is that, provided that the instruments Z_{jk} are exogenous, the fitted residuals will account for the endogenous component of GC_{jk}.

Equation 19: First stage regression for control function estimation of commuting flow model

$$GC_{jk} = \tau' Z_{jk} + U_j + W_k + u_{jk}$$

Equation 20: Control function estimation of commuting flow equation

$$N_{jk} = \exp\left(U_j + W_k + \beta GC_{jk} + \rho\widehat{u_{jk}} + \varepsilon_{jk}\right)$$

I use three instruments based on physical geography. These are: Straight-line distance between origin and destination, average slope along that straight line, and share of that straight line that falls over water rather than land. Geographic barriers have a plausibly exogenous impact on travel times between locations as they pre-exist travel demands and drive up the cost to supply transport infrastructure. (Bridges and tunnels tend to be more expensive than roads through flat terrain.) These instruments are strongly positively correlated with travel times (indicating that they are relevant instruments). Fitted residuals from the first stage model are statistically significant in the second-stage model, indicating that endogeneity is likely to be present.

Table 5 summarises results from five alternative specifications for the commuting flow regressions. The first three columns report results from Poisson regressions that do not control for potential endogeneity between travel time and commuting flows. The last two columns report Poisson regression models that use instrumental variables to control for endogeneity. These alternative specifications show that:

- Across all specifications, longer travel times have a negative impact on commuting flows after home and work location fixed effects are included.
- Poisson model 1 shows that longer car travel times and longer PT travel times have a negative effect on commuting flows. The coefficient on car travel times is around 50% higher, but this highlights the fact that both modes can affect location choices.
- Controlling for endogeneity results in a small increase in the coefficient on travel time (eg -0.10 in IV Poisson model 1 vs -0.095 in Poisson model 1).
- First stage residuals are strongly statistically significant, which highlights the likely presence of endogeneity.

The preferred model is IV Poisson model 1, which has a coefficient of -0.10 on average AM peak travel times, excluding PT boarding time.

Note that standard errors have not been corrected to account for the two-stage estimation approach. This can be done by bootstrapping standard errors.

Table 10: Commuting flow regressions

Explanatory variable	Poisson model 1	Poisson model 2	Poisson model 3	IV Poisson model 1	IV Poisson model 2
Car travel time (AM peak)	-0.0492***				
	(0.0099)				
PT travel time (ex boarding time, AM peak)	-0.0332***				
	(0.0069)				
Average travel time (ex boarding time, AM peak)		-0.0949***		-0.1008***	

		(0.0036)		(0.0036)	
Average travel time (incl boarding time, AM peak)			-0.0829***		-0.0887***
			(0.0036)		(0.0035)
First stage residuals (control function)				0.054***	0.0566***
				(0.0042)	(0.0043)
Origin area unit fixed effects	Yes	Yes	Yes	Yes	Yes
Destination area unit fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	41,209	41,209	41,209	41,209	41,209
SE type: Two-way	by: AU20. & AU20.	by: AU20. & AU20.	by: AU20. & AU20.	by: AU20. & AU20.	by: AU20. & AU20.
Pseudo R^2	0.86332	0.84886	0.8435	0.86747	0.86379
BIC	167,495	184,283	190,505	162,671	166,950

*Statistical significance indicators: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

Table 6 reports first stage regression results. Residuals from these models were used as the control function for IV Poisson models above. First-stage models are highly statistically significant (as shown by the F-stat for the entire model and the highly statistically significant coefficients on each of the three instrumental variables.

Table 11: First stage regressions for control function Poisson models

Outcome variable	**Average travel time (ex boarding time, AM peak)**	**Average travel time (incl boarding time, AM peak)**
Corresponding commuting flow model	**IV Poisson model 1**	**IV Poisson model 2**
Average slope between origin and destination (%)	169.4476***	167.9611***
	(17.6182)	(18.3113)
Share of straight line that falls over water (%)	27.6643***	26.8099***
	(2.4986)	(2.6477)
Straight line distance (km)	1.1786***	1.3382***
	(0.0423)	(0.0489)
Origin area unit fixed effects	Yes	Yes
Destination area unit fixed effects	Yes	Yes
Observations	41,209	41,209
SE type: Two-way	by: AU20. & AU20.	by: AU20. & AU20.
R^2	0.91526	0.90884

F-stat (df=407; 40801)	1083***	999.5***

*Statistical significance indicators: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

12.1.2 Home location attractiveness

After estimating the above model, I estimate a model of home location attractiveness as a function of local housing prices. This model is as described in ***Equation 5***. Home location fixed effects from the commuting flow model (Uj) are used as the dependent variable. The explanatory variable of interest is the natural log of quality-adjusted house prices (Pj), the derivation of which is explained below.

All else equal, I would expect a negative relationship between local house prices and home location attractiveness, as higher house prices tend to discourage people from choosing a given location. However, the impact of transport accessibility or other localised amenities such as schools, parks, or beaches is typically capitalised into house prices. This introduces the potential for upward bias into my estimate of the impact of local housing prices on home location attractiveness.

However, home location fixed effects exclude the impact of transport accessibility as this is separately measured in the commuting flow model. This eliminates the primary source of upward bias in coefficient estimates. Estimating the model using ordinary least squares results in a large and negative coefficient estimate, which suggests that this strategy is effective. Including controls for other measurable amenities may further increase the magnitude of this coefficient.

Table 7 summarises results from home location attractiveness regression models. Five models are estimated, using fixed effects from each of the five commuting flow models estimated above. The explanatory variable in each model is the average quality-adjusted house price in each area unit. (This measure is explained below.)

Higher house prices are strongly negatively correlated with home location fixed effects from all five commuting flow model specifications. This suggests that, controlling for transport access, higher house prices have a negative impact on local housing demand. Coefficients are larger (more negative) in the IV Poisson model specifications.

As the preferred commuting flow model is IV Poisson model 1, the preferred coefficient on housing demand in the home location attractiveness model is -4.50.

Lastly, note that these models are parsimonious and do not include variables for other amenities or disamenities. They could be extended to include further variables, such as school zones, beaches, parks, etc.

Table 12: Home location attractiveness regression models

Outcome variable	**Home location fixed effects**	**Home location fixed effects**	**Home location fixed effects**	**Home location fixed effects**	**Home location fixed effects**
Corresponding commuting flow model	**Poisson model 1**	**Poisson model 2**	**Poisson model 3**	**IV Poisson model 1**	**IV Poisson model 2**
Quality-adjusted house prices (demeaned, natural log)	-2.512***	-3.481***	-3.237***	-4.495***	-4.287***
	(0.277)	(0.311)	(0.295)	(0.369)	(0.354)
Constant	5.289***	4.986***	5.003***	5.084***	5.124***

	(0.132)	(0.148)	(0.140)	(0.176)	(0.168)
Observations	195	195	195	195	195
R^2	0.298	0.394	0.383	0.434	0.432
F Statistic (df = 1; 193)	82.023***	125.491***	120.055***	148.039***	146.986***

*Statistical significance indicators: *p<0.1; **p<0.05; ***p<0.01*

12.2 Local housing supply model

I estimate several versions of the housing supply model described in ***Equation 13*** / ***Equation 15***. To enable estimation via ordinary least squares or two-stage least squares regression, I log-transform this equation to obtain the following econometric model specification. This specification estimates log-transformed quality-adjusted house prices in home location j as a function of dwelling density relative to development capacity in the area (H_j/K_j) and available development capacity in nearby locations (the second term, which is included only in the extended model specification.) A vector of other location-specific controls is also included if needed to ensure unbiased estimation of key model parameters. Location-specific cost shifters (C_j) are subsumed into the error term (ξ_j).

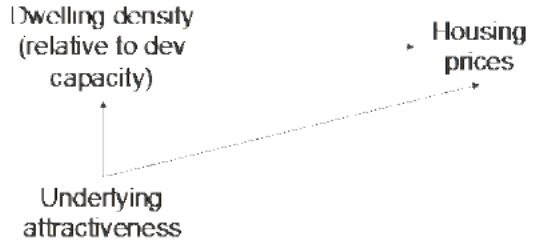
I estimate several variants of this model with different specifications of the dwelling density variable and including and excluding the variable for available development capacity in nearby locations.

Equation 21: Local housing supply regression model

$$\ln(P_j) = \psi \ln\left(\frac{H_j}{K_j}\right) + \delta \ln\left(\sum_{k \neq j} \frac{K_k}{GC_{jk}^{\theta}}\right) + \tau' X_j + \xi_j$$

The primary challenge to estimating this model is that dwelling density and house prices are endogenous. This is illustrated in the following diagram. Higher dwelling density (relative to development capacity) is expected to increase local housing prices due to increased competition for a limited quantity of development sites. However, if some areas are attractive for other, underlying reasons, this may increase both house prices (due to capitalisation effects) and density (due to the fact that more people want to be there). This may bias coefficient estimates.

Figure 7: Endogeneity in housing supply equation



There are several strategies for addressing this issue. The first is to include additional variables that control for underlying attractiveness. I use the following variables:

- Indicator variables for territorial local authorities (TLAs): These control for differences in underlying attractiveness at a relatively 'coarse' level as there are five TLAs in the Wellington urban area.

- An effective job density (EJD) variable: This measures travel-time weighted access to employment from home locations. It controls for attractiveness due to better access to economic opportunities. The calculation of this measure is defined in the section on calculation of agglomeration benefits in NZ Transport Agency's (2020) *Monetised Benefits and Costs Manual*.
- Average income in the home suburb: Higher-income people tend to 'sort' into areas with good access to jobs or high levels of amenity, and therefore average incomes may serve as a control for underlying attractiveness. Lagged incomes from the 2001 Census are used to reduce endogeneity issues.

The second strategy to use instrumental variables for the dwelling density and development capacity variables to control for endogeneity. The literature suggests several potential instrumental variables. Severn (2019) calculates a Bartik-style shift-share instrument for changes in local density in a housing supply regression. Hyslop et al (2019) tests lagged population density and lagged immigrant share as instruments in a similar regression, but finds that they are weak instruments. Grimes et al (2016) find that the proximity to historical infrastructure have a long-run impact on urban population growth in New Zealand.

After some investigation, I use instruments based on Grimes et al (2016). These are straight-line distance to the nearest pre-1890 port (Wellington Port, which was located in the Lambton area unit prior to its expansion and relocation to a slightly more northerly location in the mid-20th century) and indicators for the second-, third- and fourth-closest pre-1890 ports.[27] The argument for using these instruments is that locations that were close to historical ports were developed earlier, which has a positive impact on dwelling density (as older suburbs tend to have smaller residential lots than newer suburbs) and a negative impact on development capacity (as smaller lots are harder to redevelop, and district plans often limit demolition and redevelopment of pre-1930 buildings).

A threat to instrument exogeneity is that port proximity may have a positive impact on present-day economic outcomes. However, this threat is mitigated by the fact that (a) improvements to land transport have reduced the economic importance of close proximity to ports and (b) several of the historical ports used as instruments have closed down. Remaining issues can be addressed by including controls for present-day access to economic opportunities (ie the effective job density measure mentioned above).

The F-stat from the first-stage regression suggests that these instruments are relevant, while a Sargan Chi overidentification test fails to reject the null hypothesis that the instruments are exogenous.[28] This suggests that these instruments are likely to be valid.

I estimate twelve permutations of this basic model, including both instrumented and non-instrumented models and including different permutations of dependent variables and control variables. OLS models are reported in Table 8, while IV models are reported in Table 9.

The preferred model (IV 1b) is highlighted in grey. This model is preferred as it best corresponds to the underlying economic model outlined above, incorporates the full set of control variables, and controls for endogeneity using an instrumental variables approach.

The key findings from this analysis are as follows.

First, area units that are more built out (defined either by dwellings/development capacity or dwellings/land area) have higher house prices even after including controls for access to jobs and the presence of amenities.

[27] After Wellington Port, the nearest ports were located at Castlepoint (Wairarapa), Wanganui, Picton, and Blenheim. Castlepoint and Blenheim are now defunct, and Wanganui only serves a small amount of shipping.

[28] Sargan Chi tests whether coefficient estimates are stable when different instruments are included or excluded. Rejection of the null hypothesis indicates that at least one instrument is endogenous. Failure to reject the null hypothesis provides suggestive, but not conclusive, evidence that the instruments are exogenous. In principle, if all of the proposed instruments were endogenous, Sargan Chi would also fail to reject the null hypothesis.

This finding is qualitatively consistent across both OLS and IV models, indicating that density does increase the cost of housing supply as expected.

Second, my chosen instruments (proximity to pre-1890 ports) appear to be valid. In four out of six IV models, I reject the null hypothesis of weak instruments at the 1% level. (In models 1a and 3a, the weak instruments test has a p-value of just over 10%.) In five of six models, I fail to reject the null hypothesis of instrument exogeneity on the Sargan Chi test at the 10% level. (In model 1a, the Sargan Chi test has a p-value of 9.4%.)

Third, IV models result in higher estimates of the housing supply parameter. For instance, IV model 1b (the preferred model) provides a parameter estimate of 0.289, while the corresponding OLS model (1b) provides a parameter estimate of 0.103. This suggests that endogeneity between density and house prices leads to *downward* bias in parameter estimates. This is consistent with the idea that residents are mobile within cities and highly sensitive to local house prices – developers who build in high-cost locations without attractive amenities may find that they are unable to sell at a price that fully covers their costs and expected profits.

Fourth, models 3a and 3b include a variable for access to development capacity in other zones. This is intended to capture the impact of competition from landowners in nearby areas on local land prices. However, the sign on this variable is positive, rather than negative, in most specifications, and it is not statistically significant in IV model 3b, which includes other controls. As a result, I conclude that there is no strong case to include a competition term in the model.[29]

Finally, as a specification test, I estimated variants of OLS and IV models 1b that include separate variables for dwellings and development capacity. The underlying economic model implies that the coefficients on these variables should sum to zero. (IE coefficient on dwellings = ψ and coefficient on development capacity = $-\psi$.) Table 10 summarises the results of this specification test. Coefficients on these two variables are similar in magnitude. A linear restrictions test fails to reject the null hypothesis that they sum to zero in either OLS or IV models (at the 10% significance level). This suggests that the model specification is appropriate.

[29] I experimented with a number of different specifications for this variable, including different decay parameters on transport cost and specifications with hard cutoff thresholds. No alternative specification delivered fundamentally different results.

Table 13: Housing supply regression models (OLS)

Model specification	**OLS 1a**	**OLS 1b**	**OLS 2a**	**OLS 2b**	**OLS 3a**	**OLS 3b**
Outcome variable	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**
ln(dwellings/development capacity)	0.078**	0.103***			0.137***	0.068***
	(0.039)	(0.025)			(0.040)	(0.024)
ln(dwellings/land area)			0.106***	0.048***		
			(0.025)	(0.014)		
ln(inverse transport cost-weighted development capacity in other zones)					0.373***	-0.471***
					(0.057)	(0.083)
ln(effective job density)		0.389***		0.291***		0.555***
		(0.064)		(0.064)		(0.068)
ln(median personal income, 2001)		0.280***		0.317***		0.322***
		(0.050)		(0.056)		(0.044)
TLA fixed effects		Yes		Yes		Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Observations	165	164	165	164	165	164
R2	0.023	0.715	0.184	0.711	0.168	0.781
F Statistic	3.784* (df = 1; 163)	55.932*** (df = 7; 156)	36.705*** (df = 1; 163)	54.742*** (df = 7; 156)	16.338*** (df = 2; 162)	68.923*** (df = 8; 155)

Table 14: Housing supply regression models (IV)

Model specification	IV 1a	IV 1b	IV 2a	IV 2b	IV 3a	IV 3b
Outcome variable	ln(quality-adjusted house prices)	ln(quality-adjusted house prices)	ln(quality-adjusted house prices)	ln(quality-adjusted house prices)	ln(quality-adjusted house prices)	ln(quality-adjusted house prices)
ln(dwellings/development capacity)	1.096***	0.289***			1.160***	0.585
	(0.423)	(0.083)			(0.395)	(0.694)
ln(dwellings/land area)			0.370***	0.182***		
			(0.060)	(0.070)		
ln(inverse transport cost-weighted development capacity in other zones)					0.681***	1.095
					(0.158)	(2.546)
ln(effective job density)		0.442***		0.098		0.118
		(0.065)		(0.118)		(0.813)
ln(median personal income, 2001)		0.303***		0.454***		0.233
		(0.084)		(0.103)		(0.244)
TLA fixed effects		Yes		Yes		Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Observations	165	164	165	164	165	164
Weak instruments p-value (ln(dwellings/dev capacity) or ln(dwellings/land area))	0.102	0.000***	0.000***	0.003***	0.102	0.000***
Weak instruments p-value (ln(dev capacity in other zones))					0.000***	0.000***
Sargan Chi (p-value)	0.094*	0.981	0.647	0.818	0.838	0.999

Table 15: Housing supply model specification test

Model specification	**OLS 1c**	**IV 1c**
Outcome variable	**ln(quality-adjusted house prices)**	**ln(quality-adjusted house prices)**
ln(dwellings)	0.069***	0.306**
	(0.020)	(0.155)
ln(development capacity)	-0.066***	-0.139***
	(0.021)	(0.052)
ln(effective job density)	0.388***	0.371***
	(0.065)	(0.098)
ln(median personal income, 2001)	0.265***	0.351***
	(0.048)	(0.122)
TLA fixed effects	Yes	Yes
Constant	Yes	Yes
Observations	164	164
Linear hypothesis test p-value. H0: ln(dwellings) coeff- ln(development capacity) coeff = 0	0.902	0.249

12.3 Quality-adjusted house price estimates

Dwelling characteristics vary significantly between suburbs. Dwellings in the city centre tend to be apartments with fewer bedrooms and no garden space, while dwellings in outer suburbs tend to be larger houses with gardens. In general, developers and residents respond to higher land prices by building smaller, denser units to economise on land.

Using average house prices (or average rents) as the dependent variable in the housing supply equation will therefore cause downward bias in coefficient estimates. This is because the size and/or quality of housing will tend to be lower in denser areas.

To address this issue, I construct quality-adjusted house price estimates for each suburb by estimating a hedonic regression on residential property sales microdata. I estimate this model using My basic approach is summarised in the following equation. I regress log-transformed sale prices ($p_{i,j}$) for property sale i in suburb j on a vector of dwelling and site characteristic variables (x_i), plus a set of suburb fixed effects (d_j).[30] No location-related variables, such as distance to the city centre or coastlines, are included, as suburb fixed effects capture these impacts.

Equation 22: Hedonic regression for dwelling sale prices

$$\ln(p_{i,j}) = \sigma' x_i + d_j + \epsilon_i$$

[30] Dwelling and site characteristics include: log(land area), an indicator for sites with zero land area, dwelling floor area, dwelling type (standalone house, flat, multi-storey apartment), decade of construction, number of garagers / carports, sale quarter, building and roof condition and construction, views of land or water, and the ratio of improvement value to total rateable value (a measure of development potential – higher intensity ratios indicate sites with relatively more valuable buildings). These coefficients generally had the expected sign and relative impact.

Differences in observable dwelling and site characteristics between suburbs are captured in the coefficient σ on the vector of dwelling and site characteristics. Suburb fixed effects therefore provide (de-meaned) quality-adjusted house price estimates for each suburb. Positive fixed effects indicate that a suburb has higher housing prices than the reference suburb, and vice versa.

The following table summarises some key coefficient estimates from this model, as well as model statistics. The overall model is highly statistically significant (as indicated by the F-statistic) and it fits the data well (as indicated by the R^2).

Table 16: Hedonic regression for dwelling sale prices

Outcome variable	**ln(sale price)**	
Explanatory variables	**Coeff**	**Std err**
ln(land area)	0.058***	0.003
Zero land area indicator	0.304***	0.019
ln(dwelling floor area)	0.547***	0.004
Apartment indicator	(base level)	
Standalone dwelling indicator	0.242***	0.012
Residential flat indicator	0.119***	0.012
Decade of construction	Y	
Number of garages	Y	
Building and roof construction and condition indicators	Y	
View indicators	Y	
Intensity ratio (improvement value / rateable value)	Y	
Sale year / quarter indicators	Y	
Suburb fixed effects	Y	
Observations	24,649	
R^2	0.865	
F-statistic	587.434*** (df = 265; 24383)	

*Statistical significance indicators: *p<0.1; **p<0.05; ***p<0.01*

The following table summarises quality-adjusted house price estimates for each suburb, the standard error for each value, and the number of dwelling sales recorded in each suburb. It also reports the natural logarithm of mean house prices in each suburb. As shown in the following chart, quality-adjusted house prices are strongly positively correlated with average house prices, but there are many outliers. For instance, the Lambton area unit (in the Wellington city centre) has a lower average sale price than the regional average, but after adjusting for the fact that most dwellings in this area are small apartments, it has a higher quality-adjusted house price.

Figure 8: Correlation between mean house prices and quality-adjusted house price estimates for Wellington suburbs

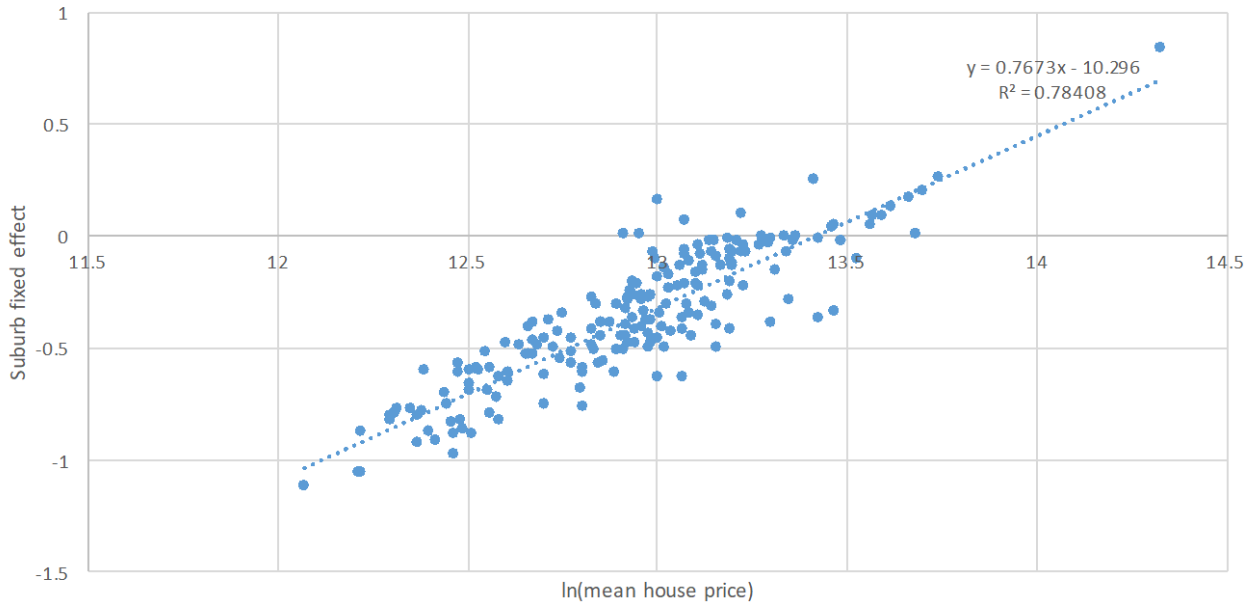


Table 17: Quality-adjusted house price estimates for Wellington suburbs

Area unit	Number of sales	ln(mean sale price)	Suburb fixed effect	Std error	Area unit	Number of sales	ln(mean sale price)	Suburb fixed effect	Std error	Area unit	Number of sales	ln(mean sale price)	Suburb fixed effect	Std error
Adelaide	65	12.958	0.000	NA	Karori Park	265	13.006	-0.189	0.024	Paraparaumu Central	566	12.776	-0.574	0.023
Adventure	85	12.911	-0.450	0.028	Karori South	262	13.169	-0.139	0.024	Paremata-Postgate	155	13.150	-0.324	0.025
Akatarawa	28	12.509	-0.604	0.038	Kelburn	150	13.620	0.127	0.025	Parkway	170	12.507	-0.668	0.025
Alicetown	122	12.928	-0.295	0.026	Kelson	171	12.854	-0.392	0.025	Pauatahanui	10	13.527	-0.105	0.057
Arakura	99	12.299	-0.809	0.027	Khandallah Park-Broadmeadows	193	13.312	-0.158	0.025	Peka Peka	8	13.096	-0.451	0.062
Aro Street-Nairn Street	84	13.143	-0.025	0.028	Kilbirnie East	123	13.076	-0.085	0.026	Petone Central	43	12.950	-0.224	0.033
Ascot Park	129	12.745	-0.555	0.026	Kilbirnie West-Hataitai South	127	13.230	-0.053	0.026	Pinehaven	184	12.830	-0.496	0.025
Avalon East	132	12.755	-0.356	0.026	Kingston-Mornington	102	13.065	-0.144	0.027	Plimmerton	102	13.196	-0.207	0.027
Avalon West	127	12.927	-0.279	0.026	Kopuaranga	9	12.466	-0.979	0.059	Poets Block	139	12.778	-0.466	0.026
Awarua	212	13.202	-0.135	0.024	Korokoro	73	13.086	-0.349	0.029	Porirua East	52	12.440	-0.702	0.032
Belmont	142	13.111	-0.364	0.026	Lambton	245	12.913	-0.002	0.025	Pukerua Bay	126	12.965	-0.410	0.026
Berhampore East	49	12.991	-0.081	0.032	Lansdowne	258	12.466	-0.887	0.024	Rangoon Heights	175	13.345	-0.078	0.025
Berhampore West	113	12.999	-0.113	0.026	Linden	207	12.832	-0.424	0.024	Ranui Heights	61	12.655	-0.531	0.030
Boulcott	143	13.073	-0.220	0.026	Lyall Bay-Airport-Moa Point	159	13.109	-0.045	0.025	Raroa	235	12.965	-0.268	0.024
Brentwood	102	12.675	-0.537	0.027	Maidstone	4	12.527	-0.594	0.085	Raumati Beach	339	12.943	-0.426	0.023
Brooklyn	161	13.270	-0.046	0.025	Makara-Ohariu	12	13.104	-0.224	0.052	Raumati South	226	12.922	-0.406	0.024
Brooklyn South	57	13.087	-0.121	0.031	Mana-Camborne	146	13.070	-0.374	0.026	Resolution	17	13.470	-0.341	0.045
Cannons Creek East	46	12.317	-0.782	0.033	Mangaroa	16	12.836	-0.518	0.047	Riverstone Terraces	145	13.158	-0.507	0.026
Cannons Creek North	42	12.219	-0.879	0.033	Manuka	79	12.747	-0.558	0.028	Roseneath	91	13.702	0.198	0.028

Cannons Creek South	40	12.302	-0.823	0.034	Maoribank	190	12.806	-0.613	0.025	Seatoun	126	13.746	0.254	0.026
Carterton	403	12.490	-0.868	0.023	Martinborough	173	12.706	-0.629	0.025	Seatoun Tunnel West	43	13.362	-0.030	0.033
Churton Park North	188	13.348	-0.291	0.025	Masterton Central	26	12.417	-0.923	0.039	Solway North	166	12.399	-0.878	0.025
Churton Park South	227	13.112	-0.232	0.024	Masterton East	163	12.221	-1.056	0.025	Solway South	192	12.374	-0.926	0.025
Clouston Park	202	12.746	-0.559	0.024	Masterton Railway	15	12.070	-1.120	0.048	Strathmore Park	126	13.239	-0.082	0.026
Cloustonville	2	12.387	-0.603	0.118	Masterton West	160	12.514	-0.884	0.025	Taita North	129	12.608	-0.658	0.026
Crofton Downs	112	13.103	-0.173	0.026	Maungakotukutuku	1	13.002	-0.469	0.166	Taita South	98	12.561	-0.594	0.027
Delaney	121	12.556	-0.700	0.026	Maungaraki	205	12.940	-0.369	0.025	Taitville	19	13.148	-0.077	0.043
Discovery	162	12.978	-0.439	0.025	Maupuia	57	13.210	-0.026	0.031	Takapu	4	13.428	-0.368	0.085
Eastbourne	302	13.465	0.034	0.024	Melling	19	12.674	-0.390	0.043	Tawa Central	231	12.877	-0.391	0.024
Ebdentown	161	12.673	-0.476	0.025	Melrose-Houghton Bay-Southgate	178	13.226	-0.076	0.025	Tawa South	181	13.007	-0.354	0.025
Elderslea	170	12.707	-0.466	0.025	Miramar	113	13.112	-0.048	0.026	Tawhai	186	12.612	-0.613	0.025
Elsdon-Takapuwahia	52	12.507	-0.692	0.031	Miramar North	108	13.189	-0.023	0.027	Te Horo	31	12.850	-0.579	0.037
Emerald Hill	164	12.775	-0.528	0.025	Miramar South	178	13.197	-0.067	0.025	Te Kainga	244	13.565	0.044	0.024
Endeavour	253	13.197	-0.423	0.024	Miramar West	22	13.125	-0.136	0.043	Te Marua	41	12.809	-0.592	0.034
Epuni East	150	12.920	-0.328	0.025	Mitchelltown	24	13.197	-0.105	0.040	Te Wharau	17	12.703	-0.761	0.046
Epuni West	136	12.960	-0.294	0.026	Moera	51	12.477	-0.574	0.031	Thorndon-Tinakori Road	248	13.222	0.095	0.024
Esplanade	122	13.021	-0.146	0.026	Mt Cook-Wallace Street	226	13.073	0.067	0.024	Tirohanga	79	13.161	-0.401	0.029
Featherston	169	12.216	-1.058	0.025	Mt Holdsworth	18	12.808	-0.766	0.045	Titahi Bay North	122	12.688	-0.495	0.026
Fernlea	83	12.450	-0.755	0.028	Mt Victoria West	206	13.419	0.243	0.025	Titahi Bay South	150	12.665	-0.531	0.025
Glendale	151	12.384	-0.792	0.025	Naenae North	159	12.479	-0.620	0.025	Totara Park	188	12.638	-0.493	0.025
Glenside North	27	12.718	-0.382	0.038	Naenae South	160	12.534	-0.605	0.025	Trentham North	150	12.548	-0.523	0.025

Greenacres	71	13.041	-0.431	0.029	Newlands East	44	13.084	-0.309	0.033	Trentham South	18	12.984	-0.484	0.045
Grenada North	33	13.067	-0.426	0.036	Newlands North	155	12.834	-0.285	0.025	Tuturumuri	12	12.560	-0.803	0.052
Grenada Village	121	13.126	-0.299	0.026	Newlands South	204	12.896	-0.310	0.024	Upper Hutt Central	12	12.664	-0.411	0.054
Greytown	194	12.897	-0.515	0.025	Newtown East	144	13.150	-0.027	0.025	Vogeltown	49	13.162	-0.102	0.032
Happy Valley-Owhiro Bay	65	13.123	-0.159	0.030	Newtown West	121	13.110	-0.050	0.026	Vogeltown West	61	13.202	-0.077	0.030
Hataitai North	192	13.367	-0.007	0.025	Ngaio South	174	13.279	-0.012	0.025	Wadestown	196	13.593	0.078	0.025
Haywards-Manor Park	17	12.979	-0.500	0.045	Ngaumutawa	76	12.486	-0.827	0.029	Waikanae Beach	285	12.944	-0.484	0.024
Heretaunga	69	13.230	-0.228	0.029	Ngauranga East	1	12.967	-0.339	0.166	Waikanae East	190	12.859	-0.562	0.025
Heretaunga-Silverstream	193	12.987	-0.387	0.025	Normandale	110	12.971	-0.384	0.027	Waikanae Park	140	12.929	-0.489	0.026
Holborn	87	12.583	-0.634	0.028	Northland	132	13.300	-0.020	0.026	Waikanae West	409	12.855	-0.452	0.023
Homebush-Te Ore Ore	3	12.577	-0.723	0.098	Northland North	50	13.076	-0.069	0.032	Waingawa	2	12.585	-0.833	0.118
Homedale East	152	12.369	-0.807	0.025	Onepoto	90	12.727	-0.504	0.028	Waitangirua	57	12.312	-0.800	0.031
Homedale West	105	12.355	-0.779	0.027	Opaki-Fernridge	6	13.004	-0.639	0.071	Waiwhetu North	61	12.840	-0.311	0.030
Hutt Central	159	13.427	-0.022	0.025	Oriental Bay	25	14.328	0.835	0.040	Waiwhetu South	172	12.744	-0.430	0.025
Island Bay East	128	13.339	-0.011	0.026	Otaihanga	70	13.020	-0.502	0.029	Wallaceville	144	12.602	-0.481	0.025
Island Bay West	156	13.297	-0.036	0.025	Otaki	426	12.461	-0.838	0.023	Waterloo East	211	13.057	-0.230	0.024
Johnsonville Central	218	12.983	-0.275	0.024	Otaki Forks	4	12.802	-0.687	0.098	Waterloo West	50	13.199	-0.127	0.032
Johnsonville East	77	13.030	-0.317	0.028	Paekakariki	77	13.037	-0.242	0.029	Whareama	26	12.890	-0.615	0.039
Johnsonville North	98	12.983	-0.283	0.027	Papakowhai North	108	13.018	-0.409	0.027	Wilford	182	13.031	-0.177	0.025
Kahutara	33	13.069	-0.632	0.036	Papakowhai South	222	13.300	-0.395	0.024	Willis Street-Cambridge Terrace	407	13.002	0.154	0.024
Kaiwharawhara	10	13.684	0.006	0.056	Paparangi	104	12.933	-0.249	0.027	Wilton	102	13.120	-0.089	0.027
Karaka Bay-Worser Bay	83	13.670	0.169	0.028	Paparangi West	70	12.936	-0.214	0.029	Woburn North	81	13.487	-0.026	0.028

Karori East	167	13.574	0.079	0.025	Paraparaumu Beach North	281	12.912	-0.510	0.024	Woburn South	17	12.937	-0.267	0.045
Karori North	146	13.470	0.043	0.025	Paraparaumu Beach South	424	12.921	-0.454	0.023	Woodridge	120	13.188	-0.269	0.026
Regional total / average	**24702**	**12.998**	**-0.352**	**NA**										

13 References

Ahlfeldt, G. and McMillen, D.P., 2014. *New estimates of the elasticity of substitution of land for capital*. 54th Congress of the European Regional Science Association: "Regional development & globalisation: Best practices", 26-29 August 2014, St. Petersburg, Russia.

Ahlfeldt, G.M. and Pietrostefani, E., 2019. The economic effects of density: A synthesis. *Journal of Urban Economics*, *111*, pp.93-107.

Albouy, D. and Ehrlich, G., 2018. Housing productivity and the social cost of land-use restrictions. *Journal of Urban Economics*, *107*, pp.101-120.

Anas, A. and Xu, R., 1999. Congestion, land use, and job dispersion: a general equilibrium model. *Journal of Urban Economics*, *45*(3), pp.451-473.

Baum-Snow, N., 2007. Did highways cause suburbanization? *The Quarterly Journal of Economics*, *122*(2), pp.775-805.

Baum-Snow, N., 2010. Changes in transportation infrastructure and commuting patterns in US metropolitan areas, 1960-2000. *American Economic Review*, *100*(2), pp.378-82.

Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L., 2011. *Cost-benefit analysis: concepts and practice*. Cambridge University Press.

Brand, S., 1995. *How buildings learn: What happens after they're built*. Penguin.

Brinkman, J.C., 2016. Congestion, agglomeration, and the structure of cities. *Journal of Urban Economics*, *94*, pp.13-31.

Brinkman, J. and Lin, J., 2017. *Freeway Revolts*. Working Paper.

Brinkman, J., 2016. Congestion, agglomeration, and the structure of cities. *Journal of Urban Economics*, *94*, pp.13-31.

Byett, A., Stroombergen, A., Laird, J. and Paling, R., 2017. *The economic impacts of connectivity*. NZ Transport Agency research report 608.

Byun, P., Waldorf, B.S. and Esparza, A.X., 2005. Spillovers and local growth controls: An alternative perspective on suburbanization. *Growth and Change*, *36*(2), pp.196-219.

Caldera, A. and Johansson, Å., 2013. The price responsiveness of housing supply in OECD countries. *Journal of Housing Economics*, *22*(3), pp.231-249.

Cheshire, P.C. and Hilber, C.A., 2008. Office space supply restrictions in Britain: the political economy of market revenge. *The Economic Journal*, *118*(529), pp.185-221.

Combes, P.P., Duranton, G. and Gobillon, L., 2017. *The production function for housing: Evidence from France*. GATE Lyon Saint-Etienne WP 1637.

Dalgaard, C. J., Kaarsen, N., Olsson, O., & Selaya, P. (2018). *Roman Roads to Prosperity: Persistence and Non-Persistence of Public Goods Provision*. University of Gothenburg Department of Economics Working Paper No 722.

de Groot, H.L., Marlet, G., Teulings, C. and Vermeulen, W., 2015. *Cities and the urban land premium*. Edward Elgar Publishing.

Department for Transport (UK), 2014. *Supplementary Guidance: Land Use/Transport Interaction Models*. Available online at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/427140/webtag-tag-supplementary-luti-models.pdf.

Donovan, S. 2017. *Going with the flow – Using commuting data to identify the effect of walking and cycling travel-time on location choice in Australian cities*. MPhil Thesis, Tinbergen Institute / Vrije Universiteit Amsterdam.

Duranton, G. and Puga, D., 2004. Micro-foundations of urban agglomeration economies. In *Handbook of regional and urban economics* (Vol. 4, pp. 2063-2117). Elsevier.

Duranton, G. and Turner, M.A. 2012. Urban growth and transportation. *Review of Economic Studies*, 79(4).

Fredrickson, C., Fergusson, E. and Wildish, B.R., 2016. *Residential Property Amalgamation and Aggregation in Auckland, 2004-2014*. Auckland Council technical report, TR2016/001.

Fredrickson, C., Fergusson, E. and Wildish, B.R., 2016. *Residential Property Amalgamation and Aggregation in Auckland, 2004-2014*. Auckland Council Technical Report 2016/001.
Ganong, P. and Shoag, D., 2017. Why has regional income convergence in the US declined? *Journal of Urban Economics*, *102*, pp.76-90.
Garcia-López, M.A., 2012. Urban spatial structure, suburbanization and transportation in Barcelona. *Journal of Urban Economics*, 72(2-3), pp.176-190.
Glaeser, E.L., 2008. *Cities, agglomeration, and spatial equilibrium*. Oxford University Press.
Glaeser, E.L. and Gyourko, J., 2018. The economic implications of housing supply. *Journal of Economic Perspectives*, *32*(1), pp.3-30.
Glaeser, E.L., Gyourko, J. and Saks, R.E., 2005. Why have housing prices gone up? *American Economic Review*, *95*(2), pp.329-333.
Grimes, A., Apatov, E., Lutchman, L. and Robinson, A., 2016. Eighty years of urban development in New Zealand: impacts of economic and natural factors. *New Zealand Economic Papers*, *50*(3), pp.303-322.
Grimes, A. (2011). *Building Bridges: Treating a New Transport Link as a Real Option*, 51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain, European Regional Science Association (ERSA), Louvain-la-Neuve.
Grimes, A. and Liang, Y., 2009. Spatial determinants of land prices: Does Auckland's metropolitan urban limit have an effect? *Applied Spatial Analysis and Policy*, *2*(1), pp.23-45.
Guthrie, G., 2029. Incentivizing residential land development. *Housing Studies*, *35*(5), pp.820-838.
Gyourko, J. and Molloy, R., 2015. Regulation and housing supply. In *Handbook of regional and urban economics* (Vol. 5, pp. 1289-1337). Elsevier.
Hazledine, T., Donovan, S. and Mak, C., 2017. Urban agglomeration benefits from public transit improvements-Extending and implementing the Venables model. Research in Transportation Economics, 66, pp.36-45.
Heblich, S., Redding, S. J., & Sturm, D. M. (2018). *The Making of the Modern Metropolis: Evidence from London*. National Bureau of Economic Research working paper no. w25047.
Homans, F.R. and Marshall, E.P., 2008. Modeling Recreational Amenities in an Urban Setting: Location, Congestion, and Substitution Effects. *Agricultural and Resource Economics Review*, *37*(2), pp.257-272.
Hornbeck, R. and Keniston, D., 2017. Creative destruction: Barriers to urban growth and the Great Boston Fire of 1872. *American Economic Review*, *107*(6), pp.1365-98.
Hsieh, C.T. and Moretti, E., 2019. Housing constraints and spatial misallocation. *American Economic Journal: Macroeconomics*, *11*(2), pp.1-39.
Hyslop, D., Le, T., Maré, D.C. and Stillman, S., 2019. *Housing markets and migration–Evidence from New Zealand*. Motu Working Paper 19-14.
Kelly, M., 2019. *The standard errors of persistence*. University College Dublin Centre for Economic Research Working Paper Series WP19/13.
Kernohan, D. and Rognlien, L., 2011. *Wider economic impacts of transport investments in New Zealand*. NZ Transport Agency Research Report 448.
Kim, R. 2019. *Applying German spatial planning in Auckland*. Paper presented at the 2019 Engineering New Zealand-Transportation Group conference.
Kulish, M., Richards, A. and Gillitzer, C., 2011. *Urban Structure and Housing Prices: Some Evidence from Australian Cities*. Reserve Bank of Australia Discussion Paper 2011-03.
Lees, K., 2014. *Big city life? Challenges and trade-offs for Auckland city*. New Zealand Institute of Economic Research working paper 2014/2.
Lees, K., 2019. Quantifying the costs of land use regulation: evidence from New Zealand. *New Zealand Economic Papers*, *53*(3), pp.245-269.
Lopes, A.S., Loureiro, C.F.G. and Van Wee, B., 2019. LUTI operational models review based on the proposition of an a priori ALUTI conceptual model. *Transport reviews*, *39*(2), pp.204-225.
Lucas, R.E. and Rossi–Hansberg, E., 2002. On the internal structure of cities. *Econometrica*, *70*(4), pp.1445-1476.
Maré, D.C., 2016. *Urban productivity estimation with heterogeneous prices and labour*. Motu Working Paper 16-21.

Martínez, F. and Araya, C., 2000. Transport and land-use benefits under location externalities. *Environment and Planning A*, *32*(9), pp.1611-1624.
Martínez, F. and Henríquez, R., 2007. A random bidding and supply land use equilibrium model. *Transportation Research Part B: Methodological*, *41*(6), pp.632-651.
Martínez, F. and Roy, J., 2004. A model for residential supply. *The Annals of Regional Science*, *38*(3), pp.531-550.
Ministry of Building, Innovation, and Employment. 2017. *Price Efficiency Indicators*. Available online at http://urban-development-capacity.mbie.govt.nz/.
Moeckel, R., 2011. Simulating household budgets for housing and transport. Paper presented at *International Conference on Computers in Urban Planning and Urban Management*.
MRCagney, 2019. *The costs and benefits of urban development*. A report for the Ministry for the Environment. Available online at https://www.mfe.govt.nz/publications/towns-and-cities/costs-and-benefits-of-urban-development.
Mulalic, I., Pilegaard, N., and Rouwendal, J. 2015. Does improving public transport decrease car ownership? Evidence from the Copenhagen metropolitan area. *Tinbergen Institute Discussion Papers, (2015-139/VII)*.
New Zealand Transport Agency, 2019. *Transformative Transport Projects (Dynamic WEBs and Land Use Benefits and Costs*. Available online at https://www.nzta.govt.nz/planning-and-investment/planning/investment-decision-making-framework-review/.
Nunns, P. and Denne, T., 2016. *The costs and benefits of urban development: A theoretical and empirical synthesis*. Paper presented at the 2016 New Zealand Association of Economists Conference.
Nunns, P., 2018. *The causes and economic consequences of rising regional house prices in New Zealand*. University of Auckland Centre for Applied Research in Economics working paper 005.
Nunns, P., 2019. *Modelling and valuing land use change*. Paper presented at the 2019 Engineering New Zealand-Transportation Group conference.
Nunns, P., 2020. The causes and economic consequences of rising regional housing prices in New Zealand. *New Zealand Economic Papers*, pp.1-39.
NZ Transport Agency, 2020. *Monetised Benefits and Costs Manual*. Available online at https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/.
NZ Transport Agency, 2019. Transformative Transport Projects (Dynamic WEBs and Land Use Benefits and Costs). Available online at https://www.nzta.govt.nz/assets/planning-and-investment/docs/transformative-transport-projects-may-2020.pdf.
Pollakowski, H.O. and Wachter, S.M., 1990. The effects of land-use constraints on housing prices. *Land economics*, *66*(3), pp.315-324.
Safirova, E., Houde, S., Lipman, D.A., Harrington, W. and Baglino, A., 2006. *Congestion pricing and land use change*. Working paper.
Saiz, A., 2010. The geographic determinants of housing supply. *The Quarterly Journal of Economics*, *125*(3), pp.1253-1296.
Severn, C., 2019. *Commuting, labor, and housing market effects of mass transportation: Welfare and identification*. Working paper.
Simmonds, D. and Feldman, O., 2013. Modelling the economic impacts of transport changes: experience and issues. In *Employment Location in Cities and Regions* (pp. 33-56). Springer, Berlin, Heidelberg.
Stevens, P. 2011. *Competition in New Zealand: An analysis using micro data*. Paper presented at the 2011 New Zealand Association of Economists conference.
Teulings, C.N., Ossokina, I.V. and de Groot, H.L., 2018. Land use, worker heterogeneity and welfare benefits of public goods. *Journal of Urban Economics*, *103*, pp.67-82.
Turner, M.A., Haughwout, A. and Van Der Klaauw, W., 2014. Land use regulation and welfare. *Econometrica*, 82(4), pp.1341-1403.
Venables, A.J., 2017. Expanding cities and connecting cities: the wider benefits of better communications. *Journal of Transport, Economics and Policy*, *51*(1).
Wegener, M., 2004. Overview of land-use transport models. In *Handbook of transport geography and spatial systems*, volume 5, pp.127-146.

Wellington City Council, 2019. *Wellington Housing and Business Assessment*. Available online at https://planningforgrowth.wellington.govt.nz/resources1/documents.

Doc 17

From:	Brendan Herder
To:	Wade, Andrew J
Cc:	Ben Wells [TSY]; Damien Looi; Ward, Stephanie J; benjamin.richards@hud.govt.nz; Danielle Bassan; Emma White; Blake Lepper; Geoff Cooper; Ross Copland; Danni Thian
Subject:	RE: ALR funding principles
Date:	Monday, 3 October 2022 3:36:41 pm
Attachments:	image001.jpg image002.jpg

Hi Andrew

Thank you for sharing this letter. I was unexpectedly out of the office last week and am sorry I didn't get the chance to respond earlier.

The draft sponsors letter on funding and financing expectations looks very good. Many of the funding principles are well aligned with the New Zealand Infrastructure Strategy and we support the guidance provided by the letter, particularly the priority placed on value for money and beneficiaries pay principles. We offer the following points for emphasis only and to highlight the types of questions that Te Waihanga will be interested in seeing explored on any project of this scale and complexity:

There are equity and opportunity cost trade-offs that result from Crown funding of last resort exceeding the value that accrues to national beneficiaries. We expect the extent to which affordability or other constraints shift the funding burden to non-beneficiaries to be transparent and note that a robust value for money case will be key to maintaining social licence for Crown spending at this scale for both this and future investment. We also consider it important that Ministers enter into funding arrangements with an appropriate level of cost certainty (including operating costs) given that the principles outlined have the Crown picking up any and all overruns due to the waterfall of constraining principles. Stronger expectations could be set in this respect.

Future investment funding and affordability should also feature somewhere in the supporting analysis for sponsors. For example, the (tunnelled) transport solution is predicated on the future commitment to a second tunnelled harbour crossing. That consequential investment will have a different set of direct and local beneficiaries but many of the regional affordability constraints may hit a lot earlier if funding for ALR has already been maximised.

We note that the letter is specific to the core transport infrastructure only, with further guidance on urban development opportunities and interventions still to come. However, options to realise value from land/property development will be important opportunities with significant interfaces between transport and property assets. Station locations and design for example may lend themselves more or less favourably to commercial partners taking a greater role and shifting costs to those best able to monetise and earn a return from theses spaces.

Kind regards
Brendan

Brendan Herder | Principal Advisor, Infrastructure Delivery | New Zealand Infrastructure Commission, Te Waihanga|
s9(2)(k) Mobile: [redacted] | Email: brendan.herder@tewaihanga.govt.nz

From: Wade, Andrew J <awade@kpmg.co.nz>
Sent: Wednesday, 21 September 2022 11:35 am
To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Cc: Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>; Damien Looi <D.Looi@transport.govt.nz>; Ward, Stephanie J <StephanieWard@kpmg.co.nz>; benjamin.richards@hud.govt.nz; Danielle Bassan <D.Bassan@transport.govt.nz>
Subject: RE: ALR funding principles

Hi Brendan

Further to the email below, please find attached the draft ALR funding and financing letter that would be sent to the Unit. The letter is consistent with the slide pack we sent earlier, but expands and clarifies some of the detail. The Unit also saw the slidepack and was generally comfortable with the content.

The intention is that this will be attached to a Ministerial briefing later this month, once we've considered feedback.

Could you please let us know of any comments by **COP September 28 (next Wednesday)**. We are meeting with the Unit later that week, so would appreciate your comments prior to then.

Happy to jump on a call if that would be helpful

Cheers
Andrew

Andrew Wade
Associate Director

Deal Advisory

KPMG
10 Customhouse Quay
PO Box 996
Wellington 6140
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s9(2)(k) **D** [redacted]0
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From: Wade, Andrew J
Sent: Thursday, 8 September 2022 8:46 am
To: Brendan Herder <brendan.herder@tewaihanga.govt.nz>
Cc: Joseph Sant [TSY] <Joseph.Sant@treasury.govt.nz>; Emma White <Emma.White@treasury.govt.nz>; Ben Wells [TSY] <Ben.Wells@treasury.govt.nz>; Damien Looi <D.Looi@transport.govt.nz>
Subject: ALR funding principles

Hi Brendan

As discussed a week or so back, please find attached the draft slide pack for the ALR funding principles. I understand Emma has recently sent you Treasury's financing principles for consideration.

Apologies for the delay. I thought I might have be able to get you the draft letter / briefing, but we are still just tweaking that a bit further. You'll get that next week for review. It is consistent with the attached pack, although with further detail and nuance (e.g. around NLTF). Happy to discuss of course.

Cheers
Andrew

Andrew Wade
Associate Director
Deal Advisory

KPMG
10 Customhouse Quay
PO Box 996
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New Zealand
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Doc 18

From: Peter Nunns
To: Ignacio Barandiaran; Amy Kearse; Gareth Fairweather; Elliot Clayton; Ben Wells [TSY]; Peter Nunns; Louelle Botes; 8:orgid:04f4e0c4-e582-4d52-897c-6b8e33ff38c3; Ignacio Barandiaran; Cameron Law; Geoff Cooper; Coral Aldridge; Sam Price; John Williamson; Anna Chau; Chris Parker [TSY]; Daniel Newcombe; John Davies; Amanda Harland; Alan Peddie; Sharon Fairbrother; Tipa Compain; Tui Gilling; Adam Nicholls; Katherine Randell; Danielle Bassan; ALR Boardroom (VC); Natalee Waiwiri-Taumata
Date: Thursday, 27 October 2022 1:14:48 pm

Within the timeframes, the main thing that would reduce risk would be to get as much of the corridor up to the surface as possible. Then you've still got utility and consenting risk, but less tunnelling risk

Doc 19

From:	Peter Nunns
To:	Ignacio Barandiaran; Amy Kearse; Gareth Fairweather; Elliot Clayton; Ben Wells [TSY]; Peter Nunns; Louelle Botes; 8:orgid:04f4e0c4-e582-4d52-897c-6b8e33ff38c3; Ignacio Barandiaran; Cameron Law; Geoff Cooper; Coral Aldridge; Sam Price; John Williamson; Anna Chau; Chris Parker [TSY]; Daniel Newcombe; John Davies; Amanda Harland; Alan Peddie; Sharon Fairbrother; Tipa Compain; Tui Gilling; Adam Nicholls; Katherine Randell; Danielle Bassan; ALR Boardroom (VC); Natalee Waiwiri-Taumata
Date:	Thursday, 27 October 2022 1:10:27 pm

My broad nervousness about making high-altitude decisions first then lower-altitude decisions later on, in the context of evolving information about geotechnical and utility risk, is that there's a lot of potential for needing to revisit earlier decisions if later, lower-altitude information is significantly adverse.

Doc 20

From:	Peter Nunns
To:	Ignacio Barandiaran; Amy Kearse; Gareth Fairweather; Elliot Clayton; Ben Wells [TSY]; Peter Nunns; Louelle Botes; Ignacio Barandiaran; Daniel Newcombe (AT); Cameron Law; Cameron Law; Geoff Cooper; Coral Aldridge; Sam Price; John Williamson; Anna Chau; Chris Parker [TSY]; Daniel Newcombe; John Davies; Amanda Harland; Alan Peddie; Sharon Fairbrother; Tipa Compain; Tui Gilling; Adam Nicholls; Katherine Randell; Danielle Bassan; ALR Boardroom (VC); Natalee Waiwiri-Taumata
Date:	Thursday, 27 October 2022 4:22:47 pm

LR projects in Europe often achieve BCRs well above one without WEBs, because they are built a lot more cheaply

Doc 21

From: Peter Nunns
To: Shelly Biswell; Sharon Fairbrother
Subject: RE: Huihuinga presentation
Date: Tuesday, 13 December 2022 9:48:57 am
Attachments: RI Dec 2022 Infrastructure cost benchmarking (short) v5.pptx
image002.jpg
image004.png
image005.png

Hi Sharon

Apologies for the delay in responding – perils of taking a holiday!

Attached are the slides. We're publishing tomorrow.

Cheers
Peter

s9(2)(k)

Peter Nunns | Director, Economics **| New Zealand Infrastructure Commission, Te Waihanga**
m: [redacted] **| Email: peter.nunns@tewaihanga.govt.nz**
Visit us online at https://tewaihanga.govt.nz/

From: Shelly Biswell <Shelly.Biswell@tewaihanga.govt.nz>
Sent: Wednesday, 7 December 2022 4:12 pm
To: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Subject: FW: Huihuinga presentation

Hi there – Just in case you're checking in (which you shouldn't be), I've touched base with Sharon. Have a good holiday and see you when you get back.

Take care,
Shelly

From: Sharon Fairbrother <sharon.fairbrother@lightrail.co.nz>
Sent: Wednesday, 7 December 2022 2:47 pm
To: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Cc: Shelly Biswell <Shelly.Biswell@tewaihanga.govt.nz>
Subject: RE: Huihuinga presentation

Kia ora,

I don't think I have received these slides, are they available to share?

Ngā mihi

s9(2)(k) **Sharon Fairbrother**
[redacted]

From: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Sent: Wednesday, 30 November 2022 12:14 pm
To: Sharon Fairbrother <sharon.fairbrother@lightrail.co.nz>
Cc: Shelly Biswell <Shelly.Biswell@tewaihanga.govt.nz>
Subject: RE: Huihuinga presentation

Hi Sharon

Happy to share – we're intending to send them out to all the stakeholders we've briefed. I'll get my colleague Shelly to coordinate this today or tomorrow.

We've made some minor tweaks to the slides since the version you saw.

Thanks
Peter

s9(2)(k) Peter Nunns | Director, Economics **| New Zealand Infrastructure Commission, Te Waihanga**
m: [redacted] **| Email: peter.nunns@tewaihanga.govt.nz**
Visit us online at https://tewaihanga.govt.nz/

From: Sharon Fairbrother <sharon.fairbrother@lightrail.co.nz>
Sent: Wednesday, 30 November 2022 12:12 pm

To: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Subject: RE: Huihuinga presentation

Hi Peter,

Thanks for presenting the at the huihuinga, it was highly appreciated.

I was wondering if you are ok with sending me the slides so that I can share them with the group or if you prefer only to have them available to the BC team?

Ngā mihi

Sharon Fairbrother

s9(2)(k) [redacted]

From: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Sent: Monday, 21 November 2022 4:34 pm
To: Cameron Law <cameron.law@aucklandlightrail.govt.nz>
Cc: Sharon Fairbrother <sharon.fairbrother@aucklandlightrail.govt.nz>; Geoff Cooper <Geoff.Cooper@tewaihanga.govt.nz>; Shelly Biswell <Shelly.Biswell@tewaihanga.govt.nz>
Subject: RE: Huihuinga presentation

Hi Cam

Thanks for following up. As discussed, if you've got half an hour on the agenda (and are willing to have me duck in and out) that would be appreciated.

My colleague Geoff Cooper may attend the meeting as well – I've cc'ed him here.

Topic is: **Benchmarking New Zealand's infrastructure costs**
Summary: A brief update on some research Te Waihanga has undertaken to develop high-level cost benchmarks for several types of infrastructure projects in multiple sectors, and identify potential drivers of any differences in costs.

I'm still in the process of updating the slides, so I'll have to send them on the day rather than circulating in advance.

Thanks
Peter

Peter Nunns | Director, Economics **| New Zealand Infrastructure Commission, Te Waihanga**
s9(2)(k) **m:** [redacted] **| Email: peter.nunns@tewaihanga.govt.nz**
Visit us online at https://tewaihanga.govt.nz/

From: Cameron Law <cameron.law@aucklandlightrail.govt.nz>
Sent: Monday, 21 November 2022 4:04 pm
To: Peter Nunns <Peter.Nunns@tewaihanga.govt.nz>
Cc: Sharon Fairbrother <sharon.fairbrother@aucklandlightrail.govt.nz>
Subject: Huihuinga presentation

Peter – I'm just pulling together the agenda for the Business Case huihuinga. Could you remind me what you wanted to cover?

Also if you have slides Sharon can include them in the huihuinga slide pack.

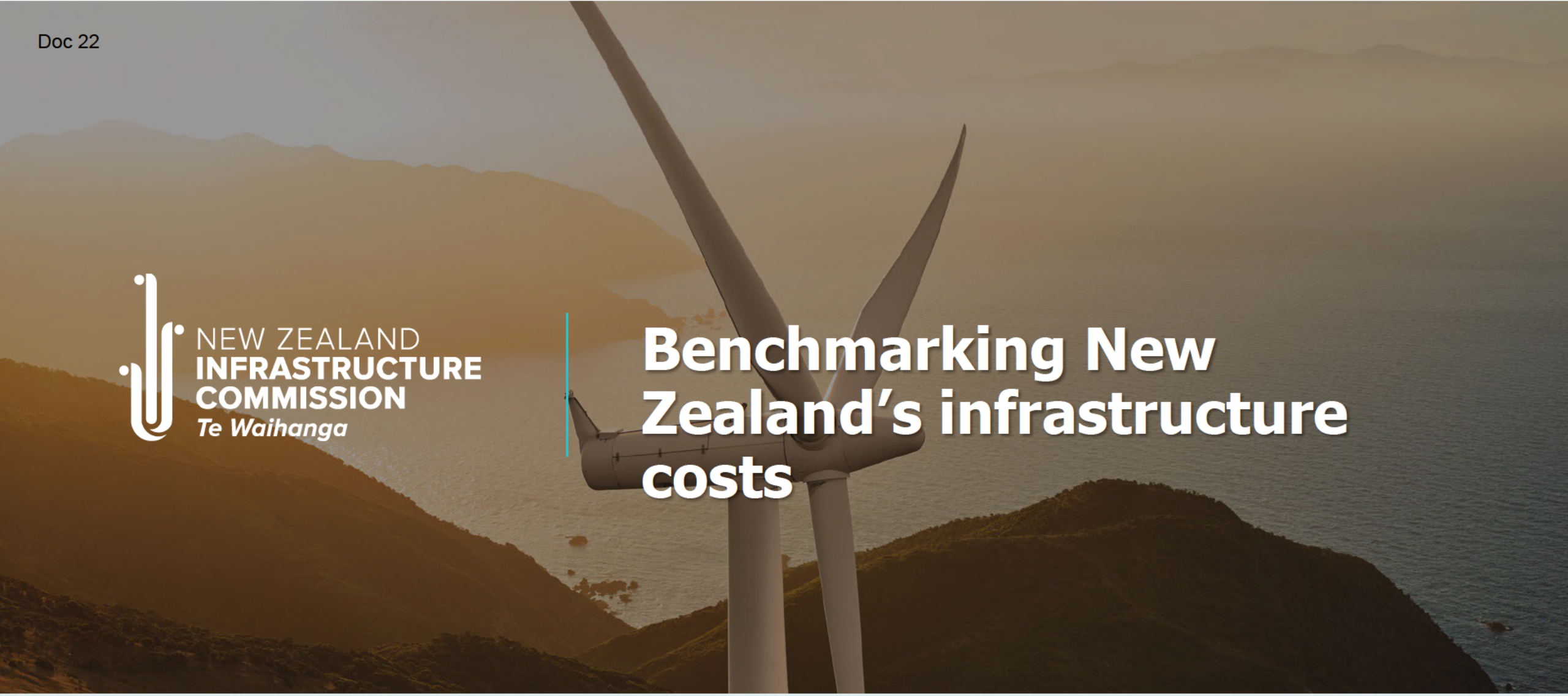
Thanks Cam

Cameron Law | Business Case, Sustainability and Consenting Outcome Owner

T. [redacted] s9(2)(k)
E. cameron.law@aucklandlightrail.govt.nz

Bringing us closer

Doc 22



NEW ZEALAND INFRASTRUCTURE COMMISSION
Te Waihanga

Benchmarking New Zealand's infrastructure costs

Peter Nunns

Director, Economics

Te Kāwanatanga o Aotearoa
New Zealand Government

DRAFT FOR DISCUSSION

Searching for opportunities

Current research questions

1. **Where do we stand:** How does the cost to deliver infrastructure in New Zealand compare with costs in other high-income countries?

2. **Why do costs differ:** What factors could potentially cause infrastructure delivery costs to be higher in some places than others?

A 'lay of the land' study

Caveats apply

- For comparisons, we draw upon two large international datasets of infrastructure project costs:
  - Oxford Global Projects. (2022). Benchmarking New Zealand Infrastructure Projects Against International Data. *Draft report for NZ Infrastructure Commission*.
  - NYU Marron Institute. (2022). Transit Costs Project. https://transitcosts.com/
- These studies provide high-level cost benchmarks for seven types of infrastructure projects (four transport, two electricity, one social infrastructure)

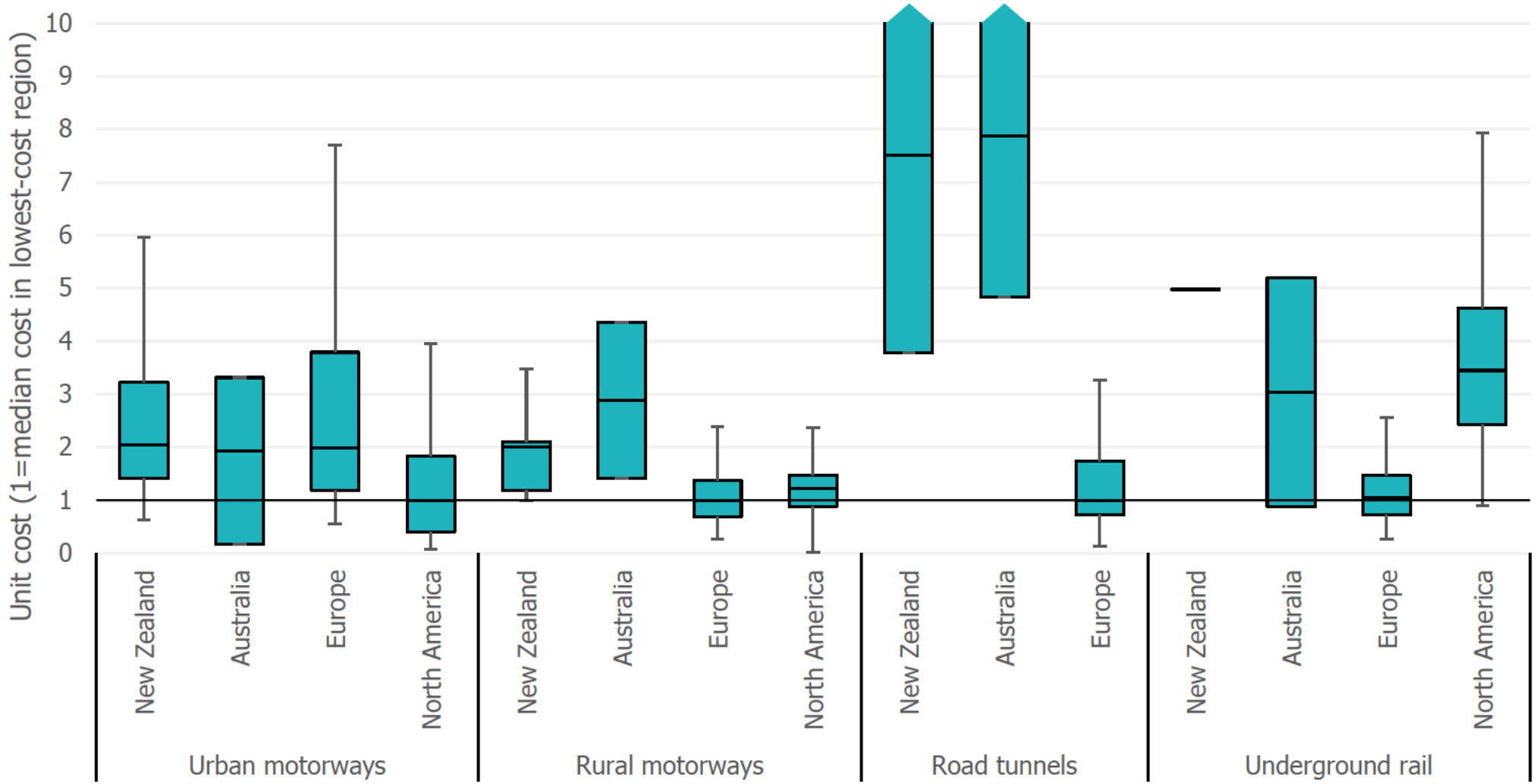
A 'lay of the land' study

Caveats apply

- True 'apples for apples' comparisons are hard
- We try to ensure we are at least comparing broadly similar types of fruit:
  - Projects in each category provide similar services, but design and scope is unlikely to be perfectly comparable
  - Project size is standardised by calculating unit costs (eg $/lane-km, $/MW generating capacity)
  - Currency conversions use constant-price purchasing power parities

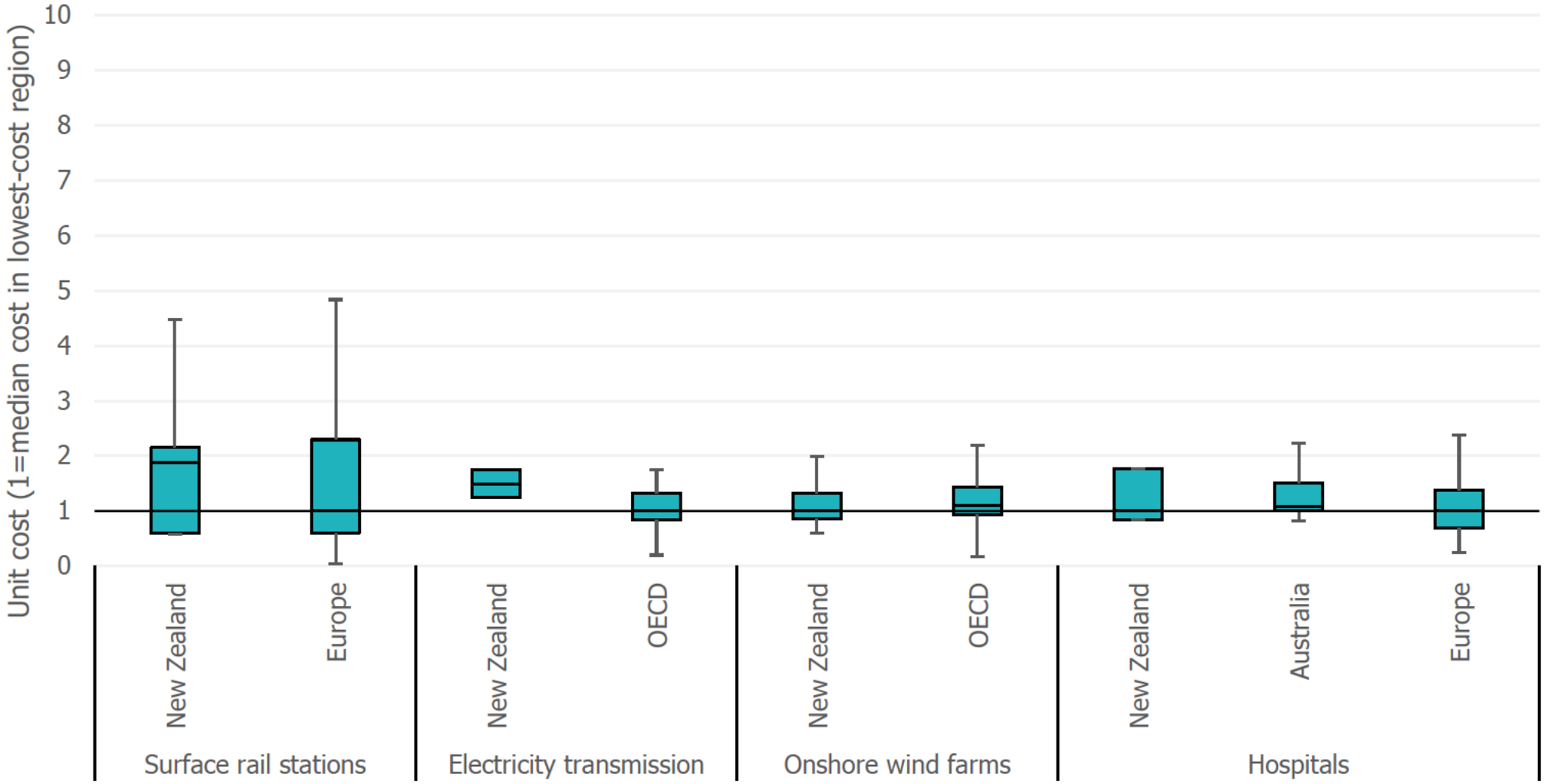
Transport projects

Complex horizontal infrastructure projects



Transport projects

Vertical infrastructure projects



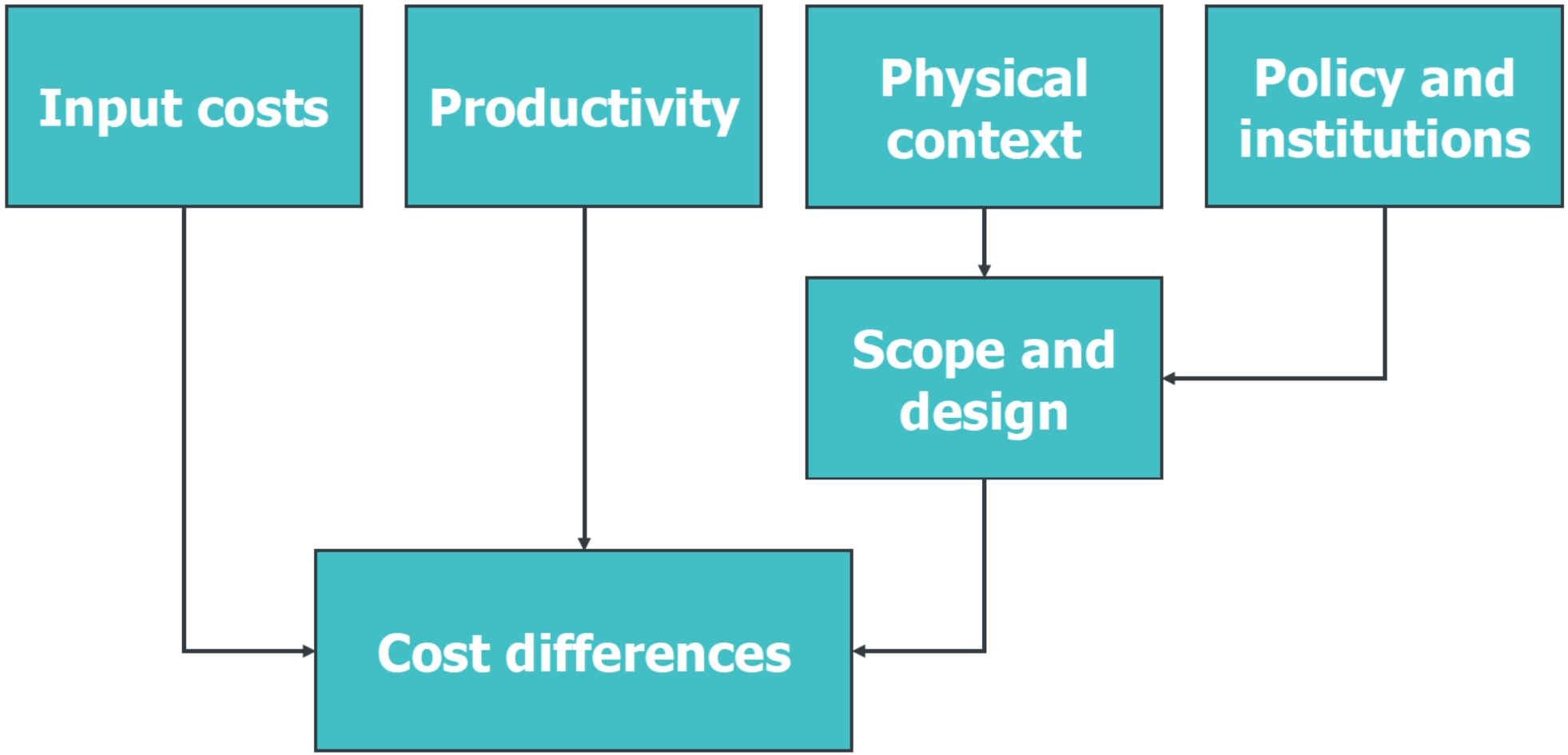
Statistical comparisons

Identifying statistically significant differences

Project category	Statistical significance on non-parametric tests (Wilcoxon test)	Statistical significance on parametric tests (OLS with project characteristics)
Transport infra		
Urban motorways	Yes with North America (10% level)	Yes with OECD in general (1% level)
Rural motorways	Yes with Europe (5% level)	As above
Road tunnels	Yes with Europe (5% level)	Yes with Europe (5% level)
Underground rail	N/A	Yes, with Europe and OECD in general (1% level)
Rapid transit stations	No	No
Electricity infra		
HVAC transmission lines	No	No
Onshore wind farms	No	No
Social infra		
Hospitals	No	No

Explanations for cost differences

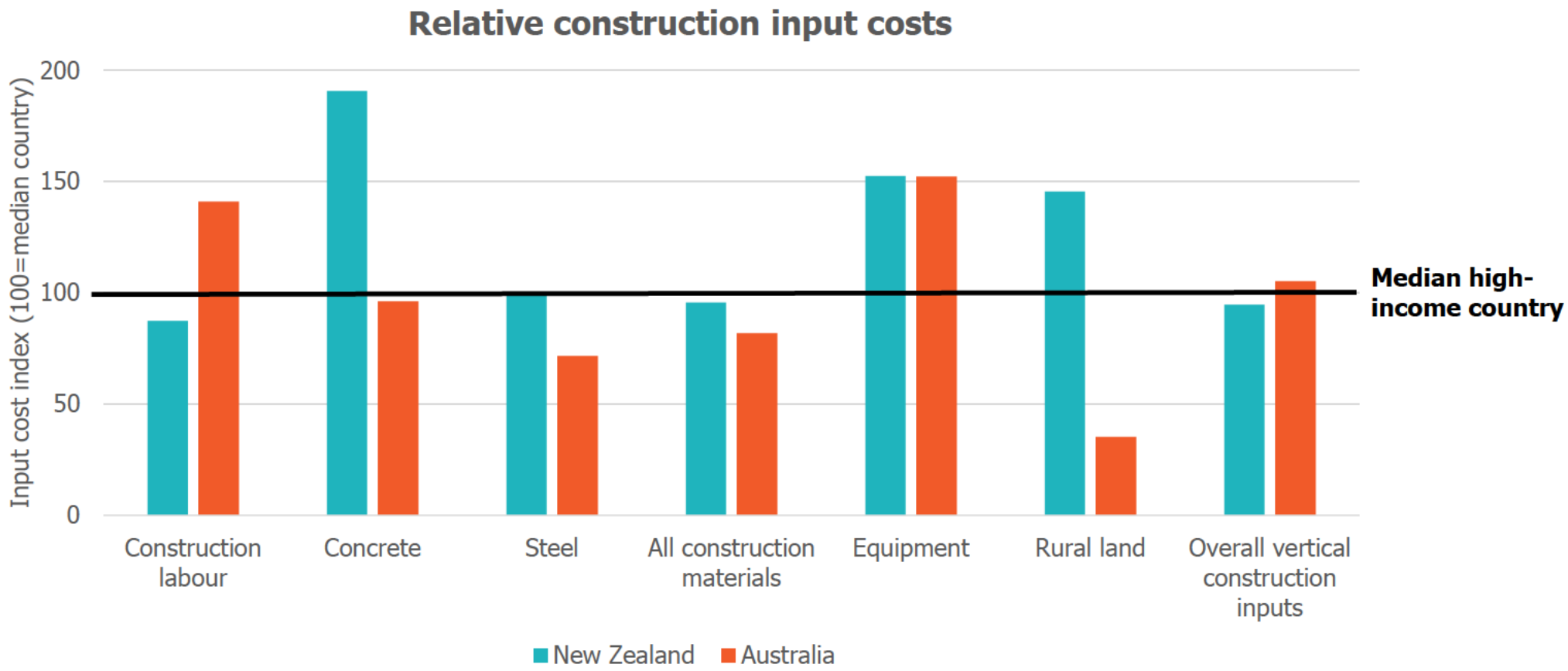
High-level causes



DRAFT FOR DISCUSSION

Input costs

Labour, material, equipment, and land costs

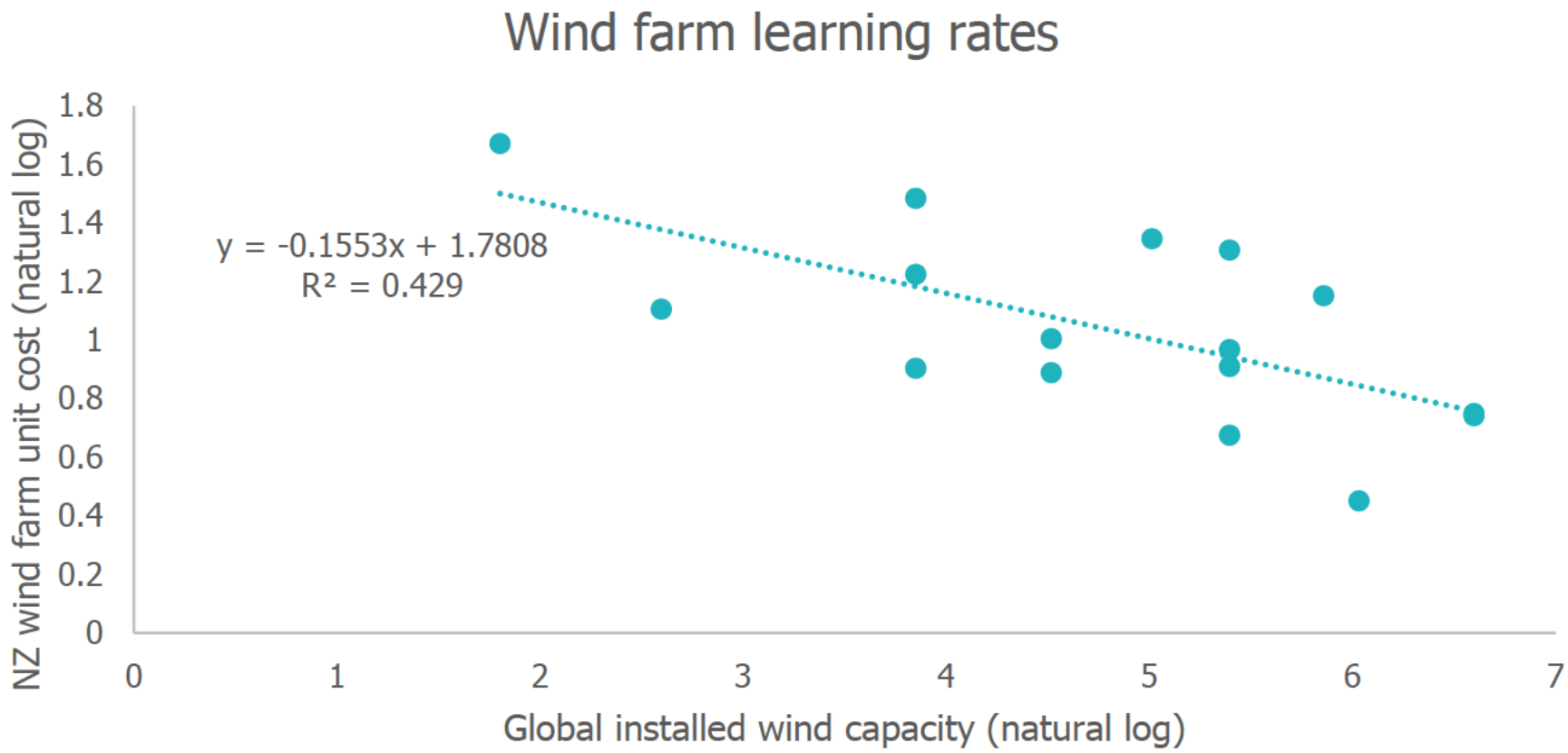


Te Waihanga analysis of data from Turner & Townsend (2022) and Savills (2020). Data is available for 9 other high-income countries.

DRAFT FOR DISCUSSION

Productivity

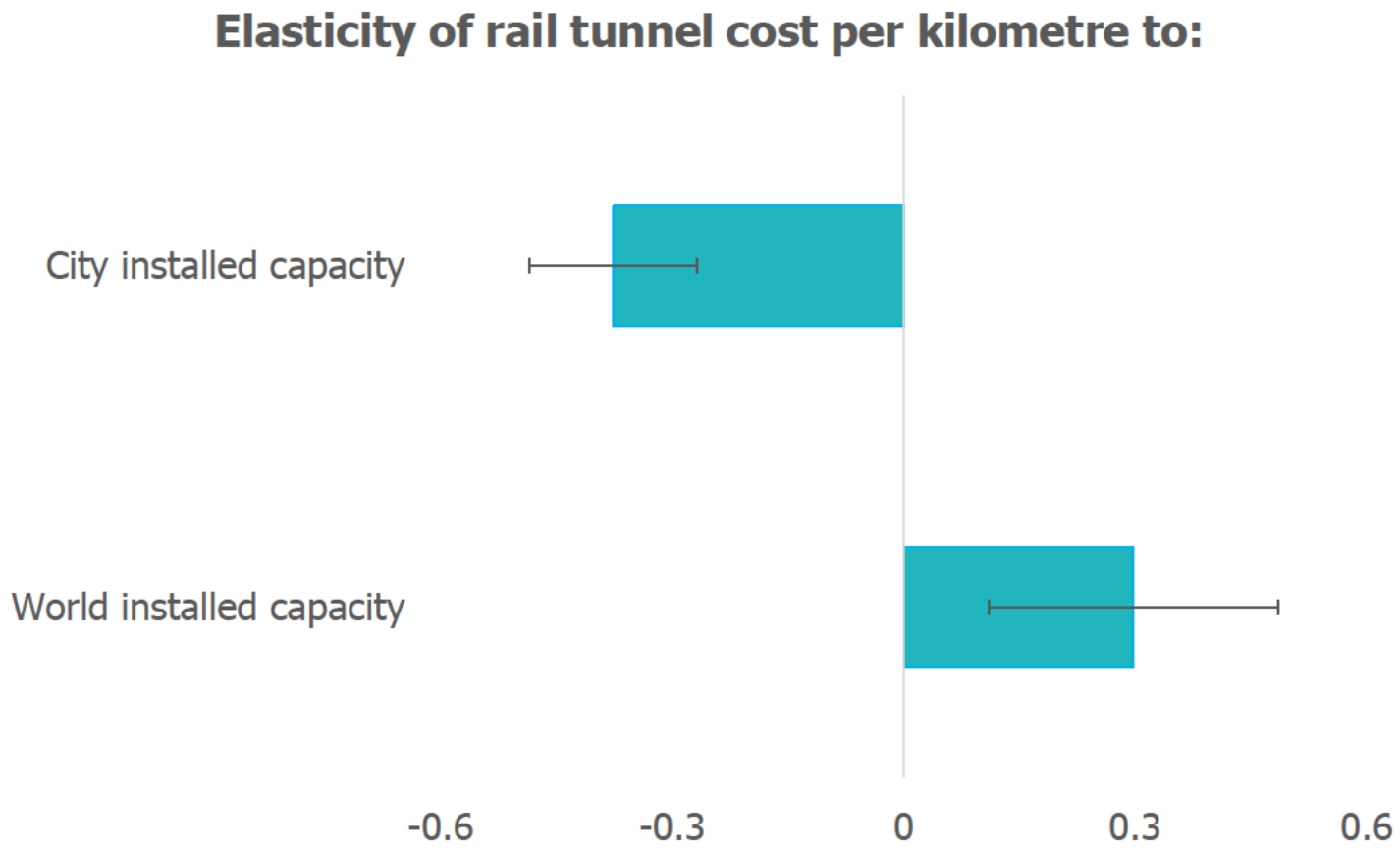
Wind farms learn globally...



Te Waihanga analysis of New Zealand wind farm data and global installed wind capacity data from *Our World In Data*.

Productivity

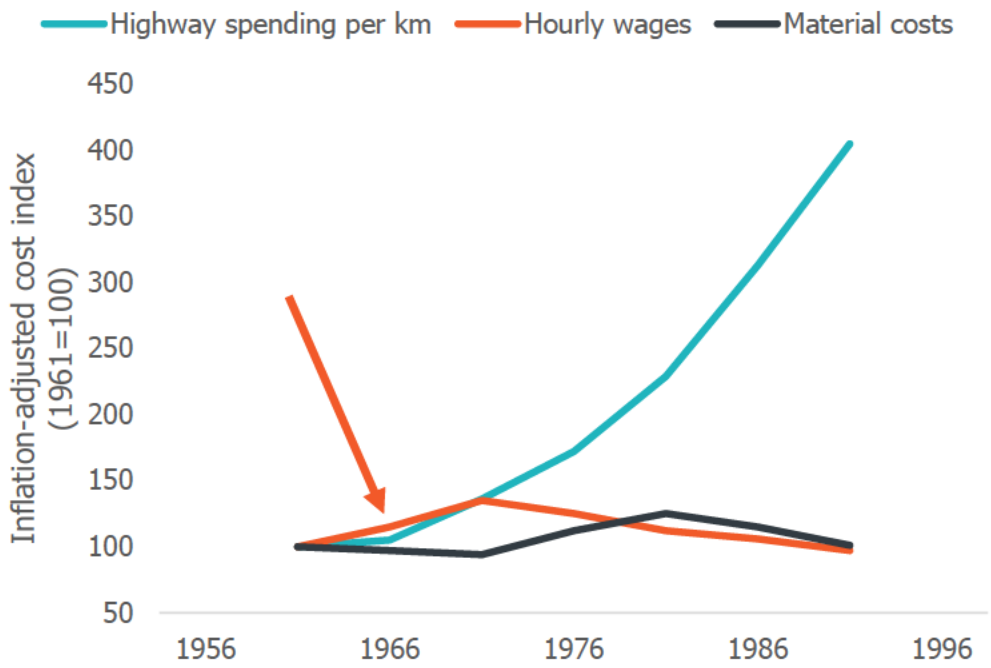
… rail tunnels learn locally

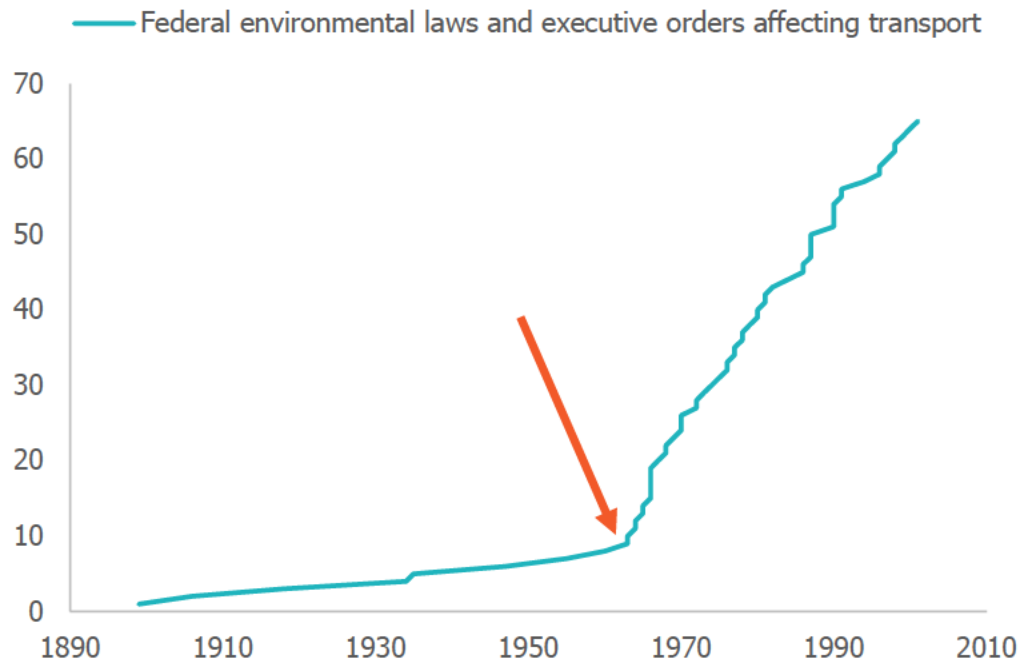


Te Waihanga analysis of data from NYU Marron Institute's *Transit Costs Project*.

Policy and institutions

Changing expectations drive changing costs





Brooks and Liscow. (2019). *Infrastructure costs*. Brookings Institute. https://slideplayer.com/slide/5984668/

Tentative conclusions

More questions than answers?

- If NZ faces a cost premium for infrastructure projects, it relates to complex 'horizontal' infrastructure projects rather than more standardised 'vertical' projects

- Broad differences in input costs or productivity levels are unlikely to explain observed differences

- Factors that affect project scope/design, like physical context or policy/institutions, are worth exploring

International lessons

Things that might help control costs

- Sophisticated client of infrastructure
  - Understand what you're building
  - Good principles and processes for scope and design decisions
  - Invest in capability
- Long term planning and pipeline certainty
- Openness to new technologies and methods
- Efficient planning and consenting systems
- Cost benchmarking to drive improvement

NEW ZEALAND
INFRASTRUCTURE
COMMISSION
Te Waihanga

Thank you for your time

peter.nunns@tewaihanga.govt.nz

Doc 23

From: Peter Nunns
To: Sharon Fairbrother; Duncan Olde; John Williamson; Daniel Newcombe (AT); Louelle Botes; Adam Nicholls; Danielle Bassan; Geoff Cooper; Chris Parker [TSY]; ALR Boardroom (VC); Cameron Law; Patrick Andison; Amanda Harland; Ignacio Barandiaran; Kate Randell; Rebecca Schepers; Tui Gilling; Natalee Waiwiri-Taumata; Antonia Robertson (NZ); Claire BoothJones; Alan Peddie; Amy Kearse; Elliot Clayton; Gareth Fairweather; Ben Wells [TSY]; Isabel Kelly [TSY]; Jessica Laing; Ignacio Barandiaran; Patrick Andison; Waldo Posthumus; 8:orgid:04f4e0c4-e582-4d52-897c-6b8e33ff38c3; Ben Wells [TSY]
Date: Thursday, 2 March 2023 2:11:02 pm

It's very good to hear the focus on cost optimisation and value for money. The challenge, as usual, is how to be clear about the basis for decisions in light of the complex mix of factors that you're seeking to balance around.

Doc 24

From: Peter Nunns
To: Sharon Fairbrother; Duncan Olde; John Williamson; Daniel Newcombe (AT); Louelle Botes; Adam Nicholls; Danielle Bassan; Geoff Cooper; Chris Parker [TSY]; ALR Boardroom (VC); Cameron Law; Patrick Andison; Amanda Harland; Ignacio Barandiaran; Kate Randell; Rebecca Schepers; Tui Gilling; Natalee Waiwiri-Taumata; Antonia Robertson (NZ); Claire BoothJones; Alan Peddie; Amy Kearse; Elliot Clayton; Gareth Fairweather; Ben Wells [TSY]; Isabel Kelly [TSY]; Jessica Laing; Ignacio Barandiaran; Patrick Andison; Waldo Posthumus; 8:orgid:04f4e0c4-e582-4d52-897c-6b8e33ff38c3; Ben Wells [TSY]; Benjamin Carr; Tom Barclay (NZ)
Date: Thursday, 2 March 2023 3:10:46 pm

Given the cost of mining out station boxes that is something I'd be keen to see tested.

Doc 25

From: Peter Nunns
To: Sharon Fairbrother; Meeting Room 9 (VC); Cameron Law; Jane Gully; Danielle Bassan; Benjamin Carr; Nathan Harper; Lucy Riddiford; Kate Randell; Patrick Andison; Kobus Van Der Vyver; Ignacio Barandiaran; Peter Nunns; Isabel Kelly [TSY]; Elliot Clayton; John Williamson; 8:orgid:46a57a56-4e6c-4308-9918-ad29b12eeb00; Benjamin Carr; 8:orgid:da349415-fcfe-4050-89e1-135dbcbce19c; Ben Wells [TSY]; Isabel Kelly [TSY]; Patrick Andison; Kobus Van Der Vyver
Date: Monday, 3 April 2023 2:07:49 pm

Non-transport enabling infra is needed to enable **some** project benefits. However, some benefit streams do not necessarily rely on achieving more intensification than viable under the do-min scenario.

Doc 26

From: Peter Nunns
To: Sharon Fairbrother; Meeting Room 9 (VC); Cameron Law; Jane Gully; Danielle Bassan; Benjamin Carr; Nathan Harper; Lucy Riddiford; Kate Randell; Patrick Andison; Kobus Van Der Vyver; Ignacio Barandiaran; Peter Nunns; Isabel Kelly [TSY]; Elliot Clayton; John Williamson; 8:orgid:46a57a56-4e6c-4308-9918-ad29b12eeb00; Benjamin Carr; 8:orgid:da349415-fcfe-4050-89e1-135dbcbce19c; Ben Wells [TSY]; Isabel Kelly [TSY]; Patrick Andison; Kobus Van Der Vyver
Date: Monday, 3 April 2023 2:54:02 pm

> **Nathan Harper (External)**
>
> Thanks Peter. Once you have the sensitivity tests complete, it doesn't take much time at all. I think it also enables a much better understanding of uncertainty, you can include factors looking at say data error, modelling error etc.

Modelling error is probably underappreciated as a source of uncertainty - the transport model parameters are not necessarily precisely estimated, or estimated without bias, but there's no way to sensitivity test them without decalibrating the model.

Doc 27

From: Peter Nunns
To: Sharon Fairbrother; Duncan Olde; John Williamson; Louelle Botes; Adam Nicholls; Danielle Bassan; Geoff Cooper; Chris Parker [TSY]; ALR Boardroom (VC); Cameron Law; Patrick Andison; Amanda Harland; Ignacio Barandiaran; Kate Randell; Rebecca Schepers; Tui Gilling; Natalee Waiwiri-Taumata; Antonia Robertson (NZ); Claire BoothJones; Alan Peddie; Heta Hudson; Andy Thackwray; Joanna Heard; Randhir Karma; Daniel Newcombe (AT); Amy Kearse; Elliot Clayton; Gareth Fairweather; Ben Wells [TSY]; Isabel Kelly [TSY]; Jessica Laing; Weiwei Jiang; Daniel Newcombe (AT); Tom Barclay (NZ); Benjamin Carr; Jessica Laing; Ben Wells [TSY]; Isabel Kelly [TSY]; Weiwei Jiang; Kobus Van Der Vyver; Steve Dudley; Anthony Belcher (AU); Phil Carter
Date: Thursday, 1 June 2023 2:45:11 pm

How much early information about costings have you had leading up to sponsor decisions about things that will affect cost, eg route and station?

Doc 28

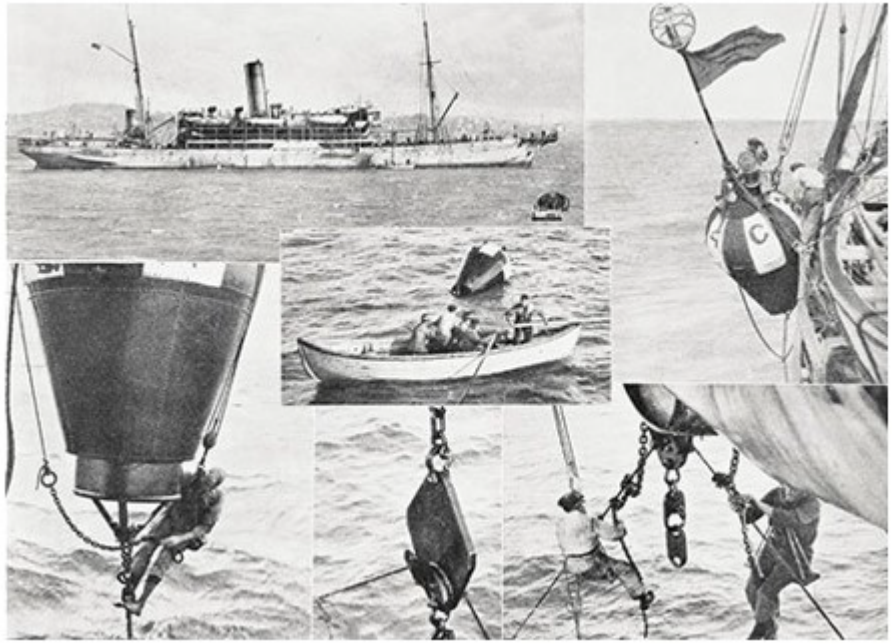
From:	Peter Nunns
To:	Sharon Fairbrother; Duncan Olde; John Williamson; Louelle Botes; Adam Nicholls; Danielle Bassan; Geoff Cooper; Chris Parker [TSY]; ALR Boardroom (VC); Cameron Law; Patrick Andison; Amanda Harland; Ignacio Barandiaran; Kate Randell; Rebecca Schepers; Tui Gilling; Natalee Waiwiri-Taumata; Antonia Robertson (NZ); Claire BoothJones; Alan Peddie; Heta Hudson; Andy Thackwray; Joanna Heard; Randhir Karma; Daniel Newcombe (AT); Amy Kearse; Elliot Clayton; Gareth Fairweather; Ben Wells [TSY]; Isabel Kelly [TSY]; Jessica Laing; Weiwei Jiang; Daniel Newcombe (AT); 8:orgid:f9bd8cd0-9001-4d87-bfe0-d917b2441201; Tom Barclay (NZ); Benjamin Carr; Jessica Laing; Ben Wells [TSY]; Isabel Kelly [TSY]
Date:	Thursday, 1 June 2023 12:10:50 pm

Also need to consider option cost - if we have too much capacity in some future scenarios what is the downside of that.

Doc 29

From:	Peter Nunns
To:	Sharon Fairbrother; Cameron Law; John Williamson; Danielle Bassan; Kate Randell; Alyssa Jones; Peter Clark; Benjamin Carr; ALR Boardroom (VC) - Level 3 CPO Building, 12 Queen Street, Auckland; Amanda Harland; John Davies; Steve Dudley; Ben Wells [TSY]; Peter Nunns; Ying Liu; Isabel Kelly [TSY]; Natasha Tod; Elliot Clayton; Steve Dudley; Isabel Kelly [TSY]; Elliot Clayton; 8:orgid:fdfc9bc4-567e-433d-b55d-7eb6fddde09a
Date:	Thursday, 22 June 2023 5:27:25 pm
Attachments:	0-eau-d3-5a87759f256cfdafb641e89ebe8627c5

Infrastructure sometimes gets cheaper over time:



Trans-Tasman Cable 1

Completed **1876** for £290,000
Around $21m per 1000 km in 2021 NZD

Capacity <100 bits/second

Hawaiki Cable

Completed **2018** for $445m
Around $31m per 1000 km in 2021 NZD

Capacity 43 trillion bits/second

https://d2rjvl4n5h2b61.cloudfront.net/media/documents/trans-tasman_telegraph_cables_report-pdf.pdf

Doc 31

From:	Peter Nunns
To:	Sharon Fairbrother; Cameron Law; John Williamson; Danielle Bassan; Kate Randell; Alyssa Jones; Peter Clark; Benjamin Carr; ALR Boardroom (VC) - Level 3 CPO Building, 12 Queen Street, Auckland; Amanda Harland; John Davies; Steve Dudley; Ben Wells [TSY]; Peter Nunns; Ying Liu; Isabel Kelly [TSY]; Natasha Tod; Elliot Clayton; Steve Dudley; Isabel Kelly [TSY]; Elliot Clayton; 8:orgid:da349415-fcfe-4050-89e1-135dbcbce19c; 8:orgid:fdfc9bc4-567e-433d-b55d-7eb6fddde09a
Date:	Thursday, 22 June 2023 4:48:43 pm

I found this book quite helpful for thinking about how to approach MC analysis in the sort of practical setting you're discussing: https://direct.mit.edu/books/book/2955/Flexibility-in-Engineering-Design

Doc 32

From:	Peter Nunns
To:	Sharon Fairbrother; Cameron Law; John Williamson; Danielle Bassan; Kate Randell; Alyssa Jones; Peter Clark; Benjamin Carr; ALR Boardroom (VC) - Level 3 CPO Building, 12 Queen Street, Auckland; Amanda Harland; John Davies; Steve Dudley; Ben Wells [TSY]; Peter Nunns; Ying Liu; Isabel Kelly [TSY]; Natasha Tod; Elliot Clayton; Steve Dudley; Isabel Kelly [TSY]; Elliot Clayton; 8:orgid:da349415-fcfe-4050-89e1-135dbcbce19c; 8:orgid:fdfc9bc4-567e-433d-b55d-7eb6fddde09a
Date:	Thursday, 22 June 2023 5:01:15 pm

Just playing out that logic about levers available to manage 'downside' risks of less demand than expected - would some of these levers also be available to manage risks of being over-capacity due to excessive 'upside' to demand? What are the costs and benefits from each approach?

Doc 33

From: Peter Nunns
To: Cameron Law
Cc: Blake Lepper; Geoff Cooper
Subject: Te Waihanga feedback on draft ALR NoR
Date: Monday, 3 July 2023 5:17:25 pm
Attachments: image001.jpg

Kia ora Cameron

Thanks for the presentation on the proposed NoR on 26 June 2023, and the opportunity to provide feedback.

As discussed by Ross Copland at the ALR/WHC Joint Governance meeting on Friday, Te Waihanga remains concerned about the process to submit an NoR prior to finalisation of the DBC. Publicly consulting on the scheme prior to that will make an objective consideration of the information presented in the DBC harder and will limit the range of decisions that are easily executable by Government. It is not clear to us that there are sufficient benefits to immediate lodgement to outweigh these costs/risks. While we appreciate the programme has been approved by Sponsors we continue to encourage the project to be free and fearless in advice to Sponsors, if they have concerns about the processes they are working to.

That being said, if it is the intention to move forward regardless of that feedback, we do have some "lower altitude" comments on the NoR. Our feedback highlights three key areas where there may be opportunities to enhance deliverability or benefits from the project:

- The degree of flexibility that the NoR would provide for the procurement and construction phases
- Implications of NoR for staging / sequencing delivery
- Implications for achieving urban development outcomes.

On the first point, tightly specified designations have in some cases limited scope for design innovation in the procurement phase or caused additional costs due to the need to work around constraints imposed by the designations. Transmission Gully is one example of this. Our key question is whether the project team has learned from past examples and what they have done to preserve flexibility in procurement and delivery.

The materials that you presented highlights a number of design decisions that have fed into the designations, including but not limited to:

- The extent of tunnelling, at-grade segments, trenched segments, and elevated segments in viaducts – noting that there are a few areas where design has not been finalised (eg the SW motorway segment)
- Tunnel depth
- The specific alignment through the city centre and the tie-ins with existing rail stations
- The alignment across the Mangere inlet, which is proposed to be in a separate bridge
- The number of stations along the route, station design, and access arrangements to reach stations
- Tunnelling and station construction methodology – the proposed approach is a single 13.5m diameter tunnel, with two tracks in it, plus room for stations, rather than two 7.15m diameter tunnels as in the case of CRL.

While a reference design is needed for the business case and NoR, there may be value in

revisiting some of these decisions in the procurement phase. The key question is whether the NoR would enable proposals that took a different design approach to achieve the desired outcome. As a potential example, would the NoR enable a proposal to build two smaller-bore tunnels plus mined station boxes, or is it sized so that it could only accommodate a single large-diameter tunnel?

On the second point, what options for staging delivery are enabled by the NoR? This is important for procurement and delivery of the project and also potentially important for sequencing delivery alongside other projects in the Auckland transport portfolio.

The materials you presented suggests that:

- Approximately half the route (Victoria St to Wesley station in Mt Roskill) is tunnelled, while the remaining half of the route (Wesley Station to Te Ararata station in Mangere) is above-ground or in trenches
- There are three points along the tunnelled section of the route where a TBM could potentially be launched or recovered: Vernon St/Victoria St intersection in city centre; Dominion Junction near Kingsland (about 40% of the way through the tunnelled section?), and Wesley in Mt Roskill
- There are several extended sections of viaduct or major cuttings along the southern half of the route
- You have excluded the Wynyard Quarter parts of the route from the NoR as that requires integration with the WHC project.

On the third point, integration of land use/urban development with the transport scheme is important for the project objectives and benefits. Given that, we were surprised that the NoR for the transport scheme isn't bundled with other designations or proposed rezoning for urban development, although we note that it does capture intersections and roads near ALR stations to facilitate supporting changes to station access and bus networks.

Our key question is how this will be considered alongside the NoR process to avoid the potential for foregone benefits, such as lost urban development or value capture opportunities around stations included in the NoR.

The materials you presented suggests that the NoR will be lodged and notified in stages, which may allow you to address these opportunities:

- August 2023: NoR lodged for Victoria St to Te Ararata parts of the route
- October 2023: NoR lodged for Te Ararata to Landing Drive (edge of Auckland Airport); coastal consents lodged for Mangere inlet crossing
- February 2024: NoR and coastal consents publicly notified.

Once again, we appreciate the opportunity to comment – please feel free to contact us with any follow-up questions.

Ngā mihi
Peter

s9(2)(k)

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Visit us online at https://tewaihanga.govt.nz/