Tauranga City

ATTACHMENTS

Ordinary Council meeting
Separate Attachments 1

Monday, 4 September 2023

Table of Contents

International Experience and Policy Trends in Urban (Including Dynamic) Road Pricing

Variable Road Pricing Study - Tauranga

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Table of Contents

Sensitivity: General

International experience and policy trends in urban (including dynamic) road pricing

1.1 Introduction

The purpose of this paper is to provide a high-level summary of international experience and lessons learned in implementing urban road pricing schemes around the world, including dynamic road pricing. This paper takes into account the context of the scale, geography, urban form and transport mode use patterns of Tauranga City in reviewing the experiences of cities across the world.

The paper is structured as follows:

- Definitions of urban road pricing, dynamic road pricing and types of urban road pricing scheme concepts;
- Identification of relevant urban road pricing systems based on functionality, rationale and scale, taking into account the conditions of Tauranga
- Summary of the characteristics of cities with urban road pricing systems, noting those with smaller populations and higher mode share by car;
- How policy objectives for urban road pricing schemes affect pricing strategies;
- Implementation considerations;
- Impacts of urban road pricing schemes;
- Modelling of operational urban road pricing schemes;
- Summary of current trends of urban congestion pricing systems, and the latest developments of policy and studies (noting specifically Singapore and Brussels, and recent studies in Australia);
- Summary of key elements in development of options for The Congestion Question and for Let's Get Wellington Moving;
- Policy issues: revenue management and system governance; and
- Key conclusions.

1.2 Definitions

Urban Road Pricing

The term *urban road pricing* is used in this paper to describe any type of pricing of existing roads that only operates during specific times of day (and days of the week). It is distinguished from tolling (as is applied in Tauranga) in the following ways:

- Tolls are used *exclusively* to recover capital (and operating) costs of the tolled infrastructure;
- Tolls operate 24 hours a day, seven days a week to maximise net revenues (and because all vehicles using the tolled road are expected to contribute towards the costs of that infrastructure), rather than seek to change behaviour;
- Tolls *may* be removed after the capital costs of the tolled road have been fully recovered, so that the ongoing maintenance costs are recovered from general highway funding (through the National Land Transport Programme).[1]

Urban road pricing may be applied to a single point on a road network, or onto an entire network of roads, with its purpose being primarily to *change road user behaviour* and raise revenue, which may or may not be applied to the network being priced. Although the primary objective of an urban road pricing scheme may be either behaviour change or revenue generation, any urban road pricing scheme will cause behaviour change (because it increases the price of travel on that road at specific times for specific types of vehicles) and will generate net revenues (as it is fundamentally a tool of revenue collection).

Urban road pricing is not permitted in New Zealand under existing legislation, which is specifically confined to permitting tolling on new road infrastructure for the purposes of recovering the costs of planning, designing, supervising, constructing, maintaining and operating that infrastructure.

Urban road pricing does not include regulatory measures, such as low/ultra-low emission zones (which apply charges or fines for vehicles that don't meet specified emission standards) or time/location-based restrictions on vehicle access. Generally such measures are not introduced to raise revenue, nor to reduce congestion, but rather to lower noxious air pollution and improve local amenity by reducing traffic volumes in sensitive locations.[2]

Managed lanes

Managed lanes is a term that encompasses any road lanes that have controls on access limiting them to a subset of vehicles which may be based on either the vehicle characteristics (e.g., bus lanes), vehicle occupancy (e.g., transit or High Occupancy lanes) or price (tolled or High Occupancy Toll (HOT) lanes). These controls only apply to selected (not all) lanes within a corridor, with general (unmanaged) lanes continuing to exist with no such controls. If all

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[1] The Land Transport Management Act 2003 (ss. 46-55) enables tolling for new road capacity only and requires that there be a feasible untolled alternative route.
[2] Low-emission zones are widespread in Germany and increasingly being introduced in UK cities. Regulatory access schemes are widely used in Italian cities to limit vehicle access to residents' vehicles, service vehicles and local deliveries.

lanes are managed by regulation, the road is only for a specific class of users (e.g., a busway) or if by price, the entire road is effectively subject to a toll or an urban road pricing scheme.

Types of urban road pricing schemes

There are five general types of urban road pricing scheme

<u>Cordon:</u> A cordon places a virtual line across a series of roads, so that all trips in either one or both directions across that line are subject to a fee during specific times of day. This type of scheme is seen in Singapore, Stockholm, Gothenburg, Abu Dhabi, Milan, Oslo, Valetta, Tehran and Durham. A cordon is a recommended option for the Auckland city centre from The Congestion Question study.

Cordons can be applied in a single direction of travel, or both, and may be applied for peak periods only, or all day, with charges varying on the time of day. All cordons apply similar charges for entering the cordon regardless of location, but multiple cordons may be applied concentrically (e.g., Oslo) with different charges.

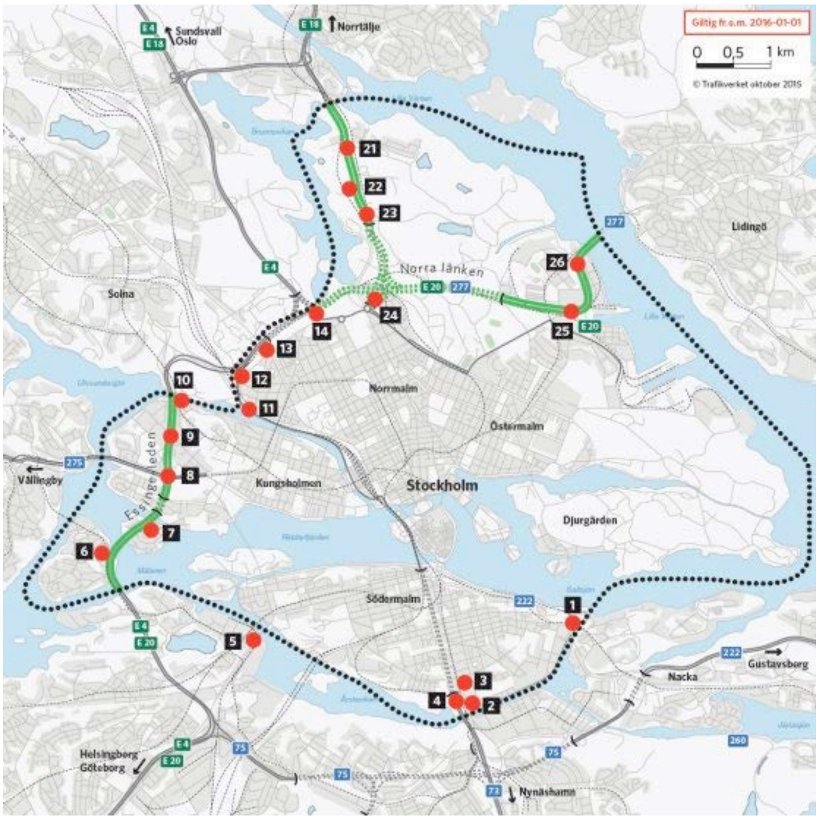

Figure 1 Stockholm congestion tax cordon with charging points

Sensitivity: General

Figure 2 Oslo's triple cordon ("toll ring")

Area: An area charge is similar to a cordon. However, in addition to trips that cross the cordon, an area charge also charges trips that commence (and may terminate) within the boundaries of the cordon. Unlike cordons, which can distinguish between individual trips crossing specific points (using fixed infrastructure at the cordon points), area charges are applied by having a network of points for charging to attempt to capture all vehicle movements within the area. As a result, area charges apply a single fee for all trips regardless of direction of travel, within a charging period. The only operational area charge scheme is London.

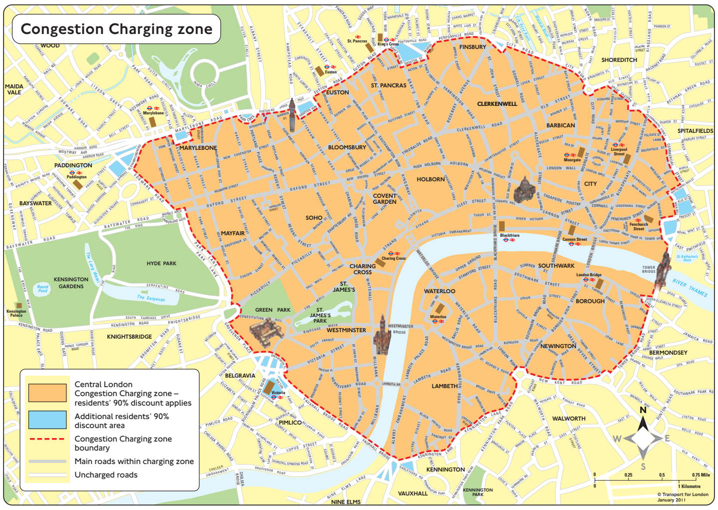

Figure 3 London Area Charge

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<u>Corridor</u>: Corridor charges are like tolls in that they may be applied to a single road, or all roads in a corridor, at one or multiple points, in one or both directions of travel. Charges can vary at each point, in either direction. Multiple corridors may have charges applied that vary by location and time of day. Singapore, Dubai and Seoul all have corridor charging schemes of various scales of operation.

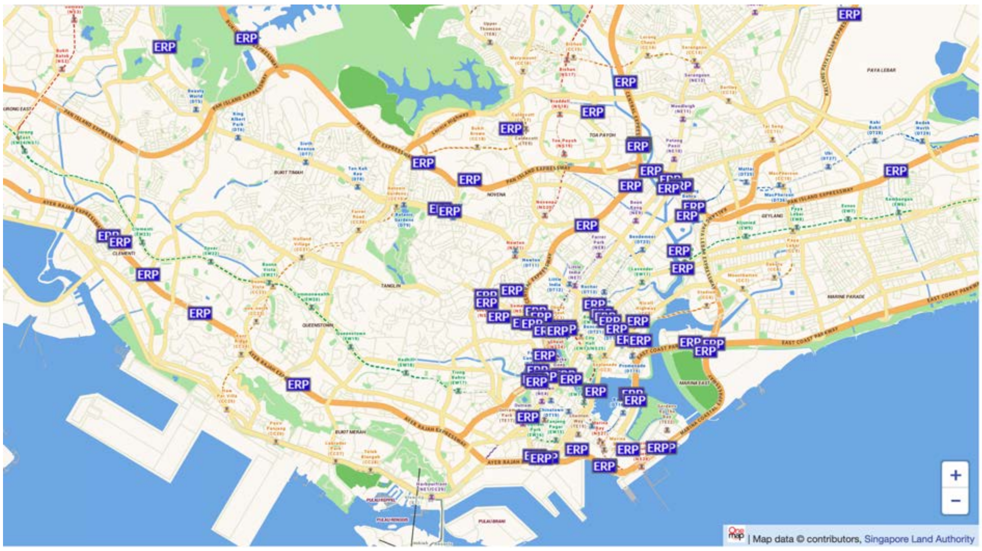

Figure 4 Singapore Corridor (and cordon) charge points

<u>Network</u>: Network pricing applies charges to use most or all roads within a defined location, by metering their road use by distance. Such charges vary by time of day and may also vary by location. No current urban road pricing schemes are network charges, but the Brussels-Capital Region Government in Belgium is planning to pilot network charges across the city/region, which vary by time of day and type of vehicle. The programme, called Smartmove, intends to trial replacing annual vehicle registration fees (which average around €1,000 a year) with a distance-based network charge, with higher charges during peak periods.[3] The technology proposed is to use mobile phones, supported by an extensive network of automatic number plate recognition cameras. There have been various proposals for network based urban road pricing schemes advanced in the UK, Netherlands and Finland, none of which have progressed, due to public opposition. New Zealand's Road User Charge system is a basic version of network road pricing, albeit applying to all public roads, with no differentiation by time of day, with variations by vehicle type.

<u>Priced, managed lanes</u>: There are two main types of priced managed lanes (including either newly built capacity or existing capacity converted to a priced managed lane:

[3] https://smartmove.brussels/en

- High Occupancy Toll lanes (HOT lanes). Lanes that allow high-occupancy vehicles (HOVs: those with two or three or more occupants) to travel untolled but permitting other vehicles to use them for a toll.

- Toll lanes. Lanes that only permit access for a toll.

HOT and toll lanes may have set prices for specific times in specific directions or may have prices that change in near real time (dynamic pricing) to manage demand to sustain a declared level of service. Pricing is applied to new capacity to ensure that demand is managed so that the improved level of service from the new capacity is sustained, and that those benefiting directly from the new capacity (although not those benefiting from the shift from the old capacity to the new capacity) pay for it. There are around 53 HOT or toll lanes in the United States and one in Israel. Most such HOT or toll lanes are formerly HOV lanes that have been converted to HOT lanes in order to increase their utilisation. A small proportion include brand new capacity or links that connect HOT or toll lanes so that they form a "network" of priced managed lanes.[4] However, rarely do new toll or HOT lanes raise enough revenue from tolls to pay for their construction.

A key feature of priced, managed lanes are that they are the only example of *dynamic* rather than *variable* road pricing. Priced, managed lanes are always placed on limited access highways (so access to and from the priced lanes can be controlled and enforced), with at least two untolled lanes in each direction, and sufficient distances between entry and exit points to avoid the need for vehicles to weave from the tolled lanes across untolled traffic. Such conditions do not exist on any highways existing or planned for Tauranga in the foreseeable future.

[4] See LA Metro Express Lanes https://rafu.com/wp-content/uploads/2012/07/ExpressLanes_Map_Toll_Entry.pdf

Sensitivity: General

1.3 Variable road pricing and dynamic road pricing

For the purposes of this paper, it is important to clearly distinguish between variable road pricing and dynamic road pricing.

Almost all urban road pricing systems have *variable* pricing.[5] Variable pricing, is road pricing that varies by time of day and location, beyond the general operating hours and location of the road pricing scheme. This is seen most obviously in Singapore's Electronic Road Pricing (ERP), where each charging point has different prices across a day. As can be seen in Figure 5, this means prices are set in blocks as short as five minutes, so that drivers do not drive erratically to avoid large increases in charges. Each charging point in Singapore has a different price schedule for different times of day and direction of travel.

Variable pricing is regularly reviewed and changed according to network performance measures. In Singapore pricing is changed at four-monthly intervals following a review of speeds at each charging point, with prices being increased or reduced (or applied for longer or shorter periods) according to that review. Singapore applies a metric of performance of speeds of 45-65 km/h for expressways and 20-30km/h for local roads (with higher speeds resulting in lower charges and lower speeds higher charges). This has proven to be highly successful in managing congestion and (with the exception of occasional incidents, such as accidents or vehicle breakdowns) maintaining acceptable levels of service on roads subject to pricing.

PIE into CTE (42)

Cars/Light Goods/Taxis (Weekdays)

07:00 - 07:30	$0.00
07:30 - 07:35	$0.50
07:35 - 08:00	$1.00
08:00 - 08:05	$1.50
08:05 - 08:30	$2.00
08:30 - 08:35	$2.50
08:35 - 09:55	$3.00
09:55 - 10:00	$1.50
10:00 - 22:30	$0.00

Figure 5 Singapore ERP variable pricing for a single corridor charging point

Road pricing systems in Sweden, Norway and Malta also have prices that vary by time of day (their road pricing system operating hours. In all of these cases, the relevant cities have found that variable prices deliver significant positive results in reducing peak traffic volumes and congestion. In Stockholm, it is notable that around half of trips that changed behaviour at the

[5] Some have fixed pricing, with a single rate during charged periods. London, Abu Dhabi and Milan are examples of those with fixed pricing.

peaks changed mode of travel, whereas others either changed time of travel or did not travel. By contrast London does not have variable pricing, as it is the same price to drive within the central London congestion charge zone at any time during its operating hours. The price is either on or off.

Dynamic pricing is a form of variable pricing that is not fixed in advance of the day of travel, but pricing that varies according to real-time demand on a specific road or lane (typically within a range of prices). Pricing may apply at all times (24/7) or just at specific operating times at a minimum rate (e.g., a base rate of say 70c to recover transaction costs), or only during specific times, with rates varying during those times. In some cases pricing may only operate in one direction of travel (as in reversible priced managed lanes)

Dynamic pricing has only been implemented on priced managed lanes, it has not been implemented nor is planned to be implemented in any cities for any other type of urban road pricing scheme.

The advantage of dynamic pricing over standard variable pricing is that it can be used to sustain a level of service regardless of variables in specific conditions (such as weather, accidents) in near real time. This also provides a clue to road users of overall demand and conditions on alternatives, as the higher the price, the more likely is it that alternatives are significantly inferior in terms of travel time.

For dynamic pricing to work effectively requires the following characteristics:

- There must be price certainty when price is notified to the driver. The price offered must be the price paid by the motorist at the time of using the road. This means the driver must be aware of the price at the time of choosing to use the route, so the driver can choose to continue to drive or to choose an alternative option.
- Price notification needs to be made in advance of the priced route so the driver can make an informed decision and consent to the price, with the final price notification by some form of electronic notification by signage at the final decision point before using the priced route. Awareness before starting a trip may be insufficient if the driver has to travel for some time/distance before reaching the priced road, during which time the price may have changed due to demand.
- Pricing must be able to be changed with little to no notice reflecting levels of demand if it is to strictly maintain levels of service.
- The choice of alternative must be easy and safe to make.

These characteristics exist for priced, managed lanes because the priced lanes simply provide a premium service parallel to unpriced lanes on exactly the same corridor. The default option is not to use the priced lanes, with the priced lanes available if the driver is willing to pay for the expectation of a faster, smoother drive. This choice is simple: use the priced lanes or remain on the unpriced lanes. This is much more complex and difficult for urban road pricing schemes that apply a price to all lanes on a route or routes to a destination. The alternatives of another route may not be available, and the alternative of another mode may not be apparent or convenient (unless a significant proportion of trips parallel a frequent public transport service). It is unlikely to be reasonable or safe to expect a motorist to choose at the final second to stop or find somewhere to wait until prices drop to a level acceptable to the motorist.

For example, if there were a cordon around central Tauranga with dynamic pricing, and a motorist wished to drive from a home in Te Puna to employment in Mt. Maunganui in the AM peak:

That motorist may be able to check before departure what the price is *at that time* from home (say $2), but a dynamic pricing system may mean the price increases during the 15 or so minutes between home and the cordon (because many more vehicles crossed the charging point during that time). If the motorist approaches the cordon and is advised by an electronic sign of a new higher price (say $5) and regards the newer higher price as “unacceptable” what options does the motorist have? To divert along a much longer route may be too inconvenient, to stop to find a park for a bus service would require the availability of convenient carpark with high quality frequent services (to the required destination) to be desirable, and to change time of travel would also likely be inconvenient once the journey has begun (the motorist is unlikely to return home and waste more time).

It is unlikely that the motorist facing a higher price once reaching the cordon would change behaviour on that occasion. However, on a subsequent day the motorist would likely *assume* there would be a price range for the cordon at the time she wishes to travel. Then would decide whether to drive or not at that time (comparing travel time, route and modal choices based on an assumption of price, not the actual price). Therefore, the impacts of dynamic charging on regular road users would be quite limited, as they would choose to accept a range of prices for a specific time period and drive regardless. It is unlikely that there would be significant benefit from dynamic pricing over variable pricing.

Critical to the success of urban road pricing is for drivers to be able to make a relatively simple comparison of the costs of travel (both financial and in time, comfort factors) before making a choice about when and how to travel. Variable pricing can enable this, although it may not always ensure the target level of service at all times in ensuring a minimum level of service, it can do so on most occasions (as witnessed in Singapore), and it can allow for changes in pricing to adjust to changes in demand. Dynamic pricing does not enable a simple comparison to be made, but although it may help provide a minimum level of service, it would only be effective for discretionary trips at short notice for drivers whose journeys started adjacent to the charging point.

In theory, such a system could be augmented by enabling motorists to book slots, prepaying at a price based on forecast demand (with pricing increasing as more slots are booked). This would mean the system is dynamic at booking time (like airfares and hotel rooms) rather than dynamic at travel time. For example, this would have serious implications for people wanting certainty about the costs of their daily commute, which is likely to be highly controversial and unworkable.

Dynamically priced managed lanes operate well for two reasons:

- Optimising level of service for the managed lanes (as a premium product that is a choice);

- Optimising utilisation (and revenue) for the priced capacity (by enabling prices to be as low as is viable to encourage use during off-peak periods, and maximising revenue and lane throughput during peak periods).

Essentially, dynamically priced managed lanes operate in a quasi-commercial sense, in that they are capable of revenue maximising for the priced capacity, by balancing demand and price in real time. Although generation of revenue is the primary objective of some urban road pricing schemes, it is not in the context of revenue maximisation in the commercial sense.

Airlines operate a dynamic pricing model, albeit for reserving seats on flights. Their objective is revenue maximisation, which sees prices heavily discounted if demand does not meet forecasts, with literally dozens of fare class categories (for essentially the same product) ranging from deep discounts to full price. The goal being to maximise revenue from sales, not merely fill the flight. For roads, there is no system of reserving “slots” on the network, but if there were, it could be easy to deep discount motorists willing to book and pay early for non-refundable slots at busy times, and to charge very high prices for those turning up “last minute” to drive. Although all of this might be theoretically possible, it is difficult enough already to obtain public support, political consent and social licence to introduce basic variable urban road pricing.

It is notable that Singapore has 47 years of experience of urban road pricing (of which 20 years has been with electronic technology) and is currently implementing a GNSS (Global Navigation Satellite System) based next generation pricing system to replace existing technology, and is *not* considering dynamic pricing. Its current plans are to simply replace the existing system with new technology and deliver better trip data to drivers, with the flexibility to add new charging points (without the need for expensive fixed infrastructure) or introduce distance-based charging. Dynamic pricing is not being considered. Similarly, early discussions on options for a next generation system for London are talking of distance, time and location based variable charging, but not dynamic pricing. This indicates that both cities do not see sufficient merits in having prices change in real time, compared with expanding the scope and the levels of disaggregation (by location, time of day and direction of travel) of existing variable pricing schemes.

Importantly, for a city with residents that only have experience with conventional tolls, it would be a significant leap in sophistication and complexity to move to dynamic road pricing, having had no experience of variable road pricing by time of day, or even a more simple basic peak price only scheme (see Figure 6). A shift to peak only tolls or a Stockholm/Singapore level type of variable pricing would be a significant advance on the status quo. Note that The Congestion Question has *not* progressed dynamic pricing, in part because of the difficulties in providing certainty to regular commuters as to the price of their commute, the lack of net benefits of dynamic pricing compared to variable pricing and also concern that radical shift from unpriced roads to dynamically priced roads, with no unpriced similar alternative would be unacceptable.

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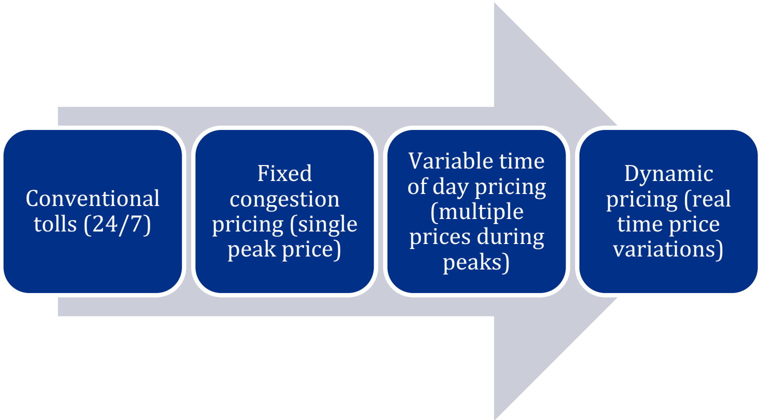

Figure 6 Levels of urban road pricing complexity

Sensitivity: General

1.4 Characteristics of cities with urban road pricing

Background

Fourteen cities have urban road pricing systems on existing roads.[6] Of those, all but London, Dubai and Seoul include cordons, whereas Dubai and Seoul[7] consist of corridor charges (Singapore, and the cities in Norway and Sweden with urban road pricing have both cordons and corridor charges). Figure 7 identifies those cities, as well as several cities (Brussels, Doha, Hong Kong and New York) which have announced an intention to progress with urban road pricing.

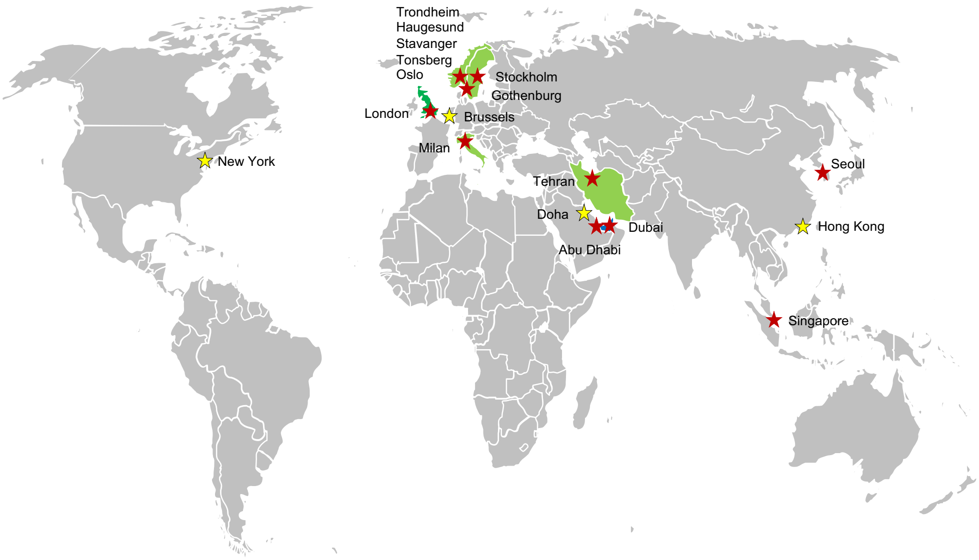

Figure 7 Cities with urban road pricing and announced intention to introduce road pricing

The cities with existing systems (excluding those with managed price lanes) are summarised in Table 1 below. This outlines at a high level how each city's scheme works (the degree to which charges vary by time of day or location), the primary objectives of each city scheme, and the scale of implementation (and type of road pricing scheme introduced or planned, according to the scheme types described above. Most have a mix of cordon and corridor charges, with a range of primary objectives, although most only have a simple structure of variable charges with charges during peaks that are higher than interpeak charges. Higher levels of charge disaggregation are seen only in Singapore, Stockholm and Gothenburg (which have a range of charges through peak and off-peak periods designed to spread demand).

City	Functionality	Objectives	Scale
Singapore	Charges vary by time, location and direction of travel	Congestion	Central city and main corridors

[6] Excluding two cities with historic urban centre protection-based schemes (Durham and Valetta) and two smaller Norwegian cities with urban cordons that operate 24/7.
[7] Seoul has congestion pricing on two tunnelled highways within a single corridor (Namsan #1 and #3).

Sensitivity: General

Oslo	24/7 charging with peak fees	Revenue, emissions, congestion	Triple cordon from inner city to outer suburbs
London	Flat charge 0700-1800 weekdays,1200-1800 Sat/Sun	Congestion[8]	Area of central city only
Stockholm	All day, higher at peaks than interpeak	Congestion	Cordon and one corridor (central city)
Gothenburg	All day, higher at peaks than interpeak	Revenue	Inner city cordon and two adjacent corridors
Milan	All day flat charge	Emissions	Central city cordon
Abu Dhabi	Peak only charges	Congestion	Central city cordon
Dubai	24/7 charging	Congestion	Seven corridors
Seoul	All day charging (HOV exempt)	Congestion	Two corridors
Stavanger	All day charging with peaks	Revenue	17 corridors
Trondheim	All day charging with peaks	Revenue, emissions	Eight corridors
Tonsberg	All day charging with peaks	Revenue	Outer cordon
Haugesund	All day charging with peaks	Revenue	Seven corridors
Cities considering road pricing			
New York	All day charging with peaks	Revenue	Central city cordon
Brussels	24/7 charging by distance with peak charges	Congestion/ emissions	Full network
Doha	All day charging	Congestion	Cordon
Hong Kong	Peak only charging	Congestion	Cordon
Auckland	Cordon/corridor	Congestion	Inner city cordon and corridors

Table 1 Functionality, rationale and scale of cities with urban road pricing

What types of cities introduce urban road pricing?

Although some of the cities most well-known for urban road pricing (i.e. London, Singapore, Stockholm) have populations well beyond that of Tauranga's current and projected population, notably higher population densities and concurrent high frequency public transport services, there are a handful of cities with lower populations and densities (and public transport service provision) with urban road pricing and many large, high density cities without urban road pricing.

Urban road pricing is comparatively rare internationally, because the primary barriers to its introduction are not technical or even geographical, but rather public acceptability (which is a function of policy and concept design, and clarity of objectives and communications) and political will. One of the key early conclusions of The Congestion Question work in Auckland was that public acceptability was the critical factor that saw urban road pricing policies be advanced to implementation or be stalled and abandoned (even following several years of planning and previous political agreement to proceed).

Leaving aside the complex issue of developing and sustaining public acceptability (and political will), there are some characteristics common to virtually all cities that have introduced urban road pricing schemes:

- Road use trip patterns have regular peaks of demand by time and location;

[8] Hours have been extended beyond congested times to raise revenue.

- Traffic congestion is widely accepted as a serious problem, unable to be resolved by simply building new road or public transport supply; and
- Sufficient geographic concentration of trips at peaks to enable an initial implementation of urban road pricing to have some demonstrable effectiveness.

The last point is notable, whether it be a central city area or a specific corridor (e.g., Seoul has only introduced pricing on two tunnels), the road network geography and trip patterns need to be sufficiently concentrated (and constrained) at specific points, corridors or areas to enable a concept to be implemented as a first step and be effective. In many cities this initial implementation may be the end point (see London, Gothenburg, Milan, Dubai), for others (Singapore, Stockholm, Oslo) the scheme geographical scope expands over time to respond to traffic issues more widely.

Table 2 depicts the population, population density and private car mode share for commuting, for cities with or considering urban road pricing. Population essentially illustrates potential for trip volumes, population density the concentration of trips by origin/destination and potential for modal shift, and private car mode share illustrates the proportion of trips that are taken by public transport and active modes.

Although most cities with urban road pricing have higher populations and population density than Tauranga (with lower mode shares for private cars, several have lower populations and densities (notably smaller Norwegian cities).

Most cities with urban road pricing have much lower commute mode shares for private cars (including passengers) than Auckland or Tauranga, though some have mode shares ranging from 60-70% (particularly the smaller Norwegian cities and Gothenburg). It should also be noted that the *proportion* of private car trips in cities with urban road pricing that are captured by road pricing schemes is in many cases, not high. This is because such schemes typically focus on the most congested roads at congested times, so many trips can be undertaken in other locations and in the busiest locations at off peak times.

Many urban road pricing schemes apply to a relatively small geographic areas (e.g., London's congestion charge covers 1.3% of the metro area) and proportion of city traffic (8% of distance travelled). Similar conditions apply in Stockholm (20% of trips subject to the charge) and Milan, but in Gothenburg the pricing scheme is proportionately larger in its scale than those cities (see Figure 8). Although no statistics have been sourced for the proportion of vehicle trips captured by the Gothenburg scheme, it is likely given the traffic volumes on the routes that are charged, to be approximately 40-50% of trips during an average weekday.

Sensitivity: General

Figure 8 Gothenburg congestion pricing scheme (circle is the CBD, dotted circle is the main traffic bottleneck (pre-charging)

Singapore and Oslo also have urban road pricing schemes on a relatively large scale, as Singapore has expanded its Electronic Road Pricing (ERP) scheme to address to traffic congestion beyond the inner city, so that all major corridors leading towards the central city have congestion pricing (see Figure 4). Oslo's scheme has expanded in recent years to implement three sets of cordons (with corridor charges) that now charge around 75% of traffic circulating during weekdays in the Oslo metropolitan area (see Figure 2).[9]

City	Metro pop.	Metro pop. Density	Private car mode share (commute)[10]
Singapore	5.5m	7,804 km^2	22%[11]
Oslo	1.6m	3,867 km^2	30%[12]
London	14.4m	1,510 km^2	37%[13]

9 Source: http://www.trafikk.info/2017-06-08%20Oslo/07%20Road%20Pricing%20and%20Charging%20in%20Norway%20(Kristian%20Warsted).pdf
10 Pre-Covid, excludes taxis and private hire vehicles.
11 Source: https://www.singstat.gov.sg/find-data/search-by-theme/population/mode-of-transport/visualising-data/mode-of-transport-dashboard
12 Source: https://citytransit.uitp.org/oslo
13 Source: https://www.london.gov.uk/questions/2020/33

Stockholm	1.6m	4,175 km^2	43%[14] (metro, 22% at cordon)
Gothenburg	1.1m	1,300 km^2	74% (at cordon/corridors)
Milan	4.3m	2,055 km^2	59%[15]
Abu Dhabi	1.5m	1,600 km^2	72%
Dubai	3.5m	860 km^2	61%
Seoul	26m	8,300 km^2	26%
Stavanger	0.3m	2,871 km^2	57%[16]
Trondheim	0.3m	557 km^2	57%[17]
Tonsberg	0.1m	367 km^2	62%[18]
Haugesund	0.04m	564 km^2	66%[19]
Cities considering road pricing			
New York	20.1m	2,053 km^2	38%
Brussels	2.5m	7,400 km^2	50%[20]
Auckland	1.7m	1,210 km^2	66%[21]
Tauranga	0.2m	1,094 km^2	80%[22]

Table 2 Cities, population, and mode share

[14] Source: https://www.sciencedirect.com/science/article/pii/S0966692319305447
[15] Source: https://www.researchgate.net/figure/Modal-split-in-the-Milan-Metropolitan-Area-baseline-case_fig2_352878210
[16] Source: https://uis.brage.unit.no/uis-xmlui/bitstream/handle/11250/2682028/Thesis%20PDF.pdf?sequence=1&isAllowed=y
[17] Source: https://www.polisnetwork.eu/member/trondheim/
[18] Source: https://www.sciencedirect.com/science/article/pii/S1361920922000554
[19] Source: https://www.tandfonline.com/doi/pdf/10.1080/21650020.2020.1862701
[20] Source: https://journals.openedition.org/brussels/1696#tocto2n5
[21] Source: https://at.govt.nz/media/1985132/census-snapshot-brochure.pdf
[22] Source: https://www.nzta.govt.nz/assets/resources/keeping-cities-moving/BoP-regional-mode-shift-plans.pdf all of BOP region and is an aspirational target for PT and active modes for Tauranga.

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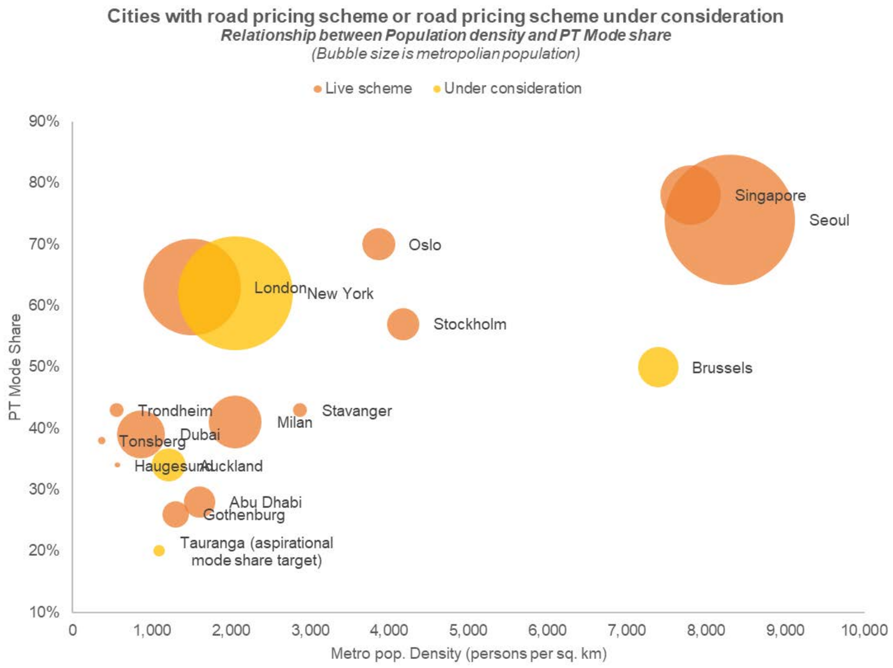

Figure 9 Population, density, and mode share of cities with urban road pricing

Outside Norway (which has had a political consensus on tolling and urban road pricing, primarily to fund urban transport improvements, although not without controversy), urban road pricing has proven extremely difficult to progress in most countries, especially for the primary purpose of raising revenue. The introduction of the London congestion charge generated some interest in studying congestion pricing in multiple UK cities, but public opposition saw serious proposals in Edinburgh and Manchester collapse (and the initial expansion of the London scheme (the Western Extension) was reversed within a few years due to opposition). In Sweden, although the Stockholm congestion tax was introduced with a bare majority of public support, the Gothenburg congestion tax was introduced despite significant public opposition, primarily as a taxation measure. Efforts to introduce congestion pricing in the Netherlands and Finland have failed due to public concern that pricing would cost them while generating significant negative impacts for some road users and businesses.

Norwegian cities

Although there are differences in average incomes, geography (and quality of public transport provision) in the smaller Norwegian cities, the experiences of those cities indicates that population and population density are not barriers to introducing urban road pricing to a scale that fits the needs of the specific city. Although in all cases, a good standard of public transport is important, this also varies in type and scale. Haugesund, Tonsberg and Stavanger having conventional urban bus services, with Trondheim recently having introduced bus rapid transit and Oslo with networks of metro, suburban rail, tram and bus services.

The Norwegian cities have all implemented urban corridor and cordon schemes that operate all day on weekdays, with higher charges during the peaks. Trondheim first introduced a cordon in 1991 to fund a series of road improvements, charges were removed in 2005 (after the capital costs of the improvements had been recovered) but reintroduced in 2010 in order to reduce emissions, congestion and fund further improvements to the transport network (roads, public transport and active modes).

This indicates that with appropriate improvements to public transport and active modes, it is possible for cities to be able to provide alternatives that enable urban road pricing to be introduced that do not seriously disadvantage those that need to travel at times when pricing is in operation. In all of the Norwegian cities, the political consensus on urban road pricing is an extension of a national policy that has supported the use of tolls more generally to help fund major highway infrastructure. However, it is important to not under-estimate the increasing difficulties in Norway in introducing new urban road pricing schemes in recent years. It has become increasingly controversial, with the Norwegian Public Roads Administration recently trialling in-vehicle units to replace tolls and urban road pricing schemes with distance, time and location-based road user charging. Appendix 1 contains maps depicting the charging scheme geography of several Norwegian cities.

1.5 How do objectives affect road pricing scheme design?

Although most urban road pricing schemes are expected to deliver on multiple objectives, virtually all urban road pricing schemes focus on one of three primary objectives:

- Congestion reduction
- Revenue generation
- Emission reduction to improve air quality

Related to those objectives may be others, such as improving the performance of public transport networks, improved urban amenity and encouraging changes to urban form, but to date all operating urban road pricing schemes have had a focus on one or more of network performance, revenue generation and improved environmental conditions.

Table 1 depicts the primary objectives of urban road pricing schemes in operation, noting that some of these have evolved over time, and many have more than one objective, but all tend to prioritise one major objective over all others.

The essential characteristics of urban road pricing schemes are that they will reduce demand for road space for the vehicles subject to the schemes at the times and locations they are charged (and with effects beyond charging points as demand changes and affects roads approaching charged locations). This reduction in demand sees four primary impacts on travel:

- Modal shift (so the same trips are undertaken using different modes);
- Time shift (same trips are undertaken during times of lower or no pricing);
- Route shift (same trips are undertaken but re-routed on unpriced routes or to minimise prices paid); and
- Trip consolidation (fewer trips are undertaken in the charged location).

The relative proportions of these changes depend very much on the road pricing scheme design details (by type, geography, time of operation and prices charged), the availability and attractiveness of alternative modes or routes, and the purposes of trips taken on the priced roads. For example, post-implementation analysis of Stockholm's congestion tax is estimated to have seen about 40% of the drop in car trips during the charged period to have shifted mode, 24% of trip reduction is due to reduced frequency of travel, 6% shifted route (to the unpriced bypass motorway) and around 20% "disappeared" (believed to be trip consolidation).[23]

Alongside reduction in traffic comes reductions in congestion and improvements in trip reliability. Reductions in traffic and improvements in the flow (and reductions in fuel consumption) of remaining traffic will reduce emissions (improving air quality and reducing contributions to climate change). Finally, it is clear that charging a fee generates net revenues

[23] Source: https://transportportal.se/swopec/cts2014-7.pdf p.14.

(assuming it is done with a basic level of operational efficiency), regardless of this being the primary objective.

The purpose of this section is to describe how these objectives affect how urban road pricing schemes are designed and operated.

Congestion reduction

Schemes in Singapore, Stockholm, Abu Dhabi and Seoul are primarily focused on congestion reduction. A focus on congestion reduction tends to mean scheme design that is more refined and focused on improved network performance. Singapore takes the most sophisticated approach to this, with specific traffic speed performance targets, and with highly refined pricing by location, direction of travel and time increments. The key elements of the Singapore scheme that directly reflect its objective of congestion reduction are:

- Pricing that varies by specific road location and direction of travel (depends on demand and capacity at each location);
- Pricing that varies by time of day/day of the week increments for each location and direction of travel (depends on demand and capacity at each location by time of day)
- Pricing that reflects vehicle size (depends on road space occupancy as a factor contributing to congestion);
- Quarterly revisions of prices at each location/time increment to reflect network performance at each location (with prices varying up, down, removed or expanded in time of operation/direction depending on network conditions).

Stockholm also has refined pricing increments by time of day and location (albeit only one location variation, as there is a price for the cordon and a separate price for the Essingeleden through route). Prices have been revised twice since the scheme was introduced to reflect inflation and growth in demand. Essingeleden (see

Figure 1 the route passing through the cordon) did not have a fee applied until 2016, which was introduced specifically because congestion had become severe on that route (which is the only route for through traffic not entering the city). Stockholm has increased fees twice (2016 and 2020), changed operating hours and introduced seasonal variations in fees as follows:

Congestion levels vary during the year. In late spring, and in summer and autumn, traffic density and congestion levels are generally higher than in winter and early spring. The congestion tax will now be adjusted to these variations with the introduction of a peak season and an off-peak season.[24]

Abu Dhabi is a new scheme that has only been in operation since January 2021. Seoul's scheme has existed for many years (since 1996) but appears only to have revised fees twice in that time (the latest to encourage low emission vehicles), with little information available on the system performance.

[24] Source: https://www.transportstyrelsen.se/en/road/road-tolls/Congestion-taxes-in-Stockholm-and-Goteborg/congestion-tax-in-stockholm/stockholm-congestion-taxes-modified-on-1-january-2020/

However, common to both systems is:

- Location targeting of routes that have poor network performance or contribute significantly to congestion on adjoining networks;
- Time of day targeting of traffic (avoiding off-peak periods without congestion).

Revenue generation

Notable urban road pricing schemes focused on revenue raising are Gothenburg and Oslo (indeed all of the Norwegian schemes have revenue as a key if not primary focus). New York's proposed lower Manhattan scheme is also motivated heavily by desire for revenue to support improvements to public transport.

For almost all schemes revenue raising is always seen as at least a secondary positive outcome from road pricing, even from schemes that predominantly exist to improve network performance. However, when an urban road pricing scheme is designed to prioritise revenue raising, this affects key elements of the design.

Gothenburg, although designated a congestion tax (to fit within the legal framework of the law on congestion taxes for Sweden), was designed primarily to raise revenue for a package of transport network investments. Before pricing, congestion in Gothenburg was focused primarily on bottlenecks at peak times (see Figure 8), but the chosen cordon scheme has a wider geographical and temporal scope than just the E6, E20, E6.21 (Lundbyleden) junction area at the AM and PM peak periods.

Gothenburg's congestion tax applies all day (06:30-18:30) and across many locations that have little to no congestion. The cordon applies to the CBD and the inner suburbs, with two additional corridors subject to the fee (E6 north and Älvsborg Bridge). This enables the scheme to generate the revenue required to help fund the package of transport improvements (known as the West Swedish Agreement).[25] Gothenburg has designed the scheme to maximise revenue, rather than target congestion. This has resulted in criticism of the fee being a "tax on mobility", including an economic appraisal indicating that there were negative outcomes for all income groups paying the fee.[26]

Oslo's urban road pricing scheme has operated for many years, and started as a flat fee with manual toll collection in the early 1990s for a single cordon, and now has peak charges (and off peak charges), across three cordons, with fully electronic collection. When it was introduced in 1990, it was intended to assist funding "Oslo Package 1" of transport improvements, primarily to build a network of bypass tunnels to take through traffic off of surface streets. In 2001 it was supplemented by "Oslo Package 2" which primarily consisted of a series of public transport improvements. As all forms of tolling in Norway are governed by law that requires tolls to be removed once projects are paid for, Oslo subsequently announced "Oslo Package 3" in 2008, as a series of further capital projects for both roads and public transport, alongside reforming the urban road pricing scheme to also target congestion. "Oslo Package 3" extends till 2032 the package of projects that the urban road pricing scheme

[25] There has been some controversy over the transport package, due to a significant portion of the cost being dedicated to rebuilding the central railway station to support increased intercity passenger rail capacity, which delivers few benefits to commuters paying the congestion tax.
[26] Source: https://link.springer.com/article/10.1007/s11116-017-9853-4

will pay for. It is worth noting Oslo's scheme operates 24 hours a day, 7 days a week (although the other Norwegian schemes listed only operate during weekdays during peaks and interpeak periods), primarily to meet revenue requirements.

New York's proposed Lower Manhattan scheme is planned to also operate 24 hours a day, 7 days a week with higher peak charges. This is also designed explicitly to raise at least US$800m per annum to pay for subway capital spending, so is planned to operate at all times (albeit those that already pay tolls on river crossings to the charged zone will have the tolls they pay credited to the scheme fees paid).

Emissions reduction

Almost all urban road pricing schemes are understood to contribute towards objectives of reducing emissions, but only one is notable as focusing on emissions as a primary objective – Milan. Milan's scheme (called "Area C") grew out of a low-emission zone (Ecopass 2008-2012) which itself had previously been a restricted traffic zone (that limited vehicle movements to residents and vehicles with a business purpose in the zone). It reportedly resulted in an 18% reduction in PM10 within the cordon, largely matching the reduction in vehicles entering the cordon after it was introduced (noting this was a reduction on top of what had been experienced by the low-emission zone that it replaced). Milan's scheme has the following key characteristics:

- Operations all day on weekdays;
- Prohibitions on higher emitting vehicles;
- Exemptions on zero emission vehicles;
- Certain exemptions for "service" vehicles and deliveries of certain commodities (e.g. perishable goods); and
- Different rules for residents' vehicles.

A focus on emissions reduction sees less interest in applying charges only at peak times or in improving network performance, but rather to reduce overall traffic volumes (with discounts or exemptions for zero or ultra-low emission vehicles). Assessment of Milan has focused predominantly on reductions in emissions.[27] Although Milan also generates net revenues, its focus on environmental outcomes is notable by its annual scheme review reporting on traffic volumes and emissions, not revenue. It also has a comprehensive schedule of restrictions and variance of fees based on vehicle emissions categories. Revenue for the Milan scheme has been relatively stable whilst it has been in operation, reflecting that it has largely kept traffic at stable levels, as it combines restrictions on classes of vehicles using the scheme, with fees targeted to encourage use of low emission vehicles.

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[27] See https://www.researchgate.net/profile/Sunny-Kodukula/publication/325987968_The_Ecopass_pollution_charge_and_Area_C_congestion_charge_-_comparing_experiences_with_cordon_pricing_over_time/links/5b31eed00f7e9b0df5cba0e3/The-Ecopass-pollution-charge-and-Area-C-congestion-charge-comparing-experiences-with-cordon-pricing-over-time.pdf?origin=publication_detail and https://nws.eurocities.eu/MediaShell/media/Milan%20congestion%20charge.pdf

Current ban	1/10/2022	1/10/2024	1/102027	1/10/2029
<Euro1 (petrol) <Euro4 (diesel)	Euro2 (petrol) Euro4 (diesel retrofitted) Euro5 (diesel)	Euro 3 (petrol)	Euro4 (petrol)	Euro6 (diesel)

Table 3 Milan Area C private vehicle restrictions[28]

In summary, the key elements reflecting Area C's focus on environmental outcomes are:

- A single all-day fee for access for eligible vehicles (indicating that the type of vehicle and emissions category is more important than the frequency of travel)
- Prohibitions on higher-emitting vehicles (with such prohibitions being broadened in future years to encourage only use of the newest, lower emitting categories)
- Electric and hybrid vehicles are exempt (unlike in Stockholm, Gothenburg or Singapore).[29]

Conclusion

All urban road pricing schemes contribute to reducing congestion, generating net revenues and improving environmental outcomes. However, the relative priority of objectives affects scheme design of various elements. This is illustrated in Table 4.

Objectives	Time of operations	Geographic scale	Scheme type	Discounts/ exemptions	Rate structure
Congestion relief	Peak demand	Targeted by bottlenecks	Corridor, cordon	Minimal exc. buses	Highly disaggregated
Revenue generation	All day	Necessitated by revenue target	Area, cordon	Minimal	Simple
Emissions reduction	All day	Location of poor air quality	Area, cordon	Low emission vehicles	Varies by emissions category

Table 4 Effect of objectives on scheme design

[28] A comprehensive list of these categories covering heavy vehicles, buses and residents' vehicles is available at https://urbanaccessregulations.eu/countries-mainmenu-147/italy-mainmenu-81/lombardia/132-countries/italy/lombardia-region/1549-milano-area-c-low-emission-zone-charging-scheme

[29] London exempts zero-emission vehicles only, as emission reduction is a major objective of the current Mayor of London.

1.6 Implementation Considerations

Key stages

Congestion pricing is not a transport policy project that is "conventional" like transport infrastructure construction projects, or even amendments to pricing of on-street parking or public transport ticketing. Globally, most transport projects commissioned by road controlling authorities or urban transport authorities comprise of the construction of infrastructure such as roads, bridges, railway lines or stations, or commissioning new public transport vehicles, ticketing systems or related systems. Systems that involve measuring use of transport infrastructure and services and charging users for that use, such as parking fees or public transport ticketing are widespread and have been in place for many decades in one form or another, and users expect to have to pay for such services.

Urban road pricing has many parallels with tolls, with a key difference that in most cases tolling systems are installed on a road at the point of construction (and replaced as technology reaches the end of its economic life). Road pricing also has parallels with Intelligent Transport Systems which are built into new highways to identify and warn motorists of changing conditions, such as weather, accidents, lane closures or changes in speed.

The key differences between tolling and urban road pricing from an implementation perspective are:

- Tolls are introduced at the time a new road (or lane) is opened. This means toll infrastructure can be installed at the same time as other highway infrastructure, and be integrated in the new road, rather than be retrofitted on an existing route. Tolls are much easier for the public to understand and accept, as they are presented as an option to pay to use a facility that previously did not exist. The option of *not* paying and continuing to use previously available roads (or lanes) makes tolling easier to implement from a public acceptability/political point of view and much less controversial, compared to urban road pricing which introduces a fee on a road that was previously not subject to one. Central to this is public scepticism that any form of pricing will make travel conditions *better* overall, especially for those subject to the fee (as few motorists typically believe that paying for a facility is anything other than revenue collection rather than managing demand).

- The impacts of urban road pricing are more significant than tolls on a new facility. Urban road pricing will change pre-existing behaviour, resulting in some trips being driven at other times, or on other routes, or by other modes, and may result in some trips being suppressed altogether. The positive impacts of this on reducing congestion (and pollution) may be significant, but if designed poorly, there may be negative impacts on drivers who have no alternative, but who may find the benefits in travel time savings and trip reliability do not outweigh the costs to them, potentially reducing their access to employment or education.

- Tolls in most cases operate 24/7, and only in some locations is there pricing that might vary by time of day (e.g., Sydney Harbour Crossings cost $1 more in the AM and PM peaks compared to interpeak). Urban road pricing only operates at times of peak demand and may only operate in one direction of traffic flow (typically inbound AM peak, outbound PM peak). It may also have prices that vary at several intervals during the day (e.g., see Figure 5 for the range of prices at just one charging point for

Singapore). This is more complex for the public to understand and respond to, and more complex to communicate (and can result in higher costs for customer management when motorists do not notice they have travelled at times of peak charges)

- Introducing pricing on *existing* roads will typically result in some relocation of trips that seek to avoid charging points (diversion), depending on the design of the scheme. Careful design choices may be made as to the location of a charging point to minimise this having a particularly negative impact, and a combination of traffic management measures (speed limits, traffic calming) or applying business rules to such trips, can also address such issues. Uncharged bypass routes are sometimes implemented (such as a ring route around a cordon, or an uncharged through route (with charges for vehicles exiting the route at some points)) so those with fewer alternatives (mainly because public transport usually cannot serve through travel as effectively as suburb – city trips) are not unduly affected. Conditional charge rules (such as has been implemented in Backa in Gothenburg) can be applied that mean that a charging point is only operational if a motorist crosses a control point first (to seek to capture trips that may divert to avoid a fee on a specific route, without charging a fee for local trips).

- For tolls the alternative is the untolled route, for urban road pricing the alternatives are changing time of travel, route of travel, mode of travel or whether to travel at all to the location accessible only by the charged road. Typically, the introduction of urban road pricing in parallel with enhancements to public transport (e.g., London and Stockholm both significantly increased bus service frequencies) to accommodate modal shift and improve public acceptability, although around half of shift in demand is usually by time of day or in consolidating trips (driving less frequently).

Although the implementation of urban road pricing may be divided into multiple workstreams through a detailed project plan, at a high level there are generally three main types of activity associated with implementing such schemes:

- <u>Governance arrangements</u>: Defining the legislative framework to authorise pricing, and the entity ultimately responsible for procuring and implementing the system. This includes management of the scheme, including use of net revenues, and the role of the private sector in supplying and operating services.

- <u>Approvals:</u> Assuming there is a legal framework to enable pricing, approvals are required from decision-makers to undertake detailed design and installation of the scheme, including undertaking public consultation, resource consents and a detailed business case.Approvals may also include the procurement approach, including whether such a scheme is simply an addition to any that may already be in place (Gothenburg was effectively an extension and variation of the Stockholm scheme, with shared account management and customer service functions).

<u>Construction/installation</u>: Once approvals have been obtained, the relevant governance agency (e.g., road controlling authority) would be expected to procure the installation, testing and operation of the scheme. This includes installation of roadside equipment and delivery of customer service functions.. The other critical activity is communication with the public on how to interact with the forthcoming scheme and what it means for them.

Governance: In the context of Tauranga, governance refers to the legislative and institutional framework within which urban road pricing would operate. It is understood that the Government is still developing this for legislation that could apply to cities across the country. In Tauranga it is clear that there are multiple government entities with some interest in the governance of an urban road pricing system, including Tauranga City Council, Western Bay of Plenty District Council, Waka Kotahi and Environment Bay of Plenty. Waka Kotahi being responsible for two toll roads and other state highways, and Tauranga City Council for virtually all local roads being considered for pricing are logical contenders, although option analysis has not been undertaken, rather the issues needed to be determined by suitable governance arrangements.

It is possible that if the Government's draft legislation for urban road pricing includes governance is should address issues such as:

- The entity responsible for procurement, ownership and management of the urban road pricing scheme (e.g., a road controlling authority or integrated transport authority);
- The entity responsible for reviewing and determining all elements of pricing;
- The management of net revenues;
- Decisions on disbursement of net revenues;
- Decisions on any changes to existing charges (e.g., tolls, parking);
- Responsibility for enforcement;
- Oversight and reviews of performance of the pricing scheme.

Determining these issues is critical to enabling the processes for approvals and construction to proceed smoothly, as well as ensuring clarity of responsibility. In every case of successful introduction of urban road pricing, governance issues have been addressed early (e.g., Singapore, Oslo, London, Stockholm, Gothenburg). In some cases that did not proceed, conflicting governance or governance by an entity with inadequate powers, responsibilities and incentives appears to have contributed to failure to obtain final public and political support (e.g., Copenhagen and Manchester).[30] Clarity of governance means that the responsible entity is able to make the decisions on design, communicate with the public and other stakeholders, and procure the necessary services/infrastructure to enable pricing to proceed.

Approvals

This includes all processes necessary to gain final approval to proceed with a mature design. It includes business case development, public consultation, planning approvals (for any construction) and any other processes defined by legislation as being necessary to implement a scheme. For example, in London, the proposed concept was modelled, with forecast impacts including revenue, and presented for public consultation on the proposed details of

[30] In Copenhagen, several small local authorities in metropolitan Copenhagen actively opposed the concept. In Manchester, the lead agency was, at the time, only responsible for procuring public transport services and infrastructure, and was not a road controlling authority.

implementation. That consultation was used to make some minor changes to the proposal (e.g., exemptions), but then proceeded. Approvals may not require detailed design but are likely to require a concept that defines where charging points will be located, and what sort of infrastructure is expected at those points. Again, legislation will define what these approvals are, both existing legislation (e.g., Resource Management Act) and the legislation that will be needed to authorise urban road pricing.

The single biggest risk in the approvals phase is public opposition. It is critical that adequate information is provided, clearly and concisely, so the public understands the objective of the scheme, how the scheme will meet that objectives and how its design and operation will minimise negative impacts and the risk of fraud. Scheme design needs to be sufficiently flexible to address negative impacts, and include complementary measures (changes to road layouts, public transport services) that support the scheme meeting its objectives.

Construction

The term “construction” here is used to include detailed design, procurement of infrastructure and services, installation, testing and inauguration of the road pricing system in operation. This also includes communications with the public, associated road infrastructure changes (signs, lining and changes to intersections etc. necessary to inform drivers and address expected significant changes in traffic flow). The scope of this will also be determined by the introduction of pricing in other cities and whether Waka Kotahi’s tolling customer support and account management systems are to be used for the system (it is reasonable to assume this). If, as in Sweden, Tauranga is simply added onto a system established for one or more other cities, it is a simple case of adding and testing infrastructure but utilising existing systems to collect revenue from road users and supply customer service. If it is a bespoke system, procurement would be more complicated.

The biggest risk during construction is poor communication with drivers leading up to scheme operation. Providing adequate information months in advance of operation is essential so drivers do not seek to overwhelm the customer service function with queries or account registration only days out from the start of the scheme. This is to encourage frequent users to set up accounts, and for motorists to be clear about when and where charging will affect them. This information will be crucial to minimise people feeling “caught” by unanticipated changes or being confused near or on the day of introduction, and panicking either by diverting journeys or contacting the system operator to inquire as to “what to do”. One way to enable this is to introduce the scheme during a quiet period (experience overseas is that school holidays outside peak holiday seasons can help) and have a campaign of information one or two months in advance, to ensure the greatest number of local motorists know what is coming and where. London was very conscious of this issue and embarked on regular communication with the public many months before the system was operational, and also set up a backup call centre to address any overflow of queries and issues in the early weeks of operation.

How was technical feasibility identified?

In most cases, technical feasibility for urban road pricing was based on a combination of the location of most severe congestion and concern, and the available technology at the time the scheme was introduced. Objectives were critical in determining this, and in more recent years it has not been technology that has been seen as the key barrier, but rather political will to implement some form of pricing.

Singapore: Singapore initially introduced a paper-based permit system (Area Licensing Scheme or ALS) in 1975, for an inner-city cordon. This was based purely on the available technology at the time and the greatest concern being the use of cars to access the inner city. The ALS provided the initial information about demand responses to pricing that was used to inform the subsequent evolution of the scheme over subsequent decades. ALS was followed in the 1990s by the Road Pricing Scheme and subsequently the now operational Electronic Road Pricing (ERP) system from 1998. Singapore identified the availability of technology for electronic detection of motor vehicles at the time as a means to save costs and enable significant scaling of the geographic and operational parameters of its road pricing scheme. The technology was adapted and designed specifically for Singapore, in part to support the city-state's objectives of presenting itself as a hub of technological and policy innovation. Extensive on-road technical trials were undertaken in advance of the decision to implement the ERP system. In the 1990s, traffic models were developed to simulate the impacts of pricing on demand and the assignment of that demand to different routes and modes, although the Singaporean Government accepted the fundamental principles of transport economics, that pricing would result in changes in demand from peak periods towards off peak periods.

London: The objectives for the London scheme were to implement a scheme in the most congested location within a three-year timeframe of the Mayor being elected with a mandate to introduce the congestion charge and demonstrating its effectiveness before the subsequent election. The area charge concept came about because it included the most congested network of roads in central London with the highest level of public transport service. An area charge was proposed because of the selection of ANPR technology, which at the time had relatively poor levels of accuracy (at the time Transport for London admitted that ANPR cameras would reliably identify around 60-65% of vehicle number plates with a single read). As ANPR systems required multiple images of the same vehicle to reliably identify a vehicle, it was decided to include cameras within an area, not just as a cordon, so that the average vehicle entering the charging area would have its number plate image taken on average 2.5 times (minimising the risk any single vehicle would not be identified). This was purely to enable reliability of operation. Cost was not important as net revenues were not considered to be the key objective (the primary objective was to reduce private car traffic to enable better flow of bus traffic and enable reallocation of road space to other modes).

Stockholm: The geography of Stockholm, with the central city area located on a large peninsula with three adjacent islands, provided the obvious location for a cordon-based scheme, with the Essingeleden motorway bypass along part of the north of the central area helping to define the boundary. With few entry points, and the concentration of public transport services (rail, tram and bus) on that area, it was technically simple to implement the proposed scheme. It was clear this concept would have a significant impact given the radial network of roads leading from the central area.

Stockholm implemented a seven-month long, fully functioning pilot of congestion pricing in 2006, which operated essentially as a fully-fledged (mandatory) road pricing scheme, before holding a referendum on whether it should be implemented permanently. Technical feasibility was tested during the pilot period, using, at the time, toll tags and ANPR cameras, to detect vehicles for invoicing. The pilot demonstrated that there was no need for toll tags given how reliable ANPR technology had become. However, the most important result of the pilot was proving how congestion pricing could work to reduce congestion in Stockholm.

A few weeks after it was introduced, traffic volumes crossing the cordon during charged periods were down by 20%, resulting in a 30-50% reduction in congestion within and approaching the cordon.[31] This dramatic impact (which was beyond expectations, as modelling had indicated the prices implemented would reduce traffic volumes by around 10-15%) demonstrated the technical feasibility for Stockholm. The subsequent public referendum saw a narrow “Yes” vote (53%) to introduce the scheme permanently, based no doubt on the experience of the impact of the pilot.

Gothenburg: Gothenburg followed on the success of Stockholm, but not because of the effects of pricing on congestion, but because Gothenburg local politicians were supportive of how Stockholm was leveraging future revenues in a deal with central government to enable significant capital spending on transport infrastructure.

From a technical point of view, it was accepted that the same technical solution as applied in Stockholm would be able to be implemented in Gothenburg (ANPR), using the same back-office and account management system used for Stockholm, as the same governance entity (Swedish Transport Agency) would procure and operate the system. However, the objective for Gothenburg were different from Stockholm. Gothenburg’s scheme is designed primarily to raise revenue to support a large-scale transport infrastructure package, with congestion reduction a secondary objective. As illustrated in Figure 8, congestion in Gothenburg is concentrated on two major motorway junctions to the north of the central city, but a scheme on this scale (and operating only at the times during which severe congestion occurs regularly) would have been inadequate to generate the revenue sought.

As Gothenburg does not have the natural geographical barriers seen in Stockholm, designing the scheme geography was more challenging. The central city area straddled the Gote River, but in order to generate sufficient revenue, the cordon was designed with extension lines to the west and northeast to capture traffic travelling between suburban areas either side of the Gote River and the E6 motorway respectively. As a result. Gothenburg has 38 charging points compared to Stockholm’s 18. The national transport forecasting model (known as SAMPERS) was used (not available for Stockholm in 2006). It is described as follows[32]:

SAMPERS consists of nested logit models for six trip purposes (Work, School, Business, Recreation, Social and Others), modelling choices of trip frequency, destination and mode (car as driver, car as passenger, public transport, walk and cycle). The demand models include private and business travel. Freight traffic OD matrixes are fixed (and thus assumed to be insensitive to congestion charge). There are three analysed time periods (morning peak, evening peak and off peak), over which demand is distributed using fixed time period factors per trip purpose applied uniformly to all origin-destination pairs. Road and transit link flows are calculated using the software package EMME/3.

This model was used to determine the optimal concept design to generate sufficient revenues, whilst focusing on the locations with the greatest congestion or potential for congestion.

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[31] Source: Eliasson, *The Stockholm congestion charges: an overview*, CTS Working Paper 2014:7.
[32] Source: Börjesson, *The Gothenburg congestion charge Effects, design and politics,* CTS Working Paper 2014:25.

Sensitivity: General

How was operational complexity decided?

Following on from technical feasibility, operational complexity is generally a function of:

- Trade-offs of objectives (congestion reduction vs. revenue generation vs. other objectives)
- How important targeting the location and time of congestion is, and the profile of such congestion
- Previous experience of pricing
- Negative impacts that need mitigating by design.

In general, the introduction of a road pricing scheme in and of itself is a significant policy step for any city, and it need not be introduced at the scale that might be considered optimal from a transport economics point of view, but rather be allowed to operate and progressively evolve in scale and complexity. For Auckland, The Congestion Question (TCQ) project acknowledged that a first step for Auckland could be an inner-city scheme, followed by corridor -based charging progressively implemented over many years targeting congestion from inner towards outer suburbs. This is depicted in Figure 10. The most important step is implementing Phase 1, not because it will have the greatest impact, but because it demonstrates the potential of road pricing as a concept, and sets up the policy, practices, systems and public understanding of the concept that will allow it to be progressively expanded over time.

Please note that boundaries are indicative only

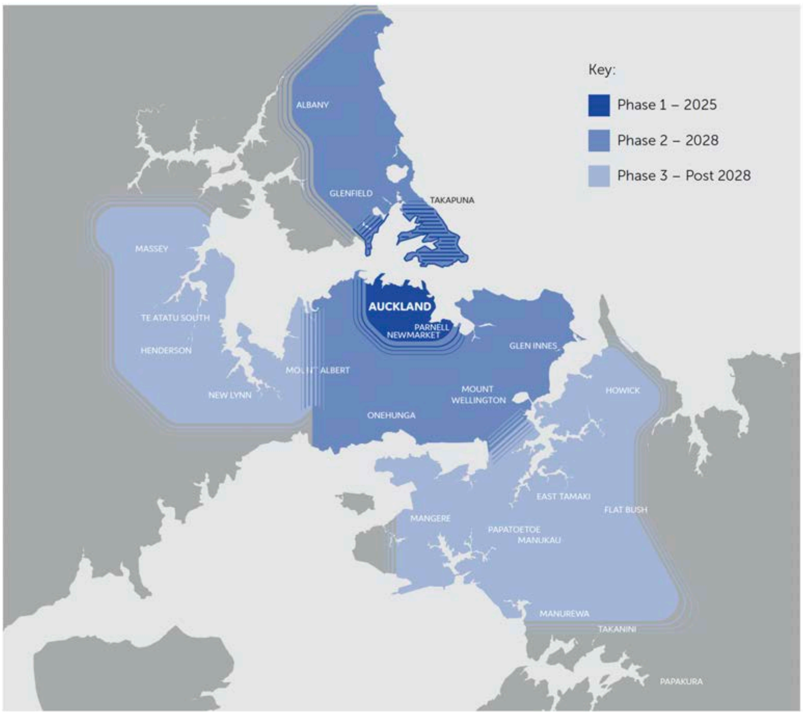

Figure 10 The Congestion Question proposed phasing of pricing

Singapore: Singapore demonstrates how a pricing scheme can be implemented relatively simply, but effectively at first (the Area Licensing Scheme in 1975 was notable for reducing peak traffic volumes by 60%).[33] Then progressively increased in sophistication over time, as it demonstrates its effectiveness and there is greater public understanding of the system. It is highly likely that very few Singaporean motorists know the prices for all times across all 78 charging points, but this is not important. They will know the prices for the roads that they use, and respond accordingly, either driving and paying (and expecting a high level of service) or driving at a different time, or less frequently or to a different destination (e.g., park and ride).

In starting with a simple cordon in 1975, Singapore had ample experience to build upon, by introducing a second cordon adjacent to the first one, and to follow with corridor charging. The push for electronic technology was not only to enable free-flow traffic and easier enforcement, but also enabled development of a prepaid stored-value transport smartcard for public transport AND the bespoke in-vehicle units designed for the electronic road pricing scheme. Such smartcards were designed to make paying for public transport, roads and parking much simpler and more efficient, and the technology chosen for Singapore's scheme was also designed to respect privacy (by enabling payment of pricing using the stored-value smartcard regardless of who owned the card or if it were registered).

Since 1998, Singapore has progressively increased the complexity and sophistication of its congestion charging system by:

- Adding charging points on corridors, at locations where congestion became sufficiently severe to justify pricing (and where it was practicable to introduce without causing significant traffic diversion). There are now 78 individual charging points on Singapore roads;
- Varying charge rates at each location by direction of travel and time of day;
- Introducing small increments of time to efficiently spread demand (see Figure 5), avoid peak bunching and encourage optimal use of existing infrastructure;
- Charging based on vehicle size (motorcycles at half the price of private cars, with trucks and buses two to three times).

[33] Source: *Electronic Road Pricing*, Land Transport Authority Singapore (presentation dated 2016).

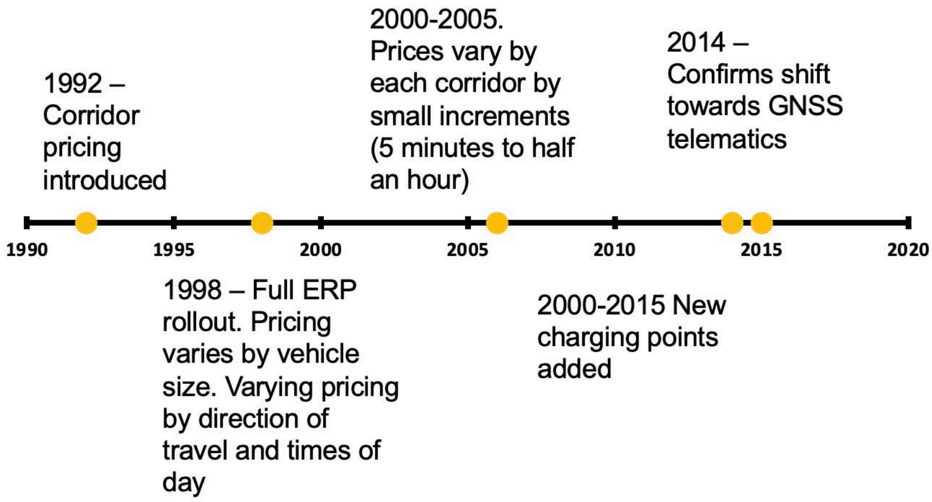

Figure 11 Timeline of Singapore system complexity

London: The political and policy imperative in London was significantly different from Singapore. In London the key constraints were the need to have a scheme operational for at least one year before the subsequent Mayoral election, this imposed conditions on the technology able to be used and the scheme concept, as it needed to be able to be implemented quickly and reliably. ANPR was selected because it would not require distribution of any equipment to vehicle owners and was necessary for enforcement.

In London, an area charge in central London was chosen because it was seen to be logical to focus on the slowest traffic area in London, with the densest network of public transport. A key trade-off of these choices was that the operating costs in the initial years were very high, with 47% of gross revenue lost in operating costs in the 2005 financial year.[34] This reflected use of live video feeds from all cameras, and a significant cost of manual number plate readings at the time. The other impact was that with an area charge, it is not feasible to vary charges by time of day (as only a single fee is charged per day to drive into the area), and it is difficult to expand without applying an equally blunt charge.

London has remained operationally quite simple since it was introduced, with a single fee, for all types of vehicles (that are not exempt or subject to a 100% discount), paying for an unlimited number of trips per day. The only expansion in operations have been in operating hours (to 1200-1800 in weekends) and the Western extension to the charging zone which operated from 2007-2011. Expansion of operating hours is relatively simple, as was the Western extension which simply applied the same charge to vehicles entering or circulating within both zones (with a single charge covering both zones).

Stockholm: The decision on Stockholm's cordon was largely made due to geography, which simplified the number of charging points needed, as the concentration of traffic congestion

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[34] Source: Figure 93, *Central London Congestion Charging Impacts Monitoring, Third Annual Report,* April 2005, Transport For London.

was on the arterials approaching the central city area. An exemption for through traffic on a single motorway was introduced as a compromise for motorists without alternatives (as public transport focuses on radial trips) but has recently been removed (with a lower charge introduced for the motorway compared with entering the city) as pressure has grown to manage congestion on that route as well. A cordon was chosen because it provided the flexibility to charge by time of day, and focus on vehicles entering the central area, rather than those circulating within it. Stockholm could vary charges by entry point on the cordon but has decided not to, because of the relative effectiveness of the current scheme, and concern that having differential charges by location would be perceived as being unfair.

Gothenburg: Gothenburg followed Stockholm, but was designed on a scale needed to meet the revenue targets set (and reflecting modelling indicating how much traffic needed to be subject to pricing to meet the revenue goals). With operating hours from 0600-1830 weekdays, with charges varying between peaks and the interpeak period, the scale of scheme was expected to generate gross revenue of €93 million per annum (nearly NZ$156 million), to meet revenue demands. Notably this is greater than that for Stockholm (which was designed to manage congestion, whereas Gothenburg was designed to generate revenue). Gothenburg's scheme was originally a simple cordon as in Stockholm, with a daily cap on charges, but has since been amended to address some of the negative impacts of the scheme design:

- An hourly cap on charges has been applied, so that no one vehicle can be charged more than once during a 60 minute period, regardless of the number of charging points it crosses;

A conditional fee has been applied to charging points adjacent to the suburb of Backa, due to the effects of the fee on local residents accessing community facilities. In effect, only vehicles travelling from outside the community pass a detection point AND the charging point, will be charged.[35] [36]

How was social licence obtained?

Social licence for urban road pricing is difficult to obtain, as is seen by the dearth of cities that have implemented the policy, compared to those that have investigated it or even discussed it. It is notable that there is urban road pricing on a significant scale in only five countries in Europe (UK, Sweden, Italy, Norway and Malta), notwithstanding the significant commitment of the European Union towards reducing emissions from transport. Furthermore, in the United States, only New York looks likely to introduce pricing in the near future, despite extensive policy commitments in many other cities (e.g., San Francisco, Seattle, Boston) to reduce emissions, primarily due to the difficulties in obtaining public acceptability.

[35] This implements a conditional charging point, requiring a vehicle to be detected twice within 30 minutes (at two separate locations) before being charged. Any vehicle detected at any one of those points without being detected at the other within 30 minutes is not charged, which enables local residents to be exempt, but those transiting the local areas to access the charged road will be charged.
[36] More details on the Backa exemption are available at https://www.transportstyrelsen.se/en/road/road-tolls/Congestion-taxes-in-Stockholm-and-Goteborg/congestion-tax-in-gothenburg/frequently-asked-questions-about-the-exemption-for-congestion-tax-in-backa-gothenburg/

For those cities that have done so, there are some clear messages about what it takes to obtain social licence to implement pricing.

Singapore: Singapore's political culture is essentially one lead by implementing policies based on merit, although there is some sensitivity around public acceptability. As Singapore started in 1975 with the ALS, and demonstrated the effectiveness of the policy, it proved to be possible to expand with the ERP scheme. It is also notable that car ownership in Singapore is effectively restricted to those on higher incomes, because of the need to purchase a permit to own a car (Certificate of Entitlement) for ten years (which can be equivalent to the cost of the car itself). Singapore's per capita car ownership rate is 0.149 (cars per capita)[37] this compares to over 0.8 in New Zealand. Although a significant proportion of Singaporeans do not drive a car, the most powerful and influential ones do. A key element of continuing the social licence for the Singapore ERP scheme is its success in managing traffic flow and reducing congestion in the city-state. Its most recent technical evolution (ERP 2.0 – introducing GNSS based technology) reflects public interest not only in reducing congestion, but in replacing the large relatively unsightly gantry arrays located at charging points across Singapore. Ensuring that any roadside infrastructure is not unsightly will be an important consideration in enabling social licence in Tauranga (and examples exist in multiple cities of the types of ANPR camera systems that have less impact that has been seen in some of the older pricing schemes).

Figure 12 Singapore ERP gantry

London: In London, the first elected Mayor (Ken Livingstone) included explicitly in his policy platform a promise to introduce a congestion charge in central London. As he had the full legal authority to implement such a scheme, this was taken as adequate social licence to proceed. Despite some opposition, the scheme was introduced in 2003. In the 2004 election, Livingstone did not explicitly campaign to extend the scheme westwards to include much of Kensington and Chelsea, but did release a consultation document on the concept, inferring that it may proceed if he was re-elected (his main opponent campaigned on abolishing the entire congestion charging scheme). Having won re-election, Livingstone proceeded to expand the congestion charge to Kensington and Chelsea in 2007, notwithstanding that public consultation was overwhelmingly opposed the extension. In 2008, Livingstone lost the Mayoral election and his successor, Boris Johnson, had promised to review the extension. Following public consultation, it was abolished. London's congestion charge has largely remained as the original central scheme since then, with expansion of operating hours and

[37] Source: https://www.ceicdata.com/en/indicator/singapore/number-of-registered-vehicles

increases in the charge rate. More recently, Mayor Sadiq Khan has focused on implementing several Ultra Low Emission Zones, to reflect his policy focus on reducing noxious emissions, rather than traffic congestion.

Stockholm: Discussions about road pricing in Stockholm had emerged many years before it was piloted then implemented but were highly controversial. In the 1990s there had been discussions about using road pricing primarily as a source of revenue to fund new transport infrastructure, following the examples in Norway (notably Oslo) implemented at the time. In 2002, a central government report recommended road pricing to help fund new infrastructure in Stockholm, although this was rejected by the Mayor of Stockholm. However, the newly elected central government needed the support of the Green Party, which negotiated a deal for a pilot of congestion charging to be introduced. The governing Social-Democrats agreed, but debate would become heated. Much media coverage was negative, and Stockholm became politically divided on the issue. Supporters were sceptical of a pilot in case it failed (and would end the debate for many years). Ultimately it was decided that the pilot would be held and be followed by a referendum on whether it should continue to operate. All political parties pledged to respect the outcome of the referendum.

The pilot was a success, in that it significantly reduced congestion, improved bus service reliability and speeds, and did not result in negative impacts on retail businesses within the charged area. Notably when the pilot *ended* traffic levels returned almost to previous levels, demonstrating the value of congestion pricing even more clearly.

Polling before the pilot (in 2005) indicated 34% support for congestion pricing, but afterwards 53% (in late 2006). By December 2007, four months after pricing was reintroduced on a permanent basis, support was at 65%, with a poll in 2013 indicating 72% support for the "congestion tax".

The referendum narrowly passed[38] essentially resolving the debate over congestion pricing. Even though the referendum coincided with a change in government (towards the centre-right parties that opposed congestion pricing), the new government proceeded to re-introduce congestion pricing, but on the basis that net revenues would be used to help fund a major new motorway bypass from outer northern suburbs to the south. The use of funds to improve conditions for motorists, at least for the first few years, helped gain support for congestion pricing. Support was further increased, as central government was willing to offer additional funds to Stockholm, to support the introduction of congestion pricing, so not only were net revenues from pricing available, but additional contributions from government.

The transport packages that have been funded by the Stockholm congestion tax have varied over subsequent years and governments, with a move back towards more spending on public transport under centre-left/green oriented governments, with more spending on roads by centre-right/conservative oriented governments. The decision to earmark some revenue for road improvements helped to dissipate concerns that congestion pricing was an "anti-car, anti-motorist" measure, rather than a measure to improve conditions for motorists. Further support was obtained by noting the environmental benefits of pricing, in reducing emissions and improving local conditions within the charged area.

[38] The referendum was itself controversial as not all Stockholm local authority areas were included in the referendum, notably outer districts where opposition was strongest.

Gothenburg: There had been little discussion about road pricing in Gothenburg until after Stockholm implemented its congestion pricing scheme permanently. The granting of a substantial package of funding to Stockholm to support congestion pricing (with funds for rail and public transport improvements), generated interest in Gothenburg that it too could receive central government funds for major transport projects if it introduced congestion pricing. From the beginning, Gothenburg political support was for pricing as a tool of revenue collection, as noted elsewhere in this paper. This significantly undermined the ability to obtain public support as it was much easier to portray the proposals as a tax raising measure, rather than a traffic management tool. Discussion about the concept generated opposition during local government elections, with a political party elected to the city council in 2010 with the single policy of opposing road pricing (although not with a majority). A petition from 57,000 citizens triggered a non-binding referendum on the issue, which was held in September 2014. This saw a 57% vote in opposition, but this was largely ignored by the city government. The position of the city government being that the revenue is needed to fund infrastructure projects.

Opposition to pricing in Gothenburg by the public reflects several elements of the congestion tax scheme:

- It operates all day long, although congestion in Gothenburg is only concentrated in AM and PM peak periods;
- It applies to many locations that did not experience significant congestion;
- The largest portion of the transport package being funded by the net revenues are being used to help fund a major reconstruction of the city's intercity railway station from a terminal to a through station (which has little impact on most commuters, and as a result little impact on traffic in Gothenburg).

The total package of transport projects costs €3.4 billion, with €1.7 billion contributed by central government and €1.4 billion from the congestion tax (the remainder by contributions from local authorities), so local authorities were primarily interested in securing the central government funding with the congestion tax, even though they bore little of the direct tax burden themselves to pay for the package of projects. In summary, most of those paying the congestion tax receive little travel time savings compared to conditions before it was introduced, and those that pay do not support the spending predominantly on an expensive railway project of dubious economic merit.[39] With a much higher mode share for private cars than Stockholm, the difficulty in obtaining social licence in Gothenburg has been clear, but as the transport infrastructure package has proceeded, politicians have almost universally reverted to the argument that without the congestion tax, other taxes would have to be increased to pay for the already committed projects.

Although there is undoubtedly adequate social licence in both London and Stockholm for their urban road pricing schemes, this has not extended nationally, nor indeed in the case of London for expansion of the scope of the London Congestion Charge. The *economic* policy case for national road pricing in the UK was demonstrated in the Road Pricing Feasibility Study

[39] The Swedish National Audit Office noted the benefit/cost ratio for the project was only 0.45.

published by the Department for Transport in 2004[40], but it was considered that the implementation of urban road pricing schemes would help advance the public acceptability of national road pricing. However, the conditions for central London congestion charging were not replicated in other cities in the UK, let alone outside cities, and there was considerable opposition to national road pricing when it was proposed in 2005. Ultimately, the proposal was scrapped, alongside proposals for multiple urban road pricing schemes in other UK cities, primarily because of public concern of double-taxation (that road pricing would be on top of existing fuel tax and registration fees) and the use of the technology to monitor drivers. In Sweden, the Stockholm Congestion Tax was followed by study into the introduction of a national road user charging scheme for heavy vehicles.[41] This was ultimately scrapped due to opposition from residents and businesses in rural areas that feared that charging for road use by distance would penalise those in rural and more remote areas.

By contrast, Norway has most recently been piloting road user charging on a distance, time, location basis for light vehicles, as a possible replacement for its extensive network of toll roads, and the urban road pricing schemes discussed in this paper.[42] This is driven, in part, due to growing disenchantment with tolling and urban road pricing schemes across Norway.[43] The pilot was focused on testing road pricing based on distance, time and location to replace Trondheim's urban road pricing scheme, in part due to concerns as to its bluntness and the wider interest in charging electric vehicles for road use (to replace fuel tax, and tolls). Whether there is sufficient public and political support for such a change is yet to be seen, but it indicates that there is at least some pressure to replace local urban road pricing schemes with a consistent national approach, that streamlines charges for road use into a single platform and fee. For Tauranga, the implications if central government decides to reform nationally collected road user taxes (fuel excise duty and RUC) with technology that could enable congestion pricing to be implemented are likely to be positive in significantly reducing the costs of implementation. However, it seems likely that even if such a policy decision were made, that the transition period towards a ubiquitous system to enable road pricing to be implemented locally would take around five to ten years.

Key conclusions

While in many ways urban road pricing resembles other ITS projects and the introduction of tolls, it has several characteristics that mean implementation is more complex, and has issues that need addressing much more comprehensively than other such projects.

Critical are:

- Clear governance and accountability structures: The scale of revenue collection, and distribution means that conventional arrangements for other fees (e.g., tolls for individual roads, parking) may not be appropriate for urban road pricing. A single

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[40] "Feasibility Study of Road Pricing in the UK: A Report to the Secretary of State for Transport", Department for Transport, 2004.
[41] ARENA study, discussed here https://trid.trb.org/view/863427.
[42] See this presentation, the pilot is called Geoflow https://uploads-ssl.webflow.com/5c487d8f7febe4125879c2d8/635fd7e52ce308adc8bed988_NW3%20Info%2021-10%20Roadpricing%20using%20geofences.pdf.
[43] See article on toll protests in Norway https://www.ft.com/content/2916df0a-cfa3-11e9-99a4-b5ded7a7fe3f

agency should be responsible for implementation, and be well incentivised to ensure pricing works efficiently, effectively, meets policy objectives and is flexible over time.

- Public acceptability: Urban road pricing is undoubtedly one of the most controversial and potentially divisive transport policy initiatives that can be implemented in a city. Design and consultation should seek to clearly communicate objectives and how pricing will help meet those objectives, and communicate in particular to those who will pay as to how it should benefit them. Ambiguity over communications (e.g., where and when pricing will be implemented), failure to communicate benefit to those who might pay and lack of clarity over the use of net revenues can all contribute to a lack of public support.

- Communications in advance of operation: Once a system has been procured, in the months approaching its commencement, it is critical to have a communications strategy to inform the public of the coming of pricing, when and where it will apply, how they should interact with the system (e.g., registering accounts or downloading an app) and who it will not apply to. This can save costs, frustration and inadvertent non-compliance when it comes to the system operating in the initial weeks.

Implementation of urban road pricing in Tauranga needs to also take into account the need for governance and institutional issues to be addressed for the city, around the delivery and operations of pricing, and the broader management of pricing in the context of the use of net revenues, and the impacts on tolls and other relevant charges. This is addressed in more detail in Section 1.9.

1.7 Impacts of Urban Road Pricing

This section discusses the impacts of congestion pricing on productivity, wellbeing and the distributional impacts of pricing (and how to address significant negative impacts).

Productivity

Productivity impacts are the direct and indirect impacts of the urban road pricing scheme on businesses, workers, and consumers. For businesses, the impacts are likely to be greatest for those that supply transport services (such as freight/logistics firms, bus operators, and taxi/on-demand transport services), followed by those highly dependent on transport (such as construction, property servicing, and waste management). However, many businesses reliant on logistics, such as retail and manufacturing are also significantly impacted by congestion, and conversely can benefit from improved trip reliability and reduced travel times that should arise from a well-designed and targeted urban road pricing scheme.

The effects of congestion on productivity for businesses can include:

- Labour and business operating costs to process late deliveries;
- Penalties or lost business revenue associated with missed schedules;
- Costs of spoilage for time-sensitive, perishable deliveries;
- Costs of maintaining greater inventory to cover the unreliability of deliveries; and
- Costs of reverting to less efficient production scheduling processes.

Trip reliability and travel time savings can deliver productivity benefits for businesses to minimise these negative impacts. Time savings through both increased trip reliability and decreased travel time enable more productive activity for vehicle occupants, which is directly more productive in some instances (such as freight operators and trade services). This includes simply being able to undertake more fee-paying work and scheduling more appointments during a given day because less time is wasted travelling. Furthermore, this productivity, in effectively lowering costs, may also increase competition in services businesses. This is because the threshold for commercial viability reduces as costs (such as travel time and fuel) reduce, and the geographic reach of such businesses can increase (as the same amount of travel time enables customers at a greater distance to access the services).

By enabling more production and more sales for the same or lower cost, their customers can also receive benefits and become more productive. These downstream effects can be considerable, but they are almost impossible to model efficiently. For workers and consumers it may mean more time for social, leisure and other discretionary activities, or to work longer hours (if there is flexibility in working hours). This can enhance wellbeing and deliver direct financial benefits.

These direct productivity benefits are further enhanced by the greater opportunities that reliable trips and reduced travel times present to businesses and employees. This includes:

- Access to more customers, as more customers can access the premises of a sales outlet, or more customers can be accessed for a service provider;

- Access to more employees, as a higher number of potential employees are willing to travel to the employment location;
- Public access to more employment opportunities, as more employers are accessible within the available travel time for potential employees (the reverse of the above); and
- Consumer access to more goods and services, lower travel times increases the opportunities to access retail, recreational, educational, and other services. This in turn increases competition for consumer goods and services, putting pressure in prices and service quality, which should enhance outcomes more generally.

Productivity benefits also arise from savings in transport investments that can be deferred, scale backed, or cancelled. Without road pricing, congestion would be more severe. This creates pressure for additional road capacity construction to be accelerated, whereas pricing capacity to spread demand would be a more efficient result. Similarly, the impact of congestion on the productivity of bus services is significant. One report from Wales indicated that a 13% decrease in bus speeds required a 26% increase in bus numbers and drivers to maintain a similar level of service.[44] In London, the introduction of congestion charging, along with incentives for bus operators on service quality, saw a 30% reduction in excess waiting time for buses after one year, with another 18% reduction in the following year. Although the proportion of this reduction attributed to road pricing is unclear, it is plausible that the significant initial travel time savings in the first year were a significant contributor to improved bus trip reliability.[45] Stockholm also reported significantly reduced travel times for bus services with reduced congestion, to the extent that some service frequencies were reduced. In short, urban road pricing has the potential to deliver higher frequencies of bus services at the same cost, or similar frequencies at lower cost.

Estimates of the productivity benefits from urban road pricing are difficult to find, primarily because most analysis considers only the direct user benefits. However, there is no shortage of estimates of the deadweight costs of congestion. It is notable that some research indicates the greatest benefits from road pricing may come from measures that prioritise trips of the greatest benefit. This is because pricing effectively prioritises trips at times of peak demand as to the value to the road user.[46]

Matthias Sweet's research of congested US cities indicated that average delays of more than 4.5 minutes per one-way trip, to specific locations, impeded job growth in those locations. The effect was:

you're either going to require higher wages to compensate you, or you're going to look for another job. And if congestion makes it harder to match the right workers to the best jobs, that's economically inefficient, too.[47]

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[44] "Source: Taming the traffic: The Impact of Congestion on Bus Services", Economy, Infrastructure and Skills Committee, National Assembly of Wales. https://senedd.wales/laid%20documents/cr-ld11145/cr-ld11145-e.pdf
[45] Source: "Central London Congestion Charging, Impacts monitoring Sixth Annual Report:, July 2008, Transport for London. p.94.
[46] "Traffic Congestion's Economic Impacts," Matthias Sweet , *Urban Studies* Vol. 51, No. 10 (AUGUST 2014).
[47] https://www.bloomberg.com/news/articles/2013-10-22/how-traffic-congestion-affects-economic-growth

These wider economic impacts are around access to labour markets, which benefits businesses (having more access to employees), benefits potential employees (with more opportunities), and increases the attractiveness of the location as a place for business. For Tauranga, this means it becomes a more attractive location because businesses in the metropolitan area become accessible to a wider geographic catchment of employees. This supports the location of a business due to proximity to potential customers and infrastructure to support the transport of goods, services, and customers further afield (specifically the port, airport, state highway connections to other regions and the East Coast Main Trunk Railway).

As more businesses choose to locate together in geographical proximity, there are also wider economic benefits from clustering. This reduces the transaction costs for trade between those businesses, but also contributes to the efficiency of the labour market.

The overall effect of efficient urban road pricing for Tauranga should lift the city's net productivity through the downstream effects of improved trip reliability and travel time savings. However, this improvement in productivity can only arise if pricing is applied at times and locations where congestion generates regular delays that are significant. The wider question is that what is "significant" depends on the trip type. Sweet's research indicates 4.5 minutes for a total trip may be applicable for commuter (and education) trips, but smaller delays may be higher for business and freight traffic making multiple trips during the day.

Wellbeing

More difficult to calculate is the impact urban road pricing may have on wellbeing. As with direct impacts, this is a balance between the impacts of the fee on people's personal budgets and the opportunity cost of the fee, against the value of the savings resulting from lower congestion and improved travel time reliability.

Generally, the enhanced wellbeing from efficient road pricing should come from:

- Trip reliability enabling more dependable planning of, and increased time for, family, leisure, and social activities around trips;
- Travel time savings enabling more time to be available for other purposes, thereby reducing stress in balancing time between work, travel, family, leisure, and social activities; and
- Reduced stress from easier travel conditions, whether by car or other modes.

These apply to private car users, bus users, and, to a lesser extent, active mode users (as they generally can bypass congestion, although may be affected by delays at traffic signals). In Singapore, attitudinal surveys after the introduction of road pricing indicated that bus drivers, cyclists, and residents within locations subjected to pricing saw the effects of pricing as positive for them. Whereas car users, taxi users, and residents of areas outside priced areas saw it as neutral or mildly negative. This appears to reflect how much people pay under the pricing system relative to the benefits they experience from decreased congestion.

Care must be taken around scheme design, as wellbeing for private car occupants is unlikely to be enhanced if road pricing is applied in locations at times where congestion is insufficient to justify pricing. In other words, if the price paid at less congested times is noticeably higher than the value of travel time savings and reliability benefits, then there is a net loss to the consumer.

As noted above, there are longer-term benefits to wellbeing that reduced travel times present in terms of opportunities for the public, whether as workers or consumers. These may be seen as more subjective and complex to assess, as they reflect the willingness to travel as a function of time.

Although people vary in what they regard as "acceptable" travel time to access different opportunities or services, everyone has a time "budget" that they may decide to "spend" in different ways. Accessing a better job may be offset by a commute that is significantly longer, as is accessing a retail outlet with cheaper goods or a wider range. One of the key benefits of living in or close to a growing city is that opportunities for employment, education, recreation and consumption of goods and services are greater than in smaller cities, towns, or rural areas. Traffic congestion inhibits access to these opportunities, by placing penalties on time that are lower or non-existent in other locations. This effectively deters residents from travelling beyond a certain threshold to access an opportunity. Similarly, service providers (such as plumbers, cleaners, and food delivery services) frequently limit the range of their customers based on travel times, which restricts their customer numbers, and access to their services for consumers. This reduces competition and increases prices for consumers. Urban road pricing could therefore increase the available service providers for consumers, thereby incentivising price decreases and service quality increases. This will have a net benefit to overall wellbeing, regardless of whether consumers pay to use the roads at peak times or not.

This could be depicted by considering the opportunities available by travel time and mode from key population centres, according to the proportion of potential employees willing to commute for certain times. In large metropolitan areas like Auckland there is willingness to commute for longer periods, reflecting the cost of housing and in some cases salary levels for certain types of jobs. In Tauranga this is likely to be less prevalent, but will grow as the city increases in population and scale.

Travel times present a barrier to opportunities for employment, education, recreation, retail, and services (including service providers at home). Urban road pricing that improves trip reliability and reduces travel times should not only increase the number of jobs available for residents of locations affected by congestion, but also increase access to education, recreation, social, and cultural opportunities.

Finally, although it may be considered an element of productivity, the effects of congestion on the access to and performance of emergency services is often ignored. One estimate from California is that traffic congestion imposes costs of USD $130–360 million (NZD $208–507 million) per annum due to delays to fire and ambulance services.[48] These costs range from additional property damage through to loss of life. Whilst these costs for Tauranga are likely to be significantly smaller, there will be similar costs arising from the effects of congestion on emergency vehicles, particularly during time critical emergencies. Addressing such congestion is likely to have a positive impact on wellbeing overall.

Effect on overall affordability of travel

The affordability of travel is a function of both price and time. Although there is understandably a primary focus on price when analysing urban road pricing, it is important to

[48] "Traffic Congestion and the Performance of First Responders: Evidence from California Fire Departments" Louis-Philippe Beland, Daniel Brent, *Louisiana State University*, May 2018

not underestimate the importance of time. For all journeys taken in an urban area, there are trade-offs around the costs of travel:

- Driving costs, such as tolls and fuel.
- Public transport fares.
- Parking costs.
- Parking availability, the scarcity of which affects time.
- Travel time, including walking time between parking and public transport.
- Reliability of expected travel time.
- Waiting time for public transport and parking, if scarce.
- Reliability of waiting time for public transport and parking.
- Comfort of travel in vehicle, at waiting locations, on topography of route and in urban environments.
- Effects of weather, especially on active modes and public transport.

These are also influenced by the purpose of travel:

- Importance of travel time reliability (e.g., commuting, education, business, or other appointments).
- Flexibility of travel time (e.g., comparing commuting, social, retail, and recreational trips).
- Transporting children or goods (e.g., retail purchases, refuse, sports gear).

Key to evaluating the impacts of urban road pricing on the affordability of travel will be the trade-off between the cost of the fees of urban road pricing and the value placed on the resulting time savings both to fee payers and those beyond the charged network. For example, in Stockholm, many of the travel time savings were upstream and downstream of the central city cordon. This is because motorists using roads approaching the charging points whose journeys terminated outside of the cordon still benefited from reduced congestion on their journeys.

Many journeys are not undertaken because the travel time is excessive. (e.g., people decide whether they will travel to an event, a shop, or a place based on how long it will take to travel there and back, compared to alternative uses of time). The price of travel is also part of the equation. For driving, there is a sense of the cost of fuel and parking, although for short trips there is little concern for the former unless someone is rationing travel due to a low income. The effect of urban road pricing to address congestion should be to reduce the time penalty at peak times in exchange for the financial penalty of using road space at a time of peak demand. The reasoning being that enough motorists have options to change travel time, travel mode, or to not travel at all on that occasion, which removes enough car trips such that others benefit from reduced congestion. *Table* 5 summarises how urban road pricing can change various factors of travel affordability.

Factors of travel affordability	Urban road pricing potential impacts
Driving costs	High (increasing direct costs)
Public transport fares	None (unless net revenues used to reduce fares)
Parking costs	None (indirectly may lower if demand reduced)
Parking availability	None (indirectly may improve if demand reduced)
Travel time	High (reducing travel times for driving/buses)
Reliability of travel time	High (improving trip reliability for driving/buses)
Waiting time	None
Reliability of waiting time	Medium (improving trip reliability for buses)
Comfort of travel	Medium (eases driving stress, reduces traffic for active travel)
Effects of weather	None

Table 5 Potential impacts of urban road pricing on travel affordability

To positively affect affordability, an urban road pricing system must offset increases in driving costs with decreases in the cost of travel time (including travel time reliability), both for driving and alternatives to driving, and use net revenues appropriately.

Evidence from Gothenburg indicates that applying urban road pricing outside periods and locations of congestion can have a net negative impact on the affordability of travel. This is because travel time savings overall do not offset the cost of the fees charged. Figure 13 shows that even the highest income drivers, which have the highest value of time, are not net beneficiaries from the travel time savings of the Gothenburg congestion tax. This is because the scheme operates between peak periods and charges multiple locations which do not experience significant congestion at *any* time of day.

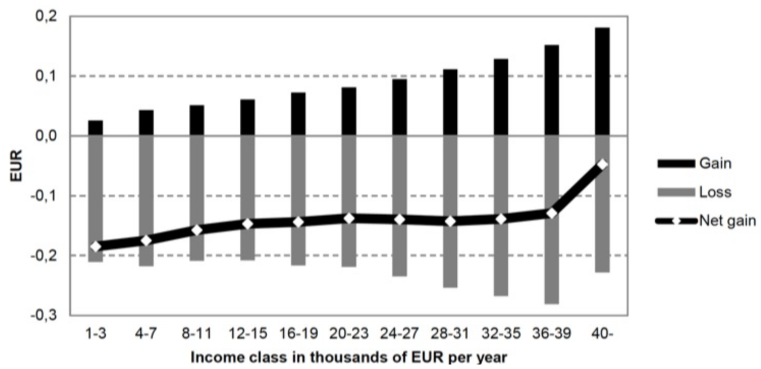

Figure 13 Net losses for car drivers by income group residing in Gothenburg labour market area[49]

This not only affects travel affordability for commuters, but also for educational, recreational, and retail trips, as the Gothenburg congestion tax is designed to raise revenue, not deliver net benefits in terms of reduced congestion.

A scheme designed to relieve congestion, such as in Stockholm or Singapore, sees affordability impacts varying. Outside of charged periods, there is no effective impact on affordability. This does not include any impacts from the use of net pricing revenue to improve transport

[49] Source: "*The Gothenburg Congestion charges: CBA and equity*" Jens West, Maria Börjesson, Centre for Transport Studies, Stockholm, Working Paper 2016:17

infrastructure. During charged periods, discretionary trips with more travel time flexibility should be less affordable (e.g., for recreational or retail purposes), but impacts for commuter, business and educational trips should be neutral. Impacts should be positive for users of non-car modes, as they should experience lower congestion without paying fees, even excluding the impacts of using any net revenues to enhance such modes. For car-users the impacts on affordability are likely to range from negative to neutral, depending on their value of time and the cost of changing behaviour.

A key factor is the use of net revenues. In Gothenburg a key criticism is not only that the scheme charges car users at times and locations where there was little previous congestion, but that most of the net revenues are used on projects that generate few benefits for those using cars or public transport. In some cases, these projects even have benefit-cost ratios of less than 1. The redesign of the central railway station for intercity passenger trains primarily benefits intercity trips primarily by visitors and those from outside Gothenburg, not local trips. This means that the Gothenburg congestion tax reduced affordability of travel for those commuting in Gothenburg, in net terms. By contrast, if net revenues are used to support funding of transport projects that benefit trips affected by the urban road pricing scheme, this can offset the impacts on the affordability of travel. In the case of Stockholm and the Norwegian urban schemes, this has included major highway projects that reduce travel times, and enhancements to commuter public transport. Another way to enhance affordability is to recycle net revenues through reductions in other fees and charges. In the Tauranga context, this could come from reducing rates, parking fees, or public transport fares. This could also come from providing credits redeemable either as cash or to use for services such as parking or public transport.

The key issue is managing the distributional impacts of urban road pricing, such that those who may face challenges in affording urban road pricing fees to access employment or essential services are not unduly disadvantaged.

Distributional impacts and solutions to such issues

Distributional impacts (sometimes referred to as “equity”) relate to whether a policy intervention applies fairly to those targeted, and how it impacts them according to their ability to pay or ability to reasonably change behaviour to avoid paying. In the context of urban road pricing this reflects two key issues:

- Charging vehicles according to the relative use of the network.
- The effect of road pricing on those on lower incomes, especially those with little flexibility to change behaviour regarding high value trips.

The first point is reflective of how an urban road pricing rate structure might apply to different types of vehicles. For example, Singapore sets rates based on the “passenger car unit” equivalent of road space occupancy. This means charging motorcycles half price of cars and charging heavy vehicles two or three times the rate of light vehicles. If urban road pricing is intended to be a charge for occupancy of a scarce resource, then this is a reasonable approach. Stockholm, Gothenburg, and London all charge the same rate regardless of vehicle size (although in London motorcycles are exempt), in part to recognise that mode shift by heavy vehicle users is extremely unlikely and that time-of-day changes are unlikely to be influenced by urban road pricing rates. The question of how to set urban road pricing charges by vehicle type should be considered as part of detailed design.

The effects of urban road pricing on more vulnerable communities are a mix of four elements: income, geography, trip purpose, and flexibility to minimise or avoid road pricing.

Traditionally, concerns about distributional impacts of those on lower incomes have been focused on values of time, based on incomes, as a reflection of how much an individual earns during employment. This is coarsely seen as a proxy for value of time such that, for example, someone on an income of $150,000 a year has a higher value of time than someone on $30,000 a year. This is then seen as meaning that a travel time saving is more valuable to someone on a higher income than someone who is not.

Early experience of toll lane users in the United States indicates that for some on lower incomes, with multiple jobs, the value of time is dependent on the specific trip type. The cost of missing an appointment or a flight may be significantly greater to those on lower incomes with less flexibility than those on higher incomes.

However, in general terms those with higher values of time benefit the most from an urban road pricing scheme because they are willing to pay the fee to use the road that is less congested. In short, they value travelling at that time and the travel time savings. Those who do not perceive such a value choose not to pay the fee, and travel at a different time, by a different mode, or to not travel at all. This is key to the effects of urban road pricing in managing demand.

The impacts of this depend on several factors, such as:

- Purpose of travel;
- Flexibility of travel time;
- Accessibility of alternative modes and their costs relative to driving; and
- The effect of the fee on disposable incomes.

At peak times of travel, business, commuting, and educational trips may be deemed as having the highest value. Business trips, because they are directly related to productivity and generation of income for the business, its shareholders, and employees. Commuting, because it provides access of employees to employment and employers to employees. Educational trips, because they provide access to education. The most vulnerable groups out of these are those on lower incomes, either accessing employment or education, who cannot access these outside of the operating hours of a peak period pricing scheme, and do not have access to cheaper alternative modes in terms of travel and waiting time.

Given this, urban road pricing schemes designed to reduce congestion seek to encourage behaviour change for two broad categories of trips:

- discretionary trips that need not be undertaken at the times of peak demand; and
- essential trips that can shift modes or vary time of travel moderately to spread demand.

It is widely accepted that discretionary trips, regardless of the demographic of those affected, should ideally be consolidated and/or be undertaken at off-peak times, so that road capacity at peak times is primarily available for essential trips, including commercial vehicles and freight. Trips for social, recreational, and retail purposes are almost always not time-bound,

Sensitivity: General

and urban road pricing should encourage such trips to be made at other times or by other modes.

Essential trips might be considered those to access employment, education, or essential services such as healthcare. Those on lower incomes tend to have less flexibility about employment times and locations. Furthermore, choices around times for education and healthcare are also likely to be largely determined by the institutions supplying those services. Urban road pricing should ideally not unduly impact those users, unless there are modal alternatives that do not penalise total travel time (including waiting time) and the cost of travel as much or more than driving. Otherwise urban road pricing may have negative distributional impacts. In short, there is a risk that urban road pricing could exacerbate socio-economic gaps for those located where their commute or trips to education or health services face higher costs of travel.

Development of the (subsequently cancelled) Manchester congestion charging scheme saw development of a proposed "low-income worker discount" of 20% off the congestion charge fee. This was proposed to function for a temporary period of between three to five years, and to provide a transition, by reducing the fee by enough so that workers on low incomes would be no worse off after accounting for travel time savings. Functionally it was proposed that employers would register workers in the scheme with a vehicle to undertake one return trip each weekday with a discount. The discount was proposed to be phased out after several years, reflecting the mobility of many low-income workers to relocate both employment and housing, but also expected improvements and changes in public transport service patterns to provide adequate alternatives.

Standard transport-economic theory indicates that the fees collected should be used to benefit those who pay, but according to Eliasson, this doesn't consider three important factors:[50]

- First: network effects. Since queues propagate "upstream", even those not going through the actual bottleneck will suffer from queues. Pricing traffic in the bottleneck to reduce queues, all upstream traffic will benefit – not only drivers paying the charge.
- Second: the effect on the urban environment. Typically, standard analysis of congestion charges takes no account of effects for pedestrians or cyclists, or the effect on the perceived urban environment.
- Third: the self-selection effect on trips and on the value of time. Congestion charges will tend to "sort" trips such that trips with high value will stay on the road (and enjoy time benefits), while low-valued ones will be priced off. Not taking this phenomenon into account will underestimate the value of the time benefits.

He notes that individuals belong to different "groups" on different days, not by income type, but trip purpose. The reason being that travel patterns are much more variable than most realise. In Stockholm, on any given day only 5% of car trips are affected by the charges, which notably operate all day from morning peak until the end of the evening peak. However, over two weeks around 43% of private cars registered in greater Stockholm will be subject to at

[50] Source: The Stockholm congestion charges: an overview, J. Eliasson, Centre for Transport Studies, Stockholm, CTS Working Paper 2014:7, p. 37.

least one charge, but only 2% of cars pay twice per weekday (as in a regular commuter). Although the conditions in Stockholm are different from Tauranga, as the public transport mode share is substantially higher, it is unlikely that trip patterns are more homogenous. Whilst a much higher proportion of employees commute by car in Tauranga than in Stockholm, the bigger question is what proportion of those vehicles would be subject to an urban road pricing fee, and how frequently they would be.

In Gothenburg, the use of net revenues is critical in evaluating the distributional impacts of its congestion tax, particularly as the net travel time savings are lower than the value of the fees collected from road users. It was noted that:

In Gothenburg the revenues are not spent to improve the local public transport system to benefit local groups. It is rather spent on a rail tunnel that will mainly benefit commuters further out in the region as explained in Section 2. As long as a congestion charge is justified from the perspective of economic efficiency and to price externalities, negative distribution effects may be less controversial. But since the congestion charge in Gothenburg is mainly implemented for fiscal reasons, to finance the rail tunnel and other infrastructure projects, the equity concern may be more problematic.[51]

Distributional impacts should be assessed in parallel with the detailed economic appraisal of the project. This should seek to identify:

- Trips that incur the most road pricing fees, ideally by trip purpose, demographic, time of day and origin/destination pairs; and
- Trips experiencing the greatest benefit, by similar factors.

This would then identify those who gain the most and lose the most from urban road pricing, excluding the impacts of how net revenues may be distributed. This would help to inform how best to use net revenues to mitigate negative distributional impacts.

Options to address negative distributional impacts and locations with high levels of car dependency

Negative distributional impacts, including impacts on locations with high levels of car dependency can be addressed through measures that affect:

- Urban road pricing scheme design.
- Conditional access rules for locations.
- Use of discounts, exemptions, or caps for user groups.
- Improvements to alternatives.
- Phased introduction of charging points, to progressively test impacts, rather than a “big bang” that could be seen as disruptive.
- Partial redistribution of revenues from residents in affected locations.

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[51] Source: The Stockholm congestion charges: an overview, J. Eliasson, Centre for Transport Studies, Stockholm, CTS Working Paper 2014:7.

Sensitivity: General

<u>Scheme design</u>: Urban road pricing schemes that target peak demand and congestion only where and when it occurs are likely to minimise negative distributional impacts. Evidence from Gothenburg suggests that if that scheme were focused only on routes with serious congestion at peak times, then the negative distributional impacts of that scheme would have been greatly reduced. Singapore's experience demonstrates how it is possible to have charging points with prices that vary by location and times of operation, which enables pricing to be highly refined. By minimising the risk of pricing trips on uncongested routes, the negative impacts of a scheme can be minimised by design.

<u>Conditional access rules</u>: The geographic nature of a road network sometimes means it is difficult to avoid placing charging points on a road which might unduly impact some trips from a specific location with few alternatives. Such examples have existed in Stockholm (Lidingo Island) and Gothenburg (Backa). In Stockholm, trips from Lidingo Island crossing a charging point were exempt, if they exited another charging point within a set period. This exemption was removed once Lidingo was connected to a new bypass highway which made it possible to enter and exit Lidingo away from the cordon. In Gothenburg, residents of the suburb of Backa were unduly affected by the city's congestion tax, which operates from 0600 to 1830 on weekdays, when making short trips across the E6 highway to the eastern part of the suburb by the river. This included a wide range of trips, such as healthcare, retail, social, recreational and access to other services. Given these impacts, Gothenburg introduced in 2020 a conditional exemption so that any vehicles passing charging points 17-21 will pay only if they have passed a control point to the west, which means the trip is a through trip. This is depicted in Figure 14.

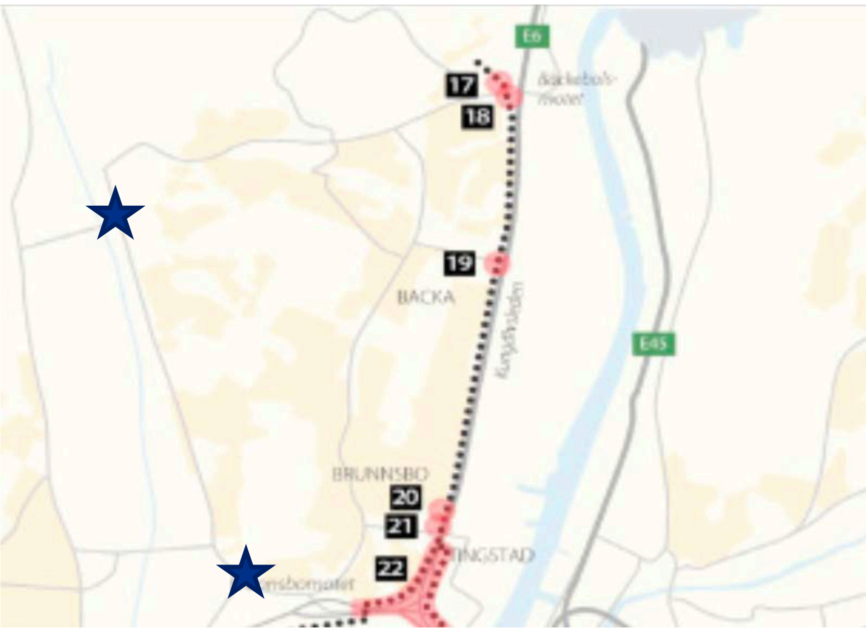

Figure 14 Backa exemption in Gothenburg

Such a conditional access system can be implemented for any local area where use of the charged route is necessary to access essential services. It is important to note that Backa residents using any other parts of the network subject to the congestion tax are still required to pay, but they are protected from being unduly affected when undertaking local trips to essential facilities.

Discounts, exemptions, or caps: Discounts or exemptions can be used to mitigate negative impacts. For example, a single return trip per day could be granted free of charge or at a substantial discount for residents with vehicles registered in a specific location that has limited alternatives. Employers, educational institutions, or health providers could be permitted to register staff, students, or clients under specific criteria (such as income or Community Services Card eligibility) for a discount over a transitional period if there are issues in accessing employment or essential services. Caps may be applied generally (limiting the number of times a specific vehicle can be charged during a day) or specifically (to vehicles owned by specific users), to limit impacts. However, this may also disincentivise more efficient vehicle use by commercial users. Care needs to be taken not to apply discounts too widely, or to define them too loosely, to avoid the risk of fraud and administrative costs from such programmes.

Improvements to alternatives: Provision of improved public transport and/or active transport options (whether to support public transport or not) can mitigate negative impacts, particularly if an urban road pricing scheme affects a specific geographic location. For public transport, focusing on peak services to key locations or to feed onto existing services may also be an opportunity to enhance access more generally for an area.

Phased introduction of pricing: A key characteristic of urban road pricing is that the impacts of charging any single point can be significant well beyond the immediate corridor. The downstream and upstream impacts can ease congestion at other points along the corridor, which may *reduce* the urgency to implement additional charging points on the corridor. This should mitigate some negative impacts without unduly undermining the effectiveness of the scheme for reducing congestion. The Congestion Question noted that there are merits in (Auckland) implementing charging on the city centre first, to identify the impacts on the major corridors approaching the city centre, before implementing corridor charges at other locations in the Isthmus and beyond. Implementing locations that may minimise negative impacts, but have significant positive impacts, first may delay or avoid adding charging points at locations where there may need to be further interventions to avoid negative impacts.

Partial redistribution of revenues to people from affected locations: A more radical, but direct, response to concerns around distributional impacts in areas with high levels of car dependency would be to redistribute net revenues, equivalent to revenue generated from such locations. This could be done through direct transfers (credits to residents) or in public projects that directly benefit the residents of such areas. Such credits could be made several times a year or be more indirect and support progressively reducing car dependency when and where it may be efficient to do so.

1.8 Modelling of operational urban road pricing schemes

There is extensive experience internationally of modelling proposed urban road pricing schemes, but the experience of modelling in advance of an operational scheme is significantly more limited. This section reviews the experience of the four most notable and sophisticated of such schemes (Singapore, London, Stockholm, and Gothenburg) in modelling results before and after the introduction of their respective schemes.

Singapore

As it dated from 1975, there was limited modelling available to develop Singapore's original ALS scheme, but rather economic estimates made of the impacts of pricing on demand for what was defined as a practical scheme at the time. Prices were derived based on an assessment of elasticity comparing responses to parking prices, as to how they might reduce demand at peak times sufficiently to relieve congestion. The estimates were below the actual demand response, and the demand elasticities identified were used in assessing expansion of the operating hours and geography of the scheme. Experience of the demand responses from the ALS and its successor (the RPS or Road Pricing Scheme) were used to assess the rate structure for the Electronic Road Pricing (ERP) scheme before 1998, to develop pricing to achieve targeted levels of service for the priced corridors. As Singapore was willing to take an iterative approach to urban road pricing over time, it adjusted charge rates by time and location as it expanded the ERP scheme, with its quarterly analysis of traffic flow and speeds used to inform changes to the scheme. This example presents limited guidance on modelling and appraising the Tauranga scheme. The key lesson that may be derived from Singapore is the value of gradualism in introducing pricing, because it enables future stages to be implemented guided by the behavioural responses seen with the first stage of implementation.

London

By contrast with Singapore, extensive modelling and appraisal had been carried out on options for urban road pricing in London over many years.

The ROCOL study which formed the basis for the final London congestion charge scheme used Transport for London's (TfL) strategic transport model to forecast demand impacts by mode and origin/destination by zone and applied these results to multiple local traffic assignment models to identify the effects on traffic flow at and approaching the charging zone. Although the overall impact was to reduce demand for road space by vehicles subject to the charge, significantly increased congestion was identified by the traffic assignment models at various locations. This resulted in a study that identified ways to mitigate those impacts through redesigning intersections, changes to traffic signal phasing and other traffic rules. Such impacts were primarily around the boundary route to the congestion charge area, which reflects traffic seeking to avoid paying the charge if its final destination is not within the area. The study was followed up by development of the final scheme design and selection of the proposed fee rate (at the time, £5) which was then applied to the strategic transport model, with the final scheme design to develop the forecast impacts. Those impacts were forecast to be a 10-15% reduction in traffic with a 20-30% reduction in delays, actual impacts were a 15% reduction in traffic with 30% reduction in delays (measured by the proportion of time vehicles are stationary or moving very slowly in queues). This suggested that the modelling approach taken was appropriate for the introduction of the scheme.

Post implementation, TfL collated detailed counts of traffic at all entry points and statistics on public transport usage. Over the subsequent five years, TfL used moving vehicle observer surveys, monitoring and enforcement cameras, trip diaries, travel surveys, data from parking providers, business surveys, environmental indicator assessment and economic case studies on specific sectors and locations to undertake annual impact monitoring reports. These reports provided data on changes in transport, economic, social and environmental policy indicators, and what could and could not be attributable to the congestion charge. Noting it is sometimes difficult to distinguish between the scheme impacts and wider economic or policy impacts (such as significant increases in bus services).

Stockholm and Gothenburg

The two examples in Sweden are two different cities that took similar approaches to appraising and modelling in advance of their respective road pricing proposals. Gothenburg with a population of only around 500,000, but with a mode share for public transport of 26% for trips passing locations that would be priced (compared to 77% for Stockholm).

Overall approach

For Stockholm and Gothenburg, the Swedish national demand forecasting model was used (called SAMPERS). It is described as follows:

Sampers consists of nested logit models for six trip purposes (Work, School, Business, Recreation, Social and Others), modelling choices of trip frequency, destination and mode (car as driver, car as passenger, public transport, walk and cycle). The demand models include private and business travel. Freight traffic OD matrixes are fixed (and thus assumed to be insensitive to congestion charge). There are three analysed time periods (morning peak, evening peak and off peak), over which demand is distributed using fixed time period factors per trip purpose applied uniformly to all origin-destination pairs. Road and transit link flows are calculated using the software package EMME/3.[52]

In Stockholm the traffic reduction effect was 20% and in Gothenburg 12%, both within the range of what modelling forecast. Price elasticities forecast and observed were similar at -0.87 in Stockholm and -0.69 in Gothenburg, but when split between peak and off peak, the elasticity in the off-peak was 1.7 times higher than the peak elasticity in both cities (-1.13/-0.67 and -0.93/-0.53 respectively). This indicates how much more price sensitive off peak trips are to pricing, primarily because they include a much higher proportion of discretionary trips compared to the peaks, but also because in both cases, the pricing proposals included pricing in both directions, so that an inbound trip in the off-peak period may also face paying for an outbound trip during the peak.

In Stockholm it appears that elasticities are increasing over time (from an average of -0.87 to -1.24 in 2014), which is attributed to the gradual growth in adaptation to the congestion tax (supported by enhanced public transport), but also the gradual increase in travel times for driving in Stockholm due to construction work. In short, people in Stockholm are becoming more responsive to the congestion tax, not less, although this responsiveness is growing for motorists that are not regular users of the congestion tax (but reducing for those that are).

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[52] Source: "The Gothenburg congestion charge Effects, design and politics", Maria Börjesson, Ida Kristoffersson, CTS Working Paper 2014:25, Centre for Transport Studies, Stockholm.

Sensitivity: General

In Gothenburg, the opposite trend has been noticed with a gradual reduction in elasticity (from -0.69 to -0.52 in 2015). This has been attributed to the lower level of public transport service and more dispersed employment patterns in Gothenburg, meaning that drivers over time "accept" the presence of the congestion tax and respond less to it. Gothenburg's level of public transport service is significantly higher than that in Tauranga, suggesting that Tauranga would have even lower demand elasticity over time, unless its growth results in transformative changes in modal use in the coming decades.

Sensitivity to the congestion tax in itself does not automatically apply to sensitivity to the increases in the charges, for those already paying them. In both cities there was a much more muted demand response than was forecast. In Stockholm, the congestion tax at peak time was increased by 75% in Gothenburg by 22%. The effect was only a 5% reduction in trips across charging points in Stockholm, and a 1% reduction in Gothenburg, suggesting elasticities of only -0.28 and -0.16 respectively for both cities. This is explained as having already priced off most discretionary trips, the initial demand response to both cities' road pricing schemes resulted in remaining users having a high value of time. Most price sensitive users have already changed travel time, mode or no longer travel so frequently, so those remaining are still willing to pay to drive. Another factor is that once urban road pricing is applied, the "zero-priced goods effect" is gone, in that decisions regarding demand for what are perceived as free goods (like road space) change once a price is applied.

For Tauranga, what this means is that the modelling of the effects of increases in pricing on an existing scheme needs to take into account the declining demand elasticities after a scheme has been in place. The greatest "return" from urban road pricing, in demand management terms, in the application of a price to a location at a specific time, in the first instance. Increasing that price will see diminishing returns in reducing demand, because the proportion of drivers with price sensitivity and discretion to not drive at that location and time reduces significantly.

Impacts

Demand stabilised in Stockholm after one month of operation, but in Gothenburg it took eight months. Gothenburg overpredicted traffic reductions in the peak, but not the off peak. *Table 6* depicts the difference in observed and actual demand after one year of scheme operation in Gothenburg.

October 2012 to October 2013	Observed	Forecast
AM Peak	-13%	-18%
PM Peak	-12%	-18%
Mid-day	-12%	-13%
Charged hours	-12%	-15%
Uncharged hours	-2%	0%

Table 6 Modelled and actual changes in trips across cordon in Gothenburg

This is not the outcome from modelling for Stockholm, where the prediction of peak traffic decline matched the outcomes, but interpeak decline was underpredicted because it did not expect sufficient of a response on discretionary trips. Note both schemes apply during interpeak hours, and it proved difficult to identify the proportion of trips that shifted from peak to interpeak vs. those that shifted mode or did not travel at all during the interpeak period (primarily because surveys of road users saw few that could recall what their previous trip patterns were). Actual traffic counts only present raw figures, so whilst peak travel traffic counts indicate a reduction in vehicle trips (suggesting some shifted mode, some shifted travel time and some trips consolidated), interpeak traffic counts will include some that shifted from the more expensive peak period, along with a reduction from those that shifted mode, consolidated trips and a few that would have shifted travel time beyond the peak/interpeak charging period. However, it is very difficult to distinguish the proportions that made these different types of behavioural responses.

The modelling of route choice behaviour over-predicted changes in route choice than that which was observed in practice. This was particularly so in Gothenburg, even though it has more opportunities to avoid charged locations than Stockholm (which was just a simple cordon). *Table 7* illustrates how the modelling in almost all cases in Gothenburg overestimated the likely changes in traffic volumes due to pricing in the AM peak at uncharged locations on the network. With only one exception, this suggests that drivers would rather continue to drive on major routes and pay a fee, than to add travel time (and uncertainty, and the discomfort of a less direct route) to avoid paying the fee.

Location	Forecast AM peak traffic change	Actual AM peak traffic change
Sœderleden	+3%	+1%
Bergsjøvågen	+15%	+3%
Bjørlandavågen	-8%	-4%
Angeredsbron	+18%	+4%
Jordfallsbron	0%	+24%
Landvettervågen	+32%	+19%
Tuvevågen	+22%	+6%
Norrleden	+34%	+26%

Table 7 Gothenburg uncharged location forecast and actual change in trips

Conclusion

The standard approach to model and appraise the transport economic benefits of an urban road pricing scheme, by using the outputs of a strategic demand model to apply to a trip assignment model on the network, appears to remain valid and deliver adequately accurate results in forecasting the effects of an urban road pricing scheme on demand and revenues.

However, experience in Sweden seems to indicate that there is a risk that models will over-estimate the willingness of drivers to divert around a charging point, to save money, but underestimate the responsiveness of drivers undertaking discretionary (non-commute, non-education, non-business) trips. Data on the proportions of car traffic by trip purposes would likely be highly informative in helping to establish the likely elasticities of demand for applying urban road pricing to various locations in Tauranga. Given Tauranga is a highly car-dependent city, this is likely to mean a relatively lower level of demand elasticity to pricing than in the cities that have implemented urban road pricing to date. This is due to the lack of alternatives to driving for many trips. What will be important is ensuring that the modelling for Tauranga assigns appropriate factors to roads beyond travel costs, to reflect the likelihood of diversion responses to charges on main routes. The existing toll roads in Tauranga provide a useful baseline for this, but there is likely to be a difference in response between introducing pricing on an existing road, with an obviously inferior alternative that has rarely been used.

However, unlike London and the cities in both Sweden and Norway that have implemented road pricing, if pricing is only applied in the peaks, the option to change trip time is likely to see higher elasticities of demand for travel in those times, at least as an initial demand respond sees discretionary trips priced out of those periods at those locations.

1.9 Latest developments

Singapore

As a pioneer of urban road pricing, Singapore has long been recognised as operating the most sophisticated congestion focused urban road pricing scheme of any city. Each priced location has its own rates by time of day increments, direction of travel and vehicle classes, and is subject to quarterly reviews of pricing to reflect network performance at that location.

Urban road pricing in Singapore has evolved in three major stages so far:

- 1975: Introduction of paper-based permits for access to central city cordon during the morning peak, later expanded to evening peak and interpeak periods (called the Area Licensing Scheme)
- 1995: Introduction of permits for access to three expressways during weekdays (called the Road Pricing Scheme)
- 1997: Introduction of electronic road pricing (ERP) for the cordon and expressways, with progressive expansion to a second cordon and multiple expressways and arterial routes.

In the past five years Singapore has been developing its replacement system called ERP 2.0. The existing system is paid on two-way in-vehicle on-board units (OBUs) that enable large overhead gantries to detect vehicles, and deduct value off of prepaid smartcards inserted into the OBUs. This is to be replaced with GNSS OBUs (see Figure 15) that measure road use by correlating location via satellite-navigation signals to an on-board map. These OBUs have some parallels to those used in New Zealand for electronic road user charge (eRUC) collection but are supplemented by a graphic user interface (GUI) screen, to display traffic, parking and other transport mode information, along with pricing information to drivers. It is important to note that Singapore does not intend to charge by distance, although ERP 2.0 will have the capability of measuring and reporting distance travelled (and could be used for distance based charging).

The reasons for introducing ERP 2.0 are as follow:

- The existing ERP system is at the end of its economic life;
- Existing ERP gantries at charging points (Figure 16) can be replaced, in favour of less visually intrusive pole mounted ANPR cameras for enforcement;
- More information can be supplied to drivers, including live traffic and parking data, and parking payment can be automated;
- More flexibility in introducing new priced points anywhere on the road network, enabling it to be more responsive;
- Potential for distance based pricing at a later date.

Sensitivity: General

Figure 15 Illustrative new Singapore ERP OBU

Figure 16 Singapore ERP gantry

All vehicles in Singapore are to have new OBUs installed to replace existing units, at no cost to owners. As of August 2022, computer chip shortages and logistical issues with delivery have delayed roll out of the new system until the second half of 2023.

Once it is introduced, it will the world's first urban road pricing scheme operating using GNSS technology and will demonstrate the technical and financial viability of introducing such technology onto a fleet of vehicles. As a city state, it is relatively easy to make such technology mandatory on vehicles, but for Tauranga this is unlikely to be viable, unless central government mandated such systems on all vehicles across the country to support wider pricing initiatives.

Brussels, Belgium

The Brussels City Region Government has been considering the merits of introducing urban road pricing across its jurisdiction with a network pricing scheme (applying to all public roads). The project called "Smartmove" proposes replacing annual vehicle registration and licensing fees with a distance-based fee, with higher peak charges.[53] Although it would replace fees for Brussels vehicles owners, the fee would apply to all vehicles entering Brussels. Annual vehicle licensing fees in Brussels currently range from around NZ$135 to NZ$4,200, depending on emissions rating and engine capacity.

The objectives of *Smartmove* are to:

- Reduce congestion (target of 30% reduction in time lost in congestion);
- Reduce emissions (target of 10% reduction in CO_2 emissions); and
- Generate new revenue to invest in infrastructure.

A stated metric is to reduce private car trips by 30% and VKT by 18% by 2030 by encouraging mode shift. Smartmove includes not just road pricing, but also Mobility As a Service, by providing a full service trip planner that includes other modes.[54]

The proposed technology to be used is a mix of a mobile phone app with ANPR enforcement.

All light vehicles circulating within the jurisdiction of Brussels City (except on one orbital motorway used to bypass the city), would be required to have a mobile phone on the vehicle, operating an app that measures and reports distance travelled by location and time of day, and paired with the vehicle (by declaring its number plate). The app would measure road use, until the vehicle is detected as having departed the Brussels City Region. ANPR cameras scattered throughout Brussels will detect vehicle number plates, which will be processed to determine if the vehicles have a mobile phone with the app operating at the time of detection. Those that have not would be fined.

Singapore had previously investigated the merits of using mobile phones to collect road pricing fees, and some US jurisdictions have considered it (and it was noted in work undertaken for The Congestion Question). In all cases significant limitations with the technology were noted including:

- Requiring a mobile phone to be "on" and the app "on" before driving is likely to result in multiple drivers forgetting to launch the app, or choosing not to do so (and claiming technical difficulties)

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[53] It is not proposed to apply Smartmove to heavy vehicles, which are already subject to the Belgian heavy vehicle road user charging scheme called Viapass (which charges travel on roads in Brussels a higher rate than in neighbouring federal states).
[54] A demonstration video is included here (French with English subtitles) https://smartmove.brussels/smartmove-c-est-quoi

- Difficulties in ensuring that the mobile phone app is "off" or not measuring travel when the phone is removed from the vehicle it is associated with (e.g., if the driver switches to a bus, can the phone detect whether it is no longer in the car?)
- Risk that a phone app for a vehicle with multiple drivers will see two phones measuring trips in parallel if both drivers travel at once
- Risk that a driver for multiple vehicles will enter the wrong number plate for the specific vehicle
- Concern that the mobile phone power supply is interrupted, either due to a faulty connection in the vehicle, a lack of suitable power, or the battery expiring
- The app being interrupted by other use of the phone (e.g., for entertainment, calls)
- Drivers unable to drive their cars if their phone is faulty.

Although the project was delayed due to the pandemic, it is now in a test phase. If successful, and it receives political approval, it is expected to be implemented in 2024.

Brussels presents an opportunity to test a technology that, if successful, would significantly reduce the costs of introducing *network based* urban road pricing on a wide scale. Given the ubiquity of smartphones in New Zealand (around 92% of households have one)[55], this offers potential for lower cost and more flexible application of urban road pricing in the longer term in Tauranga, if it can be made technically feasible. The growth in new vehicles with on-board in-vehicle telematics may equally provide a platform to more economically introduce network road pricing in the next 15-25 years.

Australia

Although three Australian cities have significant tolled roads networks (Sydney, Melbourne and Brisbane), none have commissioned any publicly available studies of urban road pricing to be applied to existing roads. There is limited interest at local, state and Commonwealth Government levels in urban road pricing in Australia. In part this may be attributed to the scale and levels of tolling in those cities, which is somewhat controversial.[56]

Most major motorway routes in Sydney are tolled (see Figure 17) with prices ranging from A$1.82 to A$8.89 for a single toll road, but a single trip can cost over A$15 for using multiple toll roads. As in Tauranga, all toll roads in Sydney have tolls to pay for the capital costs of the road or parallel route (in the case of Sydney Harbour Bridge), so perceptions from the public and politically are that tolls can be justified to pay for new infrastructure but are not acceptable for paying for existing corridors. Furthermore, Sydney has experimented modestly with peak pricing on the Sydney harbour crossings to manage congestion, but the results of this have been disappointing, largely because the surcharge at peak times is only A$1, which is insufficient to generate a meaningful demand response on top of a toll of A$3.

[55] Source: https://www.statista.com/forecasts/1143839/smartphone-penetration-forecast-in-new-zealand

[56] For example, https://www.smh.com.au/national/nsw/inconsistent-confusing-network-of-sydney-tolls-in-the-spotlight-20220425-p5afy1.html

The most significant studies into congestion pricing in Sydney and Melbourne was undertaken by the Grattan Institute thinktank in 2019.[57] The studies modelled introducing cordon pricing to the CBDs of both cities during peak times. The report indicated that as a first step a CBD cordon makes sense for those cities and would generate significant net revenues, but the key purpose of such schemes should be to relieve congestion.

The reasons for choosing a CBD cordon were:

- The highest concentration of employment is in the CBD (15%);
- The highest numbers of drivers to work go to the CBDs;
- The CBD has the highest concentration of car drivers per square kilometre;
- A high proportion of commuters to both CBDs use public transport (75 and 66% respectively);
- Most who would pay a CBD cordon would be higher income drivers;
- 21% of car trips in Sydney in the AM peak are for social, retail or recreational purposes (indicating that a proportion of such trips could easily be retimed with limited inconvenience) (11% in Melbourne).

The modelled results are that in Sydney, average speeds in the CBD would increase by 11%, with a 1% increase across metropolitan Sydney, in Melbourne average speeds would increase by 16%, with a 1% increase across the metro area. However, CBD cordons would be insufficient to significantly relieve network congestion beyond approaching roads. The report proposed corridor charges be introduced and modelled a rate of A$0.30 per km for such charges, which resulted in 10% faster average speeds on charged corridors, with 2% improvement across the network.

Although there is academic discussion about the merits of urban road pricing in Australia, concerns over the cost of tolls (especially given the annual CPI + increases in toll rate, and congestion on some toll roads) have generated considerable political reluctance to advancing urban road pricing that is not applied to new road infrastructure as tolls.

Although Tauranga has a small number of toll roads, there have not been the concerns raised about pricing or performance of those roads, as there have been in Sydney or Melbourne. However, the public perception of pricing as being equivalent to tolls may hinder communication if the primary purpose of urban road pricing in Tauranga is to improve road network performance. The key characteristic of tolls is that they are applied 24/7 at a standard rate, which may give rise to concern that any form of urban road pricing initially applied during peaks could be extended to 24/7 for revenue collection purposes. The dominance of Sydney and Melbourne CBDs on traffic generation for those cities is not paralleled in Tauranga, so should indicate that scheme options focused on Tauranga's more congested locations is more appropriate than an initial focus on its CBD.

[57] Source: https://grattan.edu.au/report/right-time-right-place-right-price/

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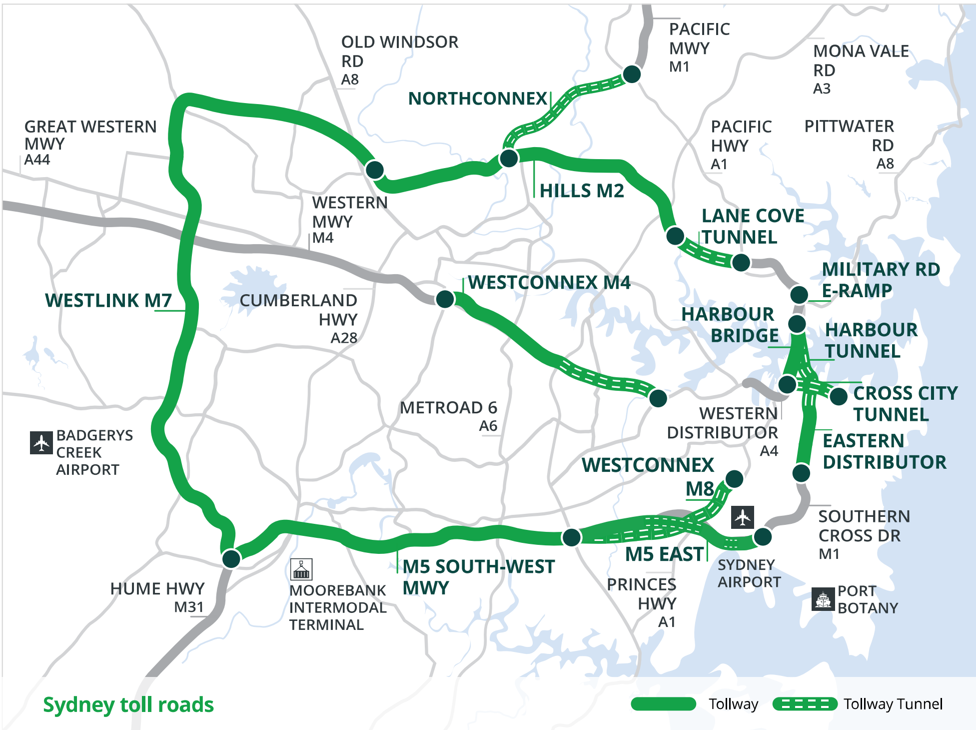

Figure 17 Sydney toll road network

Lessons on public acceptability

Undoubtedly the single biggest factor affecting whether or not urban road pricing is introduced is the acceptability of the proposed concept (and the package of complementary transport measures) to the general public.

By contrast, several larger cities with relatively high urban density and mode shares for public transport and active modes (and conditions as good as those of cities such as London and Stockholm which have introduced urban road pricing) have failed to introduce such systems. Amsterdam, Helsinki and Copenhagen have all tried and failed to introduce congestion pricing at least once in the past twenty years.

For example, Copenhagen, after some years of discussion, was to have congestion pricing introduced after the 2011 election of a government which included the policy in its manifesto. Copenhagen at the time has a mode share of around 33% of ALL trips by private car (<20% of commuter trips), with similar shares for public transport and active modes. However, Copenhagen was unable to introduce congestion pricing due to a mix of public and business opposition, and a drop in political interest (because forecasts of net revenues had proven to be higher than had been hoped). Opposition was focused on the location of charging points and the impacts on businesses at the periphery of the proposed cordon. It is *public acceptability* that is more critically important than the city's geographic and economic characteristics in determining whether or not a city introduces urban road pricing. Public acceptability includes (beyond general public opinion):

- Designing a system so that those who will likely pay will benefit from pricing and believe they will benefit (through shorter travel times, better trip reliability and/or improved infrastructure); and
- Ensuring that locations adjacent to where pricing is introduced are not disadvantaged (whether residents or businesses) from those less affected by pricing.

There is little doubt in policy or academic circles that urban road pricing can significantly reduce traffic congestion, as well as generate net revenues. As secondary consequences, urban road pricing also contributes to reducing emissions from motor traffic, and encouraging modal shift towards modes less or not subject to urban road pricing (whether public transport or active modes), as well as increasing available road capacity for such modes. It is clearly a powerful tool to enhance urban mobility, and reduce the negative externalities from high volumes of road transport.

However, there is considerable public scepticism about urban road pricing delivering net benefits either to those who would have to pay, or to those with businesses or homes affected by those who would have to pay. Although traffic congestion is frequently a major concern for residents of cities, belief that pricing existing roads will reduce this is low, because of a lack of trust that political decisions are made to benefit motorists, rather than to raise money.

Key to obtaining public support are the following elements:

- Promoting objectives that have broad public support. This includes reducing congestion and improving urban amenity. The public tends not to support urban road pricing promoted as revenue raising, unless net revenues directly improve conditions for those paying (e.g. Oslo's funding of an inner city bypass);
- Design a scheme that improves conditions for those who pay;
- Use of net revenues that is seen to generate tangible benefits (whether it be transport improvements that benefit those affected, or reduction in other taxes);
- Not applying charges at locations and times when congestion is not a problem;
- Starting at a scale that is commensurate to the city and the problem being addressed, with the flexibility to expand over time;
- Clearly communicating the objectives and how the objectives will be achieved, and how tariffs will be set and reviewed based on meeting those objectives;
- Including a complementary package of transport infrastructure measures that help contribute to the scheme objectives (e.g., more capacity for other modes, improved road capacity for vehicles bypassing the charging scheme).

1.10 New Zealand developments

Auckland

There have been three major studies into urban road pricing in Auckland commissioned by central and local government in the past 20 years. The Auckland Road Pricing Evaluation Study (ARPES) in 2006 was the first detailed evaluation of options for urban road pricing, which considered multiple options for both congestion reduction and revenue generation. This was followed by the Auckland Road Pricing Study (ARPS) in 2008 which considered two scheme options in more detail, called the Congestion Scheme and the Revenue Scheme.

The Congestion Scheme was an inner suburbs area charge scheme designed specifically to reduce peak time traffic congestion, by applying a fee to travel within that area between 0600-1000 weekdays. The Revenue Scheme was an inner suburbs cordon charge which would apply 24/7 with no variation at peak times. Neither scheme was carried further in analysis as Government focused on investment in major public transport and road projects.

The most recent study, called The Congestion Question (TCQ), was undertaken between 2016 and 2020. It emerged from parallel work called the Auckland Transport Alignment Project, which sought to achieve agreement between central and local government over capital investment in Auckland land transport over the medium term.

TCQ's main report was published in July 2020. The study was carried to investigate urban road pricing options for Auckland in light of the impacts of recent growth, completion of (and further plans to improve) major improvements to road and public transport infrastructure (e.g., Western Ring Route, commuter rail electrification and upgrades). The workstreams in the TCQ programme depicted in Figure 18.

The objectives for urban road pricing were explicitly included in its terms of Reference which:

required the TCQ to undertake design, testing and analysis of a shortlist of congestion pricing options to improve the performance of Auckland's road network by encouraging more efficient patterns of travel, taking into account economic, social and environmental outcomes.[58]

Throughout the TCQ study the objective of reducing congestion has been clear, in identifying scheme options and designs, and in assessing those options, and their economic, social and environmental impacts. Although it was recognised that urban road pricing could generate substantial net revenues, the revenue generation was acknowledged as secondary, alongside a range of other benefits such as improving air quality and reducing contributions to greenhouse gas emissions.

To give effect to that objective, the TCQ study considered a long list of options for initial evaluation to address congestion in Auckland, including urban road pricing scheme options and other pricing and non-pricing related options.

After defining the problem and developing and refining options, it evaluated a set of preferred shortlisted options, as well as investigating options for technology, the likely revenue

[58] The Congestion Question, Main Findings, July 2020, p.7.

outcomes, possible mitigations of negative impacts (e.g., traffic diversion, impacts on disadvantaged communities and businesses), and measures that would complement the possible options. A key conclusion is that Automatic Number Plate Recognition (ANPR) technology as used for tolling can be applied at scale for urban road pricing in Auckland, noting that technologies over the longer term may offer additional options.

Five shortlisted options were considered:

- City centre cordon (pricing entry/exit to downtown Auckland essentially bounded by SH1 and SH16);
- Isthmus area charge (pricing entry and driving within the Auckland isthmus bounded by Waitemata and Manukau Harbours, Blockhouse Bay/Waterview, Tamaki River and Southdown/Otahuhu;
- Strategic corridor charges (on congested corridor, whether State Highways or local roads);
- Combination of city centre cordon and strategic corridor charges; and
- Regional network charging (charging on all congested roads at congested times).

These were evaluated by network performance, practical assessment, social (distributional) impacts, environment assessment and cost/benefit appraisal. The evaluation conclusion was that a combination of the city centre cordon with a strategic corridor option had the greatest potential for positive impacts while mitigating negative effects.

The report noted:

The two preferred congestion pricing options differ in spatial scale and therefore their forecast impact on network performance. Both options represent workable solutions and have the potential to generate sensible trade-offs between improving network performance as a result of modifying travel patterns, and the requirement to minimise adverse social impacts.

Neither preferred option had the highest benefit-cost ratio, but together they did reduce delays by the highest proportion and performed best in reducing delays for freight and improving access to employment (by the measure of proportion of jobs accessible within a 30-minute drive). The city centre cordon scheme option has low impacts in itself but is a “viable and low risk” option in advance of implementing corridor charges, which themselves generate the greatest potential.

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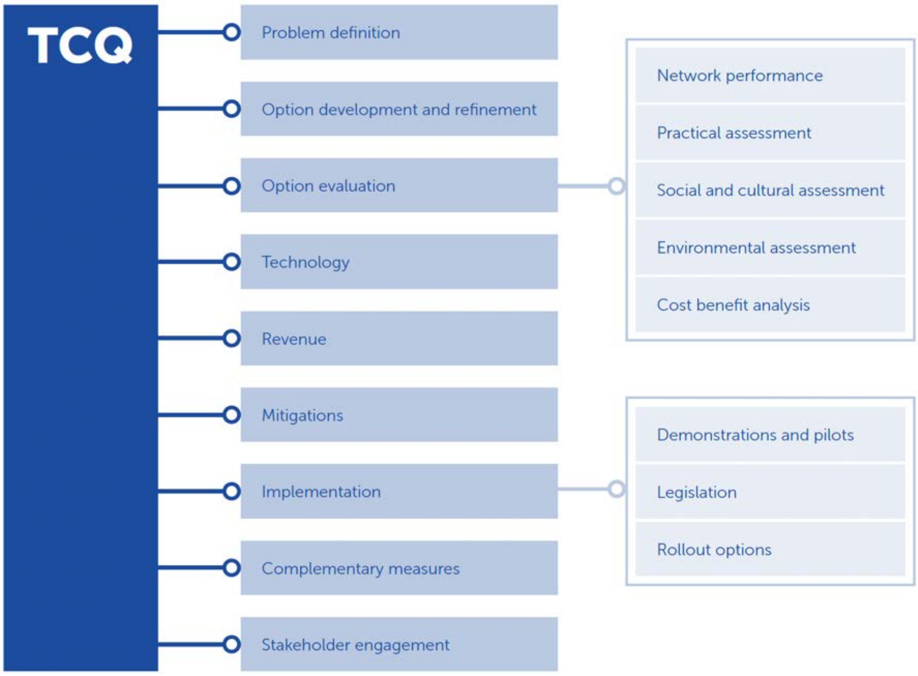

Figure 18 TCQ (Auckland) work programme

TCQ recommended:

Based on the technical work undertaken in the TCQ investigation, there is a strong case for implementing congestion pricing in Auckland for demand management purposes. However, prior to a final decision on whether or not to implement congestion pricing, the TCQ recommends that a comprehensive stakeholder and public engagement exercise be undertaken.

It is important to understand that the assessment of the corridor charging option (and indeed all of the shortlisted options) in TCQ did not include a detailed investigation into the exact locations where urban road pricing would be applied. Although some assumptions were made as to locations at which charging could be applied, (for the purposes of modelling) these were done for a strategic level analysis, not to depict the details of a preferred option. It was understood that there could be considerable debate over the exact charging points for a preferred option, when the purpose of TCQ is to obtain approval at central and local government levels for urban road pricing "in principle" to meet the programme objectives.

Sensitivity: General

Please note that boundaries are indicative only

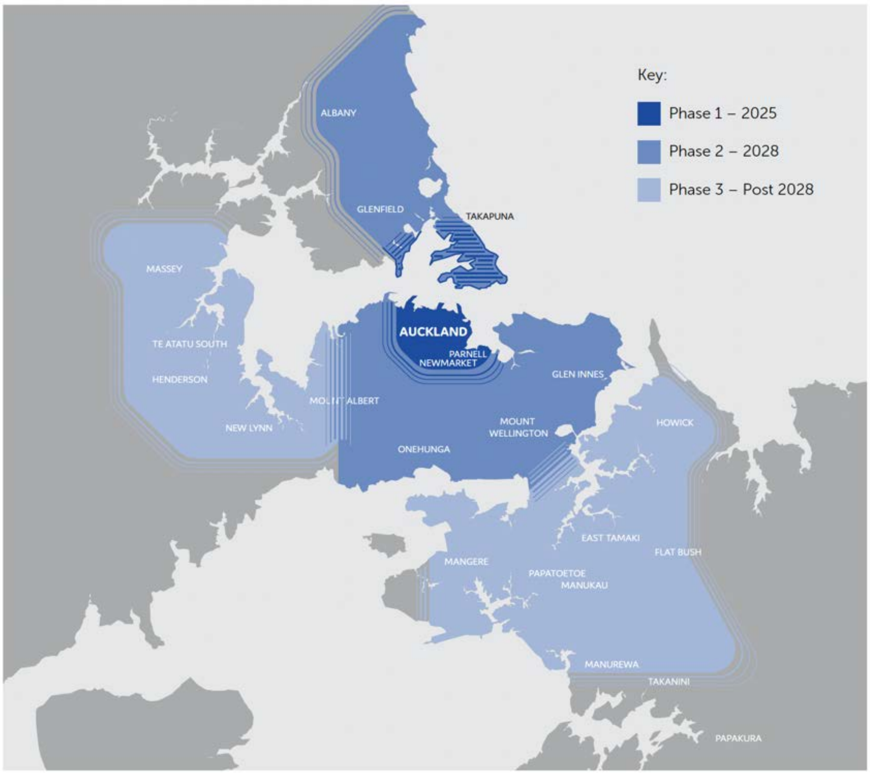

Figure 19 Auckland congestion pricing indicative phasing

The corridor charging concept for Auckland was defined as:

vehicles are charged to travel on congested corridors based on road hierarchy during congested periods.

Such corridors were not defined, but were recognised as including some combination of motorways, major urban arterials and relevant parallel arterial routes. The depiction of the preferred option illustrates this in Figure 19.

The inner-city cordon is depicted as Phase 1, which Phase 2 representing the area within which corridor charging might be introduced in the first instance, with Phase 3 as a later stage if required. As the scheme is defined as targeting congestion, its implementation and phasing would be expected to be determined by the impacts of each stage of implementation.

The rate structure option chosen was an access charge, rather than a point charge. This is similar to London rather than Singapore but does not prevent a shift to point charges at a future date. The key advantages of an access charge are:

- Simplicity of understanding (particularly for motorists unfamiliar with pricing)
- Only one vehicle detection needed (minimising risk of diversion or evasion)

- Ability to vary by time of day, but no need to vary by location

The indicative charging schedule is depicted in Figure 20, this demonstrate how access charges may be implemented with shoulder charges either side of peaks, with no interpeak charge. The proposed concept was that any vehicle entering the cordon or on charged corridors would pay the highest price for any two-hour period of travel (with higher charges for heavy vehicles, and exemptions for buses, emergency vehicles and motorcycles). Any final charging schedule may have different operating hours and tariffs, but this helps to illustrate what may be implemented in Auckland if approved.

Time	Period	Tariff
06:00-06:29	Shoulder	$1.50
06:30-06:59	Shoulder/Peak	$2.50
07:00-07:29	Peak	$3.50
07:30-07:59	Peak	$3.50
0:800-0:829	Peak	$3.50
0:830-08:59	Peak/Shoulder	$2.50
09:00-09:29	Shoulder	$1.50
09:30-15:29	Interpeak	No charge
15:30-15:59	Shoulder	$1.50
16:00-16:29	Shoulder/Peak	$2.50
16:30-16:59	Peak	$3.50
17:00-17:29	Peak	$3.50
17:30-17:59	Peak	$3.50
18:00-18:29	Peak/Shoulder	$2.50
18:30-18:59	Shoulder	$1.50
19:00-05:59	Off-peak	No charge

Figure 20 TCQ indicative tariff schedule

The outcomes modelled from the preferred option combination include:

- 8% reduction in average vehicle travel times;
- 35% reduction in total vehicle travel times;
- 19% less time spent in severe congestion;
- 26% less VKT of freight travelling in severe congestion;
- 19% more jobs accessible within a 30 minute drive;
- 0.7% reduction in CO_2 emissions
- 0.8% reduction in other (noxious) emissions (e.g., $PM_{2.5,}$ and NO_x)

These impacts were described as being broadly similar to the impacts of the school holidays on peak traffic, with reductions in traffic volumes by around 8-12% on average at peak times.

If it is decided to proceed with urban road pricing for Auckland, legislative change is required (as it would be for Tauranga), and a detailed design phase would be entered. That phase would include a detailed traffic study to identify the best locations for charging points, and the infrastructure and business rules required to address any localised issues (such as vehicle diversion, or provision for access for residents that may be stranded by a charging scheme). For example, Stockholm's cordon scheme has long included an exemption for access to Lidingo Island (which is located within the cordon) which is enforced by measuring time taken to travel between two charging points.

In 2021, the Transport and Infrastructure Committee of the House of Representatives held an Inquiry into Road Pricing in Auckland, which called for evidence on a wide range of issues and considerations around the merits of allowing road pricing to be introduced in Auckland. It concluded with eight recommendations, broadly supportive of the conclusions of TCQ.

Wellington

Let's Get Wellington Moving (LGWM) has not yet commissioned a detailed study into options for urban road pricing for Wellington. However, the concept of implementing some form of urban road pricing to support LGWM objectives has been considered, at a high level, in multiple LGWM documents for some time. A study on commuter parking levies was published in April 2021, which considered its merits as a source of revenue and to effect modal shift. It is worth noting that LGWM has already found that private car use entering the central city at peak times has been at declining levels for some years, so there is not a major issue of growing congestion due to commuter car traffic into the city. However, the geography of Wellington means some corridors (including SH1 bypassing the city and Te Aro) have severe congestion during peak and occasionally at inter-peak periods.

This was followed by an initial assessment of congestion pricing, which was published by LGWM in August 2021. That assessment indicated that urban road pricing in Wellington could contribute to a range of policy objectives. It considered a handful of concepts including a city centre cordon, an inner suburban area charge and a corridor scheme. These were presented only as high-level concepts, with the city centre cordon modelled as an illustration of what urban road pricing might achieve in transport outcome metrics.

The results of that modelling were that a peak time only, inner city cordon, bounded by State Highway 1 to the north, west and south (and Kent/Cambridge Tce to the east), could generate:

- 10% reduction in VKT travelled within the cordon zone, with a 3% reduction in VKT across Wellington City more widely
- Travel times on most corridors improve, except for one corridor (likely due to change in route choice to a corridor with constrained capacity)
- 8-20% increase in public transport patronage on key corridors

The report also indicated that the additional demand would likely require increases in public transport capacity on some corridors, enhancements to active travel within the cordon zone, and some redirection of road capacity spending from routes towards the cordon, to routes bypassing the cordon.

LGWM is expected to commission a more detailed study into options for urban road pricing within the next year, but has yet to determine what the primary objectives of such a scheme would be. Clarity on such objectives will significantly influence the choice of scheme options, geographic and temporal scope. Regardless of the objectives, it is likely key elements of a scheme for Wellington would include:

- Use of ANPR technology to detect vehicles;
- A cordon around central Wellington or a small number of corridor charging points;
- Peak only charges (except perhaps for one or two corridors);
- Complementary enhancement of public transport capacity on corridors servicing the priced roads.

Relevance of Auckland and Wellington examples to Tauranga

The TCQ study's relevance to Tauranga is in its process for developing and evaluating options. Notable conclusions from the TCQ relevant to Tauranga include:

- The merits of agreeing to a single objective to develop and assess options (in this case, seeking to improve road network performance, whilst also noting revenue potential and environmental impacts)
- Use of ANPR technology is appropriate for a large-scale urban road pricing scheme in Auckland
- Assessment of options at a strategic level can deliver indicative conclusions as to the merits of pricing and the likely best strategic options, without finalising the details of exact charging locations or times
- Corridor charging is technically feasible and is likely to have the greatest benefits, given that (beyond central Auckland) other locations of activity are not well suited to implementing cordons to reduce congestion
- Access based tariffs can deliver significant benefits, without reducing the flexibility to implement point-based (distance oriented) charges at a later date.

There are merits in considering the approach taken by TCQ in any future more detailed investigation of one or more preferred options for urban road pricing in Tauranga. Given all of the studies into road pricing in Auckland, the clear conclusion is that beyond the scale of central Auckland, a cordon scheme is not recommended for Auckland. Any positive impacts on demand are more than offset by significant negative local impacts on residents and businesses where urban form is more diverse than within the city centre, and concentrations of traffic congestion are on major corridors, not on other key urban centres in metropolitan Auckland.

Wellington's investigations are still at a very strategic level. Although it appears likely urban road pricing could have significant positive impacts on the Wellington transport system, until a decision is made on the primary objective for road pricing in Wellington, it is difficult for a detailed study to be undertaken that can develop and evaluate options based on such an objective. Wellington's urban form, employment patterns and transport system would appear to suit some form of urban road pricing focused on the Wellington downtown area, or on the small number of constrained corridors that are highly congested at peaks. However, the geographical location of pricing will significantly affect the trips that it would target, and the suitability of alternatives for those affected by pricing. A key issue is likely to be whether through traffic (traffic from the north, such as the Hutt/Porirua travelling to southern/eastern suburbs, such as Wellington Hospital and Airport) is subjected to pricing as well as traffic entering the central city. There are also careful design choices to be made as to their impacts on residential and commercial locations.

For Tauranga, some similar issues are relevant. Any pricing scheme will need to consider the geographic impacts on trip patterns, especially those not likely to shift time or mode of travel (e.g., longer distance trips bypassing Tauranga) and localised impacts on residents and businesses that may be adjacent to a charging point.

1.11 Public policy issues

This section summarises how other jurisdictions that have implemented urban road pricing have addressed the following key issues:

- Ownership and management of net revenues;
- Governance and management of transport networks in the jurisdiction, including the governance of roads, public transport and parking relative to road pricing.

Ownership and management of net revenues

In most jurisdictions, the ownership and management of net revenues is controlled either by a single entity or is determined by a multi-year agreement across central, regional/state and local government jurisdictions, associated with a package of transport expenditure supported by a range of revenue sources. Key to public acceptability for urban road pricing is that there is clear accountability for the use of revenues, and that the public knows what the revenue is used for (as it is distinct from tolls which are identified as raising revenue to pay for the capital costs of the tolled road).

Singapore: Unlike all other jurisdictions, Singapore regards net revenues from its ERP scheme to be general revenue for central government. None of the revenue is hypothecated, and it bears no relationship to funding for transport. The Singapore LTA explicitly manages the ERP scheme as a traffic management tool, and seeks to collect fees efficiently and effectively, but neither has a target for revenue, nor is influenced by expected net revenues in recommending changes to ERP prices. Although not explicitly stated, it may be considered that Singapore's ERP revenue is a form of return on capital expended on the network, with that return treated like other government commercial assets.

London: In the UK, all local authorities have the legal power to introduce congestion charges but are legally required to use net revenues from such fees on local transport projects and maintenance within their jurisdiction. Similar legislation applies to the jurisdiction of the Mayor of London and Transport for London. Although Transport for London is the road controlling authority for only the major arterial roads in London (see Figure 21), it has the powers to implement pricing on local authority roads that are essential to enabling pricing to operate effectively.[59]

The governance framework for transport in London means that use of congestion charge revenues is almost entirely up to the discretion of the Mayor of London as part of the development of the budget for Transport for London. This is subject to oversight from the London Assembly but is essentially reserved to the Mayor to determine the strategy and how net revenues are used to support that (including the mix of modes and projects it can support). In that respect the revenue is treated like all other local revenue collected by Transport for London (including public transport fares and fines from the ultra-low and low emission zones).

Central government has, until recently, largely treated London's congestion charging revenue as being not relevant to its own funding grants provided to London to support its transport infrastructure and services. However, since 2015 there has been an ongoing debate between

[59] Other roads are governed by 32 local authorities and motorways/major A roads by National Highways.

the UK Government and the Mayor of London over the extent to which London should contribute towards paying for its own transport needs through the revenue collection means it has under its control. Originally the UK Government was seeking to end all central government funding to Transport for London, but the pandemic resulted in four emergency funding deals set up to help cover the significant losses in fare revenue from 2020-2022. In August 2022 a funding settlement was reached between the UK Government and the Mayor of London, which seems to have been supported by a permanent extension in the congestion charge operating times. Part of the deal for the bailout of Transport for London included increasing the fee (from £11.50 to £15 per day) and operating hours for the congestion charge (which now operates 1200-1800 Saturdays and Sundays, as well as 0700-1800 weekdays).

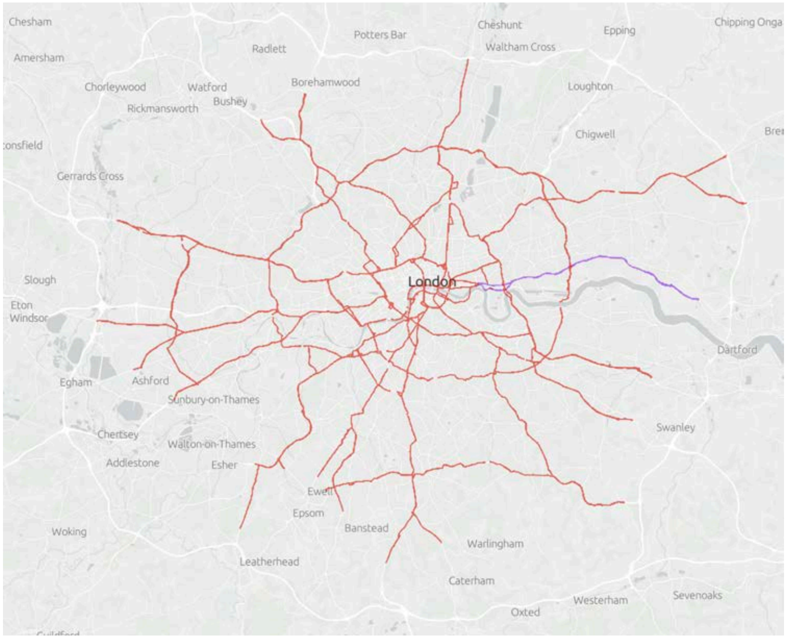

Figure 21 Transport for London's road network in the context of metropolitan London's roads

<u>Stockholm and Gothenburg</u>: Introduction of the congestion tax in Stockholm (and in Gothenburg) was undertaken by the Swedish Transport Authority – a central government agency – and in theory, the use of net revenues could be determined entirely by that entity. However, in practice central government and local authorities have sought to enable public support (or in the case of Gothenburg, acquiescence!) by setting up multi-year transport funding packages that bundle other central and local funding sources with the congestion tax, to support spending on a range of capital projects. For Stockholm this was, initially, focused on using the congestion tax to pay for the 21km long E4 Stockholm Bypass project.[60] For Gothenburg, the "West Swedish Package" of capital projects was agreed, and indeed the debt raised to pay for that package requires the Gothenburg congestion tax to service it. More recently, changes in central and local government in Sweden and Stockholm saw a new transport package authorised (The Stockholm Agreement 2013), to use net revenues to

[60] More details at https://bransch.trafikverket.se/en/startpage/projects/Road-construction-projects/the-stockholm-bypass/

support new metro lines in Stockholm (although funding was already committed to the E4 project, the mix of total spending and sources of revenue is altered as governments change).

In effect, the key policy changes related to the urban road pricing schemes in Sweden are not significant in respect of the congestion tax schemes themselves, but rather government decisions on the use of net revenues, which are treated as just another source of revenue to contribute towards transport spending. There are some parallels to past agreements for transport funding between Auckland and central government, such as through the Auckland Transport Alignment Project (ATAP), although in Sweden such packages are negotiated regularly every few years. The packages see the relevant central government agencies agreeing to deliver the package of capital improvements (e.g., Swedish Transport Agency for the congestion tax, Swedish Transport Administration for rail infrastructure and state highways, and local authorities for local roads, metro, light rail and bus infrastructure), funded from the relevant jurisdictions (central and local authorities). Changes in government after elections can see any elements of those packages up for renegotiation, for example, if a new government wishes to propose another project (and drop one that is not yet committed to construction), it can choose to do so, noting that negotiations for new transport funding packages can take as long as two years.

Does pricing get co-ordinated more widely?

From a wider transport planning and transport economics perspective, there may be merit in co-ordinating the broad range of urban transport pricing interventions, and complementary non-pricing policies, so that the impacts are harmonised and not contradictory. For example, the impacts of urban road pricing will be influenced by policies on parking pricing and availability, other fees on road use and vehicle ownership, and the pricing of alternative modes. However, most jurisdictions do *not* take a comprehensive approach across such tools, in part because many do not have the powers across many of those policy levers, but more likely because it increases the complexity of introducing urban road pricing.

Singapore is the jurisdiction with urban road pricing which has the greatest centralisation of powers and potential to co-ordinate charges across car ownership, parking, usage and public transport usage, along with regulations on car use.The introduction of ERP paralleled increases in the numbers of vehicles permitted to be registered in Singapore and a reduction in vehicle ownership fees, indicating a shift from taxing *owning* a vehicle to *using* a vehicle. However, ERP in Singapore is still seen as complementing measures to constrain the rate of growth of car ownership, and its success should be acknowledged as being within that context. Car ownership in Singapore is expensive, yet Singapore has demonstrated that it can manage demand for car use on busy roads effectively with road pricing. The primary complementary policy measure alongside ERP (and the previous ALS and RPS schemes) were in enabling expansion of public transport services, including capital investment in the metro scheme, and expanding bus service routes and frequencies. Policy on fares has not been directly related to ERP, in part because a significant proportion of the population (around 50%) does not own a car. Likewise, policy on parking has for some time discouraged kerbside use in central city areas except for loading/unloading.

In London, the Mayor of London has powers over PT fares, but not parking charges set by local boroughs, let alone private businesses. However, no changes to fares were implemented in co-ordination with the congestion charge, and local boroughs have also continued to set kerbside (and off-street publicly owned) parking charges according to their own revenue and transport management policy priorities. For the Mayor of London, the key complementary measures implemented with the congestion charge were increased bus service frequencies and road infrastructure changes along the area boundary to mitigate traffic diversion impacts. Transport for London has actively pursued road management measures to enhance access and safety for active modes and buses, but this is a general policy and is not directly linked to the congestion charge. London boroughs which have roads covered by the congestion charge area have adopted their own policies on parking and kerbside management. It is notable that subsequent to introduction of the congestion charge, the Mayor of London was more readily able to re-allocate more road space to bus lanes, cycle lanes and widening footpaths to support growth in use of other modes. This was noted by Transport for London as *increasing*

Road space reallocation and the scale of development in London have resulted in reducing the road capacity available for car users in certain areas. This has led to a reduction in traffic volumes, but static (and more recently, rising) levels of congestion.[61]

In both Stockholm and Gothenburg, congestion tax is managed by the Swedish Transport Agency, which works in co-ordination with the public transport and road managers in both cities. However, the introduction and changes to the congestion taxes in both cities are not matched with specific changes to policies on parking or fares. As with London, the primary interventions have been to increase the frequency of public transport services on corridors crossing the charging points, and to adjust signage, rules and intersection designs on routes approaching charging points, to mitigate the impacts of traffic diverting to avoid being charged. As in Singapore, Stockholm and Gothenburg had previous policies to support greater use of public transport, and active modes and discourage parking in the central cities, which the urban road pricing schemes complemented.

The Norwegian urban road pricing schemes are almost universally intended to support significant infrastructure investments, so are co-ordinated with the opening of new roads or public transport links, and the infrastructure related to those, but are not seen as affecting other fees or fares.

It appears that the challenges of introducing urban road pricing are, in themselves, sufficiently daunting for most jurisdictions to not present them as also justifying approaches to other charges, or policies that may increase the difficulties in obtaining social licence and political approval to implement the pricing schemes themselves. However, as parking, public transport and road/kerbside management continues after such schemes are introduced, there can be little doubt that the *effects* of urban road pricing, in reducing congestion and diverting traffic by time and location, are reflected in how other urban transport measures are adjusted over time. London has used its scheme to reallocate road space, at the cost of increasing congestion, Singapore has seen its scheme enhance demand for public transport improvements and indirectly, supports their viability.

Governance of transport

In only one case is the governance of transport integrated in a single agency as a road controlling authority, public transport planner and funder, parking authority and road pricing operator, and that is Singapore. As a city state, Singapore has no local government, and manages all of its roads, commuter public transport and on-road parking through the Land Transport Authority. Singapore therefore effectively manages all of these elements together, and has done so for many years. In other examples, transport governance is split across multiple agencies, although the decision on the entity responsible for road pricing has taken into account the need for an organisation that has some specific capabilities and complementary responsibilities, in no cases has a single agency been established that has universal powers across all key land transport supply and regulatory functions.

[61] Source: "London stalling, reducing traffic congestion in London", London Assembly Transport Committee, 2017, p.19

London: Transport for London has a wide range of powers as an integrated transport authority for London, but there are some key limits to its authority. It is a road controlling authority for major arterial roads in London, and although it sets road rules for its network (including parking), revenue from parking on its roads is collected by the relevant local authority. Most roads in London are governed by 32 local authorities, although Transport for London can impose congestion pricing and low emission zones on their roads, as part of a wider metropolitan scheme seeking to manage traffic and its effects across a mix of arterial and local roads. The motorway network in London remains governed by National Highways (a UK Government owned company) and Transport for London has no authority over the motorway network (and cannot introduce congestion pricing on those roads). Transport for London has *influence* over local authority roads in London because it is the conduit for central government funding to local authorities for their road network (and local authorities apply to Transport for London under central government funding programmes for their road networks).

However, Transport for London does have planning, fare setting, contracting and funding powers over most public transport in metropolitan London, including the Underground, Overground rail, bus and tram networks. It does not have such powers over rail franchises that provide commuter services in London *and* neighbouring counties outside the jurisdiction of the Mayor of London, which includes a significant proportion of rail services to south, south-west and south-east London, and some services through east London.

Although Transport for London clearly implemented changes to the road network adjacent to the congestion charge when it was introduced (and subsequently afterwards, to reallocate road space to buses and active modes), and enhanced bus services to respond to expected changes in demand, the London congestion charge has not changed substantially since 2011 (when the Western extension was abolished). There have been few changes to road or public transport service provision in response to the congestion charge in recent years (indeed, the main responses have been to introduce temporary exemptions to the charge during the pandemic, to reflect the low level of public transport service provision, to as to support emergency and health workers during that period). In recent years, the Mayor of London has focused on the implementation of ultra-low emission zones as his primary transport policy objective has been to address local air quality issues. This has not seen implementation of any notable changes to public transport or parking policies.

Stockholm and Gothenburg: The Swedish Transport Agency as the owner and operator of the congestion tax systems in Stockholm and Gothenburg is a subsidiary entity of the Swedish Transport Administration, which is the central government manager of the state highways and rail network (but not rail services). In both Stockholm and Gothenburg, the Swedish Transport Administration is a road controlling authority for state highways, but not local roads, all of which are the responsibilities of local authorities. In Stockholm, 26 local authorities are road controlling authorities, but Gothenburg is mostly located within 1 local authority. Public transport in Stockholm is managed by a separate entity, Stockholm Public Transport which itself is governed by the equivalent of a regional council called Region Stockholm (which is elected alongside municipalities). This entity sets fares, levels of service and contracts services and operations to the private sector. This has some parallels to the separation of road and public transport responsibilities in New Zealand (except for Auckland), with a central government entity and local authorities as road controlling authorities, but a regional government entity responsible for planning, funding and management of public transport. As in London, each road controlling authority is responsible for its own parking policies. Gothenburg has a similar structure, with a regional government responsible for public transport, with the local authority responsible for local roads.

Key to the success in Sweden has been the willingness of the Swedish Transport Agency to co-ordinate with both regional and local government in Stockholm (and Gothenburg) for the introduction of the congestion tax schemes in both cities. In both cases a mix of central government and local authority roads have been included in the pricing schemes, and in both cases, agreement was sought over the provision of enhanced public transport services. Although no single agency was responsible for all relevant infrastructure, agreement on the transport funding packages that accompanied the decision to introduce the congestion taxes in both cities incentivised the relevant agencies to work together for the pricing schemes to be able to function effectively. This includes agreement on the need for changes to road infrastructure (ranging from signs to changes in traffic signal phasing, and intersection redesigns to accommodate changes in traffic volumes), and public transport services and frequencies.

Price setting of existing schemes

With the exception of Singapore, all other jurisdictions with urban road pricing schemes review prices at irregular intervals. The key influences on such reviews in terms of timing and scope are:

- Timing in relation to local elections
- Effects of inflation on revenue and effectiveness of pricing on demand management
- Monitoring of traffic conditions, including any significant deterioration in travel times
- External events (e.g., pandemic)

London, Stockholm, Gothenburg and Oslo have all increased prices (and varied operating hours) on their urban road pricing schemes periodically to reflect such factors. In most cases, growth in traffic volumes and the effects of inflation are used to justify increases timed after local elections. Most recently in London, the need for additional revenue and the conditions of an agreement with central government saw operating hours for the congestion charge extended into the weekend, and the charge rate increased. However in those cities, charges are not adjusted regularly in response to changing conditions, unlike in Singapore. In London, the Mayor of London has regulatory powers to change congestion charge fees directly by order, albeit central government has powers to grant exemptions in addition to those powers held by the Mayor. This process is akin to the bylaw process seen in local government in New Zealand, but can be exercised by the Mayor solely. Stockholm and Gothenburg's rates can only be changed by legislation, so it is not legally able to be highly responsive to changes in traffic conditions. Norway similarly, is governed by legislation, so there is similarly little ability to change rates regularly.

Singapore, by contrast, has more flexibility in its process. Although rate changes need Ministerial approval, the Land Transport Authority makes recommendations quarterly on changes to ERP rates. These can be adopted by the Minister as a "rule" (equivalent to regulation in New Zealand, except it does not require Cabinet approval).

To date, no jurisdiction that has implemented urban road pricing has devolved full rate setting powers below that of a political decision-maker. Even Singapore retains final authority with the Minister, although its public policy culture lends itself to be less affected by public whims than governments in the other countries with urban road pricing schemes.

It seems highly likely that as more urban road pricing schemes are implemented, that are performance based, there will be a need to have more flexible price setting arrangements than exist in other jurisdictions. Guidance for options for such approaches could be seen in the examples of sectors such as electricity lines charges and airports.

Conclusions for Tauranga

Any decision to proceed with urban road pricing in Tauranga (beyond existing toll roads) should include a decision on where responsibility will be for decisions on the use of net revenues. This could consist of agreeing to urban road pricing as part of a wider package of infrastructure improvements and using net revenues to support that package for a number of years (effectively what has happened in Gothenburg), so there is little scope to amend the use of such revenues until after such projects have been completed and funded (or if debt funded, once debt is significantly repaid). Another approach would be to treat the net revenues as additional funds available to be allocated to transport projects in Tauranga or associated with Tauranga, and for such funding to be determined by Waka Kotahi as part of its National Land Transport Programme funding process. To fully utilise this, there may be merit in treating such revenue as a means to access financing so that the costs of major projects can be spread over subsequent years of operation. It is expected that any legislation to enable urban road pricing will include a process and governance structure for decision-making on the use of revenues, but it should also include decision-making on reviewing the setting of price rates, and business rules for the pricing scheme. Unlike conventional tolls (which set a relatively simple schedule of rates applying 24/7 on a specific road, to raise revenue for that road), urban road pricing rates schedules can become complex and vary by location and time of day. Similarly, the revenue use is likely to be broader than funding the roads subject to pricing. Stakeholders and the public will want to know who makes those decisions, and the basis for reviewing price rates (up or down), and the use of revenues, before they might be willing to accept any such pricing concept for Tauranga.

More broadly, consideration of road pricing for Tauranga raises questions about the most appropriate governance structure for land transport in the city. At present in Tauranga there are three road controlling authorities (Waka Kotahi,Tauranga City Council and Western Bay of Plenty District Council) and the regional council (Environment Bay of Plenty) is responsible for public transport. Compared to jurisdictions overseas with urban road pricing, this is not a particularly complex structure to manage an urban transport network. Most cities with urban road pricing have at least two road controlling authorities, some larger ones have many more, suggesting there is not significant pressure to have a single entity. However, to enable urban road pricing to be introduced and developed over time, one entity does need to be responsible for the operation and management of the scheme and does need to have some powers that can be exercised on roads of more than one jurisdiction, for the purposes of the scheme itself (see London and Stockholm). It does *not* mean it needs to take over maintenance, management or parking on such roads. However, there *does* need to be a clear co-ordination between the provision of public transport and the introduction of urban road pricing, for the latter to be effective in achieving modal shift towards the former. It is outside the scope of this paper to evaluate the effectiveness of Environment Bay of Plenty in this role, but more broadly as Tauranga grows, it is appropriate to consider the right mix of incentives and powers for the agencies responsible for implement significant improvements in Tauranga's transport networks and system in the coming years. Experience elsewhere does *not* indicate that there are decisive benefits in having a single transport agency across all roads and public transport, or that integrating local roads and public transport into one agency would have notable advantages over retaining separate entities. However, it is critical that in locations with multiple entities, that they have a framework to co-ordinate and work together and that the responsible agency for urban road pricing, have adequate powers to implement pricing across all the roads needed to make a scheme effective, efficient and viable.

1.12 Conclusion

Few cities have introduced urban road pricing, not because the economics or technology make it difficult, but because of the political and public acceptability issues of introducing fees on existing roads. This is often perceived as simply being another tax, rather than a way to fix an underlying problem with the supply of road space, that it gets rationed by queuing in the absence of price. For Tauranga to advance urban road pricing, it will need to ensure there is sufficient public acceptability to proceed.

A wide range of cities of various sizes have introduced urban road pricing (defined as pricing existing roads with peak time charges) of various forms, with a range of different objectives. It is critical that a primary objective be selected for urban road pricing schemes so that the geographical and temporal scope of the scheme is appropriately designed for that objective, along with a rate structure. Whether the objective is congestion mitigation, revenue generation or environmental enhancement, urban road pricing will also contribute to the other objectives, but the key objective should drive more detailed assessment and research. In Auckland, TCQ study has been focused on reducing congestion and produced a preferred solution based on balancing that objective with the relative costs and impacts of alternatives. Successful schemes in Singapore, Stockholm, Oslo and Milan have all met their objectives in addressing congestion, generating revenue or reducing emissions, because those objectives clearly directed scheme design elements. Tauranga should also be clear on its primary objective before it refines a preferred option for detailed assessment. Objectives affect key elements such as:

- Scheme operating hours
- Geographic scope of charging
- Application of discounts and exemptions
- Rate structure

Although there is extensive experience in applying dynamic road pricing to individual *lanes* on motorways, and success in using them to optimise utilisation of such lanes, dynamic road pricing (as defined in this paper) is neither necessary nor desirable to apply in an *all lanes* situation as is proposed in Tauranga. Singapore has successfully managed congestion using variable road pricing, with regular reviews of tariff levels at different locations to meet network performance targets. The success of variable pricing comes from providing certainty to road users as to the price at a particular time and location, but being able to review and adjust prices (up or downwards) to meet scheme objectives. Dynamic road pricing can do this, but does not offer certainty to drivers when commencing a journey. In all lane pricing scenarios, as proposed for Tauranga, this means that the *dynamic* element is unlikely to be effective (as drivers will simply factor in the range of prices they might face and choose to drive or not). Cities with lengthy experience in *all lanes* urban road pricing (like Singapore, Oslo, London and Stockholm) have not implemented or seriously considered dynamic road pricing because they see insufficient merit in doing so. Tauranga should consider advancing a variable road pricing solution over dynamic pricing, noting that there would be flexibility to move to dynamic pricing at a future date.

Although Tauranga has a lower population, population density and significantly lower mode share for public transport than most cities with urban road pricing, this should not be a barrier to implementing some form of urban road pricing. Several cities in Norway have similar populations and densities (although significantly higher mode shares for public transport and active modes), although in all cases the policy objective has been to raise revenue to support capital spending on transport networks (both roads and public transport).

Most urban road pricing schemes have been implemented in stages, with initial implementation being on a smaller scale (e.g., Singapore and Oslo's inner cordon, Stockholm's cordon without through route), before expanding geographic scale and scope over time. Whatever scheme option may be progressed should be capable of implementation in stages, with the flexibility to adjust geographic and temporal elements over time.

Singapore and Brussels are the only cities currently implementing or testing a next generation of technical options for urban road pricing. Both are doing so on a scale much larger than Tauranga but may enable technical options for network scale urban road pricing to be considered over the longer term.

The TCQ study for Auckland has been New Zealand's most comprehensive study into urban road pricing for some time, and offers some useful lessons for Tauranga:

- Confirm scheme objectives before assessing scheme options
- A preferred scheme need not have all geographic and operating details determined for assessment purposes
- Corridor based charging is likely to offer the greatest benefits in reducing congestion and generating revenue (although for Auckland, a CBD cordon would also support objectives)
- Flexibility and scalability are important characteristics in assessing scheme options.

LGWM has yet to determine objectives for urban road pricing in Wellington, so has not yet commissioned a detailed study into options for pricing. Preliminary studies indicate promising potential, but a likely need to consider:

- Additional public transport capacity to accommodate mode shift; and
- Additional road capacity on corridors any traffic may be diverted onto (that is not subject to pricing).

Sensitivity: General

Appendix – Norwegian urban road pricing schemes

Figure 22 Trondheim cordon charge points

Figure 23 Tonsberg cordon charge points

Sensitivity: General

Figure 24 Stavanger cordon charge points

Sensitivity: General

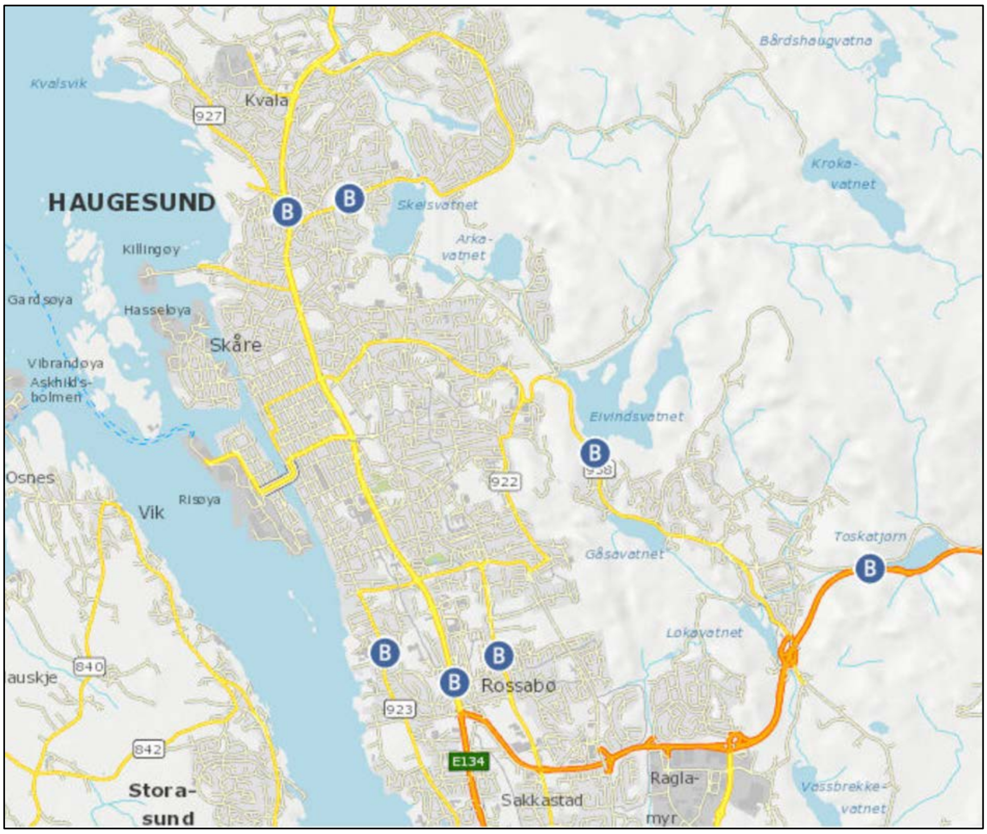

Figure 25 Haugesund cordon charging points

Sensitivity: General

Road Pricing in Tauranga Proof-of-Concept Study

Technical report of traffic modelling, financial analysis, and economic analysis

Prepared for Waka Kotahi NZ Transport Agency
Prepared by Beca Limited

9 May 2023

Creative people together transforming our world

Contents

Sensitivity: General

Appendices

Sensitivity: General

Revision History

Revision Nº	Prepared By	Description	Date
1	Matthew Hickson	First revision for client comments.	7/03/2023
2	Matthew Hickson	Second revision following client comments.	22/03/2023
3	Matthew Hickson	Third revision following client comments.	27/03/2023
4	Matthew Hickson	Forth revision following final client comments.	18/04/2023
4.1	Matthew Hickson	With correction to the number of system users quoted in the executive summary.	9/05/2023

Document Acceptance

Action	Name	Signed	Date
Prepared by	Matthew Hickson		9/05/2023
Reviewed by	Craig Richards		9/05/2023
Approved by	Andrew Murray		9/05/2023
on behalf of	Beca Limited		

Executive Summary

Introduction

Western Bay of Plenty's SmartGrowth partners have developed the Urban Form and Transport Initiative (UFTI) programme business case that presents a Connected Centres approach to cater for forecast urban growth in the region over the next 30-70 years. UFTI identified the need to consider new and different economic tools to fund the Connected Centres infrastructure investment programme. Road pricing (of some form) has the potential to optimise use of the transport network. This study considers one potential option, described as 'variable road pricing' (VRP) through a proof-of-concept investigation.

The objectives of road pricing for Tauranga as identified by the Project Partners[1] are:

- Support urban form outcomes (primary outcome)
- Optimisation of the whole transport system, including past investment and the role of each travel mode
- Improve travel time reliability and levels of service
- Raise revenue to invest in local transport solutions
- Incentivise lower carbon emissions
- Incentivise travel choice

This report is a technical report that describes transport modelling undertaken for the road pricing concepts, the assessment of the scheme using the model outcomes, financial analysis of revenue and costs and a transport economic evaluation of the scheme. This report informs Waka Kotahi's over-arching proof-of-concept study report and will include sections on Wider Economic Story and UFTI, value proposition, the wider context for road pricing in Tauranga discussion on affordability and social outcomes.

The road pricing concept in this study assumes a scheduled variable road pricing scheme. Scheduled variable road pricing is where road charges vary by time of day of the week or season following a predetermined schedule. Pricing is regularly reviewed and changed typically based on network performance measures.

Findings

The variable road pricing concept that is assessed in this study comprises of an access charge for entry onto the priced network (or in to / out of Te Papa Peninsula) and a distance-based charge on the priced network. The extent of the priced network includes the State Highway ring route around Te Papa Peninsula (SH2, SH29, SH29A), SH2 and Takitimu North Link (TNL) from Te Puna, and Tauranga Eastern Link (TEL). There would be no charge to cross a priced corridor other than at the access points around the Te Papa Peninsula. The access charge at all locations in to /out of Te Papa Peninsula allows traffic flow at these locations to be managed with price.

The variable road price scenario assessed in this study generates approximately $88m[2] in net revenue per annum in 2035[3] growing to $158m by 2048. Variable road pricing reduces overall network delay by 20%[4],

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[1] The Project Partners are Waka Kotahi and TCC

[2] 2035 variable road pricing Concept 5 assessed price model scenario compared to 2035 baseline and accounts for the allocation of funds to pay off loans on the existing toll roads and TNL.

[3] 2035 and 2048 were the forecast years represented in the transport model. The study assumes that pricing could begin in late 2029. 2035 was selected as the first modelled future year to align with one of the Emissions Reduction Plan target years of 2035.

[4] 20% reduction in delay as a result of pricing based on the comparison of the 2035 variable road pricing Concept 5 assessed price model scenario to the 2035 baseline DS, and the 2048 variable road pricing Concept 5 assessed price model scenario compared to 2035 baseline DS.

improves journey time reliability and supports some of the urban form outcomes promoted in UFTI. Road pricing reduces VKT by 6% and encourages a shift to public transport and active modes.

Road pricing can result in higher traffic flows on non-priced roads as compared to a scenario without pricing. This occurs as result of changes in travel behaviour and changes to the route choice decisions of drivers. The study predicts a 4% increase in VKT on local roads with road pricing. Some roads would be more affected that others. Given that local roads can be more sensitive to traffic movements, it is recommended that any future studies of road pricing in Tauranga should evaluate local road impacts in more detail including an assessment of potential mitigation measures if and where necessary.

The study found that the forecast public transport mode share across modelled area with Transport System Plan schemes in place and with road pricing was well below the minimum 25% public transport mode seen in the other jurisdictions across the world where road pricing was implemented or being considered.

The priced network assumed in this study is complex with over 100 entry and exits points. Based on an ANPR system it is estimated that around 95 to 100 camera sites would be needed to implement the system. The system would require complex back-office technology to operate, and the camera sites would likely have a visual amenity impact.

Road pricing schemes can raise social equity concerns because they may disproportionately affect lower-income drivers. If not carefully designed, the scheme may be seen as unfair. This study quantified an indicator of equity, which was the additional monetary cost that travellers would be faced with relative to their average income. The analysis found that the average additional cost that travellers would be faced with varies by origin location however there was no apparent regressive relationship with average household income i.e. the additional costs were reasonably evenly distributed across all income bands.

Figure A illustrates the extent of the priced network that was assessed for 2035 and the key network performance outcomes.

Sensitivity: General

Figure A: Variable Road Pricing Concept

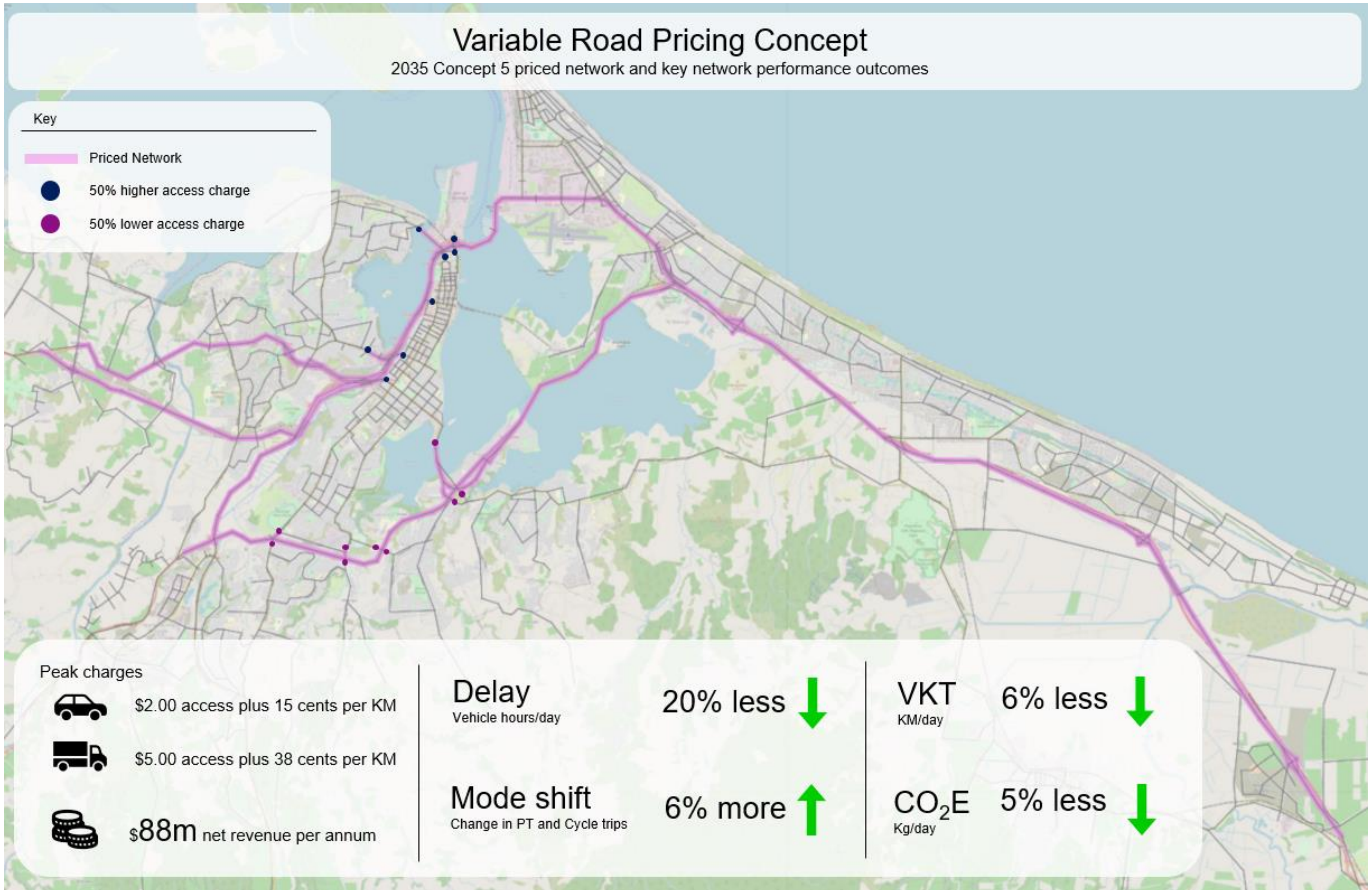


Table A below describes the key network performance outcomes of road pricing against the objectives of road pricing in Tauranga.

Table A Outcomes against road pricing objectives

Road Pricing objective	Outcomes
Support urban form outcomes (Primary objective)	*Variable road pricing supports some urban form outcomes promoted by UFTI. Variable Road pricing in the form described in this study discourages longer-distance cross city travel and provides faster and more reliable journey times between centres. But it also has potential negative impacts on the non-priced areas of the network as a result of a change in travel behaviour and route choice.*
Optimisation of the whole transport system	*Variable road pricing supports optimisation of the whole transport system by delivering a less congested road network and encouraging a shift in journeys to public transport and active modes where capacity is more readily available.*
Improve travel time reliability and levels of service	*Variable road pricing improves travel time reliability on the priced network on the network as a whole while delay reducing by 20%[5]. Levels of service improve overall, but some non-priced parts of the network may worsen.*
Raise revenue to invest in local transport solutions	*The net revenue for the variable road pricing scenario tested is estimated to be $88m in 2035 and $158m in 2048.* *Over a 40 year period this amounts to $5.5 billion of revenue to support the funding of western Bay of Plenty's Transport System Plan. This increased investment would also result in improved transport outcomes for users relative to a scenario where such improvements couldn't be funded. These benefits would be in addition to the network performance benefits of road pricing described in this report.*
Incentivise lower carbon emissions	*Variable road pricing reduces VKT by 6% and CO_2E emissions by 8%[6] through the discouragement of inefficient trip making by private car and reduced congestion for the remaining road users.*
Incentivise travel choice	*Variable road pricing incentivises a shift from private vehicle modes to other sustainable modes. We predict an 6% increase in PT and cycle trips as a result of pricing.*

[5] 20% reduction in delay as a result of pricing based on the comparison of the 2035 variable road pricing Concept 5 assessed price model scenario to the 2035 baseline DS, and the 2048 variable road pricing Concept 5 assessed price model scenario compared to 2035 baseline DS.

[6] Based on the comparison of the 2035 variable road pricing Concept 5 assessed price model scenario to the 2035 baseline DS

There are around 660,000 car, PT, and cycle journeys across western Bay of Plenty on an average weekday today. Each journey is different, each person taking those journeys is different. People will respond to a price on the road they use in different ways. They will also respond to a price in different ways on different days. Some will pay to use the priced network when they need to and will be willing to pay a premium for a faster journey time and/or a more reliable journey time. This modelling exercise predicts that 330,000 journeys will use the priced network on an average weekday and 220,000 on an average weekend day, generating $560,000 on average per day in gross revenue which (after costs and taxes) can be used to contribute to the delivery of transport network improvements. Others will choose alternatives that avoid price entirely or avoid paying too high a price for what they need. For example:

The hairdresser working in downtown Mount Maunganui may use the slower Oceanbeach Road from his house in Papamoa instead of the SH2 strategic corridor. ***This is a route choice response. This study predicts a 4% increase in vehicle KMs travelled on local roads as a result of pricing*** (but that is before mitigation is factored in).

The intercity worker who was already concerned about the cost of parking in the CBD may try the 5 minute walk to the new bus that goes by their house. ***This is a mode shift response. This study predicts a 6% increase in PT and cycle trips as a result of pricing.***

The early childhood teacher from Gate Pa may do all their Christmas shopping at Fraser Cove and Tauranga CBD rather than travel out to the Tauriko shopping centre or across the harbour to Bayfair. ***This is a destination choice response. This study predicts a 5% increase in people choosing to travel more locally.***

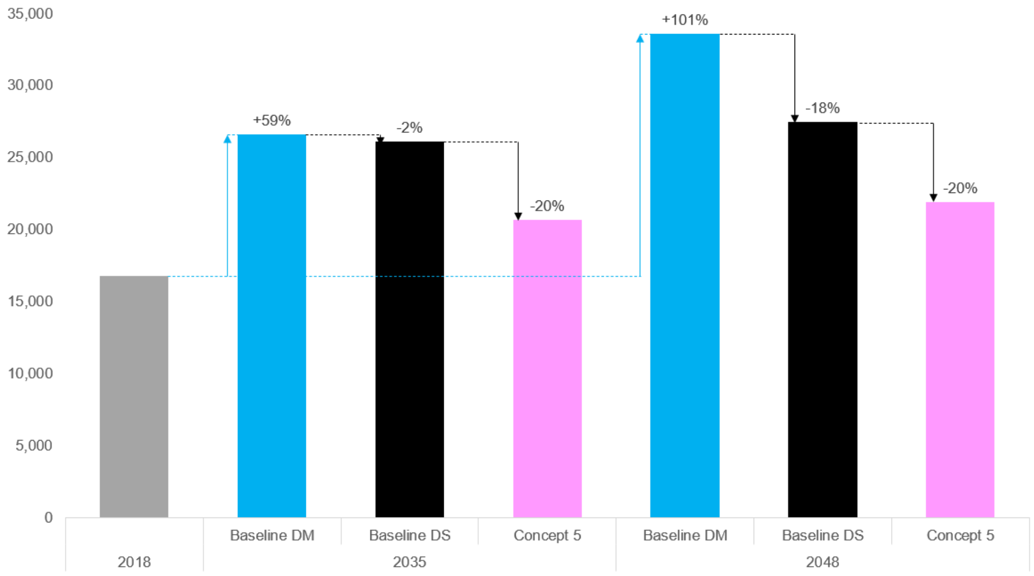
Marie may tell her friends to meet up earlier for a cup of tea before Kapa Haka practice to avoid the peak period price to travel into Te Papa Peninsula. Others with a high tolerance to price and a low tolerance to congestion may change their 9.30am trip to an 8.30am trip. ***This is time of day response. This study predicts a 1% shift of traffic from peak periods to non-peak periods as a result of pricing.***

An Architect from Katikati may arrange her Te Puke site visit and Welcome Bay sales pitch to be both on Tuesday rather than on different days to save on expenses. ***This is a trip frequency response. This study predicts an overall reduction in vehicle trips of 1% as a direct result of pricing.***

Two orchard workers who live near each other in Te Puna decide to travel together for jobs in eastern Bay of Plenty to save on travel costs. This is a vehicle occupancy response. We would expect there to be some level of vehicle occupancy response, but it is noted that this response is not included in the modelling undertaken as part of this study.

Figure B below illustrates the predicted increases in delay in the future year scenarios without road pricing (baseline Do Minimum and baseline Do Something scenarios) and then the 20% savings in network delay that is predicted with road pricing (based on the Concept 5 scheme). Note that the Baseline Do Minimum scenarios for each forecast year include only committed and highly likely schemes and are provided as indicative of a ‘worst-case’ baseline scenarios.

Figure B Network Delay (VHT)



Travel times on the priced network are predicted to reduce as indicated by the increases in average speed in the AM and PM peak periods that are predicted with road pricing in place as illustrated in Figure C and Figure D below. As shown in these figures, average travel speed is expected to increase, on average, by 5 to 7 kph across the priced network in peak periods. On average users on the priced network will experience approximately 1.3 minutes less delay in the AM peak period and approximately 1.7 minutes less delay in the PM peak period.

Figure C Travel time savings indicator: Average travel speed on the priced network, AM peak period

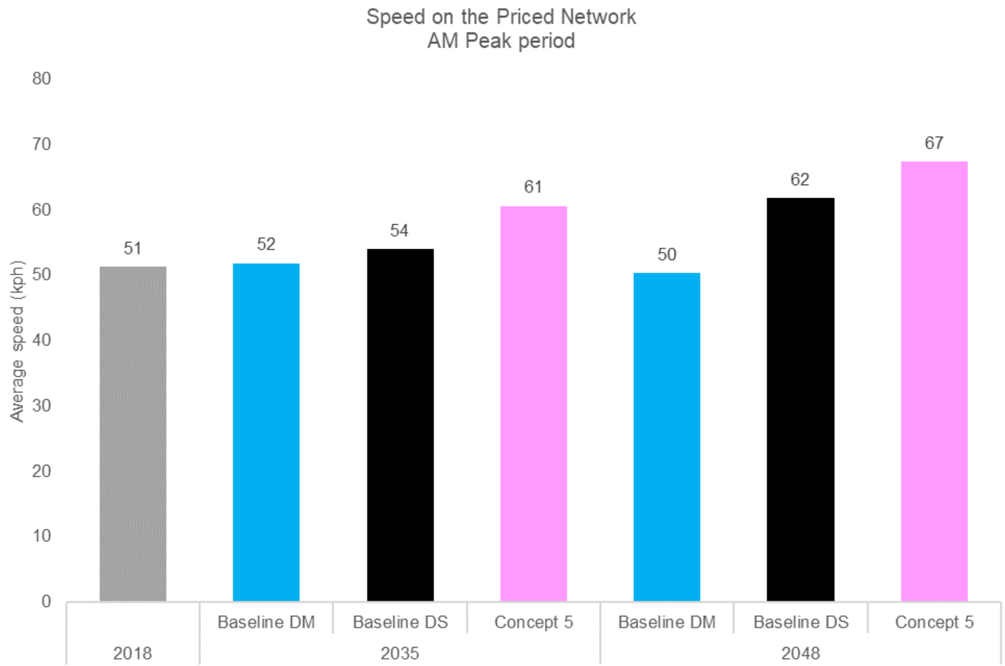
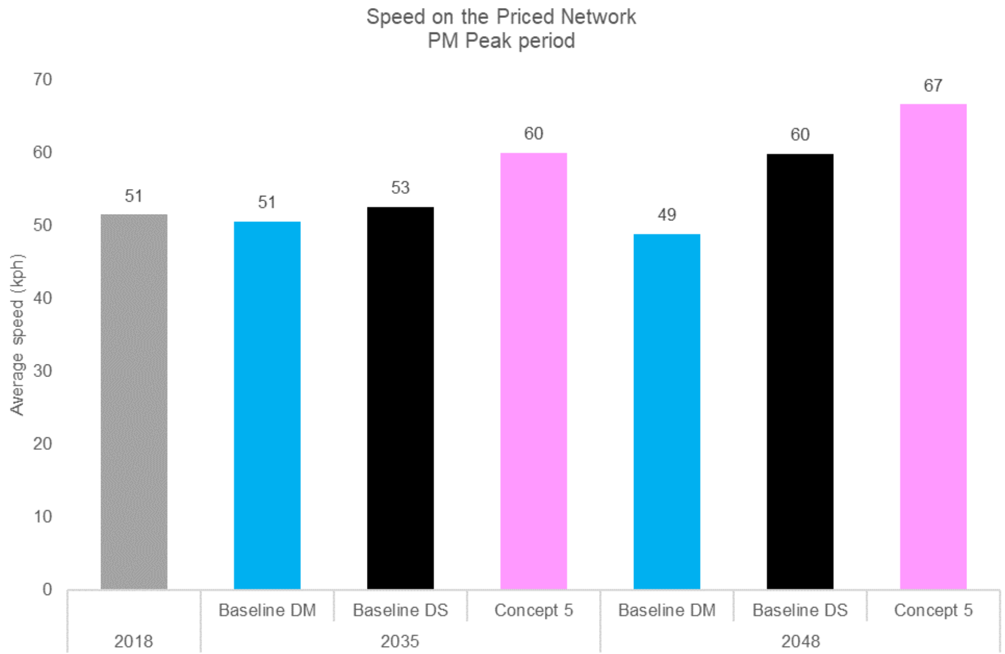


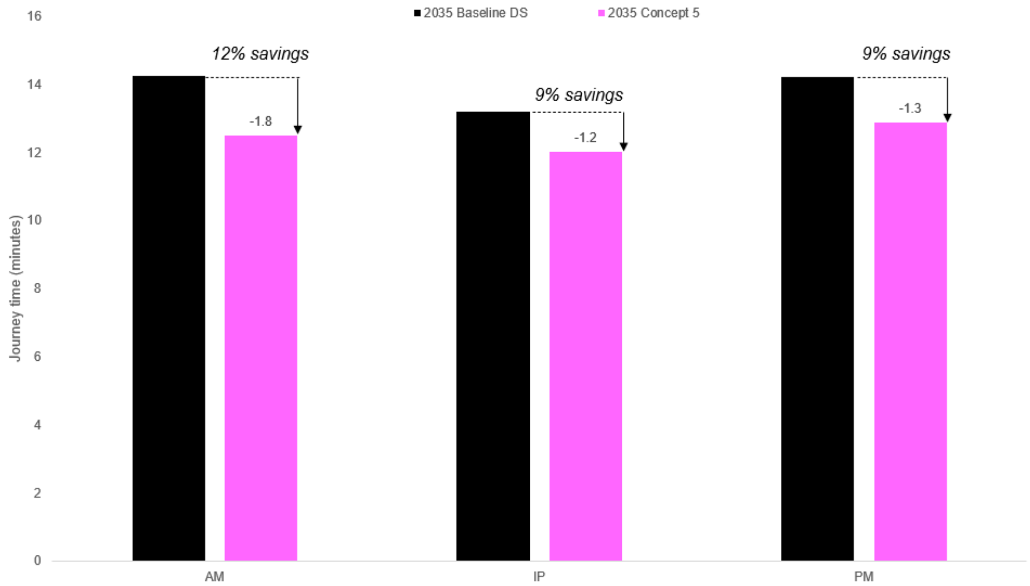
Figure D Travel time savings indicator: Average travel speed on the priced network, PM peak period



Sensitivity: General

As a major corridor example of VRP effects, Figure E below illustrates the predicted 9% to 12% journey time savings on the key state highway and national freight route for one direction from Tauriko (SH29) to Harbour Bridge (SH2) with road pricing.

Figure E Journey time from Tauriko (SH29) to Harbour Bridge (SH2)



A range of pricing levels were tested. The price point selected for the assessment scheme was selected by balancing network levels of service, the "right traffic right roads" objective, people movement, freight movement, and revenue generation. At a lower price point than the assessed scheme, much of the network benefits are achieved but with less overall net revenue. With higher prices, some improvement in network performance is achieved but based on a qualitative assessment by the project partners these were outweighed by the negative outcomes on non-priced local roads.

Stage 1 modelling

The four Stage 1 road pricing concepts were:

- Concept 1: Priced network with an access based charge
- Concept 2: Priced network with a distance based charge
- Concept 3: Te Papa Peninsula priced cordon
- Concept 4: Te Papa Peninsula cordon + CBD cordon.

Price A was $1 for light vehicles in the peak and $0.50 in the off peak with heavy vehicles charged 2.5 times that of light vehicles. Price B was twice Price A, and Price C was twice Price B (i.e. $4 for light vehicles in the peak and $2 in the off peak).

The concepts were assessed against these six network performance indications:

- **VKT** Average daily Vehicle Kilometers Travelled
- **Emissions** Carbon dioxide equivalentCO_2E Kg / Day

- **Delay** Average Daily vehicle hours of delay: Congested time - free flow time
- Public transport mode share[7]
- **Level of service** Proportion of the priced network links at LOS D or better
- **Revenue** The amount of net revenue generated.

Using these network performance indicators the concepts were assessed against the four of the five road pricing objectives[8]. Based on the assessment, Concept 1, the concept with an access charge was considered the most promising of the concepts. The access charge targets short trips, removing these from the strategic road network to free up capacity and reduce delay. It also performed well in terms of raising revenue.

The lessons from Stage 1 were:

- Scheduled variable pricing would be more effective than real time dynamic pricing in achieving road pricing objectives. Stage 2 would continue with scheduled variable pricing rather than real time dynamic pricing.
- An access charge is helpful in targeting short trips
- The distance charge alone is financially inefficient due to the relatively high transaction costs on short trips
- The cordon concept is helpful for mode share, particularly with a CBD cordon, but concerns over 1) flexibility and 2) impacts at the cordon perimeter.
- The concept needs to be able to target corridors or specific locations
- Non-price interventions should be delivered in tandem with pricing to avoid and mitigate negative effects such as high traffic volumes on local non-priced streets.

The study team also identified four success factors in the design of a pricing scheme for Tauranga:

- **Scalable** The concept needs to work on one corridor, several corridors or across a network of roads.
- **Public acceptance** The concept needs to be understandable, and it needs to be able to provide a value proposition.
- **Targeted** The concept needs to be able to target certain corridors and areas.
- **Equitable** The concept needs to be flexible to be able to design a scheme with equitable impacts.

Based on the outcomes above the recommended pricing concept for stage two was to combine the benefits of Concept 1's access charge, with the fairness of Concept 2's distance based charge. This combination means short trips on the network are deterred and longer trips are also charged appropriately. The ability to vary the access charge by location would provide the ability to target certain corridors and areas.

Varying the charge by entry point was chosen over charging by a corridor or charging the entry and exit point for reasons of simplicity of communication. The price structure will not provide the ability to apply a higher price for all users of a particular corridor only those entering that particular corridor.

[7] Public transport mode share reported in this study as the proportion of trips on public transport relative to total trips on mechanised modes. The number of trips using active modes is excluded from the calculation. This is consistent with other transport studies undertaken in Tauranga.

[8] An assessment against Urban Form Outcomes was not included as we were yet to establish parameters for the assessment of this objective in Stage 1.

Stage 2 modelling

As per the recommendation of Stage 1, the Stage 2 concept price structure (Concept 5) was a combination of:

- an access charge for entry onto the priced network or into /out of Te Papa Peninsula and a
- a distance-based **charge** on the priced corridor.

Users would be charged to access Te Papa Peninsula, but in all other locations there would be no charge to cross the network. The access charge at all locations into /out of Te Papa Peninsula allows traffic flow at these locations to be managed with price.

The extent of the priced network in the Stage 2 modelling includes the State Highway ring around Te Papa Peninsula (SH2, SH29, SH29A), SH2 and TNL from Te Puna, and TEL as was shown in Figure A.

The access charge can be varied by location and a number of tests were undertaken to assess the effects of a higher and lower access charges in different locations. This led to the selection of 50% higher access charges on Takitimu Drive SH2, and 50% lower access charges on SH29A to encourage traffic to use SH29A over the SH2 route. This price model was referred to as the Assessed Price Model and it was this scenario that was then assessed against the agreed performance indicators for each of the study objectives as well as an appraisal of the transport economic benefits of the scheme.

The results of the that assessment as described in the above Outcomes section.

Financial analysis

Tauranga's current toll roads, Takitimu Drive[9] and Tauranga Eastern Link[10] generate $9.9m gross revenue per annum and $8.7m gross revenue per annum respectively today (2020/21), and $6.5m net[11] revenue per annum and $5.8m net revenue per annum respectively.

Takitimu Drive tolling is expected to end by 2031, and Tauranga Eastern Link tolling is expected to end in 2040. This study assumes that if there was no variable road pricing in the future then there will be a toll on Takitimu North Link when it opens (noting that no decision on the tolling of TNL has been made). This study estimates that a toll on Takitimu North Link would generate $18m gross revenue in 2035 and $38m gross revenue in 2048. In the concept of variable road pricing that has been studied, these flat tolls would be replaced with variable road pricing.

Road pricing is estimated to generate approximately $150m gross revenue in 2035 and approximately $230m gross revenue in 2048. These figures of gross revenue account for the following deductions:

- Discounts – 5% less gross revenue to provide for discounts to certain road users such as those using motorbikes, or those using cars from a city carpool scheme.
- Exemptions – 5% less gross revenue to provide price exemptions for certain road users such as emergency services
- Leakage – 2% less gross revenue due to non-payments
- GST – 15% less gross revenue due to GST payments.

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[9] Takitimu Drive as a toll of $1.90 for cars and motorcycles and a toll of $5.00 for trucks.

[10] Tauranga Eastern Link as a toll of $2.10 for cars and motorcycles and a toll of $5.20 for trucks

[11] The term "net revenue" is used here to describe remaining revenue after operating costs and costs to repay debt.

Gross revenue from road pricing is converted to net revenue by subtracting operating costs which are comprised of:

- Transaction costs. 35 cents per transaction and one transaction per use is assumed
- Maintenance costs. $4m per annum

Net revenue from road pricing (before accounting for revenue needed to pay off loans) is estimated to be approximately $110m in 2035 and approximately $190m in 2048. System net revenue is then calculated by subtracting revenue needed to pay off loans for TEL and Takitimu North Link in 2035, and Takitimu North Link in 2048. System net revenue from road pricing is estimated to be approximately $88m in 2035 and approximately $158m in 2048. Over a 40 year period system net revenue from road pricing is estimated to be approximately $5.5 billion.

A preliminary estimate of potential scheme elements based on an ANPR system has been carried out. The priced network, as set out in this study, has over 100 entry and exits points. We estimate that around 95 to 100 camera sites would be needed to implement the system. The associated cost is estimated to be approximately $35m in capital costs with an annual maintenance cost of $4m per annum. Total operating costs (including maintenance costs) are estimated to be approximately $42m per annum in 2035 and $44m per annum in 2048.

Economic evaluation

Total transport user benefits from road pricing are forecast to be approximately $52m per annum in 2035. This is made up of:

- $39m in private vehicle travel time, decongestion, and reliability benefits
- $4m in vehicle operating costs benefits
- $0.5m in Public Transport travel time benefits
- $2m in crash cost savings
- $5m in emissions reduction benefit

In 2048 the estimate benefits are forecast to be very similar to those in 2035.

Over a 40 year period system net transport user benefits from road pricing are estimated to be approximately $2 billion undiscounted with a net present value (NPV) of $960m.

This study has assessed the impacts of road pricing in the context of a 2035 future year scenario and a 2048 future scenario. These future year scenarios include transport schemes that are currently not committed schemes and/or do not have a secure mechanism to fund them. It was outside the scope of this proof of concept study to determine what the associated costs (and economic benefits) of this package of schemes would be. It is also noted that the scheme assumptions do not necessarily constitute a baseline network that is required to support VRP. It was outside the scope of this proof of concept study to determine what that baseline network (in each forecast year) would constitute.

Recommendations

The recommendations resulting from this modelling and financial analysis component of the proof-of-concept study are:

- There are expected to be increases in traffic on local roads. If the concept of road pricing in Tauranga is pursued further, it is recommended that these impacts be investigated and mitigated or avoided where necessary through design in further scheme development stages.

- A finding of stage 1 of the study was that *scheduled variable* pricing would be more effective than *real time dynamic* pricing in achieving the road pricing objectives for Tauranga. If the concept of road pricing in Tauranga is pursued further, it is recommended that scheduled variable pricing is adopted as the method of pricing in future studies rather than dynamic road pricing.
- The scope of this study was limited to the proof of this concept alone and focused on a concept of charging for use of all roads on Tauranga's strategic road network. There may be other pricing regimes or extents that are more efficient and effective in achieving the road pricing objectives. It was found that the network pricing option with the access charge component of price was an effective means to influence travel behaviour in Tauranga, and that it compared well to a cordon charge concept. Nevertheless, if the concept of road pricing in Tauranga is pursued further, it is recommended that a business case approach be used to consider a full range of road pricing options.

Risk

Implementing a road pricing scheme can have several risks and challenges, including public opposition, equity concerns, implementation costs and technical challenges, and data privacy and security concerns.

Forecasting revenue from road pricing is a technically challenging task. The key risks and uncertainties to the revenue forecasts presented in this study are:

- **City wide population growth assumptions:** Population growth assumptions impact the number of vehicles on the road and the demand for the priced network
- **Scheme network extent**: The extent of the priced network may be smaller or larger than assumed in the modelled will impact the revenue generated
- **Scheme pricing**: The study assumes the priced network would have charges 24/7. Although the price assumed outside of weekday peak periods is lower than that assumed in the weekday peak periods, revenue from these non-peak time periods makes up a significant portion of the revenue estimates. If these time periods were not priced, the estimate of revenue would be significantly lower.

These key risks and others are discussed in this report, but the assessment of risk is limited to a qualitative assessment of each risk element rather than a more detailed quantitative assessment that would provide a range to the revenue forecasts. A quantitative assessment would be done in a more detailed design stage.

Limitations

This work provides estimates of traffic volumes and revenue suitable for a proof-of-concept study phase. The revenue estimates are not considered 'business case standard' such as might be required for the progression of public sector projects or 'investment grade' such as might be required for private-sector investment.

The purpose of this report is to assess the transport network impacts and revenue implications from road pricing, in accordance with the parameters of our agreed scope as set out in our proposal. Further analysis may be required in order to support future design stages and more detailed financial analysis.

Although in this report, Beca offers professional advice and may express opinions on likely or possible outcomes, we cannot guarantee any particular outcome and any decision to proceed with the next phase of investigation is a decision for the clients (Tauranga City Council and Waka Kotahi) and wider parties with a stake in the opportunity and implications, including SmartGrowth partners.

It should be noted that the road pricing revenue estimates provided as part of the Services are not a statement of absolute revenue suitable for detailed investment decisions, rather they will have an accuracy range commensurate with various factors such as the extent of relevant information provided, the certainty of data and assumptions and the level of detail available at the time of preparation.

This assessment has included the list of transport system effects that were agreed with the client partners and has not included a wider assessment against Waka Kotahi, Tauranga City Council or other Government policies or frameworks. Forecasting traffic flows for road pricing contains inherent uncertainty. While this report has attempted to identify key uncertainties, the risks associated with traffic forecasts should be considered in future design and policy decisions.

Detailed market research into willingness to pay has not been undertaken specifically for this work, however Tauranga's strategic transport model (TTSM) has the benefit that its willingness to pay values are locally calibrated to two separate toll roads. There is always uncertainty in modelling and forecasting how drivers will response to price particularly where the form of the pricing system is different to existing conditions.

In preparing this assessment we have relied on the inputs and assumptions provided by or agreed with Waka Kotahi and TCC as outlined in this report, including:

- Land use inputs from TCC
- Network project assumptions agreed with TCC and Waka Kotahi
- Concept design direction from TCC and Waka Kotahi
- Capital cost assumptions from Waka Kotahi
- Operating costs assumptions from Waka Kotahi including the transaction cost assumptions of 35 cents per transaction and the assumption of on transaction cost per use.

1 Introduction

1.1 Context

Western Bay of Plenty's SmartGrowth partners have developed the Urban Form and Transport Initiative (UFTI) programme business case that presents a Connected Centres approach to cater for forecast urban growth in the region over the next 30-70 years. UFTI has identified the need to consider new and different economic tools to fund the Connected Centres infrastructure investment programme. This study considers one solution as a proof-of-concept to support the UFTI programme. Road pricing (of some form) has the potential to optimise use of the transport network.

The objectives of road pricing identified by the Project Partners are:

- Support urban form outcomes (primary outcome)
- Optimisation of the whole transport system, including past investment and the role of each travel mode
- Improve travel time reliability and levels of service
- Raise revenue to invest in local transport solutions
- Incentivise lower carbon emissions
- Incentivise travel choice.

1.2 Road Pricing

Table 1-1 sets out different types of road pricing structures.

Table 1-1 Road pricing structures

Pricing structures	
Static	One all day and part day price that is fixed in advance of the day of travel
Variable (Scheduled)	A road price that varies by time of day, location, and direction of travel, that is fixed in advance of the day of travel Pricing is regularly reviewed and changed according to network performance measures
Dynamic	A form of variable pricing that is not fixed in advance of the day of travel, but pricing that varies according to real-time demand on a specific road

The original proof-of-concept study brief proposed consideration of a dynamic pricing structure. Dynamic road pricing is a variant of congestion pricing where charges vary in real-time as a function of current traffic conditions, as opposed to a flat charge, which stay constant over time, and scheduled variable charges, where charges vary by time of day of the week or season following a predetermined schedule. Dynamic road pricing is not currently deployed in NZ, nor is there currently a legislative framework for existing roads to be tolled. Internationally, dynamic road pricing is currently only applied on high occupancy tolled (HOT) lanes in the USA (and requires an order of magnitude more equipment and forecasting expertise to implement).

As part of Stage 1 different road pricing structures were considered. It was found that scheduled variable pricing would be more effective than real time dynamic pricing in adequately achieving the road pricing objectives for Tauranga. Stage 2 continued with the assessment of scheduled variable pricing rather than real time dynamic pricing. Further detail on this reasoning is provided in the Road Pricing Paper[12].

[12] Paper on Road Pricing in Tauranga, Scott Wilson, Milestone Solutions 2023

1.3 Study approach

Waka Kotahi and Tauranga City Council (the Project Partners) commenced a two stage proof of concept study of road pricing in Tauranga in May 2022. Beca was engaged to undertake transport modelling, financial analysis, and economic analysis of road pricing in Tauranga. Scott Wilson of Milestone Solutions, an internationally recognised expert in road pricing, was engaged by Beca as a sub-consultant to provide advice through the study and write a paper on road pricing.

Stage 1 of the study modelled four different road pricing concepts for a range of price points. This was a first step in understanding the potential for and implications of road pricing in Tauranga.

Stage 2 of the study built on the findings of Stage 1 to improve the concept, represent variable price in more detail, and deliver a revenue spreadsheet and technical report on the modelling, financial analysis (costs and revenue), and economic analysis. In Stage 2, the Road Pricing Paper was supplemented with further chapters including implementation considerations and policy issues.

1.4 Report purpose

This report is a technical report of the traffic modelling undertaken, the financial analysis of revenue from tolls and price and an evaluation of the economic benefits of the scheme. This report should be read in conjunction with Tauranga Road Pricing Paper written by Scott Wilson of Milestone Solutions.

This technical report and the Road Pricing paper support the Road Pricing in Tauranga Study Report written by Waka Kotahi in collaboration with Tauranga City Council. The Study Report will include sections on the wider economic story and UFTI, value proposition and the wider context for road pricing in Tauranga.

2 Modelling methodology

2.1 Scheme definition

Road pricing can be implemented in many forms, and there are many permutations on the extent of the network that is to be priced, or the locations of the network that are priced. There are two aspects to the scheme design that are features of the scheme being studied. These are 1) the kind of pricing form, and 2) the network coverage of the pricing scheme.

Pricing form

The study focused on scheduled variable pricing, rather than other types of pricing such as an 24/7 flat charge, a daytime flat charge or at the end of the spectrum; dynamic pricing.

Priced Network coverage

The original brief described four concept options related to road pricing covering various network extents, starting with one corridor going up to network coverage across the Te Papa Peninsula. In subsequent conversations with Waka Kotahi and TCC during the study scoping phase the study focus pivoted to the assessment of network pricing schemes only rather than including the assessment of single or multi-corridor schemes. The network coverage was defined as “Tauranga’s state highway network and Turret Road”. The exact extent of the road network included in the priced network was refined through the study as documented through this report.

2.2 Available models

The Tauranga transport models available for use for the study are the Tauranga Transport Strategic Model (TTSM), the Tauranga Transport Hybrid Model (TTHM) and the Tauranga Cycle Model (TCM).

Of the tools and analytical approaches available, TTSM was selected as the appropriate model to test road pricing. While it was not specifically designed to test network wide variable pricing, it is well established in modelling toll roads and the transport response to toll roads given the presence of the Takitimu Drive toll, the Tauranga Eastern Link toll, and past tolling of Tauranga Harbour Bridge. TTSM is the best available tool for testing long term impacts of large-scale transport schemes and policies. It offers a wide range of demand responses. The version of TTSM used was TTSM21, which was the latest available version of TTSM at the start of the study.

The strategic modelling in TTSM was supplemented with microsimulation modelling of the Takitimu Drive to Hewletts Road corridor in TTHM. This provided the functionality to test a more refined pricing profile over the AM peak hour.

2.3 Model enhancements

At the outset of the study, TTSM had the functionality to represent the following responses to road pricing:

- Route choice
- Mode choice
- Destination choice

In the scoping phase, we recognized two other potentially important responses to pricing:

- Time of day response
- Trip frequency response

The project partners agreed there was a need to represent each of these responses in TTSM for the purposes of the road pricing study. So in parallel to the Stage 1 concept modelling, we designed and implemented this functionality in TTSM.

In Stage 1 we investigated the enhancement required to represent road pricing in TTHM. This investigation led to a micro-time of day response being implemented in Stage 2 in order to test the effects of a varying price during a peak period.

2.4 Baseline assumptions

The available TTSM21 model years were 2031 and 2048. The model years requested to be used in the study were 2035 and 2048, and so a 2035 baseline do minimum (DM) scenario and 2035 baseline do something (DS) scenario were established at the start of the study to compliment the already available 2048 baseline DM and 2048 baseline DS scenarios available from TCC and consistent with the Transport System Plan at the time (early 2022). The road pricing tests are all built on the Baseline DS scenario. It is noted that the scheme assumptions do not necessarily constitute the baseline network that is required to support VRP. It was outside the scope of this proof of concept study to determine what that baseline network (in each forecast year) would constitute.

Land use, in terms of population and employment projections for 2035 and 2048 were supplied by TCC. Land use inputs are fixed across all scenarios for each model year.

Table 2-1 below presents a high level summary of network assumptions in each of the baseline scenarios.

Table 2-1 High level summary of baseline scenario network assumptions

Baseline scenario	2035	2048
Baseline Do Minimum	Committed and near certain projects scheduled to be completed by 2035 10 projects in total including projects under construction including the Papamoa Eastern Interchange, Takitimu North Link, and other projects including the at-grade signal upgrade Takitimu Drive / Elizabeth Street, Cameron Road Bus lane No Takitimu Drive toll (assumed expired) Takitimu North Link tolled Tauranga Eastern Link tolled north and south of PEI	Committed and near certain projects scheduled to be completed by 2048 11 projects in total No Takitimu Drive toll (assumed expired) Takitimu North Link tolled No Tauranga Eastern Link toll (assumed expired)
Baseline Do Something	Baseline Do Minimum plus: 13 of the 20 Transport System Plan (TSP) road schemes[13] The 2048 Transport System Plan (TSP) public transport services	Baseline Do Minimum plus: All 20 Transport System Plan (TSP) road schemes. The 2048 Transport System Plan (TSP) public transport network
Road Pricing tests are all built on the Baseline Do Something scenario		

[13] As assumed in the TTSM21 2048 Do Something scenario modelling undertaken in 2021 / 2022.

Appendix A provides a full list of land use assumptions, transport scheme assumptions, baseline tolling assumptions and other transport policy assumptions in the baseline scenarios.

Baseline performance in terms of WBoP wide network delay, network reliability, VKT, Mode share, CO_2 Equivalent statistics is presented in Table 2-2 below.

Table 2-2 Network performance of the 2018 base network and the future year baseline scenarios

	2018	2035		2048	
		Baseline Do Minimum	Baseline Do Something	Baseline Do Minimum	Baseline Do Something
Private Daily vehicle trips	641,000	830,000 *29% more than 2018*	816,000 *2% less than BL DM*	943,000 *47% more than 2018*	930,000 *1% less than BL DM*
VKT KM/day	4.97m	6.41m *29% more than 2018*	6.37m *2% less than BL DM*	7.34m *48% more than 2018*	7.59m *3% more than BL DM*
CO_2E KG/day	1.13m	1.22m *9% more than 2018*	1.22m *1% less than DS DM*	0.88m *22% less than 2018*	0.91m *3% more than BL DM*
Delay Vehicle hours/day	16,800 hrs	26,600 hrs *59% more than 2018*	26,100 hrs *2% less than BL DM*	33,600 hrs *101% more than 2018*	27,500 hrs *18% less than BL DM*
Reliability % of road network length within capacity (AM peak)	94%	93%	90%	93%	93%
PT Patronage/day	12,800	19,700 *+54% more than 2018*	34,800 *77% more than baseline DM*	22,000 *72% more than 2018*	39,300 *78% more than Baseline DM*
PT Mode share	1.6%	1.9%	3.3%	1.8%	3.2%
Cycle Trips/day	12,600	19,600 *+55% more than 2018*	26,300 *+34% more than Baseline DM*	27,100 *+114% more than 2018*	34,000 *+25% more than Baseline DM*

Road network LOS plots of the Baseline DM and Baseline DS scenarios are provided in Appendix C. These plots illustrate how poor the road network is predicted to operate in future years even in the baseline do something scenarios which include major infrastructure projects services (public transport) and policy implementation (e.g. parking strategy implementation). In particular Takitimu Drive south of the Takitimu North Link interchange, where the current toll is no longer in place, the road is operating over capacity in the 2035 baseline DM, 2048 baseline DM, and 2035 baseline DS scenarios. In the 2048 baseline DS scenario

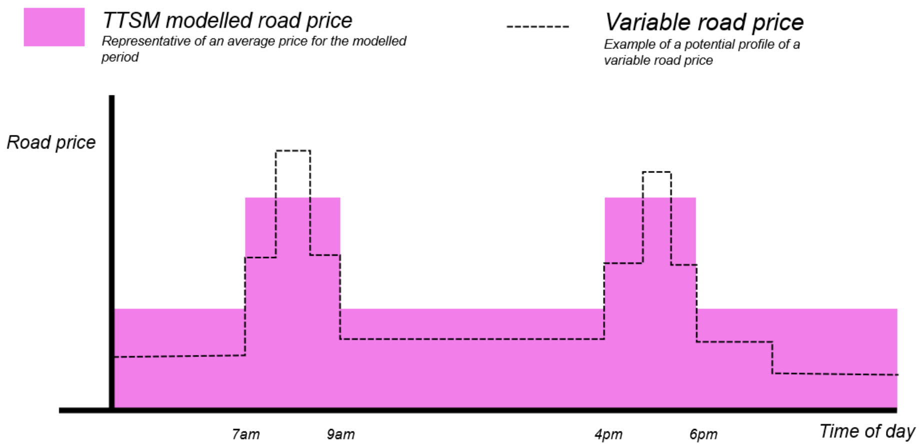
Takitimu Drive south is changed from 2 lanes to 4 lanes, this additional capacity provides sufficient capacity for the forecast road traffic on Takitimu Drive in 2048.

2.5 Representation of pricing

Input values

Three time periods are represented in TTSM, the weekday AM 2 hour peak period (AM), the weekday PM 2 hour peak period (PM) and the 7 hour interpeak period (IP). These periods are represented in TTSM as an average hour of the period represented. Therefore it should be recognised that the reported TTSM model results are a flat average of these periods and that actual profiled demand conditions are likely to be worse than reported during the 'intra-peak' high demand time slices. Travel demand, transport supply and transport costs are input as average or weighted average values for each period represented. Road price is input in the same way as illustrated in Figure 2-1. For a variable price which may rise and fall over the modelled time period, an average price is applied. For example a $2.00 price in the AM peak period is representative of an average price of $2.00 over the AM period.

Figure 2-1 Illustration of the TTSM modelled road price



TTHM represents time in smaller increments. A study of the profile of price within the AM peak period and the effects on micro peak spreading is described in Section 4.4.

The prices stated in this report and throughout the study are in 2022 price and value. Model values of price input to the model are adjusted to account for forecast changes in CPI over time, and willingness to pay parameters are also adjusted to account for forecast changes in income levels relative to CPI.

Price elasticity of demand

TTSM is well established in modelling toll roads and the transport response to toll roads given the presence of the Takitimu Drive toll, the Tauranga Eastern Link toll, and past tolling of Tauranga Harbour Bridge.

The route choice, distribution response, and mode choice response in TTSM21 are calibrated and validated to local conditions which include the Takitimu Drive toll and the Tauranga Eastern Link toll.

The parameters for the trip frequency response and the macro time of day response are taken from the London Congestion Charge study (see appendix A). These parameters were sensitivity tested and peer reviewed as part of the implementation of this new functionality.

3 Stage 1 Modelling

3.1 Overview

Stage 1 involved testing two network pricing concepts and two cordon pricing concepts with a range of pricing levels in TTSM. The two cordon pricing concepts were tested to contrast and compare with the network pricing concept. Each concept was modelled in TTSM for the forecast year 2035. Each concept was tested under a range of charges; Price A, Price B and Price C, with each price being twice that of the previous price. The four concepts were assessed against various network performance indicators. This was a first step in understanding the potential for and implications of road pricing in Tauranga. Stage 1 concluded with a preferred concept called Concept 5 to be more thoroughly assessed in Stage 2.

3.2 Concepts

The four Stage 1 road pricing concepts were:

Concept 1: Priced network with an access based charge

- Users charged to access the priced network
- All network access points (where possible) would have ANPR cameras
- Where access is difficult to control (e.g. Hewletts Road) ANPR cameras would be located intermittently along the route, meaning trips that only use a short section of the priced network would be ignored.
- Users would be charged to access the Te Papa Peninsula area, but in all other locations there would be no charge to cross the network.

Concept 2: Priced network with a distance based charge

- Users charged a price per km on the priced network
- Network access and exit points would have ANPR cameras to determine the distance travelled
- Where access is difficult to control (e.g. Hewletts Road) ANPR cameras would be located intermittently along the route, meaning trips that only use a short section of the priced network is such location would be ignored.
- Users would be charged to access the Te Papa Peninsula, but in all other locations there would be no charge to cross the network.

Concept 3: Te Papa Peninsula Priced Cordon

- Users charged each time they cross the cordon
- Assume users could cross the cordon multiple times for a defined time period (e.g. 60 minutes).
- All cordon crossing points would have ANPR cameras
- No charge to travel within the cordon.

Concept 4: Te Papa Peninsula Cordon + CBD Cordon

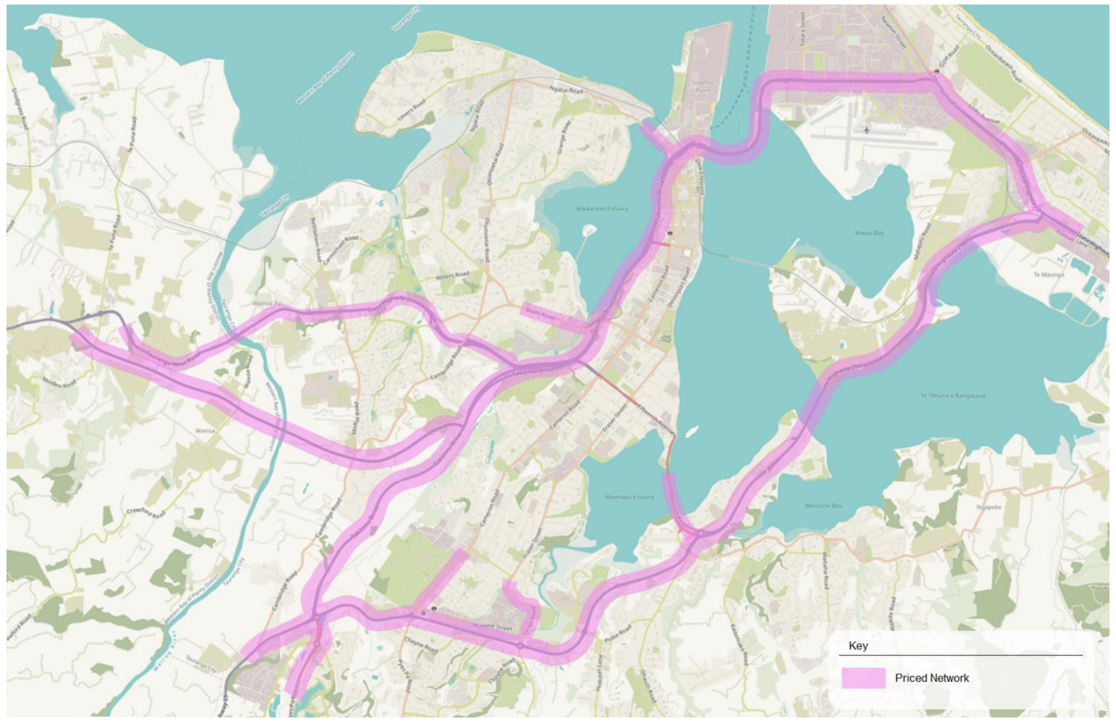
- Users charged each time they cross a cordon
- Assume users could cross a cordon multiple times for a define time period (e.g. 60 minutes).
- All cordon access points would have ANPR cameras
- No charge to travel within the cordon

The extents of the Concept 1 and Concept 2, and the locations of the cordons in Concept 3 and Concept 4 are shown in Table 3-1 below.

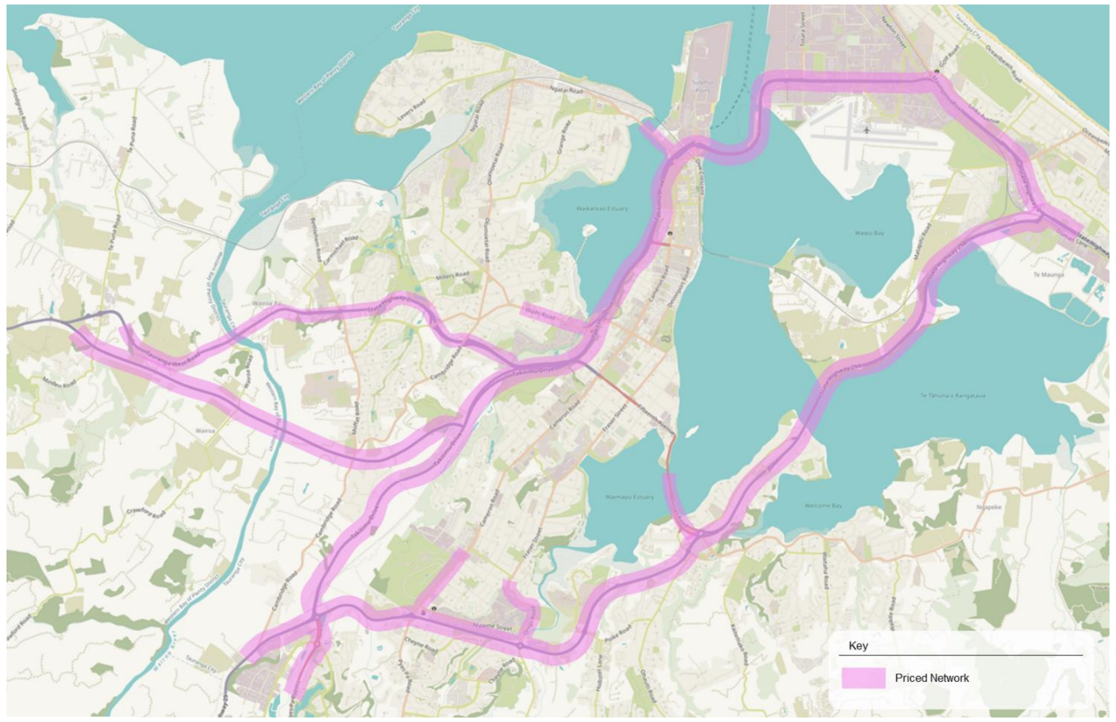
Sensitivity: General

Table 3-1 Stage 1 Concept illustrations

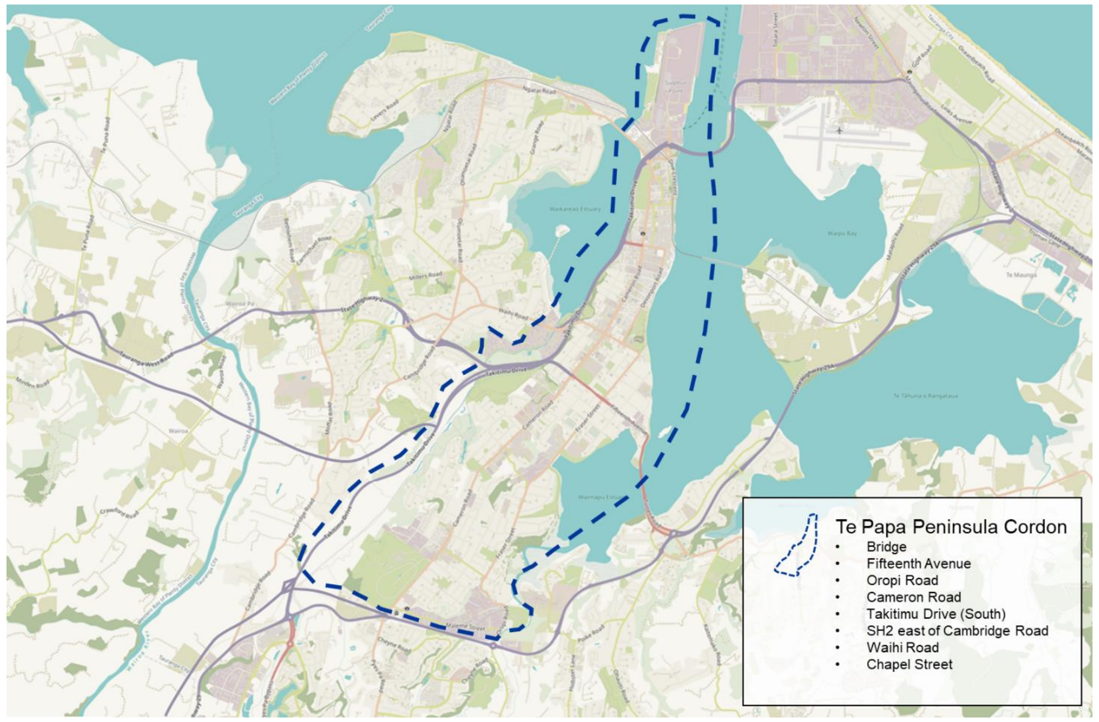
Concept 1. Priced network with an access based charge



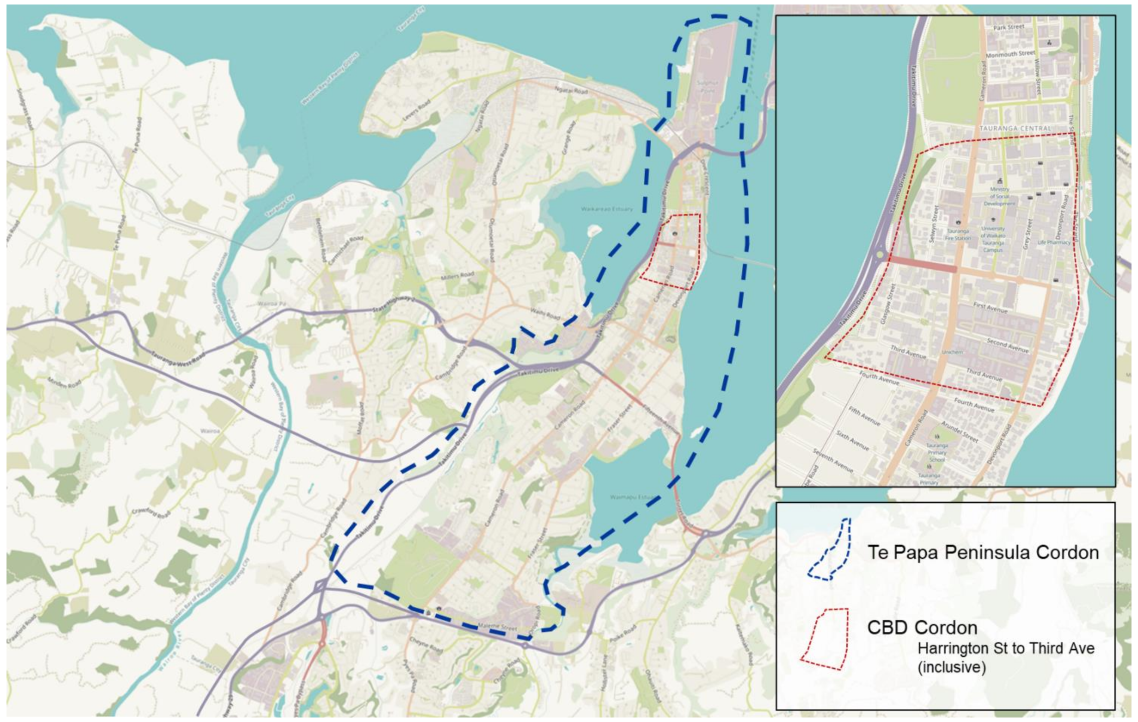
Concept 2. Priced network with a distance based charge



Concept 3. Te Papa Peninsula Cordon



Concept 4. Te Papa Peninsula Cordon + CBD Cordon



Beca

The concepts were tested in TTSM with the light vehicles priced as set out in Table 3-2 below. Heavy vehicles are charged 2.5 times the light vehicle prices that are presented.

Table 3-2 Range of light vehicle prices for Stage 1 modelling in TTSM

Concept	Time period	Price A	Price B	Price C
Concept 1 Priced network with an access based charge	AM	$1.00	$2.00	$4.00
	PM	$1.00	$2.00	$4.00
	Inter-peak	$0.50	$1.00	$2.00
Concept 2 Priced network with a distance based charge	AM	$0.10 per KM	$0.20 per KM	$0.40 per KM
	PM	$0.10 per KM	$0.20 per KM	$0.40 per KM
	Inter-peak	$0.05 per KM	$0.10 per KM	$0.20 per KM
Concept 3 Te Papa Peninsula Cordon	AM	$1.00	$2.00	$4.00
	PM	$1.00	$2.00	$4.00
	Inter-peak	$0.50	$1.00	$2.00
Concept 4 Te Papa Peninsula Cordon + CBD Cordon	AM	$1.00	$2.00	$4.00
	PM	$1.00	$2.00	$4.00
	Inter-peak	$0.50	$1.00	$2.00

3.3 Outcomes

The concepts were assessed against the road pricing objectives using six network performance indications:

- VKT Vehicle Kilometers travelled Average daily vehicle kilometers travelled
- Emissions Carbon dioxide equivalentCO_2E Kg / Day
- Delay Average Daily vehicle hours of delay: Congested time - free flow time
- Public transport mode share
- Level of service Proportion of the priced network links at LOS D or better
- Revenue The amount of net revenue generated

The full set of outcomes is provided in Appendix B.

Using these network performance indicators the concepts were assessed against the four of the five road pricing objectives. An assessment against Urban Form Outcomes was not included as we were yet to establish parameters for the assessment of this objective in Stage 1. This assessment is summarised in the Table 3-3 below.

Sensitivity: General

Table 3-3 Assessment of Stage 1 Concepts versus objectives

	Concept 1 **Priced Network with Access charge**	Concept 2 **Priced Network with distance-based charge**	Concept 3 **Te Papa Peninsula Cordon**	Concept 4 **Te Papa Peninsula cordon + CBD cordon**
Optimisation of the whole transport system	Mixed result. Appears to perform well in the AM and IP but less effective in the PM time period.	High price appears effective at reducing LOS across the network	Little impact on improving LOS across the whole network and the priced network	Little impact on improving LOS across the whole network and the priced network
Improve travel time reliability and levels of service	Performs well on delay reduction.	Performs well on delay reduction.	Performs well on delay reduction, but slightly less than other concepts.	Performs well on delay reduction.
Raise revenue	Performs well on net revenue	Lots of short trips leads to high proportion of low/negative net revenue trips.	Mid-range performer.	Performs well on net revenue
Incentivise lower carbon emissions and travel choice	Achieves C02E reduction and reasonable PT mode shift effect.	Achieves $C0_2E$ reduction but small PT mode shift effect.	Achieves $C0_2E$ reduction but small PT mode shift effect.	Performs well on CO_2E reduction and PT mode share
Support urban form outcomes				

An assessment against Urban Form Outcomes was not included as we were yet to establish parameters for the assessment of this objective in Stage 1

Based on this assessment, Concept 1, the concept with an access charge was considered the most promising of the concepts. The access charge targeted short trips, reducing the number on the strategic road network which frees up capacity and reduces delay. Concept 1 also performed well compared to the other concepts in terms of raising revenue.

3.4 Lessons and recommendations

The lessons from Stage 1 were:

- Scheduled variable pricing would be more effective than real time dynamic pricing in achieving road pricing objectives.
- An Access charge approach is helpful in targeting short trips
- The distance charge alone is financially inefficient due to the relatively high transaction costs on short trips
- The cordon concept is helpful for mode share, particularly with a CBD cordon, but concerns over 1) flexibility and 2) impacts at the cordon perimeter.
- The concept needs to be able to target corridors or specific locations
- Non-price interventions should be delivered in tandem with pricing to avoid and mitigate negative effects such as inducing the wrong traffic on local non-priced streets.

The study team also identified four success factors in the design of a pricing scheme for Tauranga:

- **Scalable** The concept needs to work on one corridor, several corridors or across a network of roads.
- **Public acceptance** The concept needs to be understandable, and it needs to be able to provide a value proposition.
- **Targeted** The concept needs to be able to target certain corridors and areas.
- **Equitable** The concept needs to be flexible to be able to design a scheme with equitable impacts.

Based on the outcomes above the recommended pricing concept for Stage 2 was to combine the benefits of Concept 1’s access charge, with the fairness of Concept 2’s distance based charge. This combination means short trips on the network are deterred and longer trips are also charged appropriately. The ability to vary the access component of the charge by location would provide the ability to target certain corridors and areas.

4 Stage 2 Modelling

4.1 Overview

Stage 1 concluded with the preferred concept (referred to as Concept 5) which was more thoroughly assessed in Stage 2 in the forecast years 2035 and 2048. Concept 5 was modelled using TTSM with its new functionality, as well as some more detailed modelling of the AM peak period using TTHM[14]. The modelling in Stage 2 involved the following components:

- Various pricing levels and pricing models were tested to determine a pricing model suitable for a full assessment of Concept against the road pricing objectives
- Full assessment of Concept 5 against performance indicators for each road pricing objective
- Financial analysis of revenues and costs
- Economic evaluation of transport user benefits
- TTHM modelling of the AM peak period
- Sensitivity testing and other analysis.

4.2 Concept 5

4.2.1 Design

As per the recommendation of Stage 1, the Stage 2 concept price structure was a combination of:

- an **access charge** for entry onto the priced network or into /out of Te Papa Peninsula and a
- a **distance-based charge** on the priced corridor.

This pricing structure deters short trips from the priced network and longer trips are charged appropriately. Users would be charged to access Te Papa Peninsula, but in all other locations there would be no charge to cross the priced network. The access charge at all locations into /out of Te Papa Peninsula allows traffic flow at these locations to be managed with price.

The access charge can be varied by location. This will be done by charging a different access charge at each entry point (or some entry points). This then provides the ability to either target congested corridors with higher prices, or to target corridors where funding is needed in the area for specific infrastructure or schemes.

Varying the charge by entry point was chosen over charging by a corridor or charging the entry and exit point for reasons of simplicity of communication. The price structure will not provide the ability to apply a higher price for all users of a particular corridor only those entering that particular corridor.

4.2.2 Network extent for modelling

The extent of the priced network, as illustrated in Figure 4-1 and Figure 4-2, is defined for modelling purposes. It includes the State Highway ring around Te Papa Peninsula (SH2, SH29, SH29A), SH2 and TNL from Te Puna, and TEL. The priced network extent could be less or more as needed at the time of implementation and can be tailored over time.

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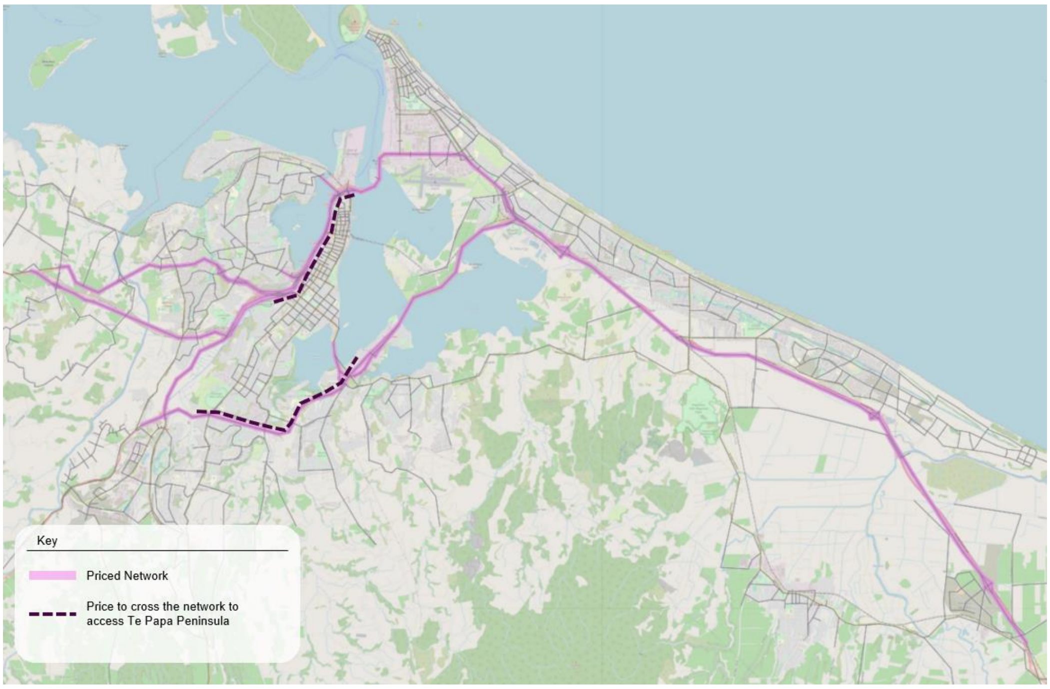
[14] Only one time period was modelled in TTHM given the nature of the study being proof-of-concept only. The forecast 2035 levels of the service on the corridor without pricing was similar in the AM and PM. Either period could have been for the TTHM modelling.

Sensitivity: General

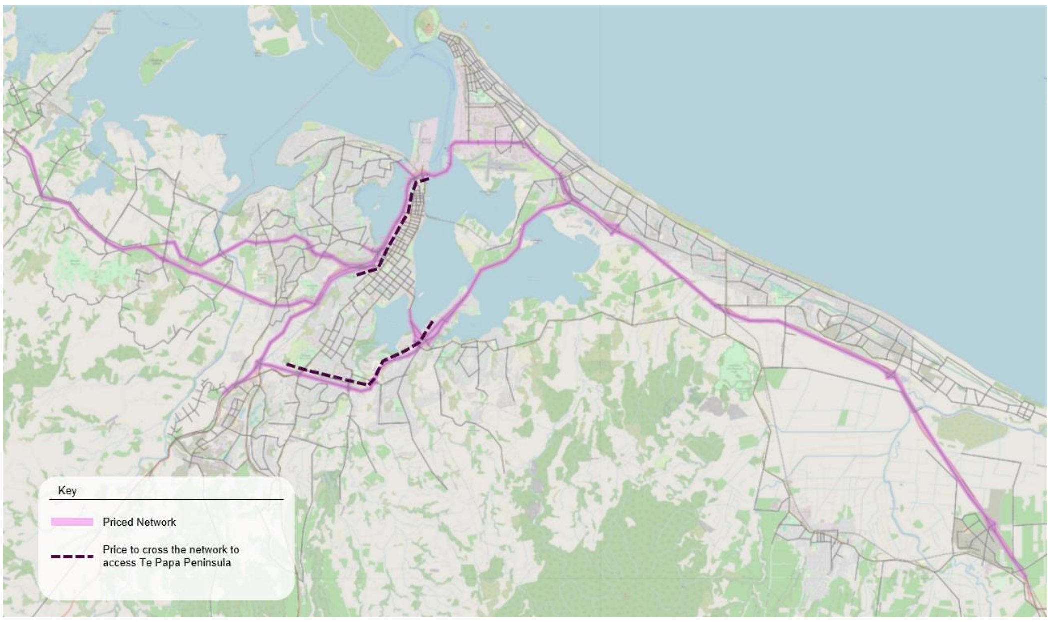
The extent of the network was chosen to allow management of demand across the entire strategic road network and key supporting arterial roads. Note that the priced network includes TEL and would replace the current toll. In Stage 1 modelling, TEL was not included in the priced network of Concept 1 and Concept 2.

Figure 4-1 2035 Priced network extent for modelling



Sensitivity: General

Figure 4-2 2048 Priced network extent for modelling



4.2.3 Pricing model testing

Pricing model tests

Nine pricing model tests were undertaken to determine a pricing model to carry out an assessment against the road pricing objectives. The tests covered a range of access charge levels, differential access charges to influence route choice, and tests targeting a mode shift. The list of tests is presented in Table 4-1 below alongside the price for light vehicles. Heavy vehicles are charged 2.5 times the light vehicle charges. The 2.5 multiplier is applied to both the access charge component and the distance charge component of price.

Table 4-1 List of pricing model tests

Pricing model test name	Description of pricing model *Charges for light vehicles shown. Heavy vehicles are charged 2.5 times the light vehicle charges.*
Price A	Peak $1.00 + $0.15 per KM Interpeak $0.50 + $0.15 per KM
Price B	Peak $2.00 + $0.15 per KM Interpeak $1.00 + $0.15 per KM
Price C	Peak $4.00 + $0.15 per KM Interpeak $2.00 + $0.15 per KM
Price D	Peak $8.00 + $0.15 per KM Interpeak $4.00 + $0.15 per KM

Differential Access Charge Test 1	Price B with 50% less on SH29A access points and double charges on Takitimu Drive SH2 access points to encourage road users to travel around the harbour (via SH29A) instead of across the harbour (SH2 harbour Bridge).
Differential Access Charge Test 2	Differential Access Charge Test 1 plus 50% less Access Charge on Welcome Bay Link Road access points to encourage road users to travel around the harbour (via SH29A) instead of across the harbour (SH2 harbour Bridge) and relieve Welcome Bay residents of full charging where alternative travel options are limited.
Differential Access Charge Test 3	Differential Access Charge Test 2 plus $8 on Harbour Bridge in the peaks ($4 in the interpeak) to further encourage road users to travel around the harbour (via SH29A) instead of across the harbour (SH2 harbour Bridge).
Mode shift Run 1	Price B test with +25% to the access charge on those roads which have high levels of PT service to encourage mode shift.
Mode shift Run 2	Mode shift Run 1 plus 50% off PT fares to further encourage mode shift.

The project partners agreed four performance indicators would be used to select the pricing model for Concept 5 to then carry out a full assessment including economic appraisal. The four performance indicators were:

1. Levels of service (targeting LOS D or better)
2. Right traffic right roads
3. People movement
4. Freight movement

Other considerations were revenue and crash costs. The detail of each performance indicator and the model outcomes are presented in Appendix C.

Outcomes

The outcomes were summarised as:

- Price A typically captures the majority of network benefits of network delay saved, network level of service and reliability and journey time savings on freight routes.
- Price A is relatively inefficient with respect to net revenue compared to the other higher price points as transaction costs are assumed fixed at 35 cents per transaction (and the assume of one transaction per use) regardless of charge amount.
- Net revenue per annum in 2035 (before GST and other gross revenue deductions, and excluding maintenance costs) was estimated to be:
  – Price A: approximately $50m per annum
  – Price B: approximately $100m per annum
  – Price C: approximately $200m per annum
  – Price D: approximately $300m per annum
- The differential access charges were effective in reducing flows on the Harbour Bridge without significant impacts on network wide statistics compared to the reference point of Price B. Although there were some decreases in network reliability for Differential Access Charge Test 3.

- Differential access charges will influence traffic flows to a degree but there are limitations in the concept's ability to target route choice of road users at key route choice decision points with the given priced network extent.
- The $8 charge on the harbour bridge in Differential Access Charge Test 3 resulted in excessive diversion to SH29A beyond its available capacity and was not progressed.

Based on the modelling outcomes and other study considerations, the project partners selected a pricing model to be used in the full assessment (referred to as the Assessed Price model). This was the 2035 Price B scenario plus the Test 2 differential charging locations and the 2048 Price C scenario plus the Test 2 differential charging locations.

As mentioned above, at a lower price point than that chosen for the Assessed Price model, much of the network benefits are achieved but with less overall net revenue. With higher prices than that chosen for the Assessed Price model, there is some improvement in network performance, but this is not without negative outcomes on non-priced local roads where there are increases in traffic due to changes in route choice (to avoid or reduce road charges) or changes in trip destination (to avoid or reduce road charges).

This Assessed Price model for Concept 5 to be used for the full assessment and appraisal of economic benefits is outlined in Table 4-2 below.

Table 4-2 Assessed Price model for Concept 5 to be used for the full assessment

Forecast year	Description of pricing model for the full assessment *Charges for light vehicles shown. Heavy vehicles are charged 2.5 times the light vehicle charges.*
2035	Peak $2.00 + $0.15 per KM Interpeak $1.00 + $0.15 per KM With: • 50% lower charges on SH29A access points and Welcome Bay Link Road • 50% higher charges on Takitimu Drive SH2 access points
2048	Peak $4.00 + $0.15 per KM Interpeak $2.00 + $0.15 per KM With: • 50% lower charges on SH29A access points and Welcome Bay Link Road • 50% higher charges on Takitimu Drive SH2 access points

4.2.4 Concept issues

The issues with the concept that were found during the study were:

- The complexity of the concept's pricing structure may be difficult to communicate to the public
- The complexity of the concept's pricing structure may be difficult to implement from a back-office system perspective
- The ability to expand or contract the extent of the priced network may not be straightforward in practice due to the complexity of the system. Noting that it is still considered that the concept is superior to the cordon concept or area charge for the application of the road pricing in Tauranga.
- Differential access charges will influence traffic flows to a degree but there are limitations in the concept's ability to target route choice of road users at key route choice decision points with the given priced network extent.

4.3 Outcomes against the objective of road pricing

4.3.1 Introduction

Concept 5 with the assessed price model was assessed against the road pricing objectives. The agreed performance indicators for each road pricing objective were agreed with the project partners. These are set out below in Table 4-3 below.

Table 4-3 Performance Indicators

Road Pricing objective	Performance indicators
Optimisation of the whole transport system	No singular performance indicator was proposed. The optimisation of the whole transport system will be a balance of the performance indicators described below.
Improve travel time reliability and levels of service	Average Daily vehicle hours of delay: Congested time - free flow time Proportion of the road network operating at LOS D or better in each time period LOS plots Delay plots
Raise revenue to invest in local transport solutions	Gross revenue, operating costs, and net revenue
Incentivise lower carbon emissions	CO_2E vehicle emissions VKT outcomes
Incentivise travel choice	Trip summary statistics by mode (e.g. mode share)
Support urban form outcomes Note that the selection of topics from the Connected Centres programme was guided by Tauranga City Council officers.	Macro-urban form[15] • Impacts on travel patterns • Impacts on Road and PT journey times between centres Mode shift and micro-mobility • Shift of local road based trips to shared and active modes (including micro-mobility) Social equity • Change in travel costs by income group • Examples of how much are people paying in road price to access essential services Strategic Corridor function • Changes in traffic flows • Right traffic right roads assessment • Impact on journey times of freight traffic on key freight routes. • Examples of traffic volumes (including freight traffic) and changes in traffic volumes in sensitive areas such as outside schools and in town centres.

As described in Table 4-3, no singular performance indicator proposed for the first objective (to optimise the whole transport system) as the system has many competing outcomes.

[15] Average bus hours per person was originally included as a performance indicator, but this statistic is blurred by changes in the trip frequency and trip distribution that results from pricing, so the direction of change is not clearly indicative of a good outcome or a bad outcome.

4.3.2 Improve travel time reliability and levels of service

The metrics to assess the impact of VRP improving travel time reliability and levels of service were:

- **Delay:** Average Daily vehicle hours of delay: Congested time - free flow time
- **% of Network at LOS D or better**: The proportion of the road network operating at LOS D or better in each time period

Traffic network LOS plots for each scenario were also produced and these are available in Appendix D.

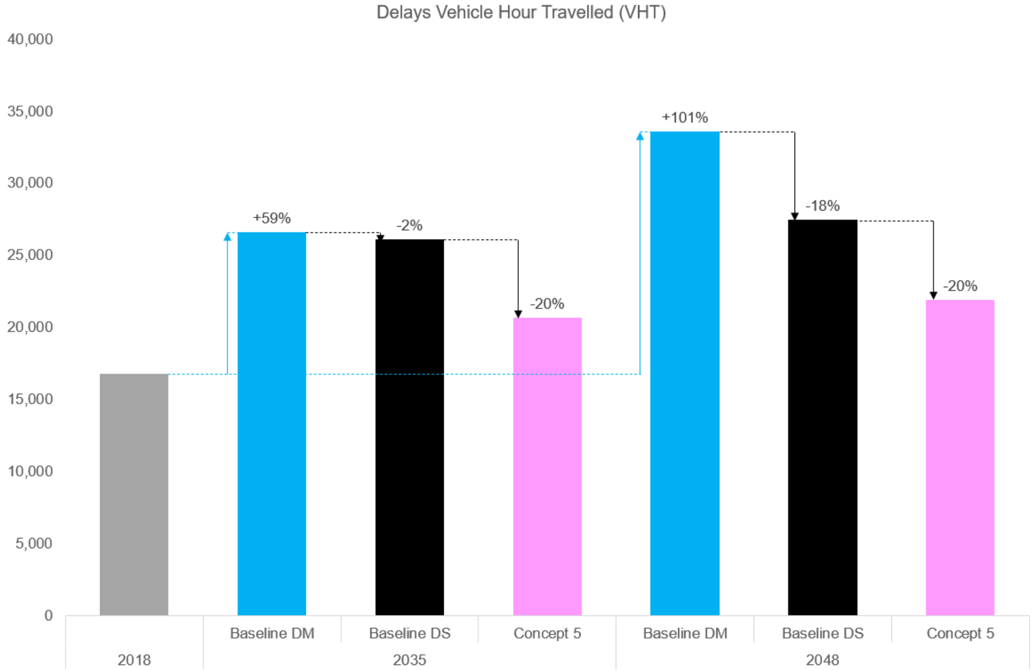
Table 4-4 below presents the outcome metrices to assess this objective. As shown the introduction of the price reduces average daily vehicle hours of delay by 20% in both 2035 and 2048. The proportion of the road network operating at LOS D or better improves with pricing in each time period in 2035 but has little impact on this statistic in 2048.

Table 4-4 Performance indicator results for the *Improve travel time reliability and levels of service* objective

		2018	2035			2048		
			Baseline DM	Baseline DS	With VRP	Baseline DM	Baseline DS	With VRP
Delay (Vehicle hours travelled)	AM	1,650	2,500 *+50% more than 2018*	2,300 *-7% less than BL DM*	1,750 *-24% less than BL DS*	3,000 *+83% more than 2018*	2,300 *-24% less than BL DM*	1,700 *-24% less than BL DS*
	IP	900	1,500 *+63% more than 2018*	1,500 *+3% more than BL DM*	1,300 *-17% less than BL DS*	1,950 *+114% more than 2018*	1,600 *-16% less than BL DM*	1,400 *-15% less than BL DS*
	PM	1,800	2,850 *+60% more than 2018*	2,700 *-6% less than BL DM*	2,000 *-25% less than BL DS*	3,500 *+95% more than 2018*	2,850 *-17% less than BL DM*	2,000 *-27% less than BL DS*
	Daily	16,800	26,600 *+59% more than 2018*	26,100 *-2% less than BL DM*	20,700 *-20% less than BL DS*	33,600 *+101% more than 2018*	27,500 *-18% less than BL DM*	21,900 *-20% less than BL DS*
% of the road Network operating at LOS D or better	AM	94%	93%	91%	93%	90%	93%	93%
	IP	97%	95%	94%	96%	93%	96%	96%
	PM	93%	90%	90%	91%	90%	93%	93%

Figure 4-3 below illustrates the delay performance indicator that is tabulated above. This graph illustrates how network delay is predicted to increase substantially in the Baseline DM scenarios. The projects in the 2048 Baseline DS have a positive impact in reducing network delay by 18%, and this is further improved by road pricing.

Figure 4-3 Change in network delay in response to pricing



In summary, road pricing improves travel times on the priced network and on the network as a whole by reducing delay by 20%. Levels of service, which has been used as a proxy for reliability, improve overall with road pricing, but some non-priced parts of the network are predicted to have a reduced level of service due to increases in traffic as a result of changes in route choice and changes trip patterns. There may be mitigation measures that could be used to reduce or avoid the negative impacts in some of these locations.

4.3.3 Raise revenue to invest in local transport solutions

Road pricing is estimated to generate **Net revenue** of:

- Approximately **$112m** in 2035
- approximately **$188m** in 2048

System net revenue is then calculated by subtracting the debt and NLTF repayment revenue that would have otherwise been collected from existing tolls (TEL and Takitimu North Link in 2035, and Takitimu North Link in 2048).

System net revenue from road pricing is estimated to be

- Approximately **$88m** in 2035
- Approximately **$158m** in 2048.

Over a 40 year period system net revenue from road pricing is estimated to be approximately $5.5 billion which could be used to support the funding of western Bay of Plenty's Transport System Plan. This increased investment would also result in improved transport outcomes for users relative to a scenario where such improvements couldn't be funded. These benefits would be in addition to the network performance benefits of road pricing described in this report.

4.3.4 Incentivise lower carbon emissions

The performance indicators for this objective were VKT and CO_2E vehicle emissions.

Table 4-5 below presents the outcome metrics used to assess this objective.

Table 4-5 Performance indicator results for the *Incentivise lower carbon emissions objective*

	2018	2035			2048		
		Baseline Do Minimum	Baseline Do Something	With VRP	Baseline Do Minimum	Baseline Do Something	With VRP
VKT KM/day	4.97m	6.41m ***29% more than 2018***	6.37m ***2% less than BL DM***	6.00m ***6% less than BL DS***	7.34m ***48% more than 2018***	7.59m ***3% more than BL DM***	6.88m ***9% less than BL DS***
CO_2E KG/day	1.13m	1.22m ***9% more than 2018***	1.22m ***1% less than DS DM***	1.15m ***5% less than BL DS***	0.88m ***22% less than 2018***	0.91m ***3% more than BL DM***	0.83m ***8% less than BL DS***

As shown, road pricing for the assessed concept and price is predicted to reduce VKT by 6% in 2035 and by 9% in 2048, and this drives a corresponding reduction in the CO_2E.

4.3.5 Incentivise travel choice

The performance indicator for this objective was total trips by mode across the WBoP modelled area. We have collated the model output statistics for Daily vehicle trips, PT patronage per day, PT mode share and daily cycle trips. Table 4-6 below presents the outcome metrics used to assess this objective.

Table 4-6 Performance indicator results for the *Incentivise travel choice* objective

	2018	2035			2048		
		Baseline Do Minimum	Baseline Do Something	With VRP	Baseline Do Minimum	Baseline Do Something	With VRP
Private Daily vehicle trips	641,000	830,000 ***29% more than 2018***	816,000 ***2% less than BL DM***	810,000 ***1% less than BL DS***	943,000 ***47% more than 2018***	930,000 ***1% less than BL DM***	919,000 ***1% less than BL DS***
PT Patronage/day	12,800	19,700 ***54% more than 2018***	34,800 ***77% more than BL DM***	36,100 ***4% more than BL DS***	22,000 ***72% more than 2018***	39,300 ***78% more than BL DM***	42,500 ***8% more than BL DS***
PT Mode share	1.6%	1.9%	3.3%	3.5%	1.9%	3.3%	3.6%
Cycle Daily trips	12,600	19,600 ***55% more than 2018***	26,300 ***34% more than BL DM***	28,400 ***8% more than BL DS***	27,100 ***114% more than 2018***	34,000 ***25% more than BL DM***	38,700 ***14% more than BL DS***

As shown, road pricing for the assessed concept and price is predicted to reduce private vehicle trips by 1% with pricing, PT trips are predicted to increase by 4% in 2035 and 8% in 2048, and cycle trips are expected to increase by 8% in 2035 and 14% in 2048. It is noted that while TSP public transport system assumptions are adopted early in 2035, the system itself has not been adapted in response to change in system operation with road pricing. The performance of the public transport system may be improved if it was. This would be considered in future studies.

4.3.6 Support urban form outcomes

Macro urban form

The macro urban form principle from UFTI is about "good quality, compact mixed-use urban development with density and destinations focused on public transport nodes and along corridors". This supports "high density PT services, agglomeration benefits, avoids unnecessary urban sprawl, and assists in emission reductions and builds climate resilience". "Urban Form should enhance transport's role in providing connections between people, product and places."

The assessment of the scheme against the macro-urban form concept looked at the following performance indicators:

- Impacts on travel patterns
- Impacts on Road and PT journey times between centres

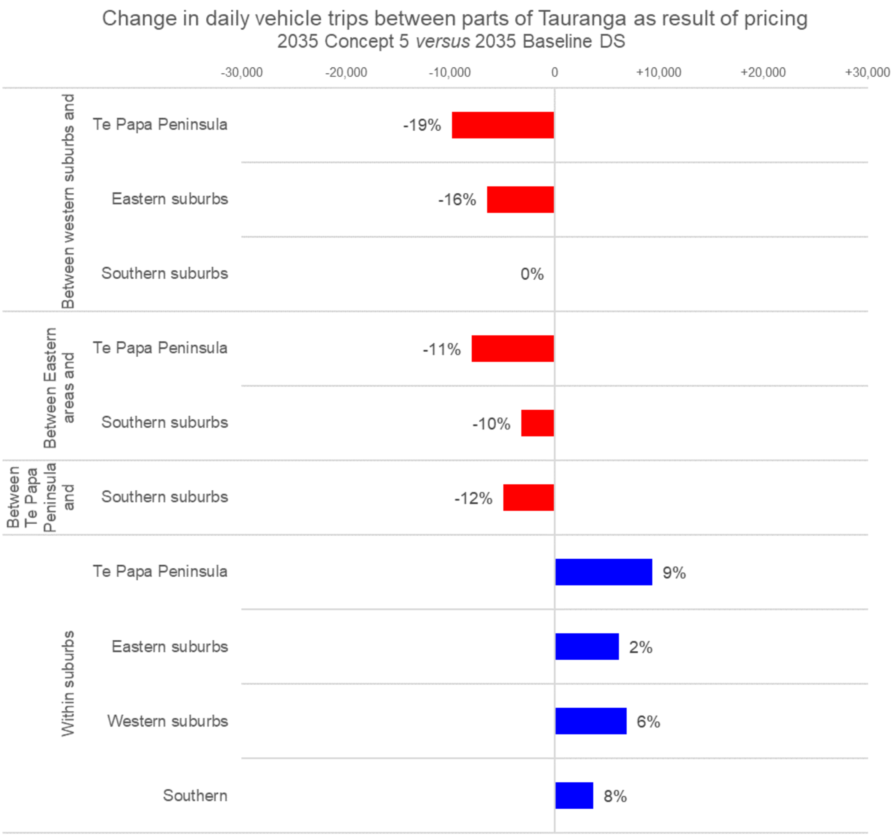
Travel patterns

Most trips in Tauranga today are relatively short local trips, for example 55% of car trips are less than 6km in trip length[16]. With pricing, the model predicts even more travel locally, and less travel between different parts of the city. That is to say, people will choose where practical to travel to places that are local rather than more distant due to price, even more so they currently do now without pricing. To illustrate the kind of change and scale of the change we have calculated the change in the number of trips travelling between different parts of Tauranga. The different parts being defined by compass direction relative to Te Papa Peninsula. The outcome of this assessment is presented in Figure 4-4 below with the change in the number of daily vehicle trips presented as bar, and the percentage change on the Baseline DS presented as a number. Red bars indicate a decrease in trips and blue bars indicate an increase in trips.

[16] 2018 Household travel survey

Sensitivity: General

Figure 4-4 2035 Change in daily vehicle trips between parts of Tauranga as result of pricing



As shown, there are more trips occurring within each part of the city, and the number of trips between parts decreases. Overall there is 13% less trips between these locations and 3% more trips within these locations. The pattern is similar in 2048.

This outcome broadly supports the UFTI Urban form outcomes particularly the objective of assisting in emission reduction. However, it is recognised that the road pricing can also lead to an increase in traffic on non-priced roads, which can be local streets that are more sensitive to traffic movements. This is discussed further under the Right Traffic Right Road heading. It is also acknowledged that road pricing could have negative severance effects by raising price barriers to move between communities (potentially reducing social cohesion and increasing economic fragmentation).

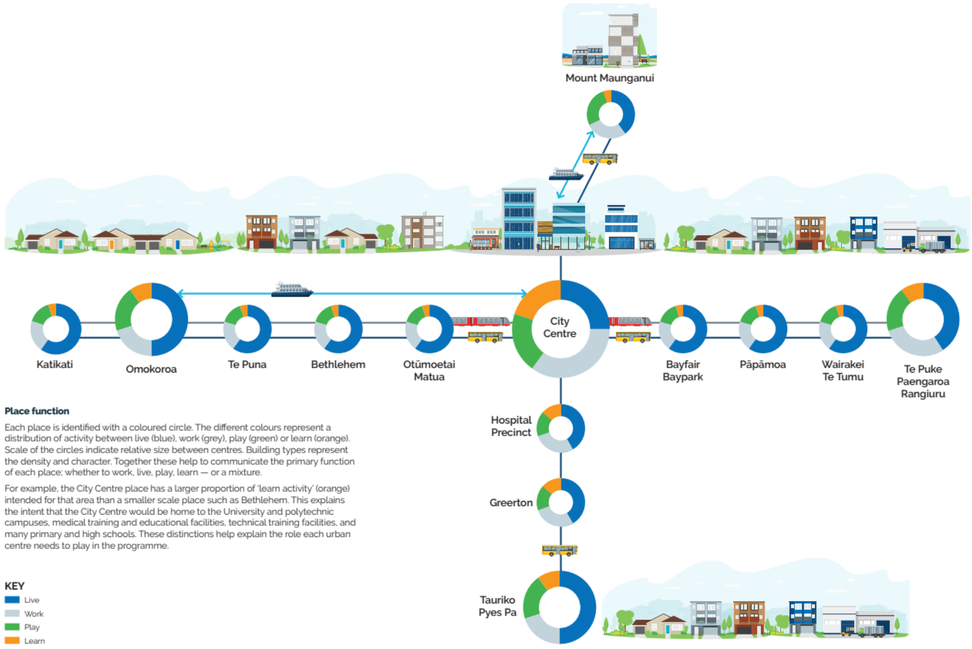
Sensitivity: General

Journey times between centres

The introduction of road pricing will impact Road and PT journey times between and within Centres. To assess the impact we have looked at changes in the modelled peak period journey times (using AM as the example peak period) between the Centres across Tauranga and western Bay of Plenty (WBoP).

The list of centres between which we have collated journey time data is from the Connected Centres programme[17] and are illustrated in Figure 4-5 below.

Figure 4-5 Connected Centres programme schematic



Source: https://www.tauranga.govt.nz/our-future/enabling-growth/connected-centres-programme

Journey times between centres by public transport in the morning peak period are presented in Table 4-7. There are moderate reductions in PT journey times between centres with pricing. There is a benefit on the route from Paengaroa to the City where there are travel time benefits on Hewletts Road with pricing. The other routes are not predicted to experience a material change in travel time for buses.

[17] The Connected Centres programme, released in July 2020, was chosen by UFTI as in their view it offers the best outcome for people to live and move around the sub-region and connect to the upper North Island in the future

Table 4-7 PT Journey times (minutes) between centres

	2035				2048			
	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Katikati to City	67.6	67.9	+0.2	0%	57.8	56.4	-1.4	-2%
Mount to City	14.0	13.8	-0.2	-2%	14.0	13.8	-0.2	-2%
Tauriko to City (via Cameron Road)	13.7	13.7	0.0	0%	14.6	14.6	0.0	0%
Paengaroa to City	48.8	44.7	-4.1	-8%	48.6	44.6	-4.0	-8%

Journey times between centres by car in the morning peak period are presented in Table 4-8 below and are shown to reduce, particularly on the Katikati to City and Paengaroa to City routes. Of particular note the Tauriko to City route via Cameron Road is not predicted to experience a material change in journey time despite the parallel route via Takitimu Drive being part of the priced network.

Table 4-8 Car journey times (minutes) between centres

	2035				2048			
	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Katikati to City	42.2	40.4	-1.8	-4%	35.2	32.9	-2.3	-6%
Mount to City	9.6	9.4	-0.2	-2%	9.9	9.6	-0.3	-6%
Tauriko to City (via Cameron Road)	17.3	16.7	-0.6	-3%	18.3	18.1	-0.1	-1%
Paengaroa to City	27.1	23.6	-3.5	-13%	27.0	23.5	-3.5	-13%

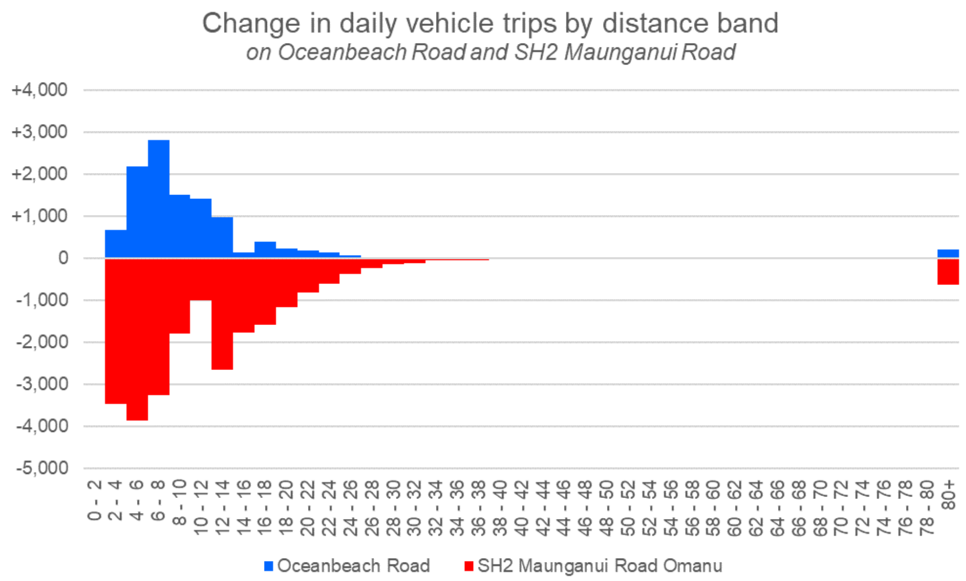
Journey times between each individual centre along each route is provided in Appendix D.

Mode shift and micro-mobility

Road pricing is likely to encourage a shift of local road based trips to active modes like walking, cycle and eScooters. The model predicts that cycle trips will increase by 8% in 2035 and 14% in 2048 with the introduction of road pricing. Mode shift to walking and micro-mobility are not represented in the model and so greater gains may be expected[18]. In addition, the modelled scenario accounts for the road price intervention, but not potential complimentary and targeted cycling infrastructure interventions[19]

Figure 4-6 below shows how the number of vehicle trips by distance band is predicted to change with pricing on SH2 Maunganui Road where price is applied in the concept, and on the parallel Oceanbeach Road which is not priced in the concept. The figure demonstrates that many of the additional trips that use Oceanbeach Road with pricing are relatively short trips, in the range of 2 to 8km in trip length. While the model currently predicts many of these trips to remain road based vehicle trips, there would be an opportunity to target interventions in locations like these to encourage a mode shift to active modes and micro-mobility modes.

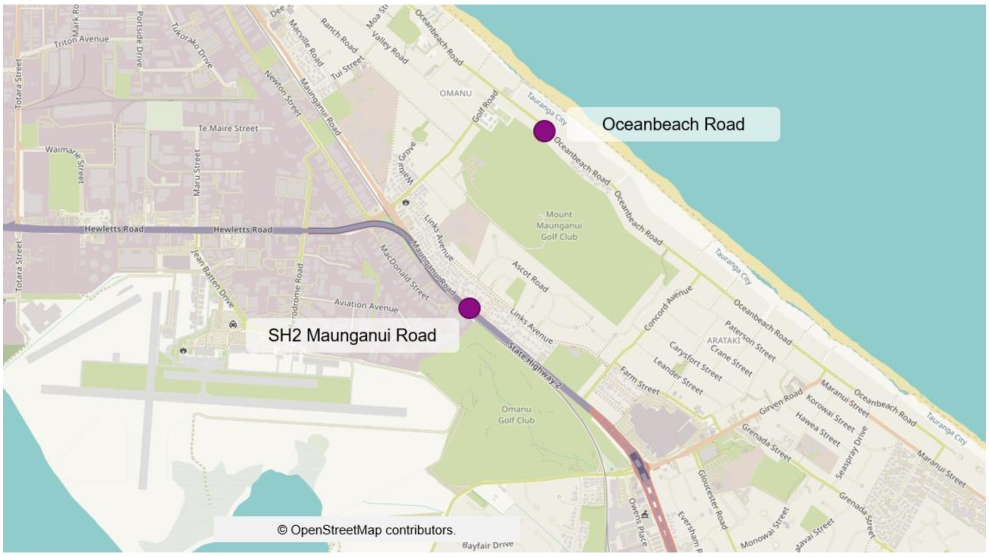
Figure 4-6 Change in daily trips on Oceanbeach Road and SH2 Maunganui Road by distance



[18] Short distance car trips in the range of approximately 0-1 km in length could potentially switch to walking or a micro-mobility mode with road pricing in place. The 2018 Household travel survey found that 12% of car trips in Tauranga are less than 1km in length, and some of these trips may, with road pricing in place, switch to walking or a micro-mobility mode. An estimate of this potential mode shift was not quantified as part of this study.

[19] The Baseline DS does assume a Do Something cycle network which includes cycleway projects in Otumoetai, Bayfair, Mount Maunganui and Te Papa East/West connection.

Sensitivity: General



Social Equity

An assessment of the equity of the scheme and pricing has been undertaken by

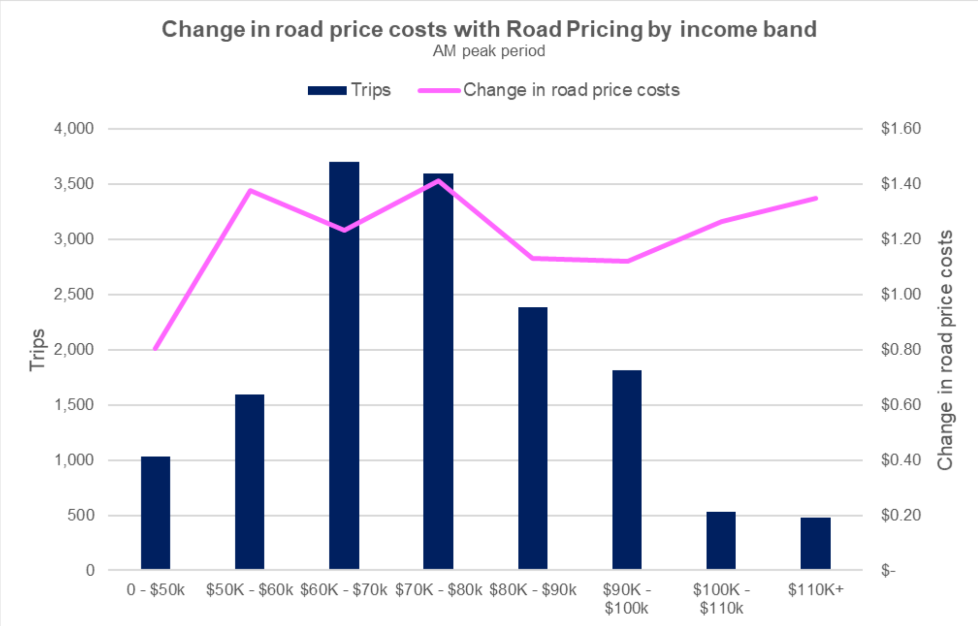
- Calculating the changes in travel costs by income group,
- Providing some examples of how much are people paying in road price to access essential services such as healthcare, grocery shopping, primary and secondary education.
- Assessment of population (by location and level on the deprivation index) subject to a road price with no or limited alternative mode choice.

Road price costs by income group

The change in road price costs[20] for the home-based work trip purpose as a result of road pricing by average household income level is presented in Figure 4-7 below.

[20] Weighted average including generalised travel time and generalised price components

Figure 4-7 Change in road price costs with road pricing by income band



As shown, for the income bands above $50,000 per household, the average additional road price costs that travellers would be faced with do not vary much by income band, and there is not a clear upward or downward trend by income band. Households earning less than $50,000 are predicted to have slightly less additional road price costs on average compared to other income groups. In conclusion, there is no apparent regressive relationship with average household income i.e. the additional costs were reasonably evenly distributed across all income bands.

Note that Concept 5 allows for differential access charges by access location, so lower access changes could potentially be used in certain locations to address (to a degree) potential localised equity concerns.

Access to services

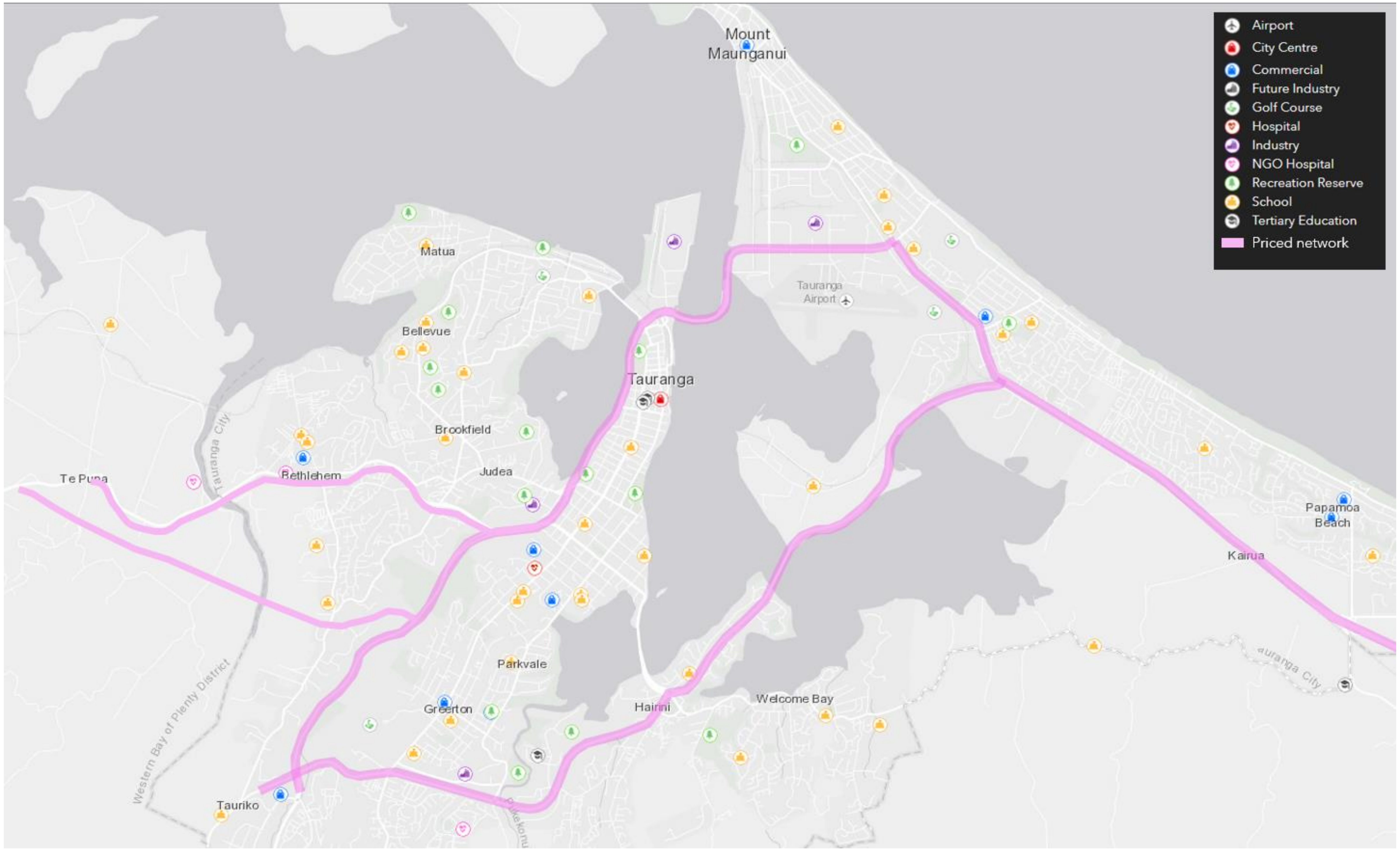
The priced network concept in this study encourages travel in local areas rather than cross-city travel. This has negative implications for neighbourhoods with limited provisions of services locally combined with the priced network being a barrier to the services local further afield. Figure 4-8 presents a figure of various types of services and land activities, the key services being Commercial Centres, Hospitals, Recreation reserves, and schools with the Priced network indicated in pink. There would be locations where the priced network is a barrier to services. Examples of this are:

- Residents of Welcome Bay are separated by the priced network from a Commercial centre and a supermarket
- Residents of Harini are separated by the priced network from a Commercial centre and a supermarket
- Residents of Maungatapu are separated by the priced network from a Commercial centre and a supermarket
- Residents of Maungatapu, Welcome Bay and Pyes Pa are separated by the priced network from high schools

Sensitivity: General

| Stage 2 Modelling|

Figure 4-8 Key services and other land uses in Tauranga and Western Bay of Plenty



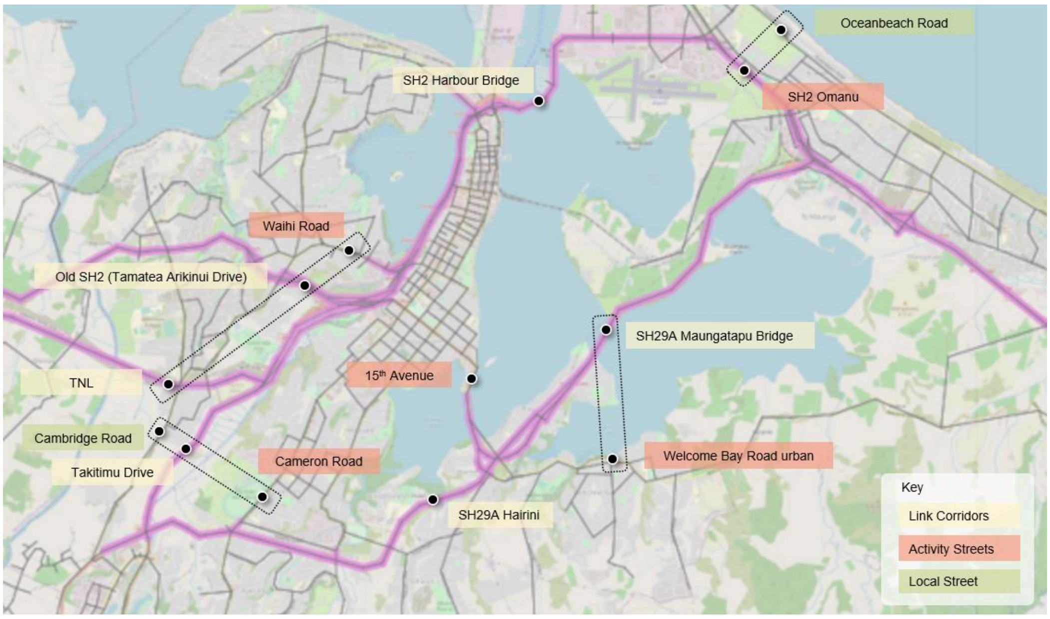
Source: https://www.tauranga.govt.nz/Portals/0/data/future/growth/files/wbop-tsof-report-2.pdf (Figure 12)

Strategic Corridor function

Right traffic right roads

To assess the Right Traffic Right Roads philosophy, we have reviewed the journey lengths of trips[21] at 13 locations across Tauranga before and after pricing. The locations are a mix of Link Corridors, Activity Streets and Local Streets, and a mix of priced locations and non-priced locations and are shown in Figure 4-9 below. The 13 locations were chosen in consultation with the Project Partners.

Figure 4-9 Locations of the journey trip length analysis

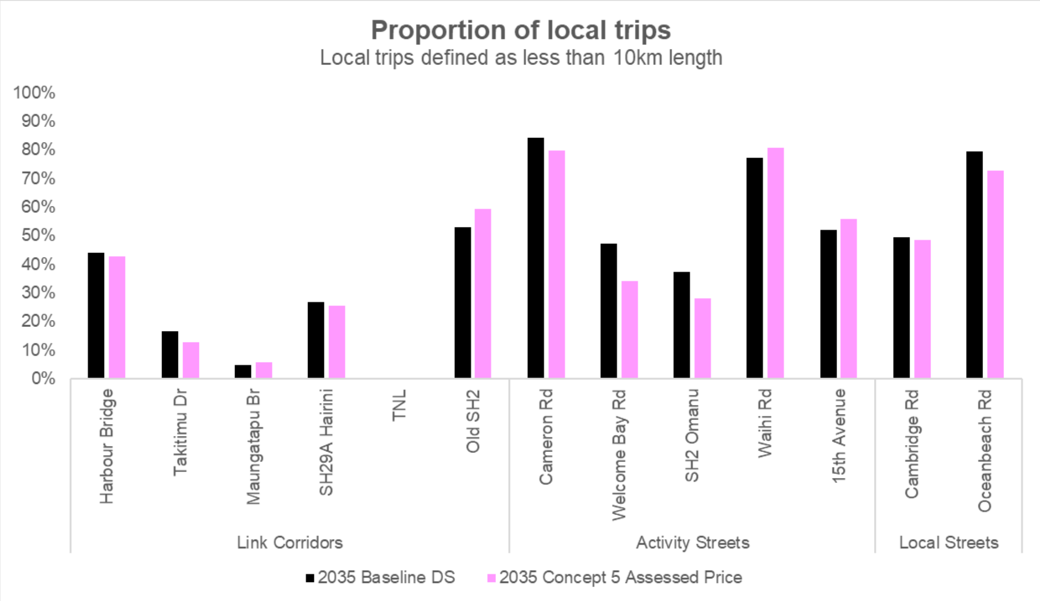


Local roads should be carrying mostly local trips. While the definition of a local trip is subjective, for the purposes of this analysis we have assumed a local trip is any trip with a distance of 10km or less. The typical trip in this range is, depending on the location, likely to be a less than a 10 minute car journey, less than a 20 minute public transport trip or less than a 20 minute cycle ride.

Figure 4-10 presents the proportion of the local trips on at each location before and after pricing.

[21] Often called a trip length frequency distribution

Figure 4-10 Impact on pricing on road function



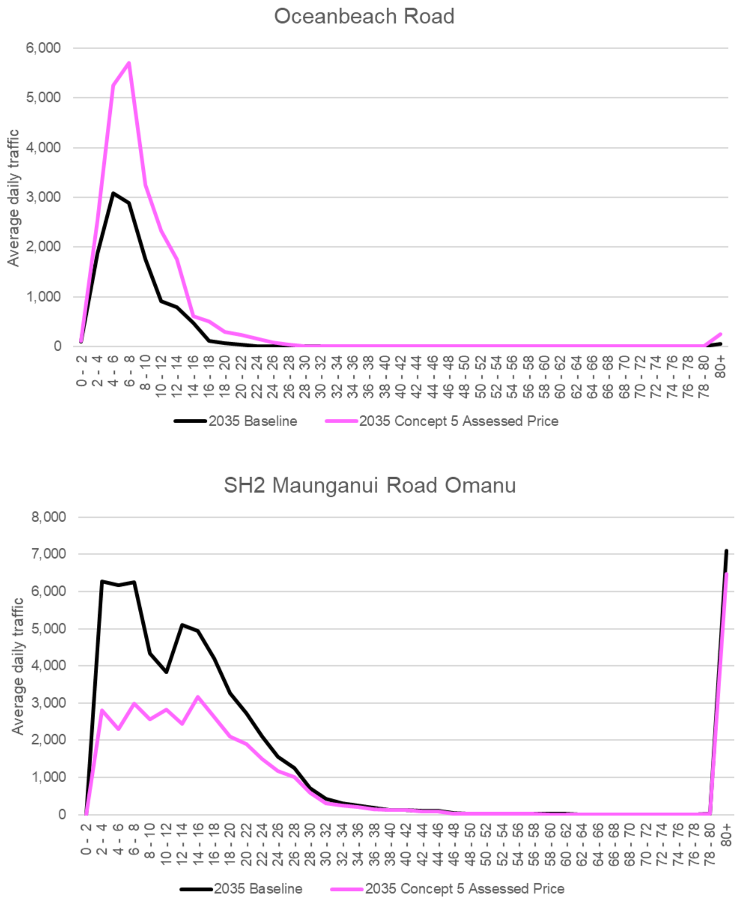
As shown in the plot, link corridors generally have a lower proportion of the local trips with TNL showing no local trips. The proportion of the local trips on Activity streets is mixed, some carry a high proportion of the local trips, others carry a lower proportion of local trips. This is expected as Activity Streets often have a dual function of supporting a Movement function and a Place function or one or the other. The examples of Local Streets (Cambridge Road and Oceanbeach Road shown on the far right in the plot) carry close to 50% or more local trips.

With pricing applied, the proportion of local trips on most of the Link Corridors reduces or stays very low. The exception is the Old SH2 where with pricing the proportion of local trips increases.

With pricing applied, the proportion of local trips on three of the five Activity Street examples reduces. These are the three where pricing is applied either on the road itself or at the end of the road where the access into Te Papa Peninsula is applied. On Welcome Bay Road pricing causes some traffic to re-route from SH2 to Welcome Bay Road. This is an example of where some mitigation may be needed to address this issue. On the other two examples of Activity Streets, Waihi Road and 15th Avenue, the proportion of the local trips increases slightly.

With pricing applied, the proportion of local trips on the two Local Street examples reduces, with Oceanbeach Road in particular reducing from 80% local trips to 73% local trips. Further analysis of Oceanbeach Road shows that the while greater proportion of additional traffic on Oceanbeach Road with pricing are short distance trips (i.e. less than 10km in length) there are more longer distance trips choosing this route over SH2 (where price is applied). The state highways in Tauranga carry a significant number and proportion of local trips and this location is an example of when road pricing is applied to the strategic corridor network many of the trips that change route on to non-priced local roads are trips to may be more suited to the local road network rather than the strategic road network. Nevertheless, this location is also an example of where some mitigation may be needed to address the issue of some longer distance strategic type trips switching to Oceanbeach Road when they should instead remain on SH2. Figure 4-11 illustrates the trip length frequency distributions on Oceanbeach Road and SH2 before and after pricing for reference.

Figure 4-11 Trip length frequency distributions on Oceanbeach Road and SH2 before and after pricing.



The trip length frequency distributions before and after pricing at each of the 13 locations are provided in Appendix D.

Impact on journey times of traffic (freight and general traffic) on key freight routes.

The journey times on three freight routes have been assessed before and after road pricing to see the impact. The routes were:

- SH2 in the west to Sulphur Point
- SH29 to Sulphur Point
- SH2 in the east to Sulphur Point.

The impact of road pricing on journey times for heavy vehicles on these routes is presented in Figure 4-12, Figure 4-13, and Figure 4-14. The graphs show reductions in journey times on these routes in all time periods, with the exception of SH2 west to Sulphur point in the AM time period. This is a result of inclusion of

Sensitivity: General

the road pricing on the old SH2 parallel to TNL in the road pricing scenario, which shifts traffic on to TNL effecting the travel time of heavy vehicles that use this route.

Figure 4-12 SH2 in the west to Sulphur Point

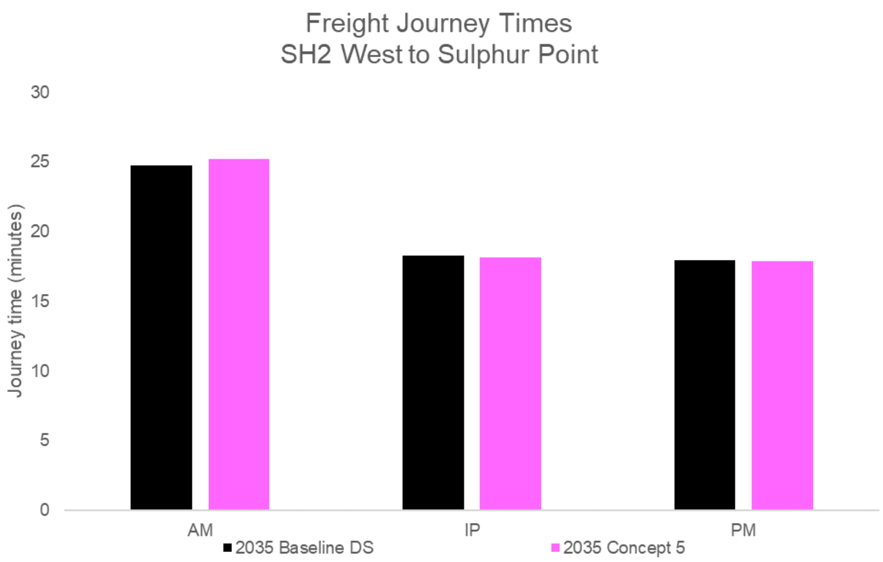
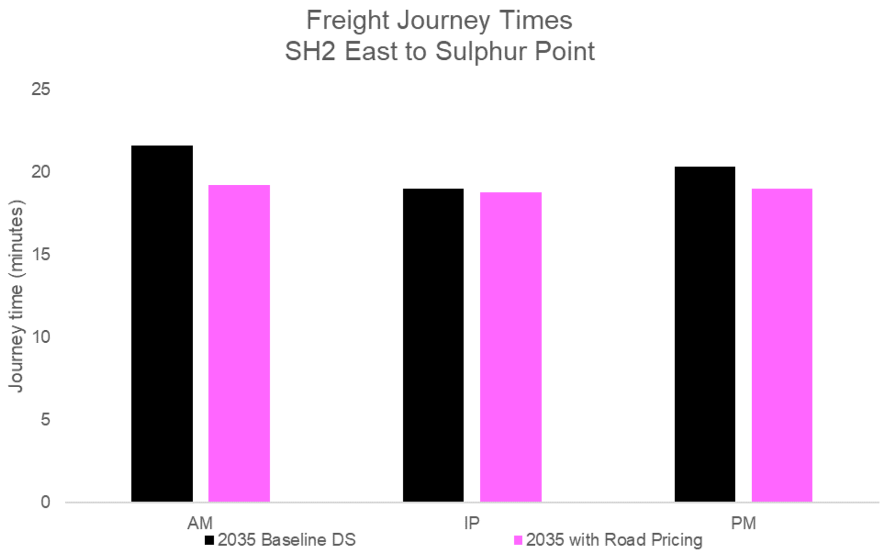


Figure 4-13 SH29 to Sulphur Point

Figure 4-14 SH2 in the east to Sulphur Point



Changes in traffic volumes in sensitive areas

For this performance indicator we have assessed the changes in traffic volumes in sensitive street locations such as outside schools and in town centres. The school examples chosen were:

- Otumoetai Primary School, Otumoetai Road
- Gate Pa School, Cameron Road
- Brookfield School, Millers Road

The town centre type examples were:

- Greerton town centre, Chadwick Road
- Elizabeth St, CBD
- Bethlehem town centre

Table 4-9 presents the changes in total traffic volumes at the 6 examples of sensitive street locations. As shown in the table, there is predicted to be an increase in traffic at each of the three school locations, and an increase in traffic in Greerton town centre. There is predicted to be a decrease in traffic on Elizabeth St and in Bethlehem town centre.

Table 4-9 Changes in traffic volumes in sensitive areas

	Average daily traffic			
Example locations	Baseline DS	With VRP	Change	% Change
Schools				
Otumoetai Primary School, Otumoetai Road	12,100	14,600	+2,500	+21%
Gate Pa School, Cameron Road	21,700	22,350	+650	+3%
Brookfield School, Millers Road	6,050	7,975	+1,925	+32%

Town Centres				
Greerton town centre, Chadwick Road	6,520	6,850	+330	+5%
Elizabeth St, CBD	10,600	9,700	-900	-8%
Bethlehem town centre	17,200	6,400	-10,800	-63%

Table 4-10 presents the changes in heavy vehicle traffic volumes at the six examples of sensitive street locations. As shown in the table, there is predicted to be an increase in traffic at each of the three school locations with the percentage change in heavy vehicles outside Otumoetai Primary School and Brookfield School being particularly high. There is predicted to be very small increase in heavy vehicle traffic in Greerton town centre and on Elizabeth Street with heavy vehicles choosing difference routes in response to the introduced price differentials. There is predicted to be a decrease in heavy vehicle traffic in Bethlehem town centre.

Table 4-10 Changes in heavy vehicle volumes in sensitive areas

	Average daily heavy vehicle traffic			
Location	Baseline DS	With VRP	Change	% Change
Schools				
Otumoetai Primary School, Otumoetai Road	440	670	+260	+60%
Gate Pa School, Cameron Road	1,370	1,420	+50	+3%
Brookfield School, Millers Road	110	200	+90	+81%
Town Centres				
Greerton town centre, Chadwick Road	320	325	+5	+2%
Elizabeth St, CBD	400	440	+40	+9%
Bethlehem town centre	1,400	265	-1,145	-81%

These examples demonstrate how the implementation of a road pricing scheme has potential negative local network impacts as a result of a change in travel behaviour and route choice. These negative outcomes would need to be addressed (and ideally mitigated) in a more detailed design of such a scheme.

Summary against the Support Urban form Outcomes objective

In summary, VRP, in the form described in this study, discourages longer-distance cross city travel, and provides faster and more reliable journey times between centres. But as mentioned above, the implementation of a road pricing scheme has potential negative local network impacts as a result of a change in travel behaviour and route choice. These negative outcomes would need to be addressed (and ideally mitigated) in a more detailed design of such a scheme.

Road pricing schemes can raise social equity concerns because they may disproportionately affect lower-income drivers. If not carefully designed, the scheme may be seen as unfair. This study quantified an indicator of equity, which was the additional monetary cost that travellers would be faced with relative to their average income. The analysis found that the average additional cost that travellers would be faced with varies by origin location however there was no apparent regressive relationship with average household income i.e. the additional costs were reasonably evenly distributed across all income bands.

Sensitivity: General

4.4 TTHM modelling

TTHM is a time-varying model where traffic flows and traffic conditions vary across the peak period. This differs from the 'macro' type TTSM where flows and capacities are averages for the period. TTHM represents the road network in greater detail, with enhanced capabilities around operational issues such as queues, merges, and traffic signal operation.

The purpose of the TTHM modelling is to assist in understanding the price profiling within a peak, potential micro-time-of-day choice (peak spreading) due to pricing and the transport outcomes as a result.

4.4.1 Modelled Network

The Takitimu Drive to Hewletts Road corridor was cordoned out of TTHM to undertake the variable road pricing test. A cordon model was used, rather than the full TTHM, for the following reasons:

- Stability of results. The full TTHM can be unstable and time consuming to run, resulting in uncertainty in results.
- Pricing response. Limiting TTHM to a corridor model and taking demand from TTSM means the route choice response to price is fixed to that determined by TTSM rather than TTHM. TTHM is less suited than TTSM to represent many aspects of how travel demand will respond to price in particular the route choice response.

The modelled cordon area is shown in **Figure 4-15**.

Figure 4-15: TTHM Cordon Area

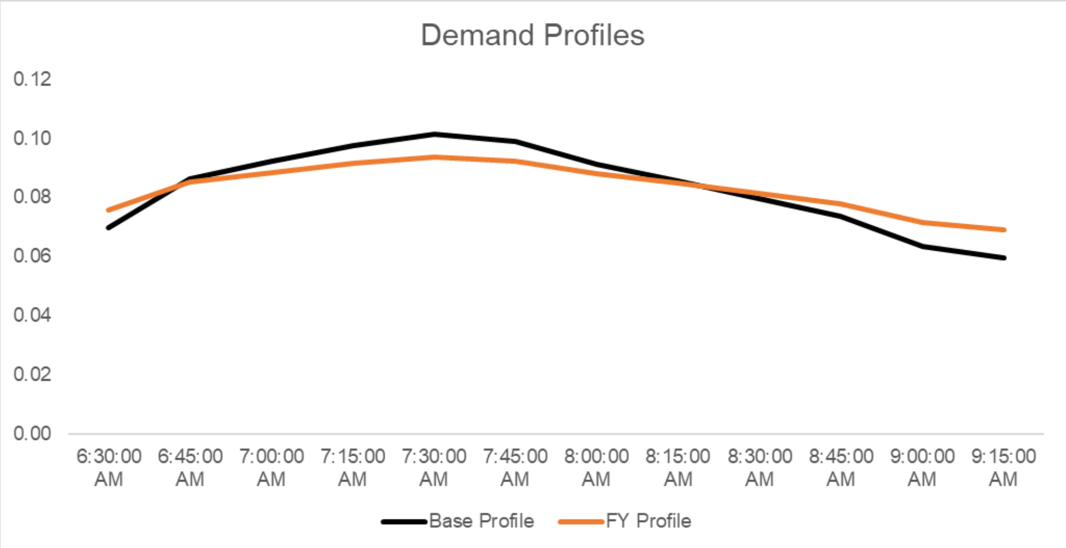
The cordon demands for the AM peak period were sourced from the TTSM 2035 Concept 5 Assessed Price scenario.

4.4.2 Approach to Pricing Profile

The 2035 Concept 5 Assessed Price scenario was modelled in the TTHM cordon. This scenario includes a $2 peak period access charge and $1 off peak period access charge, a 15c/km charge for using the priced network and 50% higher access charges on Takitimu Drive. Note that these are light vehicles charges.

While the TTSM cordon has defined the users of the priced network and passed this to the TTHM, it is unable to differentiate pricing within the 7-9am peak period and so has adopted a weighted average cost of $2. Given the dynamic nature of the TTHM, a pricing profile can be developed for within the peak period. Implementing a pricing profile in the cordon model won't change the total number of vehicles within the priced network but would change their release profile. The TTHM includes functionality to alter driver's departure time based on changes in travel time compared to the base year (2018). For example, if travel times have increased in the peak in the forecast year (FY) compared to the base year, the peak-spreading functionality will shift drivers to the pre-peak and post-peak. An example of this is shown in Figure 4-16.

Figure 4-16 Peak Spreading Demand Profile Example



Prior to this study the peak-spreading functionality only responded to travel times, and not changes in monetary cost[22]. To update the process to incorporate the pricing component, the following was undertaken:

- Develop the pricing profile across the modelled time period
- Convert the monetary cost to a time for each TTSM user class (12-classes) using their individual values of time
- Add the monetary cost (in minutes) to the forecast travel time
- Calculate the difference between the forecast cost and base year cost
- Run the peak spreading process as previously developed

[22] Note that the peak spreading functionality only applies to light vehicles. It is assumed heavy vehicles are less likely to adjust their departure times or arrival times to respond to changes in price within a peak period.

Whilst peak spreading is a known phenomenon and there is evidence of this occurring, understanding the elasticity of drivers' response to changes in cost / travel time is much more limited. Therefore, an additional sensitivity test on the response, in addition to the standard parameters developed as part of the TTHM model build, has been undertaken.

The pricing profile has been developed to give a weighted average of $2 across the 7-9am time period. The weighted average has been calculated using the base year demand profiles for this cordon network. The resulting price profile is as follows:

- $1.50 between 7-7:30am
- $2.50 between 7:30-8:30am
- $1.50 between 8:30-9am
- An additional 50% higher access charge is applied for access points on Takitimu Drive

4.4.3 Results

Several different measures have been used to assess the impact of the pricing in the TTHM cordon model. This includes:

- Network wide travel time and delay
- Queueing / congestion in the network
- Travel time along key locations

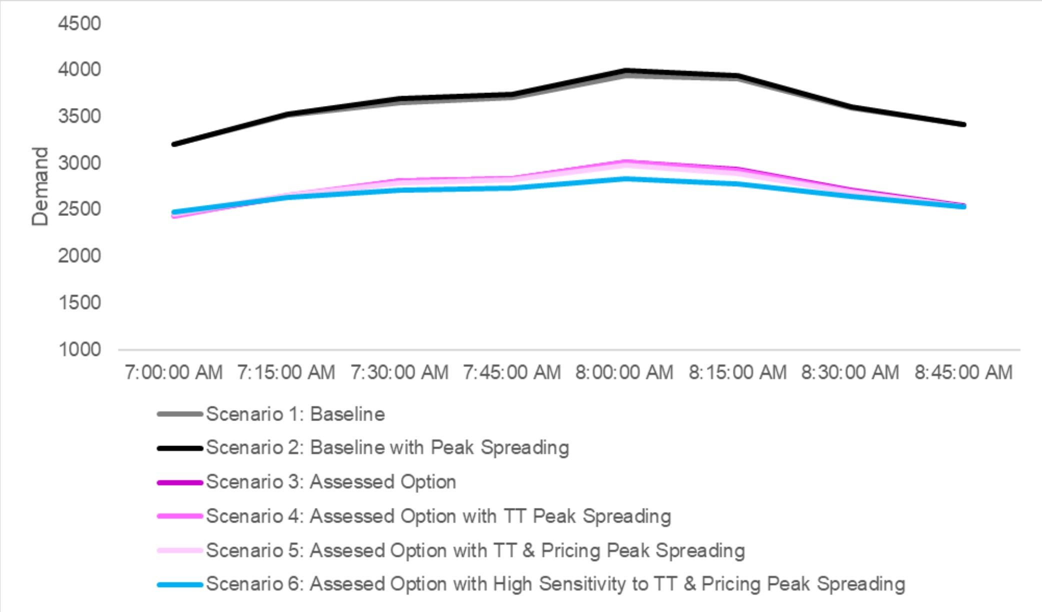
Several sub-scenarios have been run as part of the modelling. The scenarios are as follows:

1. Baseline Do Something (i.e., no pricing)
2. Baseline Do Something with peak spreading (due to travel time changes only)
3. Assessed Option (no peak spreading)
4. Assessed Option with peak spreading for travel time only
5. Assessed Option with peak spreading for travel time and pricing
6. Scenario five above, but with higher sensitivity for peak spreading

Each scenario was run for a 2035 forecast year.

The following figure shows the demand departure profiles for the AM peak period for each of the scenarios tested. This is the weighted average trip departure profile across the full modelled corridor cordoned network.

Figure 4-17: Cordon Demand Profiles 2035 AM peak



The figure demonstrates the following:

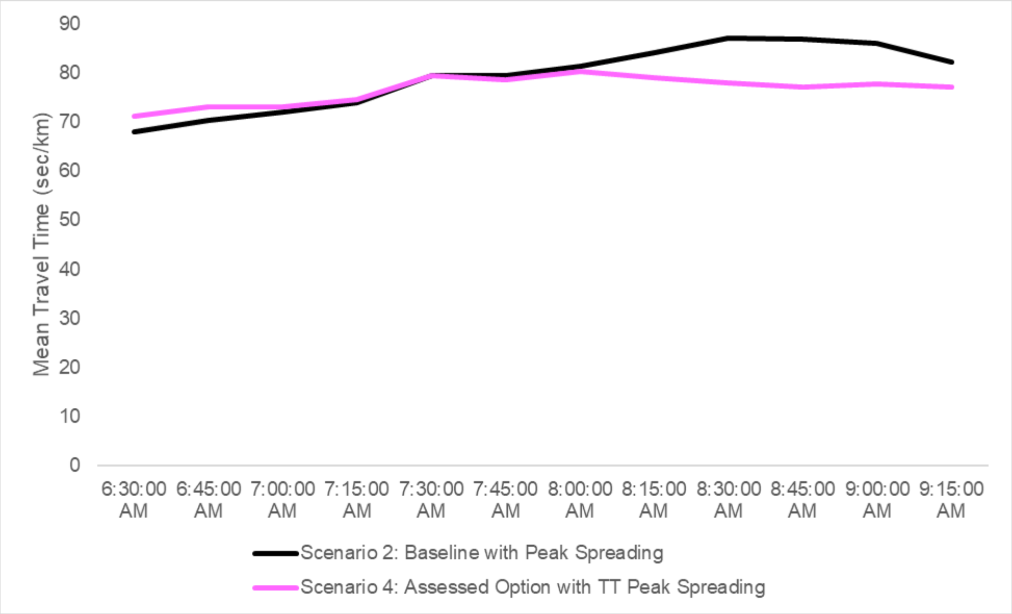
- There is some peak spreading of departures at the cordon apparent in between scenario 1 and 2
- Pricing the network results in a reasonably significant drop in overall demand (obtained from the TTSM process only) for the cordon area
- The standard peak spreading parameters do not result in any noticeable change for the priced network
- The sensitivity test results in a more noticeable change in response to the pricing

Note that the total demand for the cordon area is lower in the 2035 priced scenario than the 2018 scenario.

The following figure shows the results for the cordoned network wide travel time, with the first figure showing the impact of pricing (with a flat price profile), and the second figure showing the impact of applying a price profile.

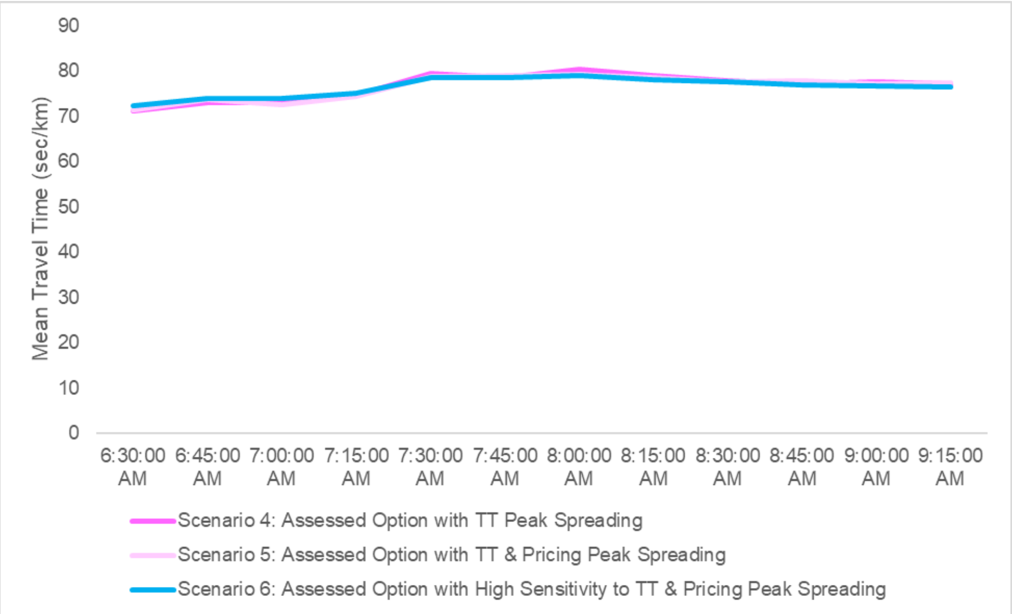
Sensitivity: General

Figure 4-18: Network Wide Travel Time (impact of pricing)



The figure demonstrates that there is a reasonably significant reduction in travel time across the cordon as a result of implementing pricing (mostly due to TTSM demand reduction in the corridor).

Figure 4-19: Network Wide Travel Time (impact of price profiling)



The figure demonstrates that with the limited congestion in the network in the priced scenarios, implementing a price profile does not have any significant impact on the network wide travel time.

There were some key locations of queueing / congestion in the baseline scenarios. These were along Takitimu Drive approaching SH29, along Takitimu Drive approaching Elizabeth Street and along Hewletts Road in the westbound direction. Travel times along the full corridor have been extract and are presented below. Again, this is separated to show the impact of pricing (with a flat price profile) and the impact of applying a price profile.

Appendix F provides a visualisation of this queueing between the baseline and the priced scenario.

Figure 4-20: Full Journey Travel Time (NB/EB) – impact of pricing

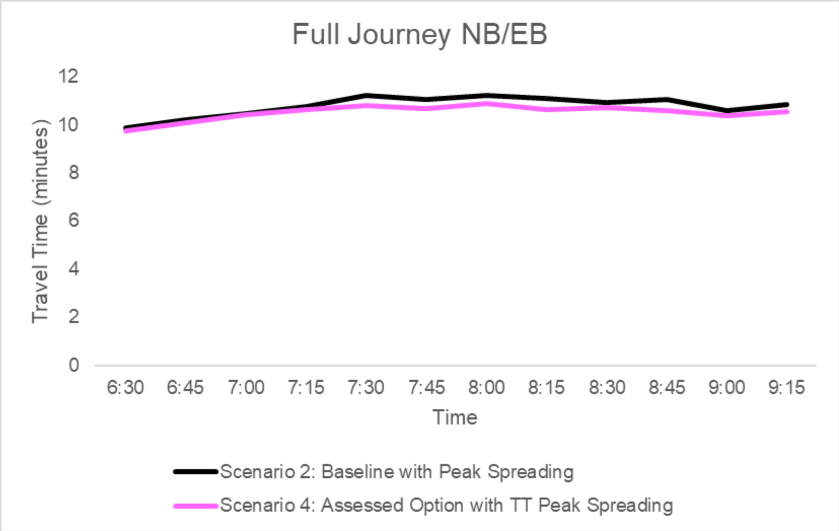
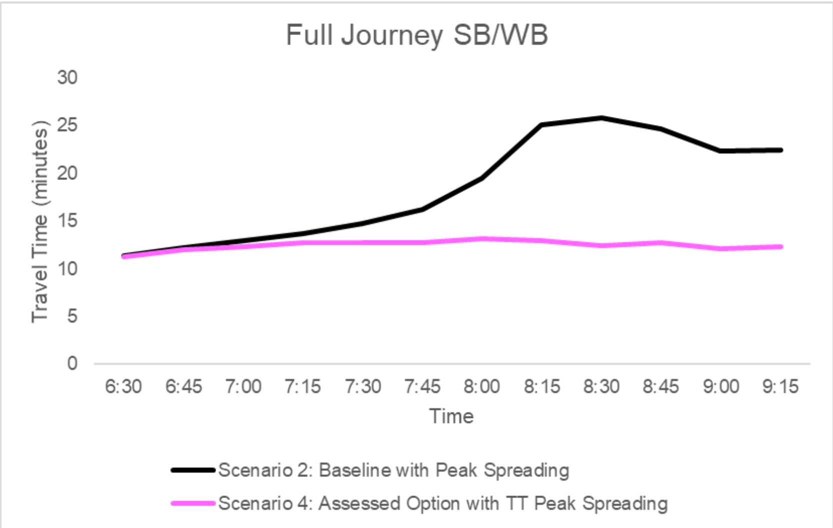


Figure 4-21: Full Journey Travel Time (SB/WB) – impact of pricing



The plots above demonstrate that the combined models estimate a significant reduction in travel time through the corridor in the southbound direction with the implementation of road pricing.

Figure 4-22: Full Journey Travel Time (NB/EB) - impact of price profiling

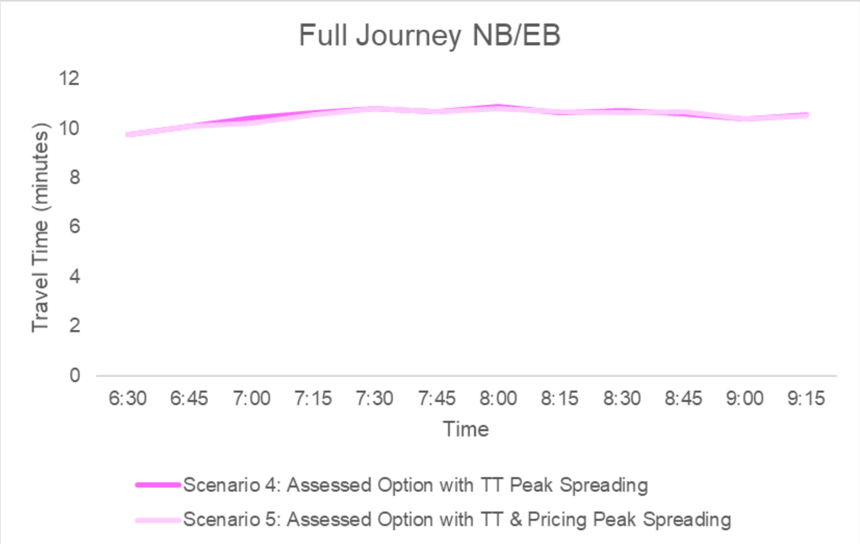
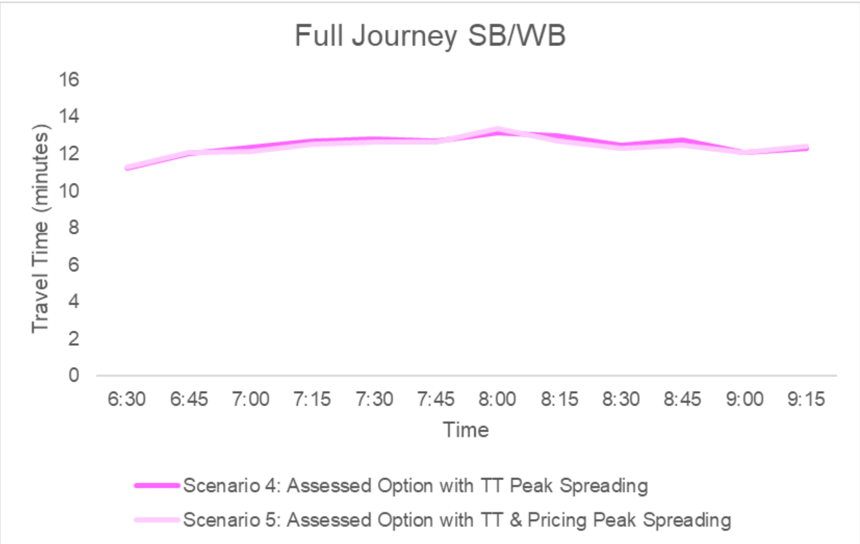


Figure 4-23: Full Journey Travel Time (SB/WB) - impact of price profiling



The modelling estimates that after demand reduction due to pricing has occurred, the travel time along the corridor in both directions sees a negligible change due to the implementation of *price profiling* within the peak period. The reason for this is that the model predicts limited congestion through the corridor as a result of introducing pricing and so further flattening the demand release profile has limited impact. It is noted that in longer-term forecasts this may not be the case, with increasing traffic demand due to population growth and an increase in willingness to pay.

Note that the sensitivity test undertaken also showed negligible difference in travel time.

4.4.4 TTHM Limitations

The TTHM modelling is showing limited impact on network outcomes as a result of implementing a price profile within the peak period. However, it is important to note some limitations of this modelling work:

- **Only modelled AM peak.** It's possible that the PM peak would yield different outcomes, for example in the southbound direction along Takitimu Drive approaching SH29.
- **Longer-term forecasts have not been modelled**. As mentioned above, longer-term forecasts are likely to have increased demand due to population growth, this could lead to higher congestion and therefore price profiling would likely yield some benefit.

4.5 Key findings from Stage 2 modelling

Modelling of the road price scenario that we have assessed generates $88m in net revenue per annum[23], reduces overall network delay by 20%, improves overall journey time reliability and supports some urban form outcomes promoted in UFTI. Road price reduces total VKT by 6%, supports a shift to public transport and active modes. Road pricing can also lead to an increase in traffic on non-priced roads, which can be local streets that are more sensitive to traffic movements. Table 4-11 below describes the key network performance outcomes of road pricing against the studies list of road pricing objectives.

Table 4-11 Outcomes against road pricing objectives

Road Pricing objective	Outcomes
Support urban form outcomes (Primary objective)	*Variable road pricing supports some urban form outcomes promoted by UFTI. Variable Road pricing in the form described in this study encourages more intra-suburb trip making over longer-distance trip making, while also providing faster and more reliable journey times between centres. But it also has potential negative local network impacts as a result of a change in travel behaviour and route choice.*
Optimisation of the whole transport system	*Variable road pricing supports optimisation of the whole transport system by delivering a less congested road network and encouraging a shift in journeys on the public transport system and active modes where capacity is more readily available.*
Improve travel time reliability and levels of service	*Variable road pricing improves travel time reliability on the priced network on the network as a whole with delay reducing by 20%. Levels of service improve overall, but some non-priced parts of the network may worsen.*
Raise revenue to invest in local transport solutions	*The net revenue for the Variable road pricing scenario tested is estimated to be $88m in 2035 and $158m in 2048.* *Over a 40 year period this amounts to $5.5 billion of revenue to support the funding of western Bay of Plenty's Transport System Plan. This increased investment would also result in improved transport outcomes for users relative to a scenario where such*

[23] 2035 variable road pricing Concept 5 scenario compared to the 2035 baseline do something scenario.

	improvements couldn't be funded. These benefits would be in addition to the network performance benefits of road pricing described in this report.
Incentivise lower carbon emissions	*Variable road pricing reduces VKT by 6% and CO_2E emissions by 8% through the discouragement of inefficient trip making by private car and reduced congestion for remaining road users.*
Incentivise travel choice	*Variable road pricing incentivises a shift from private vehicle modes to other sustainable modes. The study predicts an 6% increase in PT and cycle trips as a result of pricing.*

The predicted travel responses can be summarised as follows:

- **Route choice response**. This study predicts a 4% increase in vehicle KMs travelled on local roads as a result of pricing (but that is before mitigation is factored in).
- M**ode shift response**. This study predicts a 6% increase in PT and cycle trips as a result of pricing.
- **Destination choice response**. This study predicts a 5% increase in people choosing to travel more locally.
- **Time of day response**. This study predicts a 1% shift of traffic from peak periods to non-peak periods as a result of pricing.
- **Trip frequency response**. This study predicts an overall reduction in vehicle trips of 1% as a direct result of pricing.

The network wide approach to pricing that is assumed in the study leads the responses of mode shift, changes in travel destination, changes in time of day and trip frequency that are listed above. They may be fairly moderate responses when viewed at the overall network level, but it is noted that it is the network wide approach leads to these responses. Alternative single corridor road pricing would have a much smaller impact on these types of travel responses, i.e. each of the responses except of the route choice response.

5 Sensitivity Tests

Model tests and additional analysis was undertaken to understand the impacts of certain scenario assumptions, model functionality and the relationship between price and network performance. The tests and analysis were:

- **Optimal flow testing.** To review the relationship between price and network performance, using the whole network statistics of delay and VKT.
- **$2 flat fare test.** To review the impact of the $2 flat fare policy option in the context of a network with road pricing in place.
- **Trip Frequency response.** To review the impact of the new TTSM Trip Frequency response functionality on the forecast number of vehicle trips per day.
- **Time or day response.** To review the impact of the new TTSM time of day response functionality on the forecast number of vehicle trips per day by time period.
- **Shift to working from home.** To review the impact of a reduction in the number of home to work trips as a way of representing the impact of potential increases in the number of people choosing to work from home in the future.

The outcomes from these tests and analysis are presented in the following sections.

5.1 Optimal flow testing

Our approach to undertake the optimal flow testing was to model a series of price increments and track how network performance changes from one increment to the next to find out if there was an optimal price. To do this we looked at the 2035 Concept 5 Price A, Price B, Price C and Price D tests. Price A was $1 for light vehicles in the peak and $0.50 in the off peak with heavy vehicles changed 2.5 times the price for light vehicles. Price B was twice Price A, and Price C was twice Price B (i.e. $4 for light vehicles in the peak and $2 in the off peak)

Weekday network delay and Weekday VKT for the 2035 Concept 5 Price A, Price B, Price C and Price D tests were collated to illustrate the relationship between these statistics and price. This was also done for LOS by modelled time period (AM, IP, and PM).

Figure 5-1 below plots average price paid per user (rather than access price and as access price varies by time period in each test) against weekday network delay on the left axis and VKT on the right axis. As shown in the plot, with increasing price paid per user, the change in delay reduces per dollar paid. The change in VKT also reduces per dollar paid but the rate of decline is slower than change in delay. The trends suggest that with further increases in price beyond the Price D assumption, average delay is unlikely to reduce much further, whereas vehicle KMs travelled may further reduce.

Figure 5-1 Optimal flow testing - VHT and Delay

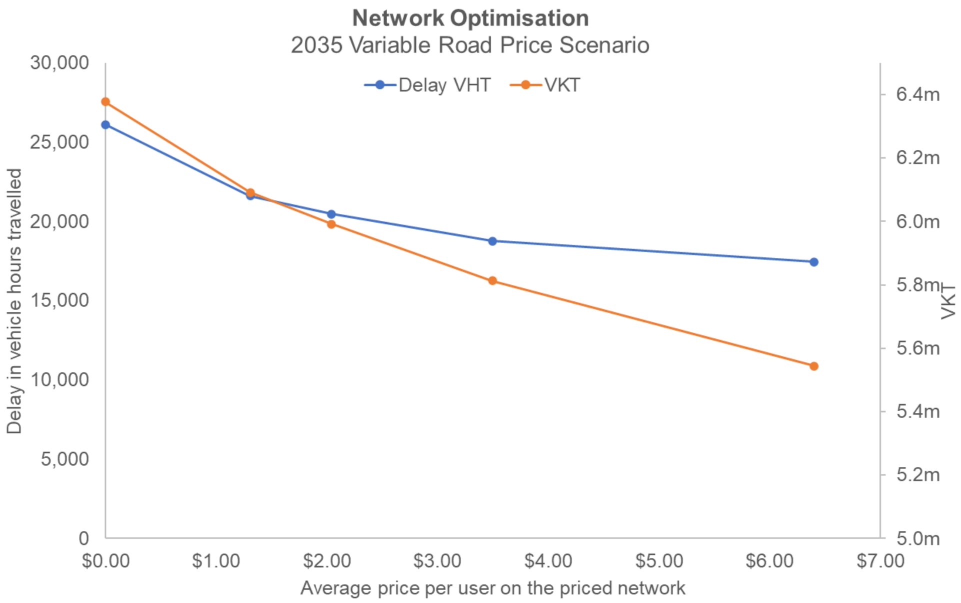
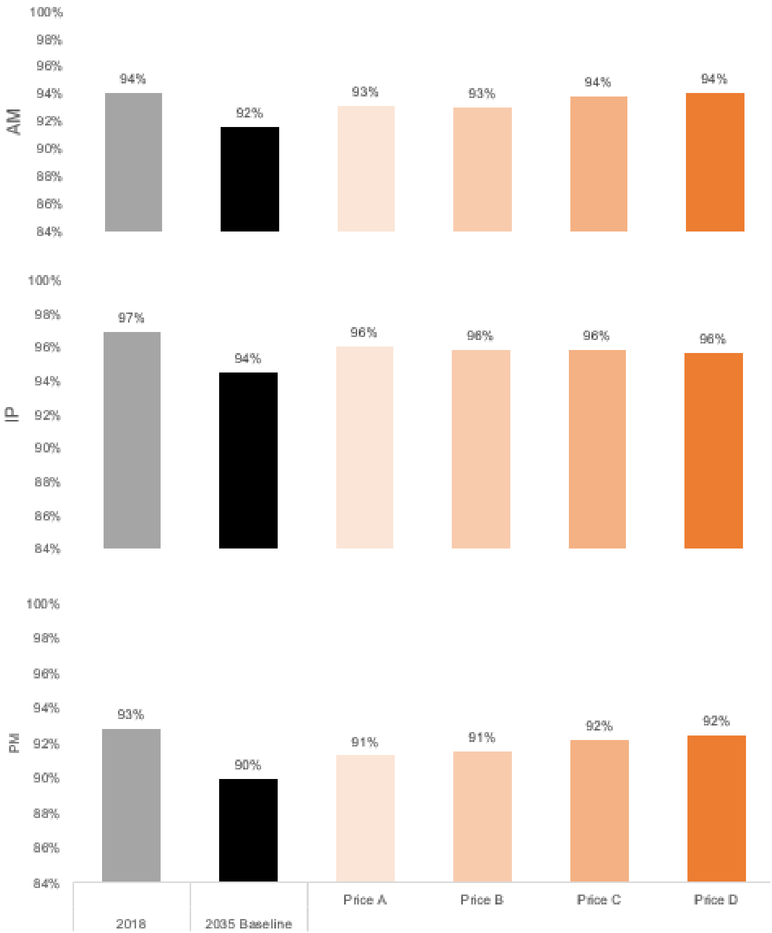


Figure 5-2 presents the LOS statistic (Proportion of the network operating at LOS D or better) for each modelled time period for the Price A, Price B, Price C, and Price D tests. This plot shows that there are no further gains in this network level of service after Price C.

Figure 5-2 Optimal flow testing - Proportion of the network operating at LOS D or better.



Based on these statistics, Price C ($4 access charge for light vehicles in the peaks) is the price at which no further material gains in overall network performance are made with further increments in price.

5.2 $2 PT flat fare test

This sensitivity test considers the impact of reduced public transport fares in the form of a $2 flat fare for public bus passengers and free fares for school students. This sensitivity test was requested by the Project Partners. The $2 flat fare policy test was undertaken as part of previous work for UFTI, and the project partners were interested in the outcomes of this policy in the context of network with road pricing. The test was undertaken using the 2035 Concept 5 Assessed Price scenario as a base on which the cheaper public transport fares are applied.

Table 5-1 presents the key outcomes from the $2 PT flat fare test as compared to the 2035 Concept 5 Assessed Price scenario.

Table 5-1 $2 PT fare test key outcomes

	Assessed Price	Assessed Price With $2 PT fares	Change	% Change
PT Patronage Average weekday	36,100	41,800	5,700	+16%
PT Mode share PT mechanised mode share	3.5%	4%	+0.5 percentage points	-
Delay Vehicle hours travelled	20,715	20,539	-135	-1%

As shown in the cheaper PT fares result in an increase in PT patronage of 16%, and an increase in PT mode share from 3.5% to 4%. Average network delay reduces slightly by 1%.

The annual farebox revenue from PT reduces by $7m from $18.8m in the 2035 Assessed Price scenario to $12.8m in the 2035 Test with $2 PT flat fares. Note that the farebox recovers approximately one third of the costs, with the remainder covered by Regional Council Rates and NLTF subsidy.

5.3 Trip frequency response

The number of trips people may choose to take in a given day or given week may change with the implementation of the road pricing. This response to road pricing was implemented as new functionality in TTSM for the purposes of this proof of concept study. The impact of the trip frequency response in TTSM on the number of vehicle trips is presented in Table 5-2 below. As shown, the trip frequency response results in 1% less trips in each modelled time period.

Table 5-2 Impact on the number of vehicle trips of the trip frequency response

	Without Trip Frequency response	With Trip Frequency response	Change	% Change
AM	58,100	57,700	-400	-1%
IP	57,700	57,200	-500	-1%
PM	63,200	62,700	-500	-1%
Average weekday	817,000	809,800	-7,200	-1%

In terms of network impacts, the inclusion of the trip frequency response reduces network delay by 3%.

5.4 Time of day response

The time of day the people choose to travel in may change with the implementation of the road pricing. For example, people may choose to travel outside of the peak period to avoid a higher price in the peak period. This response to road pricing was implemented as new functionality in TTSM for the purposes of this proof of concept study. The impact of the time of day response in TTSM on the number of vehicle trips is presented in Table 5-3 below. As shown, the time of response results in 1% less trips in the AM and PM peak time periods, and 1% more trips in the IP time period. It is noted that some of the increase in the IP will actually occur in the off-peak time period (i.e. between 7pm and 7am) however trips shifting from the AM and PM time periods are purposefully allocated to IP so the remain accounted for the assessment of transport benefits and disbenefits.

Table 5-3 Impact on the number of vehicle trips of the time of day response

	Without Time of Day response	With Time of day response	Change	% Change
AM	58,000	57,700	-300	-1%
IP	56,900	57,200	+300	+1%
PM	63,200	62,700	-500	-1%
Average weekday	809,700	809,800	+100	0%

5.5 Shift to working from home or remotely

TTSM has the functionality to test changes in the proportion of the 'home-based work' trip purpose that are assumed to work from home on a number of days per week. It does not have the ability to predict how many people would work from home in future years (or how often), nor does it have the ability to how the proportion of the people with the option to work from home may choose to in response to changes in travel costs. The reduction in 'home-based work' is complimented with an increase in home-based-other trips.

We have run a 2035 scenario to test the impact on revenue from VRP of all workers choosing to work from home (on average) one day a week. This would represent a very high level of work from home, as only certain employment types can support working from home as an option. The test is implemented simplistically with a 20% reduction in 'home-based work' trips, which over and above the baseline (2018) proportion of work from home occurrences[24]. The impact on total number of weekday trips, and the impact on revenue from VRP is presented in Table 5-4 below.

Table 5-4 Work from home test results

	2035 Concept 5 Assessed Price	With 20% work from home assumptions	Change	% Change
Weekday trips	809,800	785,700	-24,100	-3%
Daily delay (vehicle hours)	20,700	18,700	-2,000	-10%
Gross revenue after deductions	$153m	$147m	-$6m	-4%

[24] 2018 census data suggests that around 17% of workers in Tauranga City and the Western Bay of Plenty District work from home.

Operating costs	$42m	$40m	-$2m	-5%
Net revenue	$112m	$107m	-$5m	-4%
System net revenue	$88m	$83m	-$5m	-6%

As shown in the table, with this working from home assumptions, the number of weekday trips would reduce by 3%, network delay would reduce by 10%, and 2035 system net revenue would reduce by 6%.

6 Financial Analysis

6.1 Introduction

The financial analysis presented here is tailored to suit the proof of concept nature of the study. The analysis is limited to an estimate of the future gross and net revenue from existing tolls (and potential toll roads) for the modelled years 2035 and 2048 in the baseline scenarios, and future gross and net revenue for the variable road price scenario (Concept 5) for the same modelled years. In addition to revenues, an assessment of the scheme elements required to implement the scheme and the associated cost estimates of these elements has been estimated.

6.2 Revenue from existing toll roads and TNL

Tauranga's current toll roads, Takitimu Drive[25] and Tauranga Eastern Link[26] generated $9.9m gross revenue per annum and $8.7m gross revenue per annum respectively in the financial year 2020/21 ($6.5m net revenue[27] per annum and $5.8m net revenue per annum respectively).

Takitimu Drive tolling is expected to end by 2031[28], and Tauranga Eastern Link tolling is expected to end in 2040. This study assumes that if there was no variable road pricing in the future then there will be a toll on Takitimu North Link when it opens. We estimate that a toll on Takitimu North Link would generate $18m gross revenue in 2035 and $38m gross revenue in 2048. Table 6-1 presents our estimates of revenue and operating costs of baseline scenario toll roads.

Table 6-1 Estimates of revenue and operating costs of baseline scenario toll roads

	2018	2035	2048
Gross revenue (excl. GST)			
Takitimu Drive	$8.4m	-	-
TEL	$8.2m	$19.3m	-
TNL	-	$18.2m	$38.4m
Baseline tolls	**$16.6m**	**$37.5m**	**$38.4m**
Operating Costs			
Takitimu North Link	$2.9m	-	-
TEL	$2.7m	$8.1m	-
TNL	-	$5.1m	$8.1m
Baseline tolls	**$5.6m**	**$13.1m**	**$8.1m**
Net revenue			
Takitimu North Link	$5.5m	-	-
TEL	$5.5m	$11.2m	-
TNL	-	$13.2m	$30.4m
Baseline tolls	**$11.0m**	**$24.3m**	**$30.4m**

[25] Takitimu Drive has a toll of $1.90 for cars and motorcycles and a toll of $5.00 for trucks.

[26] Tauranga Eastern Link has a toll of $2.10 for cars and motorcycles and a toll of $5.20 for trucks

[27] The term "net revenue" is used here to describe remaining revenue after operating costs and costs to repay debt.

[28] https://www.nzta.govt.nz/roads-and-rail/toll-roads/toll-road-information/frequently-asked-questions/general/#estimate

6.3 Revenue from variable road pricing

Annual gross revenue from road pricing is calculated based on the following steps:

1. Gross revenue (before deductions) is calculated for the modelled time periods (Weekday AM, IP, PM)
2. Annual gross revenue for AM, IP and PM periods is calculated using annualisation,
3. Annual gross revenue in the off peak is estimated based on the assumption that the off peak is charged in the same way as the IP
4. Annual gross revenue on weekends and holidays is estimated based on the assumption that these days are charged in the same way as the IP
5. Annual gross revenue for all time periods is summed to get Annual gross revenue before deductions
6. Deductions from annual gross revenue are then made to account for potential discounts, exemptions, leakage, and GST.

Annualisation factors are provided in Appendix D.

Table 6-2 presents an indication of the amount of annual gross revenue, transaction costs and net revenue for Concept 5 alongside combined tolling revenue from existing and planned tolls[29] in Tauranga (which if still forecast to be operating in the future modelled years would be replaced by VRP in Concept 5.

The initial estimate of annual gross revenue from the forecast traffic volumes is adjusted to account for the following deductions to get actual forecast gross revenue:

- Discounts – 5% less gross revenue to provide for discounts to certain road users or types of travel such as lower income earners travelling to medical appointments
- Exemptions – 5% less gross revenue to provide price exemptions for certain road users such as emergency services
- Leakage – 2% less gross revenue due to non-payments
- GST – 15% less gross revenue due to GST payments.
- Gross revenue is converted to net revenue by subtracting operating costs which are comprised of
- Transaction costs – An assumption of 35 cents per transaction, and one transaction per use is assumed
- Maintenance costs of $4m per annum

Table 6-2 Indication of annual gross revenue, operating costs, and net revenue

	2035	2048
Initial estimate of Gross revenue Based on traffic volumes	**$205m**	**$310m**
Discounts	-$10m	-$15.5m
Exceptions	-$10m	-$15.5m
Leakage	-$4.1m	-6.2m
GST	-$27m	-$41m

[29] The existing and planned tolls being Takitimu Drive and TEL in 2018, TEL (including PEI) and Takitimu North Link in 2035 and Takitimu North Link in 2048.

Gross revenue (minus deductions)	**$150m**	**$230m**
Operating costs		
Transaction costs	$38m	$40m
Maintenance	$4m	$5m
Total Operating Costs	**$42m**	**$44m**
Net revenue	**$112m**	**$188m**

Note that intermediate values may not sum to totals due to rounding

As shown, Concept 5 the assessed price model is forecast to generate $150m in gross revenue 2035 and $230m in 2048. After operating costs and GST, net revenue is forecast to be approximately $112m in 2035 and approximately $188m in 2048.

6.4 System net revenue

Table 6-3 presents an indication of the amount of annual gross revenue, transaction costs and net revenue for Concept 5 alongside combined tolling revenue from existing and planned tolls[30] in Tauranga (which if still forecast to be operating in the future modelled years would be replaced by VRP in Concept 5.

Table 6-3 Indication of annual gross revenue, transaction costs and net revenue

	2035	2048
Gross revenue (excl. GST)		
Baseline	$38m	$38m
VRP	$133m	$239m
Operating Costs		
Baseline	$5m	$8m
VRP	$42m	$44m
Net revenue		
Baseline	$24m	$30m
VRP	$112m	$188m
System Net	**$88m**	**$158m**

Over a 40 year period system net revenue from road pricing is estimated to be approximately $5.5 billion undiscounted.

6.5 Scheme elements and associated cost estimates

The technology used to implement the road pricing is uncertain at this point in time. Overseas examples of technology options are discussed in the Road Pricing Paper. Assuming an ANPR system, the main elements of capital costs is likely to be equipment and structures required at the detection points. A detection point

[30] The existing and planned tolls being Takitimu Drive and TEL in 2018, TEL (including PEI) and Takitimu North Link in 2035 and Takitimu North Link in 2048.

would be required at all access points to the priced network where practical and at all exit points from the priced network where practical. In locations with multiple access points in close proximity, we assume the detection points can be spaced approximately every 2km. The number of detection points required for Concept 5 in 2035 is estimated to be 94 and the number of detection points required in 2048 to be 102. Figure 6-1 illustrates the locations of the detection points for the 2035 Concept 5 network extent.

Figure 6-1 Detection point locations required for Concept 5 in 2035

Other components of the capital costs on the road network would be the signage and road markings to make users aware where pricing is applied and the scheduled prices on the day. Off-site costs would include the pre-implementation costs (for planning and investigations), potential need for back office IT system upgrade or change, and an opening year publicity campaign.

Table 6-4 presents a breakdown of scheme elements and associated preliminary cost estimates. The cost estimates have been provided by Waka Kotahi for the purposes of this proof of concept study and should not be relied upon for anything beyond this study.

Table 6-4 Breakdown of scheme elements and associated preliminary cost estimates of capital expenditure

Capital Cost element	Description and assumptions	Unit cost	Units	Estimate of capital expenditure costs
Site infrastructure				
Land acquisition	Assume some site may need a small about of land acquisition	$200,000 per site	20	$4.0m
Roadside infrastructure	Cameras, structure, processor, and communication equipment	$200,000 per detection point	94	$18.8m
Static signage	2 signs per access point	$5,000	94	$0.5m
Variable message signage (VMS)	1 sign per access point	$100,000	47	$5.0m
Road markings	1 set per access point	$5,000	47	$0.3m
Total for Site infrastructure		**-**	**-**	**$28.2m**
Off-site costs				
Pre-implementation costs	Planning and investigations	-	-	$2.0m
IT System changes	Potential need for back office IT system upgrade or change	-	-	$5.0m
Publicity	Opening year publicity campaign	-	-	$0.5m
Total off-site costs		**-**	**-**	**$7.5m**
Total capital expenditure		**-**	**-**	**$35.7m**

The on-going operating costs of the scheme would include site infrastructure maintenance costs and transactions costs. The estimated transaction cost is assumed to be 35 cents per transaction. It is also assumed there would be one transaction per user for every use of the priced network. The 35 cents per transaction assumption is based on a 50% reduction on the current transaction cost rate of 70 cents per transaction. This is based on the premise that there would be efficiency gains as the number of users would significantly increase compared to today. The transaction cost includes the financing of ongoing costs of the IT system, access to the motor vehicle register (MVR), staff and office costs and publicity. Table 6-5 provides a breakdown of the annual operating cost elements and associated preliminary cost estimates. As with the capital cost estimates, the operating cost estimates have been provided by Waka Kotahi for the purposes of this proof of concept study and should not be relied upon for anything beyond this study.

Table 6-5 Breakdown of annual operating cost elements and associated preliminary cost estimates

Operating Cost element	Description and assumptions	2035	2048
Site infrastructure maintenance costs	Roadside infrastructure, signage, and markings.	$4.0m	$4.0m
Transaction costs	Assumption of 35c per transaction and one transaction per use Includes ongoing costs of IT system and access to MVR, staff and office costs, publicity.	$38m	$40m
Estimate of annual operating costs		**$42m**	**$44m**

7 Economic Evaluation

Travel related benefits and disbenefits have been evaluated for the variable road price Concept 5 in comparison to the baseline DS scenario. This economic evaluation has been undertaken in accordance with Waka Kotahi's Monetised Benefits and Costs Manual (MBCM) version 1.5 August 2021. The economic analysis has included the following benefit components as tabulated in Table 6 below.

Travel related benefits and disbenefits have been evaluated using the Variable Trip Matrix (VTM) Consumer Surplus Evaluation Calculations as specified in Appendix 1 of the MBCM. General assumptions and annualisation factors are provided in Appendix E of this report.

Since VTM method was used, that is the benefits of additional journeys is included and the decision to make these additional journeys is based on the costs perceived by car users, the measure of the benefits is also based on perceived user costs. The consumer surplus calculations as per Appendix 1 of the MBCM is deemed fit for purpose and have been used to calculate benefits. Matrix-based calculations were applied to determine the average cost for each origin-destination pair. The total project benefit is then given by the sum of the matrix total for travel time and vehicle operating costs.

The traffic modelling was undertaken for year 2035 and 2048. The benefits were calculated for the above years within the TTM module, and benefits for the intermediate years were estimated by using linear interpolations. As the scheme is assumed to open at 2030, the benefits for the options are assumed to accrue from this opening year.

The appraisal of scheme benefits and costs assumes a 40 year evaluation period from Time Zero of 2028 to 2061 inclusive. The discount factor to discount future year benefits and costs to today's value is 4%.

Table 7-1 presents the transport user benefits of the Concept 5 road pricing scheme.

Table 7-1 Transport user benefits

Benefit type	2035	2035	2035 NPV	2048 NPV	PV total net benefits
Travel time benefits	$24.4m	$15.8m	$17.8m	$6.9m	$346m
Congestion benefits	$11.8m	$12.6m	$8.6m	$5.5m	$222m
Trip reliability benefits	$3.2m	$2.6m	$2.3m	$1.1m	$51m
Vehicle operating costs benefits	$4.4m	$3.7m	$3.2m	$1.6m	$72m
Public Transport benefits	$0.5m	$2.1m	$0.4m	$0.9m	$27m
Crash Cost benefits	$2.8m	$3.7m	$2.0m	$1.6m	$60m
Emissions benefit	$5.2m	$13.1m	$3.8m	$5.8m	$183m
Total benefits	$52.3m	$53.5m	$38.2m	$23.5m	$960m

Future benefits from future revenue streams from tolling are not included in this assessment.

We understand that the parameter values for value of travel time, value of travel time in congestion, and the value of savings in crash costs will increase materially in an imminent update of the MCBM. These updates are not currently accounted for in this evaluation.

This study has assessed the impacts of road pricing in the context of a 2035 future year scenario and a 2048 future scenario. These future year scenarios include transport schemes that are currently not committed schemes and/or do not have a secure mechanism to fund them. It was outside the scope of this proof of concept study to determine what the associated costs (and economic benefits) of this package of schemes would be. It is also noted that the scheme assumptions do not necessarily constitute a baseline network that is required to support VRP. It was outside the scope of this proof of concept study to determine what that baseline network (in each forecast year) would constitute.

8 Recommendations

The recommendations resulting from this proof-of-concept study are:

- There are expected to be increases in traffic on local roads. If the concept of road pricing in Tauranga is pursued further, it is recommended that these impacts be investigated and mitigated or avoided where possible through design in further scheme development stages.
- A finding of stage 1 of the study was that *scheduled variable* pricing would be more effective than *real time dynamic* pricing in achieving the road pricing objectives for Tauranga. If the concept of road pricing in Tauranga is pursued further, it is recommended that scheduled variable pricing is adopted as the method of pricing in future studies rather than dynamic road pricing.
- The scope of this study was limited to the proof of this concept alone and focused on a concept of charging for use of all roads on Tauranga's strategic road network. There may be other pricing regimes or extents that are more efficient and effective in achieving the road pricing objectives. If the concept of road pricing in Tauranga is pursued further, it is recommended that a business case approach be used to look at full range of options.

9 Risks

Implementing a road pricing scheme can have several risks and challenges, including:

- **Public Opposition**: Road pricing schemes are often unpopular with drivers who are used to free or low-cost road access. Public opposition can make it challenging to get political support for the scheme. Tauranga has a history of supporting tolling of roads in return for early delivery of roading projects, examples include the Tauranga Harbour Bridge toll, TEL, and Takitimu Drive. The study found that the forecast public transport mode share across modelled area with both baseline do something schemes and road pricing was well below the minimum 25% public transport mode seen in the other jurisdictions across the world where road pricing was implemented or being considered.
- **Equity concerns**: Road pricing schemes can raise equity concerns because they may disproportionately affect lower-income drivers who cannot afford the fees. If not carefully designed, the scheme may be seen as unfair, leading to further opposition. We have done a preliminary assessment of the change in road price by income group (based on medium household incomes by transport zone). This found that locations with lower medium household income did not, on average, face higher road price that locations with higher medium household income.
- **Implementation Costs**: Implementing a road pricing scheme can be expensive, requiring new infrastructure such as electronic tolling systems, cameras, and sensors. The costs of installing and maintaining such infrastructure may be challenge, however current estimates of the scheme cost are significantly outweighed by the revenue generated by the scheme. The scheme would pay for itself in year one.
- **Technical Challenges**: The road pricing scheme proposed is complex and would require sophisticated systems to manage and collect tolls. Technical issues during implementation could cause delays and increase implementation costs.
- **Legislative challenges:** Tolling is a funding mechanism Waka Kotahi may establish under the Land Transport Management Act 2003 (LTMA), which enables users of a road to contribute to its cost over time. Under section 46 of the LTMA, revenue from tolling may be used to contribute towards the ‘planning, design, supervision, construction, maintenance, or operation of a new road’. Legislation changes would be required to implement the road pricing concept in Tauranga.
- **Administrative Challenges**: The implementation of a road pricing scheme can be administratively challenging, requiring significant resources to manage and operate the system. This can include issues such as processing payments, enforcing the scheme, and resolving disputes.
- **Behavioural Changes**: Road pricing schemes will change driver behaviour, potentially leading to unintended consequences such as when drivers seek alternative routes in sensitive areas.
- **Data Privacy and Security Concerns**: Road pricing schemes rely on collecting and processing driver data, including license plate information, vehicle types, and locations. There may be concerns about the security and privacy of this data, which can be subject to hacking or misuse.

To mitigate these risks, it will be essential to engage with the public, ensure that the scheme is equitable, transparent, and designed with careful consideration of the technical and administrative challenges involved. These aspects are discussed in the Road Pricing paper and Waka Kotahi’s study report.

Forecasting revenue from road pricing is a technically challenging task. The key risks and uncertainties that could influence the traffic volume forecasts and the estimate of revenue forecasts are discussed in Table 9-1 below.

Table 9-1 Risk elements to the traffic volume and revenue forecasts

Risk	Commentary
Demographics and wider external factors	
City wide population growth assumptions	Population and employment growth assumptions are also important factors to consider when forecasting revenue from road pricing, as they can impact the number of vehicles on the road and the demand for the priced network. If population or employment growth is overestimated, revenue projections may be higher than actual revenue generated, while underestimating growth could lead to lower revenue than expected.
Other measures to meet VKT reduction targets	The Emissions reduction plan includes a target to reduce VKT by 20% by 2035 as compared to the 2035 forecast (which represents a 1% reduction in Tauranga compared to 2019). Road pricing is a measure to reduce VKT, but other measures to reduce VKT across the region are likely to reduce the revenue generated by the scheme.
Unforeseen events	Unforeseen events such as natural disasters, pandemics or economic recessions can impact the number of vehicles on the road and would result in lower revenue than expected.
Scheme design	
Scheme network extent	The extent of the priced network may be smaller or larger than assumed in the modelled will impact the revenue generated. For example, it may not be justifiable to include TEL in the priced network after 2040, or there may be a staged approach to the implementation where the pricing may first start on one corridor, and then expand to a number of corridors over a decade before becoming a complete priced network.
Scheme pricing	The access price and distance based component of price may by higher or lower the set in the assessment. This will directly influence revenue. The study assumes the priced network would operate with a price during the weekday IP, weekday off peak, and on weekends. Although the price assumed outside of the peak periods is lower than that assumed in the peak periods, revenue from these time periods makes up a significant portion of the revenue estimates. If these time periods were not priced, the estimate of revenue would be significantly lower.
Political interventions	Revenue projections may be impacted by changes in government policy or public opinion on road pricing, which could lead to changes in pricing, exemptions or exemptions for certain vehicles or areas
Travel behaviour, response to price, and technology	
Willingness to pay	The willingness to pay values in TTSM influence all of the model responses. TTSM has the benefit that its willingness to pay values are locally calibrated to two separate toll roads. However there is always uncertainty in modelling and forecasting how drivers will response to price particularly where the form of the pricing system is different to existing conditions.
Willingness to pay escalation	The assessment assumes that the tolls are escalated at the rate of inflation but in forecasting we assume that the driver's willingness to pay will escalate 1% faster than inflation. If actual escalation in willingness to be pay was lower, less revenue would be generated by the scheme in future years than currently predicted.
ASC values	Alternative Specific Constant (ASC) is a more intangible variable that represents motorists' perceptions of the toll road, such as the relative safety, reliability, convenience, and general attractiveness, relative to the alternative. In the baseline scenario the TEL ASC is -1 minutes, the Takitimu Drive ASC is -1.5 minutes, and the TNL ASC is -1.5 minutes. These ASC values remain in the model in the priced scenario. The perception of these roads may be different under a different pricing environment.
Changes in technology	Changes in vehicle technology, such as increased adoption of electric bikes or scooters, remote working, could result in lower revenue than forecast, as these vehicles would be exempt from a charge.

Analytical assumptions	
Annualisation	The annualisation factors used in the forecast of revenue are based on count profiles across the Tauranga and western Bay of Plenty region but are related to the current traffic profiles across the day and week. The profile of traffic across the day is forecast to change with pricing, and likewise the profile of traffic across the week may change too. This would affect the prediction of annual revenues. The annualisation of the revenue estimates from the modelled time periods assumes that the off peak period (7.00pm to 7.00am) has a charge applied as per the IP period and also that weekends and holidays are charged as per the IP period. If these time periods were not priced or priced at a lower charge, the estimate of revenue would be significantly lower.
Baseline tolling assumptions	The toll on Takitimu Drive is assumed to expire by 2031, the toll on TEL is assumed to expiry by 2040, and a potential future toll on Takitimu Drive is assumed and is assumed to be in place from 2026 to 2060. The prediction of the system net revenue, i.e. the amount of revenue available after paying existing and future loan payments for TEL and TNL is directly impacted by these assumptions.
Revenue collection assumptions	
Exemptions	It is assumed that 5% of the priced network users would be exempt from price. This assumption directly impacts the revenue forecasts.
Discounts	It is assumed that 5% less revenue than estimated would be collected due to discounts to certain road users. This assumption directly impacts the revenue forecasts.
Revenue leakage	The assessment assumes a 2% loss of revenue from non-payments. This assumption directly impacts the revenue forecasts.
Transaction costs	The assessment assumes a transaction cost of 35 cents per transaction with road pricing, and that there would be one transaction per use. The assumption is based on a 50% reduction on the current transaction cost rate of 70 cents per transaction. This is based on the premise that there would be efficiency gains as the number of users would significantly increase compared to today. It is difficult to predict how transaction costs will change in the future with the kind of transformative change to the system that would be required for assessed scheme.

Overall, road pricing revenue forecasting requires careful consideration, and the use of the forecast revenue predictions should be used with care and an awareness of the uncertainty and risk associated with the forecasts. Given the nature of the study being proof of concept, this risk assessment is limited to the qualitative assessment of each risk element above rather than a more detailed quantitative assessment that would provide a range to the revenue forecasts. A quantitative assessment would be done in a more detailed design stage.

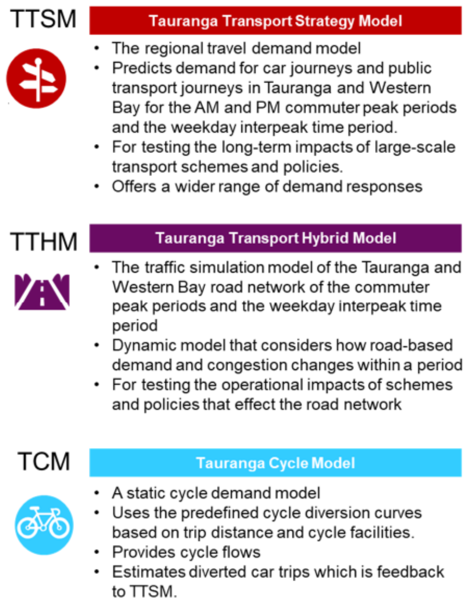
A

Appendix A – Modelling overview and assumptions

Appendix A Modelling overview and assumptions

TTSM model functionality

The Tauranga Transport Models available for use for the study are TTSM, TTHM and TCM. These models are briefly described below:



These transport models include a response to traditional toll roads (such as the two that already exist in Tauranga) but are not specially designed to test network wide road pricing.

In preparing this brief we have thought through the travel responses that network road pricing may induce and considered the scale of each response. We then considered whether the Tauranga Transport Models will account for that response. The outcome of this thinking was the identification of three model enhancements that were then implemented for the study. These are highlighted in bold in Table A1 below.

Table A1: TTM model functionality

Functionality	Comment
Land use	Static input to TTSM
Trip generation	**Response added**
Distribution	Component of TTSM
PT Mode shift	Component of TTSM
Cycle mode shift	Optional component of TTM. Included in the final model runs in Stage 2 of the study.
Macro time of day	**Response added**

Micro time of day	**Response added**
Occupancy - with differential toll	Available in a different version of TTSM21 but not used for the road pricing study because it is not directly applicable to the proposed road pricing scheme.
Occupancy - General response	Not a functionality of TTSM. Decision not to include this response, given no available research material to draw from regarding this response
Route choice and travel times	Component of TTSM and TTHM

These model enhancements are described in following slides.

6/03/2023

TTSM
Time of Day & Trip Frequency Response

Methodology of the implementation of the Time of Day & Trip Frequency Response in TTSM

make everyday better.

1

Sensitivity: General

Context

- Drivers
- Background
- Methodology
- Model response
  - Tests of the recommended values plus values either side to understand the sensitivity of the parameters
  - Global statistics on number of trips
  - Flow difference plots

2

1

6/03/2023

Sensitivity: General

Drivers

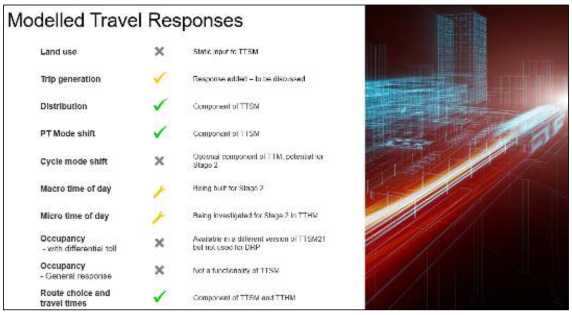
At the outset for road pricing proof of concept study in Tauranga, TTSM had the functionality to represent the following responses to road pricing:

- Route choice
- Mode choice
- Destination choice

In the scoping phase, we recognized two other potentially important responses to pricing:

- Trip frequency response
- Time of Day response

The project partners agreed there was a need to implement both responses in TTSM for the purposes of the road pricing study



Modelled Travel Responses

Land use	✗	Static input to TTSM
Trip generation	✓	Response added – to be discussed
Distribution	✓	Component of TTSM
PT Mode shift	✓	Component of TTSM
Cycle mode shift	✗	Optional component of TTM, potential for Stage 2
Macro time of day		Being built for Stage 2
Micro time of day		Being investigated for Stage 2 in TTHM
Occupancy - with differential toll	✗	Available in a different version of TTSM21 but not used for DRP
Occupancy - General response	✗	Not a functionality of TTSM
Route choice and travel times	✓	Component of TTSM and TTHM

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3

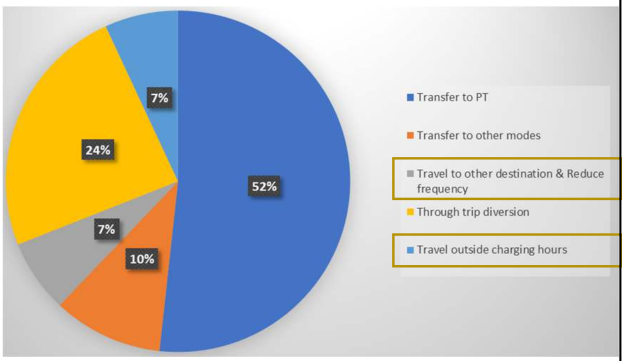
Sensitivity: General

Background

There is limited information on the specific topic of time of day and trip frequency responses to road price.

The data presented on the right (from the London Congestion Charge from the paper *"Demand Elasticities for Car Trips to Central London as revealed by the Central London Congestion Charge"*[1]) provides some insights and has been a useful source for this work. It suggests that of all types of travel response to price:

- 7% travel to another destination or reduce frequency
  - Note that change in destination is already accounted for in TTSM
- 7% travel outside charging hours (i.e. change their time of travel)



[1]Reg Evans for the Modelling and Evaluation Team September 2008, Transport for London Policy Analysis Division

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2

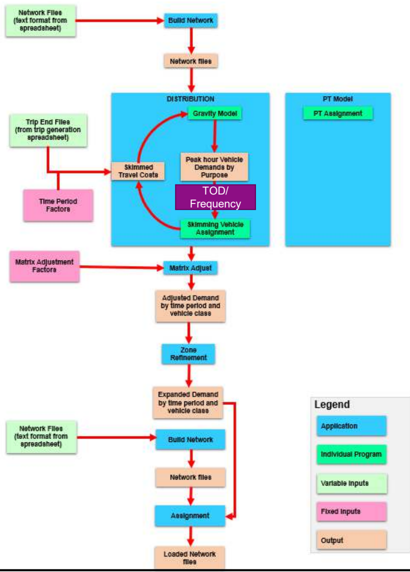
6/03/2023

Methodology

5

Methodology

- The new models are implemented in the distribution model of TTSM (as shown on the right)
  - This is the logical place for the new models to be implemented
- The costs used are generalised costs (time, VOC and toll), not just toll
  - As such, with this new functionality, TTSM will have a Time of Day and Trip Frequency response to not only to toll but also congestion and fuel price
- The response is based on the incremental change in (absolute terms) between base year costs and future year costs



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Sensitivity: General

Methodology (continued)

Time of Day

- Trips shift between AM, IP and PM time periods based on relative cost changes from the base
- We assume the modelled daily total number of vehicle trips stays the same
  - The potential shift to the off-peak time period (not modelled) is instead shifted to IP so that those trips are accounted for in assessment and economics

Trip Frequency

- Implemented at the daily trip generation level
- Daily costs were estimated based on 50% weighting of IP costs, 25% weighting of AM costs and weighting of PM costs
  - These proportions are based on our understanding of the approximate proportion of the demand in the respective time periods

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7

Sensitivity: General

Methodology (continued)

Time of Day

- Central Lambda value: $\lambda = -0.05$
- Based on the Auckland MSM Time of Day model parameters

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8

4

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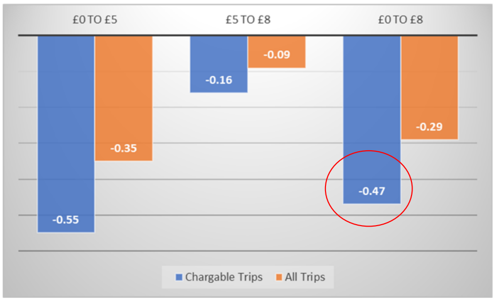
Sensitivity: General

Methodology (continued)

Trip Frequency

- Central elasticity value: E = -0.15
- This is derived from the elasticity value of -0.47 described in the Central London Congestion Charge paper[1] which is made up of 3 components:
  - Transfer to PT
  - Transfer to other modes
  - Reduced travel frequency
- We assume each 3 has a roughly equal contribution to the -0.47 elasticity value rather than the 52%, 10%, 7% ratios from the London Congestion response pie graph (because we don't expect the transfer to PT to be as high in Tauranga as it would be in central London.



[1]Demand Elasticities for Car Trips to Central London as revealed by the Central London Congestion Charge Prepared by Reg Evans for the Modelling and Evaluation Team September 2008. Transport for London Policy Analysis Division. https://content.tfl.gov.uk/demand-elasticities-for-car-trips-to-central-london.pdf

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9

Model Response

10

5

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Sensitivity: General

Time of Day tests

Time of Day

- Central Lambda: λ = -0.05
- Low test: Lambda: λ = -0.01
- High test: Lambda : λ = -0.1
- The high and low values were chosen based on our experience of the range of lambda values that are found in other logit models in transport modelling

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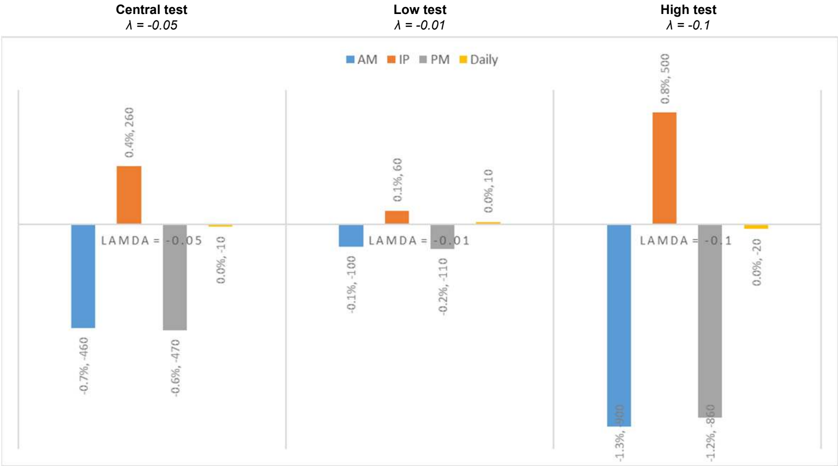
11

Sensitivity: General

Time of Day Response



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12

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Sensitivity: General

Time of Day Response

	Central test λ = -0.05	Low test λ = -0.01	High test λ = -0.1
AM	 AM Flow Difference Plot_C5_M_TOD vs C5_M_Y2048.pdf	 AM Flow Difference Plot_C5_M_TOD_ST (Lamda=-0.01) vs C5_M_Y2048.pdf	 AM Flow Difference Plot_C5_M_TOD_ST (Lamda=-0.1) vs C5_M_Y2048.pdf
IP	 IP Flow Difference Plot_C5_M_TOD vs C5_M_Y2048.pdf	 IP Flow Difference Plot_C5_M_TOD_ST (Lamda=-0.01) vs C5_M_Y2048.pdf	 IP Flow Difference Plot_C5_M_TOD_ST (Lamda=-0.1) vs C5_M_Y2048.pdf

Thumbnails are provided for illustration. Full size pdfs of the difference plots are provided in the pack supplied for the peer review.
The flow difference plot in the central test appears plausible, and we decided there was no reason not to retain the central value of λ = -0.05 as our recommended lamda value.

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13

Sensitivity: General

Trip Frequency Tests

Trip Frequency

- Central Elasticity: E = -0.15
- Low test: Elasticity: E = -0.05
- High test: Elasticity: E = -0.30
- The low and high elasticity values were chosen to see the respective effects of using half the central test value (low test), and twice the central test value (high test)

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14

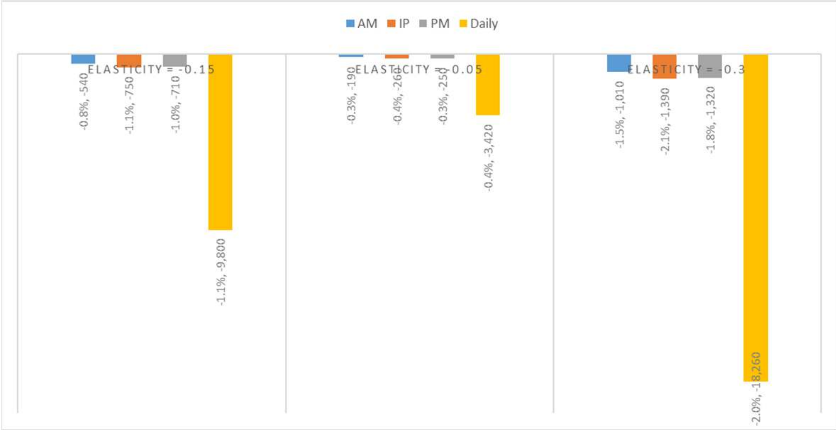
7

6/03/2023

Sensitivity: General

Trip Frequency Response

Central test	Low test	High test
E = -0.15	*E = -0.05*	*E = -0.3*



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15

Sensitivity: General

Trip Frequency Response

Central test	Low test	High test
E = -0.15	*E = -0.05*	*E = -0.3*

ADT Flow Difference Plot_C5_M_TOD_Feq vs TOD_Y2048.pdf

ADT Flow Difference Plot_C5_M_TOD_Feq_ST (Elasticity=-0.05) vs TOD_Y2048.pdf

ADT Flow Difference Plot_C5_M_TOD_Feq_ST (Elasticity=-0.3) vs TOD_Y2048.pdf

Thumbnails are provided for illustration. Full size pdfs of the difference plots are provided in the pack supplied for the peer review.

The flow difference plot in the central test appears plausible, and we decided there was no reason not to retain the central value of E = -0.15 as our recommended elasticity value.

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16

8

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Recommendations

17

Sensitivity: General

Recommendations

- Adopt the methodology as outlined
- Recommended Lamda value of -0.05
  - WHY: Because Auckland Model Refresh recommended it., plus response for -0.05 looks plausible.
- Recommended value of E = -0.15
  - WHY:

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18

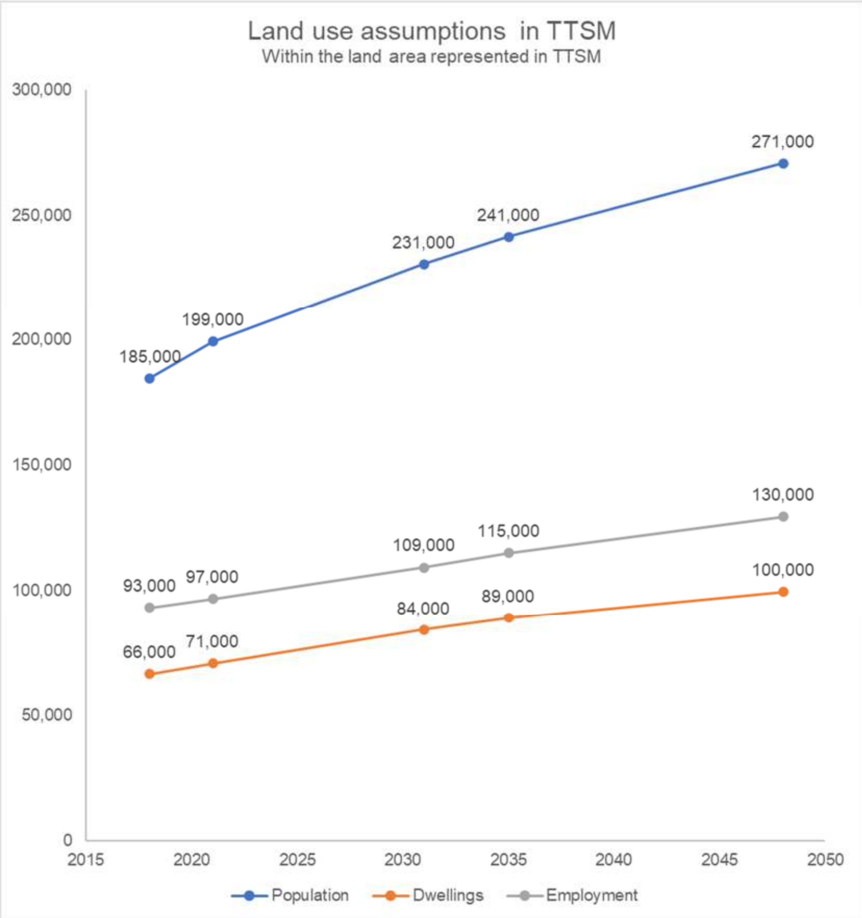
9

Baseline assumptions

Land use

- 2035 population and dwelling data provided by TCC
- 2035 employment was linearly interpolated from 2028 and 2038 employment data used in the TTSM21 interim update.

Figure A1 Land use assumptions



Baseline Do Minimum

Baseline Do Minimum schemes are presented in Table A2 below. 2031 TTSM21 DM schemes shown for context. Schemes from past Do Minimum scenarios also shown for reference.

Table A2 Baseline Do Minimum Schemes

S. No	Projects	2031	2035	2048
1	SH2 - Takitimu Drive / Elizabeth Street - At grade signal upgrade	✓	✓	✓
2	Cameron Road Bus lane (in AM/PM Peak Hours) from Elizabeth Street to 15th Avenue as per Cameron Road MMS Stage1	✓	✓	✓
3	SH29A – Oropi Road Intersection – minor upgrade (2 lane capacity for the approach movements)	✓	✓	✓
4	Tauriko Enabling Works Network Assumptions	✓	✓	✓
5	Takitimu North Link (TNL) Stage 1 from SH29 Takitimu Drive through to SH2 west of Te Puna (Loop Road)	✓	✓	✓
6	Takitimu North Link (TNL) Stage 2 from Te Puna (Loop Road) to Omokoroa			✓
7	The Boulevard Road Bus lane from Te Tumu and Wairakei			
8	Bell Road Connection to Te Okuroa Drive			
9	SH2 – Papamoa East Interchange	✓	✓	✓
10	SH2 – Papamoa East Interchange Stage2 Off-Ramp			
11	Rangiuru Business Park Interchange	✓	✓	✓
12	SH2 – Katikati Bypass			✓
13	High quality Park and Ride Station at Omokoroa	✓	✓	✓
14	Medium-quality PT interchanges (CBD and Bayfair)	✓	✓	✓
15	PT Services as per the TTSM 21 services used in 2021 model	✓	✓	✓

Baseline Do Something

Baseline Do Something schemes are presented in Table A3 below. 2031 TTSM21 DM schemes shown for context. Schemes from past Do Something scenarios also shown for reference.

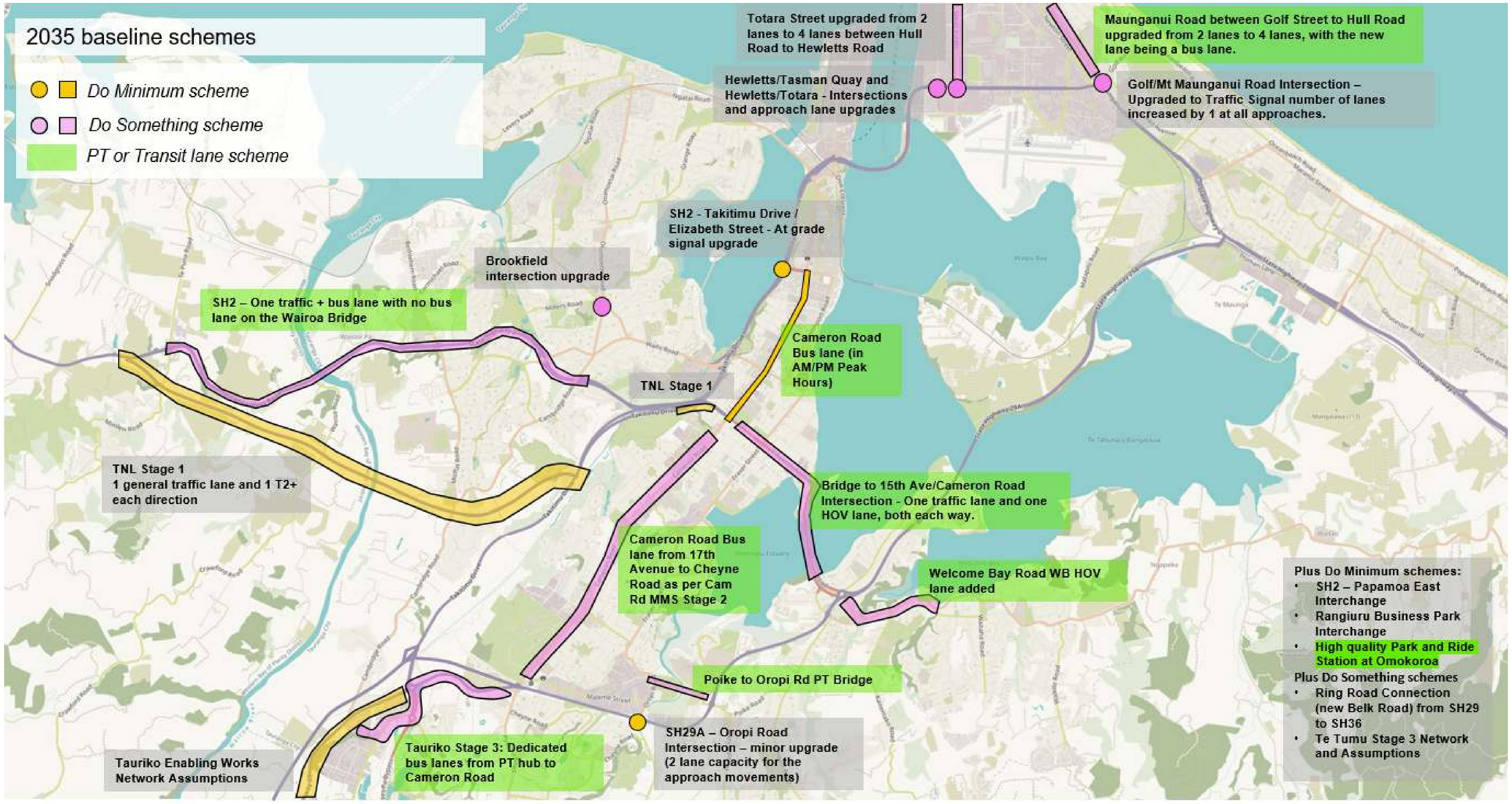
Table A3 Baseline Do Something Schemes

No.	Projects	2031	2035	2048
1	Totara Street upgraded from 2 lanes to 4 lanes between Hull Road to Hewletts Road		✓	✓
2	Hewletts/Tasman Quay and Hewletts/Totara - Intersections and approach lane upgrades	✓	✓	✓
3	Golf/Mt Maunganui Road Intersection – Upgraded to Traffic Signal number of lanes increased by 1 at all approaches.	✓	✓	✓
4	Cameron Road Bus lane from 17th Avenue to Cheyne Road as per Cameron Road MMS Stage 2	✓	✓	✓
5	SH2 between Bayfair and Spur Avenue – Freight lanes in NB and SB			✓
6	Tidal lanes between Burrow Street and beginning of Turret Road bridge (superseded by S. No 18 when it comes in)	✓		
7	SH2 between Minden to Route J – One traffic + bus lane with no bus lane on the Wairoa Bridge	✓	✓	✓
8	Brookfield intersection upgrade - 1 lane added to northbound and southbound on Bellevue road	✓	✓	✓
9	Poike to Oropi Rd PT Bridge	✓	✓	✓
10a	Tauriko Stage 2 (Dedicated bus lanes from PT hub to Barkes Corner, based on Tauriko DBC)		✓	✓
10b	Tauriko Stage 3 (new four lane highway from Redwood Lane to Barkes Corner, based on Tauriko DBC)			✓
11	Ring Road Connection (new Belk Road) from SH29 to SH36	✓	✓	✓
12	Joyce Road Extension to Oropi Road			✓
13	SH29A between Maungatapu Bridge and Barkes Corner - Upgraded Capacity to 4 lanes with Speed 100km/hr			✓
14	Oropi Road/SH29A and Poike Road/SH29A full diamond Interchanges			✓
15	SH29 Takitimu Drive South Toll Road - Upgraded Capacity to 4 lanes			✓
16	SH2 - Takitimu Drive upgrade for SH2 southbound through movement at Elizabeth Street. No Grade separation.			✓
17	Welcome Bay Road upgraded from 2 to 3 lanes with the new lane becoming HOV lane in Westbound direction b/w James Cook Drive and Harini underpass.		✓	✓
18	Harini Bridge to 15th Ave/Cameron Road Intersection - One traffic lane and one HOV lane, both each way.		✓	✓
19	Maunganui Road between Golf Street to Hull Road upgraded from 2 lanes to 4 lanes, with the new lane being a bus lane.		✓	✓
20	Te Tumu Stage 3 Network and Assumptions	✓	✓	✓
21	The Boulevard Road Bus lane from Te Tumu and Wairakei			✓
22	High-quality Park and Ride stations (Tauriko, Domain Rd, Te puke)	✓	✓	✓
23	High-quality PT interchanges (CBD, Bayfair, Brookfield, Bethlehem, Hospital, Greerton)	✓	✓	✓
24	Tauranga System Plan (TSP) Core Option PT Services (See TSP_CoreOption_PT for Routes/Headway data)	✓	Use 2048 service and frequencies	✓

Sensitivity: General

Schematic of 2035 baseline schemes

Figure A2 Schematic of 2035 baseline schemes



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Road Pricing in Tauranga - Proof-of-Concept Technical Report | 3823024-920556377-115 | 27/03/2023 | 79

Sensitivity: General

Schematic of 2048 baseline schemes

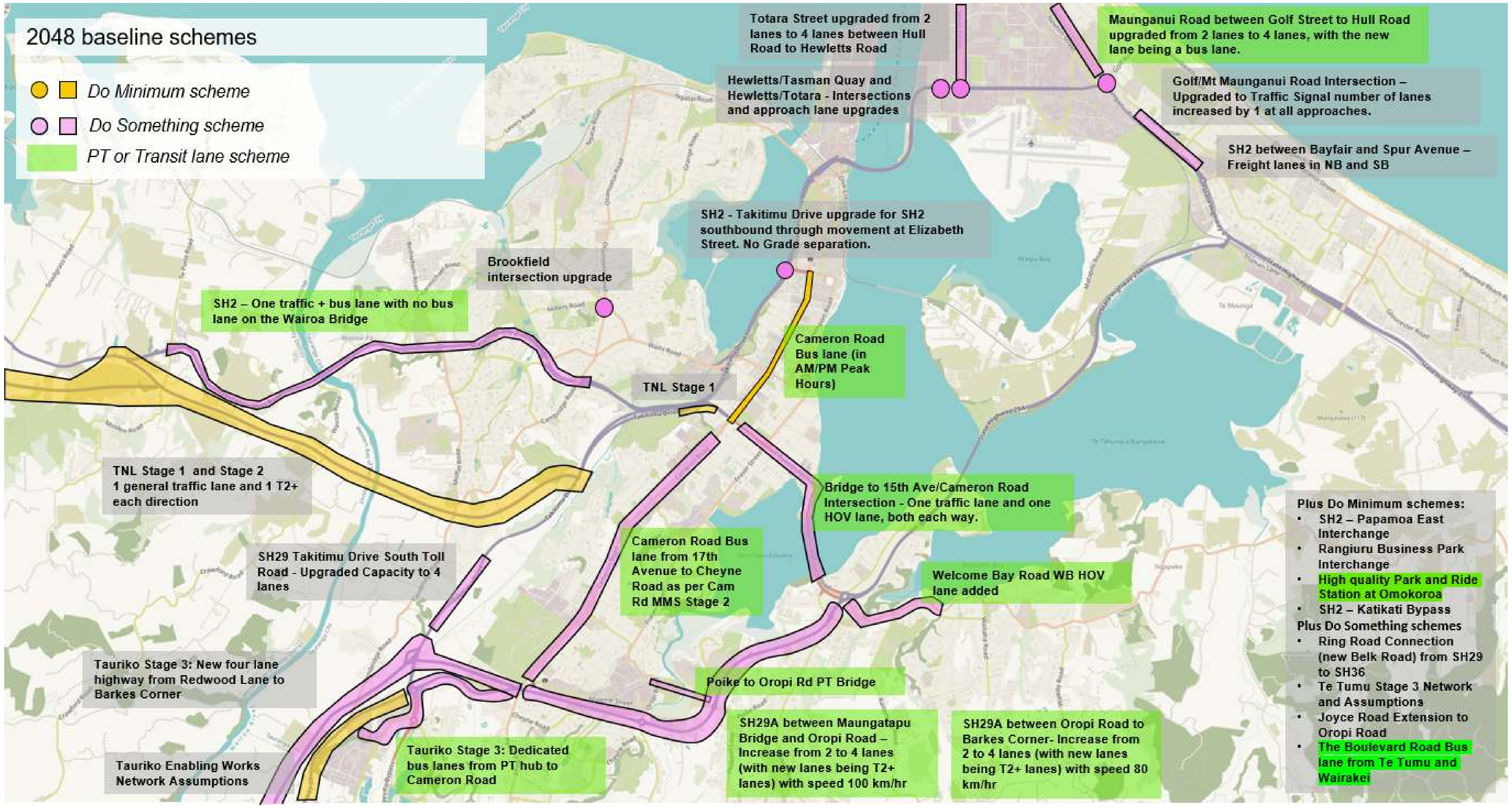

Figure A3 Schematic of 2048 baseline schemes

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Baseline non-network assumptions

Table A4 Baseline non-network assumptions

Policy	Commentary	Recommended assumption for DRP 2035 baseline scenario
Parking costs	TTSM21 DS 2031 and 2048 will have parking price increased by 50% compared to 2018. TSP Sensitivity testing assumed 150% increase on 2018 costs.	Increase parking costs by 50% compared to 2018
Parking zone	TTSM21 DS 2031 and 2048 will the Tauranga CBD parking zones extended to the Tauranga Hospital	Extend parking zone to the Tauranga Hospital
Public transport fares	TSP sensitivity testing assumed $2 flat fare	No change in Stage 1. Test in Stage 2 if time allows.
School bus service fares	TSP sensitivity testing assumed free fare for school students.	No change in Stage 1. Test in Stage 2 if time allows.

Table A5 Baseline non-network assumptions

Model parameters / setup	Commentary	Recommended assumption for DRP 2035 baseline scenario
Public transport penalty (from 2018 calibration)	TSP sensitivity testing assumed half the penalty on short trips	No change in Stage 1. Test in Stage 2 if time allows.
HBW mode specific constant (from 2018 calibration)	TSP sensitivity testing assumed reducing the HBW mode specific constant for cars from -10 minutes to -5minutes.	No change in Stage 1. Test in Stage 2 if time allows.
Car ownership response to PT accessibility	New facility in TTSM21. Not included as yet in TTSM21 future year scenarios.	No change in Stage 1. Test in Stage 2 if time allows.

B

Appendix B – Stage 1 Modelling Outputs

Appendix B Stage 1 Modelling outputs

6/03/2023

DRP Stage 1 Modelling outcomes

1

Baseline graphs

2

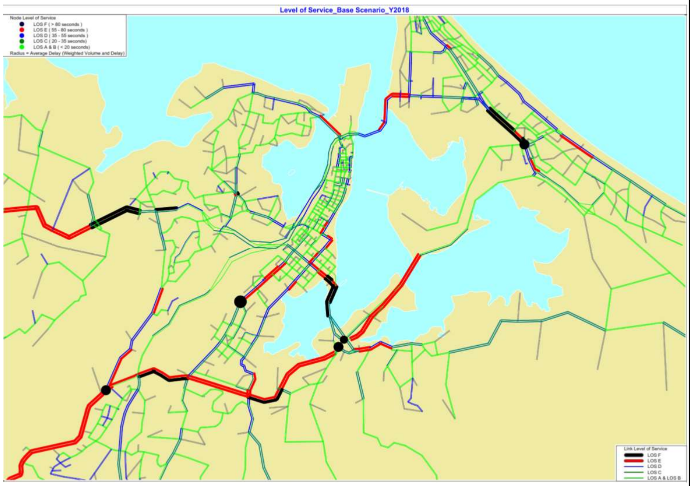
1

6/03/2023

Sensitivity: General

2018

	2018
VKT KM/day	4.9 million
CO_2E Kg/day	1.1 million
Delay Vehicle hours/day	16,800
PT PT Mechanised Mode share (%)	1.6%



LOS plot of link LOS (LOS A-F shown) and intersection LOS (only LOS F shown). This plot shows worst LOS from all model time periods (AM, IP, PM)
LOS shown represents the source congestion location but not the upstream congestion impacts

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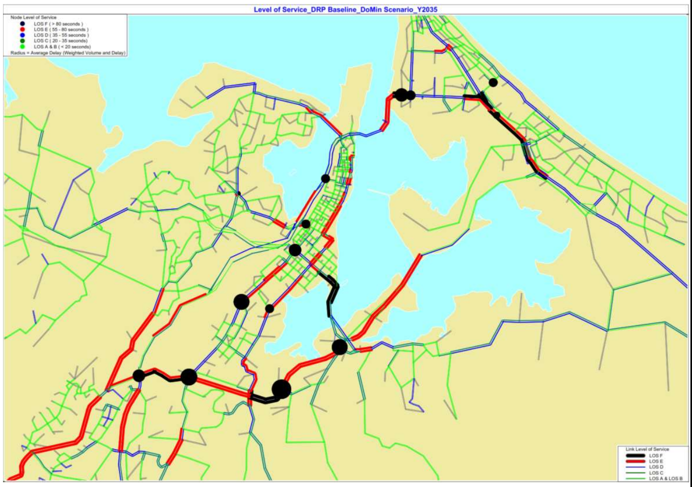
Sensitivity: General

2035 DM

	2018	2035 DM
VKT KM/day	4.9 million	6.5 million ↑
CO_2E Kg/day	1.1 million	1.2 million ↑
Delay Vehicle hours/day	16,800	27,200 ↑
PT PT Mechanised Mode share (%)	1.6%	1.9% ↑



LOS plot of link LOS (LOS A-F shown) and intersection LOS (only LOS F shown). This plot shows worst LOS from all model time periods (AM, IP, PM)
LOS shown represents the source congestion location but not the upstream congestion impacts

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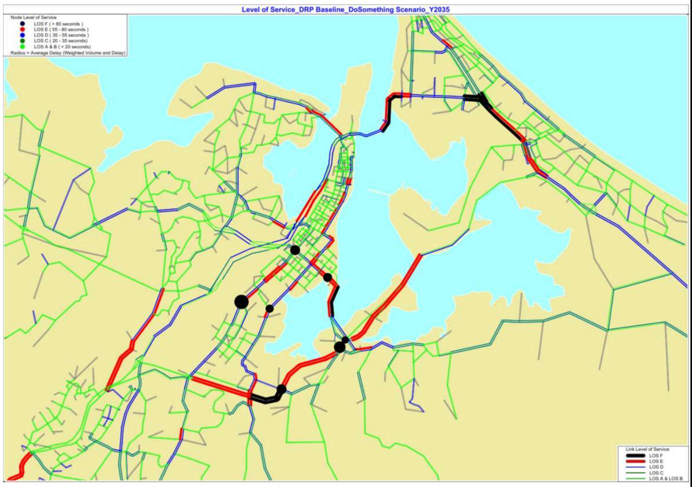
6/03/2023

Sensitivity: General

2035 Baseline (DS)

	2035 DM	2035 DS	
VKT KM/day	6.5 million	6.5 million	—
CO_2E Kg/day	1.2 million	1.2 million	—
Delay Vehicle hours/day	27,200	25,400	↓
PT PT Mechanised Mode share (%)	1.9%	3.2%	↑



LOS plot of link LOS (LOS A-F shown) and intersection LOS (only LOS F shown). This plot shows worst LOS from all model time periods (AM, IP, PM)
LOS shown represents the source congestion location but not the upstream congestion impacts

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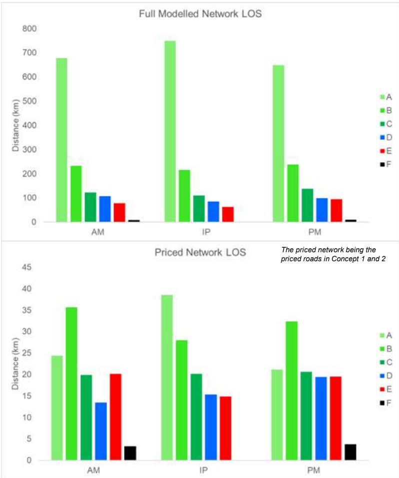
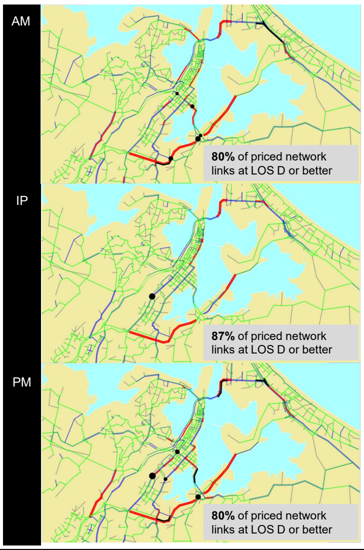
Sensitivity: General

2035 Baseline (DS)





Link Level of Service
LOS F
LOS E
LOS D
LOS C
LOS A & LOS B

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3

6/03/2023

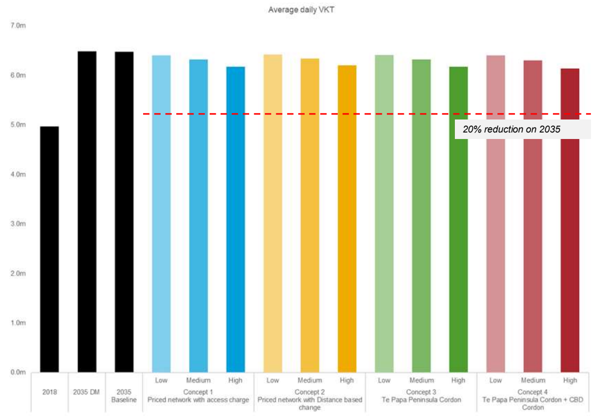
Sensitivity: General

Network impacts

VKT

Average daily vehicle kilometers travelled

- 30% increase in VKT on 2018 by 2035
- 0.2% reduction with DS schemes
- Low price results in a 1.0-1.2% reduction on the 2035 baseline
- Concepts perform similarly
- Concept 2 is best performing but there is little difference between the concepts.
- High price reductions on the 2035 baseline were:
  - Concept 1 **4.6% reduction**
  - Concept 2 **4.9% reduction**
  - Concept 3 **4.4% reduction**
  - Concept 4 **4.8% reduction**



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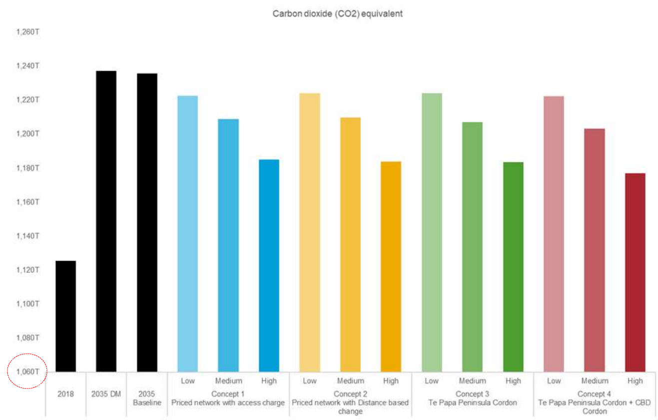
Sensitivity: General

Network impacts

Emissions CO_2E

Carbon dioxide equivalent

- 10% increase in CO_2E on 2018 by 2035
- Low price results in a 0.9-1.1% reduction on the 2035 baseline
- Concept 4 is the best performing.
- High price reductions on the 2035 baseline were:
  - Concept 1 **4.1% reduction**
  - Concept 2 **4.2% reduction**
  - Concept 3 **4.2% reduction**
  - Concept 4 **4.7% reduction**



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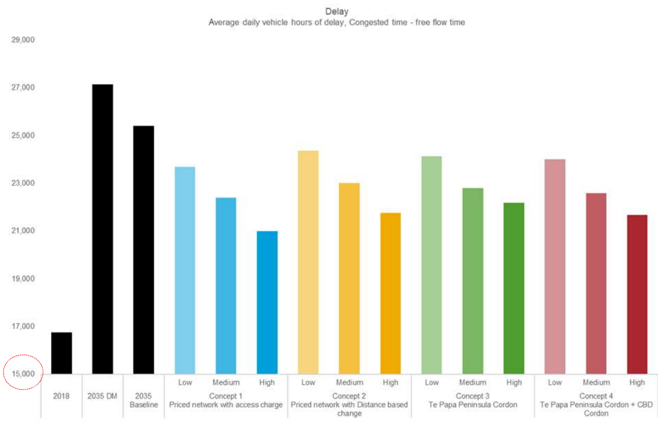
Network impacts

Delay

Average Daily vehicle hours of delay: Congested time - free flow time

- 60% increase in travel time delays on 2018 by 2035
- Low price results in a 4-7% reduction on the 2035 baseline
- Concept 1 is the best performing concept.
- High price reductions on the 2035 baseline were:
  - Concept 1 **17% reduction**
  - Concept 2 **14% reduction**
  - Concept 3 **13% reduction**
  - Concept 4 **15% reduction**



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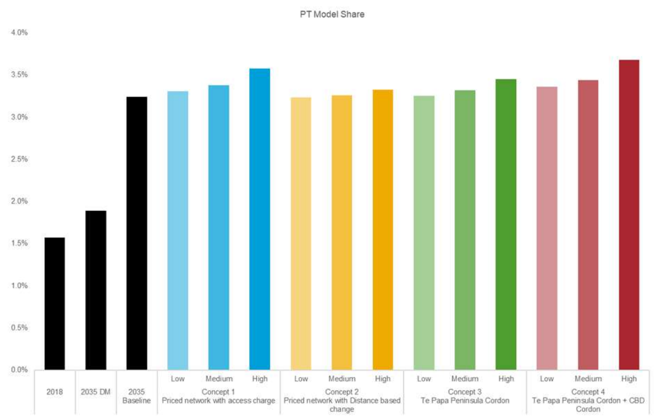
Network impacts

PT Mode share

- Double the PT mode share in the 2035 baseline compared to today
  - 1.5% to 3.2%
  - +1.7 percentage point increase
- Concept 4 is the best performing concept.
- High price percentage point changes in PT mode on the 2035 baseline were:
  - Concept 1 **+0.3% percentage points**
  - Concept 2 **+0.1% percentage points**
  - Concept 3 **+0.2% percentage points**
  - Concept 4 **+0.4% percentage points**



Mode share is the modelled network average, key corridors will be performing much better

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10

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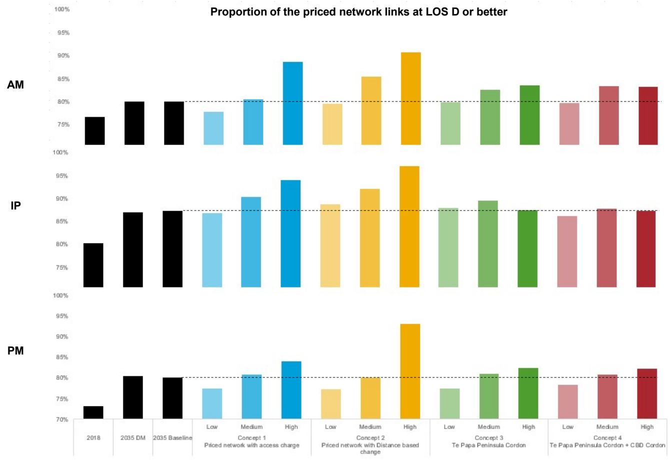
Sensitivity: General

Network impacts

LOS

Proportion of the priced network links at LOS D or better



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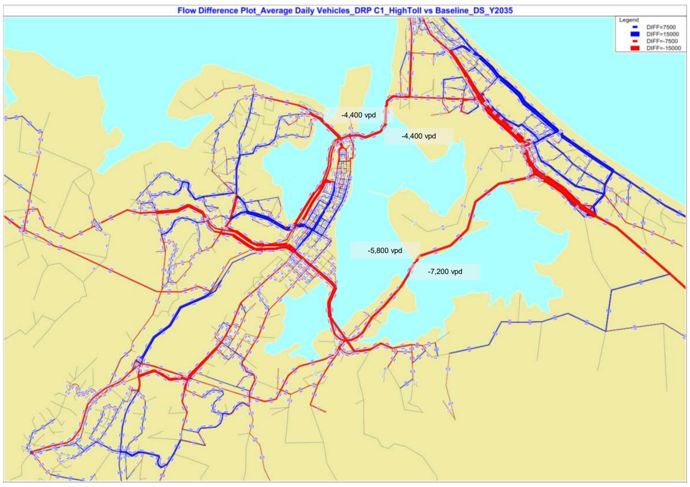
11

Sensitivity: General

Concept 1 High Price

Flow difference plots - Daily vehicle flows



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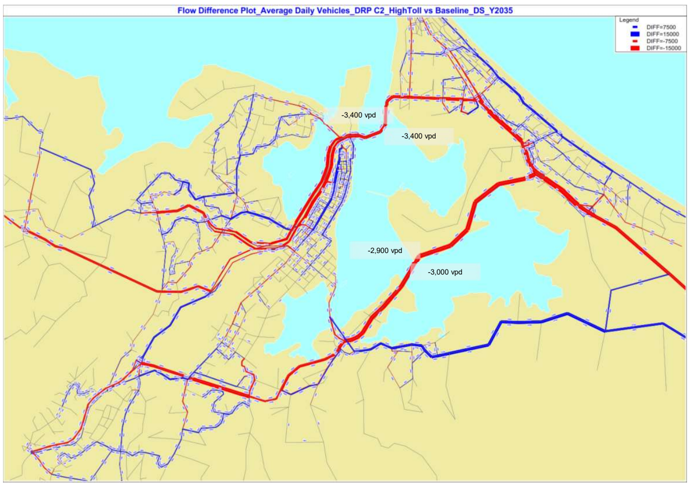
6/03/2023

Sensitivity: General

Concept 2 High Price

Flow difference plots - Daily vehicle flows



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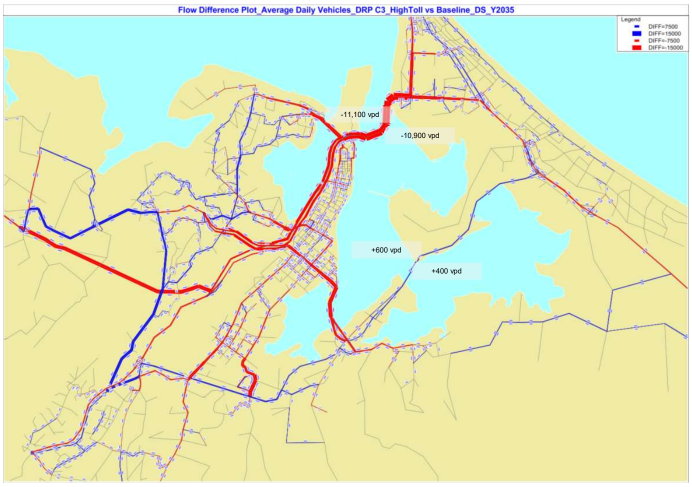
13

Sensitivity: General

Concept 3 High Price

Flow difference plots - Daily vehicle flows



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Sensitivity: General

Concept 4 High Price

Flow difference plots - Daily vehicle flows

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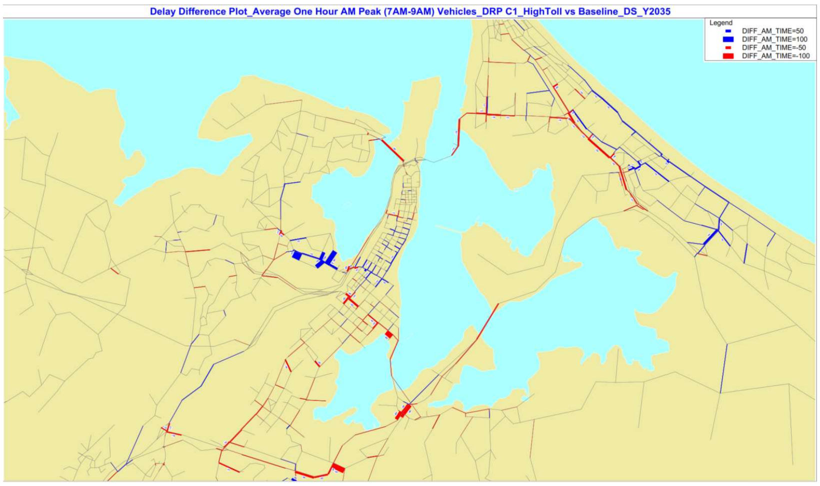
Sensitivity: General

Concept 1 High Price

Delay difference plots – AM peak period



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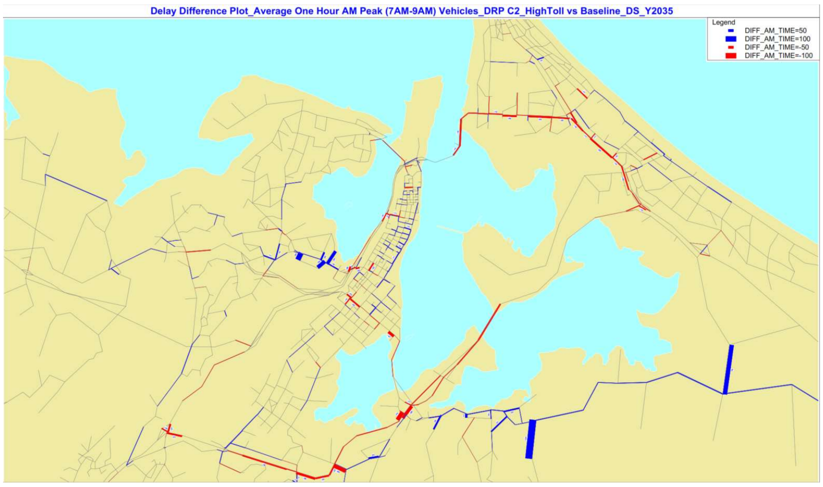
Sensitivity: General

Concept 2 High Price

Delay difference plots – AM peak period



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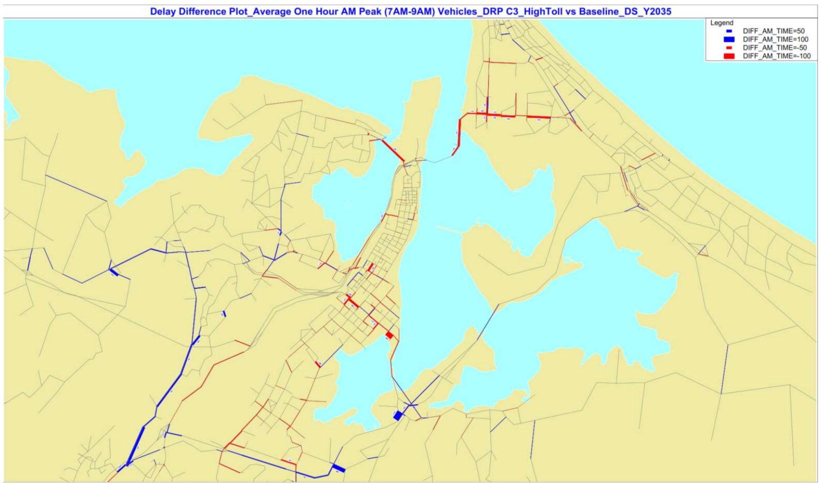
Sensitivity: General

Concept 3 High Price

Delay difference plots – AM peak period



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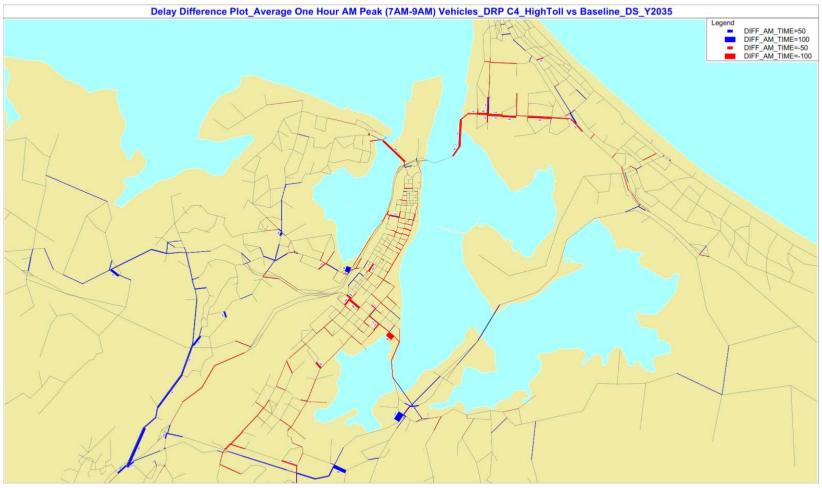
Sensitivity: General

Concept 4 High Price

Delay difference plots – AM peak period



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19

Revenue estimates

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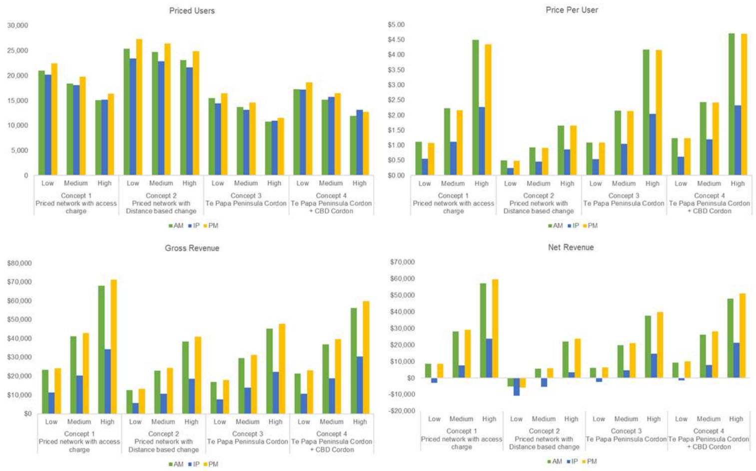
Sensitivity: General

Revenue estimates

Revenue outputs by modelled time period. Prior to conversion to daily or annual values. In today's prices. Excludes toll revenue from TEL



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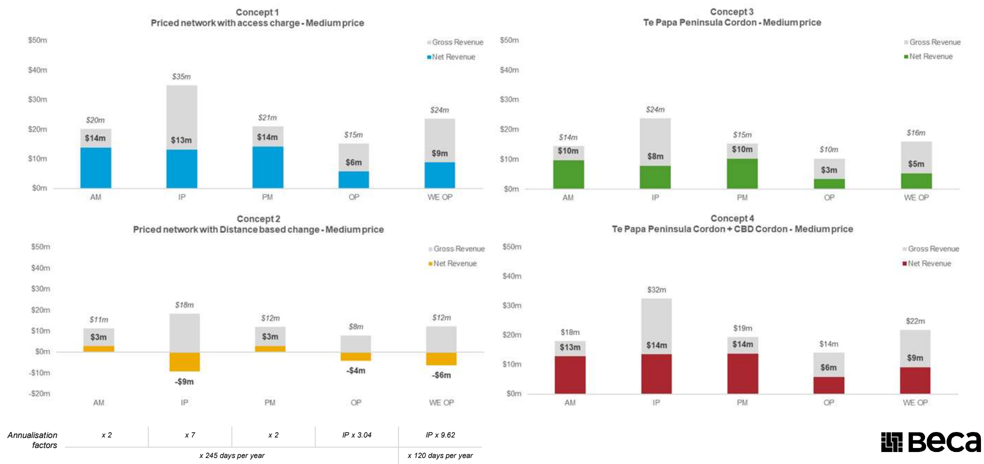
Sensitivity: General

Revenue estimates

Annual Gross and Net revenue for the Medium price, in today's prices. OP and Weekend assumed to have the IP price for each respective scenario. Excludes toll revenue from TEL



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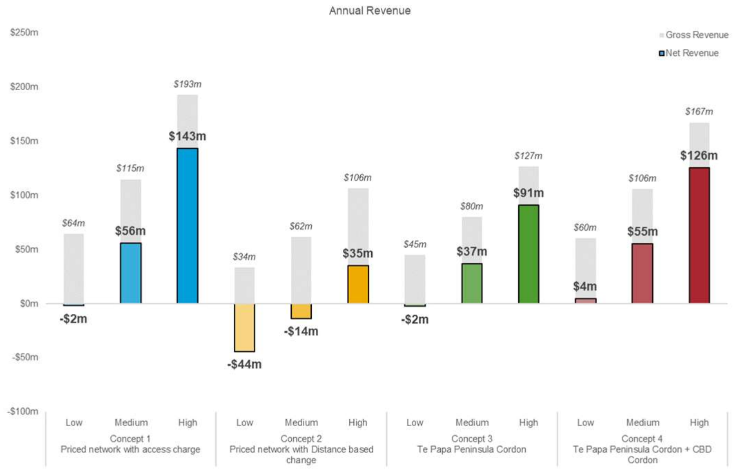
Sensitivity: General

Revenue estimates

Annual Gross and Net revenue, in today's prices. OP and Weekend assumed to have the IP price for each respective scenario. Excludes toll revenue from TEL



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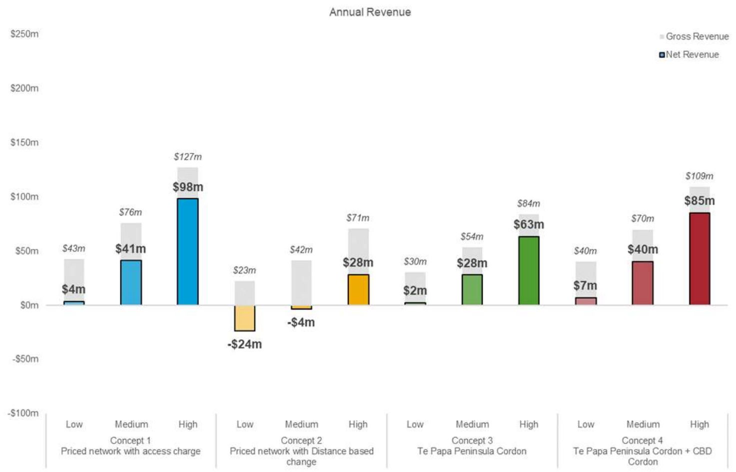
Sensitivity: General

Revenue estimates

Annual Gross and Net revenue, in today's prices. OP and Weekend assumed to have no price. Excludes toll revenue from TEL



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Concepts versus Objectives

	Concept 1 **Priced Network with Access charge**	Concept 2 **Priced Network with distance-based charge**	Concept 3 **Te Papa Peninsula Cordon**	Concept 4 **Te Papa Peninsula cordon + CBD cordon**
Optimisation of the whole transport system	Mixed result. Appears to perform well in the AM and IP but less effective in the PM time period.	High price appears effective at reducing LOS across the network	Little impact on improving LOS across the whole network and the priced network	Little impact on improving LOS across the whole network and the priced network
Improve travel time reliability and levels of service	Performs well on delay reduction.	Performs well on delay reduction.	Performs well on delay reduction, but slightly less than other concepts.	Performs well on delay reduction.
Raise revenue	Performs well on net revenue	Lots of short trips leads to high proportion of low/negative net revenue trips.	Mid-range performer.	Performs well on net revenue
Incentivise lower carbon emissions and travel choice	Achieves C02E reduction and reasonable PT mode shift effect.	Achieves C0$_2$E reduction but small PT mode shift effect.	Achieves C0$_2$E reduction but small PT mode shift effect.	Performs well on CO$_2$E reduction and PT mode share
Support urban form outcomes				

25

13

C

Appendix C – Stage 2 Pricing model testing

Appendix C Stage 2 Pricing model testing

Pricing model testing network performance indicators

The project partner technical advisors agreed the following performance indicators would be used to select the pricing model for Concept 5 from which a full assessment would be undertaken.

1. Levels of service (targeting LOS D or better)
    a. LOS plots by time period
    b. Percentage of road KMs operating at LOS D or better in all time periods
    c. Percentage of intersections operating at LOS D or better in all time periods
2. Right traffic right roads
    a. Selection of up to 10 select link analysis in locations to determine trip length distribution and compare with base. Assess against road purpose as defined by UFTI. The locations will be a mix of Centre locations and Priced network locations.
    b. Locations presented in later slides
3. People movement
    a. Journey time reliability
    b. Improved journey times
    c. By mode (Car and PT)
    d. Mode shift
4. Freight movement
    a. Journey time reliability
    b. Improved journey times

Other considerations were revenue and safety.

Outputs from Pricing model testing

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Tauranga Road Pricing Proof of Concept Study

CONCEPT 5 MODELLING RESULTS FOR THE SELECTION OF THE ASSESSED PRICE MODEL

make everyday better.

1

Sensitivity: General

TTSM modelled scenarios

Pricing Test	Description	2035	2048
Low	Peak $1.00 + $0.15 per KM Interpeak $0.50 + $0.15 per KM	Model runs complete and outputs for all performance indicators processed	
Medium	Peak $2.00 + $0.15 per KM Interpeak $1.00 + $0.15 per KM		
High	Peak $4.00 + $0.15 per KM Interpeak $2.00 + $0.15 per KM		
Very High (Run 3)	Peak $8.00 + $0.15 per KM Interpeak $4.00 + $0.15 per KM	Model runs complete and outputs for all performance indicators processed	Not requested
Differential Access Charges - Test 1	Medium Price test with Low charges on SH29A access points and High charges on Takitimu Drive access points (SH29/SH2)	Model runs complete and outputs for all performance indicators processed	Not requested
Differential Access Charges - Test 2	Differential Access Charges - test 1 plus Low Access Charge on Welcome Bay Link Road access points		Not requested
Differential Access Charges - Test 3	Differential Access Charges - test 2 plus Very High Charge on Harbour Bridge		Not requested
Mode shift Run 1	Medium Price test with +25% to the access charge on those roads which have high levels of PT service	Model runs complete and outputs for all performance indicators processed	Not requested
Mode shift Run 2	Mode shift Run 1 plus 50% off PT fares		Not requested

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Mode shift runs

3

Sensitivity: General

Mode Shift Run 1

Medium Price test with

High charges on access points with good PT services

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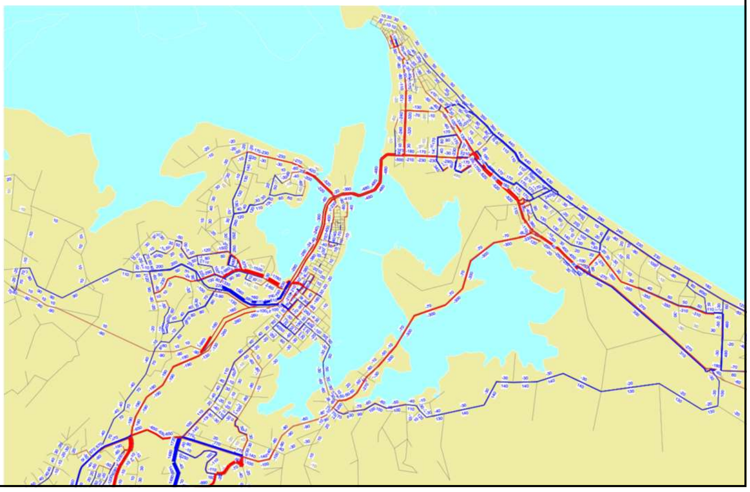
Sensitivity: General

Mode Shift Run 1

Daily vehicle flow difference

- Route choice response in some locations
- Probably some destination choice changes, but as we see in the next slide, very limited mode shift



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Sensitivity: General

Mode Shift Run 1

Daily PT patronage flow difference

- Negligible impact on PT patronage

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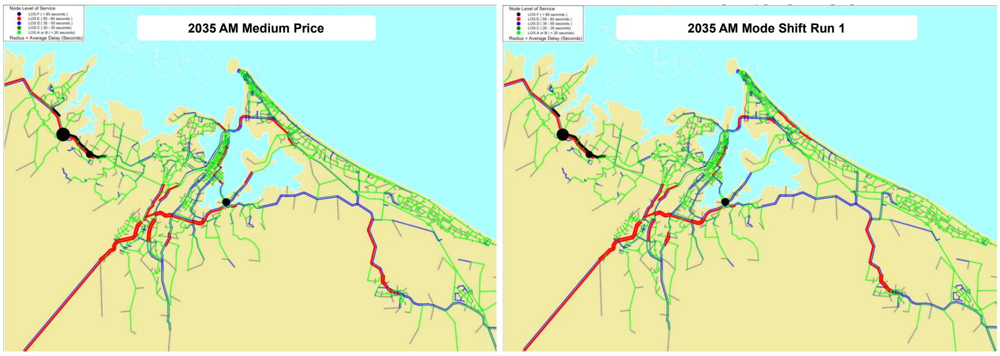
Sensitivity: General

Mode Shift Run 1



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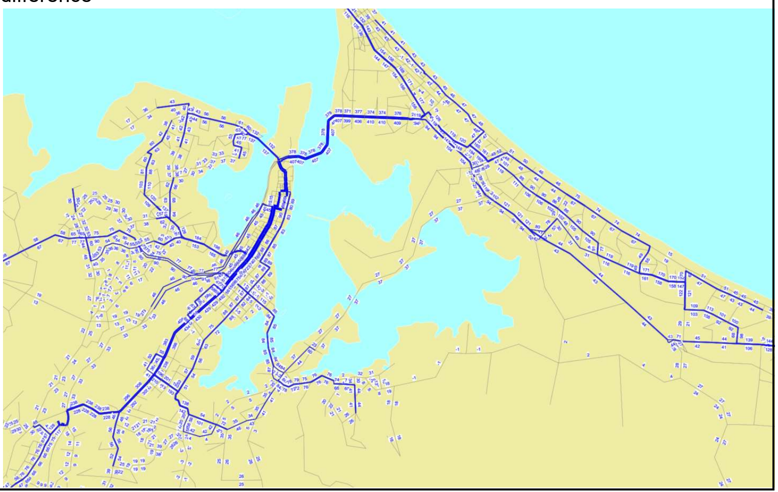
Sensitivity: General

Mode Shift Run 2

Daily PT patronage flow difference

- Significant response compared to the Run 1 targeted access prices



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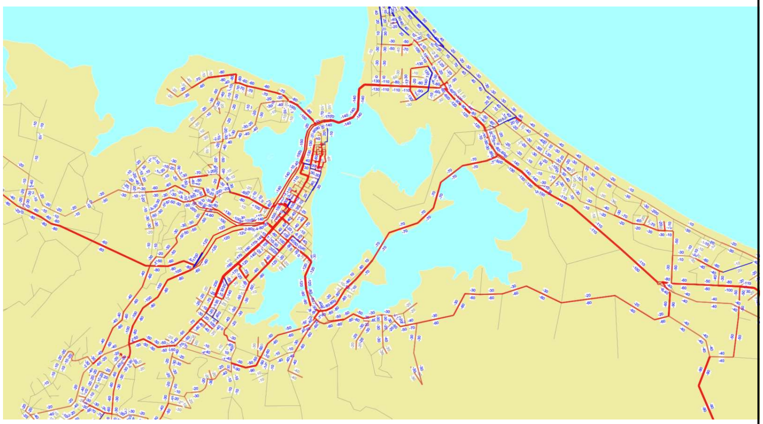
Sensitivity: General

Mode Shift Run 2

Daily vehicle flow difference

- Run 2 compared to Run 1.
- Widespread modest decreases in vehicle flows
- Some localised improvements in LOS



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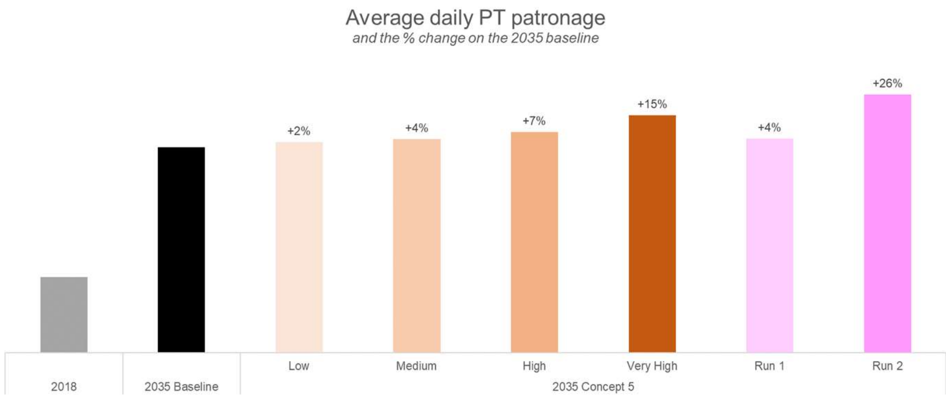
Sensitivity: General

Mode shift

Average daily PT patronage



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Differential access charge tests

Results

11

Sensitivity: General

Differential Access Charge tests

Pricing Test	Description
Differential Access Charge Test 1	Medium Price test with Low charges on SH29A access points and High charges on Takitimu Drive access points (SH29/SH2)
Differential Access Charge Test 2	Differential Access Charge Test 1 plus Low Access Charge on Welcome Bay Link Road access points
Differential Access Charge Test 3	Differential Access Charge Test 2 plus Very High Charge on Harbour Bridge

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12

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Sensitivity: General

Differential Access Charge Test 1

Medium Price test with

Low charges on SH29A access points

and

High charges on Takitimu Drive access points (SH29/SH2)

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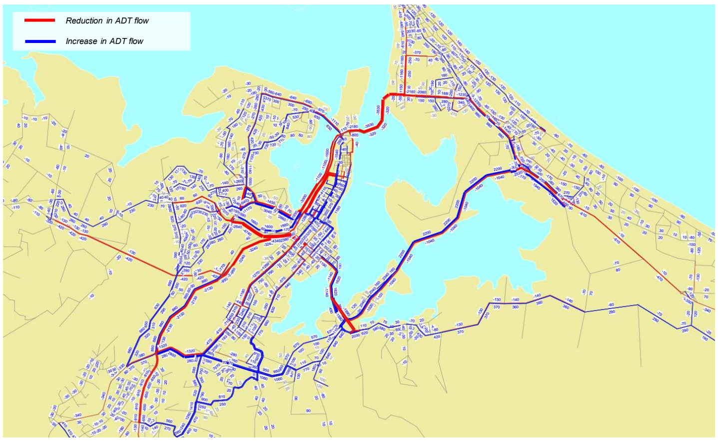
Sensitivity: General

Differential Access Charge Test 1

Medium Price test with
Low charges on SH29A access points and
High charges on Takitimu Drive access points (SH29/SH2)



Compared to Medium Price test:
-0.1% in VKT
+2.1% in VHT

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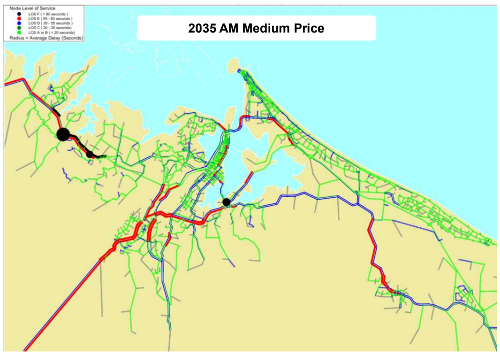
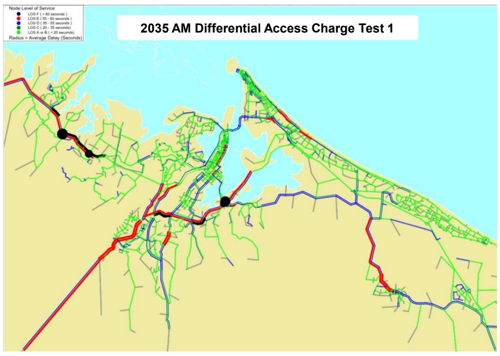
Differential Access Charge Test 1

Medium Price test with
Low charges on SH29A access points and
High charges on Takitimu Drive access points (SH29/SH2)





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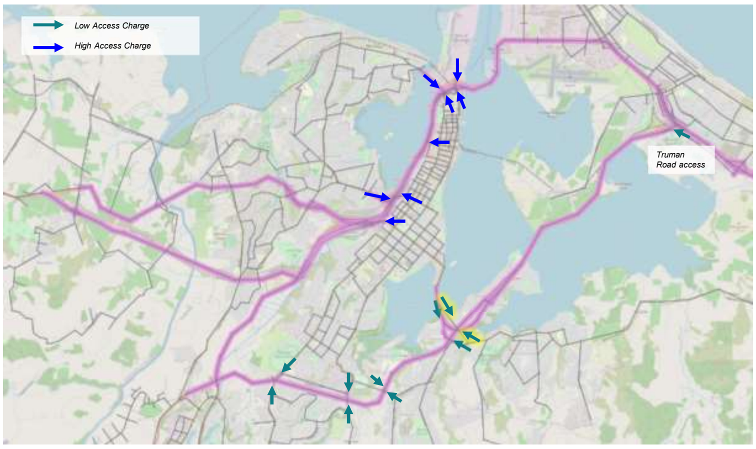
Differential Access Charge Test 2

Test 1 plus

Low Access Charge on Welcome Bay Link Road access points



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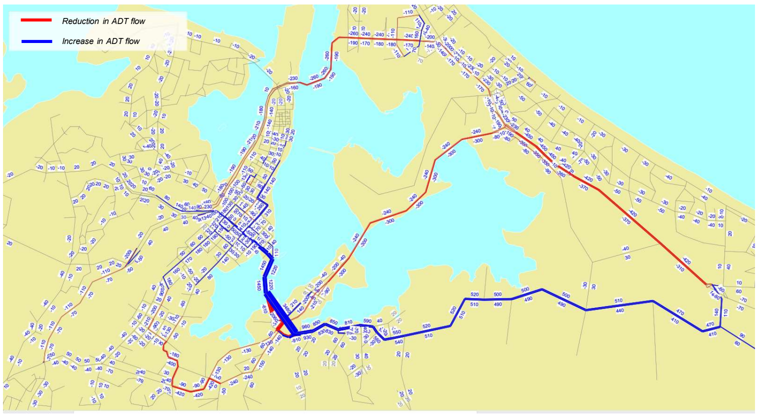
Sensitivity: General

Differential Access Charge Test 2

Test 1 plus Low Access Charge on Welcome Bay Link Road access points

Compared to Medium Price test:
0.0% in VKT
+1.2% in VHT



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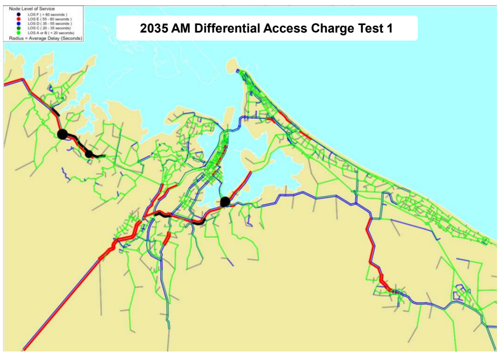
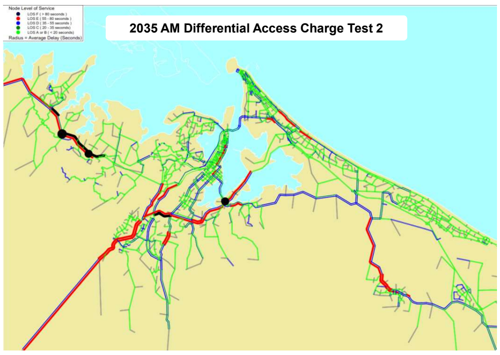
Sensitivity: General

Differential Access Charge Test 2

Test 1 plus Low Access Charge on Welcome Bay Link Road access points





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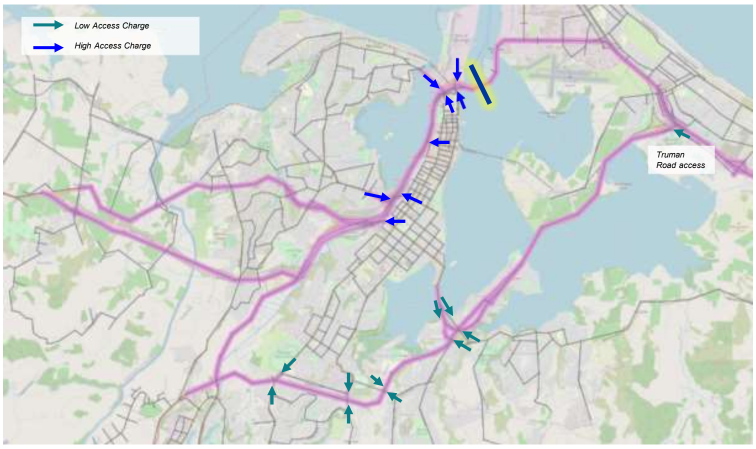
Sensitivity: General

Differential Access Charge Test 3

Test 2 plus

Very High Charge on Harbour Bridge

$8 in the peaks
$4 in the IP



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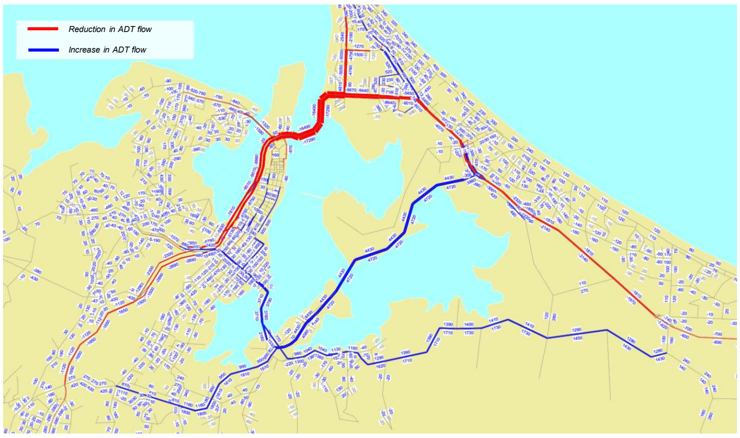
Sensitivity: General

Differential Access Charge Test 3

Test 2 plus Very High Charge on Harbour Bridge



Compared to Medium Price test:
-2.2% in VKT
+1.8% in VHT

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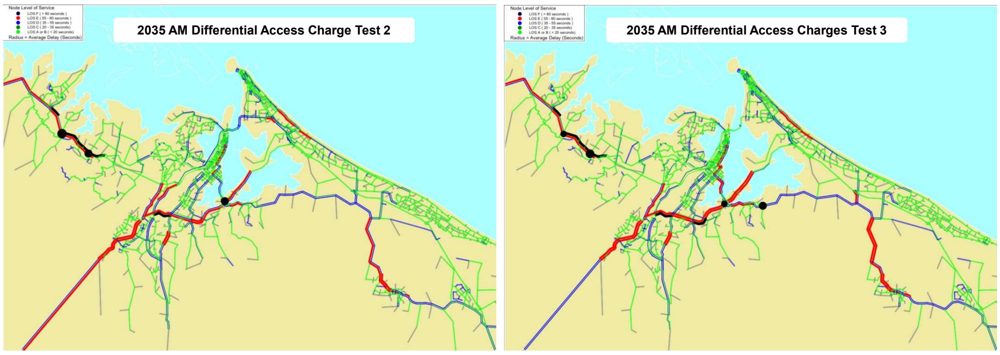
Sensitivity: General

Differential Access Charge Test 3

Test 2 plus Very High Charge on Harbour Bridge



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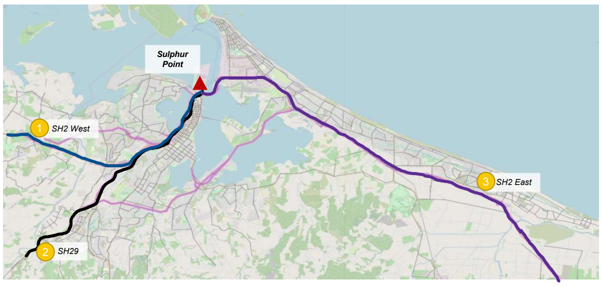
Sensitivity: General

Freight Journey Times



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Performance indicators

For the selection of the assessment price model

23

Sensitivity: General

Performance indicators for the selection of the assessed price model

1. Levels of service (targeting LOS D or better)
    - LOS plots by time period, and worst in any time period
    - Proportion of road network operating at LOS D or better in all time periods
    - Number of intersections operating at LOS E or F in all time periods
2. Right traffic right roads
    - ADT Flow difference plots
    - Select link analysis in 13 locations to compare the trip length distribution with the base.
3. People movement
    - Journey time reliability
        - Car: Light vehicle person KM travelled on roads operating at LOS E or F
        - PT: Person KM travelled on buses on roads without bus lanes operating at LOS E or F
    - Improved journey times
        - Average Daily vehicle hours of delay: Congested time - free flow time
    - Mode shift
4. Freight movement
    - Journey time reliability
        - KM of road operating at LOS E or F on routes to Port of Tauranga Sulphur Point from SH2 West, SH29 and from SH2 East to Port of Tauranga Tasman Key.
        - Number of intersections operating at LOS E or F on routes to Port from SH2 West, SH29 and SH2 East
    - Improved journey times on routes to Port of Tauranga Sulphur Point from SH2 West, SH29 and from SH2 East to Port of Tauranga Tasman Key

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24

12

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Levels of service

25

Sensitivity: General

Level of service

Proportion of network operation at LOS D or better

AM

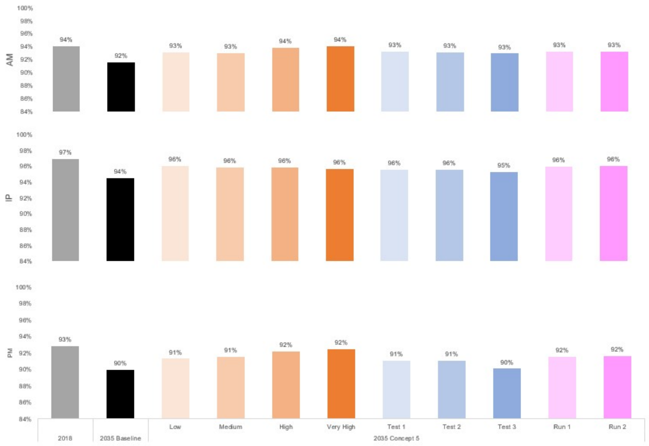
Some gains with Low price in 2035, but little gained with Medium price. Some gains with High price.
Different access price tests and mode shift runs have little impact (comparing with Medium Price scenario)

IP

Some gains with Low price in 2035, but no further improvements with Medium price and High price
Different access price tests and mode shift runs have little impact (comparing with Medium Price scenario)

PM

Some gains with Low price in 2035, but little gained with Medium price. Some gains with High price.
Different access price tests have little impact (comparing with Medium Price scenario). Minor gains with Mode Shift test.



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Sensitivity: General

Levels of service

Intersections operating at or over capacity

AM

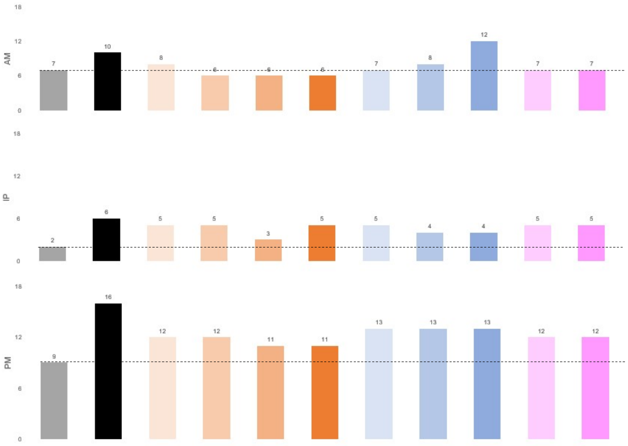
Improvement in reliability with Low price in 2035, and again with Medium price. No gain with the High price.
Negative outcomes with differential access charge tests and mode shift tests.

IP

Improvement in reliability with Low price in 2035, but no further improvement with Medium price.
Different access price tests and mode shift runs have little impact (comparing with Medium Price scenario)

PM

Improvement in reliability with Low price in 2035, but little gained with Medium price and High Price.
Negative outcomes with differential access charge tests . Not change in the mode shift tests.



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Right traffic right roads

28

14

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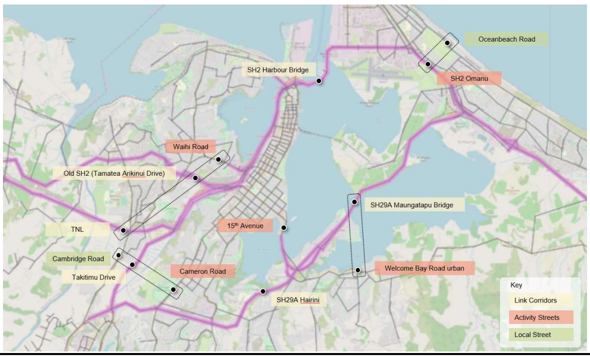
Sensitivity: General

Right traffic Right roads

- Flow difference plots: Tauranga Road Pricing\2. Right traffic right roads\Flow Difference Plots
- Trip length frequency distributions: Tauranga Road Pricing\2. Right traffic right roads\Trip Length Frequency Distributions\Trip Length Frequency Distributions.xlsx



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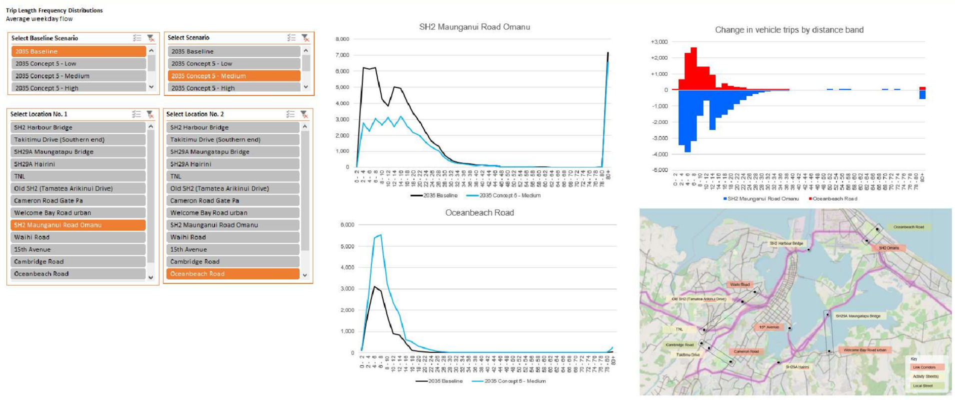
29

Sensitivity: General

Right traffic Right roads



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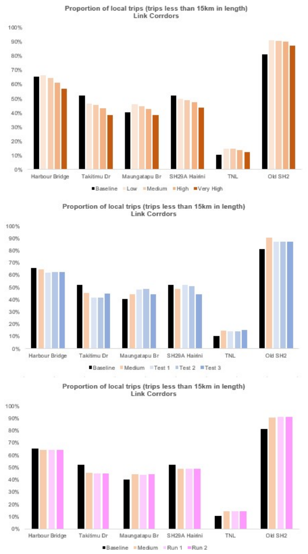
Sensitivity: General

Right traffic Right roads

Proportion of local trips on Link Corridors

- Pricing should support a reduction in the proportion of the local trips on link corridors.
- There is a reduction in the proportion of the local trips on 4 of the 6 selected link corridors.
- Possible issues on the Harbour bridge and on Maungatapu Bridge
  - Reductions in both local and strategic trips at both locations
  - The reduction in strategic trips on Harbour bridge is greater in the Low test
  - The reduction in strategic trips on Maungatapu bridge is greater in the each test
  - This illustrates the effect of the 15 cents per KM distance based component of the charge, and how the higher access charge impacts local trips relatively more than longer distance trips
- Variable access price tests having an effect on the proportion of local trips on these link corridors
- Mode shift tests have negligible impact



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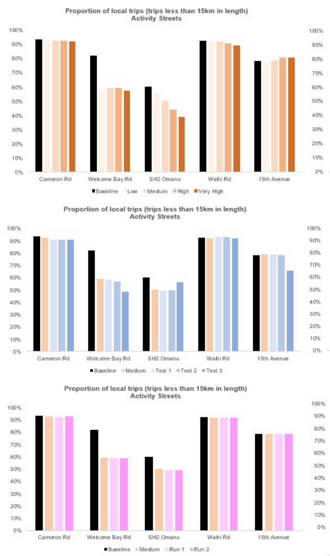
31

Sensitivity: General

Right traffic Right roads

Proportion of local trips on Activity Streets

- Pricing shouldn't radically change the trip length frequency distribution on activity streets
- Pricing doesn't radically change the trip length frequency distribution on 3 of the 5 selected activity streets
- Issue on Welcome Bay Road
  - Too many log distance trips switching to Welcome Bay Road
  - A lower distance based change helps mitigate this issue
- Issue on SH2 Omanu?
  - Not as radical a change as with Welcome Bay Road
  - With each price increment we see a reduction in the proportion of the local trips on the road
- Variable access price test 3 has impacts on 3 of the 5 locations
  - Suppressing local trips on SH2 Omanu
  - Also shift strategic trips to Welcome Bay Road and 15th Avenue
- Mode shift tests have negligible impact



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16

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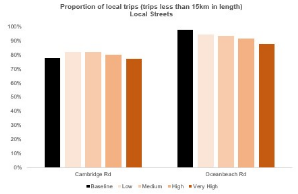
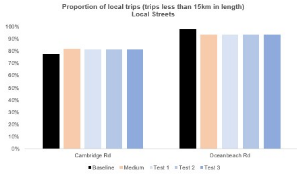
Sensitivity: General

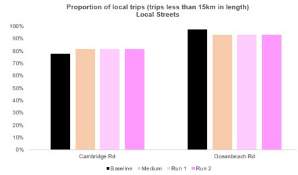
Right traffic Right roads

Proportion of local trips on Local Streets

- Pricing shouldn't radically change the trip length frequency distribution on local roads.
- Ideally pricing wouldn't push strategic trips on to local roads.
- Cambridge Road looks okay at Low and Medium price levels.
- Potential issue on Oceanbeach Road where the proportion of local trips decreases when pricing is applied.
  - Mitigation may be needed, or a lower distance based change may help
- Variable access price tests negligible impact
- Mode shift tests have negligible impact







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People movement

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17

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Sensitivity: General

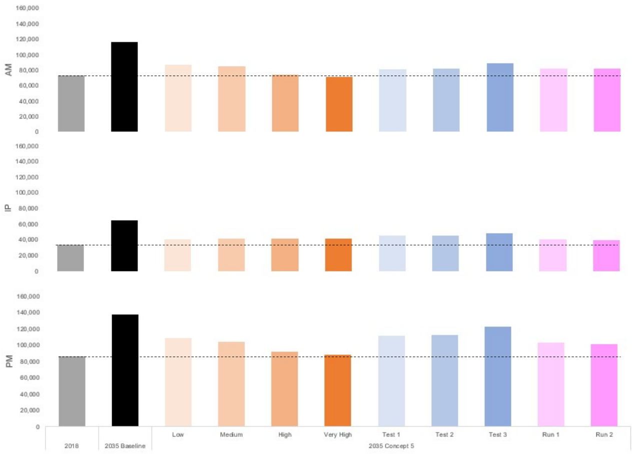
Journey time reliability for Cars

Light vehicle person KM travelled on roads operating at LOS E or F

AM Improvement in reliability with Low price in 2035. Little gained with Medium price. With High price 2018 levels of reliability at matched. Some improvement with Differential Access charge Test 1 and 2, then worse performance with Test 3. Some improvement with Mode Shift Run 1 and 2.

IP Improvement in reliability with Low price in 2035, but no further improvements with Medium price and High price.
Different access price tests and mode shift runs have little impact (comparing with Medium Price scenario)

PM Improvement in reliability with Low price in 2035, but little gained with Medium price. With High price 2018 levels of reliability at nearly matched.
Negative outcomes with differential access charge tests . Not change in the mode shift tests.



35

Sensitivity: General

Journey time reliability on PT

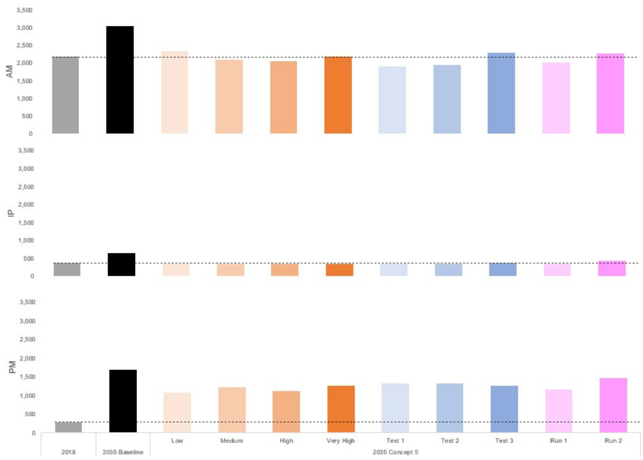
Person KM travelled on buses on roads without bus lanes operating at LOS E or F

AM Improvement in PT reliability with Low price in 2035 and Medium price. Little gained with High price.
Some improvement with Differential Access charge Test 1 and 2, then worse performance with Test 3.
Difficult to interpret Mode Shift tests as they encourage mode shift, so the outcome may just reflect more people on PT with similar reliability.

IP Improvement in reliability with Low price in 2035, but no further improvements with Medium price and High price
Different access price tests and mode shift runs have little impact (comparing with Medium Price scenario)

PM Improvement in PT reliability with Low price in 2035. Little gained with Medium and High price.
Improvement in PT reliability with Low price in 2035 and Medium price. Little gained High price.

Different access price tests have little impact (comparing with Medium Price scenario).
Difficult to interpret Mode Shift tests as they encourage mode shift, so the outcome may just reflect more people on PT with similar reliability.



36

18

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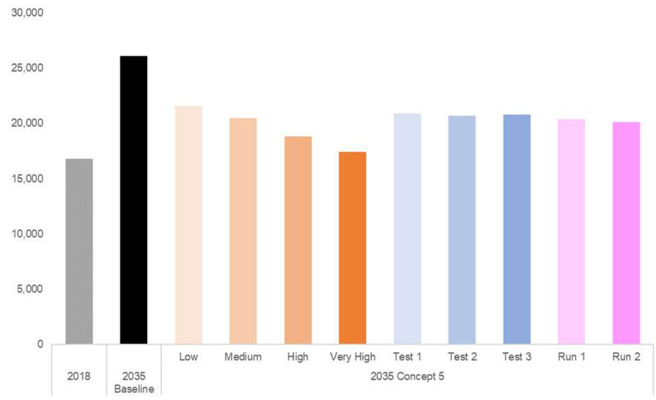
Sensitivity: General

Delay

Delays Vehicle Hour Travelled (VHT)



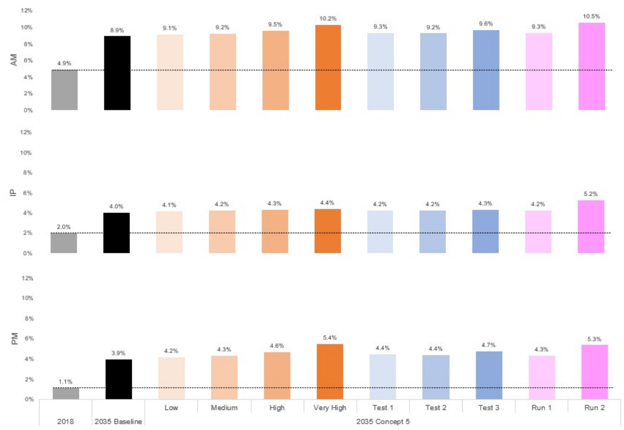
Beca

37

Sensitivity: General

Mode shift

PT mode share – Urban areas



Beca

38

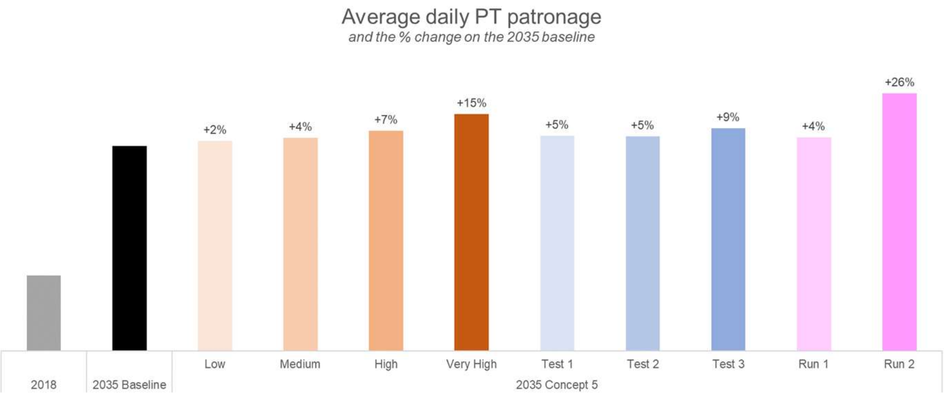
19

6/03/2023

Sensitivity: General

Mode shift

Average daily PT patronage



39

Freight movement

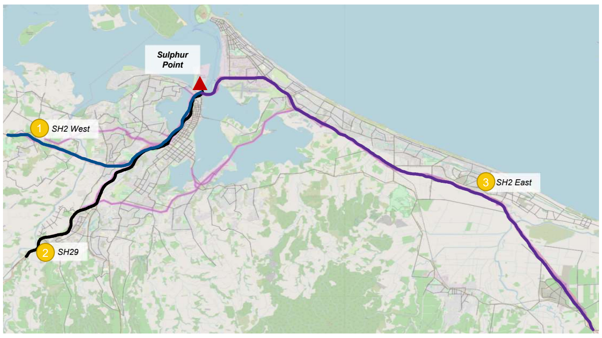
40

20

Sensitivity: General

Journey time reliability for Freight

KM of road on freight routes operating at LOS E or F

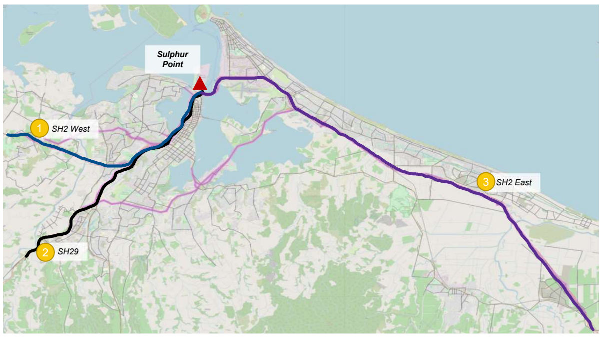


41

Sensitivity: General

Journey time reliability for Freight

Freight Journey Times



42

6/03/2023

Other Statistics

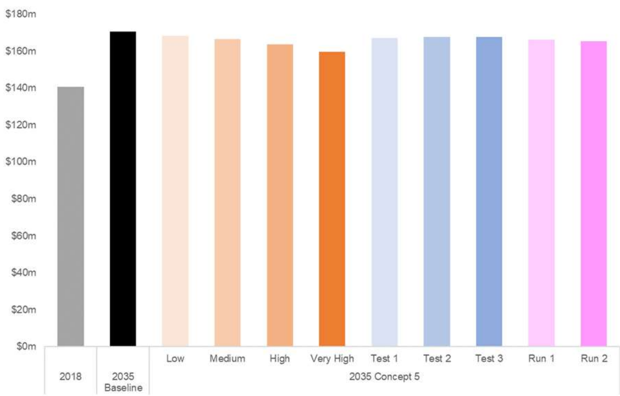
Annual crash costs and revenue estimates

43

Sensitivity: General

Annual Crash costs

- Overall reduction in crash costs with less trips on fast roads
- Increases in crash costs on local roads and lower speed categories of rural roads



Beca

44

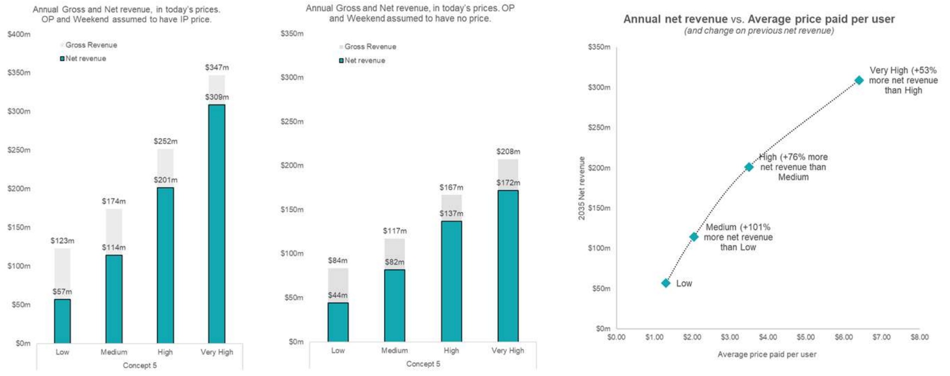
22

6/03/2023

Sensitivity: General

Revenue

Annual Gross and Net revenue, in today's prices



Beca

45

23

D

Appendix D – Assessed Price Model outputs

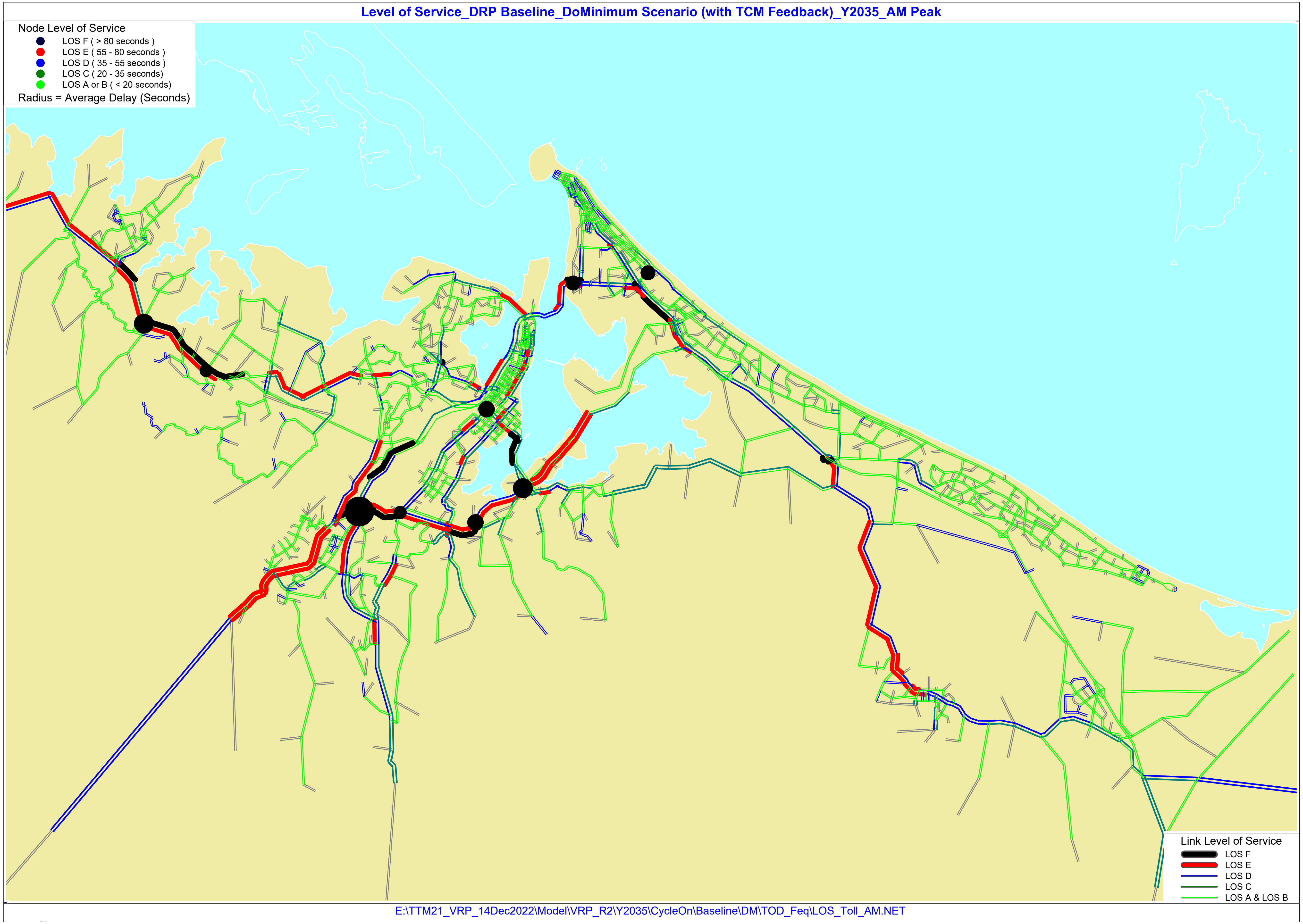
Appendix D Stage 2 Assessed Price Model outputs

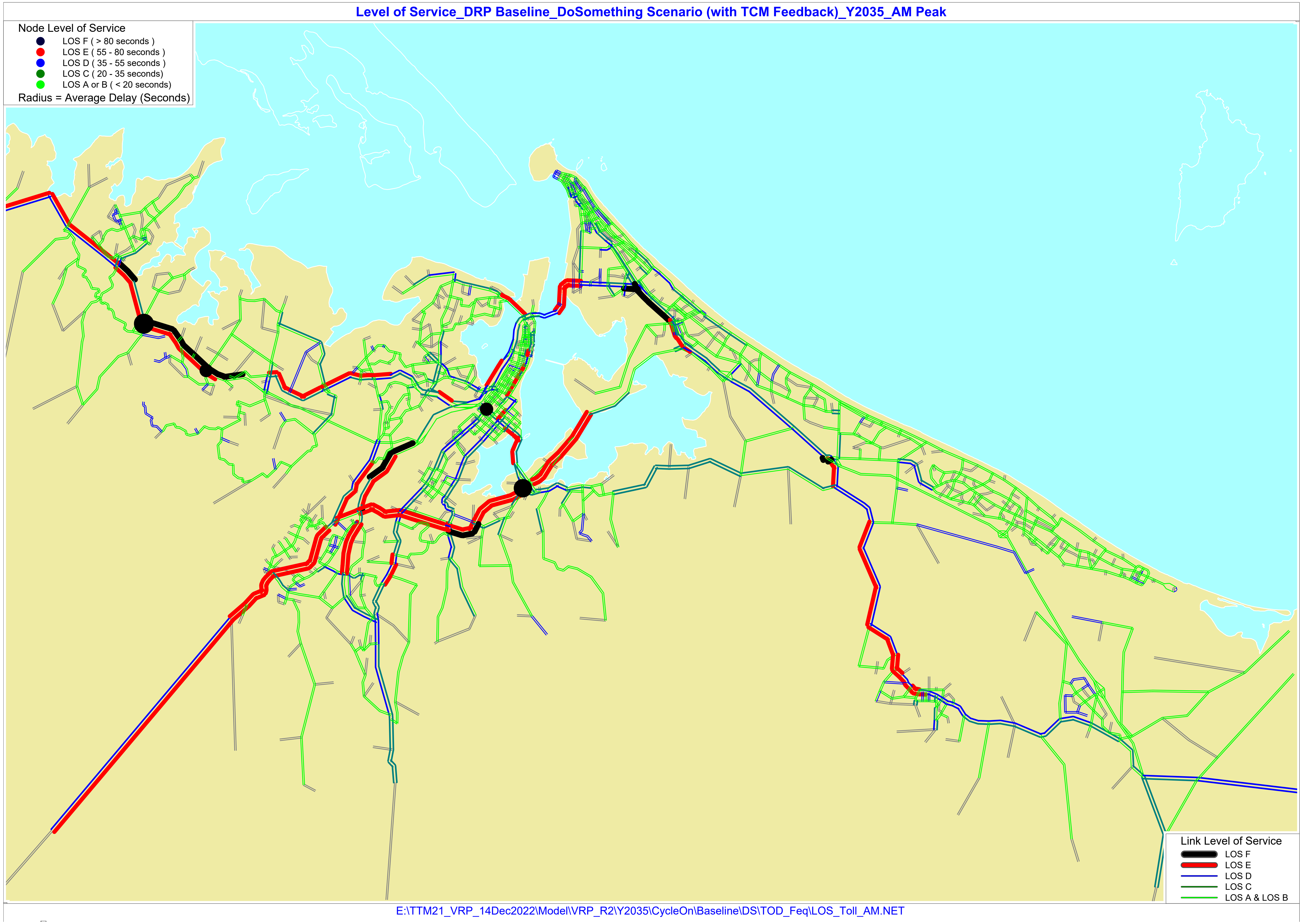
Standard Model Output Statistics

Table D1 Journey times between Centres

	Population	Employment	VKT per day	Delays Vehicle Hour Travelled (VHT) per day	Average Daily Vehicle Trips	VKT/Person	Vehicle Trips per Person	Average Trip Length (km)
2018	184,700	93,200	4,968,645	16,759	641,381	26.90	3.5	7.7
2035								
Baseline DM	241,400	115,000	6,407,187	26,568	830,322	26.54	3.4	7.7
Baseline DS	241,400	115,000	6,372,064	26,051	816,147	26.40	3.4	7.8
Concept 5 Assessed Price	241,400	115,000	5,997,690	20,715	809,816	24.85	3.4	7.4
2048								
Baseline DM	270,700	129,600	7,344,794	33,631	943,300	27.13	3.5	7.8
Baseline DS	270,700	129,600	7,590,570	27,451	930,024	28.04	3.4	8.2
Concept 5 Assessed Price	270,700	129,600	6,884,191	27,451	918,535	25.43	3.4	7.5

LOS Plots


Level of Service_DRP Baseline_DoMinimum Scenario (with TCM Feedback)_Y2035_AM Peak
Node Level of Service
LOS F (> 80 seconds)
LOS E (55 - 80 seconds)
LOS D (35 - 55 seconds)
LOS C (20 - 35 seconds)
LOS A or B (< 20 seconds)
Radius = Average Delay (Seconds)
Link Level of Service
LOS F
LOS E
LOS D
LOS C
LOS A & LOS B
E:\TTM21_VRP_14Dec2022\Model\VRP_R2\Y2035\CycleOn\Baseline\DM\TOD_Feq\LOS_Toll_AM.NET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Node Level of Service
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LOS E (55 - 80 seconds)
LOS D (35 - 55 seconds)
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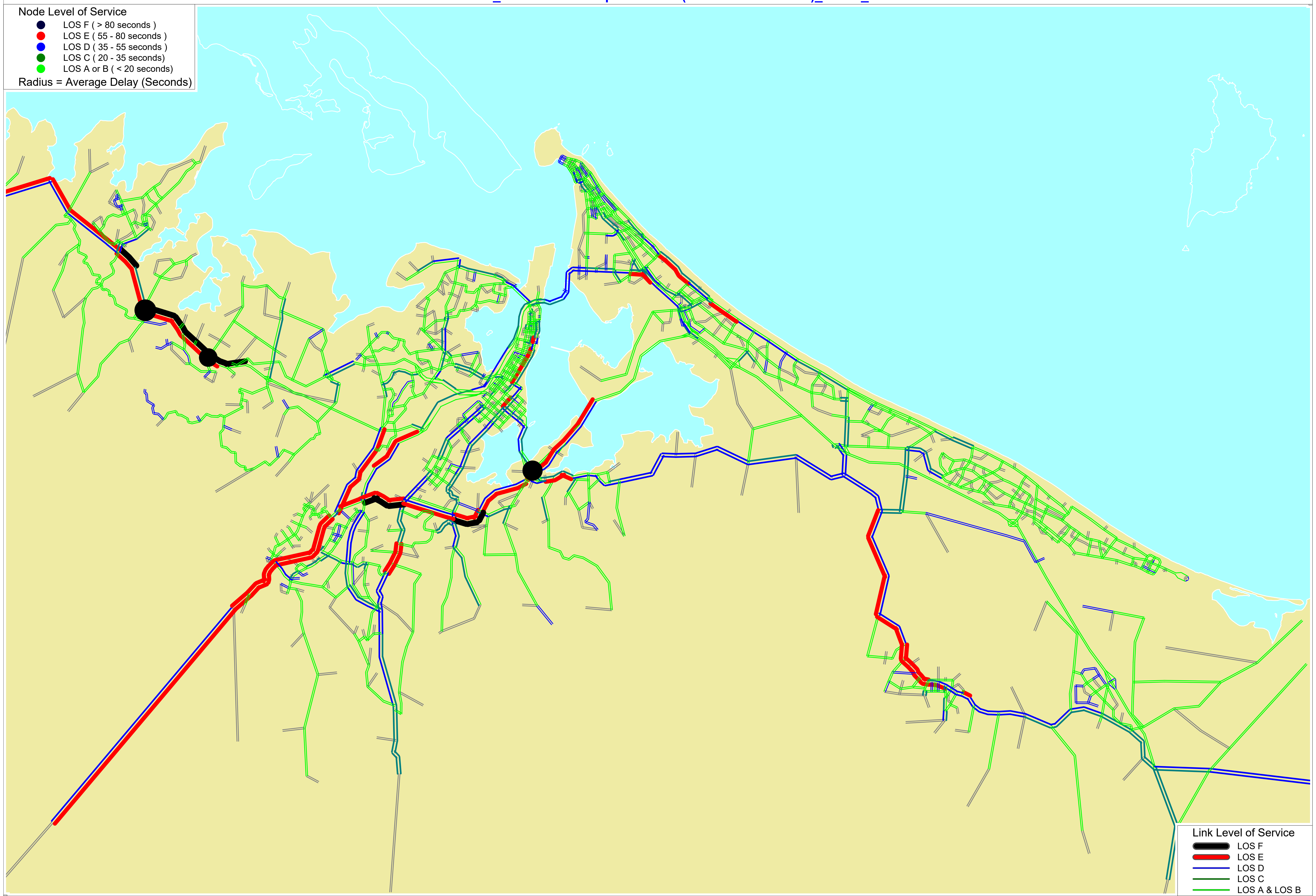
LOS A or B (< 20 seconds)
Radius = Average Delay (Seconds)
Link Level of Service
LOS F
LOS E
LOS D
LOS C
LOS A & LOS B
E:\TTM21_VRP_14Dec2022\Model\VRP_R2\Y2035\CycleOn\Baseline\DS\TOD_Feq\LOS_Toll_AM.NET

Level of Service_DRP AssessedOpt Scenario (with TCM Feedback)_Y2035_AM Peak



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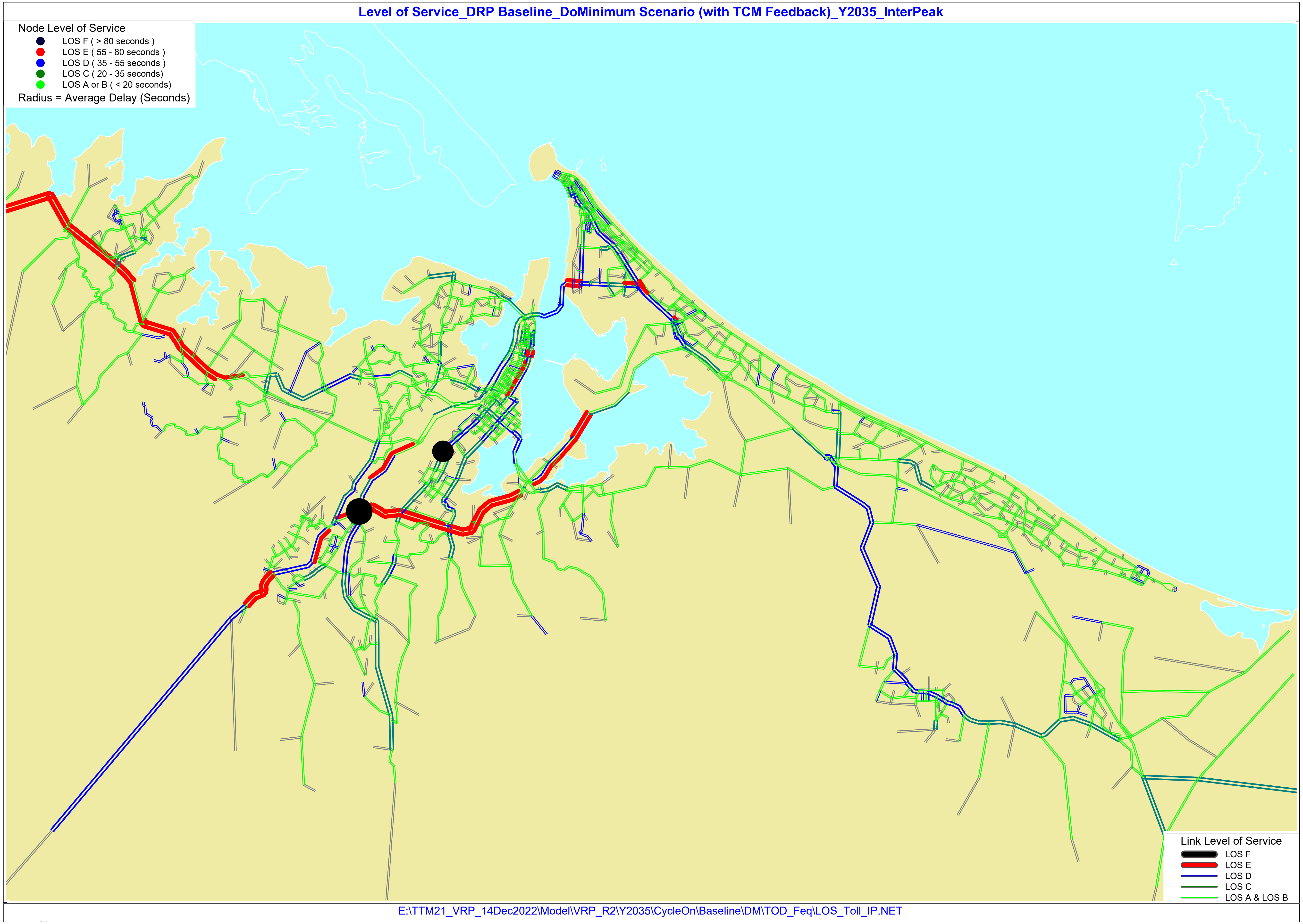
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Node Level of Service
LOS F (> 80 seconds)
LOS E (55 - 80 seconds)
LOS D (35 - 55 seconds)
LOS C (20 - 35 seconds)
LOS A or B (< 20 seconds)
Radius = Average Delay (Seconds)
Link Level of Service
LOS F
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LOS A & LOS B
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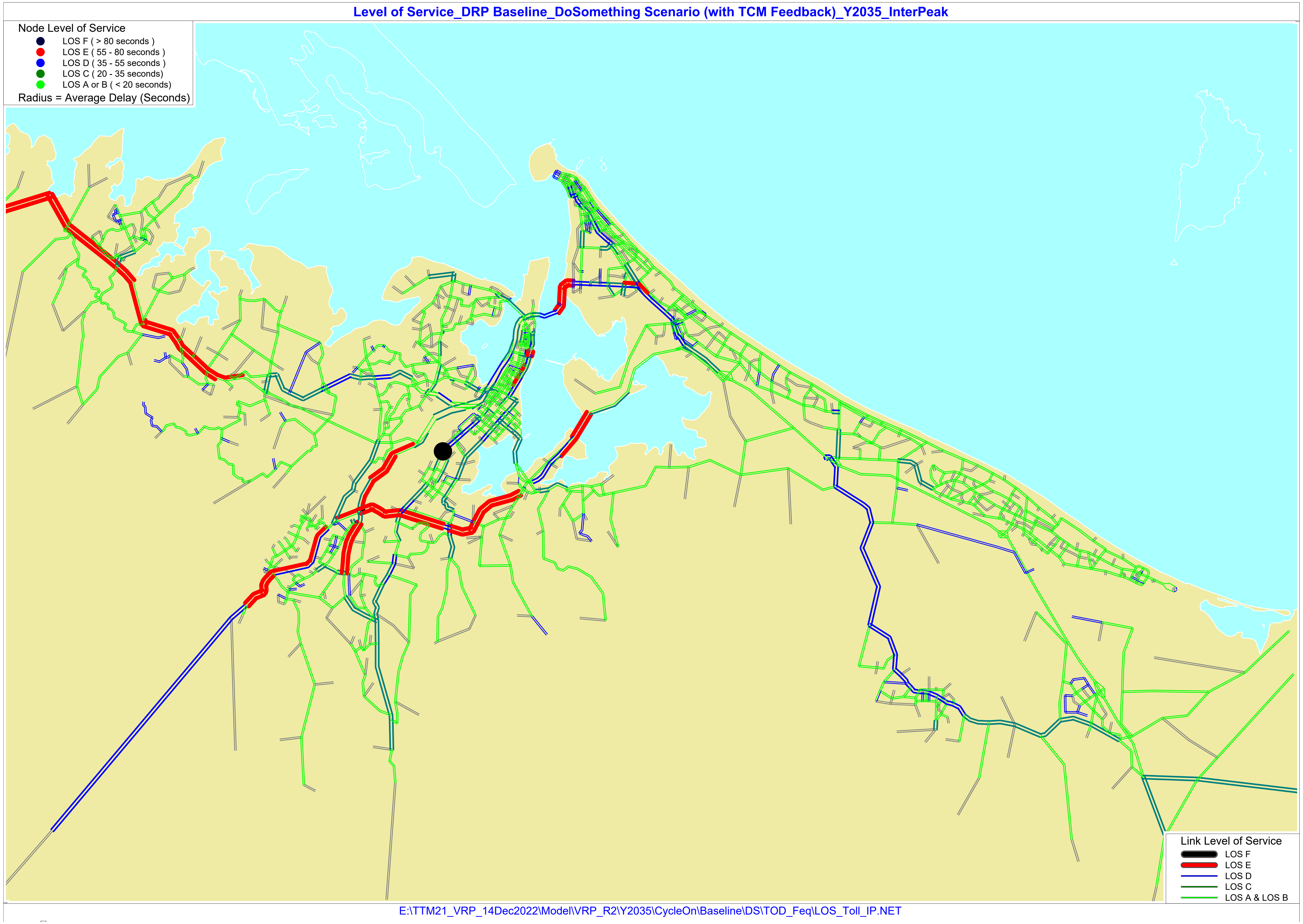
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LOS A or B (< 20 seconds)
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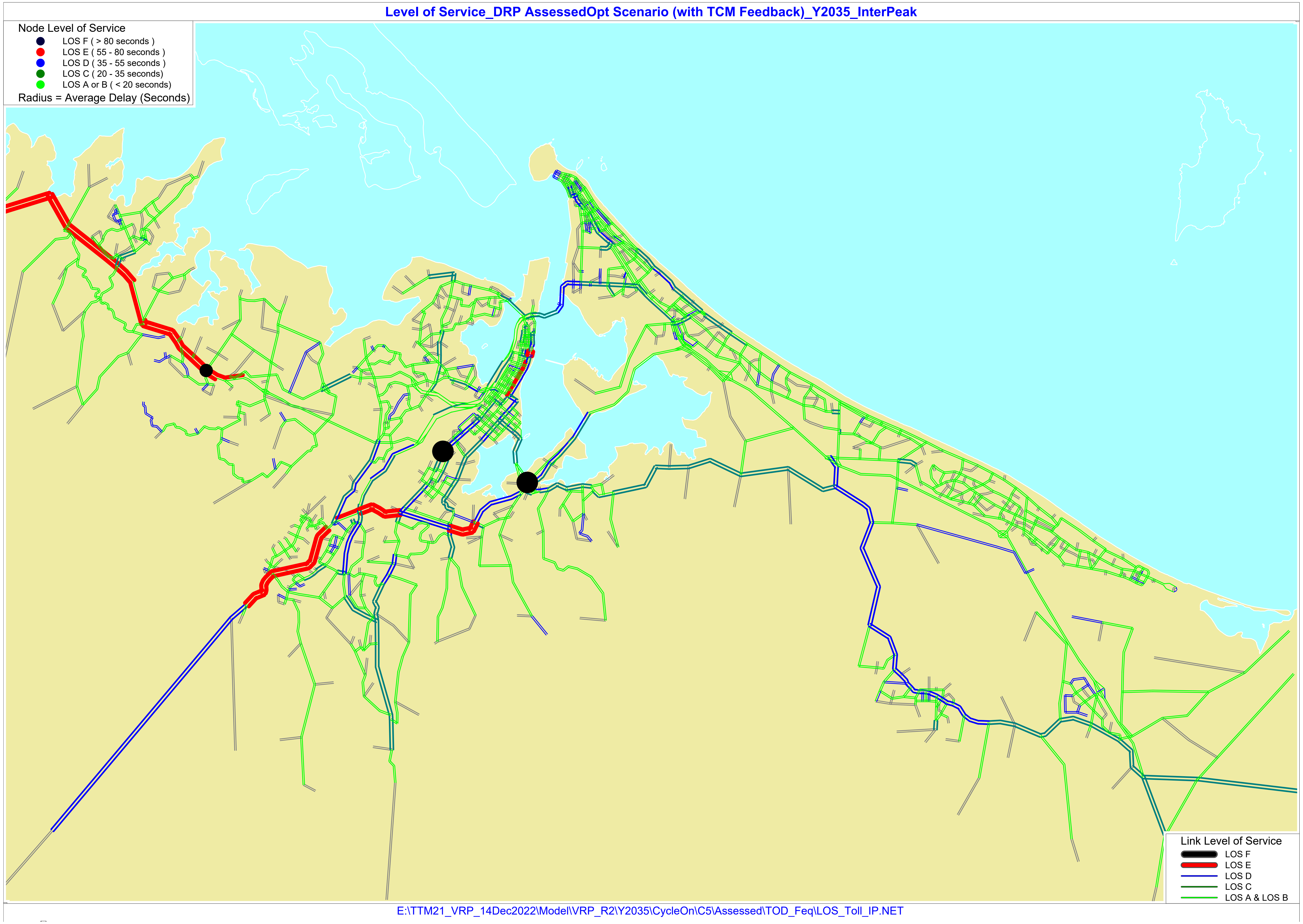
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LOS E
LOS D
LOS C
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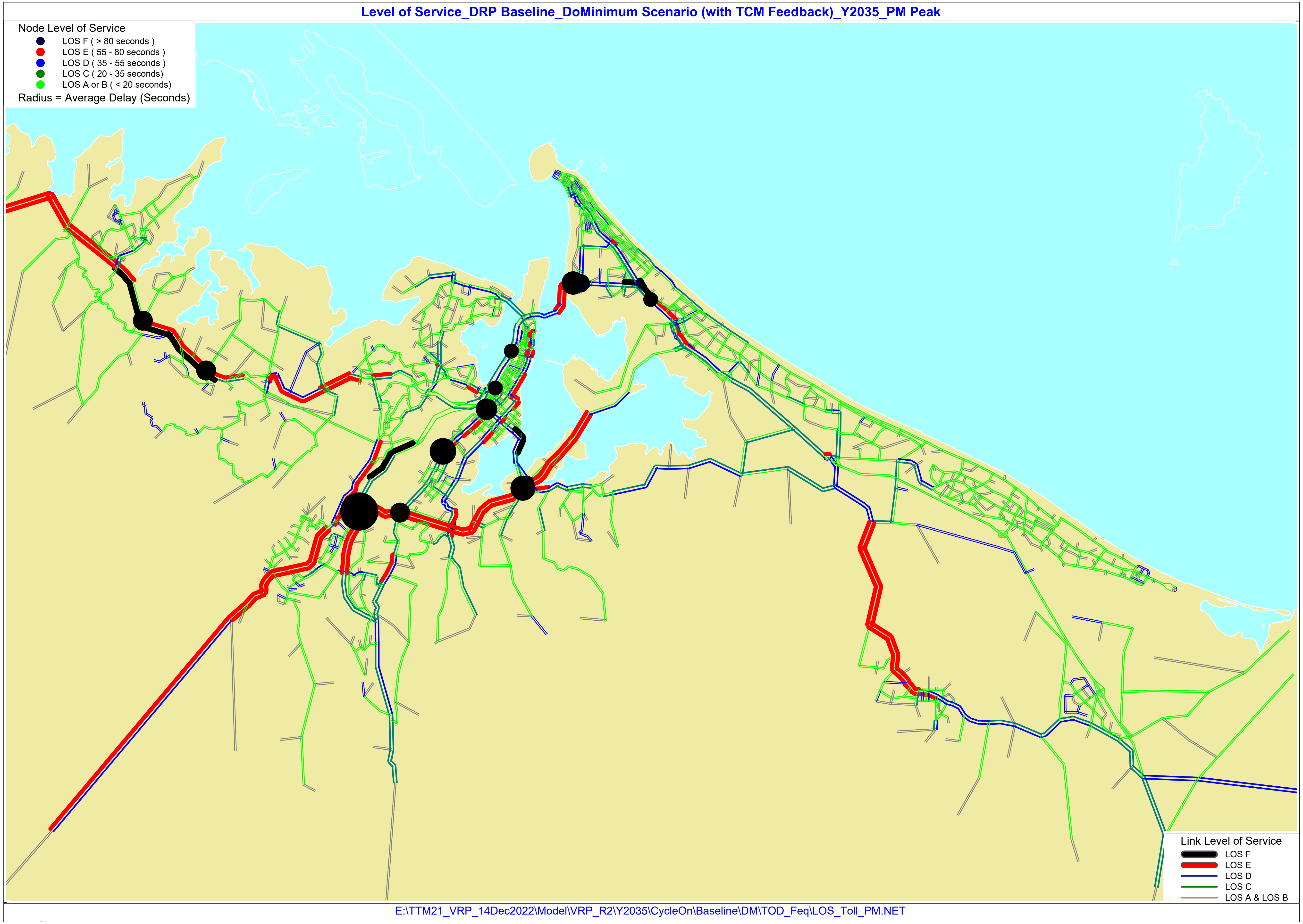
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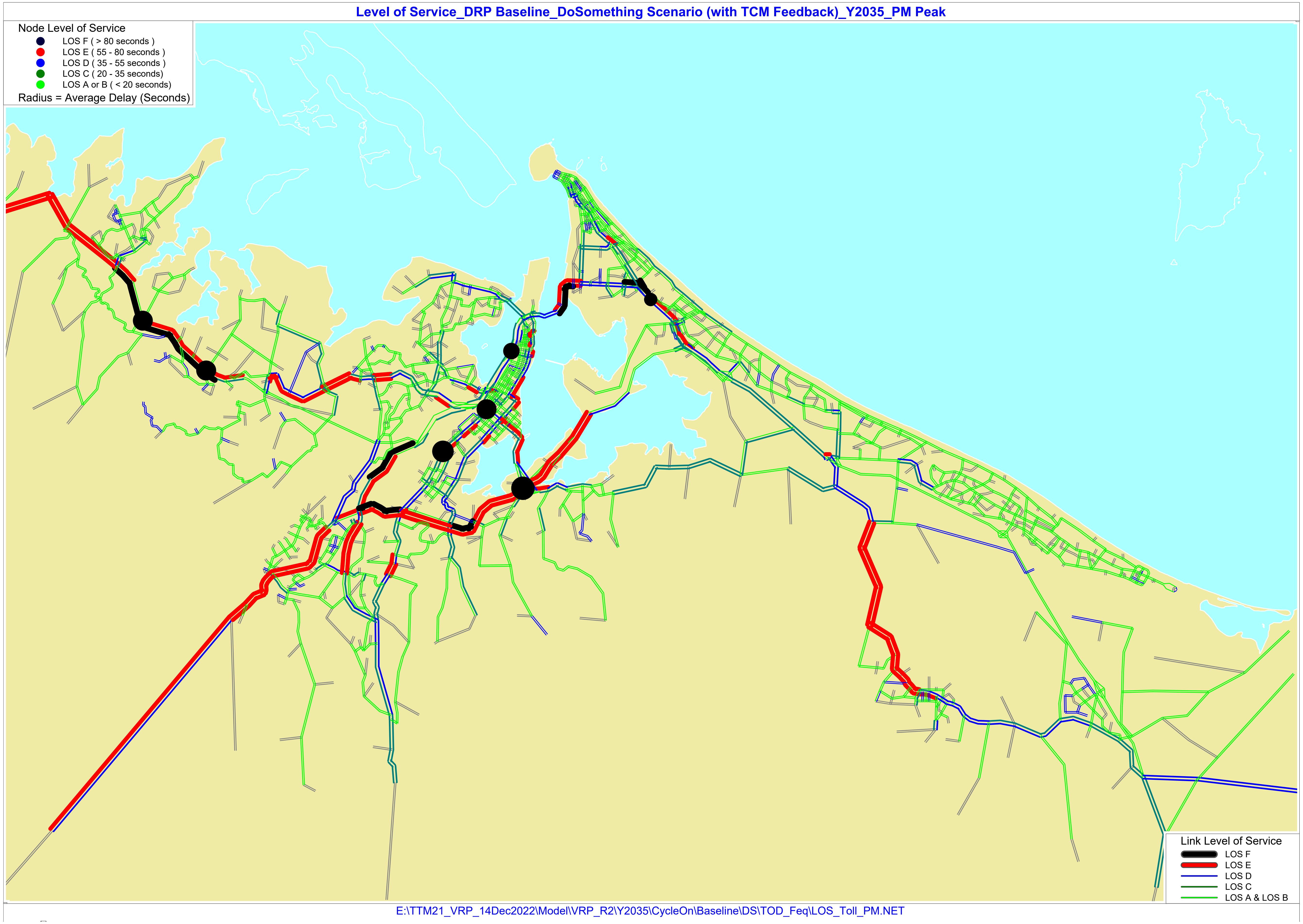
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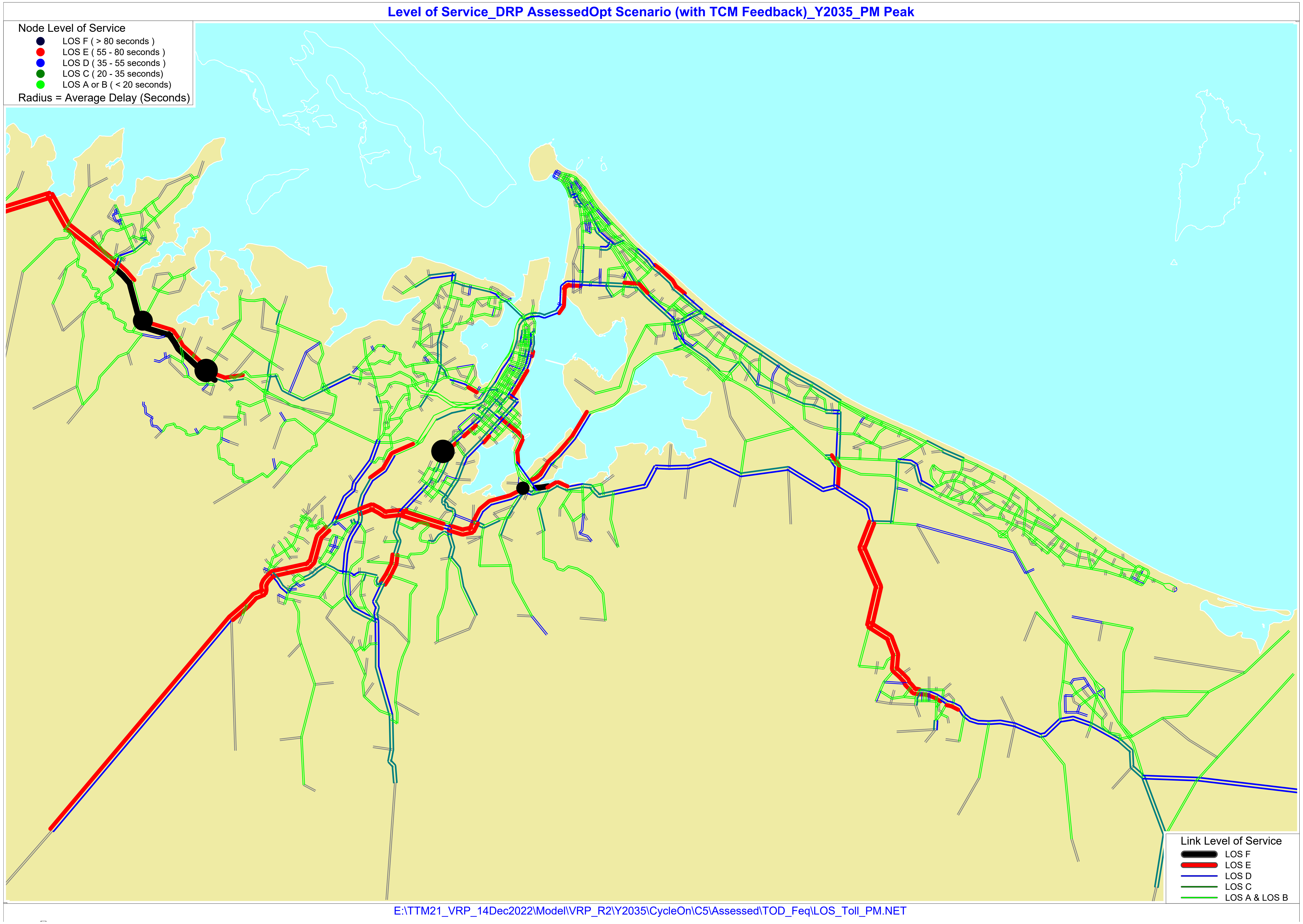
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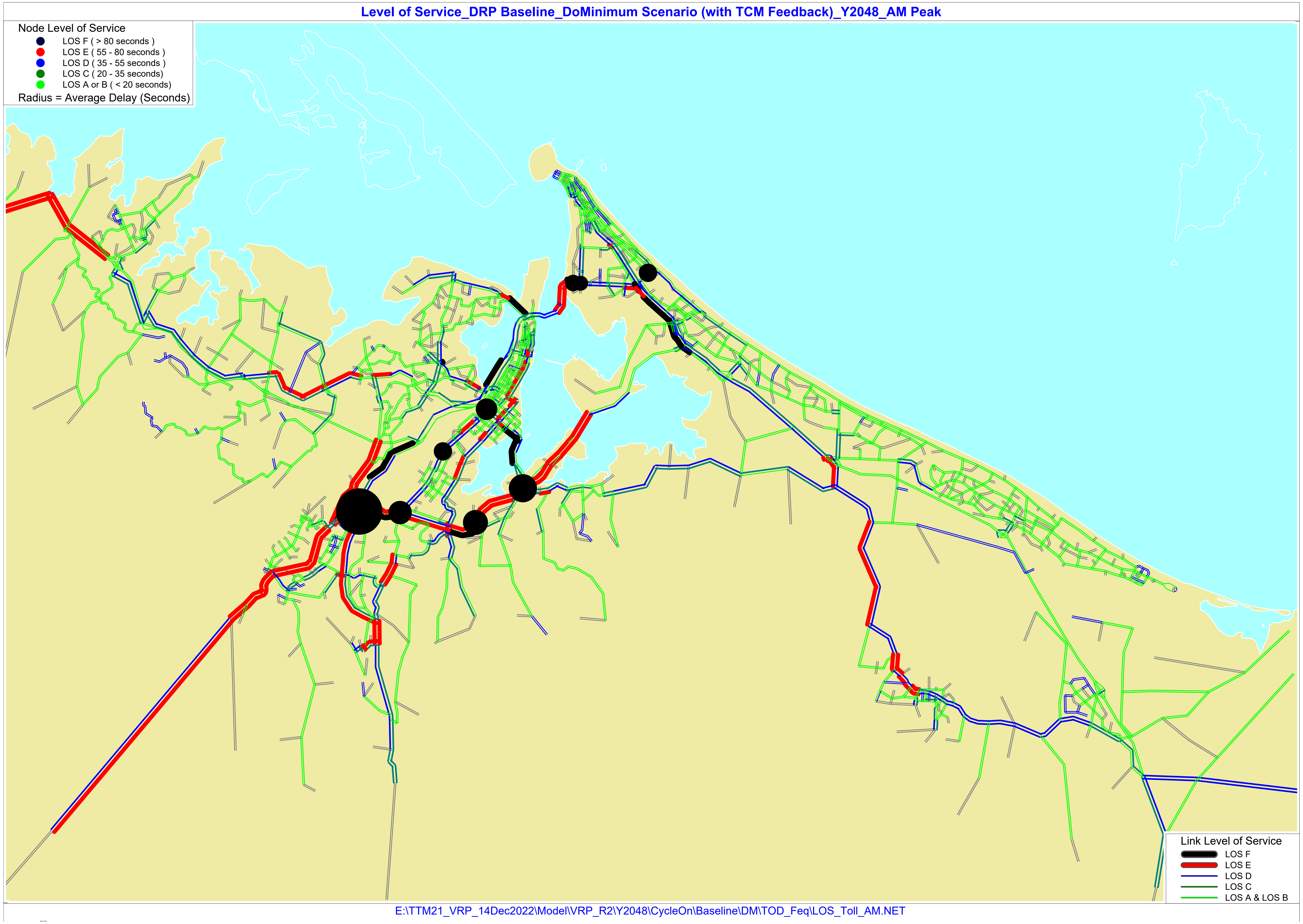
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Link Level of Service
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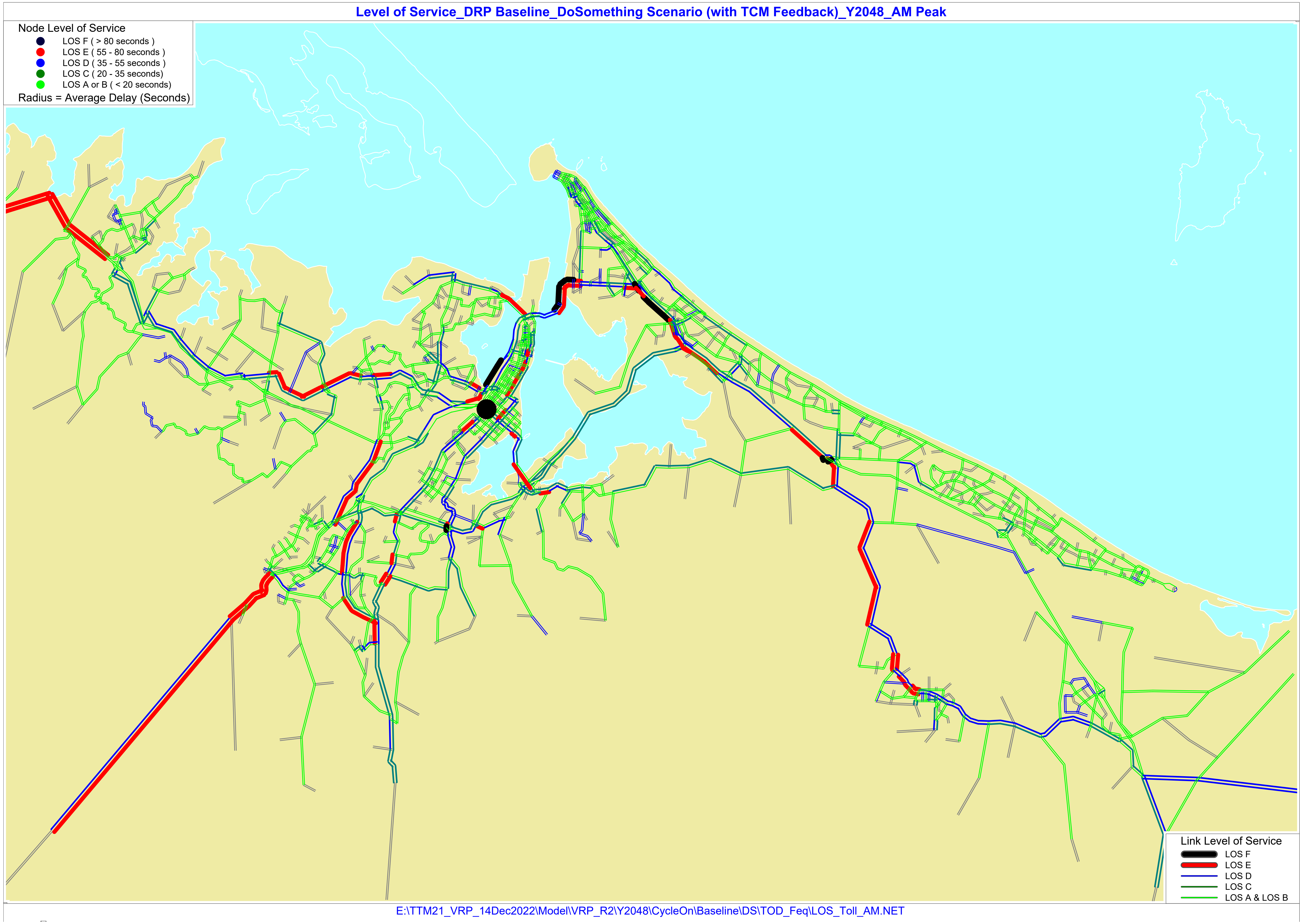
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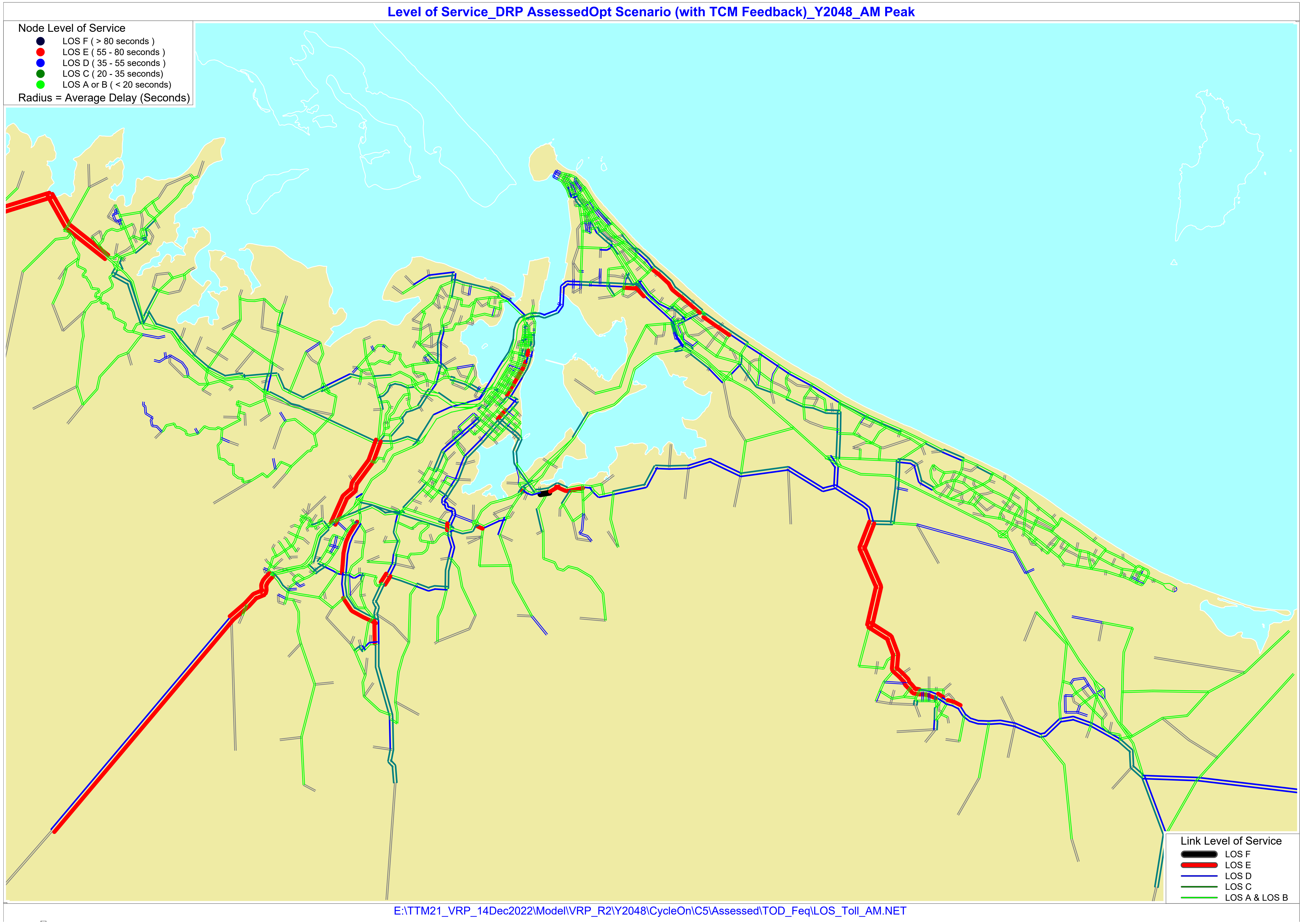
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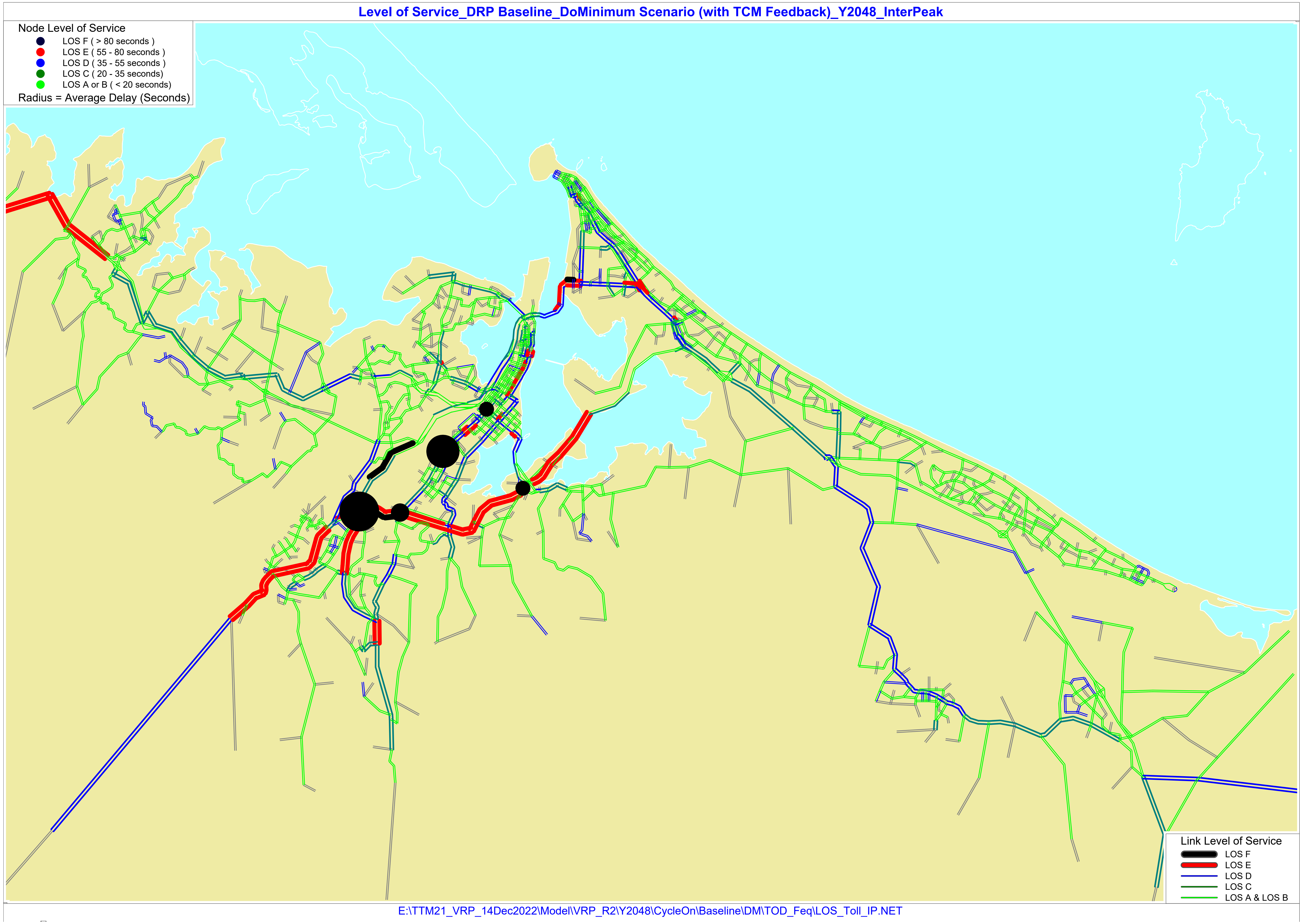
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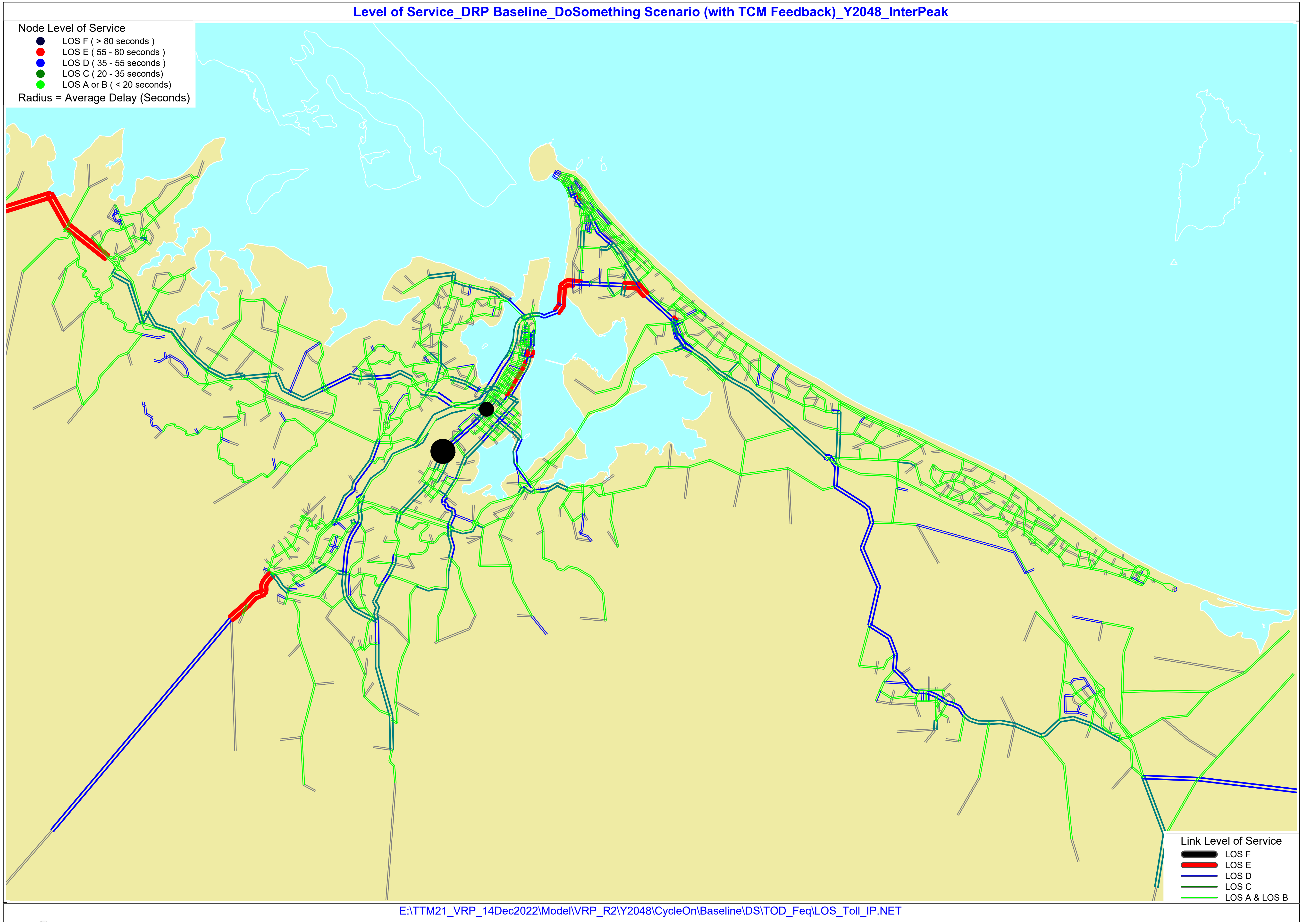
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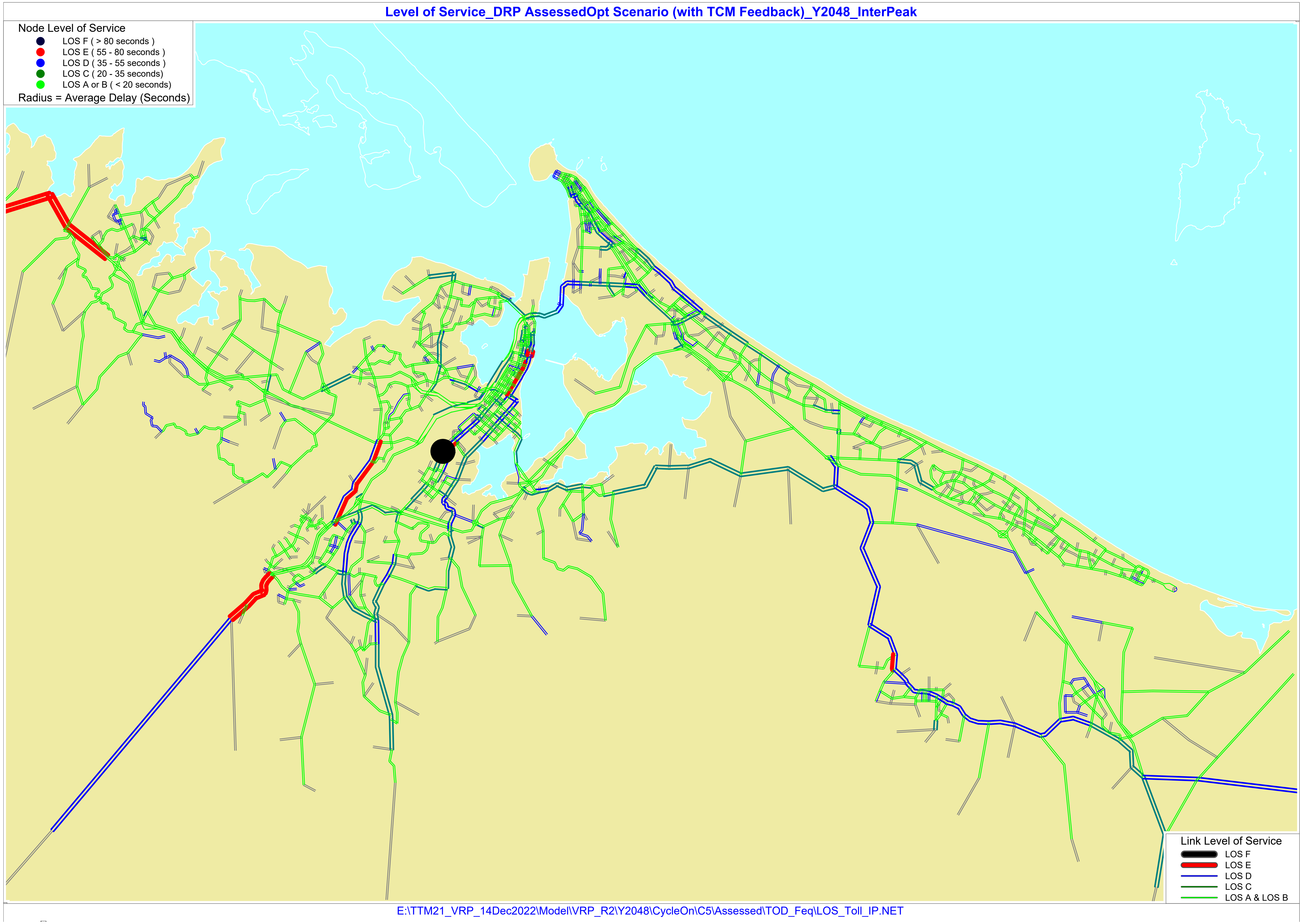
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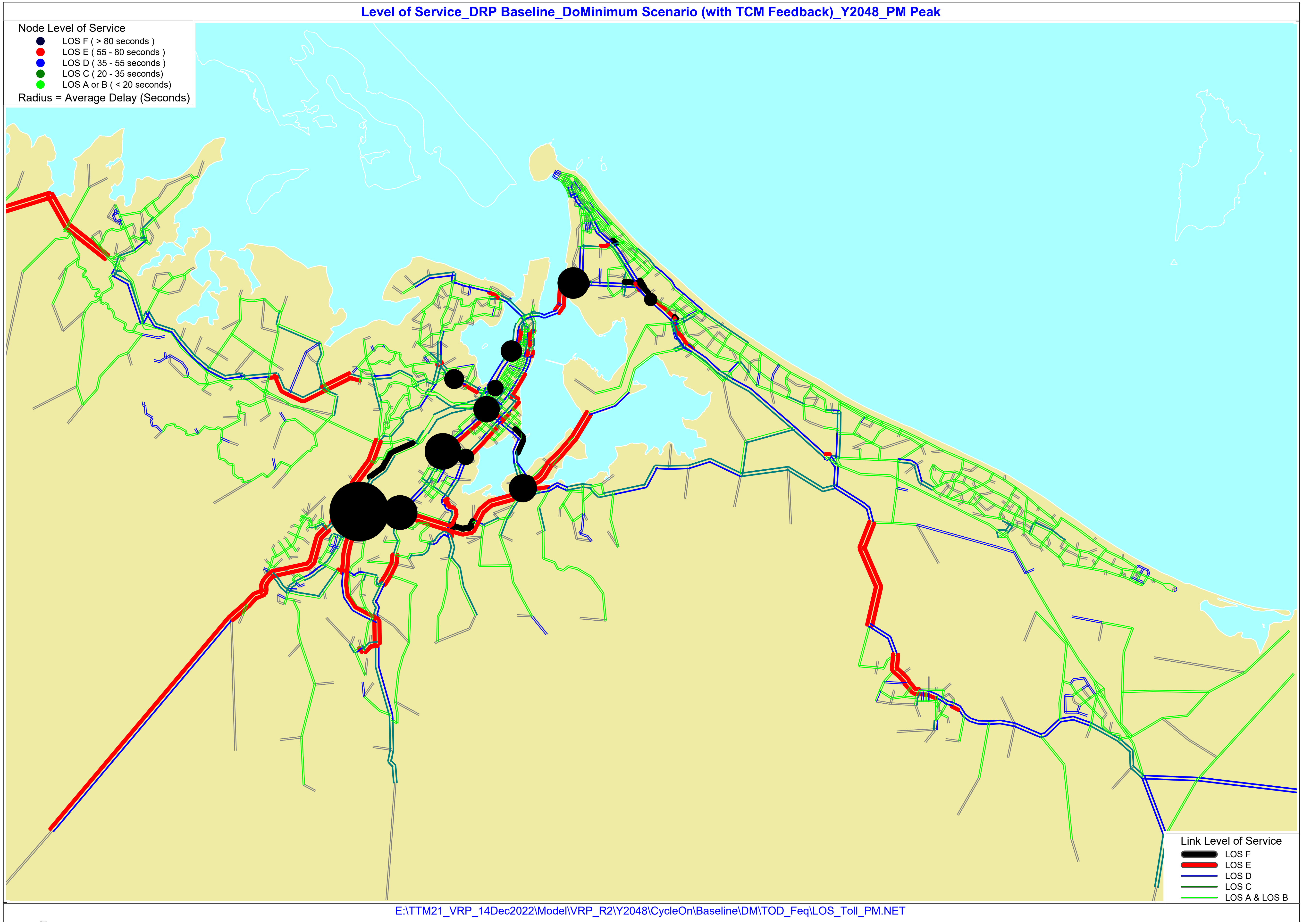
Level of Service_DRP Baseline_DoMinimum Scenario (with TCM Feedback)_Y2048_PM Peak
Node Level of Service
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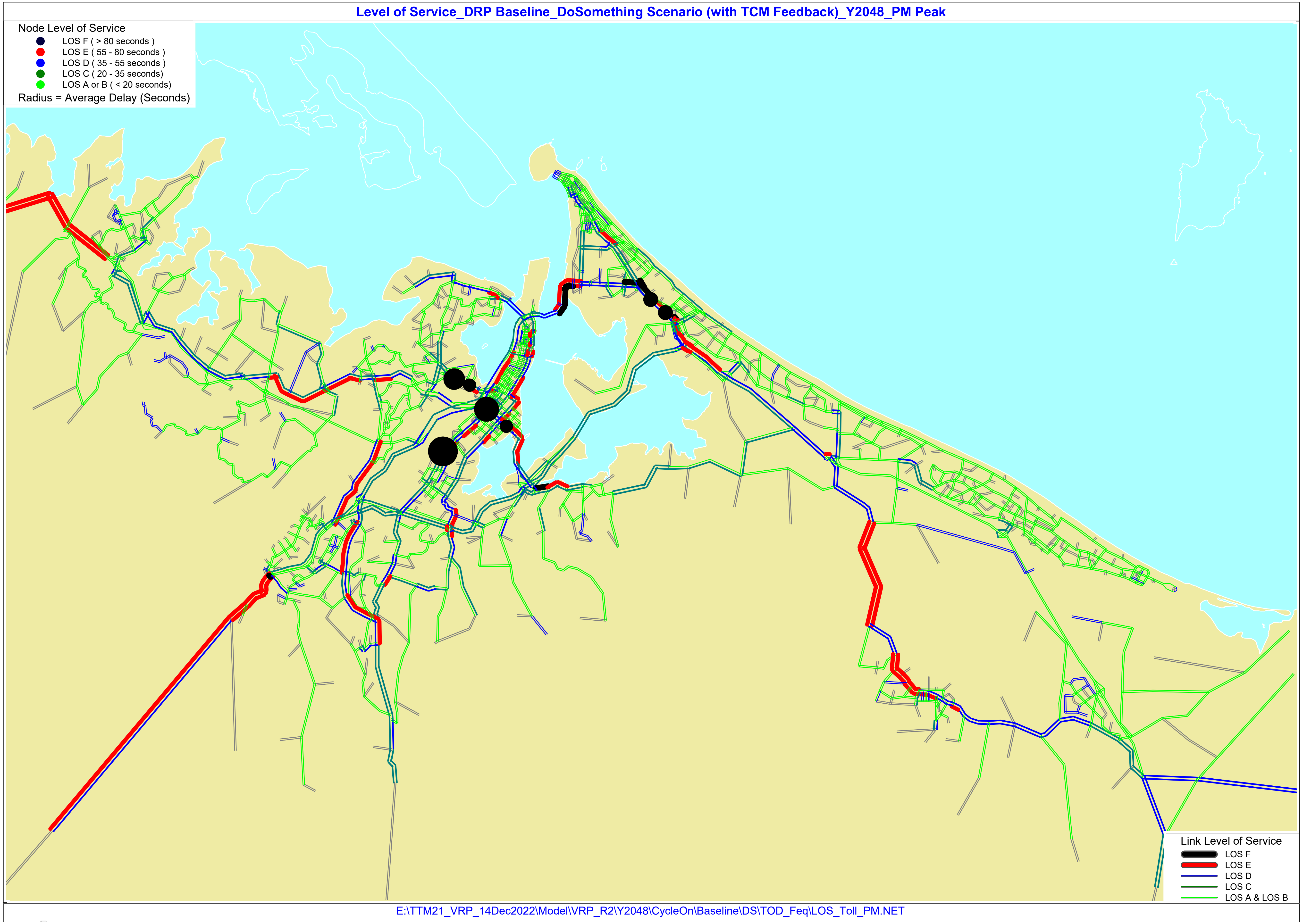
Level of Service_DRP Baseline_DoSomething Scenario (with TCM Feedback)_Y2048_PM Peak
Node Level of Service
LOS F (> 80 seconds)
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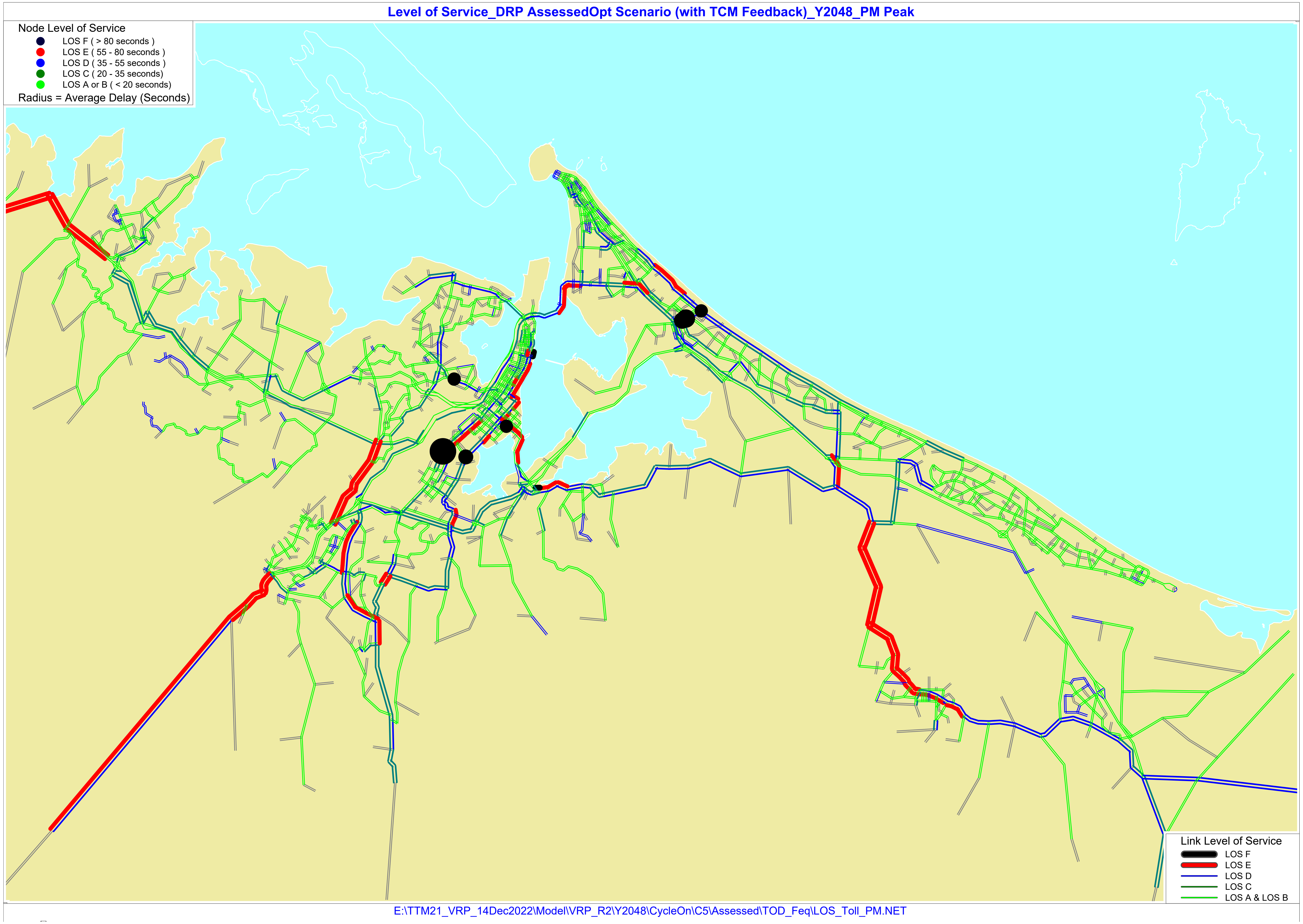
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LOS E (55 - 80 seconds)
LOS D (35 - 55 seconds)
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LOS A or B (< 20 seconds)
Radius = Average Delay (Seconds)
Link Level of Service
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LOS E
LOS D
LOS C
LOS A & LOS B
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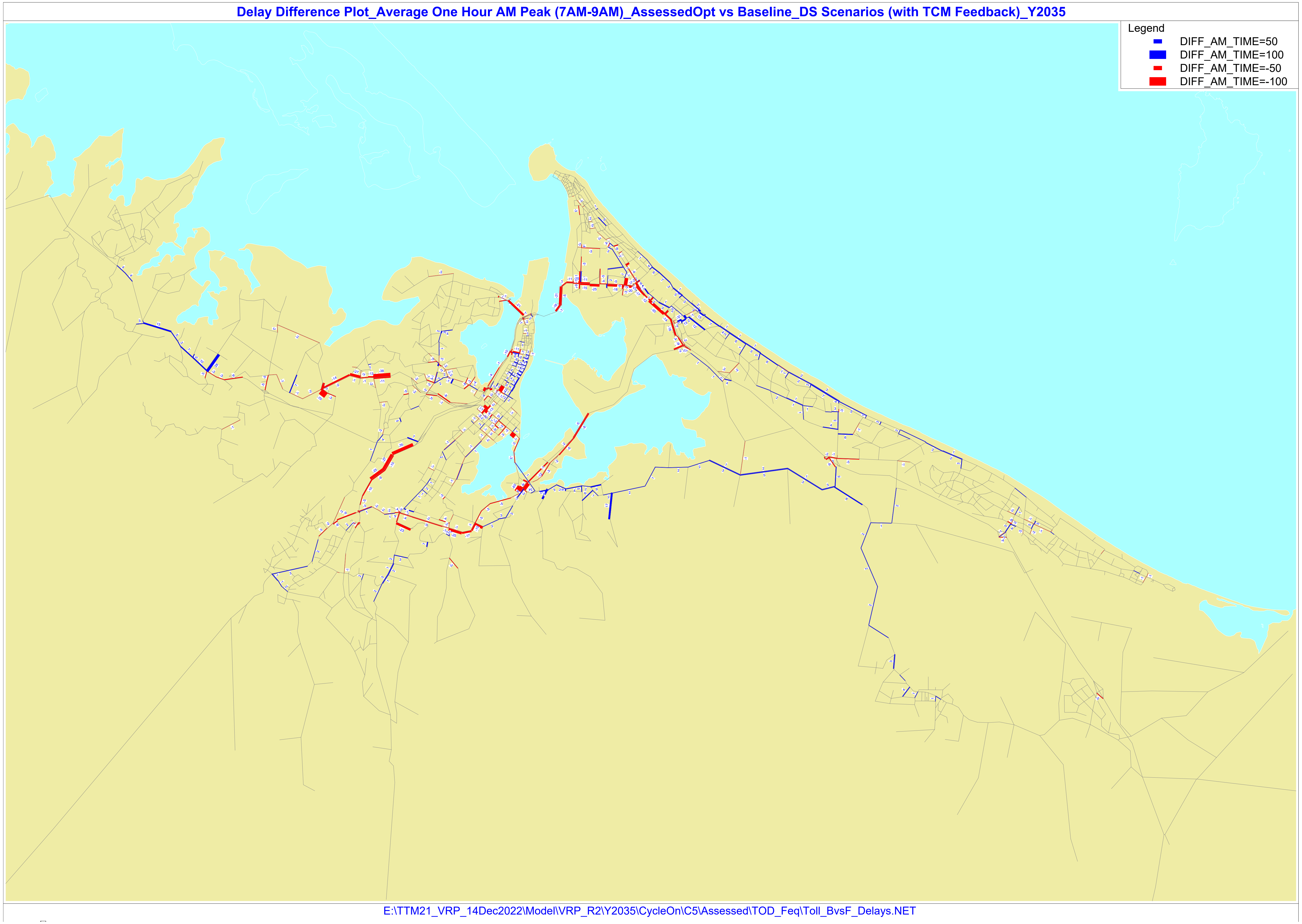
Delay difference plots


Delay Difference Plot_Average One Hour AM Peak (7AM-9AM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2035
Legend
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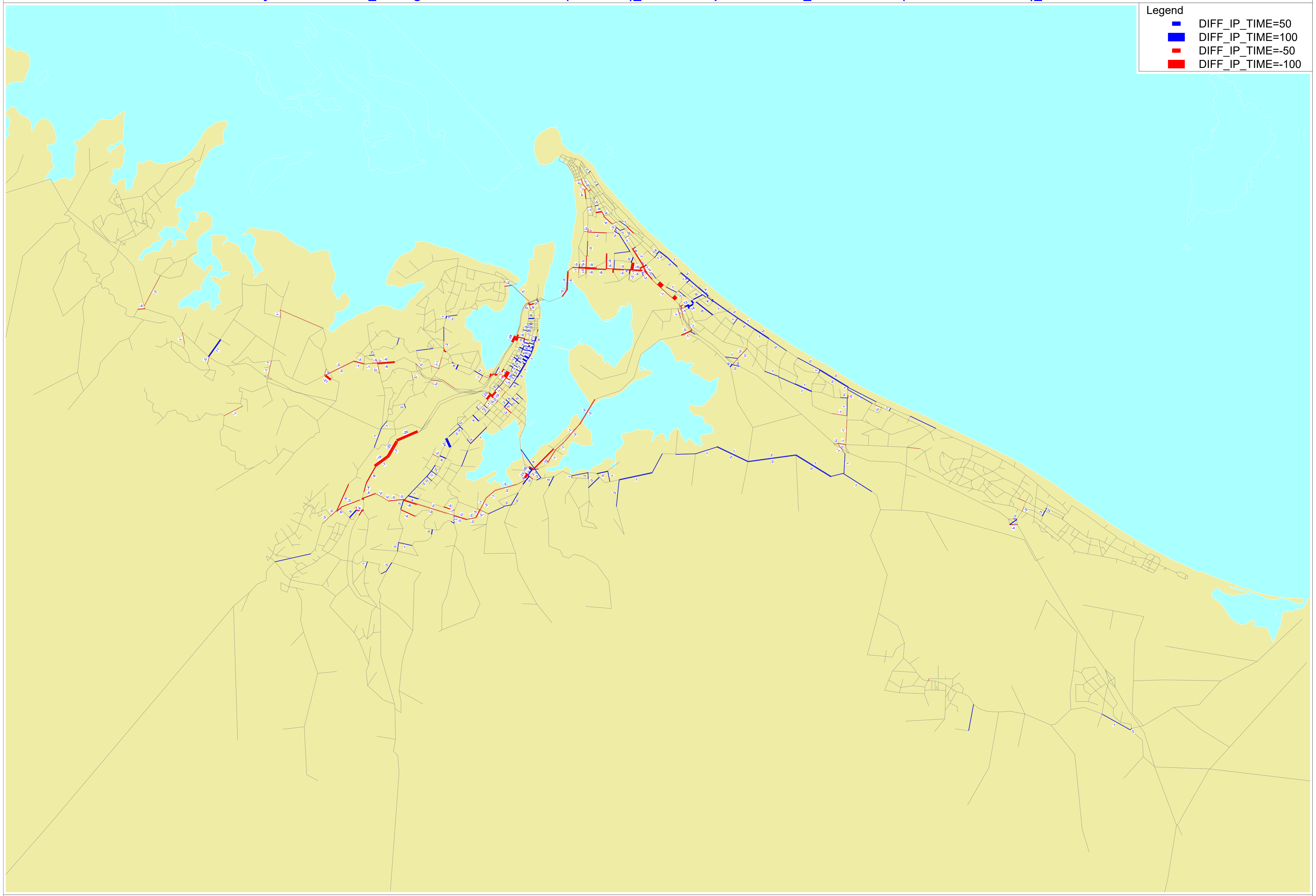
Delay Difference Plot_Average One Hour Inter Peak (9AM-4PM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2035



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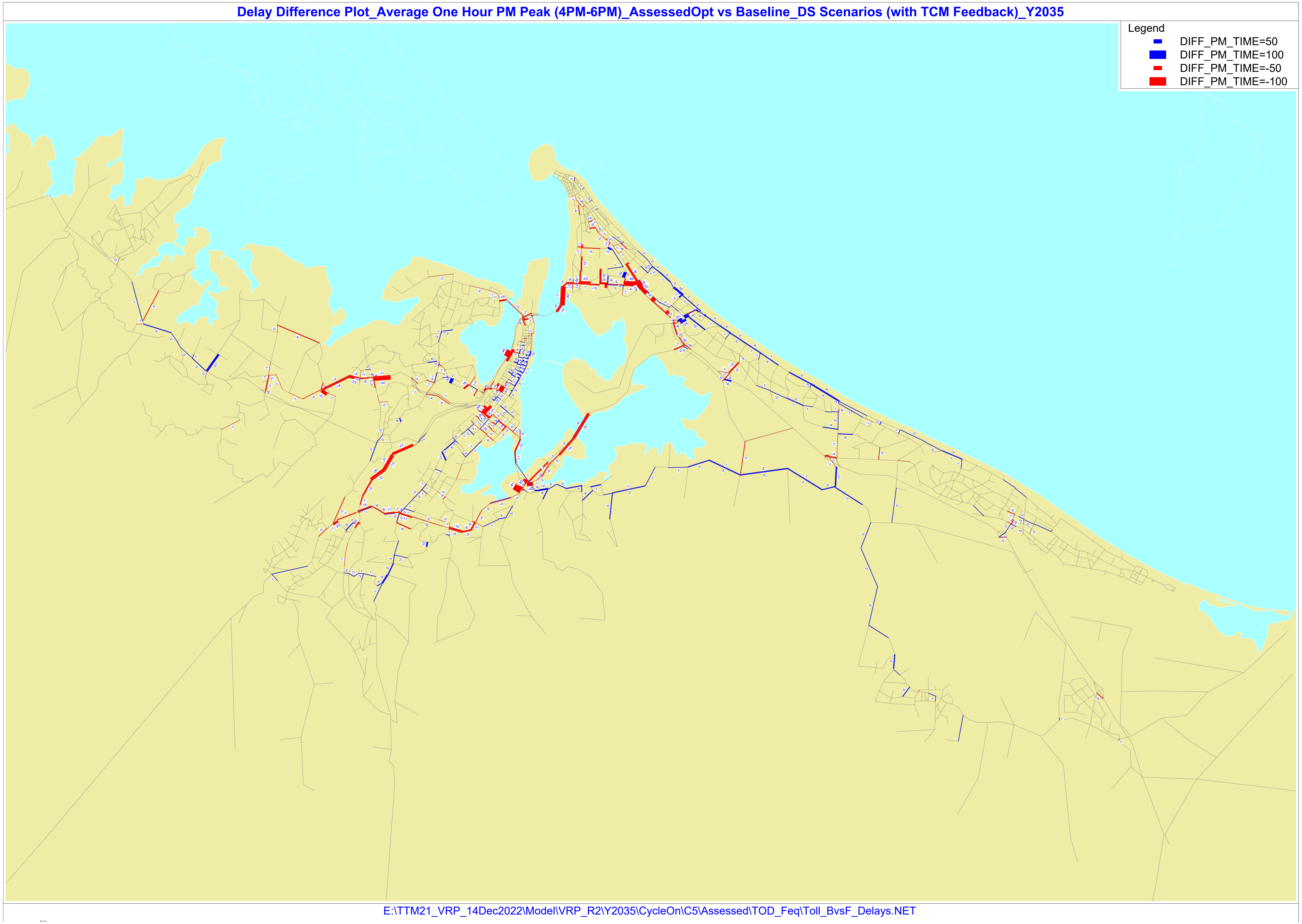
Delay Difference Plot_Average One Hour PM Peak (4PM-6PM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2035
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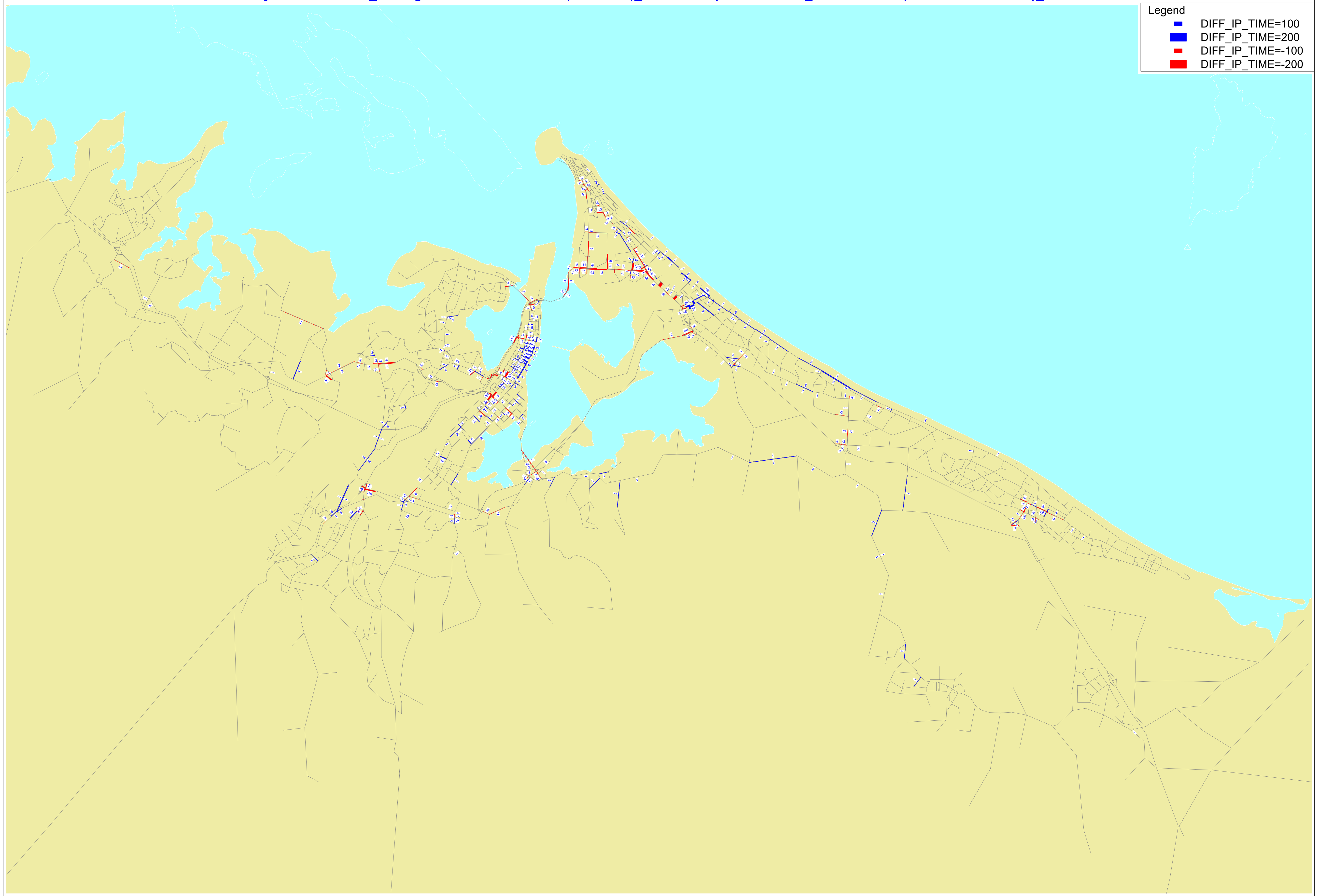
Delay Difference Plot_Average One Hour AM Peak (7AM-9AM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2048

E:\TTM21_VRP_14Dec2022\Model\VRP_R2\Y2048\CycleOn\C5\Assessed\TOD_Feq\Toll_BvsF_Delays.NET

Delay Difference Plot_Average One Hour Inter Peak (9AM-4PM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2048



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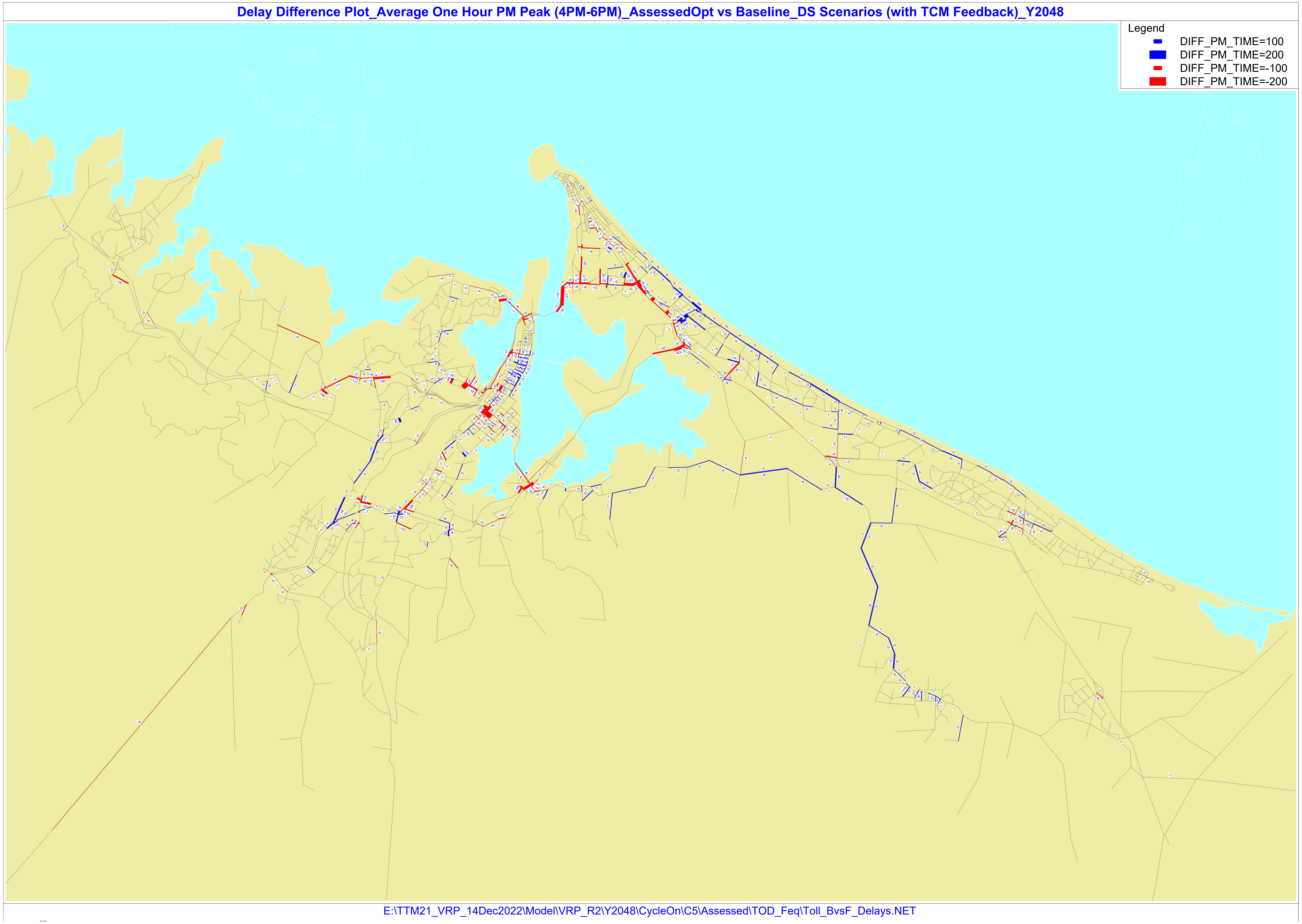
Delay Difference Plot_Average One Hour PM Peak (4PM-6PM)_AssessedOpt vs Baseline_DS Scenarios (with TCM Feedback)_Y2048
Legend
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Flow difference plots

Flow Difference Plot_Average One Hour AM Peak (7AM-9AM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2035

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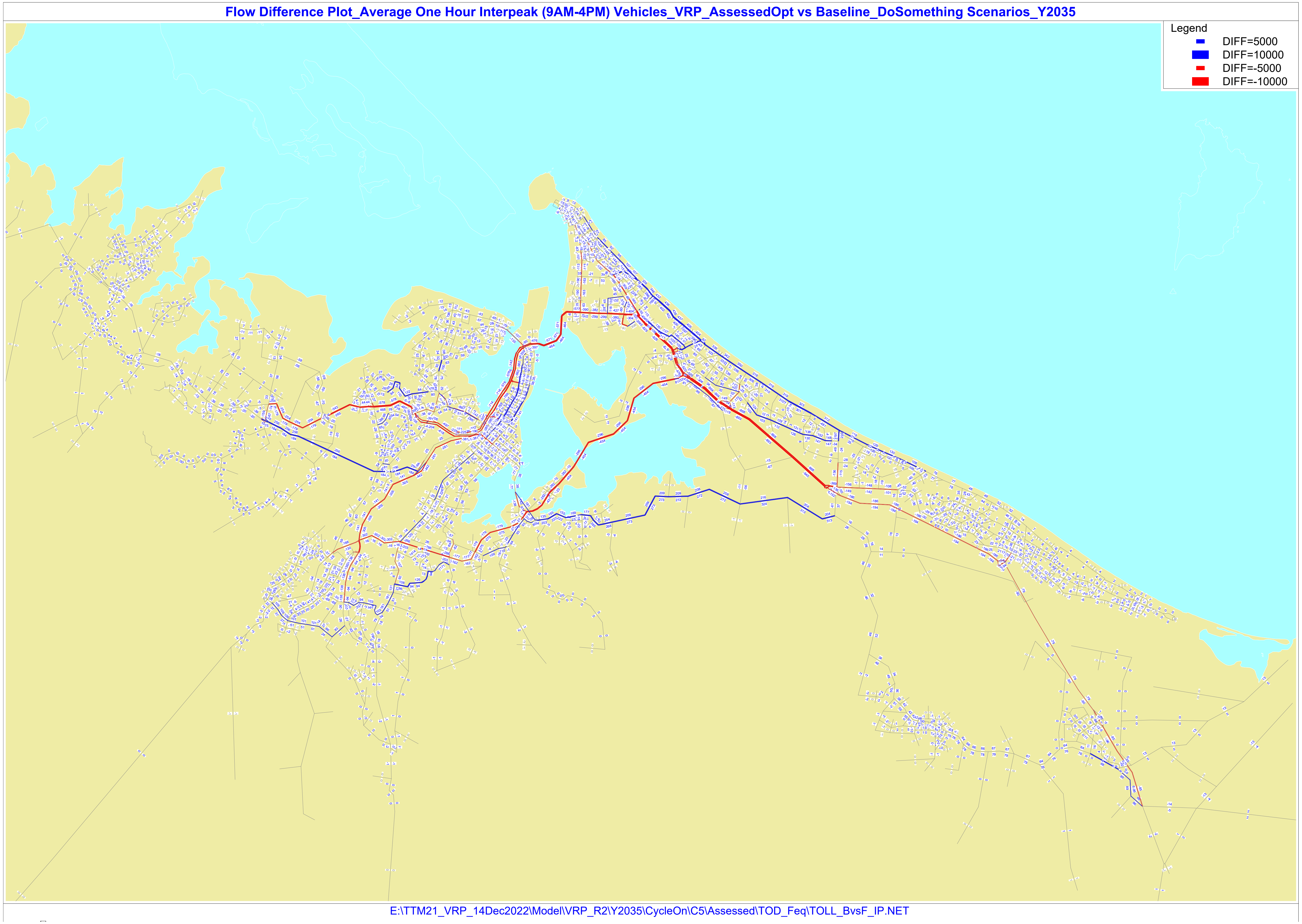
Flow Difference Plot_Average One Hour Interpeak (9AM-4PM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2035
Legend
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Flow Difference Plot_Average One Hour PM Peak (4PM-6PM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2035

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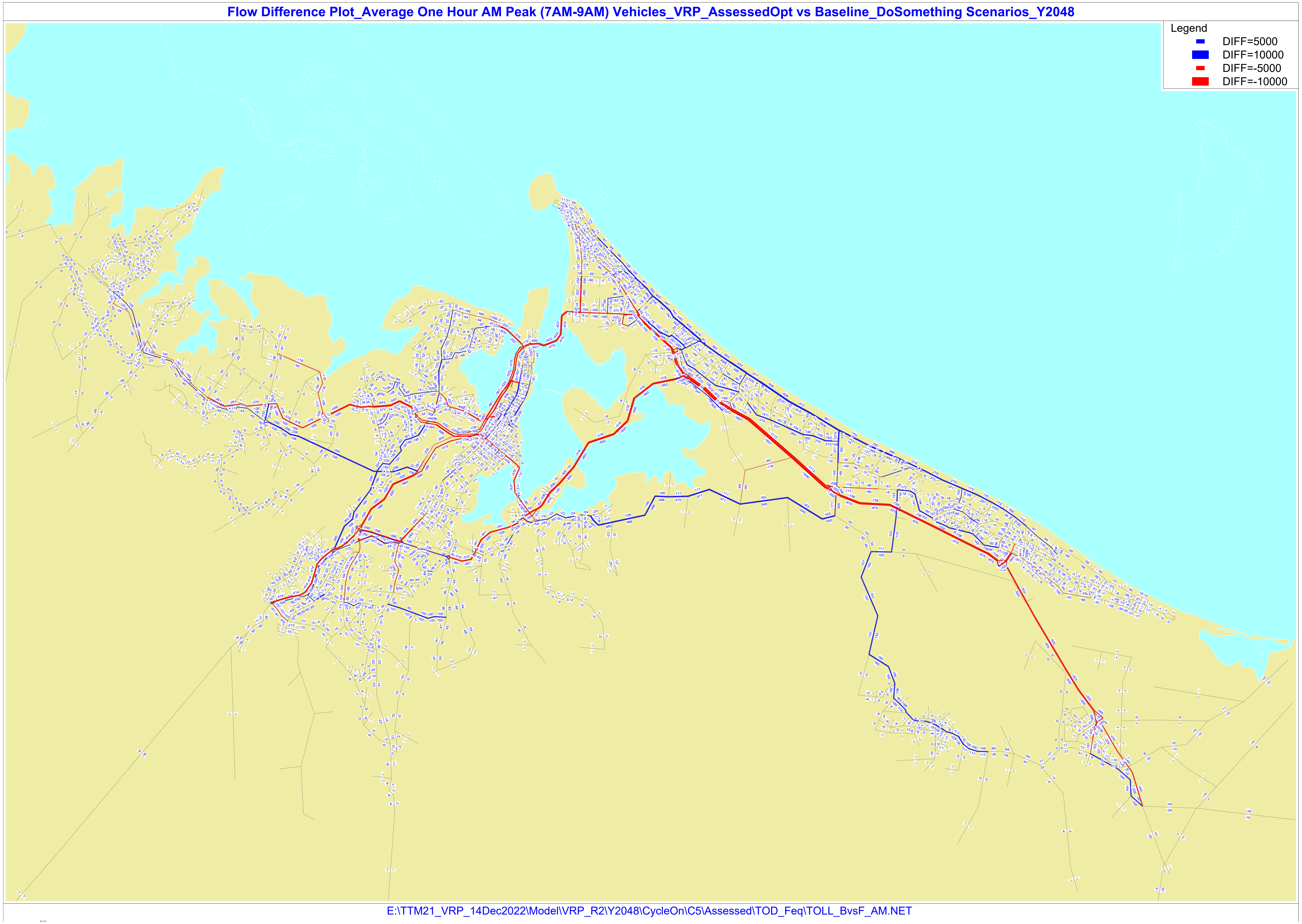
Flow Difference Plot_Average One Hour AM Peak (7AM-9AM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2048
Legend
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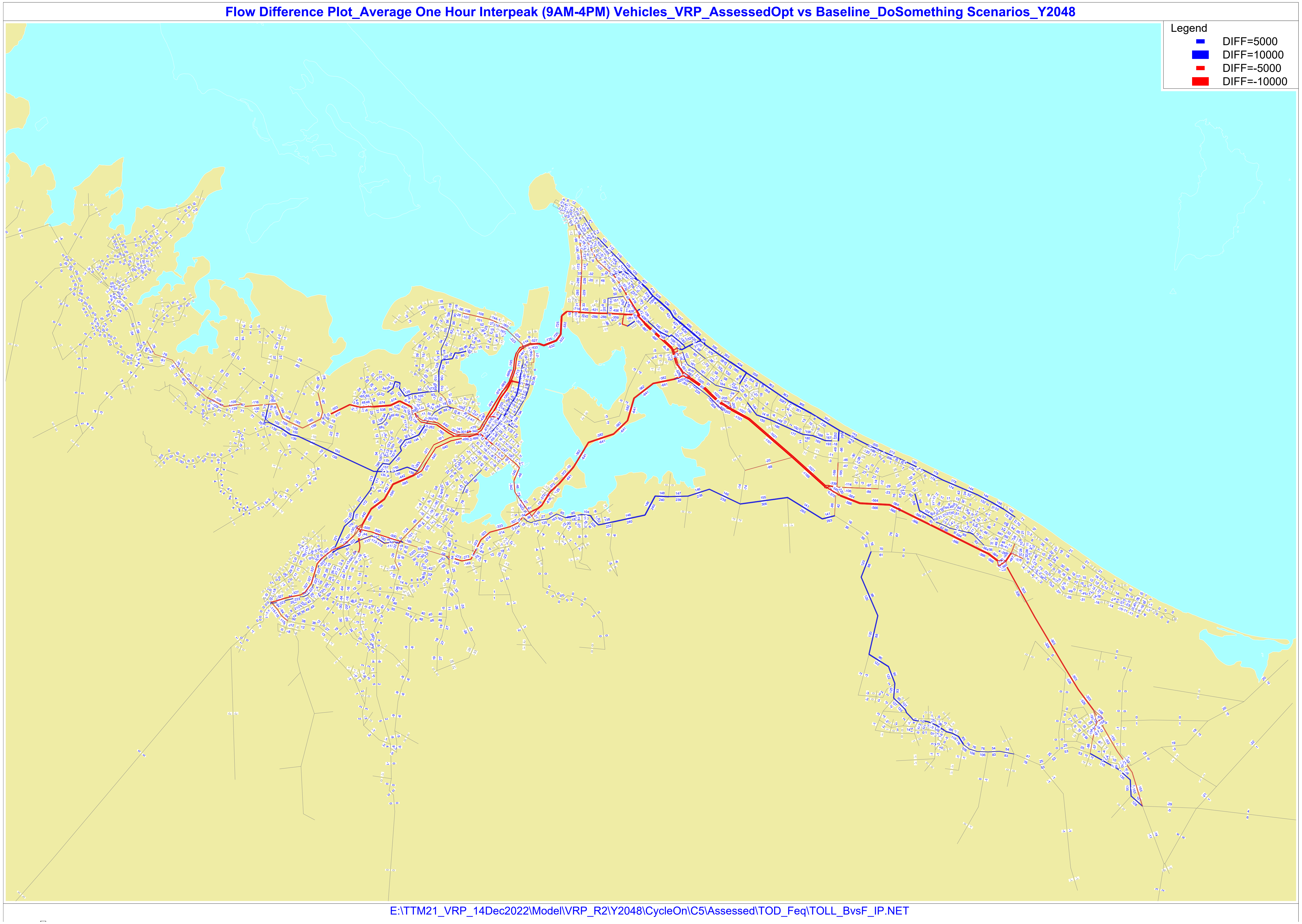
Flow Difference Plot_Average One Hour Interpeak (9AM-4PM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2048
Legend
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Flow Difference Plot_Average One Hour PM Peak (4PM-6PM) Vehicles_VRP_AssessedOpt vs Baseline_DoSomething Scenarios_Y2048

E:\TTM21_VRP_14Dec2022\Model\VRP_R2\Y2048\CycleOn\C5\Assessed\TOD_Feq\TOLL_BvsF_PM.NET

Journey times between centres

Journey times between centres by public transport in the morning peak period are presented in Table D2 to Table D9.

Table D2 AM peak period PT journey times from Katikati to City by centre (cumulative)

Centre	2035 Baseline DS	VRP	Change	% Change	2048 Baseline DS	VRP	Change	% Change
Katikati to Omokoroa	31	31	0	+0%	32	32	0	+0%
Omokoroa to Te Puna	54	55	1	+2%	43	43	0	+0%
Te Puna to Bethlehem	59	60	0	+1%	49	48	0	-0%
Bethlehem to Otumoetai	61	61	0	+1%	50	50	0	-0%
Otumoetai to City Centre	68	68	0	+0%	58	56	-1	-2%

Table D3 AM Peak period PT journey times from Mount Maunganui to City (cumulative)

Centre	2035 Baseline DS	VRP	Change	% Change	2048 Baseline DS	VRP	Change	% Change
Mount Maunganui to City	14	14	0	-2%	14	14	0	-2%

Table D4 AM Peak period PT journey times from Tauriko Pyes Pa to City (cumulative)

Centre	2035 Baseline DS	VRP	Change	% Change	2048 Baseline DS	VRP	Change	% Change
Tauriko Pyes Pa Greerton	4	4	0	0%	5	5	0	0%
Greerton to Hospital Precinct	9	9	0	0%	10	10	0	0%
Hospital Precinct to City	14	14	0	0%	15	15	0	0%

Table D5 AM Peak period PT journey times from Paengaroa to City (cumulative)

	2035	2048

Centre	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Paengaroa to Rangiuru	6	6	0	0%	6	6	0	0%
Rangiuru to Wairakei Te Tumu	15	15	0	0%	15	15	0	0%
Wairakei Te Tumu to Papamoa	23	23	0	0%	23	23	0	0%
Papamoa to Bayfair	34	33	-1	-4%	34	33	-1	-4%
Bayfair to City	49	45	-4	-8%	49	45	-4	-8%

Journey times between centres by car in the morning peak period are presented in Table K to Table N

Table D6 AM peak period car journey times from Katikati to City (cumulative)

	2035				2048			
Centre	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Katikati to Omokoroa	17	17	0	+0%	18	18	0	17
Omokoroa to Te Puna	30	31	0	+1%	23	23	0	30
Te Puna to Bethlehem	35	35	-1	-2%	28	27	-1	35
Bethlehem to Otumoetai	37	36	-1	-4%	30	29	-1	37
Otumoetai to City Centre	42	40	-2	-4%	35	33	-2	42

Table D7 AM Peak period car journey times from Mount Maunganui to City (cumulative)

Centre	2035				2048			
	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Mount Maunganui to City	10	9	0	-2%	10	10	0	10

Table D8 AM Peak period car journey times from Tauriko Pyes Pa to City (cumulative)

	2035				2048			

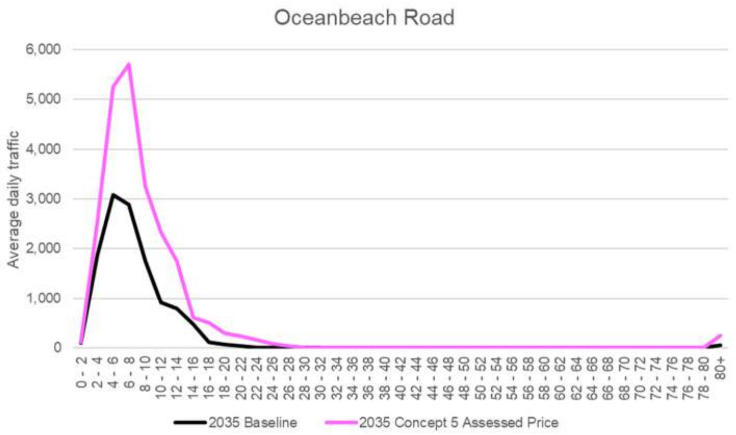
	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Tauriko Pyes Pa Greerton	4	4	0	0%	5	5	0	0%
Greerton to Hospital Precinct	9	9	0	0%	10	10	0	0%
Hospital Precinct to City	14	14	0	0%	15	15	0	0%

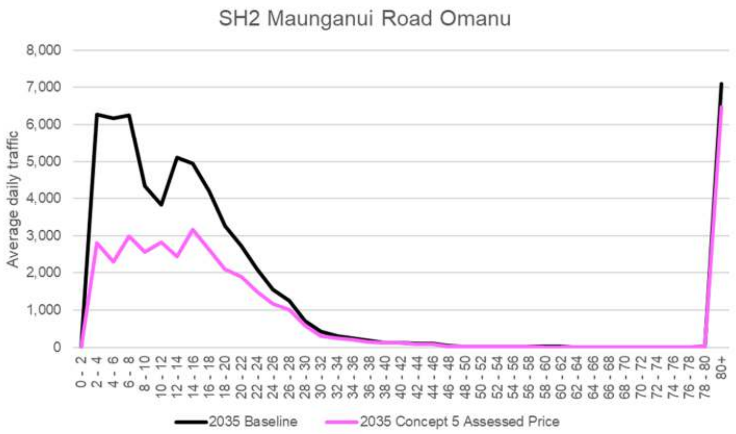
Table D9 AM Peak period car journey times from Paengaroa to City (cumulative)

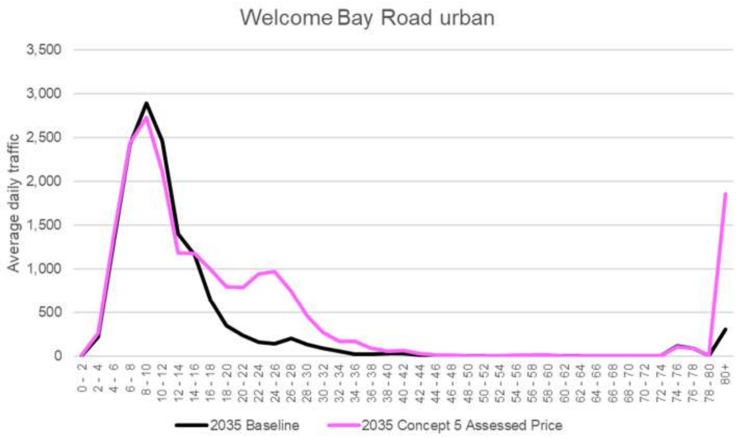
	2035				2048			
	Baseline DS	VRP	Change	% Change	Baseline DS	VRP	Change	% Change
Paengaroa to Rangiuru	6	6	0	0%	6	6	0	0%
Rangiuru to Wairakei Te Tumu	15	15	0	0%	15	15	0	0%
Wairakei Te Tumu to Papamoa	23	23	0	0%	23	23	0	0%
Papamoa to Bayfair	34	33	-1	-4%	34	33	-1	-4%
Bayfair to City	49	45	-4	-8%	49	45	-4	-8%

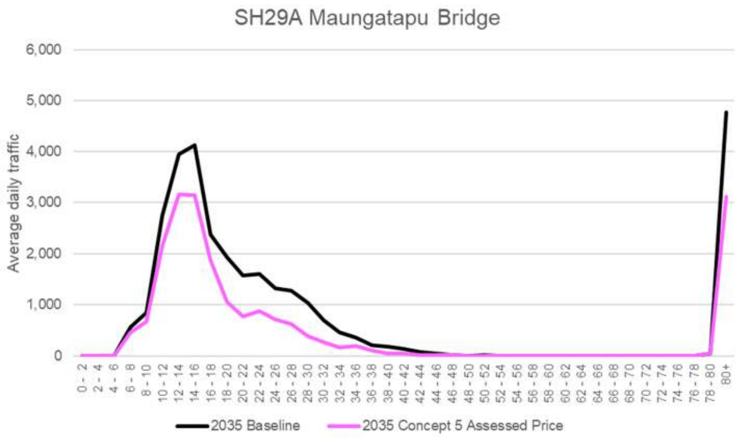
Trip Length Frequency Distributions

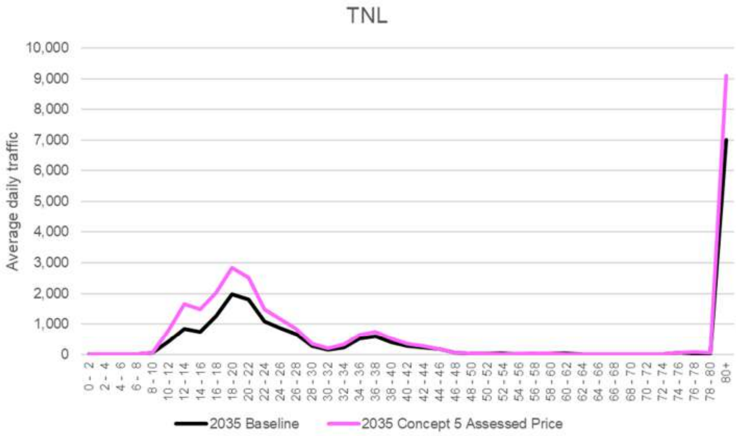
The impact of road pricing on trip length frequency distribution for the 13 select link locations are shown in the following plots:

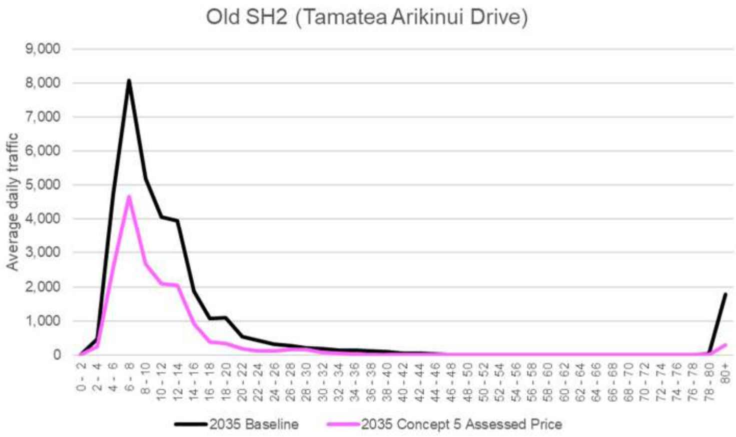




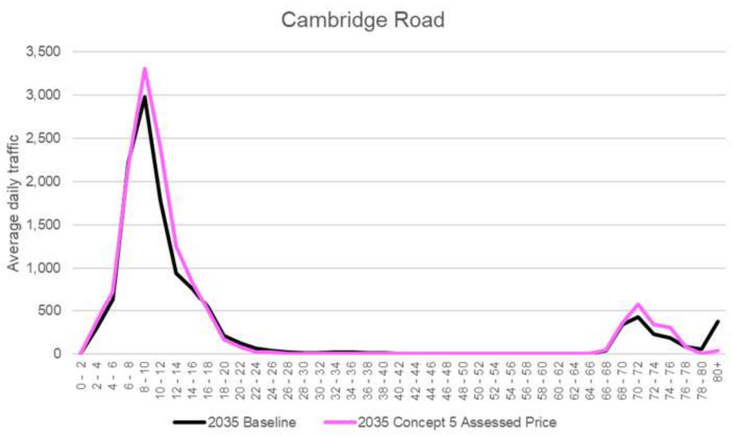

Welcome Bay Road urban
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

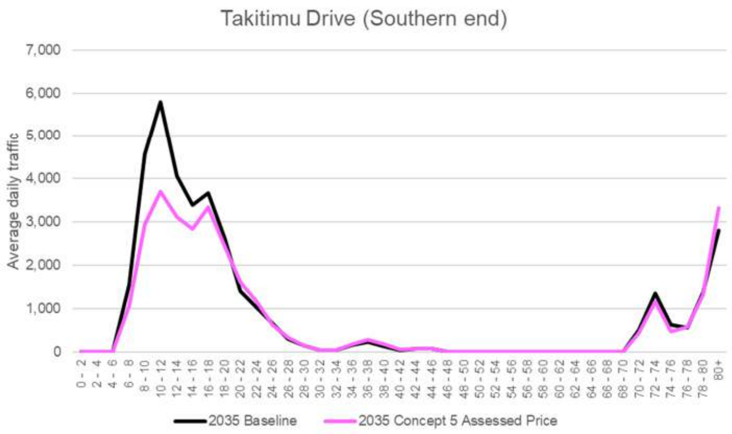

SH29A Maungatapu Bridge
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

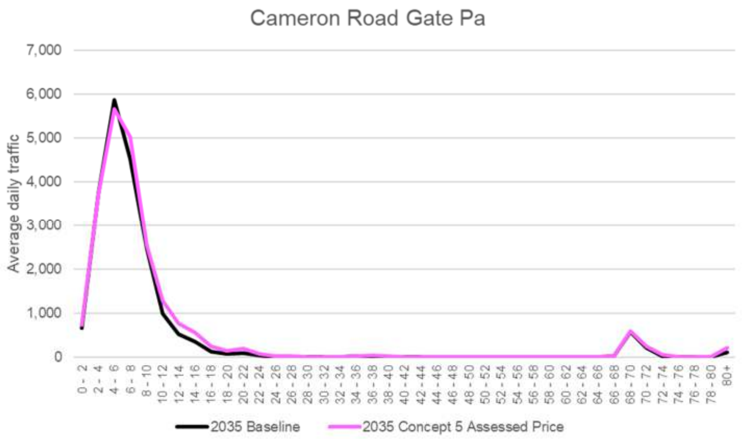

TNL
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

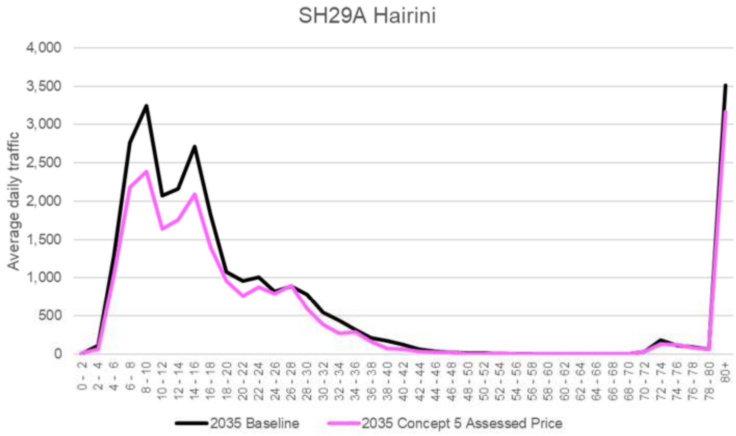

Old SH2 (Tamatea Arikinui Drive)
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

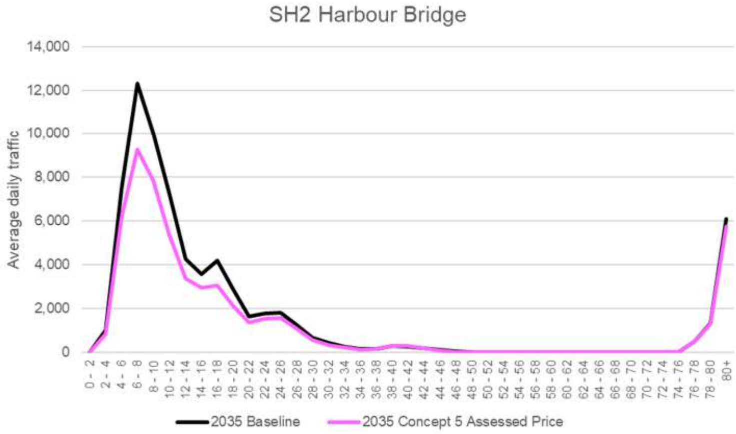

Waihi Road
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

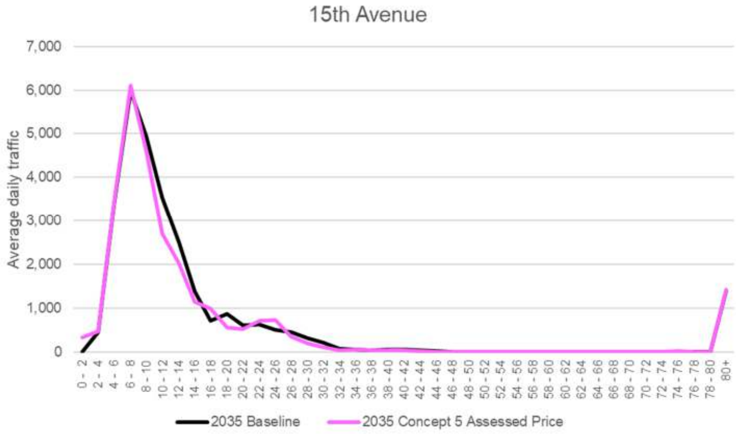

Cambridge Road
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price


Takitimu Drive (Southern end)
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price


Cameron Road Gate Pa
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price


SH29A Hairini
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price


SH2 Harbour Bridge
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price


15th Avenue
Average daily traffic
2035 Baseline
2035 Concept 5 Assessed Price

Annualisation factors

Annualisation factors used for the annualisation of the traffic volumes are shown in Table D10 below. These factors are used for the annualisation of traffic volumes in the calculation of the revenue from existing tolls and TNL in the baseline scenarios. The formula is:

$$Annual\ volume_{vehicle\ Type} = 365 \times 0.869 \times \frac{AM\ mod\ vol \times AM\ factor + IP\ mod\ vol \times IP\ factor + PM\ mod\ vol \times PM\ factor}{\text{Denominator value}}$$

Table D10 Traffic Volume annualisation factors

	Lights	Heavies
AM factors	2	2
IP factors	7	7
PM factors	2	2
Denominator value	0.79	0.81
ADT to AADT	0.896	0.896
AADT to annual	365	365

Annualisation factors usually used for the annualisation of economic benefits used for revenue from road pricing as they provide specific factors for OP and Weekends. These factors are shown in Table D11 below.

Table D11 Economic benefits annualisation factors

	Lights and heavies	Daily to Annual	Modelled time period revenue is based on
AM factors	2	245	AM
IP factors	7	245	IP
PM factors	2	245	PM
OP factors	3.04	245	IP
WE factors	9.62	120	PM

E

Appendix E Economic Evaluation information

This economic evaluation (i.e. net present calculation) has been undertaken in accordance with Waka Kotahi's Monetised Benefits and Cost Manual (MBCM). The general assumptions used in this economic appraisal are listed below:

- Base Date of 1 July 2017;
- Time Zero of 1 July 2028;
- 1-year design period starting in 2028
- 1-year construction period starting in 2029
- Project Opening Year: 2030;
- Analysis Period: 40 years;
- Urban Arterial values of travel time savings (VTTS) have been adopted;
- Discount rate of 4.0%;
- CO_2E, PM_{10}, NOx and CO benefits using MBCM's guideline;

Traffic Benefit Calculation

The two benefit streams calculated internally in the TTSM are:

- Travel Time Costs (hours); and
- Vehicle Operating Costs ($).

Travel Times Costs

For this assessment, the two considered components of travel time were:

- Base travel time;
- Congested travel time (denoted as 'CRV' in the MBCM)

Base travel time indicates whether the initiative would improve traffic flows in terms of total travel time between the option and the reference scenario. It is applied to the entire network. Congested travel time is applied only on road sections that are deemed congested. CRV benefits/dis-benefits are calculated in accordance with the MBCM as follows:

- Urban roads in the model use the methodology for urban roads, whereby CRV only applies to links with a Volumes/Capacity (V/C) ratio greater than 70%; and
- Rural roads used the Percent Time Delayed (PTD) method. The PTD was estimated from the V/C ratios by adopting values from the MBCM, assuming generally rolling terrain, and typically 50% of overtaking sight distance less than 400m.

Vehicle Operating Costs (VOC)

- The three components of VOC that were evaluated as part of this assessment were:

Base running costs

- Base running costs were calculated for each link based on the average travel speed and vehicle type by adopting the regression formulas in the MBCM and assuming an average gradient of 0%. This regression formula is defined as:

$$VOC_B = a + c.\ln(S) + e.[\ln(S)]^2 + h.[\ln(S)]^3$$

Where VOC_B = Base running cost in cents/km

S = speed in km/hr

a,c,e,h = coefficients as per table below.

Coefficients for light vehicles were estimated as a weighted average between those provided for passenger cars and those for light commercial vehicles. Similarly, coefficients for medium (MCV)/heavy commercial vehicles (HCV) were estimated as a weighted average of MCV, HCV-I and HCV-II coefficients.

Table E1 Coefficients for Base VOC Models (2015)

Coefficient	Light Vehicles	MCV / HCV
a	21.2535	-28.5846
c	27.7933	155.5623
e	-13.4476	-55.6943
h	1.6345	6.141633

Fuel costs at intersections

- Fuel costs at idle were applied to all intersection that were experiencing delays at a rate of 1.89 c/min for light vehicles and 3.96 c/min for medium and heavy class vehicles.

Additional running costs due to road congestion

- Additional VOC running costs were calculated using the following formula and by adopting the values in the table below (adopted from MBCM, Table A5.21). This can be expressed as:

VOC_{cong} = min {a, exp(b + c*VC) – exp(b)}

Where VOC_{cong} = additional VOC due to congestion in cents/km

VC = Volume to Capacity Ratio, and

a -c = coefficients as indicated in table below.

Table E2: Coefficients for Congested VOC Models (2015)

Coefficient	Urban	Rural 2-Lane Highway		Motorway
		Strategic	Other	
a	9.211	7.704	6.979	7.084
b	-1.904	-1.235	-1.563	-5.931
c	4.327	3.210	3.408	7.866

Benefit Calculation Process

For this study, a Variable Trip Matrix (VTM) benefit calculation procedure was used. The calculation is based on the formula provided in Section A11-12 of the Waka Kotahi NZ Transport Agency's Economic Evaluation Manual (MBCM). This formula is provided below:

$$Bij = (R_{ij}^{DM}\, T_{ij}^{DM} - R_{ij}^{OPT}\, T_{ij}^{OPT}) + \tfrac{1}{2}\,(U_{ij}^{DM} + U_{ij}^{OPT}) \times (T_{ij}^{OPT} - T_{ij}^{DM})$$

Where T_{DM} = Number of trips in the Do Minimum

T_{OPT} = Number of trips in the Option

U_{DM} = User cost of travel in the Do Minimum

U_{OPT} = User cost of travel in the Option

R_{DM} = Resource cost of travel in the Do Minimum

R_{OPT} = Resource cost of travel in the Option

PT User Benefit Calculation

In TTSM, PT user benefits were assessed directly from the demand and generalised cost matrices in the model, using the benefit formula in Section A11-12 of the MBCM:

Bij = [½ (T_{DM} + T_{OPT}) (U_{DM} – U_{OPT})] (perceived user benefits)

+ [(T_{DM} PTR_{DM} – T_{OPT} PTR_{OPT}) (change in public transport supply resource cost)

+ [T_{OPT} (OU_{OPT} – OR_{OPT}) – T_{DM} (OU_{DM} – OR_{DM})] (change in other resource costs)

+ [T_{OPT} F_{OPT} – T_{DM} F_{DM}] (fare resource correction)

Where, for each ij pair: T = number of trips.

U = perceived cost/trip.

F = fare/trip (as included in the perceived cost of travel).

OU = other perceived user cost/trip (e.g. generalised cost of travel time).

PTR = resource cost of providing public transport/trip.

OR = other resource travel costs (e.g. travel time and environment)/trip.

Subscripts:

DM = do-minimum, OPT = option, U = F + OU and R = PTR + OR.

In the above benefit formula, the second term (change in operating costs) is omitted as they are directly treated as operating costs (which should be added as a negative cost in the evaluation).

The PT reliability benefits should be assessed as 50% of the PT travel time benefits.

Update factors

The benefit update factors used in this economic evaluation is shown in Table E3 below.

Table E3: Benefit update factors

Variable	Base date	Update factor
Travel time cost savings	July 2002	1.59
Vehicle operation cost savings	July 2015	1.15

Annual benefits have been estimated based on the weighted factoring of the three modelled weekday periods. Other key things to note:

- AM and PM peak models were used to represent the respective 2-hour weekday periods from 7:00am to 9:00am and 4:00pm to 6:00pm respectively;
- The inter-peak model was used to represent all other periods including weekends and holidays;
- Relative flow rates and non-linear relationship between traffic flow and delay were considered when proportionating the other periods from the inter-peak model; and
- An average weekday and weekend hourly flow profiles was created from combination of a couple of traffic count locations in Tauranga.

The resulting annualisation factors are summarised in table below.

Table E4: Annualisation Factors

Period	Model Used	Equivalent hours per day	Days per year
Weekday AM	AM	2	245
Weekday PM	PM	2	245
Weekday IP	IP	7	245
Weekday evening / night	IP	3.04	245
Weekday / Holiday	IP	9.62	120

The above factors were applied to the respective model outputs to represent annual vehicle operating costs. For the travel time costs, given that the base time values are different between off peak and weekends than they are during the weekday inter-peak periods, these differences were considered and a different set of annualisation factors were applied.

F

Appendix F – TTHM Modelling

Appendix F TTHM Modelling

Figure F1 BL with Peak Spreading - 8:30am congestion at Takitimu & Tauranga Crossing

Figure F2 Preferred with Peak Spreading - 8:30am congestion at Takitimu & Tauranga Crossing

Figure F Preferred with Peak Spreading & Pricing - 8:30am congestion at Takitimu & Tauranga Crossing

Figure F3 BL with Peak Spreading - 8:30am congestion at Elizabeth Street

Figure F4 Preferred with Peak Spreading - 8:30am congestion at Elizabeth Street

Figure F5 Preferred with Peak Spreading & Pricing - 8:30am congestion at Elizabeth Street

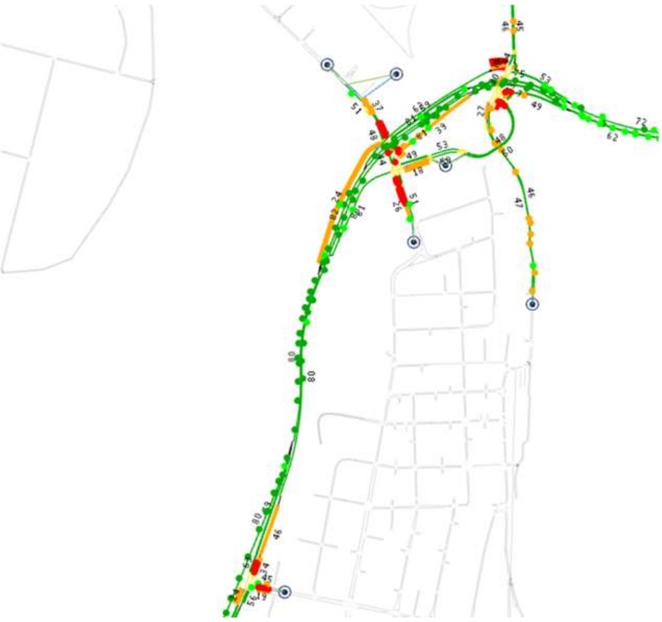


Figure F6 BL with Peak Spreading - 8:30am congestion on Hewletts Road

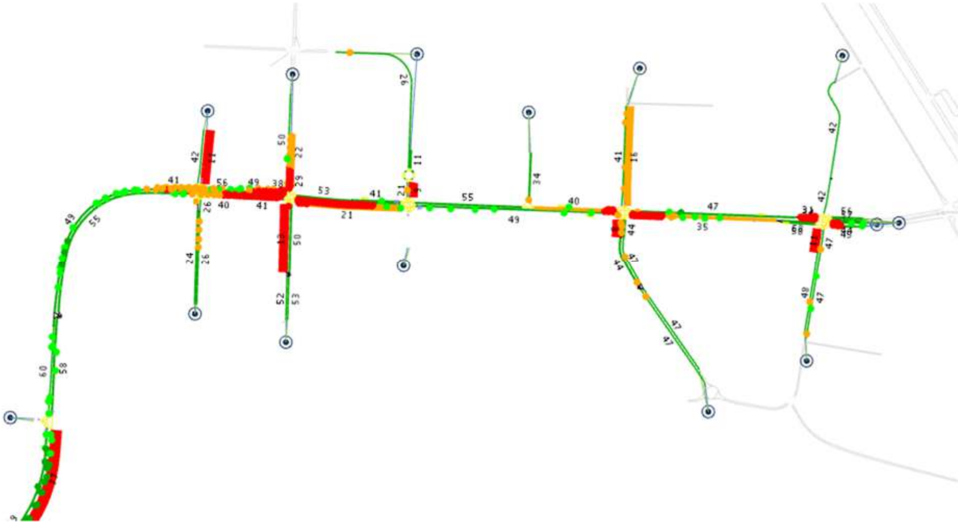


Figure F7 Preferred with Peak Spreading - 8:30am congestion on Hewletts Road

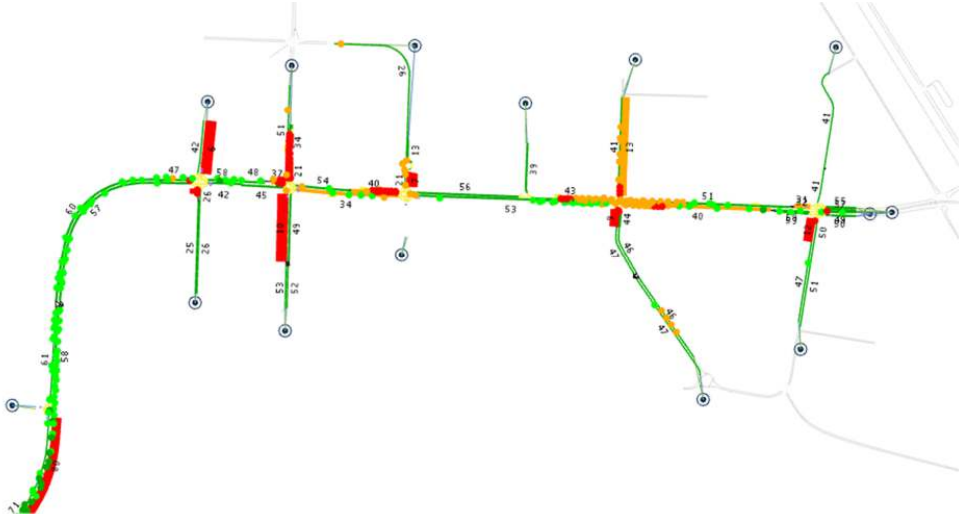
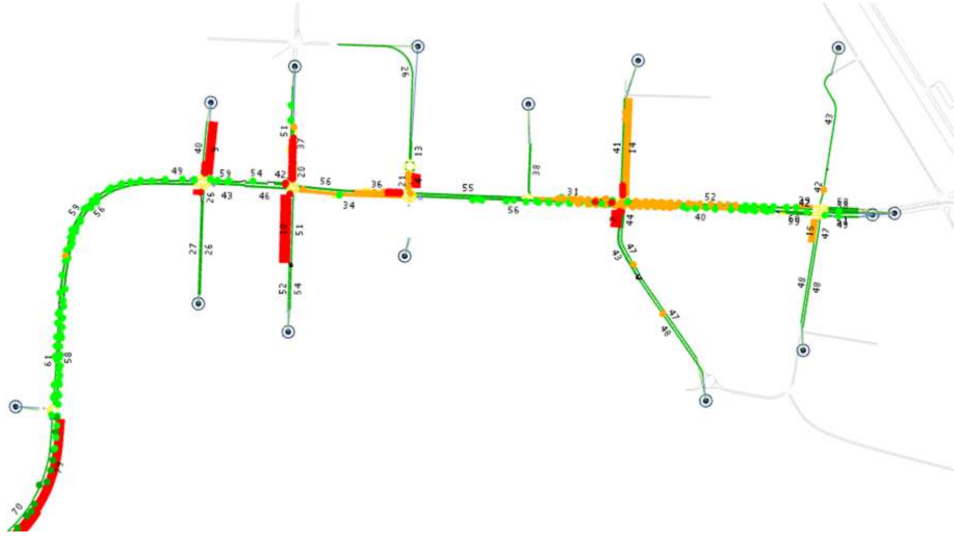


Figure F8 Preferred with Peak Spreading & Pricing - 8:30am congestion on Hewletts Road



Variable Road Pricing Study - Tauranga

Wider transport, financial and economic analysis

Proof-of-concept study carried out by Waka Kotahi NZ Transport Agency and Tauranga City Council

1. Explanatory note

The Variable Road Pricing (VRP) study is a proof-of-concept analysis about the feasibility of implementing VRP through the wider Tauranga area. The results will assist decision-makers decide whether or not to undertake more detailed work on the potential implementation of VRP in the western Bay of Plenty sub-region. The study is a technical analysis based on adapted existing transport modelling tools. These have been used to estimate the potential viability and value of implementing VRP, along with qualitative information to provide a wider context and implications associated with VRP.

No view has yet been formed by Waka Kotahi or Tauranga City Council about whether VRP might be desirable, or whether further detailed analysis should be undertaken.

The study will help inform the SmartGrowth Urban Growth Partnership's thinking about financing and funding tools to deliver outcomes for its communities through the Urban Form + Transport Initiative (UFTI).

The study has been limited to the western Bay of Plenty, so many of the assumptions and findings may not be applicable to other cities throughout Aotearoa New Zealand.

The study is technical in nature and has been undertaken to assess the feasibility of VRP. It was not scoped or developed to support public engagement.

Further work will be required before any decision can be made to implement VRP. This would need to model a wider and complementary package of interventions, such as:

- Road pricing
- The availability and quality of public transport services and bus priority infrastructure
- Walking and cycling infrastructure and facilities
- Car parking management policies and plans
- Land use development/intensification policies and/or funding opportunities
- Broader network management, travel demand management and travel behaviour change initiatives that could be deployed to optimise current networks and services and provide people with more travel choices.

Further work would also need to consider a range of pricing strategies and options to address affordability and equity and mitigate the diversion of vehicles from priced corridors onto local streets.

The proof-of-concept study scope is limited to the current Urban Form + Transport Initiative (UFTI) assumptions and predates the Government's requirements to reduce light vehicle kilometres travelled and reduce vehicle carbon emissions, noting that UFTI did include consideration of these as broader climate change impact matters. The study also assumes that VRP is a permitted lawful activity, which is not the case currently. While the Government has signalled that it is considering legislation to enable congestion charging, the Land Transport Management Act currently limits road pricing to tolling new road infrastructure, to recover cost, where there is an untolled alternative route.

Any future work on the potential introduction of VRP would need to include a focus on engagement with key stakeholders, the wider community and businesses who would both benefit from and be impacted by VRP. Any work beyond this proof-of-concept should also consider starting with a process that delivers a better understanding of resident and traveller needs and preferences.

The VRP study area is the western Bay of Plenty, which raises a number of local community and political governance issues. These include the scope of any future stakeholder and community engagement, which would need to extend to those who live within the boundaries of and/or pay rates to one or more of three local authorities. The three local authorities in the sub-region are:

- Tauranga City Council – the study area is largely within its territorial boundaries
- Western Bay of Plenty District Council – some of the study area is within the council's boundaries and many of its residents and ratepayers regularly travel to and from Tauranga City

- Bay of Plenty Regional Council – which is accountable for managing public transport (funded through a regional general and targeted rate, with services provided through contracts).

There are also implications for Waka Kotahi in its role as the state highway network manager. This is a particularly relevant to any next step investigation, given this proof-of-concept study's predominant focus on priced access to, and distance travelled on, the state highway network from the local road network.

It would be several years before VRP could be implemented, even if communities agreed to a proposal, because of the need for a significant change in legislation, the need to secure financing and funding, and the lead-time to implement the scheme.

2. Executive Summary

This Executive Summary includes observations, where appropriate, of the separate reports providing desktop analysis of international road pricing systems and transport modelling and analysis.

Study scope

The study is proof-of-concept only: it is a technical exercise to explore the viability of implementing VRP in the western Bay of Plenty sub-region and has not assessed all likely impacts associated with implementing VRP. The study findings will help inform any decision-making on managing and developing the sub-region to deliver desired wellbeing outcomes. The study is limited, in that it has only considered introducing VRP.

Rationale

The rationale for implementing some form of road pricing, and in this context VRP, is that pay-as-you-go and differential prices influence travel choice behaviour (about travel mode, destinations, routes, and times); and behaviour will in turn have an impact on the shape and the level of travel demand. Prices influence the comparative value of other travel options and act as a proxy for the need for additional infrastructure and service levels. Priced demand provides transport managers and investors with greater confidence about where to allocate scarce funds to improve customer travel experiences and outcomes.

The purpose of implementing VRP in Tauranga would be to:

1. Deliver UFTI outcomes
2. Use pricing as an effective transport management tool to specifically improve customer experiences and, more generally, land transport system performance, land transport system outcomes and economic productivity
3. Provide a new, additional funding source to finance and deliver investments.

The current locally-raised, largely property-based rates revenue is insufficient alone to provide the local share of total costs for transport improvements at the scale and pace needed to deliver UFTI outcomes. Further, the current nationally-raised revenues available for the best nationally ranked investments, through Fuel Excise Duty and Road User Charges, are not sufficient to provide the investment needed in the western Bay of Plenty.

Findings

VRP, if implemented effectively, would have the potential to deliver the SmartGrowth Urban Growth Partnership Urban Form + Transport Initiative (UFTI) benefits sooner and at greater scale, through:

- Optimised peak traffic flow on road corridors and, consequently, improved customer journeys for all road users
- Improved levels of service through more reliable, and sometimes faster trips at peak travel times (compared to not introducing VRP), as well as optimised departure times
- Increased productivity, especially for light commercial and heavy commercial vehicles
- Encouraging the choice of the right travel mode, right route, and right time for the right trip - including supporting increased active transport modes (cycling, walking, scooters, etc.) and public transport use
- Reduced carbon emissions through travel behaviour change and acceleration of particular interventions within the UFTI programme
- Providing an additional revenue stream to support funding of the transport investments needed to deliver UFTI.

Introducing VRP would impact individuals and communities differently, depending on location (e.g. traffic diversion onto unpriced streets), accessibility (e.g. choices for accessing local amenity and services), and income levels (e.g. affordability).

Some distributional impacts were addressed in the modelling parameters, such as setting network parameters to mitigate traffic diversion away from corridors with pricing onto local streets, and to avoid pricing local trips that cross-over, but do not use a priced corridor. Different equity types have also been considered (e.g. income, fairness, accessibility, trip purpose, vehicle type), as well as a range of options to address distributional impacts (from land use incentives to substitutes to subsidies). Any VRP exemptions would have a direct impact on the number of transactions available to spread total system costs over and would have a direct impact on the net revenue available for reinvestment into local improvements.

The sub-region's comparatively small population would result in moderate total annual net revenue available to invest in transport improvements and leverage borrowings. Although there are transaction costs to raise net revenues through road pricing, the value of VRP is significant because of its immediate and significant influence on travel behaviour choices.

There are very few international examples of road pricing, even though there is a lot of supportive general and location-specific evidence that road pricing would be effective. The most significant barrier is public acceptability – which relates directly to the value proposition to the person who would be paying the costs and the implications for people who would not want to pay the costs.

Public acceptability is strongest where there are significant transport constraints to be addressed (e.g. a congested corridor), and local road users consider it is fair for them to contribute to the cost of delivering an improvement. This is because the introduction of road pricing will demonstrate a tangible benefit to local road users in the short term. This approach is an easier sell than trying to position pricing as a strategy delivery or revenue-raising tool.

Value proposition
The study has found that for the price of a daily cup of coffee, VRP could get people where they need to go faster, if they drive, while also providing better choices for people who choose an alternative travel mode, assuming VRP revenue funded network and service improvements.

Road users VRP would be paying a fee for a service. This pay-as-you-go methodology would enable drivers and vehicle owners to:

- Receive benefits in real-time, such as reduced delays, more reliable journey times and more choice in their departure times
- Fund much-needed infrastructure and services, and enjoy the benefits earlier
- Invest in desirable outcomes, including supporting economic growth (more jobs) and mitigating the housing shortage (facilitating additional and well-connected housing).

Networks
The current western Bay of Plenty network does not support an efficient VRP system. Significant investment in transport solutions, particularly those that provide improved travel choices, would be needed before implementing a variable road pricing scheme.

The introduction of road pricing would result in network benefits, which drivers would experience in travel-time reliability, faster journeys and less delay. The introduction of road pricing would also result in a range of responses to price, including diversion of vehicles from the affected roads (which could have significant impacts on local streets), mostly state highways, onto unpriced local roads. Some drivers would rather drive on an unpriced corridor than consider alternative travel choices. Unpriced roads are typically not designed to carry large volumes of through-traffic. State highways in the western Bay of Plenty carry a significant number and proportion of local trips. This is a function of three factors:

1. Geography - the isthmus landform, with the harbour separating developed land
2. Settlement pattern – the city is built around the harbour and along the key corridors
3. Legacy urban and transport planning decisions about how to connect the city and strategically important land uses (e.g. Port of Tauranga).

The level of traffic diversion onto unpriced local roads would depend on whether those roads had traffic calming measures to mitigate against through-traffic use, and the quality and availability of travel alternatives, particularly public transport. There are also technical measures available to disincentivise diversion on such routes, such that some drivers would face the same price whether or not they had used the main corridor.

The viability of implementing road pricing is primarily about securing social licence, as well as being technically feasible. Technical feasibility is dependent upon the value of the intervention, network characteristics, available technology, and operational complexity (e.g. the scheme objectives and design, given the local network context). Phasing-in a road pricing scheme could be one way to deliver tangible benefits, while mitigating any significant technical viability challenges. Phasing that starts where the congestion is acute and pronounced - and where user benefits would outweigh user costs - would mitigate public acceptability challenges. Phasing could also include using pricing as a regulatory tool for broader objectives (e.g. phasing-in low emission zones in the future). Phasing, however, would have a direct impact on the number of transactions available to spread the total cost of road pricing over, and the net revenue available for reinvestment in local improvements.

The transport modelling predictions about network performance in the 2035 and 2048 scenario years, without and with VRP, assume that all UFTI projects have been fully-funded and implemented as forecast (with the exception of public transport network and service improvements brought forward from 2048 to 2035). The study modelling demonstrates that some local land transport system KPIs are worse-off than in 2018 (e.g. travel time delays), although there are improvements in PT patronage and cycle trips. This is consistent with what UFTI and TSP have previously identified and recognises the focus and priorities set out in those pieces of work, which have been strongly-guided by the 2018 and 2021 Government Policy Statements (e.g. focus on mode shift; accessibility; safety). The ”with-VRP” analysis forecasts that transport road network performance would improve compared to the “without-VRP” scenario over both years.

Further work would be required to identify what network and service improvements would be needed to enable VRP, and what any difference might be between that required investment and currently planned UFTI investments. Even if pricing was not introduced, the UFTI projects for the next several decades and the TSP refresh for the next decade need to be stress-tested for the scale of tangible benefits expected.

Financial
The type of road pricing implemented would have a significant impact on the cost of implementing VRP. In general terms, the more complex the scheme, the higher the cost. The cost would vary depending on:

- Location (e.g. network vs cordon, simple or complex road network, number of cameras needed in a location, and level of traffic diversion)
- Pricing strategy (e.g. fixed or variable, point versus access versus distance versus zonal)
- Technology deployed (e.g. GPS based telematics or ANPR and number plate and use of cellular networks)
- Scale (e.g. number of transactions) - largely driven by the number of cities with some form of pricing and daily volume of traffic charged by the relevant schemes.

The main categories of costs include: capital (system and roadside facilities) and transaction costs.

The VRP system would be revenue positive (net of all costs), generating additional revenue to support financing and funding of priority UFTI projects based on the modelled pricing concept.

Investment
Introducing a VRP intervention may have a significant influence on the type, timing, phasing and sequencing of the transport solutions needed to deliver UFTI benefits. The introduction of pricing would need to be part of a travel demand management strategy, implemented ahead of any pricing, and positioned as providing people with viable travel choices other than using a car. A travel demand management strategy may bring forward and/or rescope planned infrastructure/services and may lead to additional and/or different investments to improve the quality/availability of travel options.

If VRP was not implemented, UFTI would be delivered at a slower pace and could potentially cost more. This relates to the significance of price in influencing travel behaviours, which in turn impacts on improved network performance and the provision of revenue to invest in improvements.

Economics

The prices selected for modelling reflected a balance between three competing interests: (1) price points; (2) network performance (e.g. travel-time efficiencies, reliability); and (3) the impacts of traffic diversion. The primary driver of prices for the VRP study was network performance, noting the revenue implications. Diversion impact was a limiting factor where the network could not accommodate a significant spreading of traffic demand due to route diversion. The VRP revenue stream would be linked to economic activity, enabling it to increase over time if the economy grows.

Local residents and other travellers already incur a hidden cost when using the land transport system. That cost will continue to worsen without a significant change in transport planning and investment in the sub-region. The cost comes in time delays; a lack of certainty about how long a journey might take; suboptimal departure times to avoid the worst of the congestion; and the costs of some services, where travel time cost (including uncertainty of travel time) is passed on to customers. VRP makes the cost of travel transparent and puts a price on the cost of road use. Exposing drivers to paying to use the network in real-time can result in improvements to network performance, due to a small proportion of drivers changing behaviour, which benefit everyone.

Social licence

For VRP to be implemented, even if enabled by legislation and the with the benefits significantly outweighing the disbenefits, communities need to agree that their transport problems and opportunities must be addressed; that there is no effective alternative to road pricing; and that the people who pay will receive a tangible benefit. Road pricing is a rational way to allocate the scarce resource of road space. This concept has proven to be effective in other jurisdictions and the enabling technology is already used in Tauranga in limited ways. The primary determinant of whether or not road pricing can be implemented, at a place-based level, is social licence, or in other words, the acceptance by communities to pay to drive on the roading corridors. International experience is that acceptance is predicated on:

1. A clear, compelling, accurate and locally-agreed understanding of the value proposition to the “payer”, supported by
2. Sufficient alternatives provided before a pricing scheme is implemented, and in particular, significant improvement in travel options, especially public transport.

Further work

Further detailed technical work would be required before any decision could be made to implement variable road pricing in Tauranga, even if enabling legislation already existed. As a proof-of-concept study only, there was no comprehensive forecasting and subsequent assessment of all monetised and non-monetised impacts, nor regard to aggregating and then discounting the benefits and costs over time. That said, there are well-understood, positive associations at a general level across jurisdictions internationally between:

(1) The intervention of road pricing
(2) The implications on transport networks and travel time, and
(3) Economic productivity.

3. Introduction

The purpose of the VRP study was to test, at a 'proof-of-concept' level, the impact of road-pricing in the western Bay of Plenty and determine whether VRP would provide sufficient value to be considered for implementation in the sub-region as part of a programme of activities to deliver UFTI outcomes.

The context for the study is provided in a separate attachment entitled: "VRP Context". This attachment includes a description of the VRP project objectives, UFTI benefits, information about the sub-region's economic outlook, and a "fast facts" description of road pricing options.

The primary audience for the study output is the Tauranga City Council Commissioners, who are tasked with identifying opportunities to put the city on a stable and sustained footing which will enable long-term community wellbeing objectives to be delivered. More broadly, the study is one element of the SmartGrowth partners' efforts to identify possible mechanisms to realise and fund sub-regional UFTI outcomes.

VRP has been proven internationally as a viable intervention to influence individual travel choices. It results in improved optimisation of available network capacity. It can also, depending on the scheme, improve travel choice for everyone, albeit at some financial or convenience cost. It can also provide revenue that could be used to support borrowings to invest in improved transport services - to be enjoyed in the short-term and be paid for by the current and next generation (thus achieving inter-generational equity).

Pricing is an effective tool to efficiently allocate available road space for strategic priority transport journeys. This is because pricing influences travel behaviour decisions. Cities cannot build their way out of congestion or buy their way out of congestion with public transport alone. Other initiatives are needed to improve system performance and customer outcomes.

Significant investment is required in the western Bay of Plenty's transport infrastructure and services to unlock planned growth and support housing and commercial intensification; and achieve improved environmental outcomes, as identified by UFTI. Local and central Government are unable to fund all of the infrastructure and services required to support growth within the desired timeframe, using existing funding tools such as rates and development contributions (local funding) and National Land Transport Fund (national funding).

There are significant wider costs to the economy, beyond congestion, as a result of insufficient transport investment and limited alternative travel mode choices. In 2022, NZIER found the city's housing shortage had increased house prices, limited the growth of Tauranga's workforce, and negatively impacted the quantum of construction activities. NZIER estimated the housing shortage in 2021 was in the range of 4,267 to 5,295, and that the future additional housing shortage could be as high as 3,140 dwellings by 2032. The consequence of a housing shortfall, and its constraint on population growth, will be to limit the size of the workforce. Under the NZIER baseline projections, this will lead to lost GDP of $540 million by 2032 and it could be as high as $1.609 billion in a more competitive environment.

This wider transport, financial and economic analysis identifies other benefits (e.g. network optimisation, impacts on the shape and level of travel demand, additional revenues for reinvestment to deliver UFTI land transport improvements) and disbenefits (e.g. a significant change process, traffic diversion onto local roads, affordability and equity). The analysis of these distributional impacts will inform conversations about the sub-regional response to the study results.

No engagement with stakeholders or communities has been undertaken as part of developing this proof-of concept study. Decisions on the nature and form of future engagement would follow, if the sub-region determines that the study results justify more detailed work being undertaken.

4. Rationale for Variable Road Pricing

The general rationale
From an economic perspective, road pricing is primarily about optimising the efficiency and effectiveness of a transport network, while also being a means of raising revenue for new infrastructure which otherwise would not be built. The transport network efficiency and effectiveness are improved when road pricing is implemented by making the costs of transport supply and operation more transparent so that transport users make more optimal travel decisions.

From a financial perspective, road pricing raises revenue (for the supplier) but also adds costs (to the user). However, there are many costs (economic and financial) associated with using a road corridor that are not directly considered by the motorists when they are making a decision to travel, and are therefore not factored into their decision-making. The result of unpriced supply, and therefore demand, is that it can cause significant negative impacts to the environment (in terms of carbon and other harmful emissions), to other road users (in terms of travel time delays and increased crash risk), and to ratepayers who have to fund the local share of necessary local transport improvements. The National Land Transport Fund consists of revenues that are raised from various sources (FED, RUC, etc) and these are expensed on activities to meet transport demands nationally. Unpriced local demand for additional infrastructure, if funded in part by the NLTF, is usually funded in an allocatively efficient way (i.e. the highest priority projects nationally get funded first) rather than NLTF funding being used for a local transport priority unless this local priority coincides with the national prioritisation for the allocation of NLTF funds.

The rationale for implementing some form of road pricing, and in this context, VRP, is that pay-as-you-go and differential prices influence travel choice behaviour (about travel mode, destinations, routes and times), and behaviour will in turn have an impact on the shape and the level of travel demand. Prices influence the comparative value of other travel options and act as a proxy for the need for additional infrastructure and service levels. Priced demand provides transport managers and investors with greater confidence about where to allocate scarce funds to improve customer travel experiences and outcomes.

When roads reach capacity, motorists don't pay for the cost of the delays on other motorists, so queuing rations space where demand exceeds supply. Queuing wastes time, wastes fuel and consequently generates unnecessary carbon emissions. It also undermines the effectiveness of other road space and environmentally sustainable modes, specifically buses. Road pricing addresses this by exposing road users to a marginal cost of using a scarce resource, particularly at times of peak demand. As a result, a small proportion of users make different travel choices (time of day, mode, route choice, or not to travel), freeing-up capacity for those who do need to travel at the time in question, and enabling more efficient operation of other travel options. It also sends signals about transport investment and raises revenue to support those investments.

VRP would provide an additional revenue stream, which would be linked to economic growth. As such, it could be used to support borrowings to bring forward investment and fund required transport infrastructure and services to deliver UFTI outcomes. The opportunity to borrow funds using the road pricing revenue stream has two main benefits for local communities:

1) It is fair for both present and future road users to fund infrastructure improvements, because future road users would benefit from the long-term investments and should therefore contribute to the costs; and

2) The borrowings would enable transport improvements to be brought forward in time.
It is also fairer, and more affordable, if all of the people who rely on using the land transport system pay for the required improvements, rather than just property owners/ratepayers based within the relevant territorial boundaries.

Why VRP is being considered for Tauranga
The form of VRP being considered for Tauranga is one where there are different access charges for different strategic transport corridors (e.g. State Highways 2, 29a and 29) to reflect strategic objectives, as well as changes in price during the day, to reflect network conditions (e.g. travel speed conditions). Maximum and minimum prices would change periodically (e.g. 3-monthly) depending on the network performance

generally and the value to road users specifically. This makes VRP different from tolling, which is static and has consistent prices which are rarely varied.

The purpose of implementing VRP in Tauranga would be to:

- Deliver UFTI outcomes
- Use pricing as an effective transport investment planning tool to improve customer experiences specifically, and more generally land transport system performance, land transport system outcomes, and economic productivity
- Use pricing as an additional funding tool to finance and deliver investments.

While VRP is about implementing price to improve land transport outcomes, the ultimate objective is to improve wider economic, social and environmental outcomes. In this respect, introducing VRP would be result in social benefits and disbenefits. Social benefits include improved access to opportunities and services. Disbenefits include the distributional impacts associated with route diversion, low-income frequent drivers, and limited travel choices.

Implementing VRP in the western Bay of Plenty could provide significant wellbeing, economic and transport benefits for local communities, as well as delivering Government expectations. Some of these benefits were considered directly in the study, and some are indirect potential benefits over time. Possible benefits include:

- more compact urban form
- more and better-connected houses
- additional and more-accessible jobs
- higher GDP
- reduced carbon emissions
- improved road network performance and
- better public transport services.

UFTI provides a framework to consider investment plans, at an outcome level, to ensure a wider system-focused package approach. This includes non-transport measures, such as land use policy controls and social infrastructure; and transport policy decisions and investments. The transport activities need to include demand interventions, such as road pricing and enhanced public transport services, as well as supply intervention activities such as road infrastructure assets and new public transport services. Non-transport and transport activities need to be timed, sequenced and phased to optimise the value of all decisions and investments and achieve the desired outcomes.

The rationale for considering VRP in Tauranga now

As the sub-region continues to grow in both population and economic activity, the increasing levels of demand will create additional pressure on existing transport infrastructure, particularly at key intersections and on corridors providing multiple functions at peak travel times. In a growing city, transport solutions are needed to:

1. Better manage the level and shape of travel demand
2. Improve customer journey experiences
3. Improve the performance of the land transport system.

The rationale for considering variable road pricing in the western Bay of Plenty now is that current transport demand pressures are significant, as evidenced by traffic demand outstripping the available network capacity at peak travel times; and because additional transport infrastructure investment is needed to deliver wider urban development outcomes, as evidenced by the high costs of land for housing, insufficient land for additional housing and jobs, and wider economic constraints locally and nationally.

The current locally-raised and largely property-based rates revenue is insufficient alone to provide the local share of total costs for transport improvements, at the scale and pace needed to deliver UFTI outcomes. The current nationally-raised revenues available to fund the best nationally-ranked investments, through Fuel Excise Duty and Road User Charges, are also not sufficient to provide for the investment needed in the western Bay of Plenty.

Allocative efficiency (best use of scarce resources) is improved where there is a close nexus between price and service offering. The sub-region needs more investment, and faster investment delivery, than would be available from the usual current local and national revenue sources. VRP is one mechanism that could both contribute to better managing current road corridor infrastructure assets and influence the level and shape of travel demand, as well as providing additional revenue for transport investment.

Any further work on the possibility of implementing VRP should consider engagement with key stakeholders, communities and businesses about the benefits and costs of road pricing. This would include gaining a better understanding of resident and traveller needs and preferences, and their ideas about how VRP could be implemented to deliver tangible benefits.

5. Network analysis

The VRP pricing concept, modelling outputs and analysis are contained in the Beca report. This section draws on the information in the Beca report, as well as wider observations from participating in the study and applied experience and judgment.

The current western Bay of Plenty network would not support an efficient VRP system. Significant investment in transport solutions, particularly those that provide improved travel choices, would be needed before implementing a variable road pricing scheme.

The viability of implementing road pricing is primarily about securing social licence, as well as being technically feasible. Technical feasibility is dependent on a number of factors (e.g. scale of value of the intervention, network characteristics, available technology) and operational complexity (e.g. objectives and scheme design - given the local network context). Phasing-in a road pricing scheme could be one way to deliver tangible benefits while mitigating any significant technical viability challenges. Phasing that starts where the congestion is acute and pronounced - and where user benefits would outweigh user costs - would mitigate public acceptability challenges.

Road pricing schemes can divert state highway or main corridor traffic onto local streets. This is unavoidable, because it is not practical to price all roads. Activities to mitigate diversion, such as including works to reduce traffic and reallocate space on local streets to active transport modes (cycling, walking, etc.), need to support the principle to use the right mode/road for the right trip. A VRP scheme would need to be designed to limit the likelihood of diversion where possible. Tactics to mitigate the negative impacts of diversion include:

- better design of the scheme boundaries
- traffic-calming local streets, and
- improving alternative travel options on the local routes
- Use of technology to detect arterial traffic seeking to avoid charge points.

Road pricing has a higher impact on (time shift and) route diversion than on mode shift. Typically, people will look at rerouting before other responses. The likelihood of mode shift is also partly a function of the viability of public transport and the viability of the alternative route.

Trip decisions may be influenced by price, resulting in trip delay, diversion, use of alternative modes, or suppression. Behavioural responses would have a material impact on some UFTI trip generation and even possibly land-use density assumptions.

Transport modelling shows that the introduction of variable prices would reduce a percentage of total trips. This is to be expected. The higher the prices, the more significant the reduction in total trips (note that the relationship is not linear). Price-setting has to strike a balance between ensuring that prices are affordable and are effective in terms of delivering UFTI outcomes. Being affordable is about willingness and ability to pay to drive on the network. Being effective is about incentivising alternative travel choices, but not reducing trips to an extent where access, wellbeing or economic output are affected.

Why implementing VRP would have a significant impact on local trips made on state highways
Modelling shows that state highway corridors in Tauranga are used for a significant number of local, short trips. This is because there are a limited number of local arterials for traffic to use. Much of the modelled diversion shows vehicles moving off the state highways with road pricing and onto local roads.

The reliance on state highways for local trips is because of three factors:

1. Geography - the isthmus land-form where water separates developed land areas
2. Settlement pattern – the city is built around the harbour and along the key transport corridors
3. Legacy transport planning decisions about how to connect the city and strategically important land uses (e.g. Port of Tauranga).

Why implementing VRP would have a significant impact on local trips on local road corridors

A significant implication of variable pricing on the main corridors, which are mainly state highways, is that there would be diversion of traffic onto local unpriced roads. These characteristics have a significant implication when pricing is applied to the network, because while people are sensitive to the introduction of a price (more than a change in price), some drivers would prefer to drive on unpriced streets rather than consider other alternatives. This behaviour would be more likely where there is an easily-accessible alternative to the corridor with pricing (e.g. Oceanbeach Road / State Highway 2). The shorter the trip, the more likely the diversion. The longer the trip, the higher the total cost under a VRP approach and the more likely trips may be deferred, or an alternative travel mode used. Therefore, less diversion of longer trips onto local roads. These local roads are not designed to carry high volumes of traffic or heavy vehicles, with the associated impacts on pavement failure and additional costs, as well as affecting community wellbeing and undermining intensification objectives. UFTI proposes transforming (including traffic calming) a number of these local roads, to ensure that they serve strategic land-use objectives.

1. The modelled diversion onto local roads is based on two human behaviours: People are generally sensitive to price
2. Drivers first inclination is to find an alternative route and keep driving, rather than change travel mode or defer travel.

There are several main responses to mitigate diversion from priced to unpriced roads:

1. Price roads that are not priced
2. Significantly increase the viability of travel alternatives, particularly through public transport services and priority route infrastructure improvements, and safe and connected walking and cycling facilities for shorter trips
3. Traffic-calm the alternative corridors
4. Price diverted/through trips without pricing purely local trips.

There is a balance between using pricing to incentivise the right traffic onto the right road, which is an UFTI objective and therefore an objective of this study, and the need to mitigate diverting traffic onto local roads, especially those repurposed as local access streets with associated improvements in local amenity.

In this proof-of-concept study, it has not been possible to sensitivity-test a range of pricing strategies, and packages of complementary transport initiatives, to use price to encourage the uptake of public transport and mitigate traffic diversion. The transport model included the planned public transport services agreed in the UFTI plan. This brings forward to 2035 PT services and PT priority infrastructure improvements that were planned to be in place by 2048.

The traffic-calming would need to be more significant than is the usual practice to best-serve local community needs. By way of comparison, Carmichael Road is used as a diversion for congestion on SH2, despite traffic-calming. Most diversion in Tauranga would be short trips using local roads for local trips, rather than "rat running" by going off and then back on the strategic road network.

Wider network implications if VRP was implemented

Any decision to implement VRP would have a significant implication on the type, timing, sequencing and phasing of additional transport investment in the coming decade. For example, significant and earlier investments in corridor infrastructure, facilities and services, to improve the availability and quality of public transport services, would be required before introducing VRP. Concurrently, an agreed investment plan for addressing transport corridor backlogs, growth needs, and improving freight efficiency would be necessary, so that road users would see the value they were getting from paying for access. These requirements indicate a need for a significant, system-wide and sustained investment plan, with sufficient scale of financing and funding to deliver outcomes across the sub-region and transport modes.

While the modelling shows that the introduction of price would reduce a small percentage of total trips, it would have more impact on shorter rather than longer trips, because of the access- rather than distance-based component of the total charge. As the sub-region grows, the model shows that the number of trips on the network continues to grow, while the number of shorter trips reduces, resulting in a small reduction in total number of trips.

The transport modelling uses UFTI assumptions about land-use density, trip generation and travel mode shares, with one variation, which is to bring forward from 2048 to 2035 specified public transport service improvements. Introducing pricing may impact on peoples' future choices about housing location, housing density, travel choices, proximity between housing and employment, and intensification. These possible implications are outside of the study parameters, although could have a material impact on the predicted outcomes. VRP is a transport intervention that may incentivise intensification which would support the UFTI strategic direction of enabling a centres approach to long-term development.

The introduction of pricing across the network would result in improved network performance on the corridors connecting the Port of Tauranga with the upper North Island. This would create freight efficiency (journey time reliability and travel times) improvements. The scale of benefits, and the value of those benefits, could be considered in any further work.

Wider implications of VRP

Meeting national and regional emissions reduction targets will be challenging and road pricing provides a lever that could assist. The Government's Emissions Reduction Plan includes a 20% reduction target in total vehicle kilometres travelled (VKT) by the light vehicle fleet by 2035, through improved urban form and providing better travel options, particularly in our largest cities. Achieving this target is vital to reducing transport emissions by 41 percent by 2035, and to meeting New Zealand's overall emissions reduction targets. The Ministry of Transport is identifying regional targets for the interim 2035 target.

Effective long-term land-use planning, integrated urban development and transport planning and aligned transport investments will improve outcomes and contribute significantly to reduced VKT.

In the short-term, however, much of the settlement pattern up to 2035 is already in place. Land-use impacts on VKT are slow, while pricing has the potential to have a quick and effective impact on VKT. Reducing VKT in our major urban growth areas is unlikely without using Travel Demand Management (TDM) tools, along with changes to land use, transport activities and urban form. TDM tools help create and manage transport system capacity by redistributing trips across a variety of transport modes and routes, at a range of times, or by removing them completely.

Effective TDM tools, such as parking and road pricing, influence behaviour directly, and also indirectly by promoting shared and active travel modes, how road space is allocated, and the quality of public transport services. VRP is a powerful TDM tool that could underpin a reduction in VKT, while enabling a thriving community and growing economy. VRP is a powerful TDM tool because it is an economic lever and therefore has a significant impact on behaviour, choices, and decisions.

UFTI identifies the need for additional road infrastructure and services in the coming decades, to accommodate the increasing daily flows of traffic along the eastern and western corridors. Shifts in travel demand, including through VRP, could help to manage the timing of the delivery and form of these network improvements and services. In the SmartGrowth sub-region, the challenge and opportunity is to provide residents and businesses with smart planning about how growth is allocated and managed. Providing more life choices, such as schools, jobs and parks, within centres and more options to travel, is more effective when underpinned by economic measures, such as pay-as-you-go pricing, because of the impact pricing has on decision-making.

The Tauranga urban road corridor system is characterised by a need for the state highways to perform strategic and nationally important functions, such as providing freight access to the port and also carrying local traffic, because on several corridors, there are no separate parallel local roads. The competing interests of efficient mobility and effective access will remain for the foreseeable future, given the land-use pattern and land transport system. The study identifies that VRP could be used to allocate available corridor space for the highest value purposes in real-time. This is on the basis that price is a proxy for the strength of individual demand, and therefore comparative individual value.

Wider future network implications if there was no tolling of Takitimu Drive

If there was no toll on Takitimu Drive, once the financial toll road repayment obligations have been met, and there was no replacement road pricing, this could trigger a significant shift in travel behaviour. In the absence of pricing, there would be an increase in use of the corridor by private vehicles. That would result in eroded levels of service for network users on impacted corridors, particularly for traffic to and from the port on both the western and eastern corridors. It would also result in additional VKT at the expense of other travel mode options and would result in parking availability challenges in the city centre. It is estimated that repayment of TDTR will be in 2031, at which point the toll will be removed, unless ongoing costs justify keeping it in place. If, however, there was a tolled Takitimu Northern Link connecting to TDTR, Beca modelling shows the traffic volume and revenue projections could result in the repayment time being brought forward to 2029. The study's 2035 and 2048 baseline scenarios assume that there is no toll on TDTR, and the road pricing concepts for both scenario years assume variable pricing is in place on that corridor. The expiry of the toll on TDTR, and its consequent impact, may be a significant matter to consider in any further work, including any implication for efficient port access.

Wider future network implications if added the Tauranga Northern Link as a toll road in future

The VRP pricing concept is based on the assumption that only one pricing regime is applied across the study area. On that basis, the current toll tariffs on TDTR and the Tauranga Eastern Link (TEL) would be replaced by the VRP pricing concept. The VRP revenue would continue to repay the finance costs of those two toll roads. If there was a toll created to repay costs of the TNL (stage one and stage two) the same "replacement" principle would apply.

If there was no VRP and only toll roads, the sub-region may end up with three or more separate toll roads. At some point, a strategic perspective would be required to consider managing the separate toll roads as one (integrated) network. Adding individual toll roads over time in one spatial area is very unlikely to lead to the most effective performance of the land transport system, or customer experiences and choices.

6. Value propositions of VRP

This section of the report identifies the potential benefits of VRP to different communities and stakeholders. The statements below are general descriptions about who the beneficiaries would be, along with qualitative statements about what benefits are expected. There would be disadvantages associated with VRP, which would impact some individuals and communities. These would need to be fully understood, accepted and/or mitigated, depending on the context.

VRP offers the following value proposition:

1. Supports UFTI objectives, including economic and population growth
2. Improves traffic flow conditions
3. Provides additional funding for network improvements.

Supporting UFTI objectives, including economic and population growth

> *UFTI objectives of supporting economic and population growth* will help determine whether or not to implement VRP. VRP would be an effective tool to help get the most from the region's transport networks and services that supports the UFTI objectives of connected centres, intensification in specific locations, and neighbourhood liveability.
>
> Variable Road Pricing is a mechanism for road users to invest in personal benefits, as well as the wider wellbeing and economic and population growth of the sub-region.

Improved traffic flow conditions

Improved traffic flow conditions mean an improved level of service for users. This is typically experienced by reduced delays and improved journey time reliability. For those who currently travel earlier or later to avoid the worst congestion, it means they can travel closer to their preferred time of departure.

VRP works by pricing a proportion of vehicles off the roads during periods of high demand, or encouraging uptake of other travel modes. Trips of lower economic value are impacted by price. This may result in the removal of some discretionary trips. The resulting improved traffic conditions may be further enhanced by network improvements, funded by the new revenue stream. By paying a price, road users purchase reduced delays, improved travel time reliability and improved departure time choices. Depending on the trip purpose, the value of reduced trip delays, improved travel time reliability, and more choice of departure times may vary.

For example, travel time reliability is likely to be important for trucks that need to be on time before a ship sails, or for people catching a flight. UFTI's primary focus is off-peak travel time predictability, as freight demand generally avoids peak travel times where possible.

Additional funding for network improvements

Network Improvements are an important part of the value proposition. People value using high-quality roads and transport infrastructure. VRP can enable new infrastructure that would otherwise not be built, as VRP generates net revenues as part of the function of demand management.

Any additional improvements would likely benefit all transport users, including the provision of more viable and attractive travel choices.

The VRP revenue stream would be linked to economic activity. It could increase over time, if the economy grows, and it would support the delivery of UFTI outcomes.

Road users paying VRP would be paying a fee for a service. This pay-as-you-go payment method enables:

- Drivers and vehicle owners to purchase benefits in real-time, such as reduced delays, more reliable journey times, and more choice in their departure times
- Funding of much-needed infrastructure and services, and earlier enjoyment of the benefits

- Investment in outcomes, including supporting economic growth (more jobs) and mitigating Tauranga's housing shortage (additional and well-connected housing).

Beneficiaries
Given the local context, the characteristics of pricing and the study results, potential benefits to specific segments of the economy and communities are set out below.

Beneficiary	Potential benefits
Vehicle users	Consistent journey times, improved travel timeframes, and significantly improved travel experiences could be expected in the future (compared with no pay-as-you-go pricing). This would be the result of reduced travel demand, as some people would choose other travel options. The additional revenue would also fund the transport solutions needed to provide an improved level of service for all modes.
Communities	Benefits include: - travel time savings for personal, family, and recreation activities, reduced stress, more travel choices, and choices about where to live and work; - optimisation of existing infrastructure assets and services; - incentivising people to take the right route, right mode and right trip to deliver UFTI benefits; and - freeing up future Council rates to fund wider community services, rather than transport improvements. The revenue from VRP could be used to bring forward funding for transport investment. This has two main benefits for communities: - It is fair for present and future road users to fund infrastructure improvements; and - Any funding would enable the timing of benefits to be brought forward.
Ratepayers	The benefits for ratepayers are future improvements are paid for by road users, who are the primary beneficiary, rather than being funded by property owners as part of their rates. Road users from outside of the city would also contribute.
Commercial road users	The benefits include improved journey time reliability, supporting freight logistics and better productivity.
Local businesses	There are indirect benefits to businesses that do not use transport directly, but who rely on logistics, such as retail and manufacturing. These firms may be impacted by congestion expressed in labour costs, time delays, and inventory management costs.
Sub-regional economy	Optimised use of transport infrastructure enabled by pricing, and the creation of a revenue stream to invest in future transport improvements to support regional and sub-regional employment and housing opportunities, while also helping to meet emission reduction targets. An efficient transport network supports businesses clustering together where that increases value and productivity and provides wider economic benefit.
Local and central Government, including Waka Kotahi as a partner in planning, investing and delivery	Benefits include improved use of current assets and services, increased confidence in the forecast demand for additional levels of service improvements, and enhanced outcomes. VRP could be a useful travel demand management tool to enable the sub-region to meet its commitments to national emission reduction targets.
Aotearoa New Zealand economy	Efficient access to the Port of Tauranga is nationally-important, given its role in the upper North Island economy. Implementation of VRP would sustain efficient access to the port over the short-, medium-

	and longer-term. This supports improved productivity, as measured by GDP.
Port of Tauranga and port customers	The benefits include maintaining efficient port access, which is important to manage cross harbour flows as the city continues growing to the east and west.
Visitors	The benefits include less congestion and more consistent travel times, coupled with more effective and efficient travel choices.

7. Financial analysis

System costs
The type of road pricing implemented would have a significant impact on cost. In general terms, the more complex the scheme, the higher the cost. The cost would vary depending on:

- Location (e.g network vs cordon, simple or complex road network, number of cameras needed in a location, and level of traffic diversion)
- Pricing strategy (e.g fixed or variable, point versus access versus distance versus zonal)
- Technology deployed (e.g. GNSS telematics or ANPR, or the use of cellular networks)
- Scale (e.g. number of transactions, largely driven by the number of cities with some form of pricing, and the scale of schemes in those cities).

The main categories of costs include:

- Capital (system and roadside facilities)
- Transaction costs.

Capital - system
An assumption was made that the Waka Kotahi tolling system could accommodate the VRP, although that assumption would need to be validated and the upfront and ongoing financial implications identified.

System costs include digital technologies that enable customer point-of-sale, connection to local infrastructure and management of national transaction processing. Costs to configure the Waka Kotahi system (assuming a bespoke system build would not be required) have been assumed for the purposes of this study at $5m, plus annual system technology costs have been assumed at $10m p.a.

Capital - roadside facilities
Roadside facilities costs have been assumed for the purposes of this study to be in the order of magnitude of $30m. Further work would be required to identify appropriate roadside technology solutions. For several reasons, including costs and visual amenity, it is assumed that roadside technology to implement a VRP would not replicate the current gantries and roadside hubs that support current peri-urban toll roads. The VRP roadside facilities requirement assumption is approximately 95 specialist ANPR cameras, camera poles and variable messaging signs, as well as property, consenting and construction.

Waka Kotahi experience with gantry systems suggests that these cost in the order of $7.5 to $10 million per gantry. This cost includes a large overhead structure and a roadside technology cabinet. International experience finds that the operating costs of these systems ranges between 6% and 20% of gross revenue. Based on Waka Kotahi experience, maintenance costs are expected to be between $500 to $1500 per gantry annually and $1000 to $2000 annually per unit for electricity.

Different technologies, such as satellite-based positioning, local data from the cellular network, use of gantry-based schemes, including cameras for Automatic Number Plate Recognition (ANPR) and Dedicated Short Range Communication (DSRC) are commonly used to support Road Pricing schemes. The technology is usually selected based on the ease of implementation, cost, enforcement difficulty and privacy. For this study, the ANPR system was considered appropriate, partly because there is no need to identify the vehicle with an in-vehicle transponder. Waka Kotahi and TCC are both experienced in using ANPR technologies.

(The Tauranga Transport Operating Centre already has an ANPR camera system for traffic management purposes.)

ANPR system technology is widely gaining popularity across the globe, having supported such projects as the London Congestion Charging system. Some research papers indicate that ANPR provides more than 90% accuracy, considerably higher than cellular network technologies. While the DSRC technology provides higher accuracy than ANPR, the implementation of DSRC technology for Tauranga VRP would have a higher cost and it has no net benefit given how successful ANPR technology has been in NZ to date with existing toll roads. This could be explored in more detail during any further stage, if required. The accuracy of ANPR generally depends on the quality and positioning of the camera used. ANPR uses camera-based systems and prices depend on the complexity of camera functionality. There can be problems with number plates being obscured by other vehicles. This can result in higher costs to better position cameras. These cameras may also provide other useful functionality for network management, justifying the use of more expensive cameras.

Transaction costs

Transaction costs include:

- Transactions (e.g. personnel costs, transaction charges [bank charges], depreciation (recovering the cost of capital), information technology support, maintenance and system costs and upgrades, and other operating costs such as enforcement). This was assumed at circa $0.35 per transaction, based on 50% of current costs
- Compliance – direct cost recovery.

Each road price trip would create revenue, some of which would be required to cover costs. The study assumed that for every trip through an “access point”, there is a transaction charge. This is the current situation for toll roads. While all costs need to be recovered, by way of a transaction charge, there may be options about how those costs are recovered, such as an accumulation of trips per transaction.

The amount of fully-allocated costs per transaction would have a material impact on the pricing strategy and net revenues available to support funding and investment. The minimum price charged per trip needs to be set to recover transaction costs, pay GST and make a meaningful contribution to wider funding requirements. The higher the price, the less revenue is absorbed by costs. The greater the volume of transactions, for example from systems in other cities, the less the fully-allocated cost is per transaction. Increased numbers of pricing systems throughout New Zealand would be expected to exert downward pressure on (fully-allocated, including transaction) costs, which in turn would increase net revenue throughout New Zealand.

Initial thoughts about cost recovery

The current toll transaction volumes in Tauranga are circa 9m p.a., and under the VRP forecast this would increase to circa 107m transactions p.a. in 2035, with further increases in later years. A VRP system would be significantly more complex than a simple toll system and the cost structure would reflect the complexity and volumes involved. In this respect, there would be different pressures on transaction costs, depending on the total number of transactions and operating model.

The greatest cost – and net revenue – risk is the forecast number of trips on the priced network and therefore the number of trips to recover costs from. If there was congestion charging in other parts of NZ (e.g. Auckland or Wellington), that would have an exponential impact on transaction volumes and impact the transaction cost locally (assuming a consistent national cost recovery system).

Further work would be required to assess the extent to which any equipment used by the Tauranga Transport Operations Centre (which has some closed-circuit cameras for traffic management purposes) could support VRP. Decisions may be based on the technology anticipated to be available and in place at the time in the future that any VRP was implemented. Such a decision would be a question about technology functionality, regulatory integrity, and physical and cyber security. Using (future) TTOC equipment may be feasible from a technical perspective, although further work may indicate that a separate pricing operation may be required. Either way, this may have an impact on implementation costs.

Tolling costs to be recovered
Tolling does not provide a revenue stream for general expenditure. Tolling tariffs in New Zealand are set to recover all or some costs of new roading infrastructure in defined circumstances, both initial capital and to recover ongoing costs. There are currently two toll roads In Tauranga. The net toll revenue for each is used to recover costs. If VRP was to be implemented, it would replace the tolls. Provision would, however, need to be made to continue to meet toll road financial obligations.

Current toll road financial outlook:

- TEL current annual gross revenue is $8m (GST exclusive), less $2.6m transaction costs, leaving $5.4m available for debt repayment. The level of remaining debt to be repaid for TEL is about $107m (as at the end of 2022), estimated to be repaid by 2040
- TDTR current annual gross revenue is $9.5m (GST exclusive), less $3.2m. transaction costs, leaving $6.3m to repay NLTF. The level of remaining NLTF repayments for TDTR is $52m (end of 2022), estimated to be repaid by 2031.

Revenues
If VRP was implemented, it would provide an additional revenue stream to those that currently exist (e.g. rates; National Land Transport Fund). That additional revenue could support funding the transport interventions needed to deliver UFTI outcomes. The revenue stream could be used to raise finance for improvements, to be repaid by net revenue. A VRP revenue stream would be linked to economic activity. It could increase over time, if the number of vehicle movements increases, and the local economy continues to grow.

VRP could be phased in over time. This approach could go some way towards mitigating opposition to pay-as-you-go pricing as a way to deliver outcomes, by demonstrating the benefits and ameliorating negative impacts. The phasing could be by location, starting with only part of the proposed priced network, by price level, for example, starting with a low price and increasing it over time, or by time of day, setting the price of travel in the inter-peak periods at nil for the first decade.

The disadvantage of a phased approach includes:

1) it would not maximise the behavioural benefits of implementing pricing, and
2) it would result in less revenue available to invest in improving in customer levels of service in the early years.

The ability to provide a phased approach could be looked at in more detail during any next stage of investigation, or a business case process.

8. Economic analysis

General economic perspective

Behavioural economics
VRP is an economic tool. If road pricing was introduced there would be an impact on behaviour, with a substantial number of people choosing to delay or reroute trips, or change their travel mode or route.

If the net-of-costs revenue from implementing VRP was estimated to provide only modest revenue for investment, that would not be the only or primary determinant in deciding whether to introduce VRP. The potential annual net revenue may be provided in some other way, without incurring the transaction and wider costs associated with road pricing. This could perhaps be by way of a recurring government grant, for example. This would remove the potentially greater value to the sub-region, which would be to influence behaviour by making the costs of travel choices more explicit. Introducing pricing could provide individual, and more importantly, wider community and sub-national benefits as a result of improved performance of the land transport system in the western Bay of Plenty.

Communities may oppose a road pricing scheme for a variety of reasons, some specific to a proposed scheme in the local context. Broad reasons to oppose schemes include: road pricing may be perceived as anti-car; people do not want to pay additional prices generally; privacy concerns; and affordability. Specific reasons to oppose schemes include: communication failure by the scheme proposer; negative (accessibility) impacts on existing businesses; the use of net revenue does not give the pay-as-you-go driver a tangible benefit; people may not want to pay a price for a service where there is no congestion relief benefit; and there are limited viable alternatives to having to drive and pay the cost.

Pricing influences behaviour which impacts on network levels of service
Implementing a VRP would have three main influences on network levels of service:

1. Pricing acts as an economic instrument and influences travel choices, which results in improved use of available network capacity and travel mode options. It has a significant influence on demand and the viability of alternatives, such as travelling at a different time, travelling by a different mode or on the right corridor. These potential results are similar to experiences in the utility sectors, such as electricity and telecommunications, and are consistent with the introduction of water metering and volumetric charging in Tauranga. Transport modelling showed people generally preferred to continue to drive and find a free alternative route, rather than change travel modes. This could result in significant diversion onto some local streets, but in reality, the level of diversion would be limited because of the inconvenience drivers would experience, assuming local streets had been transformed (e.g. by traffic calming) and retrofitted to be more suitable for local community access.
2. Pricing provides a clear and measurable means for the expression of preference by road users about the transport access they value. That information better informs transport managers and investors about what additional capacity and enhancements are needed, especially in relation to locations and timing.
3. Pricing can provide revenue to improve future levels of service. Road users are likely to be more supportive of paying a price to use a network if the funds generated will be ringfenced to provide an agreed or improved level of service.

How prices are set would have an impact on behaviour, diversion, and equity. For example, sensitivity testing in the modelling process indicated that sliding scale fees by time periods are required to prevent compressed induced trips, and if there was to be one access fee only within a time window, that could lead to people paying different access charges on the same corridor at the same time.

Pricing may be characterised as regressive
While a VRP could be categorised as regressive (impacting lower income households more significantly), the overall impact could also be categorised as progressive (providing greater overall benefits for all drivers who pay to drive). The reality is that higher income households often live closer to major employment

(CBD) centres; have more discretion on how they use their time; have higher trip-making rates and often have good public transport options (the costs of which are subsidised by about two thirds, on average, in New Zealand); and would be less impacted financially if some form of road pricing was introduced. It can also be the reality that lower income households may live further way from a city centre and from work, don't always have the same public transport choices (if their employment is in dispersed light industrial areas), and may be more impacted financially if petrol prices rise and/or if some form of road pricing was introduced. The introduction of pricing may have a more significant impact on lower income households' preference for diversion off a priced corridor onto an unpriced corridor. These matters and their impacts have not been considered by this study. but require detailed analysis, should there be any next step investigation of VRP for Tauranga.

Setting VRP prices

The prices set out in the modelling report reflect a balance between three competing interests: price points and network performance (e.g. travel time efficiencies, reliability) and the impacts of traffic diversion. This means that there is a trade-off between primary objectives (e.g. pricing for demand management (optimisation, congestion and revenue; and between forecast available network capacity to accommodate diversion).

If applying a "congestion relief" conceptual approach to using pricing, the aim would be to set prices low if the primary objective is revenue (mitigate diversion) and set prices high if the primary objective is network throughput efficiencies. The VRP study identified that the introduction of a price (rather than the price point or a marginal change in price), provided much of the network benefits. On that basis, modelling of higher prices provided more revenue, although this created more diversion (that results in more local roads and intersections operating at or over capacity) and increased affordability challenges, and modelling of lower prices indicated that total costs could perhaps be higher than total revenue for short trips, or there would be little net revenue available for reinvestment to provide an enduring value proposition to those paying for a service.

Implementing VRP could provide an additional revenue stream to supplement rates (and a moderate amount of additional revenue to invest in sub-region transport improvements). The study modelling of Concept Five indicates that VRP could provide a net annual revenue stream of up to $88m in 2035 and up to $158m in 2048. This accounts for the need to repay existing debt for the TEL and the NLTF obligations for the TDTR.

Further detailed work might identify a more effective pricing strategy than what has been modelled, and which might provide less revenue, for example, no price in the inter-peak period for the first decade. The potential additional revenue may not support significant borrowings and investment in the transport system, at a scale required to deliver UFTI benefits, unless higher road pricing charges are contemplated.

Setting prices is one of the future issues that would need to be resolved if there is any further work on VRP. Prices would need to be based on several factors:

1. Detailed analysis of options and comparative costs and benefits. This may include analysis of the comparative value of time, vehicle type, motive power, trip purpose, trip frequency, road space consumed by a vehicle, and the marginal or average total costs incurred to provide, maintain and improve networks. VRP is about managing transport access and the prices could therefore be the same for all vehicle types. That approach, however, would not recognise the difference in costs and benefits between different customer segments. A VRP pricing strategy should reflect both sunk costs and the marginal additional, rather than average, costs. A VRP pricing strategy should also recognise that the economic context is different for commercial rather than private travel, and any pricing strategy should reflect the greater benefits, as well as costs. If prices are set too high and drivers have no alternative (e.g. poor PT), this would have a negative suppression effect (e.g on employment, productivity, wellbeing). Much of the benefit can be estimated by using the value of time. Value of time is the standard and economically rational way to set prices and to manage overall demand. Waka Kotahi has published values of time as a function of trip purpose in its Monetised Benefits and Cost Manual (MBCM). The value of time varies by trip purpose, but does not vary across transport mode.

2. Pragmatism - setting prices is about giving effect to the UFTI strategy and aligning prices with a value proposition for the people paying. A pricing strategy would need to strike a balance between several, competing, objectives:
   - Managing travel demands (relieve congestion)
   - Optimising use of infrastructure (to support UFTI outcomes)
   - Collecting revenue (to invest in transport improvements)
   - Encouraging mode shift (particularly an increase in public transport), or
   - Encouraging a reduction in carbon emissions (by incentivising the uptake of EVs).

A package of road pricing and other complementary and interdependent activities would form a package of integrated interventions that maximised benefits and mitigated costs. The VRP study ranked pricing objectives and the modelling adjusted pricing and network parameters at a detailed level to understand and mitigate the scale of disadvantages. That information would support any further work.

Distributional impacts

There are costs, benefits, and other impacts (e.g. traffic diversion) associated with the introduction of VRP. Some distributional impacts may be positive or negative, with negative impacts often being characterised as equity matters, usually associated with lower income groups. Distributional impacts may be accepted as consequences of a decision, or may be mitigated.

Some distributional impacts were addressed in the modelling parameters, such as network mitigation of traffic diversion away from corridors with pricing onto local streets, and avoiding including local trips that have to cross-over, but do not use, a priced corridor.

Topics to be considered, if there is any further work, include:

1. Income or affordability, ability to pay based on income
2. Multiple trips per day, for people such as home care support workers or childcarers, rather than a commercial operator who can recover the cost as a business expense
3. Access choices, such as for people in suburbs with limited travel choices and where most services, such as supermarkets and schools, are located some distance away
4. Trip length
5. Trip purpose, such as hospital visits
6. Vehicle type, for example emergency vehicles
7. Vehicle occupancy, comparing driver only vehicles, with high occupancy vehicles.

Options to consider, in any future work, about how distributional impacts could be mitigated and minimised in the Tauranga context include:

- Land use development decisions and incentives - Ultimately many of the transport metrics will be improved when people have more choices to live, work, learn and play in their community locations, and more travel choices about how to move around in and between communities. Development requirements and incentives can have a significant impact on distributional impacts over the longer-term, and over costs in some development areas in the near-term
- The design of the VRP - How access and pricing is set on the network can provide flexibility to target congestion and encourage route choice, as well as provide the ability to reduce the price impact on certain community areas
- Conditional access rules for locations - For example, not charging for trips crossing certain charging points within a specific timeframe (to supported accessibility to key services within certain time periods)
- Use of discounts, exemptions, or price caps for user groups - The VRP would capture the vehicle number plate only and not the driver or trip purpose. That said, there may be an efficient mechanism to provide free or reduced prices for using the priced network for lower income earners and households
- Improvements to alternatives to driving a car on a priced network - Focusing investment in PT and active mode infrastructure and services on key routes during peak periods, early in the implementation planning phase, would improve the comparative value of travel substitutes. Early network and service improvements could be focused on priority community locations

- Permanent or temporary revenue support - There may be an option of providing additional or recycled monetary credits to targeted residents in particular community areas, which could then be phased-out as network infrastructure and service improvements are provided or continued as a support mechanism
- The potential to introduce subscriptions and service bundling for different customer segments, depending on their needs, that provide viable and affordable travel choices and revenue streams to deliver the benefits. For example, providing service bundles (e.g. road pricing credits, public transport and other shared transport hours, e-bicycle rental credits) at different price points, with prices set to incentivise the right mode for the right trip that reflect where the customer lives or works.

Different types of financial mitigation options
Where there are particular financial implications, these may be mitigated by organisations, or the Government, for public policy reasons. One example of a financial mitigation is that a subsidy could be provided in some circumstances to recognise an equity issue, such as affordability. That would be very challenging from a VRP perspective, because roadside technology can only recognise vehicle number plates and not drivers, or trip purposes. The current toll roads in Tauranga do not provide exemptions or discounts to the general public, or to any vehicles other than exemptions for emergency vehicles.

Any VRP exemptions would have a direct impact on the number of transactions available to spread total costs over and the overall operating cost of any scheme. VRP exemptions or discounts would also have a direct impact on the total amount of net revenue available for reinvestment into local improvements. Exemptions or discounts may also erode the effectiveness in addressing congestion. The appropriateness, deliverability and public acceptability of such distributional impact mitigation methods would need to be further investigated and assessed following this proof-of-concept phase.

Distributional impacts would be considered in detail if there was any further work.

Benefit perspective

Benefit cost estimation
Costs and benefits, and their implications, have been considered within the limited context of estimating the possible viability of using VRP to improve land transport outcomes. The study did not, however, undertake an in-depth analysis about all costs and impacts and did not calculate a benefit cost ratio (BCR). The study is proof-of-concept only. That means there is no comprehensive forecasting and subsequent assessment of all monetised and non-monetised impacts, either benefits or disbenefits.

Although the toll revenue is accounted for in the calculations of a BCR for a toll facility, the future benefits of projects funded from this revenue stream are not included in the BCR for a toll facility. A conventional economic analysis is that a price charged to a toll road user needs to deliver greater benefits than the costs, such as travel time savings, trip reliability, vehicle operating cost savings and safety enhancements. This indicates that charging a price to use a road may be more justified when there is congestion than when there is no congestion. The assumption for the Tauranga VRP proof-of-concept is that the net revenue is reinvested locally to deliver additional transport benefits, as this additional revenue only available because of the road pricing scheme.

A standard BCR works most effectively where the core assumptions are stable and there is limited interdependence on other factors. Counting all of the benefits and costs of a significant transport investment in a main urban area can be challenging, because in such situations, land transport is part of the wider urban, not just transport, system. Transport economic methods are generally better at assessing the value of a capital project in its own right, and are less suited to assess the wider indirect (e.g. long term impact on urban form and land utilisation) and direct impacts (such as GDP receipts and land prices) from accelerating or delaying a significant land transport investment.

Assessing the economic value, including social and environmental values of the VRP in the future, would need to use a mix of existing economic evaluation methods and values, along with a wider set of strategic assessments from the urban system performance perspective.

The government benefit–cost ratio

The government benefit–cost ratio (BCR_G) is used to indicate the level of benefits obtained from investment of local and central Government funds in activities where Government funding is supplemented by the availability of third-party funding or tolling revenue, or where it is necessary to cover service provider costs in the event of a funding gap for the operation of public transport services. The BCR_G is not an alternative to the BCR_N and it will not replace the BCR_N in the Waka Kotahi Investment Prioritisation Method (IPM). Rather, the BCR_G is additional information that is helpful when considering both the business case and the financing of an activity.

Sensitivity analysis

It would be difficult to try and compare the VRP study results with studies or operational systems in other countries, because each road pricing system tends to reflect its unique problem, spatial characteristics and authorising environment.

The specific objectives of a VRP concept would have a significant impact on the costs and benefits, which may have different implications for communities, depending on how VRP was operationalised and whether disbenefits might be mitigated.

There are well understood positive associations internationally between:

1) the intervention of road pricing
2) the implications on transport networks and travel time, and
3) economic productivity (and calculating a BCR), which is normally a standard requirement to inform investment decisions about significant size and complex proposals.

VRP costs perspective

The financial section sets out the VRP costs (rather than UFTI investment costs).

The possible total annual accumulated cost to the owner of a car being driven to work on most working and many weekend days of the year, under a VRP scenario, could be more than $1,800 per annum. This estimate is based on one seven-kilometre return trip each day, for 300 days per annum, on a priced corridor with a $2 access charge and 15 cents per kilometre charge. Many households would undertake fewer or more trips per annum, and many vehicles may have different drivers and occupants for different trips. Put more simply, the estimated price under a VRP scenario could be about $30 a week for a commuter. This is on top of existing Fuel Excise Duty/Road User Charges.

For the purpose of the VRP proof-of-concept study, an assumption has been made that there would continue to be a price differential between light vehicles and heavy vehicles (defined as all vehicles 3.5 tonne and over), and that heavy vehicle drivers are less sensitive to changes in price. This reflects the differences and priorities of the commercial sector, compared to private travel. There is a long-standing price differential on toll roads: a factor of 2.5 times higher for heavy vehicles. This price differential recognises several factors, the primary one being the value of time, which is perceived as higher for freight than private travel.

For the purpose of the VRP proof-of-concept study, an assumption has been made that vehicles would be charged the same access and use price, irrespective of:

- Motive power, for example EV or internal combustion engine - some cities globally have or will impose additional charges or restrictions on internal combustion engine vehicles, to reduce vehicle carbon emissions, others grant discounts or exemptions to EVs or other zero-emission vehicles
- Trip purpose - all vehicles (other than specifically-identified emergency vehicles, as defined or enabled by the LTMA S52(6), which are exempt under legislation from paying toll tariffs)
- Number of trips per day - no daily maximum price cap, irrespective of the number of trips a driver makes. This is primarily because the study is a proof-of-concept only, and because there is insufficient evidence about the number of trips a vehicle may make each day. In addition, there is no practical or cost-effective way to identify the vehicle driver rather than the vehicle number plate. More detailed information and analysis would be needed if there was to be differential pricing based on vehicle

motive power, axle mass, or trip purpose; and whether there should daily price maximums per vehicle. Any exemptions or price reductions would impact on both the level of net revenue and operating costs.

Other financial costs
Vehicle owners and drivers incur a number of financial costs before or after, but not during a trip, and those costs do not usually inform their decision to make a trip. Those costs include cost of ownership (capital), general use (e.g. petrol, maintenance), and vehicle storage (e.g. parking).

Examples of other transport costs borne by a vehicle owner or driver are as follows. (Note: prices are as at March 2023 and are GST inclusive):

- All-day parking each work-day in the main CBD parking areas could be up to $2,900 per annum, depending on the specific location. This is based on a daily maximum parking fee of $12 and 247 working days per annum. The daily maximum parking fee is a significant discount to the accumulated hourly fee
- There are two toll roads in Tauranga. The VRP study assumes that the toll tariffs would be removed from both toll roads and replaced by VRP. That would mean that many existing motorists would have an incremental, rather than significant, change in the cost of driving on those corridors with pricing
- A price differential applies to the existing toll roads between light vehicles and heavy vehicles. The one-way cost per trip on the Tauranga Eastern Link Toll Road is $2.10 for light vehicles and $5.20 for heavy vehicles (over 3.5 tonnes). Toll tariffs per trip on Takitimu Drive Toll Road are $1.90 for light vehicles and $5.00 for heavy vehicles (over 3.5 tonnes)
- A daily commuter on the toll roads could already be paying up to $1,000 per annum, assuming one return trip per day for 247 working days per annum.
- A return trip each day by a heavy vehicle, every working day, could be up to $2,500 per annum.

Private drivers must pay the full price of current toll roads and are not able to reclaim the GST component. Commercial drivers may be able to reclaim the GST component and/or reclaim costs from customers, usually indirectly.

Nationally set FED/RUC charges also apply, and can be assumed to continue in some form.

Examples of costs borne by ratepayers who pay for land transport road maintenance, public transport services and improvements
Currently ratepayers, rather than other residents or road users, pay for the local share of costs that councils incur (net of NLTF funding subsidies) in providing local road corridors and public transport services. For example, Tauranga City Council rates (allocated based on property value) fund road maintenance and improvements, and BoP Regional Council rates subsidise public transport services and fund improvements. These ongoing costs will continue to increase over time, to keep pace with resident expectations and transport costs.

Investment in UFTI outcomes

To deliver the UFTI Connected Communities strategy, the western Bay of Plenty subregion has created a Transport System Plan (TSP). TSP is both a 30+yr programme of works for services and infrastructure, and describes the partnership model that delivers the programme in a collaborative manner.

The TSP investment programme is being refreshed currently, to:

- Determine the PT service and capital investments required over the coming decade to improve travel mode options
- Include insight about and responses to recent wider Government policy requirements (e.g. carbon emissions and light vehicle travel reduction)

The investment planning refresh work is being undertaken by the western Bay of Plenty Transport System Plan (TSP) partnership, consisting of Council, Waka Kotahi and key stakeholder partners. In general terms the investment planning approach emphasises people-centred investments in the first decade especially over significant road infrastructure asset capacity investments. This is required to deliver the conditions that enables UFTI Connected Centres. The investment is prioritised toward the central government-agreed

Priority Development Areas for new housing (spread across the sub-region), and on network improvements that support improved travel mode choices and creates a safe network.

The UFTI transport demand forecasts predate the government's recent requirements for a light VKT reduction programme which is likely to influence the form, timing, sequencing and phasing of transport activities. The focus on VKT and emission reduction is unlikely to alter the UFTI land-use and settlement pattern significantly. During the evaluation of UFTI scenarios similar metrics were considered and the options were not significantly different to each other.

The priorities for transport investment to deliver UFTI activities in the current decade is being refreshed. The forecast costs could be approximately $200m p.a. in each of the next three years, and $300m p.a. in the following years four to ten (includes both capex and increased opex, particularly for PT service improvements). This level of proposed investment is higher than recent annual average. The scale of total investment in the coming decade is likely in the order of $2.0b. Additional significant service and infrastructure investment is forecast to be required in the subsequent decades.

The longer-term TSP transport programme investment (subject to present refresh) has been estimated to cost about $7 billion in 2020 dollars over the next 50 to 100 years. This includes capital expenditure on new infrastructure of about $3.2 billion and operational expenditure, on public transport services and road maintenance of $3.8 billion. Based on cost increases since 2020 these costs are likely to be a considerably under-estimated.

This level of long-term investment is unaffordable with the current mix of funding and financing instruments. SmartGrowth has concluded that the current funding sources will be inadequate, and UFTI has identified particular challenges around funding the peaks of expenditure including in the first decade (2020 to 2030). An alternative funding and financing approach is needed to fund sub-regional infrastructures and services because:

1. There is no clear funding plan to deliver UFTI benefits – and the sub-region remains reliant on ad-hoc funding and uncertain funding bids that have different objectives and business rules
2. Rates alone can't be continually increased to pay the local share for growth-related transport improvements. Property rates continue to be most appropriate mechanism to pay the local share to maintain transport access/core services. However this funding source is not sufficient for all required investment, especially in a growing sub-region.

The TSP programme financials do not assume there would be VRP, however VRP could be a part of a funding and financing strategy.

If VRP was implemented it would impact the form, timing, sequencing and phasing of transport activities – both for travel demand initiatives and network capacity and utilisation initiatives.

Any further work would need to include an assessment of the possible transport activities to be invested in over the next 30 years, identifying the activities and associated costs and a finance and funding plan that would enable implementation of VRP.

Wider costs and benefits

There are significant wider sub-regional costs and benefits associated with the performance of the land transport system that are outside the scope of the VRP study, and are therefore not addressed in this report, although they may be relevant in informing any decision-making about VRP. Many of these are categorised in the land transport monetised and non-monetised benefits manuals used to assess the value of transport investments. Decisions about the provision of land transport networks and services can have significant and long run implications on a number of factors beyond provision of transport infrastructure and services to access opportunity. These include:

- visual amenity
- protection of productive soils

- land values
- air and land environmental impacts
- community wellbeing
- economic productivity
- freight efficiency, and
- employment.

These wider impacts exist to a varying degree, depending on context, because land transport in an urban area is part of the urban system. While transport is key enabler of a quality compact urban form, affordable housing and accessible jobs and education and health services, the investment in transport can have a significant influence on wider social and economic factors. As a result, wider social and economic costs and benefits should inform any decision about VRP.

The wider economic costs could include some businesses relocating, to help customers avoid the pricing system, if the prices were excessive. A detailed analysis would be required to estimate whether this would primarily be a disbenefit, and the significance of that.

Wider benefits of investing in UFTI

Some of the necessary transport investment in Tauranga will deliver wider urban system benefits and outcomes. From an economic geography perspective, these transport investments will improve land use, trigger private sector investment and unlock productivity constraints. In some urban locations, the transport benefits may be secondary to the wider urban economic benefits.

Addressing transport infrastructure inefficiencies will deliver local and national benefits, in several different outcome areas:

1) Improved local transport outcomes, as defined by more efficient access and consistent journey times; improved choice in departure time and reliability, especially for access to the port and airport and the commercial centre along the Hewlett's Road corridor
2) Improved wider national economic productivity (as defined by ongoing increases in GST and business tax collection), business growth, and economies of scale in industry, agriculture and transport, etc.
3) Improved urban outcomes, as defined by quality urban form, with consequent emissions reductions and wider benefits, including improving wellbeing and employment opportunities.

UFTI and the housing shortage

NZIER (August 2022) has investigated, for Tauranga City Council, the impact of the housing shortage in Tauranga and the western Bay of Plenty on economic development. NZIER has concluded that the shortage in housing increases house prices, limits growth in Tauranga's workforce and impacts on construction activities.

NZIER estimated that the current housing shortage in 2021 was in the range of 4,267 to 5,295 houses and says Tauranga's future housing shortage is projected to grow by 867 dwellings annually through to 2032, under baseline projections. Under a more competitive environment, this housing shortage could be as high as 3,140 dwellings annually in 2032. This means a cumulative 3,355 people would be unable to live in Tauranga because of the housing shortage. This number rises to 14,951 in a more competitive environment. The consequence of this housing shortfall, and its constraint on population, will limit the size of the city's workforce. This could lead to foregone GDP of $436 million in three years and $1.609 billion in ten years.

If events play out as NZIER predicts, the housing shortage over the next decade will dampen population growth and business activity for Tauranga City and the western Bay of Plenty. NZIER suggests that the housing shortage may correct itself towards the end of the next decade and so this may be a temporary constraint on the Tauranga economy. Either way, VRP could have role in managing the workforce and economic output impacts of a housing shortage over the next decade.

Tentative observations about UFTI assumptions

Some UFTI assumptions may need to be revised (such as the price of parking in 2048), updated (such as public transport mode share and patronage assumptions), or reviewed (such as for alignment with improved evidence and in response to the Emissions Reduction Plan and the urban light VKT reduction programme).

Some UFTI land use density and trip catchment assumptions may be conservative if VRP was implemented, because road pricing may result in reduced trips within some catchments, and land-use densities may increase in some locations.

Bringing forward some public transport service improvements from 2048 to 2035 makes only a modest, albeit statistically significant, total impact on the shape and level of sub-regional travel demand.

9. Implications

This section of the report identifies topics that could be considered by appropriate organisations, if further work is undertaken.

Further work required to inform a decision about implementation
Further detailed technical work would be required before any decision could be made to implement variable road pricing in Tauranga, even if there was already enabling legislation.

Business cases are used to build the case for investment in a phased way, ensuring that the problems/opportunities are clear and compelling, and that the proposed solutions are effective and deliver value for money. Business case requirements are determined, based on the particular risk and complexity of the transport problems/opportunities and possible solutions. In the Tauranga VRP context, the business case requirements of strategic assessment have been met, as largely has the strategic programme optioneering, albeit the study objective was to assess the feasibility of VRP rather than consider a broad range of options to realise the study objectives. An in-depth analysis, through development of a business case, would be required of the proposed solution to inform a decision about whether to invest in implementation.

The in-depth analysis would include:

1) How to ensure that value of VRP would be maximised, and possibly phased-in (as a way to demonstrate the benefits and ameliorate negative perceptions and impacts), within a broad mix of travel demand and supply interventions, to provide improved travel choices and journey experiences, and
2) Identifying implementation implications, including the economic case (option selection & value for money), the commercial case (viability), the financial case (affordability), and the management case (achievability).

VRP is a transport intervention with sufficient risk and complexity that a fit-for-purpose business case would be more detailed than the analysis undertaken in a Single Stage Business Case. Assuming there is a commitment to explore the implications of implementing VRP, the emphasis of further work would need to focus on the how, including responding to risks and uncertainties. Other work may be required, such as considering the trade-off of revenue against other objectives important to the Government. This could include an analysis about forgoing revenue by granting varying levels of discounted pricing for special classes of vehicles, such as electric vehicles, and/or shared transport services, and/or road freight.

On this basis, a separate Indicative Business Case to evaluate the short-listed options, followed by a Detailed Business Case, would likely not be required, with any next phase being a Detailed Business Case. This would include elements of an IBC, such as confirming the optimal package of interdependent and aligned initiatives to maximise the value of implementing some form of VRP.

DBC scope and costs differ, depending on context-sensitive complexities, uncertainties and risks, which is why many DBCs emphasise the economic case. The Management, Commercial and Financial Cases would be significant components in any VRP DBC. The Management Case would have to deal with complex governance issues, as well as operational management, who does what and how, including the digital technologies and procurement. How the required integrated UFTI network improvements are financed and funded would also need to be considered. This phase is estimated to take two years and cost $3 million (GST exclusive). There would be other interdependences, such as enabling legislation. In terms of scope, which would be decided by partners with a financial and governance stake in the outcomes, there is a decision to be made about the extent to which VRP is integrated within a wider Travel Demand Management context.

Any decision to invest National Land Transport Funding into further work would require a funding application. This would include an estimation, and then assessment, of appropriate further technical work required before an implementation decision could be made.

Any future work would provide an opportunity to undertake a people-centred detailed study, rather than a technical study, followed by consultation.

VRP implementation could be phased
VRP could be phased in over time. That approach could be perceived as a way to mitigate opposition to introducing pay-as-you-go pricing, noting how difficult it has proven to introduce in many jurisdictions elsewhere. The phasing could be by location, starting with only part of the proposed priced network; by price level, starting with a low price and increasing over time; or by time-of-day, setting the price of travel in the inter-peak periods at nil for the first decade. The disbenefits of a phased approach include:

- It would not maximise the behavioural benefits of implementing pricing, and
- It would result in less revenue available to invest in improving customer levels of service in the early years.

VRP could also be used in the future as a regulatory tool with a pricing outcome, such the creation of low emission zones (noting that this is unlikely to generate anywhere near the same net revenue or network reliability based outcomes).

VRP is one, albeit significant, intervention that if implemented would be an activity within an integrated package
For VRP to be effective as a tool, it would need to be part of an integrated package of transport initiatives, so that the benefits of road pricing were achieved and negative consequences minimised. A package approach would help with implementing solutions in an integrated way. This approach would likely result in bringing forward investments in the strategic transport network, local roads (e.g. transformation including traffic-calming), and public transport infrastructure to improve the quality of public transport services and provide viable travel choices.

A package would be developed to optimise the potential value of all complementary, and sometimes interdependent initiatives associated with road pricing. These initiatives may include investment in public transport infrastructure; additional subsidising of public transport to accommodate mode shift and encourage increased patronage; investments in other asset classes, such as community amenities and education facilities; and decisions on land use controls in District Plans, car parking policies and fees. The development of a Business Case would identify this package of interventions.

Pricing is likely the most effective demand management tool in the short- and medium-term (with land use having a significant impact in the longer-term). A transport investment plan that includes VRP would result in a faster implementation of interventions. Pricing would have the potential to delay and even avoid investing in some additional infrastructure. By introducing pricing, the mix of transport solutions would be more-optimally selected, better sequenced economically, and more-efficiently timed.

The pace and scale of transport investment to deliver the UFTI outcomes during the next 20 years would need to be timed and sequenced to support the introduction of VRP. The investment plan would have significant cost implications in the next decade, because some future planned investments would need to be brought forward. The benefits include earlier delivery of community wellbeing, greater national economic output and a reduction of carbon emissions.

Investment implications
VRP would have major investment implications for Waka Kotahi as the state highway service provider, the Bay of Plenty Regional Council as public transport operator, Tauranga City Council as the primary network planner and manager, and the Western Bay of Plenty District Council as a sub-region network planner and manager. The role of rail is increasingly important to ensure each network plays its part in the transport system, and that freight efficiencies continue to improve over time. This is dependent on significant investment and demand management being implemented in the western corridor.

Any decision to implement VRP would have a significant implication on the timing and phasing of transport investment during the next decade and beyond. An agreed investment plan would enable road users to see the value they are getting by paying for the convenience of travel. These requirements indicate a need for a significant, system-wide and sustained investment plan, with sufficient scale of financing and funding to deliver outcomes across the sub-region and across transport modes. Advanced investment in high-quality and locally-valued public transport services, as well as improved walking and cycling infrastructure, which will lead to additional rather than redirected trips, is critical to implementing road pricing. A Business case would be required to confirm these implications.

Possible future toll roads in the western Bay of Plenty
At the time of writing this report, it was not known whether any additional toll roads and toll road debt may be established under the current LTMA in Tauranga City, for example with new access interchanges to the Tauranga Eastern Link, or with the Takitimu Northern Link Stages 1 and 2).

Strategic alignment nationally and locally
If road pricing schemes were implemented locally, whether labelled as variable pricing or congestion charging, it would raise issues about the fit between local road pricing proposals and:
1) Future national road pricing revenue/national cost recovery tools (including Road User Charges) needed to replace petrol excise duty in the longer term
2) The value propositions to existing road users for paying an additional price, especially to use an existing state highway
3) The use of funding raised locally, whether off a local corridor or a state highway
4) The relationship of any additional new charge to existing FED & RUC requirements.

There are pricing strategy considerations of national and local interest
Any agreement to implement and finance and fund a sub-regional road pricing system would be influenced by national road pricing system policy. For example, the extent to which funding might be used to:

1) Fund ongoing road maintenance or public transport services
2) Improve network throughput efficiencies
3) Invest in improvements that transition networks, to change the shape and level of demand, such as public transport infrastructure and services and walking and cycling networks
4) Fund major road infrastructure capacity improvements Manage congestion in a revenue-neutral way.

Determining some of the pricing components is straightforward, such as provision for GST, transaction costs and advancing high-value transport projects. What would be challenging, however, would be if a pricing strategy was required to assess the components of the price, such as whether to recover average or marginal costs, and willingness-to-pay surveys.

Several countries are grappling with the future revenue systems for land transport investment, because of the disruption from changes in petrol engine efficiencies and adoption of EVs. There is a need for more stable and reliable revenue streams. The costs of maintaining and improving land transport networks and services are consistently increasing and will remain significant. Both local and central Government are exploring the viability and value of new revenue tools, but there are no easy answers. There is consensus in a number of countries that some form of pay-as-you-go pricing should be part of future land transport funding, setting prices based on usage which might vary on a range of factors such as location, time-of-day, distance travelled, vehicle type, and motive power used. It may be some years before the New Zealand Government, and other governments, decide on the future revenue system.

There may be some form of transition between current and future state in New Zealand. Some councils may want to progress road pricing at a local level, to deliver broader urban form and transport and community outcomes ahead of any future long-term national policy.

Business and operating models
The VRP business model implications of who does what along the customer value stream include:
1) Systems integration - the extent to which there needs to be one network-wide VRP system, rather than a separate tolling business in the same spatial area
2) Network and service integration and improvement - so networks and services are managed as one system, to improve the customer experience, the performance of the land transport system, outcomes, and value for money from expenditure in networks and services

3) Pricing integration - there needs to be a coherent pricing strategy across products, such as road use prices, parking fees and public transport fares, to ensure all prices and complementary interventions support shared objectives
4) Pricing agility - empowering a network manager to adjust prices to ensure these provide consistent customer value.

Service bundling and subscriptions

The land transport sector is a latecomer to the disruption faced by some other infrastructure, utility or service sectors, such as energy, telecommunications, and banking, over the last two decades. Disruption at a sector level is largely at the intersection with technology advances and is driven by consumer preferences. In this respect, land transport is being disrupted by energy and technology (e.g. electric vehicles – and ultimately autonomous vehicles), technology (e.g. digital technologies embedded in vehicles and infrastructure asset networks, software as a service platforms, ticketing systems), and consumer preferences (commoditisation of travel, service innovations).

Pricing in land transport may follow innovations observable in other sectors, including the provision of a wide variety of service offerings, offered at different price points. There are examples internationally of road pricing, and traditional “monthly passes” for public transport, but very few examples of service bundling – e.g. service bundling for different customer segments, combining road access, taxi rides, public transport trips, and perhaps non-transport benefits as well).

Further work may identify (affordable) opportunities to create innovative solutions for different customer segment needs that provide both viable and affordable travel choices and revenue streams to deliver the benefits. For example, creating daily, monthly, annual offerings that bundle road pricing, public transport and other shared transport, and bicycle rental credits, with prices set to incentivise the right mode for the right trip, taking into account where the customer lives or works. Strategically, this approach represents an innovative way to provide effective transport access, rather than a continued focus on individual mobility, and uses pricing of other modes (e.g. public transport) in a way that may increase the value proposition.

One of the primary benefits of road pricing, however, is the nexus in time between having to pay a price and making a travel mode choice (whether to drive or not), and travel time choice (when to travel) and this important behavioural aspect needs to be retained in any service bundling.

The operating model implications of how accountabilities and capabilities are organised include:
1) Validating the Waka Kotahi 2022 procurement of an upgrade to its national tolling system which has the technical capability to accommodate changes in prices by location and time-of-day could accommodate the VRP scheme
2) Determining the extent to which the financial and funding functions might be separate to, or integrated with, broader network management and network operations functions
3) Identifying the extent to which the TCC closed circuit digital camera system, including ANPR cameras used for local traffic management – which are subject to regular technology refreshes, might be integrated within a road pricing system
4) The extent to which a local road pricing system could be integrated within a multi city road pricing system.

Governance and management topics

Systems integration: whether there would be one network-wide variable road pricing system for Tauranga, rather than a variable road pricing scheme and a separate tolling business.

Network integration: for example. managing four separate networks (three councils, plus Waka Kotahi) as one system; determining whether there would be one pricing strategy, managing pricing across all products, such as road use prices, parking fees, public transport fares.

Decisions on how net revenues are managed, and distributed, and how decisions on pricing are made to be sufficiently responsive to changing conditions.

Financing and funding accountabilities
How the financial arrangements are set up, governed and managed is important in establishing an effective road pricing system.

There are organisational accountabilities associated with, and choices about, revenue ownership, revenue use, and subsidies to recognise equity implications.

National factors to consider in the local context include the structural form of finance and funding arrangements, borrowing time periods, and investment-to-revenue ratios.

Lessons for successful delivery
Social licence from communities is essential to be able to introduce VRP. There are very few international examples of road pricing, even though there is a lot of supportive general and location-specific evidence that road pricing would be effective. The most significant barrier is public acceptability – which is directly about the value proposition to the people who would be paying the costs, and the implications for people who did not want to pay the costs.

Public acceptance is strongest where there are significant transport constraints to be addressed (e.g. a congested corridor), and local road users consider it is fair for them to pay to help deliver an improvement. This is because the introduction of road pricing would demonstrate a tangible benefit to local road users in the short-term. This approach is an easier sell than trying to position pricing as a delivery strategy or revenue-raising tool.

The research of The Congestion Question in Auckland identified that internationally, the lack of public acceptance is the biggest barrier to implementing urban congestion pricing schemes. People resist paying further charges, so need to understand and support the expected benefits. International experience suggests that the agreement of the community to pay road charges is not a technical question, but a political one.

The technology is available to implement road pricing. International experience suggests that two key ingredients are required to gain the permission of the community to implement road pricing. These are:

1) Strong political leadership
2) A strong value proposition (refer to earlier comments on the value proposition).

Strong political leadership, supported by a strong and convincing value proposition, is important in persuading a population to accept road pricing. The Norwegian experience highlights the importance of having a convincing value proposition. People in Norwegian cities, such as Oslo, Trondheim and Bergen, have accepted toll rings on the premise that the revenue stream is used to fund much needed tunnels, bridges, roads and other facilities to improve access. When the agreed tolling period was completed, a further tolling period was negotiated with the community to fund a new package of road improvements. With the payment of a toll being linked to tangible benefits, the community accepted the need to pay.

Distributional impacts
Possible equity mechanisms, if there was any further work, could include:

1) Subsidies – if it was feasible to identify the customer base and provide discounts efficiently and fairly, whether by way of a funding top-up or discount code
2) Frequent user discounts (part trips or whole trips) - although it would not be feasible technically to distinguish whether the driver was same person for each vehicle trip
3) No charge for network use at off-peak times, especially beneficial for people with limited travel choices
4) Exemptions, for essential service vehicles.

Some types of trips or category of drivers could receive an equity benefit or a reimbursement of costs through appropriate organisations and businesses.

Innovation measures could include businesses buying VRP kilometres to give to customers.

Toll System

A toll system's complexity and costs would depend partly on the pricing strategy. Dynamic pricing is technically complex, while static pricing (which varies by time of day and location) is simpler. Variable pricing may be less complex if pricing changes were limited to a small number of time periods, such as week-day morning and afternoon peaks, inter-peak and off-peak, Saturday peak, and weekend and long weekend peaks and off-peaks, with limited pricing changes by corridor to improve access and limit traffic diversion. In addition to charges by vehicle type as they cross a toll ring, the western Bay of Plenty VRP proposal requires a distance-based charge. Such systems are already available in New Zealand through the operation of eRUC (a national revenue tool). The VRP proposal is to use ANPR technology and not eRUC. The requirements of the VRP pricing strategy are not expected to create issues for the Waka Kotahi toll system.

Waka Kotahi currently operates several toll roads in New Zealand using a back-office system in Palmerston North. This system can process a tariff by vehicle type when it crosses under a gantry, and is currently being upgraded. Legislation would need to provide for varying price by time-of-day, although current payment functionality does not allow for this.

The VRP Proposal would require the back-office system to have the capability to accommodate variable charges by vehicle type. This functionality is already in place for light and heavy vehicles, and for exempt vehicles. The VRP Proposal would also require journeys to be priced by kilometre. Some form of journey length functionality is part of the current system upgrade.

A western Bay of Plenty-based VRP system would impact on the functionality of the new back-office system in Palmerston North. The implications would include the need for increased capacity to process transactions, and increased operations management to adapt to a large scale. The greater the increase in the number of transactions, the better the economies of scale per transaction.

10. Study limitations

This study is proof-of-concept only. It is a technical exercise to estimate the potential viability of implementing VRP in the western Bay of Plenty, to inform strategic thinking. There was no comprehensive forecasting and subsequent assessment of all monetised and non-monetised impacts, or aggregating and then discounting the benefits and costs over time (to create a Benefit Cost Ratio). The study applied current UFTI assumptions and has not considered the impact, if any, of the Government's Emissions Reduction Plan requirements for Tauranga and the region's other main urban centres. The study is based on changing one variable only to the UFTI assumptions, which is price. In a formal business case, a package of price and non-price initiatives would need to complement and optimise the value of VRP, such as vehicle parking, public transport, road network optimisation, and travel behaviour education. The study parameters assumed that the LTMA would enable road pricing, however the current LTMA only provides for tolling to recover costs of a new road length, where there is a free alternative route.

Future work to consider VRP would need to focus on engagement with the communities and businesses who would be impacted by pricing. It would need to start with a better understanding residents' and travellers' needs and preferences, and their ideas for implementing VRP in a way that would deliver significant tangible benefits. It is likely that it would be several years before VRP could be implemented, even after communities had agreed to a proposal.

This study has not considered the implications of adopting a road pricing system. If VRP was to be implemented in the western Bay of Plenty, local governance and management would need to be integrated with any national system functionality, for example the Waka Kotahi national road pricing system, and aligned over time with any future national policy.