Infrastructure costs and urban form

A proof-of-concept model

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SENSE PARTNERS
DATA LOGIC ACTION

Summary

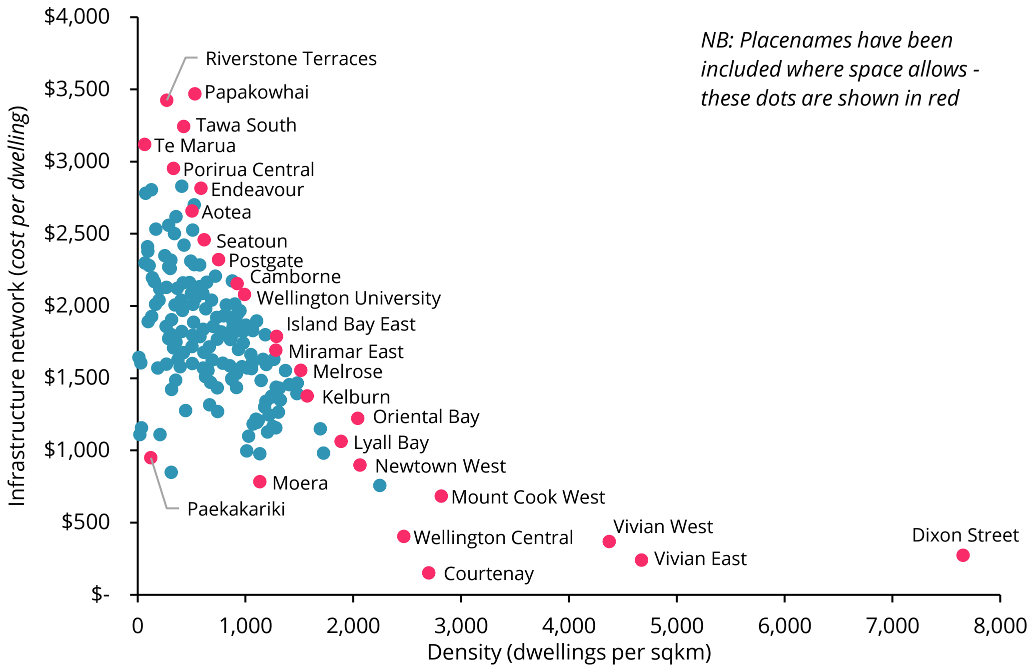
Our proof-of-concept shows value through preliminary findings

- Sense Partners was commissioned by Greater Wellington Te Pane Matua Taiao to build a proof-of-concept model of the costs of infrastructure and urban form across the region.
- This report sets out the proof-of-concept model and the preliminary findings. Even at this stage, our results yield valuable insights into how urban planning decisions can impact the infrastructure costs local government faces.
- We focus on the financial costs faced by local government, both territorial authorities and the regional councils. Our model does include the cost of maintaining the state highway network across the region, but we present these results separately.
- We examine costs across Wellington City, the Hutt Valley, Porirua, and Kapiti Coast. These are highly urbanised areas that, from an economic lens, function as a single urban area.

Density and proximity lower costs, as does being in the right place

- Our analysis indicates that density lowers the per-dwelling costs. Economies of density mean the higher cost of larger roads and pipes in dense areas is amply offset by the number of dwellings that can be serviced.

FIGURE 1: LOCAL GOVERNMENT COST (LOCAL ROAD AND THREE-WATERS PIPES)



Source: Sense Partners

- Density is not the only factor, particularly in transport costs. Proximity to the city centre is also a cause of lower costs, through lower levels of driving and public transport use. For local government, walking is comparatively cheap to provide for through infrastructure.
- If people live in closer proximity to activity centres, the road network, including state highways, do not need to cater to such a high volume of traffic. A reduced need for capacity reduces the future cost of accommodating growth in the road network.
- There is a quirk in how our infrastructure is funded. The state highway network, which does the heavy lifting in connecting the region's urban areas to the Wellington CBD by road, is funded by central government. The benefit is most keenly felt by central government.
- This is visible in figure 3 below, showing estimated cost per dwelling of the local road network (excluding state highways). Here, it is proximity to a state highway, not the CBD, that lower costs to local government.
- For three-waters infrastructure, the bulk of the cost lies in local connection pipes. Proximity to reservoirs or treatment plants does count but is less influential. Density is more influential when it comes to three waters costs, visible in figure 4 below.
- Beyond density and proximity to activity centres, costs can be lowered by "being on the way". Areas that lie between major travel destinations benefit from sharing costs with the through traffic. This also applies to three-waters infrastructure.
- This is visible in figure 3, which shows that areas on the periphery of the urban boundary, like western Karori, Seatoun, Eastbourne, and Otaki have higher costs. In-between areas, like Hataitai South, Petone East, and Aotea have lower costs as their roads also service through-traffic.

Altering the level of service is a valid option

- There is plenty of local variation in costs beyond that explained by density and proximity. One is the quality of infrastructure, which our model generally does not control for. The data required for this is not, by and large, available.
- Another factor is the level of service provided. Our analysis shows that some low-density areas have low costs because a lower level of service is provided. Paekākāriki has no reticulated waste water system, with properties having their own septic tank.
- It is not obvious this should be considered a problem. People may be willing to accept – indeed actively choose – a lower level of service provision if it means lower costs, or conversely because the benchmark level of service is considered unaffordable.

This has important implications for how our region grows

- Our region is growing. The population is projected to increase by 187,000 residents by 2052.[1] Ensuring we have the capacity to welcome these new residents would be a challenge on a good day.
- Not only do we need to accommodate new neighbours, we also have a massive backlog of work to deal with – just to stay where we are. Wellington Water estimate the cost of fixing existing water infrastructure at $30 billion over the next 30 years.[2]
- Our model indicates that how we choose to accommodate growth will have a major influence over how much this growth costs. Enabling density will be key to growing while lowering costs.
- A spatial alignment of rates and levels of service may be beneficial. This would incentivise density, though some may be happy to pay the higher price to live in a low-density area. Local government shouldn't rule out adjusting levels of service in order to manage costs where residents don't want to pay.
- Enabling density and aligning revenue to costs by area means we can grow the city faster than total costs rise. This will lower the per-household burden of fixing and growing our infrastructure.

Our proof of concept lays the foundations for planning models

- This proof of concept is a static snapshot of the current network and uses estimates of cost that assume regular maintenance and amortised capital cost.[3] Improvements to the data inputs will enable deferred maintenance to be added, giving a better view of how our current infrastructure challenges can be managed on top of growth.
- As a planning tool, developing the model beyond proof-of-concept will enable detailed scenario planning. This will help us understand how different growth patterns and charging mechanisms will shape the costs faced by local government.
- More detailed data on the costs of the road network, public transport, three waters, and rates revenue is needed to advance beyond a proof-of-concept.

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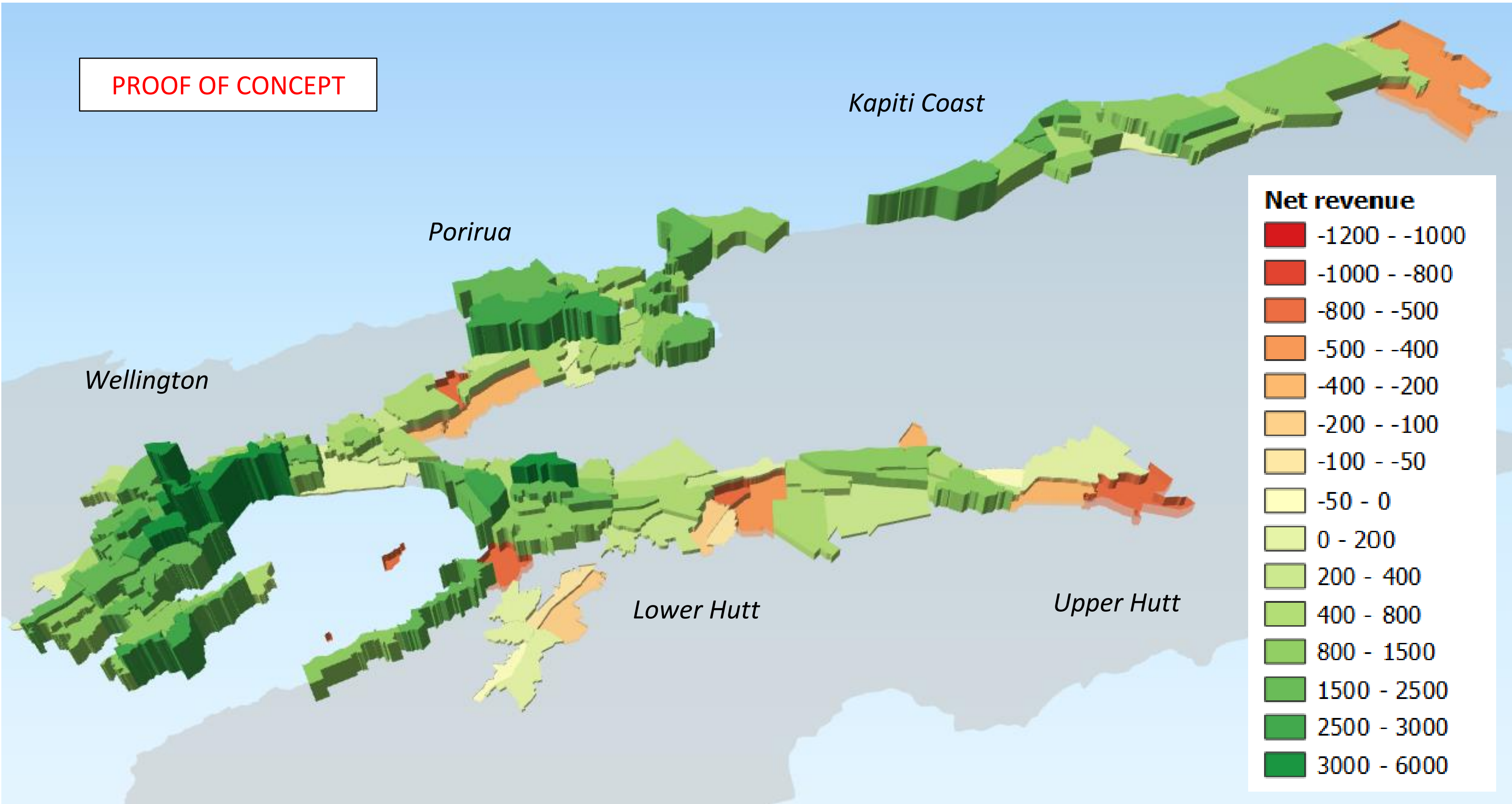
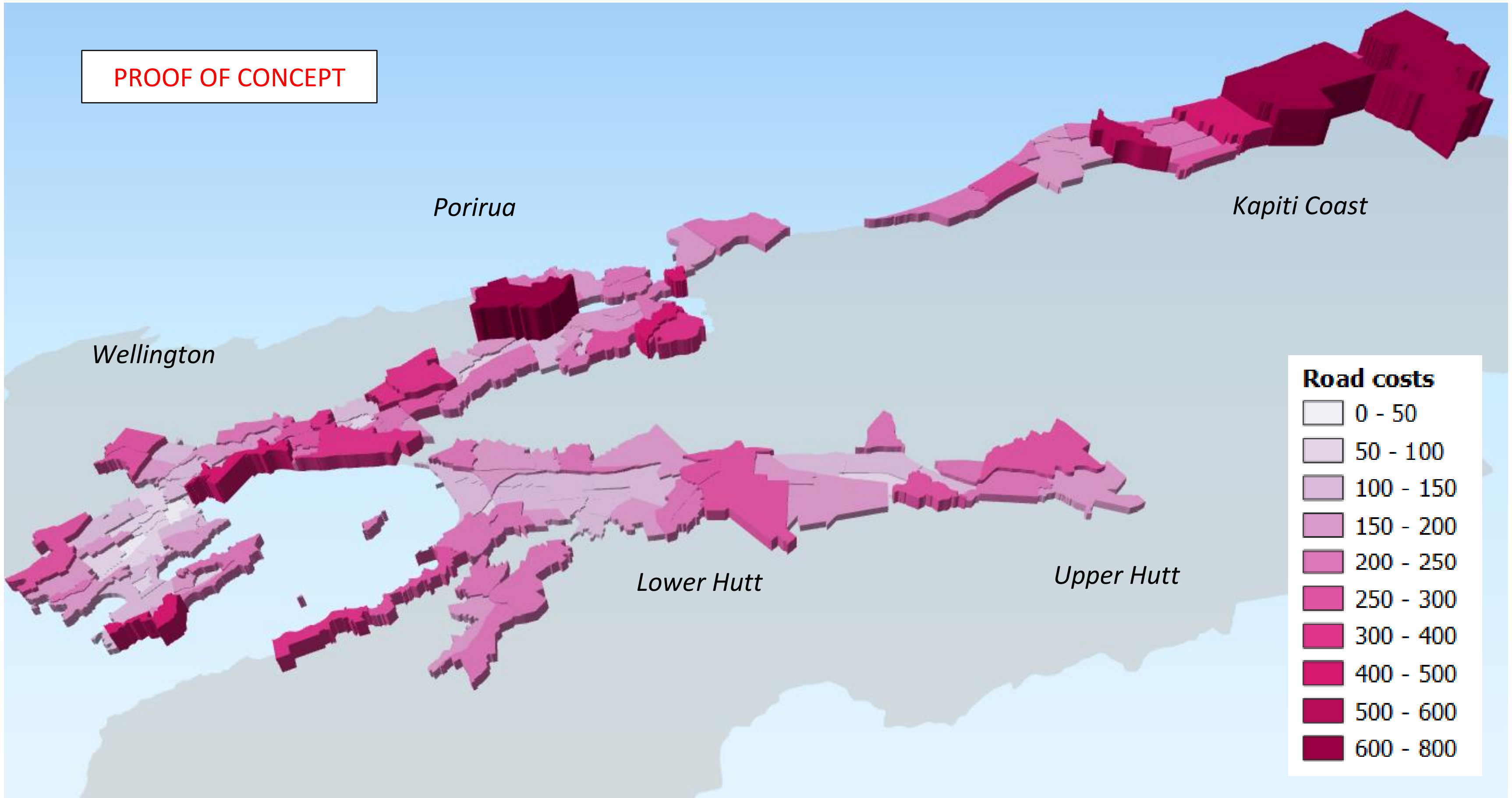
[1] Greater Wellington (2023) *Wellington Regional Housing and Business Development Capacity Assessment: Wairarapa-Wellington-Horowhenua.* September 2023.
[2] Radio New Zealand (2023) *Wellington's water woes could cost $1 billion a year to fix.*
[3] Amortisation is an accounting practice. It is how the high up-front cost of an asset can be spread out over the life of that asset, in even annual sums.

FIGURE 2: NET REVENUE (ANNUAL - PER DWELLING – 2023 DOLLARS)



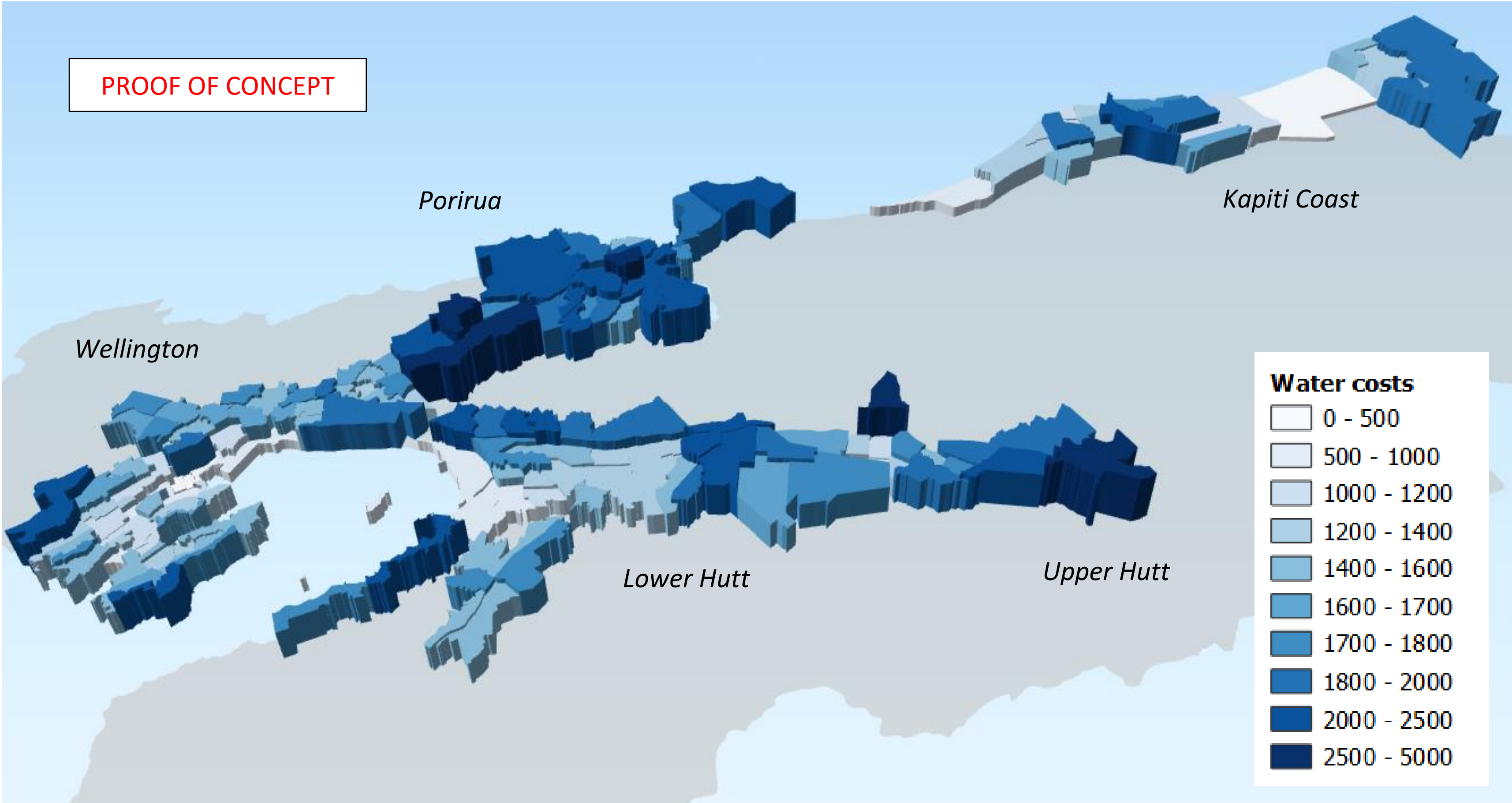
Source: Sense Partners

FIGURE 3: LOCAL ROAD COSTS (ANNUAL - PER DWELLING – 2023 DOLLARS)



Source: Sense Partners

FIGURE 4: 3-WATERS COST (ANNUAL - PER DWELLING – 2023 DOLLARS)



Source: Sense Partners

Contents

1. Purpose

1.1. We have produced a proof-of-concept

Our results demonstrate the value in this type of modelling

The purpose of this exercise is to produce a proof-of-concept that demonstrates it is possible to attribute infrastructure costs to those who benefit, on a neighbourhood basis. By doing so, we can identify the role of urban form and location in determining the cost to local government of accommodating future growth.

Planning regulations are one of many factors that influence urban form and the location of future growth. It will be of value to local government to know how planning regulations may shape the costs they face now and in the future.

The need for a proof-of-concept is driven by the shortcomings of readily available data. This will require significant time and effort to address. We also require buy-in and permission from all stakeholders to access detailed data from Wellington Water.

By building a proof-of-concept before commencing the heavy data work, we have demonstrated that the effort will be worth it. A fully developed model will provide council with valuable insights into how planning rules influence the costs of infrastructure and how councils can manage growth sustainably.

Our proof-of-concept model takes a first-principles approach

The relationship between urban form and infrastructure cost is not a novel question. The body of literature that explores the topic, helpfully summarised by SGS Economics & Planning (2016)[4], generally finds that:

- Infrastructure costs per dwelling are typically lower in higher density areas, adjusting for the quantity and quality of infrastructure provided.
- Cost is highly contextual, and it is difficult to generalise study findings to other locations and scales.

Given cost is so contingent on local context, local modelling is needed.

We use data on Wellington's infrastructure networks, and how people use that infrastructure, to identify area-specific costs across the Wellington Region. Our approach is a first-principles approach in that we start with the known physical attributes of the road, bus, and water networks in Wellington. From there, we build area-specific estimates.

[4] SGS Economics & Planning (2016) *Comparative costs of urban development: a literature review*. Prepared for Infrastructure Victoria.

This contrasts to the more common case-study approach, which looks at specific examples of different developments and extrapolates across the region from there.[5]

We focus on assessing the financial costs to local government

Our focus is on the costs that local government[6] faces in providing road, bus public transport, and three-waters infrastructure networks, and where they 'originate'. We include costs faced by central government as well, namely the state highway network and its share of funding the bus network.

We do not consider external costs, such as from emissions or congestion. Nor do we consider the private costs of the system, such as the personal transport costs faced by households.

We do not consider the efficiency of *how* the infrastructure networks are paid for (e.g. rates, user charges), or alternative financing mechanisms (e.g. equity, debt, private partners). Our proof-of-concept compares costs to rates revenue but does not explore whether the current rating mechanism is an efficient approach.

Our inclusion of non-rate revenue is also limited. Further work is needed to unpick the various funding mechanisms, such as rates, user charges, and central government grants. Our proof-of-concept model demonstrates the value in going further.

The proof-of-concept modelling does show the potential for councils to use this tool to observe the extent to which beneficiaries of infrastructure pay for that infrastructure. If developed beyond a proof-of-concept, this model could inform rate- and charge-setting.

For example, it is likely that an efficient approach to paying for infrastructure will consist of user charges that reflect the (short run) marginal cost, including to reflect congestion, and a fixed charge.[7]

As a proof-of-concept there are limitations in our results

The primary limitation we face is the quality and extent of data. There is reasonably comprehensive geospatial data available on the physical form of the roads, bus services, and three-waters networks. We are not certain how accurate or comprehensive this data is, though we have no reason to suspect there are major shortcomings.

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[5] See for example, Centre for International Economics (2015) *Cost of Residential Servicing*. Prepared for Auckland Council.
[6] These costs are spread across territorial authorities and regional councils. For brevity, we refer to both collectively as "local government". At this stage, our model makes no meaningful distinction between these two levels of local government.
[7] Coase R. (1946) "The marginal cost controversy". *Economica* 13(51): 169-182. Prices should reflect marginal costs to achieve efficiency in use. But such pricing may not cover the largely fixed costs of providing the infrastructure. Nobel Laureate Ronald Coase compellingly argued that efficiency required that users of infrastructure should face the full opportunity cost of infrastructure investment, to avoid excess demand for infrastructure and ensure efficient locational and investment decisions by consumers. Multi-part pricing (fixed + variables charges) allows the total cost of infrastructure to be recouped while maintaining marginal price signal. In practice, it may be too costly to identify beneficiaries, and a low broad-based tax may turn out to be a relatively more efficient (low distorting) alternative mechanism, despite the deadweight loss of taxation. Also see Frischmann B. and Hogendorn C. 2015 "Retrospectives: The marginal cost controversy." *Journal of Economic Perspectives*, Vol 29:1

The real data limitation is on the expenditure side. Road and bus network costs are only publicly available at an aggregated level. For state highway expenditure, this is limited to a region-wide level, while local road expenditure is available at the territorial authority level.

How roads and pipes depreciate over time will depend on very local conditions. Volumes of traffic, topography, ground conditions, and weather will all affect the rate of wear and tear. Using regional aggregates of spending can't tell us much about how costs change across the regions' varying ground. Cost aggregates also can't give much insight into the quality of infrastructure being provided, and how this impacts cost.

This means we have to make reasoned assumptions about the physical attributes of the network, and to attribute network costs to more fine-grained locations. For example, we must assume that a kilometre of residential road in one part of a district or city is the same as in any other part. While we know the physical attributes of specific roads in specific areas, we do not know their specific costs.

The lack of disaggregated data also limits our ability to fit a more general model that could estimate the cost based on known physical attributes.

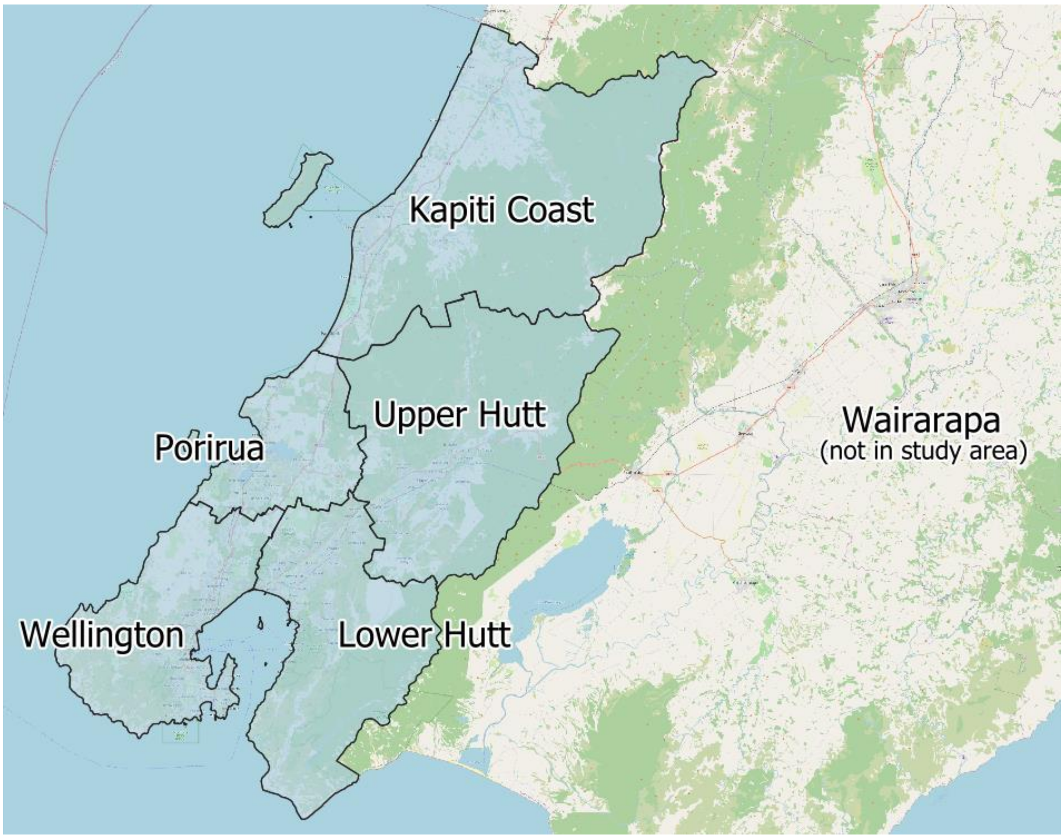
For the water network, there is considerably less data in the public domain, particularly detailed expenditure data. For Wellington Water to provide this data, we require approval of all stakeholder councils.

Data limitations, such as those in the examples above, will require considerable time to address, as well as buy-in from all councils in the relevant 'catchment' of the model. This is the primary reason for starting with a proof-of-concept.

Our study area focuses on capital, coast, and valley

Our study examines costs across Wellington City, the Hutt Valley, Porirua, and Kapiti Coast. These are highly urbanised areas that, from an economic lens, function as a single urban area.

FIGURE 5: OUR STUDY AREA



Source: Sense Partners

2. Road network costs

2.1. We assign network costs to their beneficiaries

Roads are designed to support each other in a network

FIGURE 6: ONE NETWORK ROAD CLASSIFICATION

Source: Waka Kotahi NZTA

To do their jobs, roads need to be able to convey traffic along their length. To do their jobs well, they need to be designed to convey traffic across the whole network. This means each road needs to do more than just connect together. They must be designed in such a way as to mutually support each other as a network.

The road network hierarchy describes how we can achieve this. Access roads are typically the first stage for a journey from home. These smaller roads feed into collectors. As the name suggests, these collect traffic from many access roads and feed them into arterials. These are the main roads that convey traffic across the network.

In New Zealand, we use the One Network Road Classification to classify different roads, their design parameters, and their role in the network.[8]

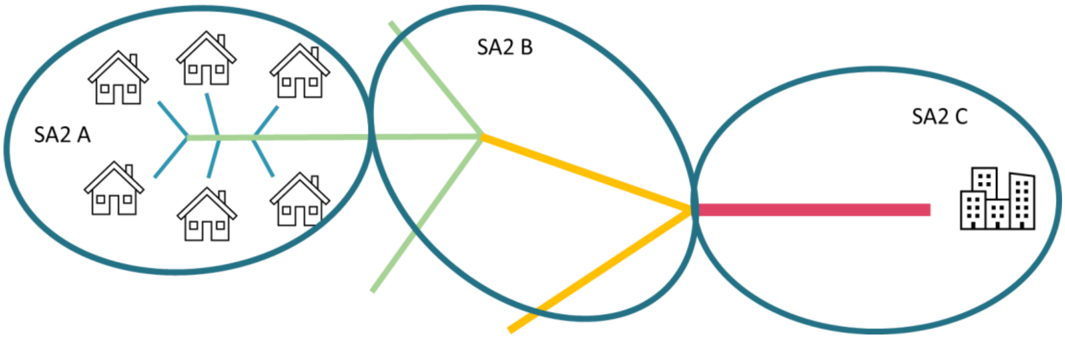
We use this hierarchy to assign costs to localities

Like a river, the flow of traffic builds, and the network ideally expands to accommodate this. Homes dispersed across space are connected through the road hierarchy to clusters of employment. From the home to work, the flow of traffic builds as many vehicles converge on an increasingly smaller space (see Figure 7).

Using the logic of the One Network Road Classification, access roads connect homes to the network. They are not intended to facilitate through-traffic. This means the beneficiaries of access roads in a geographic area will be those homes in that same geographic area. On this basis, we assign the costs of access roads entirely to the locality they are in.

Other roads are intended to facilitate through-traffic. This means their beneficiaries are not necessarily in the same geographic area. We assign the cost of these other roads based on modelled use, not simply to the locality they are in. This means that residents in outer areas, who commute into the city centre, will share a portion of central city road costs, based on their share of use.

FIGURE 7: WE ALLOCATE NETWORK COMPONENTS TO ACTUAL USERS



Source: Sense Partners

[8] Waka Kotahi NZTA (2013) *One Network Road Classification (ONRC)*

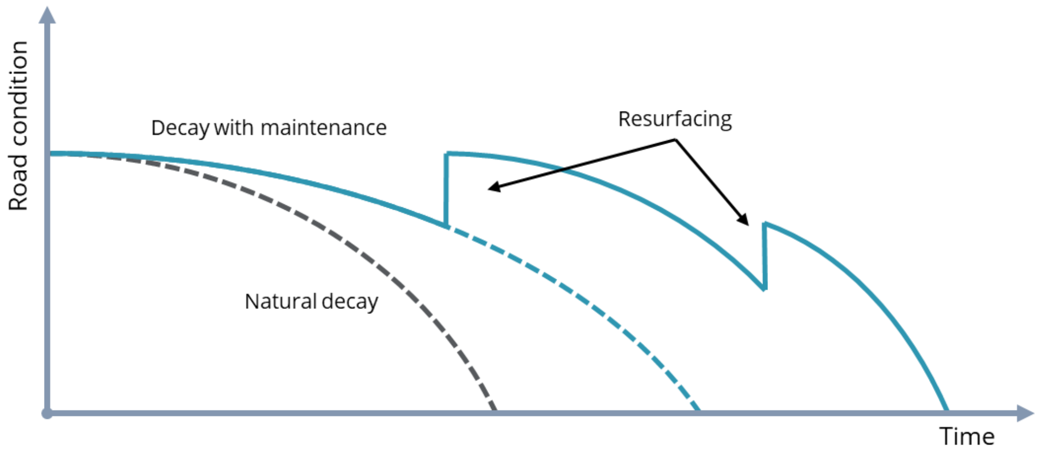
2.2. We allocate build and maintenance costs

We assign a roads' whole-of-life cost as a smooth, annual instalment

We aim to assign the full lifecycle costs of the road network to localities. This includes the initial construction cost of building each road, the cost of maintaining the road throughout its useful life, and the end-of-life renewal cost.

This spending will come in waves over the life of the road. But financial tools like debt can be used to amortise this into a smooth annual sum. This ideal annual figure is a good way to align local government's annual responsibilities to annual revenue.

FIGURE 8: STYLISED DECAY CURVE OF A ROAD



Source: Austroads [9]

Estimating this annual figure is challenging with existing data

The land transport funding system in New Zealand takes a pay-as-you-go approach.[10] Expenditure in any year is met through revenue raised in that same year. The cost of building and maintaining specific roads is not amortised. In addition, the decision to spend and what to spend it on is not necessarily linked to maintenance needs.

In theory, funding agreements are made between Waka Kotahi and local councils based on meeting agreed levels of service.[11] This would direct funding to road maintenance as and where it is needed. In practice, the link between road condition and expenditure isn't automatic.[12]

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[9] Austroads Ltd. (2018*) Measuring and Reporting the Value of Road Maintenance and Renewals Works*, Research Report AP-R588-18.
[10] Infometrics (2008) *Economic Assessment of the Cost Allocation Model.* Prepared for Ministry of Transport Road User Charges Review Group.
[11] Waka Kotahi (2012) *Maintenance guidelines for local roads*
[12] Parick, J. & Arampamoorthy, H. (2012) *Factors influencing the decision to rehabilitate a pavement.* NZTA research report 491.

Funds may be prioritised by local government according to condition, but the total pool of funding in the National Land Transport Fund (NLTF) remains a policy choice. Policy makers are allocating funds across many priorities. A deviation from the ideal maintenance spend may be a necessary trade-off when responding to other budget pressures.

This means reported annual spend isn't *necessarily* a good estimate of the smoothed lifecycle cost of the network depicted in figure 7. It could reflect a policy choice to temporarily redirect funds to more pressing concerns. Alternatively, it could include additional maintenance cost from previously deferred work.

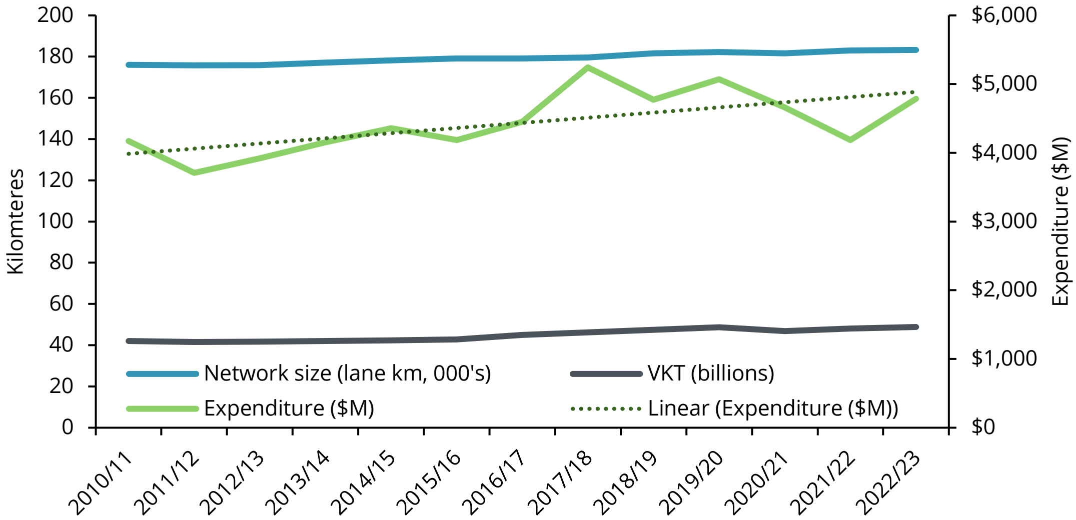
Spending is stable enough to give a suitable first approximation

Even under the pay-as-you-go system, there are conditions under which the annual spend is a reasonable approximation of cost:[13]

- The size (relative to demand) and quality of the network is constant.
- Expenditure does not fluctuate markedly.
- Traffic growth is steady and matches investment in network capacity.

Figure 8 below shows annual spending data across the entire New Zealand road network, alongside vehicle kilometres travelled and the physical size of the network. Spending is adjusted for inflation to 2023 dollars.

FIGURE 9: ROAD NETWORK SPENDING – ALL ROADS ACROSS NEW ZEALAND



Source: Waka Kotahi data; Sense Partners analysis

The size of the network, measured in lane kilometres, has grown 4.1% over the last 12 years Demand, measured in vehicle kilometres travelled, has grown 16.4% in that same period. This could imply the capacity of the network has not kept pace with demand, that network extensions were high-capacity, or that spare capacity has been used up.

[13] NZIER (2008) *Literature Review: Road use charging & cost allocation*. Report to Ministry of Transport.

Real spending has fluctuated somewhat, with a standard deviation of $431m, 9.7% of the average. It is not clear whether this constitutes a “marked fluctuation,” or an acceptable level of variation. A simple trendline indicates trend growth of 23.5% over the period. Network and demand growth could explain much of this rise.

We take an average over 12 years of expenditure data for the whole network. This will smooth out short term oscillations and give a suitable first approximation of the annual cost of the road network. It would be possible, with more detailed data, to refine these numbers, but our estimate suffices for proof-of-concept modelling.

We use territorial authority level data to estimate costs for each road class

Table 1 below sets out our estimate of costs by road class. To get costs by class, we pair territorial authority (TA)-level spending with TA-level data on vehicle kilometres travelled and the size of the network. From this, we estimate the annual average daily traffic per km of road in each city or district.

We line this up with the One Road Network Classification, meaning each city or district is representative of a certain road class. For example, the average volume of traffic across the Auckland local road network is 2,963 vehicles per km per day. This is the level of traffic expected on a primary collector. We use the Auckland per-km spend (along with areas like Christchurch and Hamilton) as an estimate of the cost of a km of primary collector road.

TABLE 1: MODEL ROAD NETWORK COST PER-KM BY ROAD CLASS

Road class	LV share	HV share	Bus share
Motorway	$309,888	$49,818	$932
Trunk	$149,984	$28,516	$11,096
Primary	$30,990	$15,126	$283
Secondary	$17,479	$9,086	$857
Tertiary	$2,924	$2,150	$396
Residential	$2,924	$1,367	$1,179

Source: Waka Kotahi data; Sense Partners analysis

Light vehicles have very little impact on pavement maintenance

Light vehicles, like cars, vans, and small trucks, have very little marginal impact on a road’s pavement condition.[14] Damage to the road pavement relates to axle load, that is the amount of weight concentrated where the tyre and road meet. With small vehicles, this weight is not enough to deteriorate the road’s surface.

[14] Te Manatū Waka (2023) *Domestic Transport Costs and Charges Study: working Paper C1.1: Road Infrastructure – Marginal Cost.*

This is captured in the fourth power rule, which the Government uses to set road user charges and fuel excise duty.[15] For the 2019/20 National Land Transport Programme funding cycle, 93% of pavement wear costs were attributed to heavy vehicles, even though they only accounted for 7% of vehicle kilometres travelled.[16]

We expect that, as urban form changes across areas, it is light vehicle usage that will change most. Higher density living may promote higher public transport use, and proximity to the central city promotes walking over driving. It is not clear to us that heavy vehicle usage would be much influenced by urban form.

Given this, we are able to focus on attributing costs to light vehicle usage. This means we exclude pavement costs. Instead, we focus on the other costs that are not influenced by the weight of vehicles or the volume of traffic – such as road drainage, traffic light maintenance, signage, vegetation management, and so on. These make up 61.3% of the average annual spend.

We use both maintenance costs and network improvement costs to estimate a per-km fixed cost for each km of road in the network.[17] We attribute this cost to light vehicles in proportion to their share of VKT across the Wellington region – approximately 93%.[18] This is broadly the same approach used in the Ministry of Transport's Cost Allocation Model (CAM).

TABLE 2: ROAD MAINTENANCE SPEND BY ACTIVITY (2023 DOLLARS)

Road maintenance activity	2010/11 – 2022/23 average annual spend
Drainage maintenance	$134.7m (6% of total)
Emergency works	$371.3m (16.5%)
Environmental maintenance	$143.3m (6.4%)
Level crossing warning devices	$1.9m (0.1%)
Network and asset management	$253.5m (11.3%)
Operational traffic management	$79.3m (3.5%)
Pavement maintenance	$512.3m (22.8%)
Sealed road resurfacing	$358.9m (15.9%)
Structures maintenance	$110.4m (4.9%)
Traffic services maintenance	$231.8m (10.3%)
Unsealed road metalling	$53.9m (2.4%)

Source: Waka Kotahi data; Sense Partners analysis

[15] Te Manatū Waka (2022) *Background to the road user charges (RUC) system*
[16] Te Manatū Waka (2022) *Annual Motor Vehicle Fleet Statistics.*
[17] Allocating costs on a per-lane km basis would be better, but there are limitations with the geospatial data that require extensive work to overcome.
[18] Calculated from: Te Manatū Waka (2022) *Annual Motor Vehicle Fleet Statistics*

We use census travel-to-work and -education data to identify users

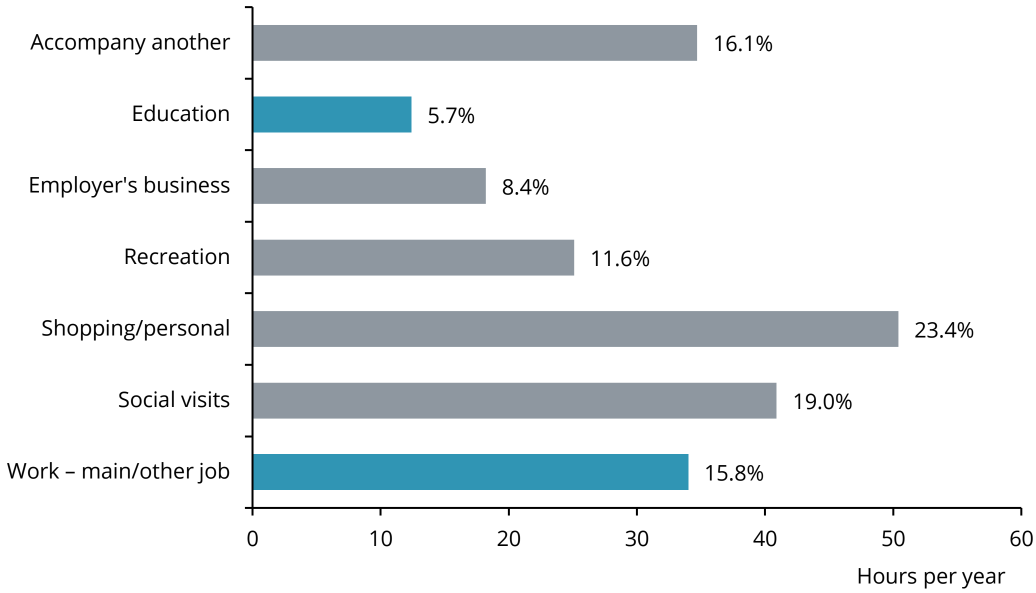
The census is the only public source of location-specific origin-destination-mode data. This gives us an indication of where people travel from, where they travel to, and the main mode they used to get there.

There are a range of limitations with this approach. First, the census is a snapshot of a specific day (census day.) This day may not be representative of people's usual travel patterns. For example, if it was raining that day, fewer people may have cycled than would have if it were sunny.

The census also only covers people's travel to work and to education. Data from the Ministry of Transport indicates these two activities account for just 21.5% of non-home-bound travel (i.e., travel to a destination other than one's home). Shopping, social visits, and accompanying others are all larger shares of weekly travel time.[19]

Due to the way this data is recorded, stopping by the shop on the way home would categorise that trip as a shopping trip, rather than just coming home from work. This means the actual portion of travel time related to work and education is likely to be higher than 21.5%. For example, research shows that travel which involves education or work (but may involve miscellaneous other tasks) makes up 48.2% of kilometres travelled by car.[20]

FIGURE 10: TIME SPENT TRAVELLING BY PURPOSE (ANNUAL 2020-2023)



Source: Te Manatū Waka

The share of work and education in travel may also vary across neighbourhoods. People living closer to their work would spend less time commuting. However, being closer to work also

[19] Te Manatū Waka (2024) The New Zealand Household Travel Survey (2020-2023).
[20] Sense Partners analysis of data presented in: O'Fallon, C. & Sullivan, C. (2005) *Trip Chaining: Understanding How New Zealanders Link Their Travel*. Transfund New Zealand Research Report N. 268.

means a person is typically closer to amenities, like shopping. This means a shorter commute may be a reasonable indicator of shorter trips to non-work destinations.

Ultimately, there is no publicly available origin and destination specific data on non-work travel. If this model is advanced beyond a proof-of-concept, we may need to test access to confidential or proprietary data sets. In the meantime, we use census data as a suitable first approximation.

We allocate roads to localities in proportion to residents' use

We aim to attribute the costs of a road to localities based on whether residents use the road, and in proportion to their use. While we have data on where people are coming from and where they are going, we do not have data on which specific routes they take.

To bridge this gap this, we use a route-finding algorithm[21] to link origins and destinations in the census data via the actual road network.

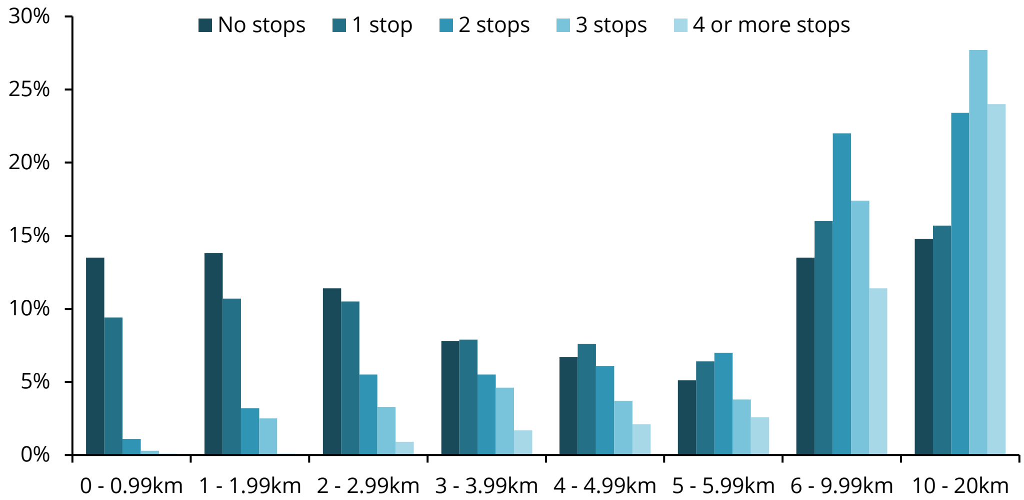
This algorithm identifies the fastest light vehicle path between two areas, with additional preference weightings for large roads like motorways. There are examples of roads which, in free-flow conditions, aren't the shortest route to anywhere, but are nonetheless used in peak hour. We assign these manually.

One potential issue is that the fastest route between home and work or school may not reflect actual travel behaviour. For example, a parent may drop their child off at school on the way to work, necessitating a detour from the fastest route. Research and data on this "trip-chaining" is limited.

Research from Waka Kotahi gives a breakdown of distances travelled for journeys with varying numbers of stops.[22]

[21] Padgham, M. (2019) "dodgr: An R package for network flow aggregation", Transport Findings.
[22] O'Fallon, C. & Sullivan, C. (2005) *Trip Chaining: Understanding How New Zealanders Link Their Travel*. Transfund New Zealand Research Report N. 268.

FIGURE 11: COMPARING TRIP DISTANCES AND STOPS ON THE WAY



Source: O'Fallon & Sullivan (2005)

In 2005, the average trip less than 20km in total, with no stops, was 3.47km. The average trip with 1 stop was 3.82km, a 353m (10.2%) increase. The average trip with 2 stops is 5.46km, a 1,640m (42.9%) increase on the 1-stop average. For 3-stop trips, the average is 6.34km, an 880m (16.1%). And for 4 or more stops, the average is 7.34km, a 1km (15.5%) increase.

Of all trips analysed, 80.9% had either no or a single stop (in addition to their end point). With no stop (48.3% of trips), the shortest route is a safe estimate. For a single stop (32.6% of trips) the extra distance is, on average only a 10.2% increase. This indicates that, for proof-of-concept purposes, plotting the shortest trip is not so far off the mark, even for trips detouring to make a stop on the way.

2.3. Our results indicate density is more cost efficient

They also confirm that costs are sensitive to local context

There are three main determinants of cost in our results. **The first is density**. There are economies of density in infrastructure. This means an increase in the number of houses in an area can be efficiently served by a much smaller increase in infrastructure. This results in lower per-dwelling costs.

Even when we account for the higher per unit cost of the infrastructure required, the cost per dwelling still falls. In our model, higher density means higher capacity roads are needed (and more public transport services), at higher per-km cost. Despite this, costs per dwelling are still lower.

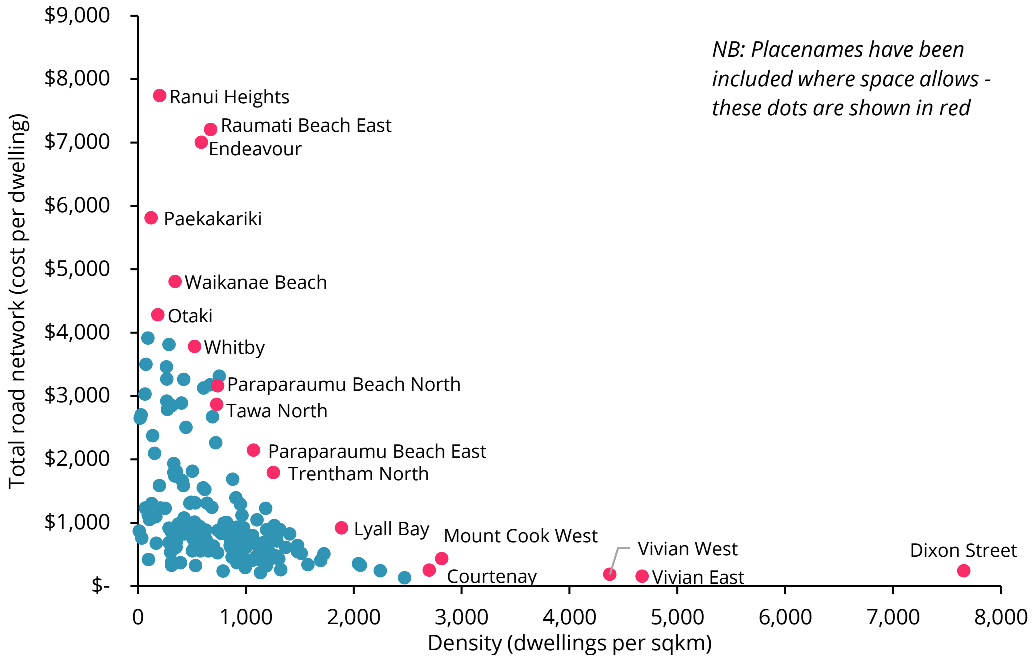
The second is proximity. Being close to the central city, or major employment centres, lowers the distance people travel, which lowers the cost to local government. It also tends to shift people to alternative forms of transport, like walking or public transport, which our model indicates are cheaper. High density areas tend to be those in close proximity to the central city, meaning the lower costs faced by local government here are a product of both of these factors.

This means that replicating the density of the Dixon Street area in, for example, Seatoun will not result in the same low cost per dwelling, due to the latter's distance from CBD (lower proximity). However, increased density will reduce costs.

Our analysis separates out the state highway network from the local road network. We are assessing the financial implications of urban form for local government. This means we only want to look at the local road network, as that is where local government faces costs.

The state highway network spans the entire region, and as a result travel along state highways will make up a dominant proportion of most commuter journeys. What this means is that when we strip out the state highways, we are stripping out a large portion of the costs that are caused by distance in our model.

FIGURE 12: TOTAL NETWORK – ANNUAL COST PER DWELLING

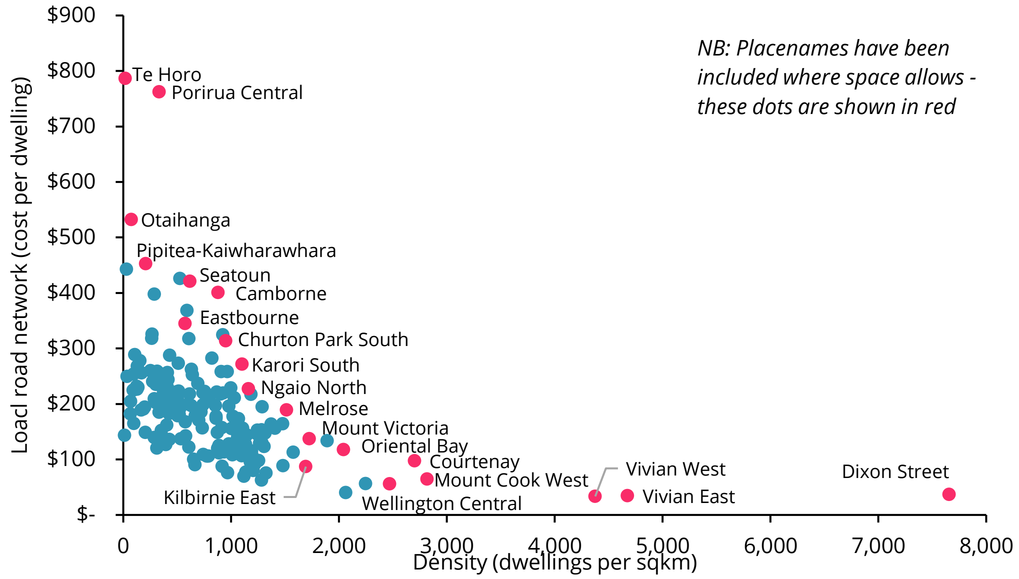


Source: Sense Partners

Figure 12 above shows the cost faced by government on a per-dwelling bases for the total network, combining local roads and state highways. Figure 12 shows only the costs for local roads. On average, local roads only account for 21% of total road costs. Once we strip out highway costs, the pattern of lower cost in higher density remains.

From a local government perspective, the cost of distance is largely covered by state highways. This means that density, as opposed to proximity, is the main concern from a local government view.

FIGURE 13: LOCAL ROAD NETWORK – ANNUAL COST PER DWELLING



Source: Sense Partners

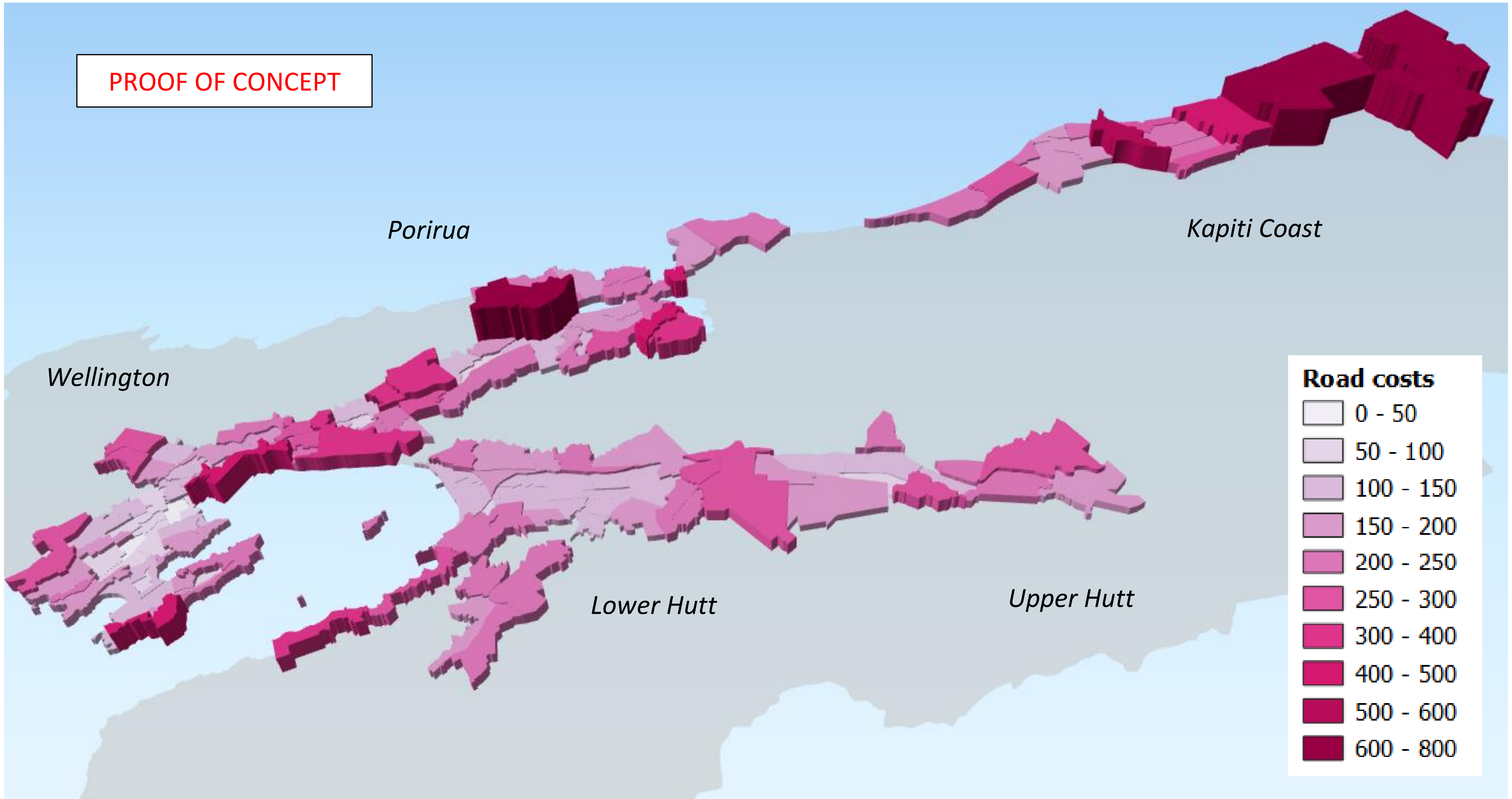
The third factor that lowers cost is to "be on the way".[23] This refers to an area that lies between a main destination and the origin of many trips. This leads to many trips passing through the area because it is on the way. And as a result, those trips end up sharing some of the cost of the 'on the way' area . While the roads would need to be bigger (and more costly) to accommodate this, economies of scale mean the per trip cost is lowered.

Some low-density areas, like Hataitai South (1,334 dwellings per km^2), also achieve costs not much higher than central city areas (local road costs of $76 per dwelling versus $97 in Courtenay with 2,700 dwellings per km^2). The reason for this is Hataitai South lies in between the eastern suburbs and the central city. This means that the roads connecting Hataitai South also connect the eastern suburbs, and thus the cost is shared with those suburbs.

This impact is also apparent at the other end of the line. Those suburbs that are at the end of the road are not on the way to somewhere else. Consequently, the roads that connect them to the next area over are not shared, and neither are the costs. This pattern is visible in figure 13 below.

[23] This is one of Jarett Walkers principles for successful public transport planning. See: Walker, J. (2009) "Be on the Way! Moral Implications of Location Choice" in *Human Transit*. Island Press.

FIGURE 14: LOCAL ROAD COSTS (ANNUAL - PER DWELLING – 2023 DOLLARS)



Source: Sense Partners

2.4. Things to keep in mind when looking at results

NZ wide spending is not a great predictor of Wellington costs

Table 3 below gives a breakdown of the estimated costs attributable to each territorial authority for the total network. This also includes a breakdown of the state highway and local road spend. These costs are made up of the share of road expenditure we attribute to light vehicles and buses. They exclude the cost attributable to non-bus heavy vehicles.

Comparing this to actual network expenditure in the Wellington Region (excluding the Wairarapa) indicates these preliminary results are optimistic. In particular, they are not a good predictor of the state highway expenditure in the region.

To go beyond a proof-of-concept, we will need to investigate access to Wellington region spend data that is disaggregated enough to identify different costs for different road classes.

TABLE 3: MODELLED ROAD NETWORK COSTS BY AREA

Area	Total network	State Highways	Local roads
Kapiti Coast	$73.6m	$68.6m	$5.0m
Porirua	$42.8m	$38.3m	$4.5m
Upper Hutt	$21.1m	$18.6m	$2.6m
Lower Hutt	$27.0m	$20.5m	$6.6m
Wellington City	$56.1m	$44.8m	$11.4m
Modelled total	**$220.7m**	**$190.7m**	**$30.0m**
Actual (2022/23)[24]	**$348.0m**	**$312.1m**	**$35.9m**

Source: Sense Partners

Table 3 above gives a snapshot of how costs in each TA compare when we include state highways and when we exclude them. The cost of the state highway network makes up the bulk of per-dwelling costs.

This is because the highway network connects the whole region, and many trip origins and destinations are both in close proximity to the state highway network. This means a large portion of the typical road trip within the region ends up going via the state highway network. In other words, it is generally a convenient option for those driving.

Proximity is a big factor in people's travel choices

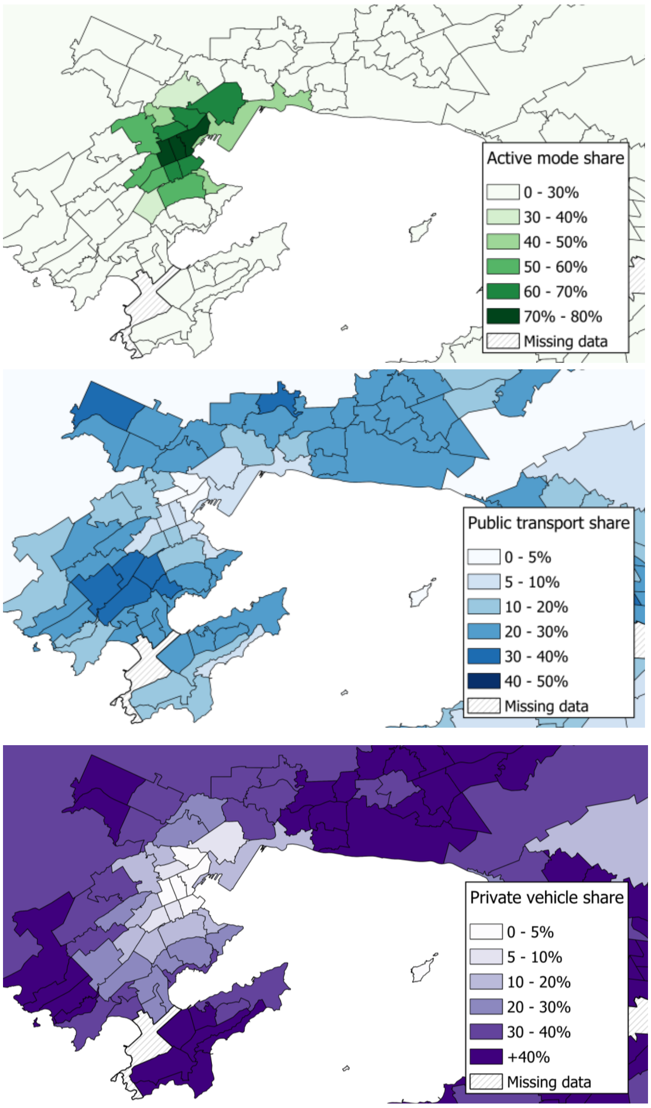
People make decisions about whether and how to travel across the region. There are many factors that go into this decision, but one of the biggest will be the "cost of travel". This is itself

[24] We apply our modelled light vehicle share to Waka Kotahi spend data.

a broad category, including things like the financial cost of travelling (such as petrol or ticket prices), the time cost, and comfort.

When we look at the census data on how people get around, we see that proximity plays the key role. Being within walking distance of your destination makes it a viable option, and so many more people opt to walk.

FIGURE 15: MODE SHARE PATTERNS – AN EXAMPLE FROM WELLINGTON CITY



- Walking dominates in the central city and adjoining suburbs.
- Mode share is very sensitive to distance, and active modes drop significantly as distance increases.
- PT mode share tends to be highest in a goldilocks zone – not too close, not too far from the centre, but "just right".
- The capacity of the road network, and how that is shared with PT, influences where "just right" is.
- Private vehicle mode share peaks further out from the city centre.
- For many, the balance tips away from PT as greater distance and more stops combine to increase travel time.

Source: StatsNZ data; Sense Partners analysis

The share of private vehicle use increases the further from centres people live. In these areas, walking isn't really an option. Public transport can be slow due to the need to stop at many stations or stops before getting to the city centre, among other factors. The result is a high share of driving.

For the same reason, public transport use is highest in areas of moderate proximity from centres. Here, walking distances are high, while buses can be fairly quick due to having fewer stops before reaching the destination. Any perceived hassle of PT isn't big enough to warrant the increased cost of driving for many.

Case study: what about public transport?

An exploratory analysis of the bus network

When looking at the road network, we see that higher density tends to go with lower costs. This raises the possibility of lowering costs by promoting density. However, shifting people from driving onto the PT network may just lead to a shifting of cost, rather than a saving.

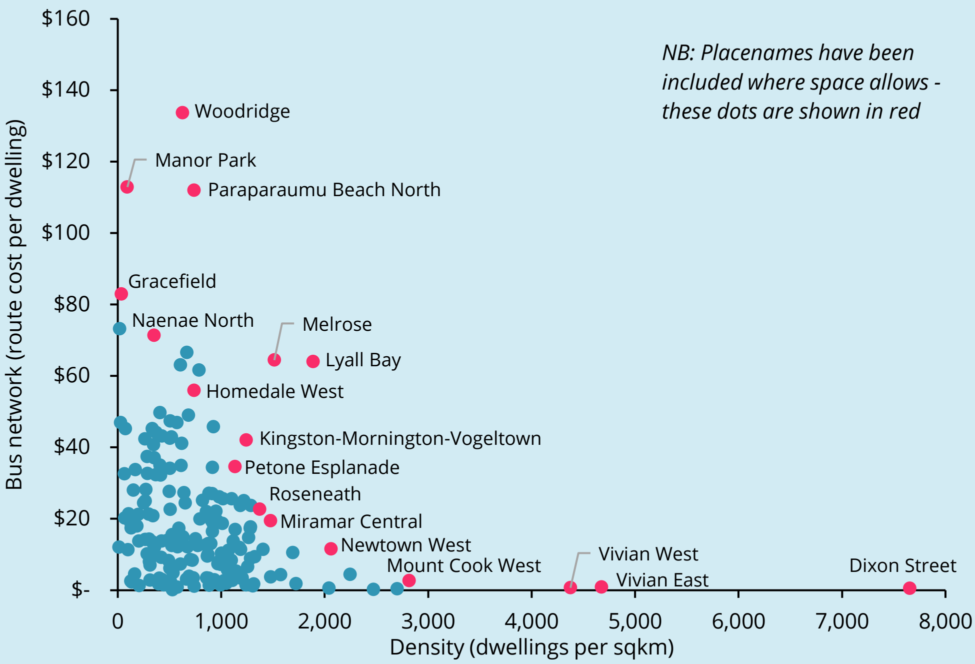
To check this, we have done an exploratory analysis of the bus network. We already account for the impact of heavy bus vehicles on road network costs. This made an extension to the wider bus service costs a logical next step.

Going beyond a proof of concept will need to account for the full PT network, including rail, ferries, and on-demand PT.

We use publicly available Metlink data on the network, paired with cost analysis from the Ministry of Transport.[25] There are fewer issues with data compared to roading or three-waters, though detailed analysis is time consuming.

Many dwellings make light cost

FIGURE 16: BUS NETWORK – ANNUAL COST PER ROUTE, PER DWELLING



Source: Sense Partners

[25] Te Manatū Waka (2022) *Domestic Transport Costs and Charges Study: Draft Report v2.1.*

Our analysis indicates that the inclusion of bus network operating costs does not lead to results that diverge from our earlier conclusions. The same three determinants of cost in the road network are also at play in the bus network. Areas with higher density, closer to major employment centres, and that are “on the way”, have lower per-dwelling costs.

Higher density areas also tend to have far greater levels of service. That is mainly because bus network converges on the central city, and that is where the density is. Our results in figure 16 adjust for this by looking at per-route costs. That is, the cost per bus route rather than the total of all routes.

Distance is important, but so is the level of service

Unlike the road network, there is no central public transport spine connecting the region whose cost is wholly covered by central government. This means that distance plays a larger role in the costs faced by local government. Enabling density in areas further away from centres will not achieve that same cost efficiency as enabling it in more proximate suburbs.

In addition, public transport costs are influenced by a fourth factor. This is the level of service that is provided. Some low-density areas have low public transport costs simply because they have few bus services connecting them. The relationship between density and cost is partly a choice of how much service we choose to provide.

Altering that level of service in public transport is a valid way to manage costs. We also find this when looking at three waters infrastructure.

3. Three waters

3.1. We apply our road modelling approach to water

Water networks have a similar hierarchy to roads

Much like the road network, water networks connect spread-out homes and businesses to centralised facilities, like reservoirs or wastewater treatment plants. The volume carried is larger nearer to the reservoir or treatment plant, meaning the pipes must be larger to accommodate this.

The network can be thought of as split into two parts. One is the transmission network, made up of larger trunk or main pipes. This conveys water from the source to a neighbourhood in large volume. The second part is the distribution network, made up of the web of smaller service pipes. These bridge the gap between the mains, and the homes and businesses in need of water.

From a modelling perspective, we aim to use this simplified relationship to attribute the costs of the network to users. This is the same approach we have used for the road network. Local service pipes that connect homes are attributed to those homes. That is a simple spatial attribution – the service pipes in that area are costed to that area.

The assets of the transmission network cannot simply be attributed to the area they are in because they connect many other areas to the source. Large reservoirs typically service many neighbourhoods, and so a share of the costs must be attributed to all who benefit from that connection.

Data on the physical network is a tightly binding constraint

Wellington Water splits the potable water network into District Metered Areas (DMAs). This approach is intended to manage water pressure and leaks by splitting the network into distinct parts. Flows between DMAs are monitored, helping to better track pressure across the network and identify where high use is.[26]

The split into DMAs is based on topology, demand, and network constraints. Each DMA is linked to a primary reservoir. We use this as the basis for allocation of transmission costs. However, it is our assumption that DMAs are not limited to that primary reservoir alone.

This may be an issue where reservoirs act as primary source to only a few DMAs but provide backup storage to a much larger number. By doing so, those reservoirs provide value which is not reflected in our allocation of costs. Better data on the water networks functioning is needed to address these issues beyond proof-of-concept.

[26] Savic, D. & Ferrari, G. (2014) "Design and Performance of District Metering Areas in Water Distribution Systems." *Procedia Engineering*.

Identifying the transmission network needs further refinement

We use publicly available geospatial data to map out the physical attributes of the three-waters network. This data identifies the shape of the network, and whether pipes belong to the transmission network or the local distribution network.

However, this breakdown of the transmission network and distribution network is not clean. For example, many DMAs are not directly serviced by pipes marked as being part of the transmission network.

This poses an issue for our modelling approach. There are pipes connecting DMAs to reservoirs and plants which we want to attribute to those DMAs. However, they are not identified as being part of the transmission network, making it difficult to identify which pipes ought to be attributed.

For this proof of concept, we have opted for a simplified approach. We allocate pipes not marked as being part of the transmission network to the neighbourhood they are in. For the transmission network, we take a different approach.

Unlike the road network, we do not identify specific transmission pipes connecting specific areas. The data simply doesn't allow for this. Rather, we attribute the total transmission network costs to areas in proportion to the distance between them and their service point (reservoir, treatment plant, etc.)

Data on the cost of the network is an even greater limitation

There is little data on water costs available in the public domain. Due to commercial sensitivity, Wellington Water require the consent of all stakeholder councils to provide more detailed financial data. This will be an essential prerequisite to moving beyond a proof of concept with this analysis.

Even with access to data, there will be challenges in interpretation. Much like roads, the annual spend does not necessarily reflect the underlying network cost. In part, this comes back to spending being a policy choice influence by many factors other than the pipe condition.

This also reflects the impact of events like the 2016 Kaikoura earthquake, which may have done considerable damage to the Wellington pipe network.[27] Current annual costs are more likely to reflect ongoing repercussions from damage and deferred maintenance, rather than an idealised, smooth annual maintenance and amortised build cost.

A previous report commissioned by Greater Wellington Regional Council quantified the expected annual maintenance cost over a 50-year lifecycle.[28] Estimates for the pressurised pipe network are set out in table 4 below, including a comparative cost across greenfields, existing suburban areas, and the central city.

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[27] Boyack, N. & Gourley, E. (2024) "Wellington's water crisis: How did we end up in this mess?" *The Post.*
[28] Koru Environmental Consultants Ltd. (2019) Economics Work Package 11: SRL1: The Urban Intervention Options Work Brief – Deliverable 2: Summary of life cycle costs for water supply infrastructure solutions.

The higher cost in the central city reflects the complexity of installing and maintaining pipes in heavily developed areas. In comparison, greenfields work is eased by the lack of existing traffic to manage, the relative lack of existing services to work around, and so on.

TABLE 4: THREE-WATERS PIPE NETWORK ANNUAL COST (2023 DOLLARS)

Diameter	Low (greenfields)	Mid (suburban)	High (CBD)
20 – 63 mm	$19 per metre	$28	$32
100 mm	$21	$33	$40
150 mm	$25	$37	$45
200 mm[29]	$29	$43	$52

Source: Koru Environmental Consultants Ltd. We update to 2023 using StatsNZ PPI index.

3.2. Our results indicate higher density lowers costs

Our results are limited to broad spatial patterns of the pipe network

Our analysis focuses on allocating the cost of the pipe network. We do not include costs for reservoirs, pumps, treatment plants, or any other water asset. The main reason for this is the relative lack of cost data on many of these other assets. That is in large part driven by how site-specific these costs are, making a generalisation difficult and probably misleading.[30]

However, we also expect the largest change in cost across different spatial forms will come from the pipe network, rather than reservoirs or treatment plants.

Because of the limitations in the data, our results should only be interpreted in terms of general spatial patterns. Little weight should be placed on the values for specific areas.

The modelled annual spend on the pipe network is set out in table 5 below. It should be borne in mind that this is a smoothed out annual cost over the life of the pipe (rather than the periodic lumpy costs as works actually occur). This also do not account for any deferred maintenance from previous years.

In the full implementation of our model further analytical work would be required to further test and establish an appropriate annual cost estimate.

[29] For pipe larger than 200mm, we apply this same 200mm costing, unadjusted.
[30] Koru Environmental Consultants Ltd (2019).

TABLE 5: MODELLED ANNUAL WATER PIPE NETWORK COSTS BY AREA

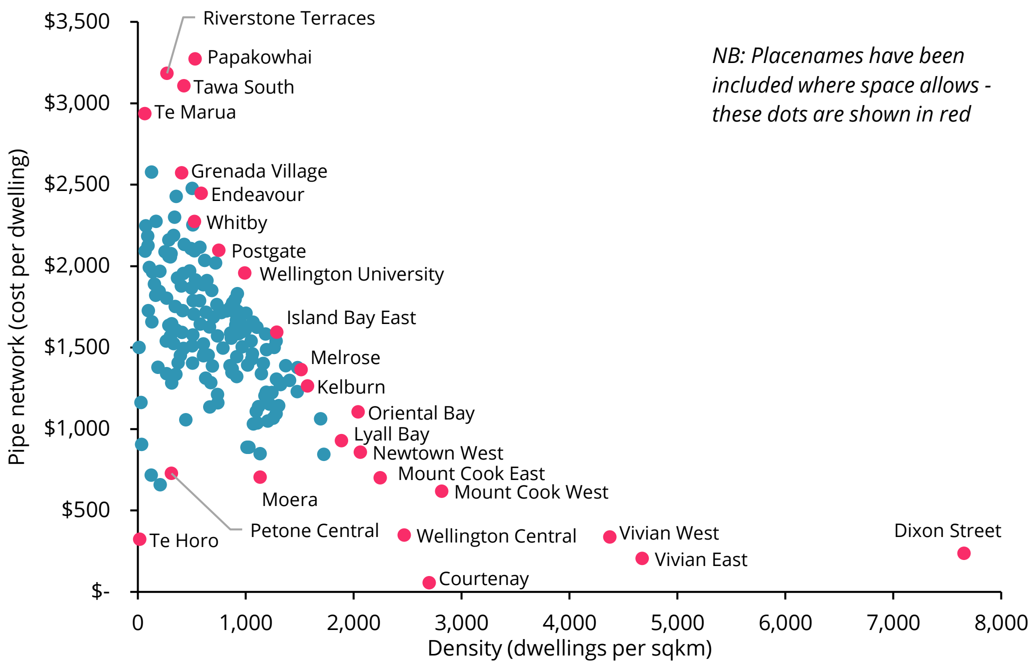
Area	Potable water	Waste water	Storm water
Kapiti Coast	$12.1m	$8.3m	$7.1m
Porirua	$12.9m	$12.9m	$8.0m
Upper Hutt	$10.6m	$9.8m	$4.6m
Lower Hutt	$21.0m	$18.8m	$12.8m
Wellington City	$38.8m	$34.7m	$19.6m
Modelled total	$56.6m	$49.8m	$32.5m
Actual (2022/23)	$126.7m	$150.6m	$60.1m

Source: Sense Partners

Table 5 also includes the actual total spent across the region on three waters in 2022/23. This is a combination of operating expenses on the whole network, not just pipes. This gives a sense of the costs not captured by the proof-of-concept model, and the work required to bridge the gap.

Our results show cost distribution similarities between water and road infrastructure

FIGURE 17: THREE-WATERS COSTS (ANNUAL PER DWELLING)



Source: Sense Partners

As with the road network, a determinant of cost is proximity. In this case, we are talking about proximity to reservoirs (for drinking water) and treatment plants (for potable and waste water). However, unlike roads, these key locations in the water network do not coincide with density.

Our results show a strong relationship between per dwelling costs and density. The higher density areas are not particularly close to reservoirs or treatment plants, yet still have lower per-dwelling costs.

Greater distance from reservoirs/plants requires more transmission pipes. Yet the difference in cost between local service pipes and transmission pipes in our model is low. The far more numerous local service pipes make up a larger portion of costs. How efficient the local pipes are used is the main driver of costs, not the distance to reservoir or treatment plant.

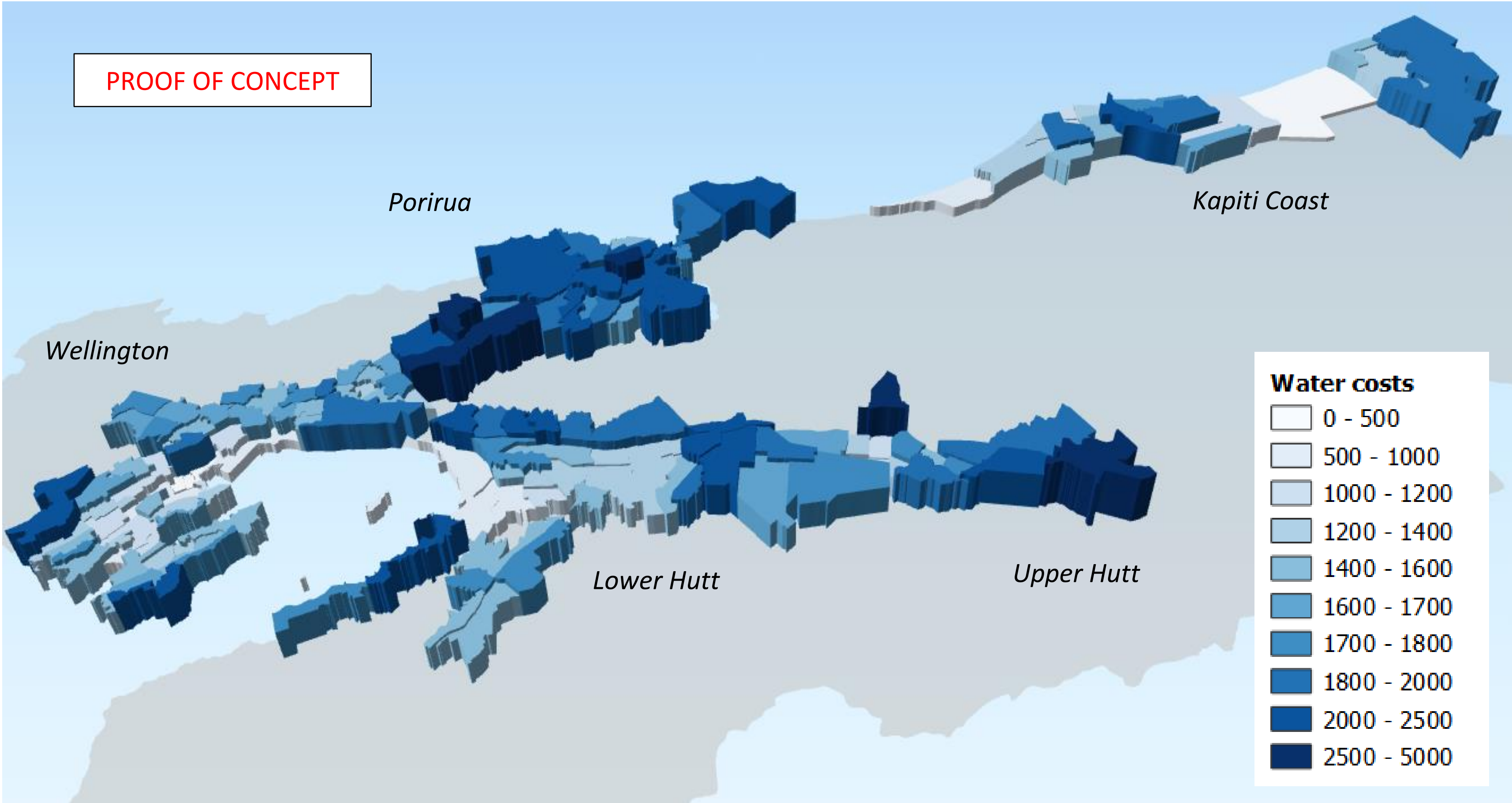
The pipes in higher density areas do tend to be larger, which our model accounts for with a higher cost. Much of this is also due to the higher cost of installing pipes in built up areas, with greater risk and complexity involved. Yet, as with roads, this higher cost is not enough to offset the scale economies of greater density.

There is also a similarity with public transport, namely the decision to provide a level of service. A good example is Paekākāriki, which figure 17 below shows to have low water costs. This is driven by the lack of a reticulated wastewater network in the area. Properties here have to have their own septic tank.[31]

In this case, infrastructure costs to council are lower because a lower level of service is provided. Managing costs is not just a case of prompting greater density. There is a discussion to be had about how much infrastructure is provided, and taking different approaches to infrastructure that can lower costs in smaller communities.

[31] Kapiti Coast District Council (2024) *Wastewater services*

FIGURE 18: THREEWATERS COST (ANNUAL/PER DWELLING, IN 2023 DOLLARS)



Source: Sense Partners

4. Matching costs and revenue

4.1. Revenue is a policy choice

We take a first look at comparing costs to revenue

We have estimated the costs of the road network and the three waters pipe network. These are significant line items in councils' budgets (29% of OPEX in the case of Wellington City, for example).[32] However, they are just four of many services provided by local government.

In figures 18 and 19 below, we match our estimate of rates revenue to the cost of providing road network and three-waters pipe infrastructure. The purpose of this is to have an initial look at whether rates revenue matches costs in each area.

We note councils gain revenue from a range of sources, including general rates, targeted rates, service charges, and grants from central government. However, we have not considered this detail within the scope of this proof-of-concept modelling. This could be part of future work, depending on insights sought by councils.

There is no automatic relationship between density and revenue

Sources of revenue are a policy choice, whether that of local government or central government. The revenue to be collected is determined, and then rates and charges for local government and road user fees for the national land transport fund are set accordingly.

This is important, because while high density areas generate a higher net revenue, that isn't necessarily going to be the case if more density is enabled. It is not an automatic relationship, and it will depend on how councils choose to allocate rates charges.

Data limitations strike again

We estimate rates revenue by area and per household using data on property valuations across the Wellington Region. This data conforms to the structure prescribed in Land Information New Zealand rating valuations rules.[33] Despite this, matching each council's differential ratings categories to individual properties proved challenging.

For example, different rates apply to properties connected to water networks, but the presence or absence of these connections was not apparent in the valuations data. Ultimately, we anticipate that if we move beyond proof-of-concept, councils will be able to provide exact data on rates by area.

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[32] Wellington City Council (2023) *Annual Report 2022/23: Volume 1: Performance Overview and Service Statements*
[33] LINZ (2010) *Rating Valuations Rules 2008.*

The spatial distribution of rates is inverse to costs

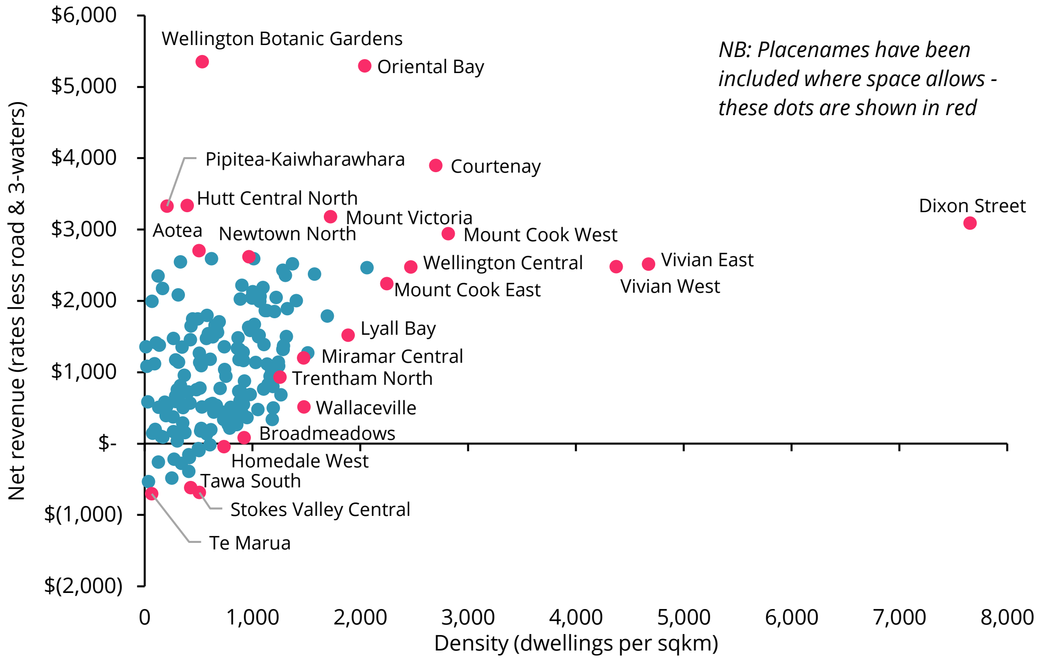
Rates are typically set as a percent of the capital value of a property. The capital value of a property is a combination of land value and improvement value. Both of these tend to be much higher in areas that are denser and more proximate to central areas.

Proximity drives the land value up, while density requires capital investment which causes a higher improvement value. There are some telling exceptions, such as the Botanic Gardens area in Wellington City. This has low density, but its unmatched proximity to the CBD means land values are substantial. This attracts a high share of rates revenue.

As our analysis has shown, these denser and proximate areas are also where infrastructure costs are lowest. As costs rise, rates tend to fall. Rates are set to cover costs at a district level, but not at a more granular spatial level.

Higher density areas have lower per-dwelling rates revenue, but even lower costs. Other areas have higher per-dwelling rates, but this is typically not enough to compensate for higher costs.

FIGURE 19: PER DWELLING NET REVENUE – RATES MINUS ROAD & 3-WATERS COSTS



Source: Sense Partners

Spatial alignment of costs and revenues could promote efficiency

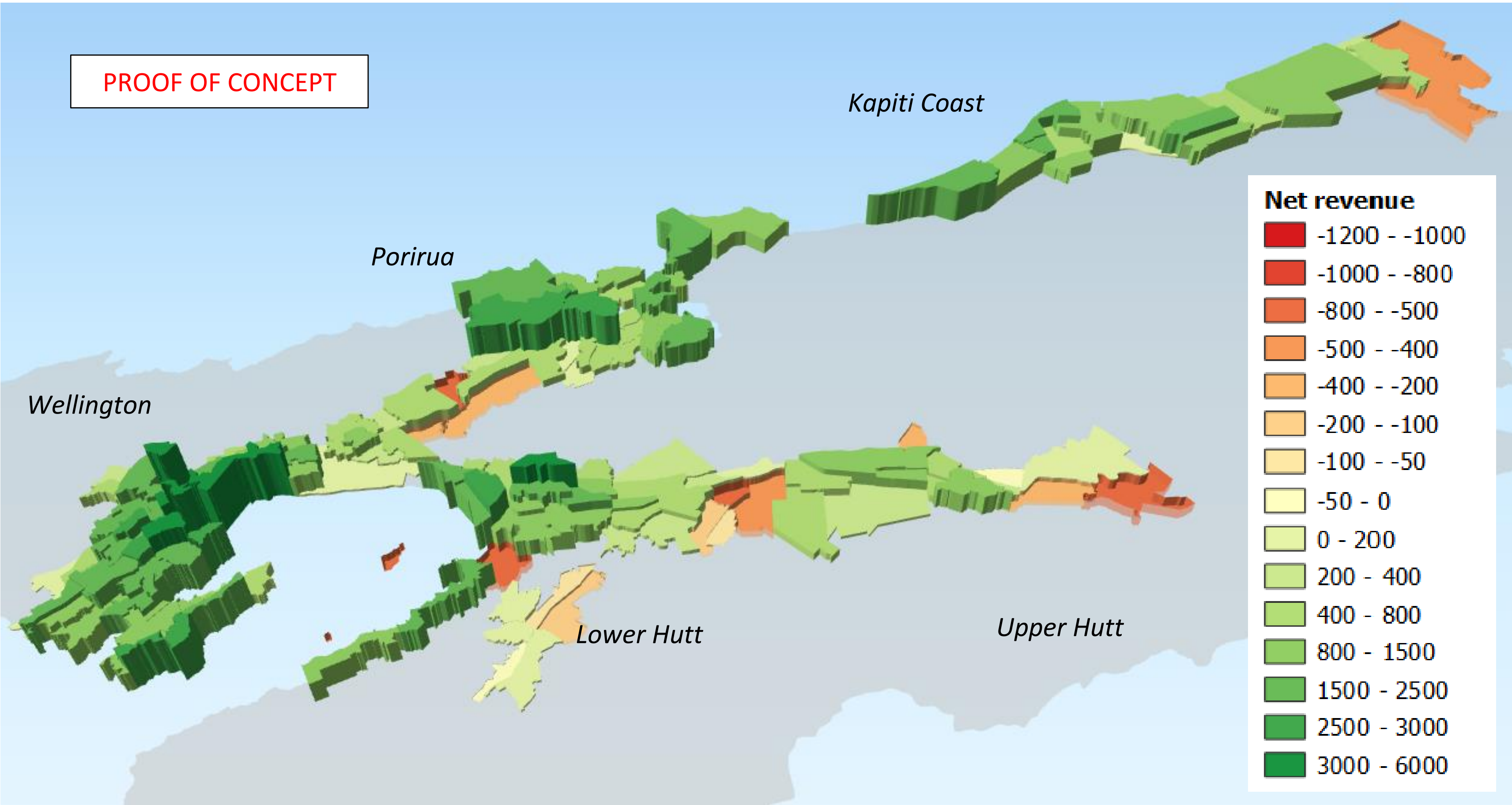
This exploration of the spatial alignment of rates revenues and costs illustrates a further use of the spatial model considered in this report. A spatial alignment of costs that are attributed to beneficiaries and revenues could promote efficiency, as discussed in footnote 6 above.

A spatial alignment of costs could incentivise a more efficient urban form by passing costs on more accurately. Faced with the full cost of local infrastructure, people may choose to live in areas with lower per-dwelling costs, whether it be from higher density or lower levels of service. This, in turn, could lower the infrastructure cost burden facing local government.

Of course, there are reasons why local government may not want to match costs to revenue. Spatial cross subsidisation could be used as an equity tool, having higher-income areas pay a share of the infrastructure and other local government services provided to lower-income areas.

It is also not the case that simply aligning revenues to costs that have been assigned to beneficiaries (by area) necessarily will result in greater efficiency. This does depend on the specific pricing design. Considering the efficiency and equity considerations of different approaches to general and targeted rating and user charges is beyond the scope of this proof-of-concept report however.

FIGURE 20: NET REVENUE (ANNUAL - PER DWELLING – 2023 DOLLARS)



Source: Sense Partners

5. Conclusion

5.1. Our proof-of-concept model shows value

Our objective was to develop a proof-of-concept

Our objective was to develop a proof-of-concept model showing how urban form influences infrastructure costs. Many studies have looked into this, finding that higher density lowers costs. They also find that cost is highly sensitive to local context.

Given this, it was important that we developed an area-specific estimate, using data on the physical network. Our model takes a first-principles approach to building an estimate of costs facing local government in road transport and three-waters.

Despite data limitations, we can still draw valuable conclusions

Data is never perfect, but there are a number of limitations in the data we use. Chief among these is the lack of publicly available data on the costs of water infrastructure. The good news is that much of this can be accessed through Wellington Water – if stakeholder councils consent.

Moving beyond a proof-of-concept will require further work on identifying region specific cost estimates for road, public transport, and three-waters infrastructure. Despite these data issues, we can still draw a number of preliminary insights that demonstrate the model's value.

5.2. Enabling density can lower costs

The way road funding is split changes what matters

When it comes to the total road network, our analysis shows that areas close to activity centres tend to have lower costs. This is caused by fewer people driving and typically driving a smaller distance. From this perspective, **density is not the cause of lower costs**, but rather **a way to take advantage of proximity, which does lower costs**.

When we look at only local roads, which are the responsibility of local government, proximity is less influential. This is because most commuter car journeys will typically go via the state highway network for a dominant portion of their distance. With the state highway network funded by central government, the role of proximity in lowering local government costs is less influential.

At a glance, this may suggest that local government ought to encourage greater density without regard to where that density occurs. In contrast, central government finances may benefit from compact growth *in certain areas*.

This change is relevant, but shouldn't be overstated

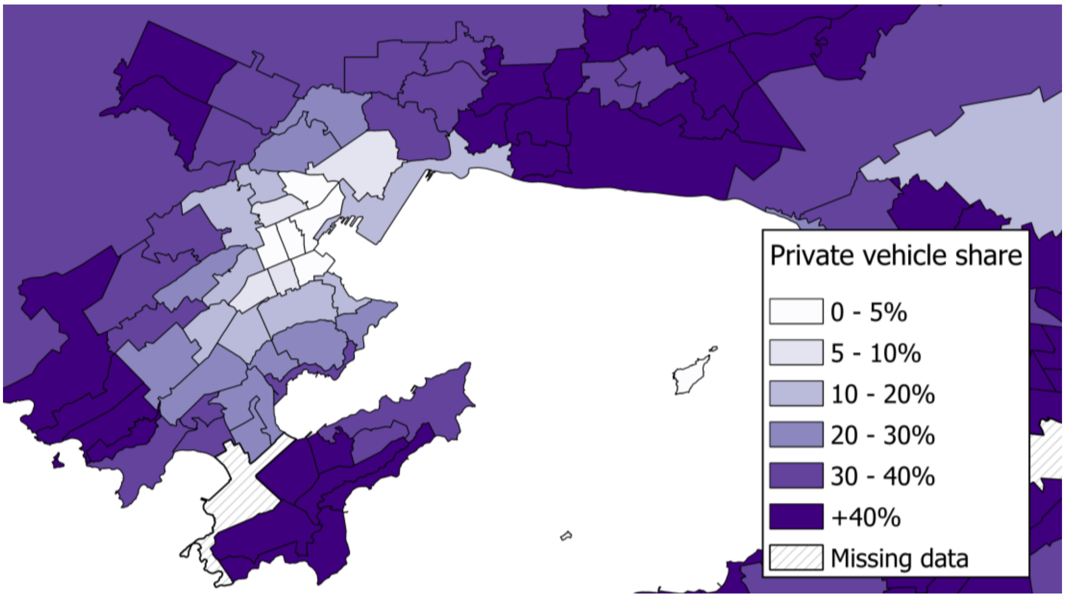
Density is the product of high land value, which in turn is caused by proximity to desirable areas. **Density doesn't cause high land value**. This is important, because we can't simply replicate the density of the central city in just any old place and expect the same result.

What this means is that density permitted further out won't have the same travel patterns. High density areas in proximity to the central city have a high mode share of walking in travel **because they are proximate. Density didn't cause the walking**. Replicating density beyond walking distance of activity centres won't achieve the same low transport cost.

There is little doubt that walking patterns won't be replicated if we shift density to areas with less proximity to centres. But what about private and public transport? The relationship between public transport and private transport is not mechanical. It largely depends on how local and central government invest in either one to improve capacity.

If growth in an area is serviced by road network expansion, then local government may benefit from the role of the central government in funding the state highway network.[34] Alternatively, if it is serviced through public transport, there is no solely central government network that covers the distance cost. In this case, proximity still matters to local government finances.[35]

FIGURE 21: PRIVATE VEHICLE MODE SHARE BY AREA, CENSUS 2018



Source: StatsNZ data; Sense Partners analysis.

[34] This depends on whether the growth is near enough to the highway network to make use of it. Residents in areas like Karori, and southern suburbs like Island Bay, will have to travel a comparatively greater portion of their trips along local roads.

[35] This assumes that people don't have strong preferences about mode (e.g. wanting to drive) and will opt for the lowest cost option (personal financial cost and time cost). If they have strong preferences, people may opt to drive regardless of the provision of PT. However, they will soon need to contend with the limited capacity of the road network, particularly if they are not willing to pay the high cost of expanding said network.

Proximity to public transport can yield economies of scale

Our exploratory analysis of the bus network indicates that there are economies of scale in public transport.[36] Adding new users lowers the per-person cost for existing users. This can be seen in the areas with relatively low density but also very low bus cost.

They happen to be on routes that connect many other areas to centres of employment. Large portions of their bus journeys are shared with many others, and consequently the costs are lower. This means that while proximity to the city centre lowers costs, **proximity to public transport spines also lowers costs**.

For three-waters, proximity is far less influential on costs

The cost data we use applies a higher cost to larger pipes, imparting a higher cost to the transmission network. Despite this, proximity to reservoirs and treatment plants is far less influential on costs than density. Ultimately, the local pipe network makes up the highest cost.

Higher density means economies of density can be achieved. Larger pipes are required, which do cost more. But the increase in dwellings that can be services is proportionally greater. This lowers per-dwelling costs. By far the lowest per-dwelling costs are in dense central city suburbs.

5.3. Density can help the city grow, affordably

Our region is growing, at the same time we face a huge bill

Our region is growing. The population is projected to increase by 187,000 residents by 2052.[37] New residents increase productivity and vibrancy. We don't want to exclude these new neighbours.

This growth will require investment in our infrastructure. We will need new homes, services by pipes and connected via the transport system. This is a considerable planning challenge in its own right.

However, we also face two additional challenges on top of meeting growth. First, the impacts of climate change mean our cities need to be more resilient to heavy rain and sea level rise. Our cities will need to be increasingly hydraulically neutral, with additional flood-protection infrastructure.[38]

Second, our existing networks are not in good shape. This is most acute in three-waters. Wellington Water estimates a cost of $30bn over the next 30 years to maintain and grow our water infrastructure.[39]

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[36] This is not a novel finding. For a good summary see: Ian Wallis Associates Ltd. (2023) "Appendix 1: User Economies of scale (Mohring effect), in *Domestic Transport Costs and Charges Study: Working Paper C12 Urban Public Transport*. Prepared for Te Manatū Waka Ministry of Transport (NZ)

[37] Greater Wellington (2023) *Wellington Regional Housing and Business Development Capacity Assessment*

[38] Wellington Water (2023) 2023-34 Investment Planning and Advice: Wellington City Council: Set 2: Council direction on investment options – pre-reading.

[39] Radio New Zealand (2023) *Wellington's water woes could cost $1 billion a year to fix.*

Our results show that urban form plays a role in shaping this cost

Enabling density will help to lower the per-dwelling cost of transport and three-waters infrastructure. This will accommodate growth at a lower cost. The benefit of this is increasing the ratings base, sharing the burden of existing infrastructure costs across more households.

For areas where no density is enabled or likely to be achieved, a frank conversation may be needed around levels of service. Where residents are not willing to pay the high cost of low-density infrastructure, they may need to accept a lower level of service. Some may be happy with this trade-off, just as some may be willing to pay the price for good services.

Developing our model will help analyse these complex trade-offs

Our proof-of-concept has yielded some valuable insights. Advancing beyond a proof-of-concept offers the chance for detailed assessment of infrastructure costs by area, and to what degree local beneficiaries pay for it.

Looking toward a growing region, a developed model will help accommodate new neighbours in the most cost-efficient way. The evidence base this model establishes will offer a firm foundation for more complex scenario modelling of urban growth.