D'ARTAGNAN CONSULTING
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Review of international road pricing initiatives, previous reports and technologies for demand management purposes

For Ministry of Transport

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Preface

D'Artagnan Pacific Pty Ltd (DPPL), with Ian Wallis Associates (IWA) were appointed to prepare a report for the Auckland Smarter Transport Pricing Project that consists of a:

- Review of international pricing schemes and initiatives;
- Review of previous Auckland road pricing studies;
- Summary of the functional elements of road pricing systems;
- Review of the technology options for road pricing systems; and
- Review of the main operating models for road pricing systems.

DPPL undertook the first, third, fourth and fifth tasks, and the non-economic review of the second task. IWA led the economic review of the second task. The contents of this report are supplemented by Appendices A-T contained in another document.

Executive Summary

Introduction. Today, eight cities operate congestion pricing schemes to manage traffic demand. For each city with a system in operation, a greater number have discontinued development for lack of public acceptance. Successful implementations carefully aligned the case for pricing with policy decisions reflecting public and political acceptance factors while building the institutional capacity to deliver the scheme. Schemes that ignored one or more of these elements failed. Together, successes and failures offer a rich set of lessons that, viewed in proper context, may be applied as Auckland considers options for a feasible, scalable, publicly-acceptable programme that delivers net benefits.

This Executive Summary presents key lessons on high-level policy objectives, analytical approaches, scheme design methodologies, public engagement, and system delivery. The full report offers detailed case studies of over a dozen global examples of congestion pricing, both implemented and abandoned, as well as more extensive lessons learned from each. The report also reviews past studies of road pricing for Auckland and describes prospective technologies for future implementation.

A single lesson stands out: Auckland's urban form, trip patterns, and governance require bespoke policies, public engagement, design, and delivery that build incrementally to address the most widely acknowledged problem(s)

From experience across the world, a single lesson stands out: Auckland's urban form, trip patterns, and governance require bespoke policies, public engagement, design, and delivery that build incrementally to address the most widely acknowledged problem(s). Other cities offer features to borrow and lessons to heed, but a high-stakes policy like congestion pricing requires deep understanding of local geography and responsiveness to local conditions and concerns.

Objectives and goals. World experience with congestion pricing reveals a range of schemes with varying objectives, from establishing free flow traffic conditions to improving urban amenity. The more generally recognised the problem, the higher the likelihood of agreement on objectives. Singapore focused solely on using charges to address congestion, and explicitly not to raise revenue. In other cities, success often required addressing multiple objectives at once. London and Stockholm established congestion management and transport expenditure as key objectives.

Diverse and sometimes competing interests can lead to many objectives (e.g., the Netherlands). With too many objectives, project sponsors struggle to explain the scheme's purpose and articulate its benefits. Public scepticism typically grows over a scheme's purported ability to address too many problems (e.g., Edinburgh).

How the schemes emerged. Starting from agreed objectives, schemes typically focus on the most obvious problem or at least the problem that regional stakeholders collectively acknowledge. To date, schemes usually focused on the central city due to pronounced economic and environmental impacts and ready availability of travel alternatives (e.g., London, Singapore, Stockholm, Gothenburg, Milan).

Schemes typically focus on the most obvious problem

As these examples show, making the case for the fundamental public value of congestion pricing rests on articulating a broadly recognised problem and designing a solution that persuasively addresses the problem. However, the solution is typically not solely charging, but also complementary transport infrastructure improvements.

Review of international road pricing schemes, previous reports and technologies

The fastest conception to implementation timeframe, Dubai, took about one year, but its design has been criticised for not effectively addressing congestion. London took two and a half years at considerable determination and cost. Stockholm took two and a half years from deciding to run a pilot until the pilot started operating (including a legislative change). Most schemes followed with continuous evolution of policy and operations after initial launch, in some cases even redefining the purpose of pricing (e.g. Milan).

Long timeframes create challenges for sustaining broad agreement on problem definition, objectives, scheme design, and delivery, especially if governments change throughout the development period. Some schemes (e.g., the Netherlands, Edinburgh, Copenhagen) achieved early agreement but stumbled later with communications or delivery, with political or public sentiment turning against them. Edinburgh, a prime example, started with strong apparent public support, but the public soundly rejected congestion charging in a referendum seven years after its debut in the city's transport strategy.

There is no "ideal" timeframe from conception to implementation

There is no "ideal" timeframe from conception to implementation. Successful schemes maintained momentum via clear focus on scope and objectives irrespective of any imposed time frame. That said, based on others' experiences, Auckland should be able to implement a pilot or small scheme within two and a half years of agreement to proceed on a chosen option.

Analytical tools used. All schemes, even those abandoned, made strong cases for congestion pricing using conventional transport demand modelling. At present, models can capture changes in trip numbers, routes, mode choices, travel times, and network speeds. They cannot identify all behavioural responses (e.g., time of day shifts) or reliably account for trip purposes.

Modelling proved reliable in London, Singapore, Stockholm and Gothenburg to determine the demand impact of initial charge levels. However, as Stockholm learned, the accuracy of such models wanes with charge complexity and time, particularly as charged users respond differently to changes in price signals, to uncharged users. Sponsors used surveys of businesses and residents to identify local economic and social impacts. The effectiveness of surveys to separate charging impacts from wider economic or local factors, or to reliably identify changes in user behaviour, is questionable.

Methodology for choosing systems/scheme design. Once a problem is defined and a high-level scheme concept takes shape, with clearly defined objectives and capable analytical tools readied, detailed design choices remain. Successful schemes adjusted design to respond to local conditions. Some examples of detailed scheme decisions include the following:

- *Price setting basis and structure*. Approaches differ widely. Singapore delivers on reducing congestion by setting and reviewing prices based on network performance, with prices varying by each charging point and across small time of day increments. This ensures a guaranteed level of service as well as minimising the risk of overcharging for time savings. Aside from dynamically priced express toll road lanes in the U.S., no other city adjusts prices so frequently according to performance. Stockholm and Gothenburg both use differential peak and off-peak charging to encourage time of day trip changes based on modelled demand responses. London by contrast has a blunt, flat charge based on a political judgment call that considered public acceptability and sufficient demand response.
- *Discounts and exemptions*. Most schemes were modelled targeting all vehicles, but each handled the question of discounts and exemptions in a distinct manner. London granted a significant proportion of users discounts and exemptions (now constituting 50% of traffic in the zone). Singapore conversely

Granting of discounts and exemptions encourages lobbying for more

only exempts emergency vehicles. Stockholm initially granted an exemption to low emission vehicles that it has since withdrawn to maintain the focus on congestion. Scheme planners expressed concern that the granting of exemptions encourages lobbying for more, which increases costs, increases risks of fraud, and can reduce scheme effectiveness.

- *Use of revenues*. Most active schemes dedicate net revenues to transport. The precise mix of spending varies by place. London legally hypothecates revenue for local transport purposes (across modes). Stockholm dedicated the revenue primarily to major road projects, but an increasing portion now goes to public and active transport modes. Gothenburg dedicated its revenue to fund a regional transport package. However, public support in Gothenburg has suffered in part because the scheme funds major projects several years from completion. Evidence shows that public acceptability improves when government dedicates charge revenues to improving transport, but the question of which modes (roads vs. public transport) depends on local conditions. In successful and failed cases alike, more than any other single factor, credibility of spending proposals and perceived benefits to those paying for them determined public sentiment toward the scheme overall (e.g., Gothenburg, Stockholm, Manchester, Edinburgh).

Most active schemes dedicate net revenues to transport

Credibility of spending proposals and perceived benefits to those paying for them determined public sentiment

- *Technology*. All schemes require automatic number plate recognition (ANPR) for enforcement and most also use it as the sole vehicle identification technology for charging purposes. Since the earlier ARPES and ARPS studies, ANPR technology has improved considerably in accuracy and reduced in cost, effectively rendering DSRC (tag and beacon) technology unnecessary for new systems. GNSS technology is no longer seen as unproven, but the risk, timing, and cost to retrofit a large urban vehicle fleet remain a barrier to implementation. Auckland's technology choices will be about whether it uses ANPR exclusively or includes a GNSS option (enabling charging by distance) that a scheme can evolve into over time.

All schemes require automatic number plate recognition (ANPR) for enforcement and most also use it as the sole vehicle identification technology for charging purposes

- *Privacy*. Approaches to privacy also vary. Singapore designed privacy into its system, whereas the Swedish schemes have much less privacy because of the Swedish approach to transparency in taxation. What is most important is that privacy concerns are considered and addressed in scheme design.
- *Interoperability with tolls and fuel duties*. No schemes operating to date have any interoperability with tolls or fuel duties. Several schemes have been planned to replace existing taxes with road pricing, but none have proceeded. Oregon's distance based RUC offers fuel tax credits for those paying the scheme, but on a small scale (fewer than 1000 users) and not for congestion pricing. Particular care will be needed in policy design to address issues of efficiency and equity, if congestion pricing is linked to offsetting nationally collected motoring taxes.

Engagement requires articulation of precisely what feedback and opinions the programme seeks from the public

Public engagement and consultation. Effective public engagement and consultation proved critical success factors in all congestion pricing schemes. High quality public engagement and consultation start with providing clear, consistent, simple information about the proposal, including relevant complementary measures. Engagement requires articulation of precisely what feedback and opinions the programme seeks from the public. Singapore conducted elaborate consultations primarily about the user experience, and the location of charge points. Stockholm took public consultation about as far as possible, to the point of a fully operational six-month pilot followed by a referendum.

Failed schemes offer perhaps the best lessons on public engagement. Muddled or inaccurate communications often preceded growth in negative public reactions. Manchester and Edinburgh only sought minimal public feedback on design elements. Manchester, moreover, saw inconsistent messaging and inaccurate media reporting on the timing and location of proposed charges. The Netherlands, by contrast, sought too much public feedback, as the programme morphed from its focus on congestion into a complete reform of the national road charging system. Project sponsors then lost control of messaging about the scheme's purpose.

Development and implementation. Practical development and implementation of congestion pricing requires patience and agility. All active schemes evolved from conception to implementation, and continue to evolve to this day. Initial implementation represents the most significant challenge; to date, although London removed its Western Extension, no city has dismantled an active scheme.

Demonstrations or pilot, although not essential, can be helpful. Stockholm and Singapore both successfully implemented their schemes following a major pilot (6 months) and demonstration, respectively. As both cities learned, pilots or demonstrations help for both outward and inward reasons. Outwardly, they focus public discourse on something concrete, making the feedback more meaningful and relevant to the scheme design. Inwardly, they prepare agencies for the challenges of delivery by identifying gaps in competence, systems, or inter-agency linkages. They also reveal opportunities for technical improvements, such as Stockholm's decision to abandon costly and redundant DSRC and utilise ANPR exclusively for vehicle detection.

Successful systems mitigated risks by moving incrementally with systematic policy adjustments

Demonstrations, pilots, and full implementations alike reveal the importance of rigorous "end-to-end testing" prior to launch to minimise technical glitches and maximise the likelihood of achieving intended outcomes. Moreover, given the added sensitivity around road pricing as a policy, successful systems mitigated risks by moving incrementally with systematic policy adjustments.

A pricing system must undertake a mix of monopoly and competitive functions, including customer service/account management, charge processing, enforcement, and back office administration. Cities have pursued a range of delivery models, with schemes varying between owning and managing operations in-house under contract or having a single PPP offering an integrated solution. The risks of the latter include lack of cost transparency and difficulty unwinding the scheme when seeking further evolution.

Outcomes. Broadly speaking, active schemes achieved initial traffic suppression of 15-30% in line with forecasts (except Dubai, which reduced traffic on charged routes only to divert much of it to parallel routes). This level of demand suppression allowed for expected travel time savings and emissions reductions. Some schemes (London, Stockholm) used this as an opportunity to improve urban amenity in the charged zones.

Economic outcomes, on the other hand, proved difficult to measure. London declared the economic impacts "neutral" overall following rigorous monitoring of local business impacts.

Conventional benefit-cost assessment of Stockholm and Gothenburg (as has also been seen in ARPES and ATAP) indicated that benefits to those paying were lower than the charges paid. However, more refined appraisal of the benefits may go some way to addressing this, such as the value of travel time reliability and evaluation of wider economic benefits. A key element in ensuring net economic benefits is to ensure spending net revenues on activities with high net economic benefits or perhaps offset by reductions in other forms of taxation.

User experience and public reaction. Analysts tend to measure user experience and public reactions via ex-post surveys and media monitoring. Some schemes do not survey travel experiences, assuming if the network performs well and traffic flows, customers must be satisfied (e.g. Singapore). By contrast, London conducted meticulous surveys of travel time, delays, and public opinion. In general, public acceptability increases after scheme introduction and demonstrable congestion reduction. However, not all schemes enjoyed such success.

Decision makers should expect a range of feedback depending on the scheme delivery and design impacts. Stockholm serves as the exception to the rule: given the positive result of the referendum on charging; there have been few calls to discontinue its scheme.

- *Customer service*. If done poorly, customer service complaints will proliferate. Aware of this risk, London poured extra resources into capacity for call centres and customer service more generally.
- *Delivery of objectives to reduce congestion*. Scepticism in London today focuses on recent worsening of congestion, raising concern that the charge is about revenue, not about improving conditions for those who pay. This has contributed to political difficulty in expanding the London scheme. Likewise, worsening traffic conditions on Dubai's uncharged routes curtailed appetite for further expansion.
- *Delivery of transport improvements*. London and Stockholm delivered promised improvements. In Stockholm, leaders prioritised spending on road improvements to improve public acceptability. Among active schemes, Gothenburg reports perhaps the greatest opposition after introduction (in a non-binding referendum, 62% opposed continuation of the charge), due in part to dedication of revenues to large transport projects whose benefits remain several years off and perceptions the problem was not severe enough to justify charging.

Distributional impacts. An on-going issue in nearly every scheme are complaints related to those who pay versus those who benefit versus those who do not pay. Some abandoned schemes (e.g., New York, Edinburgh) schemes arguably failed due to inability to articulate a response to fundamental concerns about equity. One way to reduce these impacts is to design a scheme that only charges congested roads at congested times of day, as in Singapore. Most schemes have also sought to mitigate such impacts through provision of additional public transport and careful attention to scheme design to minimise division of residential areas. Highly targeted discounts and exemptions (e.g., registered disabled vehicles, residents in an area charge scheme) also assist in addressing direct negative impacts.

Complementary mitigation measures. The two most common and effective mitigation measures in active schemes are provision of alternatives (typically public transport) and extension of discounts or exemptions to those most affected to achieve political acceptance.

A key success factor for congestion charging has been the existence of alternatives for users

- *Alternatives for users*. A key success factor for congestion charging has been the existence of alternatives for users, whether public transport, alternative routes or driving at different times of day. London, Stockholm, and Singapore all have extensive public transport services as reasonable alternatives for road users, and each provided additional bus capacity at the launch of their congestion charges. London and Stockholm also introduced traffic management measures for the bypass routes for their schemes to improve effectiveness outside the area/cordon. Lower off-peak charges in Singapore, Stockholm, and Gothenburg also encourage discretionary trips to shift time of travel.

- *Discounts, exemptions, design adaptation*. For users impacted harshly by the scheme, exemptions or discounts can serve a useful role in mitigating negative impacts (though the cautionary note about too many exemptions still applies). The island of Lidingö in Stockholm serves as perhaps the best example. "Trapped" by the cordon with no access into or out of the charged zone other than by driving, Lidingö residents faced no choice but to pay the charges or stay at home. To address this unusual case, the scheme initially exempted trips by Lidingö residents until revenues from the scheme helped build a road bypass that "freed" the residents from the charged zone.

For users impacted harshly by the scheme, exemptions or discounts can serve a useful role in mitigating negative impacts

Conclusion. The lessons presented here represent the collective global experience with congestion pricing, edited using the authors' judgment to provide inputs most relevant for Auckland.

From prior studies (ARPES and ARPS), it appears large cordons (or area charging schemes) in Auckland could have considerable impacts but, due to their bluntness, create distributional impacts seen as unfair by those living, working, or taking short trips near a cordon. Similarly, strategic network charging is likely to create negative impacts on local roads as seen in Dubai's experience. Where results from earlier studies point to full network charging as viable from a technical standpoint, the worldwide case studies suggest higher odds of success by pursuing a smaller-scale implementation that builds public experience, institutional knowledge, and scheme credibility, then expanding or evolving in due course.

Case studies suggest higher odds of success by pursuing a smaller-scale implementation that builds public experience, institutional knowledge, and scheme credibility, then expanding or evolving in due course

For all their differences, successful schemes share one common factor: a willingness to develop a solution that targets local priorities and takes policy and design risks, rather than awaiting others to prove that an approach works. In other words, congestion pricing is not yet a policy to import or replicate wholesale. Auckland's geographic and political context lends itself to some features from several existing schemes, but ultimately, to address its transport challenges successfully, Auckland requires a scheme designed for its objectives and local conditions.

Definitions & Abbreviations

TERM/ABBREVIATION	DEFINITION/DESCRIPTION	REMARKS
ANPR	Automatic Number Plate Recognition. Technology to identify vehicles based on video technology to read their number plates and match that number to a database of vehicle owners.	
Area charging	Charging vehicles for crossing a ring or driving within that ring at specific times of days, typically to manage demand. London's Congestion Charge is an area charge.	
ARPES	Auckland Road Pricing Evaluation Study	
ARPS	Auckland Road Pricing Study	
ART	Auckland Regional Transport	In reference to the Auckland Regional Transport Model
ATAP	Auckland Transport Alignment Project	
Congestion charging	Charging vehicles for use of specific roads during specific times and days, in order to reduce the severity and duration of congestion on the network. Revenues from such charging are not necessarily linked to any road or transport infrastructure costs.	
Cordon pricing	Charging vehicles for crossing a ring or line of charge points across a series of roads at specific times of day, typically to manage demand. Cordon pricing does not charge for traffic movements within the cordon. Stockholm's congestion tax is a cordon.	
Corridor charging	Charging vehicles to use all of the roads in a corridor (main highway and secondary routes).	
CSP	Certified service provider. A contracted commercial entity providing the account management, revenue collection, equipment supply and customer services functions for a road charging system.	
Demonstration	In the context of road charging, a live trial of a series of possible policy/technology options for implementing a road charging system. A demonstration is time-limited, includes a limited set of participants and tests a range of technology and product options to assess whether one or more of them have sufficient merit for more detailed consideration. A road charging demonstration does not collect revenue, although it may operate a simulation of how much revenue might have been collected for illustrative purposes.	

Desktop study	A research and analysis study involving only a review of literature, analysis of statistics and modelling of future costs, revenues, demands and economic impacts. It does not include any test or trial of systems or technologies, but may include the use of surveys or other forms of gathering statistics to inform a study.
DfT	Department for Transport (UK)
Discount	Specified discount from the full road charge rate for a user group, based on vehicle or vehicle owner characteristics. This discount may be 100%, and is within the powers of the scheme authority to introduce or remove, rather than being set by legislation or regulation.
DSRC	Dedicated Short Range Communications. Also known as tag and beacon road charging, whereby a small battery powered device is installed in a vehicle to enable identification in a toll system. Not used in New Zealand.
eRUC	Electronic Road User Charging. The electronic system providers in New Zealand that provide a GNSS platform to charge RUC. Currently Eroad and Coretex.
ERP	Electronic Road Pricing – the congestion pricing system operational in Singapore (also used the terminology used for proposals in Hong Kong and Jakarta)
Exemption	Legal exemption from having to pay in a road charging scheme, based on vehicle or vehicle owner characteristics.
Expenditure plans	The expenditure plans profile maintenance expenditure and capital investments planned by all levels of government on key road segments over the next four years.
FATF	Future Auckland Transport Funding study
Forward Looking Cost Base (FLCB)	A life cycle approach using forward looking costs for the purposes of determining what spending would be required to efficiently maintain infrastructure to sustain specified service standards and meet future needs of users.
Full Network Charging	Charging all vehicles on a road network varying by time, location and vehicle type, typically by some form of metering of distance or time spent on the network.
GALILEO	European Union GNSS system
GLONASS	Russian GNSS system
GNSS	Global Navigation Satellite System. A

	generic term for such systems which includes GPS, GALILEO and GLONASS
GPS	Global Positioning System, the US Government provided GNSS system
Heavy vehicles	Vehicles 3.5 tonnes and over – typically rigid and articulated trucks and buses as well as special purpose vehicles such as cranes.
HOT lane	High Occupancy Toll lane. A highway lane that is exclusively for use of buses and high occupancy cars, or for single occupancy vehicles if they pay a toll.
Hypothecated charges	Where taxes and charges collected from users of a service are directly returned to service providers to be reinvested in those services.
Light vehicles	Vehicles less than 3.5 tonnes including both passenger cars and light commercial vehicles.
LKW-Maut	"Lastkraftwagen-Maut" or heavy goods vehicle toll. The German heavy goods vehicle distance based road charging system that has been in operation since 2005 using GNSS technology.
LTA	Singapore Land Transport Authority. Owns and manages ERP
Market based model	A scheme where the supply and demand for a service reaches a classic microeconomic equilibrium which reflects both the users' willingness to pay for a level of quality at a given price and the suppliers' willingness to supply that quality at a given price.
NZTA	New Zealand Transport Agency
Pilot	A live trial of the proposed policy/technology option as an initial small-scale implementation of a road pricing system. A pilot may or may not be time-limited and may or may not be limited by number of participants. It is a pre-implementation step as a final test of the selected technology, system and products, obtain user feedback and will include the collection of revenue from users (and any rebate or offsetting payments from existing charges if relevant).
PPP	Public-private partnership. A contract between a public road manager or owner and a private company for many or all of the following activities related to a specific road or network of roads: Finance, design, construction, maintenance and operation.

Review of international road pricing schemes, previous reports and technologies

Road Charging	Direct charging of road users for the use of the road network, distinct from tolls in that charging is not applied to a single part of the network to recover the infrastructure costs for that part of the network.
RUC	Road User Charge. The New Zealand weight/distance road charging system applicable to heavy vehicles and light diesel vehicles.
Salik	The urban congestion charging scheme in operation in Dubai
TfL	Transport for London. Responsible for the London Congestion Charge
Tolls/ toll roads	Direct user charges in the form of regulated, facility-based tolls for usage of specific road corridors.
Toll lane	One or more lanes on a highway that may only be accessed by paying a toll, typically physically segregated from other untolled lanes.
Trials	Demonstrations and pilots. Any form of application of technology or systems in a form primarily to obtain information, data and feedback about its performance in advance of full implementation of the concept as an operating policy.
ULEZ	Ultra Low Emission Zone - planned environmental charge for London to be implemented in addition to the congestion charge

1. Introduction

1.1. Background

The report "Road Pricing: The Economic and Technical Possibilities" (commonly referred to as the Smeed report)[1] in 1964 was the first significant report undertaken by government, anywhere in the world, proposing the introduction of road pricing to manage congestion in cities (particularly London). This was followed by a World Bank report about congestion in Singapore, which informed the first implementation of demand management based pricing in 1975, Singapore, called the Area Licensing Scheme (ALS). That simple cordon scheme with paper permits saw a 76% reduction in vehicles crossing the cordon in the morning peak. By the late 1980s, technology for electronic road pricing has emerged and in 1998, Singapore introduced the world's first demand management based road pricing scheme, which is still today the world's most sophisticated scheme.

As with many other cities around the world, Auckland faces considerable challenges as growth in population and economic activity has seen growth in road vehicle traffic that far outstrips the capacity of the network at certain times of day. Although there has been a fivefold increase in expenditure on transport in Auckland[2], this has been unable to meet the growth in demand. As is common with most major cities, it is neither financially viable nor publicly acceptable to grow road capacity in Auckland to adequately manage congestion along with growth in demand. Similarly, enhanced public transport can provide options for some road users undertaking trips on higher density corridors, but it is unlikely to provide a feasible option for many trips, and is not an option for freight or many businesses that need to move tools and materials to work sites. Demand management based road pricing provides an option to encourage better use of the existing road network by spreading demand by time of day, encouraging consolidation of trips and encouraging use of other modes.

1.2. Purpose and structure of report

Developing a system that is effective, equitable and publicly acceptable is the key challenge, particularly when such a scheme means road users paying more for some trips than they do at present. A similar challenge is convincing road users that paying to use roads at peak times will give them a meaningful improvement in service by reducing travel times and improving trip reliability. The core challenge for Auckland is to develop and implement a scalable, feasible, equitable, effective and publicly acceptable demand management based road pricing programme.

The purpose of this report is to bring together a summary of global experience with such pricing and to derive the key lessons learned from successful and not so successful programmes, to enable Auckland to consider options that are more likely to deliver a programme that is feasible, delivers net economic, social and environmental benefits and is publicly acceptable, as well as scalable to meet Auckland's changing needs. It also reviews the past reports on Auckland road pricing to establish what key lessons can still be carried forward from that work, and what key points from those reports are worthy of review. It summarises the key functional elements of a road charging system, the technologies and operating models available, and how these should inform the development of a system in Auckland.

The report is structured as follows:

- Chapter 2 Summary of international experience

[1] Smeed,, R.J. (1964). Road pricing: the economic and technical possibilities. HMSO, London
[2] Source: ATAP, Interim Report: Findings and Conclusions – May 2016.

- Chapter 3 Functional elements of demand management based road pricing systems
- Chapter 4 Technology options for pricing systems
- Chapter 5 Operational models and delivery programme for pricing systems
- Chapter 6 Review of previous reports on road pricing in Auckland
- Chapter 7 Conclusions and next steps for Auckland
- Appendices.

1.3. Terminology

Many different terms are used internationally to name the introduction of direct user fees on existing roads, as there is a wide and somewhat inconsistent use of terminology across different jurisdictions internationally. This is in part due to different legal frameworks used in various countries that define the way a fee is charged (e.g. in Sweden only a tax could be legally enforced), but also due to different political and cultural contexts as various authorities seek to use terms that are easily understood.

Singapore's scheme is called Electronic Road Pricing (which is also the term used in Hong Kong and Jakarta for their developing schemes), which is technically correct. London has a "congestion charge", Swedish schemes are called "congestion tax"

In the United States, the term congestion pricing is used extensively, although it is primarily used to refer to High Occupancy Toll (HOT) lanes. For the purposes of this study, the term "congestion pricing" is being used to encompass all of the schemes that are under review. This explicitly means any policy to directly charge road users for the use of existing roads to manage demand in order to address congestion, by setting prices to reduce congestion. This does not include the introduction of tolls as a measure to recover the capital and operating costs of specific roads. These are considered *toll roads* in the widely understood use of the term, with the direct charging of road users exclusively or primarily related to recovering the capital costs of the tolled road and related infrastructure. The UK and Sweden both have toll roads, but these are legally and functionally distinct from the congestion pricing schemes in both countries, as the tolls are for revenue related to the costs of infrastructure being charged.

This review also does not include the use of parking charges for demand management purposes, including demand based pricing of parking, taxation on parking or other means to control the supply of parking. This report does not consider the use of *national* road pricing measures or similar policies that may have, as one effect, an impact on aggregate demand. New Zealand's existing Road User Charge (RUC) system is in this category, although a handful of such systems have a minor element of demand management incorporated in charge rates.[3] For the avoidance of doubt, it also does not address the significant number of environmental charge or access control systems in place in many cities across Europe. For example, 70 German cities have environmental charges on certain types of vehicles entering inner city zones. Over 100 cities in Italy have access control systems to restrict the use of vehicle traffic in historic inner cities, limiting such traffic to local residents and delivery. As these are not primarily about reducing network congestion (but about urban amenity) they are excluded.

[3] The Belgian Viapass system charges heavy vehicles more for the use of local roads in Brussels than other roads that are charged, in part to discourage distance travelled on the city's congested network

1.4. Selection of schemes reviewed

A total of 16 schemes, including those in operation, those that did not proceed and two of which are at early stages of development, are reviewed in this report. This is not an exhaustive list of such proposals, but the ones that have been selected cover variations that encompass all of the relevant experience to consider in the Auckland context. The justification for including the schemes selected for detailed review and research is outlined below.

1.4.1. Singapore

Singapore was the first major congestion pricing scheme, having started with a paper based Area Licensing Scheme in 1975 progressing to today's refined cordon and expressway point based charging scheme. Singapore's Electronic Road Pricing (ERP) scheme is demonstrably successful, and performance based, having an objectively defined and evident impact on congestion in the city-state. The current scheme targets congestion by individual charging point, direction of travel, time of day (down to small increments according to demand) and vehicle type (based on road space occupancy) and is the world's most advanced to this day, even though it was introduced in 1998. Today, Singapore is leading the world in developing the first GNSS based congestion pricing system, which will enable it to evolve into a distance, time and location based system in due course. As the world's most sophisticated such system, its relevance to the Auckland context is clear.

1.4.2. London

London was the first European city to introduce a congestion charge in 2003 and contrasting with Singapore, did so in the face of a more vibrantly competitive political culture. London has the first area charge scheme in the world, charging not only for crossing a cordon but also for movements within the cordon (as part of the same charge). However, it is also a simple scheme, introduced after a specific political mandate. London's Congestion Charge was expanded, geographically, once, which proved not to be a success politically. This extension was abandoned. More recently, London's focus has been on establishment of ultra low emission zones. A recent report indicated that the Congestion Charge was no longer "fit for purpose" and the Mayor's draft Transport Strategy proposes full network road pricing based on time, location and distance over the longer term.[4] Given London is the city with the closest political and cultural parallels to Auckland with an operating scheme, it is worthy of review.

1.4.3. Stockholm

Stockholm's congestion tax was introduced as a cordon scheme, with price varying by time of day in 2007. This followed the operation of a pilot that saw the proposed scheme implemented, in effect in full, for six months, to give the public exposure to what its impacts could be. This was followed by a referendum that gave a narrow mandate for its introduction. Stockholm's scheme is of interest because it represents an evolution from the single price for all day access of London, and is a city with a geography that has its own challenges (and opportunities). Stockholm has made minor changes to its scheme since it was introduced, has a relatively high degree of public acceptability, so is worthy of review.

1.4.4. Gothenburg

Gothenburg is a further implementation of the concept in operation in Stockholm. As it commenced operations in 2013, it is the most recent implementation of urban congestion pricing. Gothenburg had much less serious congestion than Stockholm and a much lower mode share for public transport. The Gothenburg scheme has nearly as many users as the Stockholm scheme, even though Gothenburg has a

[4] https://tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/the-mayors-transport-strategy

much smaller population, because the Gothenburg scheme captures a much higher proportion of car trips than the Stockholm. However, Gothenburg's scheme has poor public acceptability. A consultative referendum held over a year after the scheme was introduced saw a majority vote to abolish it. Despite its unpopularity, it remains primarily because local politicians do not have any other source of funding for the regional transport package. Given that users do not perceive major benefits from the scheme, it is worthy to review Gothenburg's progress.

1.4.5. Hong Kong

Hong Kong has had four attempts at introducing congestion pricing and was the first city to ever embark on a technical trial in the early 1980s. It is now developing a cordon scheme on Hong Kong Island. It is of interest because it has been perhaps one of the most thorough of all cities in investigating and considering options for road pricing, but had not implemented it because it has failed to sufficiently address public acceptability factors in a city with a high level of public transport use.

1.4.6. HOT/express lanes in the Silicon Valley area

In the United States, some cities have developed networks of high occupancy/toll lanes that enable motorists willing to pay for priority to bypass congested part of the highway network. They are a subset of "managed lanes" (lanes that have access limited to specific sets of vehicles, such as buses or vehicles with 2 or 3 or more occupants).

The key advantage of such (HOT – high occupancy toll) lanes is that they provide an option to bypass congestion by paying for priority. They are not, strictly speaking, congestion pricing schemes as they do not relieve congestion, but provide a congestion free alternative. There are a number of such schemes in the US and one in Israel, but such schemes have not been implemented in other countries. The Silicon Valley Area HOT lanes have been included as an example and have been reviewed to determine if there is any merit in reconsidering such an option for Auckland.

1.4.7. New York

New York has not implemented a congestion pricing scheme, but the former Mayor, Michael Bloomberg advocated for such a scheme and did not succeed in progressing it. New York's scheme had some parallels to that of London, but would essentially have placed a cordon on half of Manhattan and implemented tolls on untolled East River crossings. The New York proposal had a mixed response from various interest groups, with a range of concerns. Ultimately, the scheme did not proceed because it needed political support at the state level that was refused. New York's problems persist, and a revised proposal to reform the existing toll crossings in New York is currently under discussion that would deliver many of the benefits of the original plan. New York's failure to progress its original proposal is worthy of review to see what lessons can be taken from that policy.

1.4.8. Manchester

Manchester, UK attempted to introduced a two cordon peak time (and peak direction) only congestion charging scheme, as part of a wider UK Government programme to encourage cities to introduce congestion charging in exchange for funding of major transport improvements. The intention of the Manchester scheme was to be a more refined policy than that of London, by having smaller prices at two sets of crossing points, that would only apply for short peak periods to manage congestion, with a pilot of a GNSS based charging option available to volunteers as well. Manchester's scheme failed after a referendum was held on whether it should proceed, and it was rejected nearly 4 to 1, in the context of the UK's banking crisis and extensive public distrust of politicians. As Manchester was seeking to implement a large scheme but only at peak times, to address problems on a series of corridors, and failed due to public acceptability, it presents some key lessons for Auckland.

1.4.9. The Netherlands

The Netherlands is the only example of an advanced proposal to introduce a national road pricing scheme specifically designed to include time of day and location based charging to manage congestion. As one of the most congested countries on average in Europe, congestion problems were identified as being not just in major cities like Amsterdam, but more endemically across the network. The Netherlands sought to replace high registration and vehicle sales taxes with time, distance, location based charges for all vehicles on all public roads, and so was the most advanced national road pricing proposal advanced at any time. The concept was advanced several times, and on each occasion the political will to proceed eroded. The ambition of the Netherlands (and the policy is being revived once more) means it is worthy of review.

1.4.10. Other relevant charging schemes

A smaller list of other schemes is also being reviewed, although only by desktop research.

Dubai's Salik system is an interesting implementation of road pricing on existing roads that has been for demand management purposes, but is not widely considered to be a success. It is a series of point based charges on major highways intended to reduce traffic on the most congested charging points in the emirate. However, it is not a cordon, and in some cases alternative routes are available that are highly congested. It is the only point charging system for congestion management that does not charge all possible routes for a trip.

Edinburgh sought to replicate London's scheme on a much wider geographic area, by introducing a double cordon to reduce congestion and raise revenue to fund public transport improvements. It followed closely behind the London scheme and was thought of as being able to build upon the success in London. However, it was subject to a public referendum and debate that was highly negative and saw a negative vote of around 4 to 1. Edinburgh, like Manchester, presents a series of lessons to follow.

Copenhagen was to introduce a series of cordons around the city, and had explicit political endorsement from the government (as it was included in its manifesto). As a city with a high mode share for cycling and public transport, and following on from success in London and Stockholm, politicians saw there being considerable merit and ease in being able to introduce congestion charging in this city. However, it was subject to considerable resistance from various interest groups and concern about the impacts that various charging proposals would have locally around the edges of charging zones. The government decided to abandon the proposal due to these concerns. Given that the original conditions for advancing charging appeared to exist in Copenhagen, it is another useful example of a scheme from which lessons can be learned as to why it did not proceed.

Helsinki most recently was subject of an extensive study and proposal to introduce distance time and location based charging to manage congestion. As it sought to be a more advanced system that those currently in placed and already has a relatively high mode share for public transport, it was seen as a natural evolution from previous policies. The Helsinki proposal was wound into a wider national scheme to reform road charging based on replacing some existing taxes, but was abandoned because the distributional impacts of the proposal were seen as highly regressive (in part because the major reduction in tax was on sales of new cars).

Jakarta has been advancing the conception of congestion pricing for the past three years with extensive advice from Singapore. It seeks to introduce charging on a series of highly congested roads towards the city centre as an initial pilot, with a wider network of major highway subject to charging over time. It is of interest because it is still under development, faces severe congestion and is currently constrained by issues of enforceability.

Portland does not have a scheme or a proposal, but is included because of the original Oregon Road User Fee Pilot Project (2006-2007) which included a demonstration of distance based charging to replace fuel tax, with an option of paying a higher charge within the city limits of Portland at certain times of day. This was intended to replicate the very blunt impacts of some form of demand management for Portland as part of a state wide scheme. Due primarily to privacy concerns, the Pilot did not result in such pricing being advanced for the subsequent road usage charge pilot program or implementation of OReGO in 2015, but saw a demand management response and gathered useful data to inform any such future policy.

Milan originally implemented an environmental charge for driving to the city centre that has since evolved into "Area C" as a congestion charge. It resembles the London scheme and is intended to reduce congestion in the downtown area. What is of interest in Milan is that the scheme was introduced, then temporarily suspended and reintroduced, highlighting a major increase in traffic during the period it was suspended.

Oslo is included despite it being an exception to all of the other schemes in that it was not introduced for the purpose of demand management. It was a "toll ring" (a cordon by any other name) intended to raise revenue to recover the cost of placing Oslo's major highways in a tunnelled network under the CBD and improvements to public transport. After the capital in those projects had been recovered, the toll ring was retained for demand management purposes and to raise revenue for further transport projects. Oslo is a useful example of applying charging for revenue raising purposes, but it evolving to effectively manage traffic in the city.

Other schemes that were considered for review but rejected include:

- Tehran (a very large cordon with many exemptions, and limited access to data about results and few parallels to Auckland that are not available from other projects);

- Bergen (a toll ring that has changed in purpose to a congestion charge, but still operates 24/7 with only a peak time surcharge);

- Dublin (proposals developed and rejected for a small cordon to manage demand, with parallels seen in UK schemes);

- Minor schemes such as Durham UK (on one historic route) and Valetta Malta (historic city centre) have also been excluded because of the lack of parallels with Auckland

1.5. Challenges of Auckland

The challenges of introducing congestion pricing in Auckland are considerable. In particular, patterns of congestion in Auckland are not concentrated in radial trips at peak times. 86% of commuting in Auckland is not to or from the CBD.[5] Notwithstanding a recent revival of employment and residential population in downtown Auckland, the CBD is unlikely to be a dominant trip generator. As a result a simple cordon around the CBD, may be technically feasible and serve a location with feasible public transport alternatives, but may have limited impacts across the network in reducing aggregate congestion levels (and indeed have limited impacts on trips to the CBD except on corridors adjacent to the charging points). As reflected in the ARPES, ARPS and ATAP reports, unlike all other cities that have introduced charging, Auckland is a much more dispersed lower density city. Whatever option is progressed in Auckland will need to balance the

[5] Source: *Journey to work patterns in the Auckland region Analysis of Census Data for 2001-2013 Executive summary*, Richard Paling Consultancy, July 2014. Pg.4.

necessary level of sophistication and complexity to be effective alongside public acceptability, minimisation of distortions and scalability. The real challenge is in ensuring any such options do not generate negative impacts that offset those benefits.

2. Summary of international experience

- **Singapore** was the first and is by far the most sophisticated and effective system, and will be the first to introduce GNSS based full network pricing. It has demonstrated the effectiveness of scalability and building upon the success of each stage of implementation and evolution.
- **London'**s great success was in public engagement and building acceptability and consensus, but it has not sustained congestion reduction gains and still operates a blunt, expensive system that has been declared "no longer fit for purpose". For now, London is focusing on environmental charging to improve air quality, but longer term is likely to implement full network pricing.
- **Stockholm** gained public acceptance through a full pilot that proved charging would reduce congestion, and subsequently by using much of the net revenue to improve roads.
- **Gothenburg** has had difficult gaining public acceptance in part because the scheme was designed to raise revenue, lack of belief that the congestion problem justified charging and because of negative local impacts in some areas which the cordon bisects
- **Dubai**'s scheme has reduced congestion on the routes that are charged, but worsened congestion on parallel, uncharged routes.
- **Oslo** has had an urban toll ring in place since 1990 to fund three packages of transport improvements. The toll ring remains controversial, and the option to convert it into a congestion charge was rejected as not being acceptable. Norway has a long tradition of using tolls to pay for major highway improvements so the toll ring has remained.
- **Hong Kong** has spent over 30 years investigating congestion pricing and is only now proceeding following a successful process of public engagement.
- **Edinburgh** and **Manchester** both sought to introduce large double cordon schemes, but had fierce public opposition. Many didn't believe the congestion charging schemes would reduce congestion, the use of revenues did not generate support and there was strong belief that the schemes themselves were unfair. In both cases, opposition campaigns led the media narrative and debate.
- **New York** sought to introduce a de-facto cordon in Manhattan applying tolls to the untolled East River crossings. It failed in part because of a belief that the cordon boundary was arbitrary and unjust, and fear of negative impacts dominated debate at the state level.
- **Copenhagen** was to implement a large cordon scheme and the national government was elected on a platform that included a Copenhagen congestion charge. However, enthusiasm waned politically when modelling indicated much lower revenue than originally hoped and concerns were expressed about a cordon scheme compared to full network pricing (which was deemed unaffordable).
- **Helsinki** had developed a preferred option, but this was subsumed by the national government advancing a national road pricing system to primarily replace taxes on buying new vehicles (with modest reductions in fuel tax). This was cancelled due to public opposition, as it was thought to mainly benefit the rich.
- The **Netherlands** has attempted several times to replace existing motoring taxes with full network road pricing but came up against public opposition on every occasion, with concerns over the cost of introducing charging and lack of belief that it would benefit motorists.
- **Oregon** successfully piloted distance based congestion charging for Portland, in exchange for credits to fuel tax.

2.1. Locations of congestion pricing

Compared to the number of cities that have investigated the use of pricing for demand management, those that have implemented it on existing roads are relatively few. Singapore was the first implementation in 1975 with its Area Licensing Scheme, remodelled into its Electronic Road Pricing scheme in 1998. London introduced the Congestion Charge in 2003, followed by Stockholm in 2007 (following a pilot in 2006). Dubai introduced its Salik system in 2007, and Valetta, Malta introduced a small scheme. Milan introduced an emissions charge in 2008 that was converted into a congestion charge in 2012. Gothenburg is the most recent implementation in 2013. Bergen converted its revenue collection toll ring to a congestion charge scheme in 2016. In all cases except Singapore and Dubai, the schemes chosen have been cordon or area charges. Singapore has a cordon charge, but also has charges on specific corridors, whereas Dubai has charges on a small number of major highways only. None of the cities that have implementing congestion pricing have the decentralised urban form seen in Auckland, with most employment distributed widely across the metropolitan area. Most of the cities that have implemented such a charge have extensive public transport, with the exception of the two Middle Eastern cities.

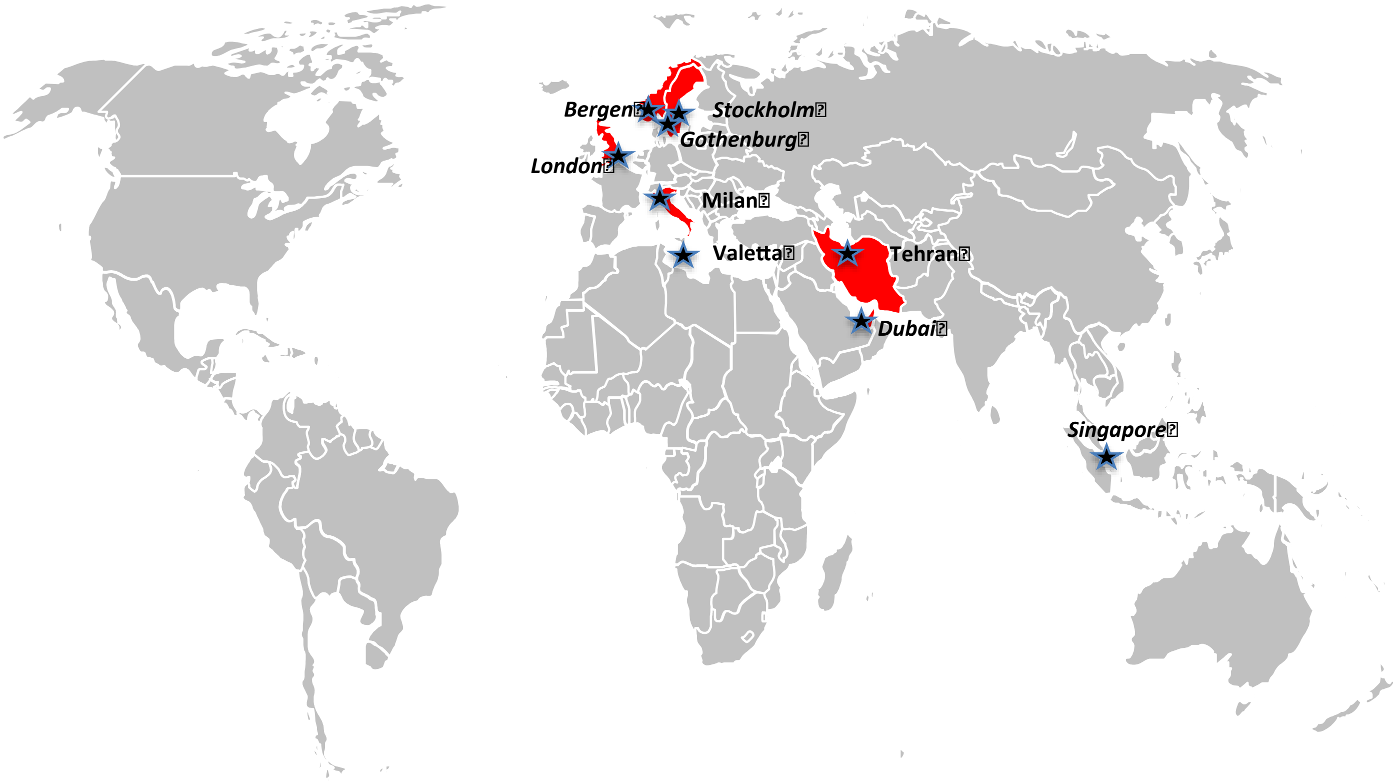

Figure 1 - Location of congestion pricing schemes globally

This section of the report reviews the following operating systems:

- London;
- Stockholm;
- Gothenburg
- Milan;
- Dubai; and
- Singapore.

Review of international road pricing schemes, previous reports and technologies

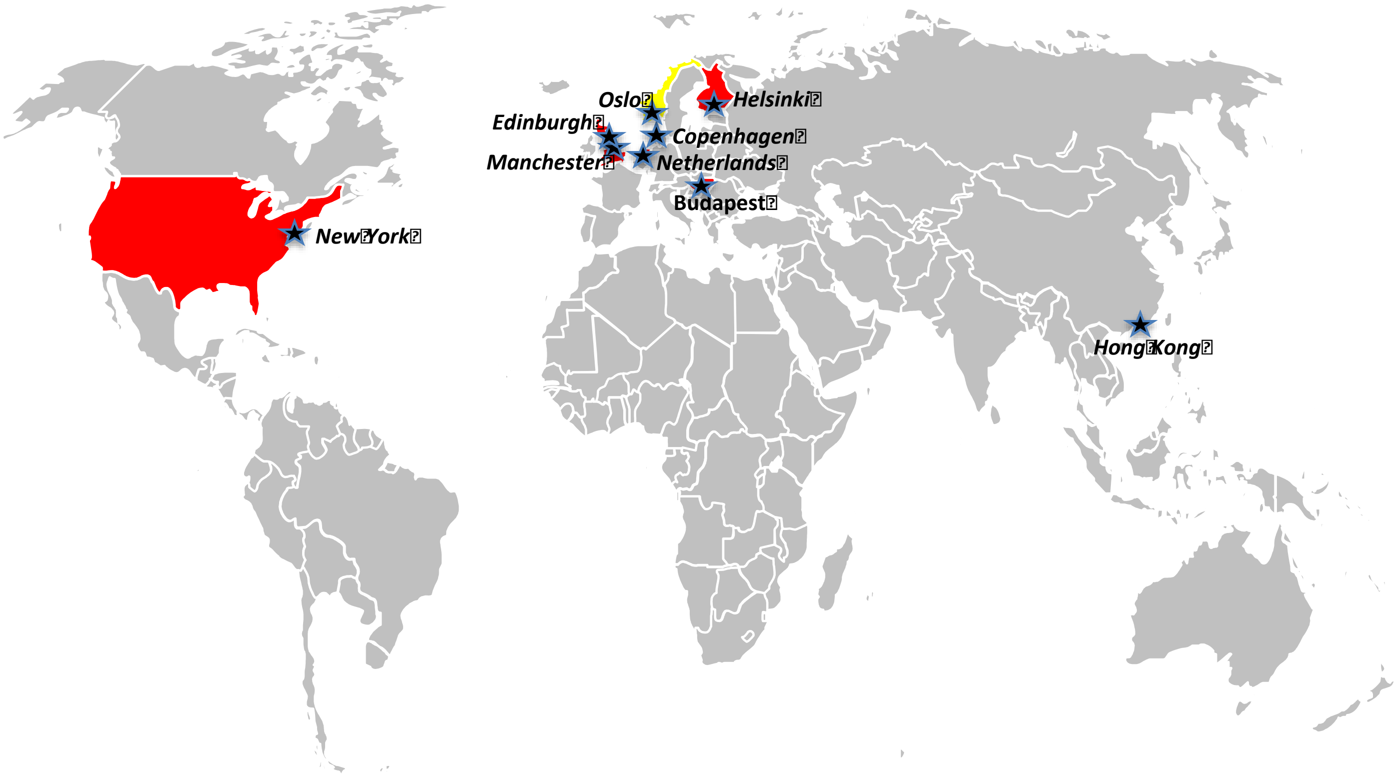

Figure 2 - Cities that discontinued development of congestion pricing schemes[6]

Figure 2 identifies many cities that have developed formal congestion pricing proposals and discontinued them. Of those, Oslo has an operating revenue raising scheme that it sought to convert into a congestion charging scheme, but did not succeed. Hong Kong abandoned a previous attempt to introduce charging, but is now considering a new proposal. All of the cities on this map, except Budapest, have been reviewed for this report. Other cities not displayed have made early investigations of congestion pricing, but none have developed major proposals that have been discontinued. The only other city on this map actively developing a scheme is Jakarta, which has been reviewed in this report.

Scheme location	Type of scheme	Basis for charges	Objectives	Summary results	Operating cost as % of revenue	Use of revenue	Key challenges
Singapore	Cordon and expressway charges	Economically efficient road use	Optimise traffic flow	Free flow conditions where charging applied	11%	General revenue (offset other tax cuts)	Shift to GNSS system
London	Area Charge	Reduce car use by 15-20%	Reduce private car traffic	20% reduction in private car traffic on introduction	40%	London transport (all modes)	Congestion returned to pre charge levels
Stockholm	Cordon	Spread demand	Reduce congestion	20.9% reduction in traffic	30% (shared with Gothenburg)	New roads some public transport	High operating costs

[6] Hong Kong has recommenced development.

Gothenburg	Cordon	Revenue collection target	Raise revenue	12% reduction in traffic	12% (excluding shared costs)	Regional transport package (rail and road)	Lack of public acceptability
Milan	Cordon	Discourage car use	Reduce congestion	30.7% reduction in traffic	33%	Public transport	Compliance
Dubai	Corridor	Reduce demand	Improve traffic flow	Up to 45% at charging points only	n.a..	General revenue	Diversion onto other roads
Silicon Valley HOT lanes	HOT lanes	Optimise traffic flow	Provide alternative	n.a.	60%	Transport	Equity impacts

Table 1 - Congestion pricing schemes summarised

2.2. Operating schemes

2.2.1. Singapore

2.2.1.1. Map of system

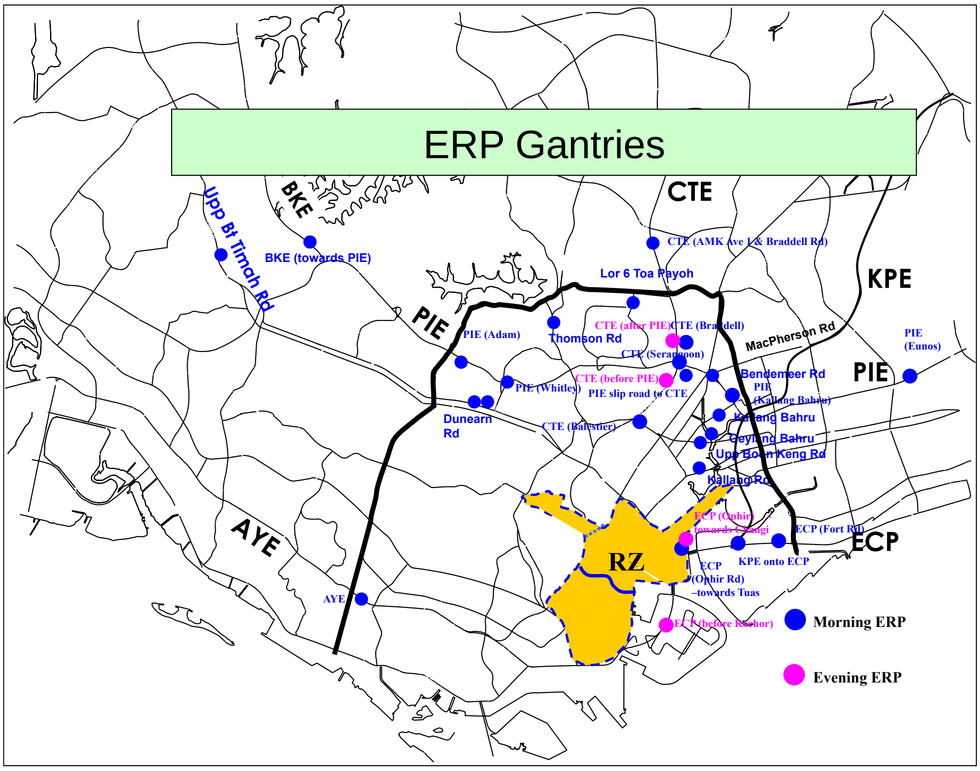

Figure 3 - Location of Singapore ERP charging points

2.2.1.2. Objectives and goals of scheme

Singapore ERP's has a simple objective to reduce congestion, more specifically to ensure speeds on the routes that are charged are managed within a range of 45km/h-65km/h for expressways and 20km/h-30km/h for local streets. The system is owned and managed by the Land Transport Authority (LTA), which is responsible for managing and developing roads, and public transport in Singapore. All new vehicles in Singapore are issued with an ERP on-board unit.

Rates on the ERP system are adjusted at three-monthly intervals to reach that target (based on an 85th percentile of speeds sampled). If speeds are too low at specified charging points (as prices vary by charging point and direction of travel), prices will be raised at the times of congestion. If speeds are above the target, it is assumed that the ERP is suppressing traffic demand *excessively* so prices are incrementally reduced.

2.2.1.3. Current scheme concept

Type of scheme	Two adjacent cordons and a network of strategic highway points. Charges based on passenger car unit equivalent size, time of day and location
Vehicles charged/discounts exemptions	All charged. Emergency vehicles exempt
Charging times	Varies by charging points from peak AM only to all day weekday and several hours Saturday
Charging technology	Bespoke DSRC system with prepaid smartcard inserted in OBU (to be replaced with GNSS based OBU). Payments through OBU deducting value from card
Use of net revenues	General government revenue
Range of charge rates	NZ$0.51 to NZ$4.05 per charging point, depending on time of day and vehicle type (PCU based)

2.2.1.4. How the system/scheme emerged

Singapore starting investigating options to manage traffic congestion and urban transport in the early 1970s, culminating in a high-level ministerial committee that was established in 1973 that recommended a series of options to constrain the growth of private car traffic. The concept of the Area Licensing Scheme (ALS) arose from that committee. Singapore became the first city to introduce some form of price based demand management of road use upon introduction of ALS in 1975. The ALS required motorists to purchase and display a paper licence to access a CBD cordon. Motorists purchased licences for a month or a day of access, allowing unlimited access during the operating hours of the licensing scheme (0730-0930, later extended to 1015 weekdays). The scheme evolved over the following 14 years, as exemptions for taxis, goods vehicles and cars with four or more occupants were removed in 1989, charging extended to the evening peak in the same year, and applied all day from 1994. Enforcement was undertaken by police observing vehicles crossing the cordon without a paper licence. The system was expanded further in 1995 and called the Road Pricing Scheme (RPS) by requiring licences for three major expressways.

While ALS/RPS successfully reduced congestion, the administration of manual inspections of vehicles grew costly and Singapore sought to develop a more flexible, scalable, and efficient system. The decision to introduce electronic road pricing (ERP) in 1989 followed examination of the first phase of trials in Hong Kong and interest in the first generation of tag and beacon technology for toll roads. ERP replaced both ALS and RPS in 1998, and over the following years the inner-city cordon was expanded and the number of expressway/highway charging points increased in number.

One of the key advantages ERP offered was to enable rates to be charged separately for each charging point, including hours of operation and direction of travel for charging. Singapore now has the most sophisticated road pricing system anywhere in the world, as each charging point has its own price schedule based on time of day, direction of travel and even day of the week (some operate on Saturdays).

Core to the ability of the Singapore Government to introduce its charging schemes has been high levels of public trust in the government to act in the wider interests of the public and the economy. It also has a long standing set of transport policy objectives to promote public transport, manage road usage and acknowledge the social role of transport.

To assist this, the Singaporean Government has sought to discourage car ownership with the Certificate of Entitlement (CoE) programme to restrict car ownership, (an auction system to grant people a right to legally own a car for a period of ten years). The price of a CoE is similar to the retail price of a new car, severely constraining the affordability of car ownership. The effect has been for Singapore to have lower per capita car ownership than almost all other developed economies.

Undoubtedly, it has proven much easier for Singapore to develop and evolve its ERP system after successfully operating the ALS system for over twenty years. Not only did ALS prove that pricing *can* effectively constrain road traffic growth, but that the system had been introduced for congestion management, not revenue generation. With the introduction of ERP, this was proven further, as the policy of varying rates based on performance (both up and down) demonstrated the policy commitment to optimising traffic flow, not simply taxing road users.

The decision to develop a GNSS-based system follows the success of ERP, but is also an attempt to move beyond the limitations of the ERP system. The next generation GNSS system is under development to provide greater flexibility for system expansion and enable a much wider range of value added services.

2.2.1.5. Analytical tools used

Singapore's focus on evaluation of ERP has been on traffic performance and system performance, measuring traffic speeds on charged roads to determine if they are within the 85th percentile of a specified range (of 45km/h-65km/h for expressways and 20km/h-30km/h for local streets). This directly informs rate setting every three months. If traffic at a charging point is below or above the range specified within at least 85% of the period sampled, the charge rate will be changed accordingly.

2.2.1.6. Methodology for choosing systems/scheme design

The locations of the ERP charging points were originally based on the ALS/RPS charging points, and have since focused on corridors with severe congestion. New charging points were selected based on regular congestion levels dropping below the target range identified in 2.2.1.5 above and the effect and practicality of installing a charging point.

The choice of technology and system was based on the need to achieve very high levels of reliability (which only tag and beacon technology could achieve in the 1990s). The choice of the system of using prepaid smartcards (and now credit cards) inserted into on-board units was to enable automated payment (in an age before e-commerce and internet payments had developed) and to help protect user privacy. By directly associating identifying a vehicle at a charging point, with instant receipt of payment, the system was easy to understand and also avoided extensive use of back-office processes for billing or processing of accounts and reconciling number-plate images for those avoiding payment.

The bespoke DSRC system, which takes payment through the gantries means Singapore, has some of the largest and most expensive and elaborate road pricing gantries anywhere. The gantries take up 11m of road length to locate camera, OBU controllers and antennas to enable the reading of OBUs and the collection and writing of data for the collection of money from OBUs.

The choice of target vehicles provided an equitable basis for charging. All vehicles except emergency vehicles have to pay without exemptions. The rate for payment is directly related to road space occupancy.

Enforcement is undertaken using ANPR cameras identifying vehicles with no valid on-board unit or insufficient payment in their ERP smartcards/accounts, with vehicle owners fined accordingly.

2.2.1.7. Public engagement and consultation

Development of ALS, RPS and ERP all involved public consultation and engagement. The government authority conducted a large scale public engagement exercise, including stakeholders such as road freight companies, fleet operators and motor vehicle associations, prior to introducing all three schemes. The public learned when and where the systems would operate and how they could pay and be compliant.

Although several technical trials occurred in advance of the introduction of ERP, the final trial demonstrated how it would work and helped with public familiarisation. The scheme was introduced on one road as a pilot, before rolling it out to other roads to replace the ALS and RPS, helping build familiarity further.

Acceptability was enhanced by offering taxis and commercial vehicles a discount for a brief period. Reductions in vehicle taxation, by transferring charges from owning to using a vehicle, also increased acceptability.

2.2.1.8. Development and implementation

Singapore took two years to develop the original paper based ALS scheme after the decision to proceed in 1973. In 1989, it was decided to proceed with ERP. Design was re-scoped 1991 to include prepaid smartcards and active tags, and to use ANPR technology. In March 1995, final bids were received with a decision made in October 1995 for the Philips, Mitsubishi, Miyoshi/CEI consortium at S$197m with a five-year maintenance contract worth S$39m. System testing was undertaken in 1997 on an unopened road, with in vehicle units installed from September that year. Finally, charging commenced on one road in April 1998 and was extended to the inner-city cordon in September, replacing the ALS.

For the forthcoming GNSS system, the LTA undertook successful technical trials of GNSS technology in 2012; the government decided to proceed in 2015 and tenders were called. In March 2016, the winning bidder was announced and launch should occur in 2020 at a cost of NZ$523m.

2.2.1.9. Outcomes

The ALS originally reduced morning peak traffic volumes by 60%, and when it was extended to the evening peak in 1989, it reduced volumes at that time by 40%, both indicating a very high elasticity of demand. It is notable that ALS applied initially only to private cars but was expanded to all vehicles since 1997.

On top of the ALS gains, ERP further reduced traffic volumes by an average of 7% on its introduction, which has been sustained. ERP has enabled vehicle numbers in Singapore to increase, but without congestion worsening at the places and times where ERP operates. Overall traffic volumes have reduced by between 17% and 4% depending on the charging point, but traffic volumes have increased during non-charging periods and on other minimally congested routes.

2.2.1.10. User experience and public reaction

Since Singapore delivers a minimum level of service on charged roads and reduces charges when speeds rise, the government regards the user experience as paramount. Key to public acceptability has been gradual expansion of the scope of the scheme once the positive impacts on congestion have been demonstrated. LTA believes that motorists regard ERP as effective and necessary, and, as it reduced other fees to own a car, as fair. The public tends to oppose new ERP gantries as unsightly. The proposed GNSS system is seen in the media as an evolution that will enable LTA to deliver more information on charges, route and modal choices to drivers, and enable ERP to be expanded without new gantries.[7] The new system will initially just replace the current one, indicating a certain sensitivity remains.

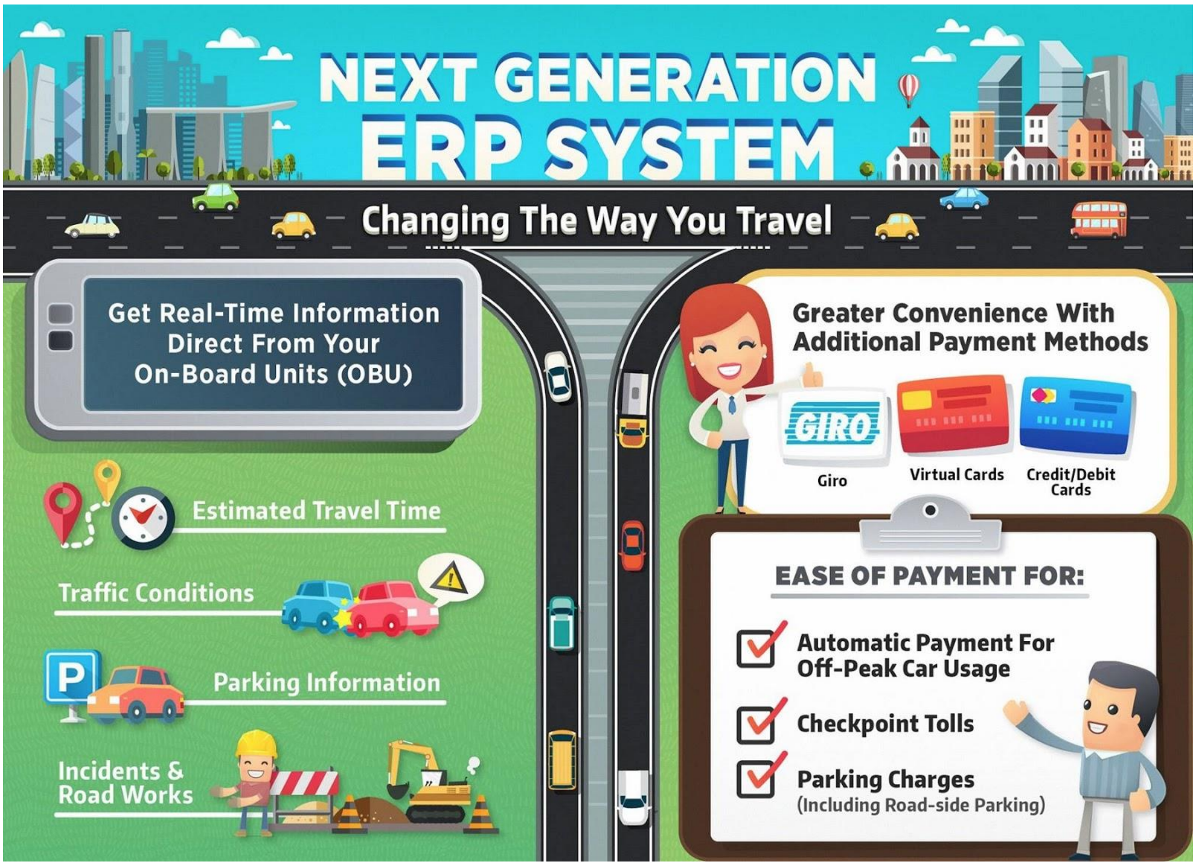

Figure 4 - Publicity material marketing GNSS ERP in Singapore

2.2.1.11. Complementary measures

A core element of Singapore's strategy has been to develop adequate alternatives for road users, so that road pricing is not seen as an unreasonable imposition. Extensive improvements to public transport were undertaken during the period of the ALS and this has expanded since the ERP was introduced. New metro lines, additional bus services and bus lanes have been added, with real time information systems for public transport. Air conditioned bus interchanges also helped to integrate the overall policy message that road users were offered reasonable alternatives to driving.

2.2.1.12. Key lessons for Auckland

Singapore is an example of a mature successful urban congestion pricing scheme that has delivered sustainable management of congestion in the city. Furthermore, it will almost certainly be the first city to evolve urban congestion pricing to an even more variable time-location-distance based system after 2020. The urban form/geography and political culture of Singapore are significantly different to that of Auckland.

[7] Source: http://www.straitstimes.com/singapore/transport/ncs-mhi-to-build-islandwide-satellite-based-erp-for-556m

Housing in Singapore is of much higher density than in Auckland, with much lower car ownership levels and more intensive provision of public transport. Although it is easy to characterise Singapore's political culture as being much more trusting of government with fewer opportunities to vigorously oppose or protest policy measures, it has a media and political discourse that challenges government. There has been regular coverage of concerns and scepticism about ERP in the Singaporean media. It has not been possible for new ERP gantries to be installed wherever LTA believes it to be appropriate, so Singapore's government has had to be aware of ensuring public support for the development of ERP.

The key positive lessons from Singapore come from what it does well:

- Performance management based approach to price setting;
- Highly targeting pricing by vehicle type, route, time of day and direction of travel;
- Evolving system building on success and confidence building.

The approach of setting and reviewing prices based on measurement of traffic speeds on the network ensures that the system actually delivers on its intentions, in managing congestion. By not allowing speeds to drop too low, it means that those who pay are effectively guaranteed a level of service is going to be maintained. By reducing prices if speeds are consistently higher, then the system also minimises the risk of overcharging for travel time savings, so that the network is not overpriced and underutilised.

Highly refined charging with minimal exemptions means charges avoid *blunt* impacts. This helps to promote equity, fairness and public acceptability. Singapore did not get to this level of charging sophistication immediately. This developed over the years of ALS and ERP, with charges increasingly developed for each location. It has successfully applied evidence from actual charging to supplant modelling pricing impacts.

The technology and design of Singapore's system is dated and would be expensive and physically intrusive to apply in Auckland. Auckland should be able to develop a system that incrementally evolves to have a level of sophistication akin to Singapore. Different roads should have prices that vary by time of day and location to reflect congestion, and if prices are reviewed regularly to track both up *and down*, this could be expected to improve public acceptability as well as minimise negative impacts on access and equity.

Finally, as the first city that will adopt GNSS based pricing, Auckland should carefully observe Singapore for lessons to embrace from deployment of a platform for full network pricing. It would be challenging for Auckland to advance such pricing initially, but the Singaporean experiences should prove useful in informing future steps towards full network charging. Singapore intends to use its new GNSS system initially to replicate what it does now, gather data on traffic movements and then to evolve its system incrementally.

Review of international road pricing schemes, previous reports and technologies

2.2.2. London

2.2.2.1. Map of system

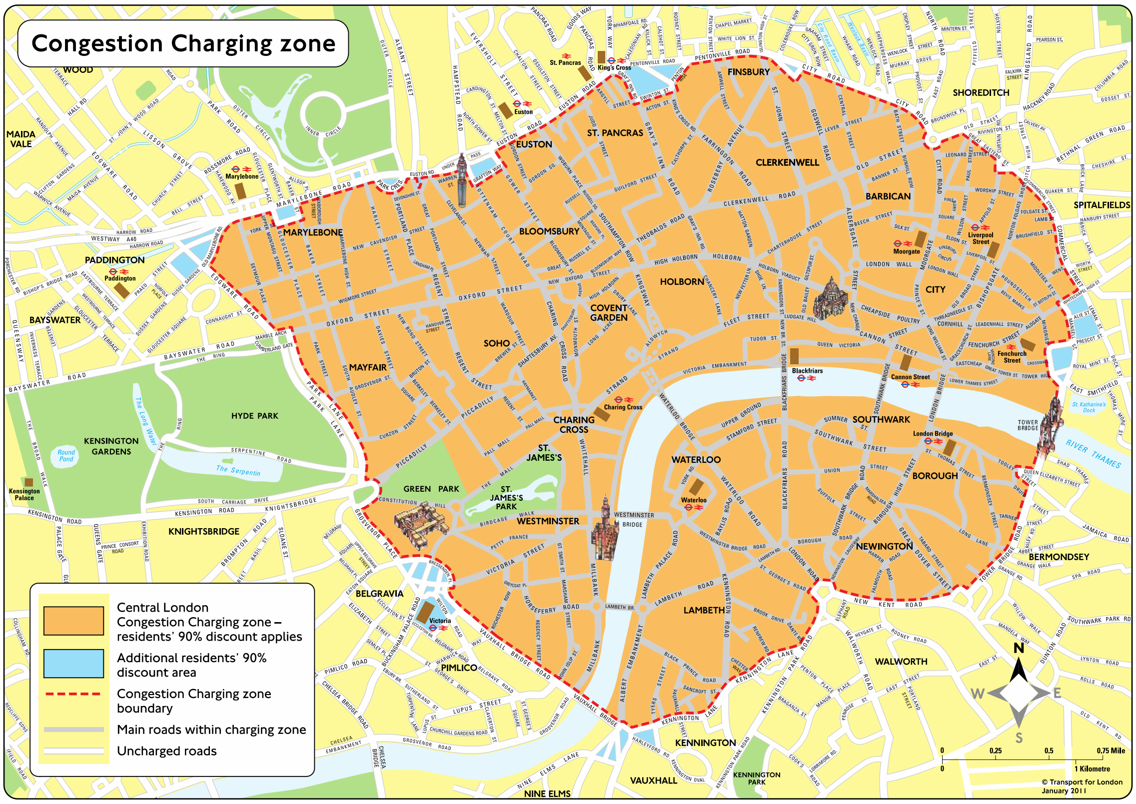

Figure 5 - London congestion charge zone map

2.2.2.2. Objectives and goals of scheme

The primary objective of the London congestion charging scheme is to reduce private car traffic in central London, by encouraging trips into central London by public transport or active modes. It does not have any specific goals around metrics of congestion. As a secondary matter, the scheme was introduced in part to enable road space to be reallocated for priority lanes for buses, taxis, bicycles and selective widening of footpaths. It was also considered a useful measure to raise revenue, but given the high operating costs at the time, it was stated by the then Mayor as "not being something you do to raise money".

2.2.2.3. Current scheme concept

Type of scheme	Area charge
Vehicles charged	Cars and goods vehicles
Charging times	0700-1800 weekdays except public holidays
Discounts/exemptions	Emergency vehicles, all buses and coaches, all taxis and private hire vehicles, all disabled (blue badge) and all zero-emission vehicles are either 100% discount or exempt. Residents' vehicles 90% discount

Charging technology	Declaration based system using ANPR. Registered fleet or account vehicles pay by detection using ANPR
Use of net revenues	Transport for London revenue for transport purposes
Range of charge rates	NZ$18.95-NZ$25.30 depending on registration or if paid the next day

2.2.2.4. How the systems/scheme emerged?

London had severe traffic congestion for decades preceding the congestion charge scheme. London had developed along railway corridors largely built in the 19th century and an Underground network, all of which easily rivalled the average speeds of the road network. Given those conditions, travel times by car have not been competitive with rail or underground for many years for trips to the CBD.

London first considered congestion pricing since the 1960s when the original Smeed report was published, but the technology available at the time made it unfeasible. Only when London's economic revival in the 1980s and 1990s had seen traffic congestion grow considerably did interest re-emerge in the policy. With ANPR technology becoming sufficiently reliable and the emergence of the first electronic, free-flow, toll roads, initial investigations were undertaken in the late 1990s concluded that some form of congestion pricing would be effective in helping address chronic traffic congestion. The difficulty of expanding road capacity in the historic centre of London and the density of public transport seemed to indicate that such an approach could be viable and that sufficient transport alternatives already existed to enable its implementation.

The main step that catalysed the introduction of congestion pricing was election of London's first metropolitan Mayor in 2000, following the creation by legislation of Transport for London (TfL) in 1999 as a single London wide transport authority and the Greater London Assembly. Newly elected Mayor Ken Livingstone had long campaigned on reducing the use of private cars in inner London and he was elected on a policy platform that included the introduction of a congestion charge. He immediately commissioned the ROCOL (Review of Charging Options for London) study that concluded in 2001 that a central city area charge would be the best first step, given the seriousness of congestion in that location. As the Mayor wanted the scheme to be operational before the 2004 Mayoral election, choices were made as to the area boundary and the applicable technology for it to be operational in 2003. Cost was a second order consideration because it was believed that gross revenues would offset the costs of implementation.

The mode share for private car access to central London at the time of the introduction of the charge in the AM peak was only 12% (76% by rail/underground).[8] Given such a low mode share and with car ownership in London much lower than in the rest of the UK (around 54% in 2005, compared to 73% of UK households having access to a car)[9], it was seen as relatively easier to implement in central London than elsewhere.

2.2.2.5. Analytical tools used

The ROCOL study applied TfL's London wide strategic transport model to forecast demand impacts and applied these results to local traffic assignment models to identify impacts around the charging zone. A

[8] Source: Figure 6.1, Impacts Monitoring, First Annual Report, Transport for London, 2003.

[9] Source: Road Use Statistics Great Britain 2016, Department for Transport, 7 April 2016 and Roads Task Force - Technical Note 12, Transport for London.

local traffic engineering study was used to identify expected impacts on the charging area boundary and identify necessary improvements to the boundary route for traffic seeking to bypass the charging area.

Following implementation, TfL collated detailed counts of traffic at all entry points and statistics on public transport usage. The next 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.

TfL collated this long list of data sources into impact monitoring reports of over 200 pages in length to report on changes in transport, economic, social and environmental indicators, providing compelling evidence as to the impacts of the London scheme. It is difficult to distinguish, however, between the scheme impacts and wider economic or policy impacts (such as significant increases in bus services).

TfL used extensive strategic and traffic modelling resources to identify the impacts of the charging scheme and refine the scheme design. The monitoring activity consisted of five workstreams: traffic impacts (Traffic counts, vehicle types and vehicle distance travelled), other transport mode impacts, social impacts, economic impacts, and environmental impacts.

TfL assessed this activity by using traffic counts, data on public transport boarding, surveys of businesses, residents and users of the scheme, air quality monitoring stations and other independent data sources. The annual budget for this activity was over £500,000 (NZ$880,000) and was later scrapped by a new mayor.

2.2.2.6. Methodology for choosing systems/scheme design

The selected charging zone was objectively determined by the traffic conditions and geography of London. The location had the most serious congestion and highest density of public transport alternatives in greater London. ANPR was selected as the preferred technology because it was needed for enforcement regardless and was the quickest technology to implement in the required timeframe. Because of the reliability of ANPR technology at the time, it determined that the congestion charge zone would be an area not a cordon charge. The locations of area charge points were selected to ensure than the average number of cameras a vehicle would pass on a trip would be about 2.5, minimising the risk of non-detection.[10]

Taxis and private hire vehicles were granted exemptions in part due to the need to gain political approval of the taxi industry. A residents' discount of 90% was applied to improve acceptability among residents.

Payment options initially provided (both channel and payment type) were the widest range available at the time, including payment by cash at retail outlets and cheque by post. Over time, those payment channels have been rationalised (with the removal of cash and cheque options), as users move towards online, app and direct debit options.

Enforcement is undertaken strictly, with payment required no later than midnight the next weekday otherwise a penalty notice is issued at NZ$114.50 to be paid within 14 days, doubled between 14 and 28 days and increased another 50% beyond that. Non-compliance rates are around 4% of identified vehicles during charging hours as of January 2017.

Net revenues are hypothecated for transport purposes by TfL and used to support the Mayor's transport budget, covering underground, commuter rail, bus, tram, road and cycling infrastructure. In the first five years, around 80% of net revenues were applied to improving bus infrastructure and services.

[10] At the time, the accuracy of ANPR technology was between 60-70%.

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The London scheme was successfully introduced on time and within budget, but the speed at which it was introduced (two years) came at a cost, in that the operating costs were between 40-50% of revenues for the first five years, partly attributed to the price agreed with Capita (the original contractor) to deliver and manage the scheme on time and reliably. These costs have been reduced in real terms over eleven years (NZ$222m in 2005 to NZ$149m in 2016 (in 2016 values)), but are still relatively high compared to other schemes, largely for the management of a large number of exempt and discounted vehicles (around 160,000 as of January 2017).

2.2.2.7. Public engagement and consultation

The proposed congestion charge and all major proposed changes were subjected to formal public consultation. Beyond formal notice and correspondence, the Mayor consulted directly with major business and transport stakeholders, and engaged surveys of residents and businesses. Owing to the electoral mandate to introduce the policy, the Mayor’s consultation focused on elements of policy, rather than the merits of the policy itself.

The annual monitoring surveys provided ongoing consultation on attitudes toward the scheme. Early on, 2300 households across the charging zone and neighbouring areas were surveyed about perceptions.

2.2.2.8. Development and implementation

After the ROCOL study in 2000, the Mayor embarked on detailed design and procurement for the scheme, with the intended date of introduction in February 2003. No technical trial or pilot was included, but there were several months of testing and commissioning before "going live".

In February 2004, consultation began on expanding the congestion charge to the west (Western Extension), with the Mayor deciding to proceed with the proposal in July 2005. Tenders were issued to install the necessary ANPR equipment and communications system, and the system began operation in February 2007.

Other notable dates for the scheme are:

- June 2004: Mayoral election. Ken Livingstone re-elected for a second term on a platform of extending the congestion charge.
- July 2005: Congestion charge increased from £5 to £8 a day.
- February 2007: The scheme was expanded to western London, effectively doubling the charging zone, with much controversy. Dubbed the Western Extension, it meant that vehicles entering many of the suburbs of Kensington & Chelsea would pay the same as if they entered the central zone (and one charge applied to both zones). Residents of either zone would have a 90% discount for driving in both zones.
- February 2008: Low Emission Zone introduced across Greater London, requiring commercial vehicles to meet a minimum Euro emissions standards or pay £100-£200 per day of operations.
- June 2008: Mayoral election. Ken Livingstone defeated by Boris Johnson, who campaigned on reviewing the future of the Western extension, but to retain the original congestion charge zone.
- December 2010: Autopay introduced.

- January 2011: Congestion charge increased from £8 to £10 a day and Western Extension removed, following a consultation process that found a majority in favour of its abolition.
- June 2012: Mayoral election. Boris Johnson re-elected. Campaigned on no major changes to the congestion charge. Green Party campaigned on introducing London wide road pricing.
- April 2013: 100% discount for low emission vehicles replaced with a 100% discount for zero emission vehicles only.
- June 2014: Congestion charge increased to £11.50, but £14 if paid after the day of travel.
- June 2016: Mayoral election. Sadiq Khan elected. Campaigned on addressing air quality issues in London. Proposed ultra low emission zone on top of the congestion charge.
- February 2017: London Assembly report deems congestion charge "no longer fit for purpose". Mayor announces ultra low emission zone to be introduced initially in the congestion charging zone.[11]
- June 2017: Mayor's draft Transport Strategy proposes consideration of full network road pricing over longer term.

2.2.2.9. Outcomes

The 2008 impacts report[12] concluded that demand impacts from the scheme appeared very quickly and the initial reductions in congestion were at the "high end" of expectations (20-30% reduction in delays), but these have been eroded by reallocation of network capacity to other purposes and increases in road works. There have been no significant traffic related problems arising from the scheme. The scheme improved bus system capacity and performance, reduced accidents and improved air quality. TfL reports that the volume of private car traffic entering central London fell 39% between 2002 and 2014, although this was not solely attributable to the congestion charge, but also growing capacity and reliability of public transport services.

The impacts report said there was a broadly neutral impact on the central London economy, with other unrelated factors having a more pervasive impact on business. There is little evidence of impact on access to shops and services. The scheme was calculated as generating net economic benefits of £55m per annum in 2005, with both business and non-business travellers gaining greater benefits, mostly in travel time savings and travel reliability that the cost of paying the charge.[13]

The impacts report said the system in operational and enforcement terms works well. On the Western Extension, surveyed users of the scheme and residents considered that, on balance, air quality, the environment, bus services and journey times had improved since the introduction of the charge.

2.2.2.10. User experience and public reaction

In January 2003 (one month before the scheme went live) 43% of those surveyed opposed the scheme and 38% were supportive. As of October 2003, 28% opposed it and 48% were supportive.[14] This indicates a greater degree of public acceptability once the charge is in place and both users and the general public

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[11] More details about the future expected development of the congestion charge are contained in Appendix F.
[12] Source: Central London Congestion Charging, Impacts monitoring, Sixth Annual Report, July 2008, Transport for London.
[13] Source: Table 2, Central London Congestion Charging Scheme: ex-post evaluation of the quantified impacts of the original scheme, Transport for London, 29 June 2007.
[14] Source: Table 5.2, Congestion Charging Central London Impacts Monitoring Second Annual Report April 2004, London.

experience the benefits of reduced congestion, and discover fears about the scheme's scope and effects were not well founded. A key part of building acceptability around the congestion charge has been the high level of transparency of information provided. To this day, TfL publishes a three month factsheet of data about the scheme's operation. Most recently, a London Assembly survey[15] indicates that 48% support the congestion charge and 27% oppose it, but that 54% think it is too high. This indicates that while the congestion charge is supported, it doesn't have overwhelming levels of support, believed in part because congestion in central London is now back at levels seen before the charge were introduced.

The user experience is a rather different story. Delays in 2005 were reported by TfL as being 30% lower than before the charge was introduced, but by 2017 TfL admitted to the London Assembly that conditions in the charging zone were now similar to those before the charge had been introduced. However, without the Congestion Charge, congestion in central London would still be worse.[16]

In addition, light commercial vehicle traffic (subject to the charge) has grown by 11% in four years. Private hire vehicle (booked taxis) traffic (exempt from the charge) has also increased by 54% since 2013. In interview, TfL admitted that it was difficult to identify the reasons behind these trends. It is likely but that the light commercial traffic is linked to the growth of ecommerce. The private hire vehicle market has grown because it is now easier for potential customers to choose to make such trips using mobile phone apps to quickly identify availability and price for a trip.

Support for the congestion charge can be understood in the context of the very small proportion of Londoners who drive into central London during charging hours. It is notable that 57% of Londoners surveyed by the London Assembly did not believe that further road pricing would reduce journey times, but 50% believe it would raise more money. This is seen as indicating a growing belief that the congestion charge is now more about revenue than managing congestion.

2.2.2.11. Complementary mitigation measures

Complementary measures introduced alongside the congestion charge include a significant increase in bus services (with higher frequencies for services entering central London); an upgrade of the inner ring route network of roads that would form the boundary of the charging area; complementary traffic management measures (such as an expanded residents' parking zones and measures to limit diversion of traffic onto residential streets); and introduction of exemptions and discounts for disabled drivers and residents. One study indicated that around 40% of former car drivers are likely to have transferred to bus services, with the remainder transferring to the underground or other modes.[17] However, that same study stated that it is difficult to attribute changes in public transport patronage primarily to the congestion charge:[18]

2.2.2.12. Key lessons for Auckland

The conditions in London are considerably different from those of Auckland, with levels of traffic congestion, density of public transport provision (and usage) and very low mode share for private car usage to the charging zone. Nevertheless, London has a mix of lessons for Auckland, both positive and negative.

Positively, London is a good example of public engagement and communications. TfL sought to dominate the media coverage of the congestion charge proposal, installation and implementation and succeeded. This helped ensure there was no organised campaign against the proposal and little mistaken reporting of

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[15] Source: London stalling. Reducing traffic congestion in London, Transport Committee, London Assembly, February 2017.
[16] Ibid. Pg.22.
[17] Source: Re-Examining The Results Of The London Congestion Charging Scheme – A Critical Review, Moshe Givoni, Transport Studies Unit, University of Oxford, 2010.
[18] Ibid p.15.

the details of the congestion charge (maps, hours of operation, rate and discounts/exemptions were all clearly and repeatedly explained). TfL said it "flooded the media and the public with information" to minimise confusion and any distortions about the charge, and believed that this willingness to dominate the narrative about the charge and to respond quickly to concerns and criticisms helped to diffuse opposition. It also generated confidence that TfL "knew what it was doing" and so would implement it successfully.

In addition, London has undertaken perhaps the most thorough and detailed evaluation of impacts. It has used a long list of metrics for measuring transport impacts, economic, social and environmental impacts, both for the central charging zone and for the now discontinued Western extension. These provide an enviable record of annual reports for the first five years of the scheme outlining impacts that have helped to build confidence around the policy and answer claims around negative impacts and inform policy evolution.

The biggest negative lessons for Auckland are threefold:

1. **Minimise discounts and exemptions**. London has had a significant number of user categories that either have a 90% or 100% discount or which are exempt, meaning a growing proportion of traffic in the charging zone does not pay. When the congestion charge was introduced, TfL estimated that around 30% of traffic circulating in the charging zone was subject to a discount or exempt; today it is 50%. This reflects the decline of charged car traffic and growth in bus and taxi trips.[19] Any scheme for Auckland should seek to minimise discounts and exemptions, to minimise costs and any effect of undermining the scheme.

2. **A flat area charge scheme is poor at sustainably and equitably managing demand**. The single flat charge for entering the charging zone has two main shortcomings. The first, identified by the London Assembly report, is that users who pay the charge once have no incentives to constrain use of the network during the day. For example, freight and business traffic paying a single daily charge have greater incentive to maximise their use of the network during charging periods, to spread the cost over multiple business trips. The second shortcoming is that it doesn't distinguish by time of day or the entry point into the zone. Congestion in much of the zone at 0700-0800 is much lower than at 1100 or 1600, but the only incentive to time shift is before 0700 or after 1800. The charge is too low for some roads at certain times and too high for others. A scheme for Auckland should have more flexibility to price by time of day and location, and better reflect actual road usage.

3. **Failing to sustain travel-time savings for users undermines support for further charging**. The congestion charge has not sustainably managed congestion in central London. This is due to growth in traffic that is exempt (private hire cabs) and traffic with low price elasticity (freight), neither of which have access to dedicated lanes, but also the policy of reallocating available road capacity to other modes. This means that those paying the charge have increasingly paid more for a lowering level of service, reducing the economic benefits to those paying and increasing scepticism that the charge is about congestion. This is one reason why there was relatively less support for the Western Extension, as it was not believed that the extension was primarily about reducing congestion, but rather raising revenue.

The congestion charge does not currently give the impression to users that it reduces congestion (although undoubtedly delays would be worse if it did not exist at all). Given the much higher usage of private cars in Auckland, it is likely to be important in sustaining public acceptability that any charging scheme ensures at least some minimal level of service for those paying the charging, even if there is some reallocation of road space to other road users.

[19] While much of the growth in bus traffic is due to the increase in services franchised by TfL, bus traffic growth also includes tour coaches and schedule coach services, all of which operate commercially and are exempt from the charge.

2.2.3. Stockholm

2.2.3.1. Map of system

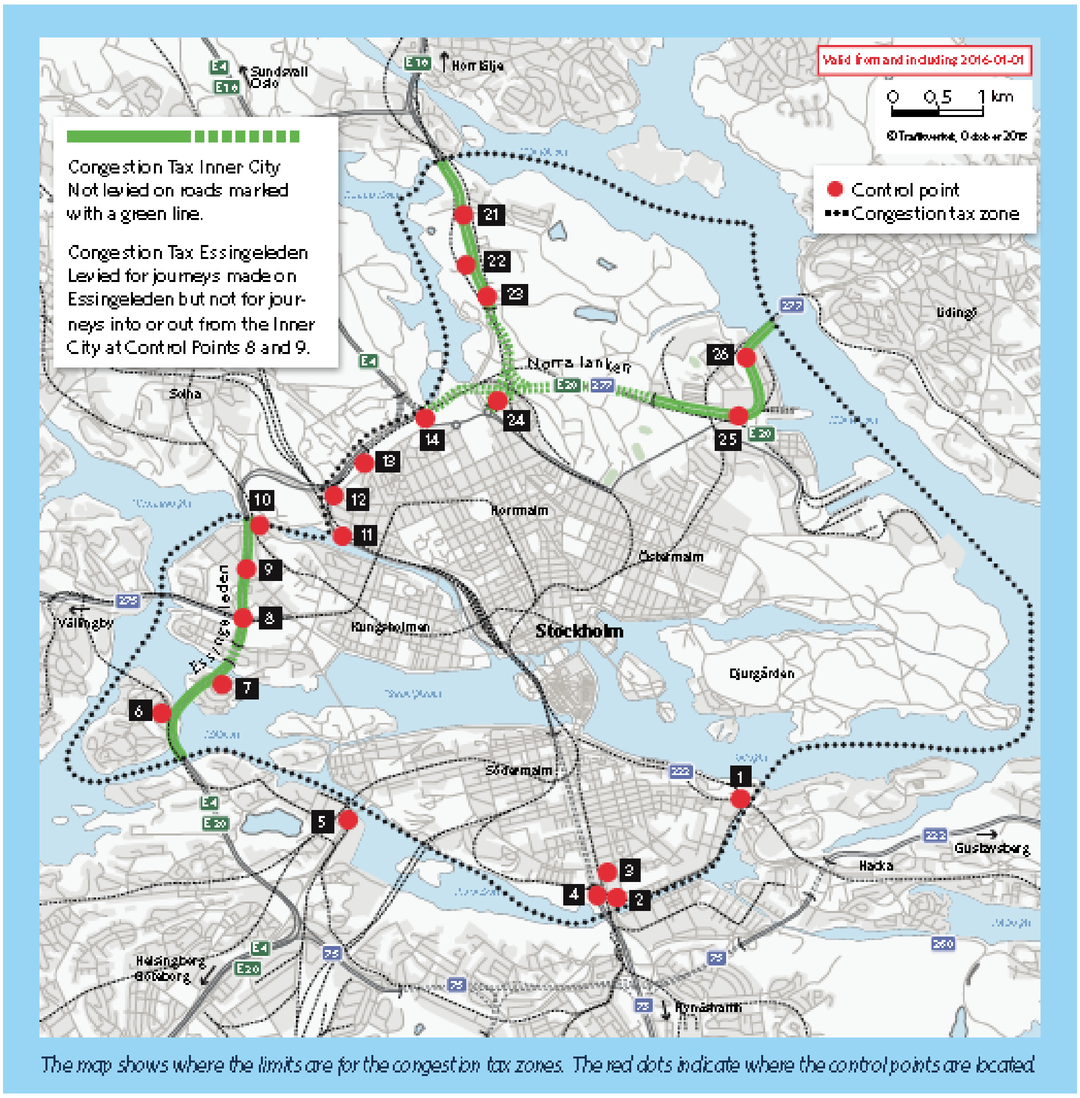

Figure 6 - Stockholm congestion tax cordon and charging points

2.2.3.2. Objectives and goals

The purpose of the Stockholm scheme is primarily to manage congestion and secondarily to raise revenue to enhance transport in Greater Stockholm. Early discussions about congestion pricing were initially driven by interest in raising revenue for major transport funding packages. The pilot was intended to test if the scheme would "reduce congestion, increase accessibility and improve the environment".

2.2.3.3. Current scheme concept

Type of scheme	Cordon charge
Vehicles charged	All vehicles except buses and motorcycles
Charging times	0630-1829

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Discounts/exemptions	Emergency vehicles, buses over 14 tonnes, motorcycles, military vehicles and those with disabled parking permits all exempt (exemption for low emission vehicles removed)
Charging technology	Declaration based system using ANPR. Registered fleet or account vehicles pay by detection using ANPR
Use of net revenues	Hypothecated transport fund for road and public transport improvements
Range of charge rates	NZ$1.79-NZ$5.68 depending on time of day and route

Congestion tax amounts for **Essingeleden** from and including 1 January 2016.

Period	Tax amount
6.30 - 6.59	SEK15
7.00 - 7.29	SEK22
7.30 - 8.29	SEK30
8.30 - 8.59	SEK22
9.00 - 9.29	SEK15
9.30 - 14.59	SEK11
15.00 - 15.29	SEK15
15.30 - 15.59	SEK22
16.00 - 17.29	SEK30
17.30 - 17.59	SEK22
18.00 - 18.29	SEK15

Congestion tax amounts for the **Inner City** from and including 1 January 2016.

Period	Tax amount
6.30 - 6.59	SEK 15
7.00 - 7.29	SEK 25
7.30 - 8.29	SEK 35
8.30 - 8.59	SEK 25
9.00 - 9.29	SEK 15
9.30 - 14.59	SEK 11
15.00 - 15.29	SEK 15
15.30 - 15.59	SEK 25
16.00 - 17.29	SEK 35
17.30 - 17.59	SEK 25
18.00 - 18.29	SEK 15

The max. tax is SEK 105 per day and vehicle summarized for Essingeleden and the Inner City.

Figure 7 - Stockholm congestion tax cordon and charging points

2.2.3.4. How the system/scheme emerged and developed

Discussion about congestion pricing in Stockholm emerged in the 1990s as an option to help fund a major transport infrastructure package for the city. Some momentum emerged as some politicians and environmentalists saw potential in congestion pricing to manage traffic demand and reduce emissions. The success of the Oslo toll ring helped to encourage growth in interest in the concept.

In 2002, the government set up a commission to negotiate an infrastructure agreement for Stockholm. The idea of congestion pricing was controversial at the time, with the major opposition (Conservative) party resisting it. The governing Social Democrats promised "no road tolls" if it were re-elected, but although it was the largest party following the 2002 election, it needed the support of the Green Party which strongly supported road pricing. The Greens demanded a full scale congestion charging trial in exchange for support in government, which was agreed.

There was heated debate, with media coverage generally far more negative than positive. Opponents suggested that there be a referendum on road pricing after the proposed trial, expecting that it would be rejected. The Social Democrats agreed as it was seen to be a way to separate out campaigning for government and campaigning on road pricing. They agreed to hold the referendum at the time of the 2006 general election, with the pilot proposed in advance of that for a period of six months.

The pilot was designed with charge rates set at what demand modellers assessed would be sufficient to reduce traffic volumes by around 10-15%. The cordon design itself, more than any other scheme, was based on the topology and geography of Stockholm. This minimised the number of charging points and largely encompassed only the CBD, and neighbouring residential districts. The option of having different charges at each charging point was rejected as being too complex for users in the first instance.

The trial ran from January to June 2006 and operated as a full-scale pilot, requiring everyone who wished to cross the cordon to pay the congestion tax. The pilot was considered a success, as volumes of traffic crossing the cordon dropped by 22% per day on average, with emissions dropping over 30%. Media coverage significantly improved. The 2006 referendum was not held in all Stockholm municipalities, but a majority (53%) voted in favour of the congestion tax from those that did hold a vote. At the same election, the government changed (to parties that had opposed the proposal), but it agreed to abide by the referendum result. The key change was that it decided to dedicate most of the net revenues to a series of major road projects around Stockholm, including extensions to a major orbital route (that now forms part of the cordon) and more recently a major north-south bypass. A total of NZ$15b in future transport projects were agreed as a package (predominantly roads, but also public transport, and active mode infrastructure) for funding by the congestion tax.

The system was reinstalled[20] and recommenced operation on 1 August 2007. Since then, congestion tax rates have only been increased once (by 75% in 2016), and the only major change to the scheme has been the inclusion of Essingeleden (the motorway that is located through the western edge of the cordon) in the charge from 2016.

In conclusion, the key relevant and determining factor for Stockholm was political agreement that the problem of congestion (and the environmental impacts of road traffic) needed to be addressed, and that a pilot should be undertaken to demonstrate whether it would be effective and acceptable to the public. The pilot was a success, and the risky use of a referendum to demonstrate acceptability removed the controversy for introducing and maintaining the congestion tax. A relatively high mode share for public transport and active modes for travel to the CBD (80% at peak times) undoubtedly increased public acceptability.

2.2.3.5. Analytical tools used and Methodology for choosing system/scheme design

Demand modelling previously undertaken indicated rates that could reduce traffic across the cordon by 10-15%, but it was decided that it would be better to set charges based on targets for traffic speed instead of vehicles crossing the cordon. To achieve this, measurement of congestion at major bottlenecks was seen as a useful metric to achieve this. The static network equilibrium model that was used was tested with different charging rates, and with small variations in cordon design based on charging at different bridges (within what is now the cordon).

However one of the key design criteria for the scheme was also simplicity and ease of understanding. This resulted in compromises in the charging scheme, so that the same charges were set for each charging point, and the same for the AM peak inbound and PM peak outbound periods. Stockholm spent some time optimising the charging points and charge levels, and believes this was worthwhile, although the decision to adopt a single cordon and the broad location of that cordon meant that optimisation of charging points and levels was a less complex exercise than comparing single/multiple cordon/ area charges with corridor charges as in ARPES.

[20] All charging equipment was removed after the pilot, as had been the agreement, so that there would not be an opportunity to "switch it on again" if politicians decided to override the decision of the referendum.

No forecasts were made of the impacts on access, as the static network equilibrium models that Stockholm had were not considered to be reliable for this purpose.

The models were proven reasonably accurate in forecasting demand responses. Forecasts indicated a 17% reduction in peak trips and 16% in off-peak trips over the cordon, the actual demand responses were 19% during peaks and 20% off-peak. Half of the reduction in trips were forecast to reappear on public transport and that proved to be accurate as well.[21] This contrasts considerably with the accuracy of travel surveys applied at the same time, whereby respondents recorded a reduction in trips of 5-10%. Stockholm City now believes that this demonstrates how unreliable travel surveys are as a data collection device for past travel behaviour. What happened to the trips that did not shift by mode is unknown, as models and surveys are not able to reliable identify if road users have changed travel times, destinations or simply stopped travelling (or increased vehicle occupancy). The model also did not predict travel time savings accurately for road links subject to congestion overflowing back across intersections, or congestion at intersections more generally. These travel time savings were reportedly underestimated by 34%. Eliasson concludes that even if these shortcomings could be addressed, it would have made no substantial difference to the scheme design and the related complimentary measures. [22]

The choice of ANPR was made for the permanent scheme primarily because, as the scheme was legally a tax, the only evidence that would support enforcing the tax was an image of the number plate according to Swedish law. DSRC was seen as redundant, and non-inclusion of DSRC also saved additional capital, maintenance and renewal costs. With the exception of emergency vehicles, buses, military vehicles, diplomatic vehicles and those with disabled parking permits, there were no other permanent exemptions.[23] An exemption for alternatively fuelled vehicles was included, to encourage sales of such vehicles, but only applied for five years, due to concerns that it might undermine the congestion reduction objective of the scheme. The proportion of registered alternatively fuelled vehicles in Stockholm increased from 3% to 15% in that period.

As the scheme was legally a tax, the entire payment and enforcement system corresponded to provisions for paying taxes and enforcement of tax law. Invoices are sent monthly to vehicle owners identified through the motor vehicle registry with an accumulation of charges over that period. Payments can be made by direct debit, electronic bank transfer or credit/debit card. Enforcement is undertaken on vehicles that have been issued charging tax notices and have not responded or paid within the minimum time period (30 days). For those that have not paid a charge within 6 months, an order to ban the use of the offending motor vehicle can be issued.

2.2.3.6. Public engagement and consultation

Public engagement on the congestion tax became focused on the establishment of the pilot and monitoring of the pilot results. Because the pilot was mandatory (it operated as a scheme for anyone driving into central Stockholm during weekdays), the experience of the public that used the roads, paid the congestion tax, rode public transport or biked or walked in central Stockholm became central to the consultation. That consultation was in the form of a referendum effectively asking if people wanted the scheme to be permanent. Up until the pilot came into operation, extensive information was provided to inform people of how to acquire an account and a tag (as was required for the pilot) and what the forecast impacts would be.

[21] p. 27. Jonas Eliasson, The Stockholm congestion charges: an overview, CTS Working Paper 2014:7, KTH Royal Institute of Technology, Stockholm.
[22] Ibid p.28.
[23] Foreign vehicles were exempt for some years because of the difficulty in enforcing charges against them.

Before the pilot was introduced, opposition increased, but the effect of the pilot and the subsequent introduction of the congestion tax on public opinion is seen in Figure 8 below.

2.2.3.7. Outcomes

Demand outcomes are described in 2.2.3.5

The economic analysis by Eliasson[24]indicates that the travel time savings and reduced externalities do not offset the cost of the congestion taxes paid or the costs of maintaining and renewing the system (see Figure 9). The congestion tax is estimated to have reduced CO_2 emissions by 2.7% due to the decline in traffic, and a 10-14% reduction in noxious emissions within the cordon).

The scheme generates around NZ$95m in net revenues per annum (after operating costs of around NZ$30m which now also includes the back office and administrative costs of the Gothenburg scheme).

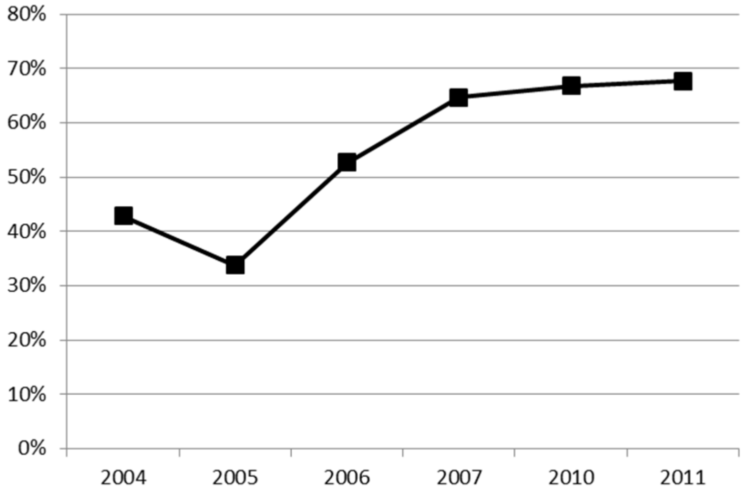

Figure 8 - Positive support for Stockholm congestion tax[25]

[24] Cost-benefit analysis of the Stockholm congestion charging system, Centre for Transport Studies, Royal Institute of Technology, 2008.
[25] Source: Figure 8, Jonas Eliasson, The Stockholm congestion charges: an overview, CTS Working Paper 2014:7, KTH Royal Institute of Technology, Stockholm.

million SEK per year	Loss/gain
Shorter travel times	496
More reliable travel times	78
Loss for evicted car drivers, gain for new car drivers	-68
Paid congestion charges	-763
Consumer surplus, total	***-257***
Less greenhouse gas emissions	64
Health and environmental effects	22
Increased traffic safety	125
Other effects, total	***211***
Paid congestion charges	763
Operational costs for charging system (incl. reinvestment and maintenance)	-220
Increased public transit revenues	184
Necessary increase in public transport capacity[1]	-64
Decreased revenues from fuel taxes	-53
Decreased road maintenance costs	1
Public costs and revenues, total	***611***

Figure 9 - Benefit/cost analysis of Stockholm congestion tax

2.2.3.8. User experience and public reaction

As the congestion tax has reduced queuing times by between 33-50% at peak times, it has significantly improved the user experience for those paying the charge, and improved bus travel times.

By contrast, the recent introduction of the charge on Essingeleden has been less popular. This is attributed to the lower convenience of using public transport for cross-city trips (as this may necessitate a transfer) and the relatively low demand response from the introduction of the charge (indicating much lower demand elasticity for that traffic), with consequential modest impacts on congestion.

2.2.3.9. Complementary mitigation measures

Additional bus services were provided for the pilot and continued for the operation of the congestion tax. However, one study indicates that the proportion of users of these increased services that had used cars before the congestion tax is very low (0.1% of patronage).[26] The expansion of services is now considered to have been excessive, and bus frequencies were slowly scaled back some months after the scheme was introduced permanently to better match supply with demand. Sweden does not undertake equity impact assessments of transport policy measures because it assumes they are addressed nationally through the welfare system.

Two geographically based exemptions were applied. One for Lidingö Island because until completion of the Northern portion of the E20 ring road, the sole road access to this largely residential island was through the cordon. The exemption meant that vehicles leaving the island would not be charged if they entered the cordon and exited again within half an hour (indicating a trip had not terminated in the city). The Essingeleden exemption applied so that north-south traffic bypassing the city would not have to pay. This has since been removed due to the severity of congestion on this road and the use of congestion tax revenue to build a new bypass to relieve this road.

[26] p. 16. Jonas Eliasson, The Stockholm congestion charges: an overview, CTS Working Paper 2014:7, KTH Royal Institute of Technology, Stockholm.

2.2.3.10. Key lessons for Auckland

Stockholm's pilot proved not only the effectiveness of the concept in reducing congestion (and improving environmental conditions), but also became the focus for public debate about the congestion tax. This was very expensive, but it worked. Support that had been at 43% in 2004 increased to 53% in 2006 after the pilot demonstrated the scheme could work. The value of a pilot in focusing debate and discussion is clear as congestion pricing is more acceptable to the public once it is operational and its effects demonstrable. Support for the scheme is now 65-70% in opinion polls.[27]

Stockholm minimised the use of exemptions this has helped maintain the effectiveness of the scheme.

Demand modelling can effectively predict the demand responses for the scheme, but is much less effective in forecasting the effect of increasing prices, or applying them to a route with a different demand profile, such as a bypass route to the inner city (for which public transport is much less substitutable).

Using net revenues for road projects can increase public acceptability, because of the clear link between use of revenues and benefits to road users (e.g. the completion of the Norra Lanken ring road enabled the Lidingö exemption to be abolished and improved accessibility around the perimeter of the cordon), but over time a wider use for other modes does not undermine this acceptability.

Applying both peak and off-peak charging was effective in spreading demand, although there is no evidential basis to prove time shifting, because travel diary surveys have proven useless as motorists seem unable to reliably recall their past driving habits.

About *half* of driver trips switch to public transport, the rest either suppress trips/consolidate trips or change travel time, but it is difficult to establish exactly what that behaviour change consists of.

[27] Source: Maria Börjesson, Jonas Eliasson, Muriel Hugosson, Karin Brundell-Freij, The Stockholm Congestion Charges, Lessons after 5 years, Professor Transport Systems Analysis, Royal Institute of Technology, Stockholm, 2012.

2.2.4. Gothenburg

2.2.4.1. System map

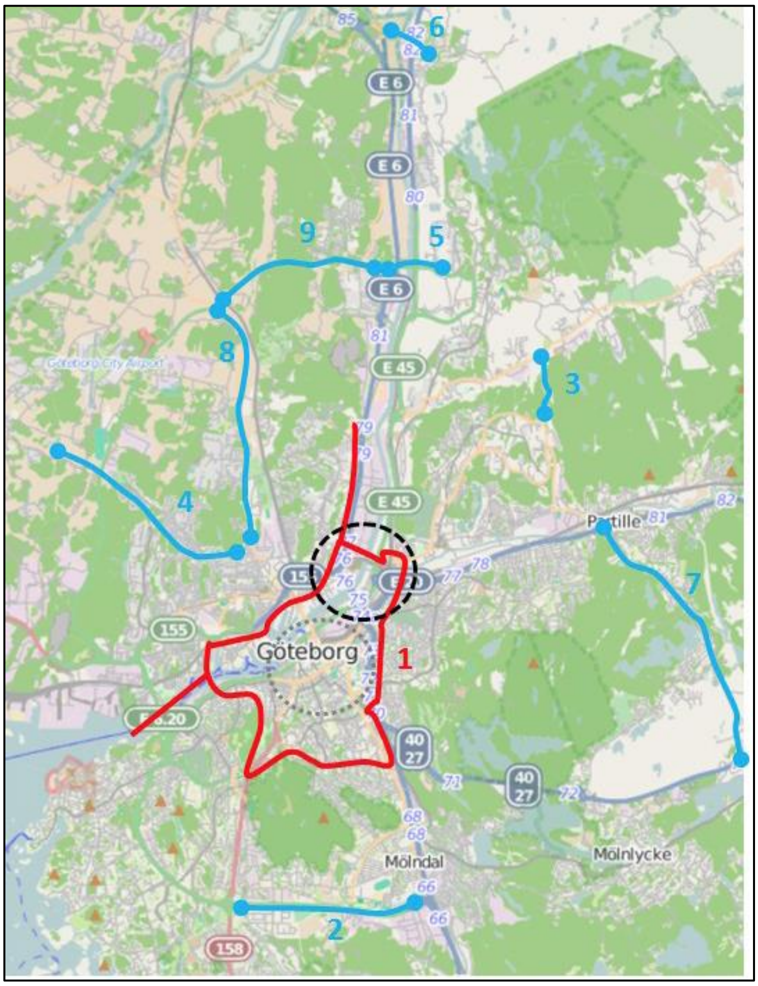

Figure 10 - Gothenburg congestion charge cordon and point charges[28]

2.2.4.2. Objectives and goals

The purpose of the scheme is primarily to raise revenue to help fund the West Swedish Agreement package of transport improvements[29], with a secondary objective to reduce congestion and pollution

The West Swedish Agreement is a NZ$5.4b package of transport projects for the region. The highest profile project is the Västlänken (West Link) underground railway tunnel, designed to restructure Gothenburg's main railway station from a terminus to a through station. This is intended to improve travel times for regional and intercity rail services. Other projects include a new road tunnel under the River Göta and many smaller road and public transport projects.

2.2.4.3. Scheme concept

Type of scheme	Cordon charge plus one corridor charge and one crossing charge

[28] Circled on the map is Gothenburg's primary traffic bottleneck. Source: The Gothenburg congestion charge, Effects, design and politics. CTS Working Paper 2014:25, Centre for Transport Studies, Stockholm.

[29] http://www.vastsvenskapaketet.se/english/

Vehicles charged	All vehicles except buses and motorcycles
Charging times	0600-1829
Discounts/exemptions	Emergency vehicles, buses over 14 tonnes, motorcycles, military vehicles and those with disabled parking permits all exempt (exemption for low emission vehicles removed)
Charging technology	Declaration based system using ANPR. Registered fleet or account vehicles pay by detection using ANPR
Use of net revenues	Hypothecated transport fund for road and public transport improvements
Range of charge rates	NZ$1.46-NZ$3.57 depending on time of day

2.2.4.4. How the system/scheme emerged

Gothenburg is Sweden's second largest city with a metropolitan population of around 1 million. Employment is located predominantly in industrial areas north of the River Göta and in the CBD. Interest in applying a congestion tax to Gothenburg emerged after the success of the Stockholm scheme. Legislation for the Stockholm scheme enabled other cities in Sweden to introduce congestion tax schemes. In addition, the platform and back office systems procured by the Swedish Transport Agency for Stockholm had the capacity for additional schemes, meaning that a system in Gothenburg only largely needed the installation of roadside equipment and communications.

Congestion in Gothenburg was highly concentrated at peak times and primarily adjacent to major highway junctions in the north-east (see Figure 10). Gothenburg city and neighbouring municipalities have a strategic goal of increasing the mode share of public transport to 40%. The West Swedish Agreement package of transport improvement is one of the key elements to reaching that objective. To help fund that package, the target of NZ$102-118m (2009) for annual net revenues from the scheme was identified.

Investigations began on options for congestion charging in 2009 with the final decision on the preferred option agreed after the 2010 municipal election. The proposal was developed further in 2011, with tenders called later that year, a contract signed in March 2012 with the system installed and live in January 2013. The contract for the scheme was at a value of around NZ$23m (2012) for delivery of road side equipment, and infrastructure, with maintenance for 2 years.[30]

2.2.4.5. Analytical tools used

The key tool used to develop the scheme was the national SAMPERS multimodal travel demand model, which included a regional model for the West of Sweden including Gothenburg. For traffic assignment, Gothenburg uses the "Emme3" model to calculate the effect on routes and travel times, whereas SAMPERS models frequency of travel, destination choices and modal choices. Freight and professional (e.g. commercial trade) traffic demand was assumed to be insensitive to the congestion tax, because of the lack of modal choice, but route choices were considered (because of options for through trips to avoid the proposed cordon options). [31] One limitation of the models was that it could not model departure time

[30] Source: http://www.cisionwire.com/q-free-asa/r/q-free---contract-award-in-sweden-worth-143-mnok-confirmed,c9230027

[31] Source: Source: p.6 The Gothenburg Congestion charges: CBA and equity, Jens West/Maria Börjesson, CTS Working Paper 2016:17, Centre for Transport Studies, Stockholm.

choice, so it was difficult to establish what time of day variation in travel would occur. Travel demand was modelled for the two peak periods and the off-peak periods separately.

2.2.4.6. Methodology for choosing system/scheme design

Twelve options were evaluated using the transport models described above. The process was led by the National Transport Agency. The national parliament was legally required to approve the final design.

It was decided early to implement a cordon and some key metrics were use to evaluate options:

- meeting the minimum revenue target (NZ$102m per annum by 2015);
- ensuring charge rates are not "too high" (not higher than Stockholm);
- ensure the scheme charges trips from inner as well as outer suburbs;
- avoid diversion of traffic onto unsuitable routes.
- avoid double cordon options that charge the same route with a short distance between each charge

Exemptions, technology and enforcement are the same as in Stockholm. The only scheme variation is that no vehicle pays for crossing more than one charging point per hour.

Although rational trade-offs between revenue, traffic management and high-level equity objectives were made in option selection, the focus on raising revenue meant that a cordon size and location was selected (and operating hours) that meant some roads were charged during periods (interpeak) of little to no congestion and some communities (notably Backa in the north)[32] had residential and local retail districts separated by a charge. Had the scheme been more focused on congestion, then charging would have been limited to a smaller number of charging points during peak hours. That may have improved public acceptability, but significantly reduce net revenues.

2.2.4.7. Public engagement and opposition

There was limited public engagement on the congestion tax proposal, with few efforts to promote the concept and explain it. The primary focus for Gothenburg City Council was the full transport package. Public consultation of the package indicated concern about the cost and value of the projects.

During the proposal's development, public opposition grew. A newspaper poll in 2010 indicated 65% opposition.[33] A new political party (Vägvalet) was elected in 2010 to city council on the single issue of opposition to the congestion tax and Västlänken gaining 5 seats on the 81 seat council.

Key concerns were that congestion in Gothenburg was not serious enough to justify road pricing (unlike Stockholm), that alternatives were not well developed and that the costs of the West Swedish Agreement were unjustified. This was exacerbated by the announcement in 2012 that the costs of Västlänken had increased by one-third (about NZ$870m). With no major projects expected to be open until 2020, there was concern that the congestion tax was to be paid before the projects it would fund could be used. 15% of citizens signed a petition to hold a referendum on the congestion tax, which was held *after* the scheme had been introduced, in September 2014. That referendum saw a 57% negative vote for the question "Do you think that the congestion tax should continue after the 2014 election?''[34]

[32] Source: http://trangselskattibacka.se/ (Swedish)
[33] Source: pg. xxii Implementing Road Pricing: Standards, Institutions, Costs and Public Acceptance, Carl J. Hamilton, KTH Architecture and the Built Environment, Stockholm, 2012.
[34] http://web.archive.org/web/20140923051452/http://www.goteborgdaily.se/news/referendum-no-to-congestion-charges

The council has since confirmed it would ignore the referendum and has confirmed support for the congestion tax, because it has no other means to pay for the package. However, there is considerable pressure to end or amend the scheme.

Analysis as to why the referendum was lost compared to Stockholm concluded that the key reasons were:

- Much higher proportion of residents drive to work in Gothenburg so many more are affected by the congestion tax in Gothenburg than in Stockholm;
- The congestion tax has been primarily justified as a means to generate revenue in Gothenburg, but not in Stockholm;
- A small proportion of those paying experienced any significant travel time savings (only those travelling on inner arterials in the AM peak gained significantly travel time savings, but this comprises a five minute saving on what was a ten minute trip)
- Positive attitudes to the package declined significantly after 2012, when the National Audit Office criticised the economic evaluation of the Västlänken project.

Politicians believed that once local residents in Gothenburg had experience over a year of the congestion tax, they would be more positive towards the congestion tax as had happened in Stockholm. A critical additional factor was the guarantee that the net revenues would be spend on a local transport package (unlike Stockholm, where use of revenue was determined by central government). This increased acceptability for *local politicians*, but does not appear to have positively influenced local public acceptability. More recent reports of threefold increases in the cost of the Västlänken project are challenging the entire transport package and raising the possibility the congestion tax would be cancelled along with the project.

In conclusion, Gothenburg's process for public engagement was minimal, which has contributed greatly to its high level of unpopularity. It is only through the agreement and determination of local politicians that the scheme was advanced and implemented, largely because of their strong support for the package of transport improvements.

2.2.4.8. Outcomes

In the first month of the charge, peak traffic volumes dropped by 20%, but in the subsequent month that had dropped back to an average range of 8-11%. The reason for this is due to the billing system and the lack of public information about the congestion tax. The congestion tax is charged to users on a monthly billing cycle, and in the first month many road users were unsure how much they would have to pay, so reduced their road usage to avoid an unexpectedly high bill. However, once they received their bills, and noted they were lower than expected, some increased their driving once more.[35] Figure 11 depicts the reduction in vehicle trips as a result of the congestion tax in Gothenburg during charging hours. However, traffic in Gothenburg has increased considerably since 2013. Around NZ$158m in revenue was generated in 2016, almost 50% higher than originally forecast, with a 4% annual increase in traffic volumes.[36] The congestion tax is still attributed to reducing overall demand.

Travel time savings per trip have been relatively small. The most significant savings are in the northeast of the cordon, where travel times have been halved due to the congestion tax, although this still represents a trip travel time saving of only five minutes. West and Börjesson analysed the economic impacts and distributional impacts of the scheme.[37] Their analysis indicates that the benefits to users are below the

[35] Source: interview and Endurance e-update May 2015, "Congestion Charging", EPOMM, European Commission.
[36] Source: https://www.svd.se/bilismen-okar-i-goteborg-trots-trangselskatt (Swedish)
[37] Jens West, Maria Börjesson, The Gothenburg Congestion charges: CBA and equity, CTS Working Paper 2016:17.

value of charges paid, so that any positive net economic impact could only come from analysis of the use of net revenues.

A much higher proportion of Gothenburg residents pay the charge compared to Stockholm. This was noted by Börjesson and Kristoffersson:[38]

The congestion charges in Gothenburg generated gross revenue of 71 million EUR during its first year. This is close to the 76 million EUR generated by the Stockholm system in 2013, although Gothenburg is less than half the size of Stockholm and the charged amounts are lower. This implies that a considerably larger proportion of the population of Gothenburg, compared to Stockholm, pays congestion charges.

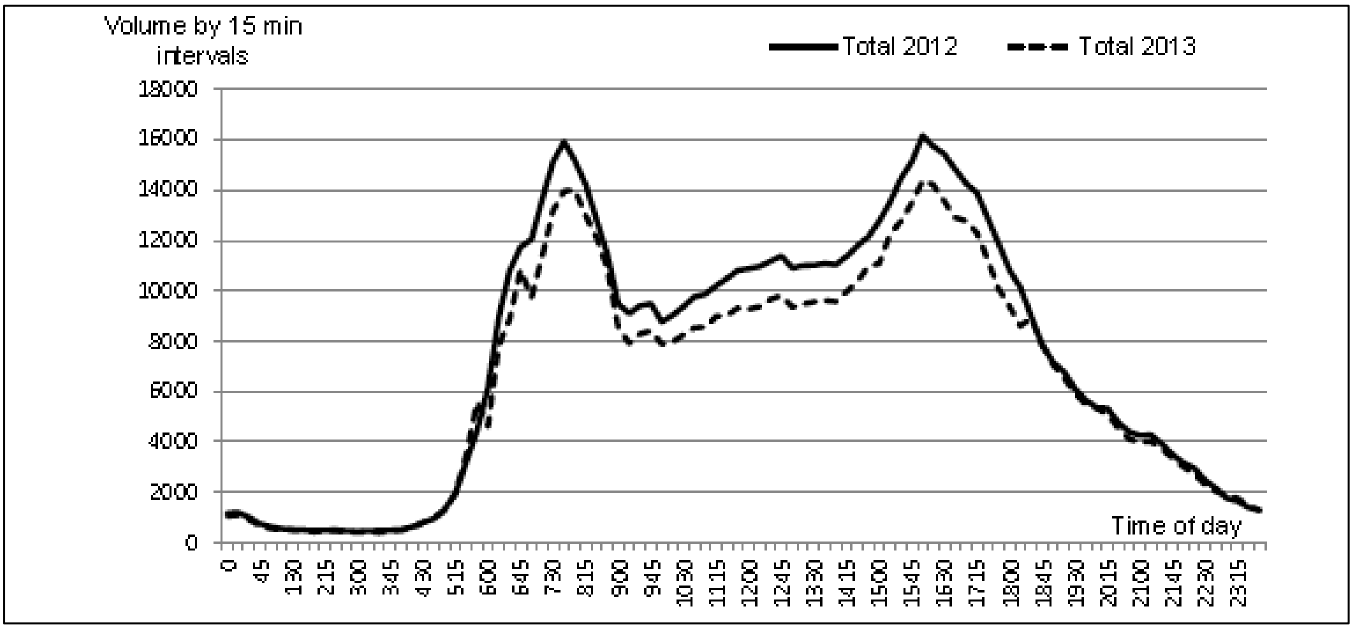

Figure 11 - Gothenburg congestion tax demand impacts

However, more critically, as can be seen in Figure 12, they concluded the scheme was regressive, with the greatest negative impacts being on those with the lowest incomes. This is due to the high use of private cars in Gothenburg by people on low incomes and their relatively low value of time. The scheme already generates low benefits for many paying, because congestion in Gothenburg is concentrated in one zone in the AM peak, but the scheme generates almost as much revenue as the Stockholm scheme. This reflects the scheme's intended purpose of revenue raising rather than managing congestion. Gothenburg congestion was not located on radial arterials to and from the city, but on arterials leading to a major hub of the highway network to the northeast of the city centre. Further analysis indicated the geographic dispersion of impact saw residents of suburbs to the north and west adjacent to the cordon lose the most because their trips were affected the most by the charge and their incomes were relatively low. Higher income residents within the cordon benefited the most because few had to pay, but most gained from reduced travel times.

[38] Source: The Gothenburg congestion charge Effects, design and politics, Maria Börjesson and Ida Kristoffersson CTS Working Paper 2014:25.

2.2.4.9. User experience and public reaction

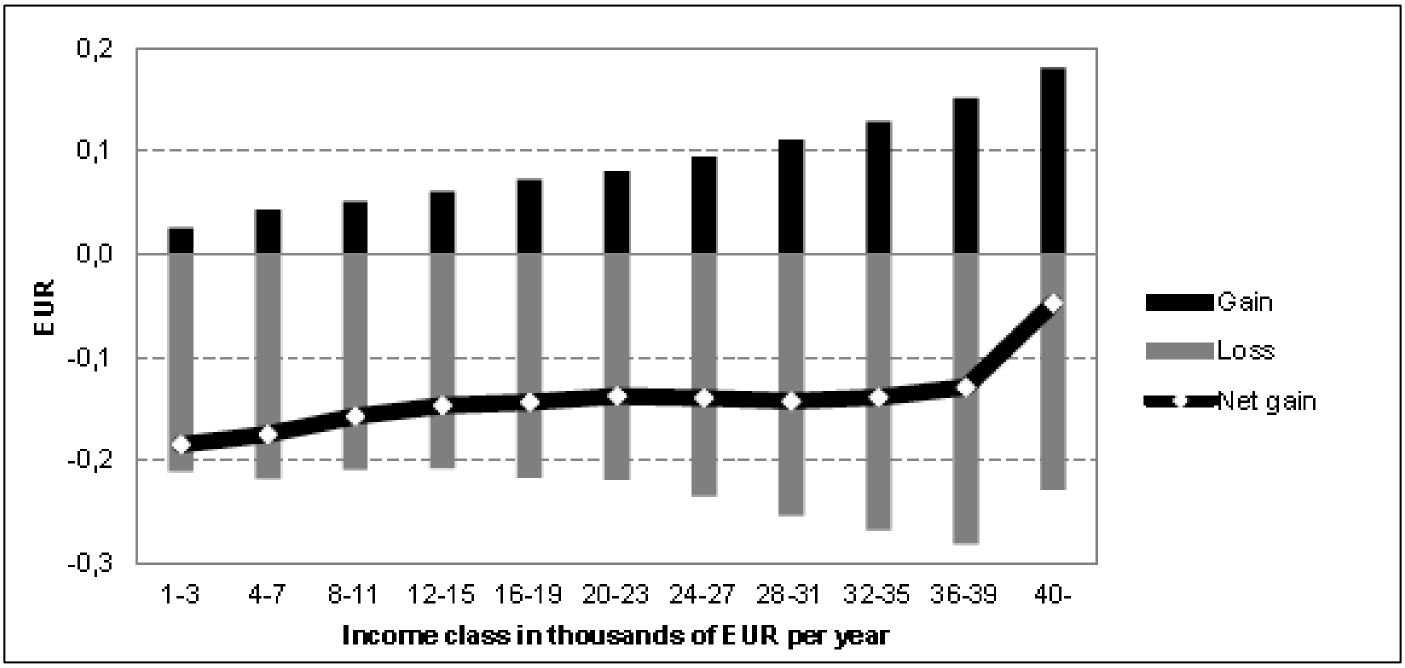

Figure 12 - Net impact on users of the Gothenburg congestion tax by income

2.2.4.10. Complementary mitigation measures

Bus services were increased in frequency, but there was considered to be ample spare capacity in existing public transport services to accommodate the forecast modal shift.

Since the scheme has been introduced, severance issues in two suburban areas have become a concern. Consultation is currently underway on introducing an exemption for trips that cross some charging points only once a day to ameliorate impacts on local residents and businesses.

2.2.4.11. Key lessons for Auckland

Gothenburg developed and implemented a scheme quickly and efficiently, and pushed it through government processes in spite of considerable public opposition. Key lessons from its experience are:

- It is critical to inform and engage the public to build understanding and acceptability. Gothenburg didn't do this;
- Design should follow objectives. Gothenburg did this and delivered a revenue raising scheme;
- Avoid designing a scheme that severs communities and charges uncongested traffic during off-peak periods. Gothenburg is having to consider options to address inequities arising from this;
- A transport package funded by the scheme should already have some significant public support and ideally some elements should be implemented in parallel with the charging scheme (perhaps with capital costs borrowed and recovered in the future) so those paying can benefit from the projects;
- An ANPR system can be installed quickly and relatively cheaply;
- The initial demand response may be higher than what is sustained if the public has limited awareness of what they are likely to pay for their regular trips;
- A charging scheme can be regressive if it is poorly targeted.

2.2.5. Dubai

2.2.5.1. System map

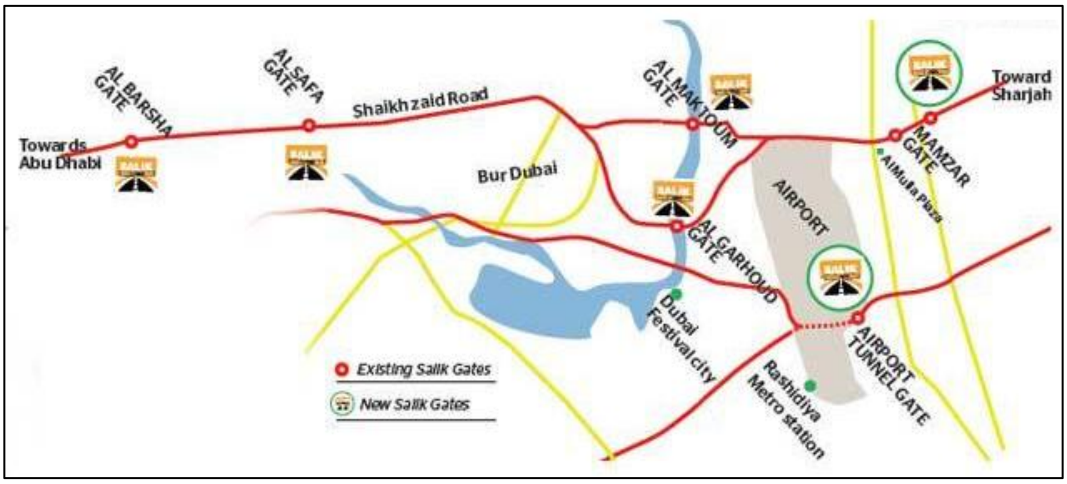

Figure 13 - Dubai's Salik road pricing system charging points

2.2.5.2. Current scheme concept

Type of scheme	Strategic route charge
Vehicles charged	All vehicles except buses
Charging times	Depends on charging point, ranging from 24 hours to 0900-2200
Discounts/exemptions	Military, emergency vehicles, buses or vehicles with disabled owners
Charging technology	Detection based system using DSRC
Use of net revenues	General government revenue
Range of charge rates	NZ$1.50

2.2.5.3. Background and relevance

Dubai's scheme (branded Salik) was introduced to manage traffic on the main highways through Dubai, but has been widely criticised for largely diverting traffic onto parallel routes. It is the only example of congestion pricing that only applies to major highways in a city.

2.2.5.4. How the system/scheme emerged

The Dubai Road and Transport Authority (RTA) announced in February 2007 that it was introducing "Salik" (meaning "open") with it coming into operation on in July 2007. A supplier and technology had already been selected (Transcore using DSRC). A key motive behind the scheme was Dubai's drive to modernise. As it appeared that congestion pricing was becoming more popular (due to London and Stockholm), it was seen as appropriate for Dubai to introduce such a scheme, as congestion had become a problem in the city. The Dubai government had also been developing a metro scheme as an alternative and this was seen as being supported by the introduction of Salik.

2.2.5.5. Analytical tools used

It is unknown what analytical tools were used. It is presumed that simple toll road demand management modelling was used to establish a rate to reduce demand at the chosen charging points based on estimated values of time for Dubai. All six charging points have the same charge rate.

2.2.5.6. Methodology for choosing system/scheme design

The explanation for the scheme design was that it was designed to capture congestion on major routes. Taxies were exempt from 2007 until 2013, as a concession to the taxi industry. The exemption was removed once new taxi meters were issued that incorporate Salik charges in taxi fares. Net revenues are treated as general government revenue, although recent news reports have proposed selling revenue rights to raise money for major infrastructure projects.[39] A daily cap on charges was removed in 2013, although that was expected to only affect 5% of users.[40]

2.2.5.7. Public engagement and consultation

There appears to have been little public engagement and consultation about the scheme.

2.2.5.8. Outcomes, user experience and public reaction

Dubai RTA reports a 25% reduction of traffic at one of the first charging points, with a 50% reduction in travel time, and another charging point reportedly had a 45% reduction in vehicle numbers.[41] However, no statistics are provided for the increases in traffic and travel times for parallel routes. Reports after two additional charging points were opened indicated significant congestion on parallel routes.[42] Soon after Salik was introduced, websites appeared displaying alternative routes to bypass the charging points.[43]

70% of users polled by one media outlet were critical of the scheme following significant increases in congestion on parallel routes. The similar poll indicated 46% thought traffic had worsened since Salik had been introduced.[44] Another newspaper in 2015 indicated that traffic congestion was one of the top concerns for Dubai residents[45] and congestion in Dubai is costing the economy around NZ$1b a year.[46] The conclusion is that although Salik has had some effect, it hasn't been implemented in a way that has addressed congestion in Dubai adequately.

2.2.5.9. Complementary mitigation measures

Dubai's metro and tram network have been extensively expanded since Salik was introduced, which has helped improve acceptability. RTA believes that further expansion will help to relieve congestion by providing a reliable and comfortable alternative, although Dubai's climate has meant accessibility to public transport on foot is limited.

2.2.5.10. Key lessons for Auckland

The key lesson for Auckland is that applying charges to main highways only can cause significant diversion of traffic onto parallel routes and undermine the public's belief in the effectiveness of the scheme. The technology choice of Dubai has meant that only large gantries can effectively detect the tags that were

39 http://www.thenational.ae/business/banking/dubai-to-sell-future-salik-receipts-to-finance-projects
40 http://www.arabianbusiness.com/dubai-set-scrap-aed24-salik-daily-cap-506870.html
41 http://www.arabianbusiness.com/dubai-gives-resounding-no-salik-expansion-121833.html
42 http://www.arabianbusiness.com/salik-expansion-brings-dubai-halt-43680.html
43 http://gulfnews.com/news/uae/general/avoiding-the-salik-road-toll-1.465571
44 http://www.arabianbusiness.com/salik-expansion-brings-dubai-halt-43680.html
45 http://www.thenational.ae/uae/government/traffic-and-cost-of-living-top-list-of-concerns-for-dubai-residents
46 http://gulfnews.com/news/uae/traffic-congestion-costs-more-than-dh700-000-per-kilometre-in-dubai-1.1452783

issued, a future refresh of technology may enable alternative routes to be charged and help reduce congestion more effectively.

2.2.6. Milan

2.2.6.1. System map

Figure 14 - Milan Area C

2.2.6.2. Current scheme concept

Type of scheme	Cordon
Vehicles charged	All vehicles except motorcycles; during active hours, access to Area C is forbidden to Euro 0 petrol vehicles and to Euro 0, 1, 2, 3 diesel vehicles with a length of more than 7.5 metres
Charging times	0730-1930 weekdays except Thursdays (0730-1800)
Discounts/exemptions	Emergency vehicles, motorcycles, registered disabled. Low emission vehicles until October 2019. Residents' vehicles have 40 free entrances per annum
Charging technology	Declaration and detection based system using ANPR
Use of net revenues	Public transport fund

Range of charge rates	NZ$3.17-NZ$7.91 per day depending on vehicle type (e.g. passenger, service vehicle) and residential status

2.2.6.3. Background and relevance

Milan has a metropolitan population of over 7m, with a per capita car ownership of over 50 vehicles per 100, with around 45% of trips undertaken by car.[47] Milan has demonstrated the success of introducing a small cordon scheme, but also the challenges of changing objectives and being able to scale beyond a small scheme and avoid negative impacts.

2.2.6.4. Scheme description and public support for reform

In 2008, Milan introduced the ECOPASS. This was an environmental charge intended to reduce particulate pollution in the inner city. It was replaced in 2013 with Area C, essentially a reform of ECOPASS to become a congestion charge. A referendum held in June 2011 saw almost 80% support for a more restrictive approach to traffic than ECOPASS on condition that it would improve conditions in the city.[48]

The purpose of Area C was to reduce congestion, raise revenue for public transport and active modes and improve urban amenity by reducing accidents, noise and air pollution.

Area C establishes a cordon with 43 entry points around the central city. Seven of the access points are reserved exclusively for buses and trams. Purchase of an electronic "ticket" is required for entry into the zone. Motorists have until midnight the day following entry into the zone to purchase and activate the ticket. Activation entails linking a PIN on the ticket to a vehicle's number plate, either by SMS message, website, by telephone to a customer service centre, or in person at a customer service centre. ANPR monitors access points and the scheme administration reconciles activated tickets against number plates entering the cordon. Daily access for most passenger vehicles is NZ$7.68, with discounts for residents. Fines for non-payment are significant (NZ$107-438) but motorists who miss the payment deadline may pay retroactively, within 7 days, at a rate of NZ$23 without incurring any penalties.

Residents who register their vehicles with the scheme receive 40 free entries per year, and discounted rates for additional entries.

2.2.6.5. Outcome

Area C has been effective at reducing traffic and improving travel speeds for both private and public transport during operating hours.[49] Traffic inside the charged area reduced by 16.2% with ECOPASS and a further 30.7% with Area C. Crashes were also reduced by 21.3% with ECOPASS and a further 20.8% with Area C. After six months, bus speeds in the zone had increased by 7% on average.

Milan studied the feasibility of an extension of Area C during development of its 2015 *Sustainable Urban Mobility Plan*. The scheme it analysed included a second cordon around Cerchia Filoviaria, as well as the introduction of a Low Emission Zone (LEZ) similar to that in London. It was found that, while a second cordon and LEZ would have congestion and air quality benefits, there were significant negative *social* impacts that could not be mitigated given the current public transport network. Therefore, extension of the Area C scheme is unlikely to occur until public transport is more fully developed.

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[47] Source: Mobility in Cities Database Synthesis Report, June 2015, UITP, Brussels.
[48] Source: http://www.eltis.org/discover/case-studies/area-c-milan-pollution-charge-congestion-charge-italy
[49] Speed during peak hours increased 6.9% for buses and 4.1% for tram.

2.2.6.6. Lessons for Auckland

ECOPASS, as an environmental charge, had gained some degree of public acceptability in Milan, but changing its purpose to the reduction of traffic and easing of congestion seemed difficult to understand for the public. The change in policy objective to demand management seemed to many of the public to be arbitrary, leading to questions about whether ECOPASS had been a failure, and whether congestion reduction as a new policy goal was credible.[50] This led to significant political criticism, and public demonstrations against the scheme. Opponents attempted to organise a referendum against it but were unable to collect the required number of signatures in support of such a referendum. Clear consistent objectives that are sustained are easier to communicate than changes to policy objectives.

Ultimately, many public concerns about Area C were mitigated through direct citizen involvement in its design and clear communication about how revenues would be utilised. For example, local government developed a revenue utilisation plan for Area C that would improve public transport and active mode infrastructure that gained public acceptability. This should have been developed as part of the early phase of policy development. Also relevant has been the mitigation measures for residents within the cordon. Residents receive 40 free days each year, and significantly discounted daily rates beginning on the 41st entry. Furthermore, the scheme included a provision for discounted parking in participating garages, which helped enhance acceptability.

[50] Source: http://www.academia.edu/10359496/The_Ecopass_pollution_charge_and_Area_C_congestion_charge_-_comparing_experiences_with_cordon_pricing_over_time

2.2.1. Silicon Valley toll (express) lanes

2.2.1.1. System map

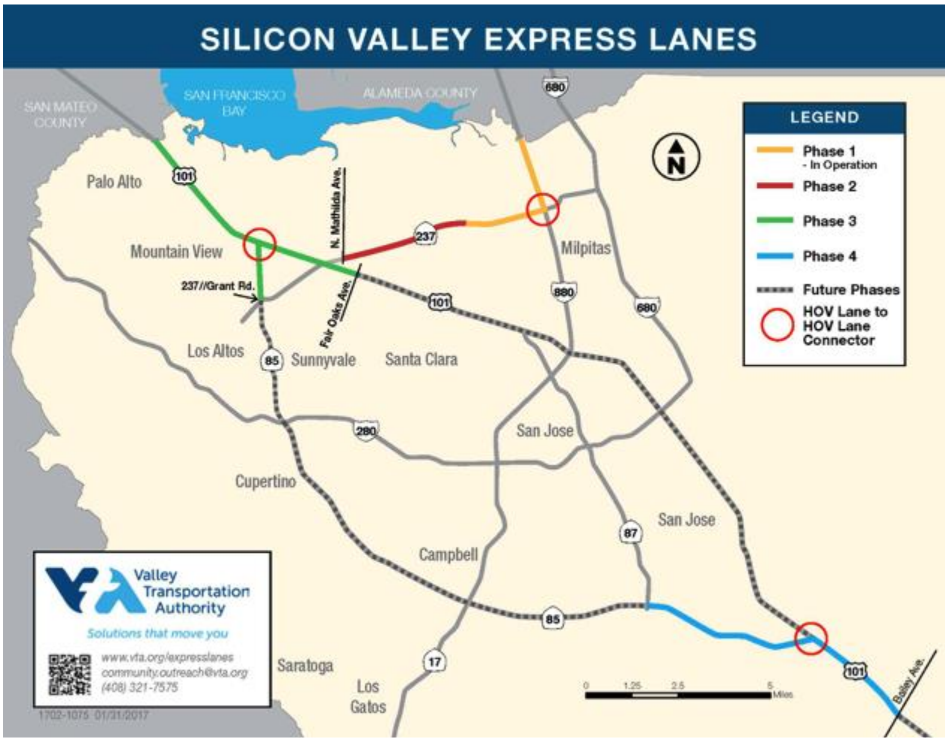

Figure 15 - San Francisco Bay Area HOT lanes

2.2.1.2. System concept

Type of scheme	Tolled lane
Vehicles charged	All vehicles except high-occupancy vehicles ("Carpoolers"), electric, hybrid, and CNG vehicles participating in California's "sticker program" for clean vehicles, and motorcycles
Charging times	On Phase 1 lanes (currently open), M-F 0500-1000 (westbound lane), 0500-0900 (eastbound lane), and 1500-1900 in both directions
Charging technology	DSRC
Use of net revenues	Transport improvements to the corridor and improvements to public transport
Range of charge rates	Rates are updated every 5 minutes based on traffic flow in the charged lane. Minimum toll is NZ$0.41, with a maximum of NZ$9.64 for travel the length of the toll lane. Depending on conditions, the toll may be waived for high occupancy vehicles (HOV) or the lane may be restricted to HOV only

2.2.1.3. Background and Relevance of Silicon Valley Express Lanes

Express lanes have been widely implemented in the United States as a strategy to leverage existing restricted access lanes (e.g. high occupancy vehicle) (or existing right-of-ways) to provide improved level of service on poorly-performing highways for those willing to pay a toll. As such, pricing is intended to guarantee travel speed, not manage demand on the facility or broader network, but this may be seen as an attractive option compared to the public concern over pricing existing lanes. Nevertheless, the process of converting "free" (if underutilised) lanes to priced lanes carries with it political and public opinion challenges not dissimilar to broader network charging and demand management schemes.

2.2.1.4. Description of system

The Silicon Valley Express Lanes system converted existing high occupancy vehicle lanes (HOV) lanes into tolled "express" (HOT) lanes. This conversion involves installing electronic toll collection equipment, signage, and lane markings. The toll varies dynamically based on travel speed within the lane, rising as congestion increases in order to maintain a minimum speed in the express lane of 45 miles per hour (72.4 km/h). If utilisation of the express lane causes travel speeds to fall below that mark, the lane is restricted to high-occupancy vehicles only, and no other vehicles may use the lane regardless of willingness to pay.

Revenues generated by the express lanes are used by the Valley Transportation Authority (VTA) to operate and make improvements to the express corridors, as well as broader highway improvements and spending on public transport.

2.2.1.5. Outcome

Phase 1 conversions had a total cost of NZ$15.1 million and generate NZ$413,000-$689,000 each year in net revenues. Future phases involve constructing additional lanes, so will have significantly higher implementation costs (but also higher revenue potential).

2.2.1.6. Lessons for Auckland

During the planning process for Phase 1 of the managed lane network, VTA conducted public opinion polling and focus groups. It found that ongoing outreach to maintain the support of the public and elected officials was critical to programme success, particularly as political conditions and project objectives change. Ensuring that, when in operation, HOT lanes provided excellent customer service, including rapid response to customer questions, is also important to maintaining the public's support. VTA recently commenced a study examining social impacts of the express lane program, to examine whether transit improvements could offset any social or economic inequities.

The Silicon Valley Express Lane system was able to be developed because of the pre-existence of restricted access HOV lanes that could be converted into HOT lanes, because they were poorly utilised. Auckland's motorway network does not have lanes with those characteristics that could be converted.

2.2.2. Oslo

2.2.2.1. System map

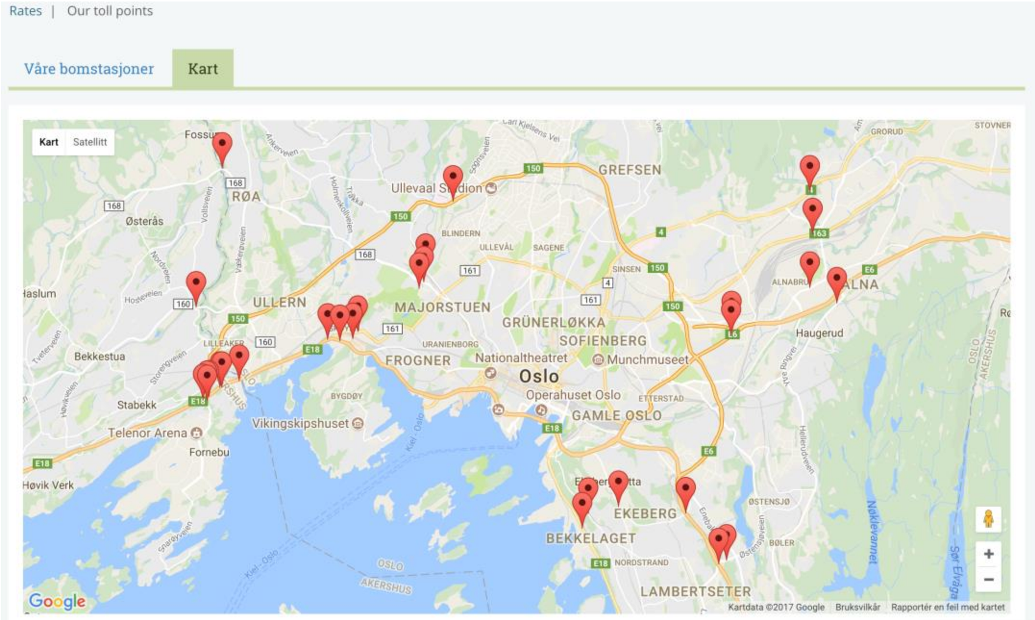

Figure 16 - Oslo toll ring charge points[51]

2.2.2.2. Current scheme concept

Type of scheme	Cordon and corridor charging
Vehicles charged	All vehicles except motorcycles
Charging times	24/7
Discounts/exemptions	Emergency vehicles, electric vehicles, buses and the registered disabled
Charging technology	Detection based system using DSRC and ANPR
Use of net revenues	Funds packages of urban transport improvements
Range of charge rates	NZ$5-NZ$17 depending on vehicle size and time of day

2.2.2.3. Background and relevance

Metropolitan Oslo has a population of around 1.7m, with trip mode shares of 36% by car.[52] Around 13% of driving in Oslo is spent in congested conditions. [53]Oslo has had an urban road pricing scheme in place since 1990 in the form of a cordon, and is the only example of a pure revenue based scheme in this report. There was one attempt to reorient the scheme towards being a congestion charge, but this failed due to public opposition. The scheme remains controversial.

[51] An interactive version of this map with charge rates for each point is available at http://www.fjellinjen.no/private/rates/our-toll-points/

[52] 53% if walking is excluded. Source: http://www.epomm.eu/tems/result_city.phtml

[53] Source: INRIX http://inrix.com/scorecard-city/?city=Oslo&index=45

2.2.2.4. How did the scheme emerge and how was the scheme design selected

In 1982, the Norwegian government agreed to provide additional capital funding for urban transport projects if cities introduced tolling to assist with funding. Norway has 80 years' experience of using tolls to fund highway projects. The first urban road tolling system was introduced in 1986 in Bergen to fund major highway improvements. In 1990 this was followed by Oslo, as main parties in Parliament were in support of the proposal, even though opinion surveys indicated significant public opposition. The toll ring was set up to pay 56% of the cost of "Oslo Package 1" (NZ$1.8b in 1990), primarily consisting of urban road tunnels to enable through traffic to bypass inner Oslo and 20% on related public transport improvements. The choice of a cordon was intended to capture traffic entering Oslo, but its location was a compromise (located halfway between the CBD and the city boundary) to balance political acceptability and revenue targets.

In 2001, Oslo Package 2 was agreed (80% spending on roads), with another NZ$2.5b (2001) in spending, of which 12% was to be funded by the toll ring. In 2008, both were superseded by Package 3 at a value of NZ$8.7b until 2027. This is to support a range of public and active transport and road capital projects, and support for public transport operating subsidies. 60% of the spending in Package 3 is for public transport. Nine additional charging points were introduced to increase revenue raised by 27%.

2.2.2.5. Congestion charging? No

In 2008, as Package 1 funding had come to a close, the issue was raised as to whether the toll ring would be dismantled. However, Oslo City was concerned that this would exacerbate congestion and so proposed to convert the toll rings into a congestion charge, by adding two more cordon, doubling peak charges and ending evening and overnight charges. This was rejected, but as part of Package 3 it was agreed that a peak surcharge would be introduced (this will be implemented on 1 July 2017) worth an additional NZ$1.70 over the base charge, with no offsetting reductions in tolls at over times. Essentially, the Oslo scheme remains a toll, as it applies every day at all times. However, mode shares for trips by car in Oslo have declined from 45% in 2005 to 34% in 2015, indicating a long term trend towards less car use in the city.

2.2.2.6. Public acceptability still low

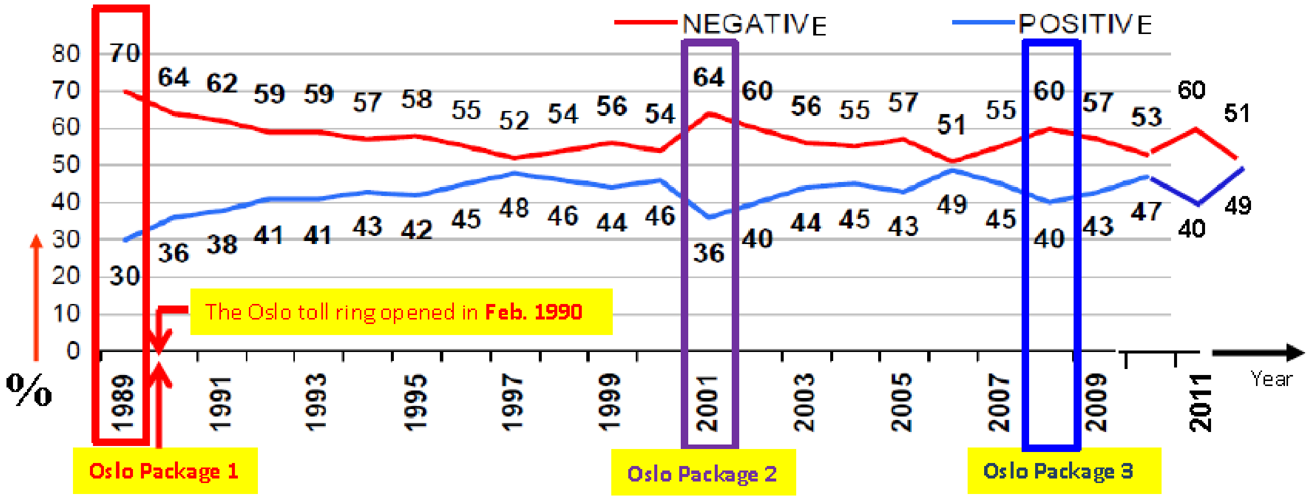

Figure 17 - Public attitude to Oslo toll ring[54]

It was believed that public acceptability of the toll rings would grow once they saw the benefits of the improved transport projects. However as of 2012, public acceptability still has never reached a majority of those polled by the Norwegian Public Roads Administration as seen in Figure 17 above. One reason could be because the toll ring has been retained for each new funding package, contrary to how tolling has worked in other parts of Norway (where tolls are removed once a package of projects have been fully funded).

2.2.2.7. Key lessons learned

Oslo has demonstrated some of the difficulties of gaining acceptance for a scheme that charges primarily for revenue, and that development of a revenue based scheme does not necessarily ease the introduction of charging based on congestion.

[54] Source: Waersted K. *An Urban Toll Ring as a Financial Instrument for better Public Transport - the Oslo Experience*, for UITP Geneva conference, 2013.

2.3. Proposals under development

2.3.1. Jakarta

2.3.1.1. Proposed system map

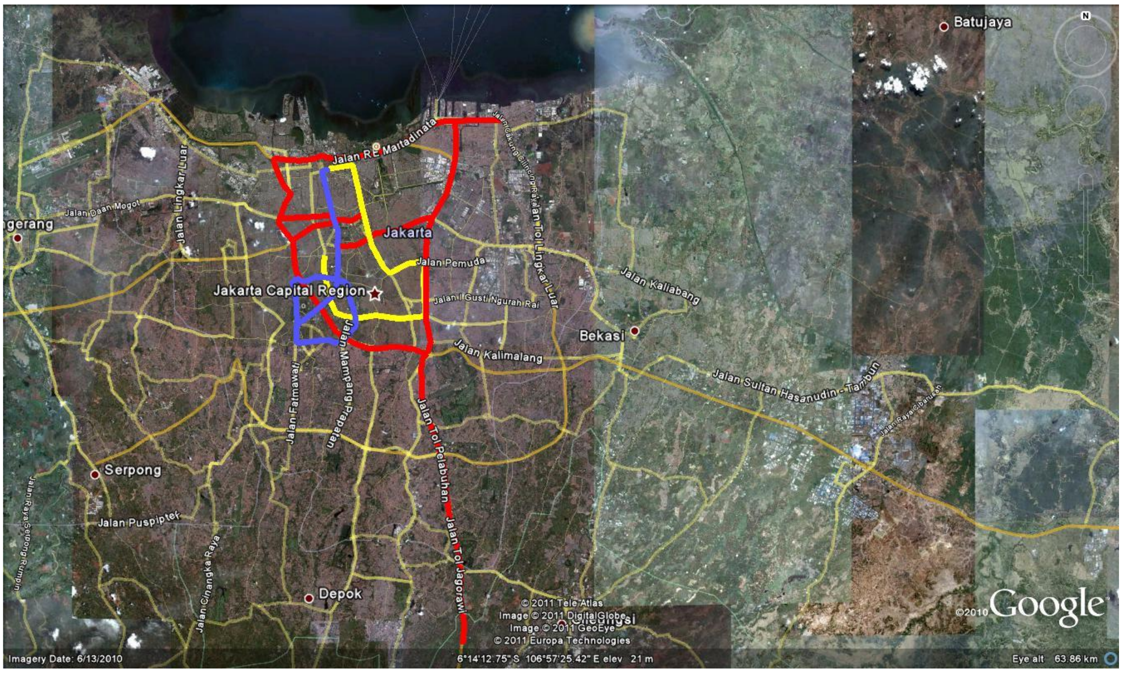

Figure 18 - Jakarta ERP full proposal

2.3.1.2. Scheme background and relevance

Jakarta has a population of nearly 10 million, in a metropolitan region of over 30 million people, and is among the worst cities in the developing world for congestion according to a report quoted by the Jakarta Globe.[55] The Tom Tom Index of congestion is that the average delay due to congestion is 48 minutes per trip over the free flow travel time.[56] Core reasons for this congestion include rapid growth without commensurate expansion of the road network and very limited public transport on dedicated rights of way to bypass congested roads as car ownership increases. Over 57% of trips in Jakarta are undertaken by car.

Jakarta is included as a city that is developing congestion pricing rapidly, but has failed to take into account the need for a key enabler - number plates that are readable by ANPR camera.

2.3.1.3. Scheme description

The core proposal for Jakarta is depicted in Figure 18 as is to charge a series of major roads only using DSRC with pre-paid smartcards, enforced with ANPR. The proposal is called ERP (Electronic Road Pricing). Vehicles would pay only between 0700 and 1000 and 1630-1930 weekdays between NZ$1 and NZ$3.50 per road depending on the route and time of day. Only emergency vehicles and buses would be exempt. Net revenues would be spent on significantly improving public transport, initially bus rapid transit

[55] http://jakartaglobe.id/news/jakarta-worlds-worst-traffic-gridlock/
[56] https://www.tomtom.com/en_gb/trafficindex/city/jakarta

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and the commuter rail network. The proposal is forecast to reduce delays by 40% on the roads that are to be charged.

2.3.1.4. How the systems/scheme emerged

Indonesia introduced a high-occupancy vehicle rule (minimum 3 occupants) on three major roads some years ago. In 2010, it was announced that a regulation would be passed to authorise "Electronic Road Pricing" in Jakarta, following the model of Singapore, to replace this controversial rule.

2.3.1.5. Methodology for choosing systems/scheme design

Scheme design has been based on main routes that have the slowest average speeds. Jakarta has been heavily influenced by the success of nearby Singapore. Main highway charging has been preferred because Jakarta Transportation Agency believes parallel local streets are already too heavily congested for road users to seek to divert onto them.

2.3.1.6. Public engagement and consultation

There has been relatively little public engagement and consultation to date. The Mayor is considered to have a democratic mandate to implement charging, following the decision of the Indonesian Government to grant Jakarta the powers to introduce ERP.

2.3.1.7. Development and Implementation

In 2014 two series of technology demonstrations were held. One with three suppliers using 50 vehicles crossing one site in the city (all equipped with DSRC), a second with two suppliers, but specifically using tags with prepaid stored value smartcards. These tests demonstrated the technical capabilities of supplier technology. At the time it was intended that ERP would be introduced in 2014, but that date has been deferred several times. The Mayor in 2015 wanted GNSS technology to be tested out of concern of cost. This idea was abandoned because of the need for gantries for ANPR based enforcement regardless. Procurement was launched in 2016, but was suspended in February 2017 because the Business Competition Supervisory Commission (BCSC) found that the regulation specifying the technology (DSRC 5.8GHz) would restrict competition among suppliers and is illegal. Once regulations are amended, the scheme is expected to be implemented in 2018.

2.3.1.8. Complementary measures

Additional bus services and expansion of the bus rapid transit network are planned, and the odd/even number plate rule will be removed.

2.3.1.9. Fundamental difficulties

Jakarta has been receiving significant technical advice from the Singaporean LTA, which reports that Jakarta's most fundamental problem is the difficulty in applying ANPR enforcement. Number plates in Jakarta are frequently made by small independent businesses, with non-standard fonts, rendering ANPR cameras unreliable. Toll roads in Jakarta have not shown interest in introducing free flow technology to replace manual toll plazas because of fear of revenue loss. Meanwhile, Jakarta has been implementing an odd/even rule for number plates that has had a modest impact on congestion as an interim step.

2.3.1.10. Lessons for Auckland

Although Jakarta undertook a technology demonstration with several vendors with DSRC technology, it has not been able to confront the key barrier to implementation, the unreliability of the provincial number plate system. This indicates that a demonstration should seek to test *all* of the key enablers for an urban road charging system and involve the general public (not just vehicles that vendors select to demonstrate their technology) to help to involve them in the development of the solution, to identify ways it might be evaded.

2.3.2. Hong Kong

2.3.2.1. Proposed system map

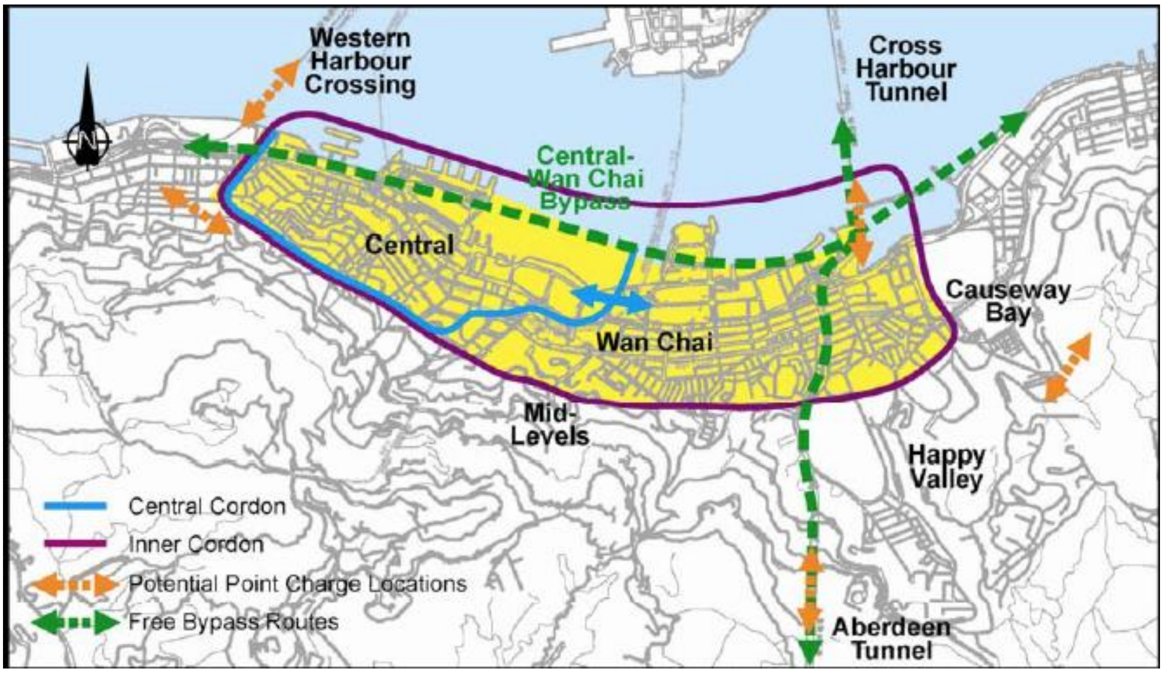

Figure 19 - Depiction of two Hong Kong road pricing scheme options

2.3.2.2. Background and relevance

Hong Kong has only an 11% mode share for private car trips to Central and Wan Chai, and has been investigating congestion pricing for over 30 years. Yet it is only recently that it has appeared to show a serious commitment to implementing the concept. Hong Kong has high population density, dense provision of competing public transport operations and severe congestion, but obtaining public acceptability for congestion pricing has been challenging for each of the last four occasions it has been studied. Auckland can learn from Hong Kong's most recent experience in undertaking consultation and strategic engagement.

2.3.2.3. Objectives

The purpose of congestion pricing in Hong Kong (called ERP) has long been consistent around improving the mobility of people and goods, adopting the user-pays principle and providing a more efficient equitable and flexible way of managing traffic. Hong Kong started investigating congestion pricing in the 1980s following concern over the severity of growing congestion in the colony. There was considerable appeal in applying user pays and market principles to the management of roads for the colonial administration at the time.

2.3.2.4. Analytical tools used

Traffic demand modelling was used in each of the four studies, using a WAYS model in the 1997 study. That model was replaced with a CUBE model, which included sub-model forecasts for freight, public transport and overall trip demand. For the 2006 study Transport Department Hong Kong sought a "Congestion Charging model" to incorporate stated preference surveys with demand modelling, along with cost and revenue modelling, to determine the economic value of introducing road pricing.

2.3.2.5. Methodology for choosing systems/scheme design

In Hong Kong, early analysis from the first and second studies identified the most severe congestion in terms of delays over free flow conditions, and duration of periods of congestion as being the Central-Wan Chai area. Analysis has focused on this area as the priority. Technology selection has varied from study to study as it has evolved, no decisions have been made, but both DSRC/ANPR and ANPR alone are under consideration. No decisions have been made on exemptions, payment systems or interoperability, as these are all have been the subject of public consultation.

It is intended that any net revenues be used both to reduce vehicle registration and licensing fees, and to help fund complementary transport measures.

2.3.2.6. Public engagement and consultation

All reports have sought public feedback, but the most detailed and elaborate exercise was undertaken in the most recent development of ERP. Transport Department Hong Kong embarked on detailed public engagement from December 2015 until March 2016. A report on this exercise was published in January 2017. That exercise consulted on six basic elements of the charging scheme (area, mechanism, period, level, exemptions and technology) and three key concerns identified in the previous survey (privacy, effectiveness and complementary measures).

The consultation focused on three key concerns, privacy, effectiveness and complementary measures. A dedicated website was set up[57]for the consultation which includes materials and reports for public consumption. TV, radio, leaflets and posters were all used to engage the public. 20 events were hosted for major stakeholders groups, such as professional bodies, academics, transport industry, business groups and environmental organisations. A District Council forum was held, and separate meetings had with various elements of the transport industry (freight, bus and taxi sectors). Detailed responses and feedback were received about the scheme design elements.[58] This included views on discounts and exemptions that ranged from having none, through to a long list of categories that seemed "justified",

This exercise has helped to inform policy and justify the commencement of a new feasibility study for a preferred option informed by public engagement. Instead of consulting on whether the policy was appropriate, this was assumed and consultation focused on key issues and elements of the proposal.

2.3.2.7. Development and Implementation

Hong Kong has undertaken four sets of investigations into congestion pricing:

1. Hong Kong Road Pricing Study 1983-1987: The world's first demonstration of electronic road pricing, with 2500 vehicles in a 21 month trial proving 99.7% reliability. Modelling indicated a single cordon (with reductions in vehicle registration fees) would reduce traffic volumes by 20-24%. Did not proceed due to public concerns about effectiveness, cost and privacy.

2. Hong Kong Electronic Road Pricing Feasibility Study 1997-2001: Included field testing of DSRC and GNSS technology. Proved both could be effective for zone based charging. Modelling indicated a single cordon could reduce traffic volumes by 24%, but needed to include taxis and buses. The report proposed that GNSS technology as the best choice in the longer term for flexibility and

[57] http://www.td.gov.hk/mini_site/erphk/en/home/index.html

[58] Full text of the consultation report is available at http://www.td.gov.hk/filemanager/en/content_4838/eng_td_pe1report_main.pdf

scalability. [59] However it was decided to defer further consideration until 2006, because of the prevailing economic slowdown.

3. Hong Kong Electronic Road Pricing Modelling and Technology Update 2006-2009: The 1997-2001 study was updated with creation of a dedicated congestion charging model, with updated costs. This study found an all day cordon with charges varying by time of day could reduce average trips circulating in the cordon by 22% with traffic speeds modelled to increase to 17-20km/h, an increase in public transport trips by 2-4% and reduction in emissions by 2-8% in the cordon. Yet the report concluded that "there are no strong arguments" for introduction pricing at present. It proposed that until a free bypass route was available around the charging zone (the Central-Wan Chai Bypass), the cordon would not be effective. It also recommended an extensive public engagement programme.

4. Hong Kong Electronic Road Pricing Pilot Scheme Development 2015 onwards: A Transport Advisory Committee report in 2014 recommended that road pricing be reconsidered, and a study on congestion found traffic speeds had dropped 11% in ten years. It recommended that a pilot cordon scheme be implemented once the Central-Wan Chai Bypass had opened.

A recent survey indicates over 60% support road pricing and 52% of drivers support it. Taxi and truck drivers were most opposed (as they were sceptical of the benefits). A full scale public engagement programme was subsequently undertaken which has provided detailed feedback about many policy and design elements. The Hong Kong Government is now commissioning a feasibility study to undertake detailed design of the "Central District ERP Pilot Scheme". It believes that the public consultation exercise has helped to boost understanding and support for the concept.

2.3.2.8. Complementary mitigation measures

No decisions have been made to date as to what complementary measures may be implemented, but measures previously identified include enhanced bus corridors, improving bus/metro interchanges and pedestrian connectivity in the charging zone. Reform of harbour crossing tolls, parking charges, reduced vehicle ownership taxes and improved enforcement of loading/parking rules are also under consideration

2.3.2.9. Key lessons for Auckland

Hong Kong has conditions that would appear to ideally suit the introduction of urban congestion pricing. 78% of motorised trips are undertaken by public transport, with only 11% by private vehicle (11% by taxi). It has car ownership at less than half the rate of Singapore. It has been investigated and been subject to technical trials for over 30 years. Yet political and the public concern around the effectiveness and appropriateness of road pricing has hindered its development. For Auckland, the lesson is that studies and trials in themselves may not produce the political and public acceptability necessary to proceed.

Most recently, momentum has emerged by acknowledging congestion is a problem, that a wide range of measures are needed to address it including road pricing, then for there to be engagement about road pricing as an option. It has taken official endorsement of those *other measures* as well, to demonstrate that a comprehensive commitment to reducing congestion exists. Finally, undertaking a comprehensive focused public engagement exercise appears to have been a considerable success in engaging stakeholders, road users and the public and helped to build acceptability. However, Hong Kong did have to identify the charging scheme option that it is proposing before starting engagement with the public.

[59] Paragraph xii, Executive Summary, Hong Kong Electronic Road Pricing Feasibility Study 1997-2001.

2.4. Proposals abandoned or deferred

2.4.1. New York

2.4.1.1. Proposed system map

Figure 20 - New York congestion pricing East River crossing and lower Manhattan cordon proposal

2.4.1.2. Proposed scheme concept

Type of scheme	Area/cordon charge
Vehicles charged	All vehicles except buses, taxis, emergency vehicles and those with disability plates
Charging times	0600-1800 weekdays
Charging technology	Detection based system using DSRC e-Tag system already used in tolled crossings
Use of net revenues	Fund road maintenance improvements and public transport
Range of charge rates	NZ$9.69-NZ$29 depending on vehicle size

2.4.1.3. Background and relevance

New York's geography would appear to make congestion pricing easy to implement in lower Manhattan. With many vehicles already accessing the area by toll (and exempt from an additional charge), and a high public transport mode share[60], it still proved difficult to gain political support.

New York started considering adding tolls to the untolled East River Bridges in the early 1970s, but the idea was dropped in 1981. On Earth Day in April 2007, Mayor Michael Bloomberg launched PlaNYC containing 127 initiatives to reduce air pollution and the city's contribution to climate change and improve the city's transport system. The plan included a congestion charge in lower Manhattan to support those goals and raise revenue to spend on public transit and repairing city streets. The proposal had been developed by a coalition of business, community and environmental groups, and was in part inspired by the relative success identified in London from its scheme

2.4.1.4. Proposal development and reactions

The original PlaNYC concept was for a NZ$11 daily charge for cars entering or leaving the congestion charge cordon or a NZ$5.50 daily fee for movement within the zone ((NZ$29 and NZ$7.60 for trucks respectively) to operate between 0600 and 1800 weekdays. Any road users that pay tolls on the Hudson or East River crossings would not be charged again. In August 2007, the New York Metropolitan Transportation Authority and New York City were granted Federal funding (US$354m) to help implement the proposal and complementary transport improvements (conditional on the New York State Legislature approving the proposal, for it to be operational by April 2009. The proposal was refined to a simpler proposal, which was modelled (using a strategic demand model to inform a traffic assignment model) to reduce total vehicle miles travelled in the cordon by 6.8% and delays by around 30%. It was supported by the Mayor, the Governor and a coalition of business, labour and environmental groups, along with major city newspapers. Polling indicated varying levels of support ranging from 33-67%.

2.4.1.5. Opposition

Opposition came from four New York boroughs outside Manhattan, particularly Queens and Brooklyn. They saw it as being unfair that other motorists who already paid tolls (particularly from New Jersey) would not pay more, but they would have to pay, indicating backlash from an exemption designed to increase acceptability. Yet only 5% of commuters from Queens and Brooklyn travelled by car to Manhattan.

Opposition at the State Assembly proved to be the final barrier to implementation. The Assembly needed to grant New York City the legal authority to implement the scheme because it included some state roads, but there was opposition due to claims the scheme would exacerbate congestion in neighbourhoods outside the cordon and would disproportionately hurt the poor. Other opponents claimed there was no viable alternative and that the travel time savings were insufficient. Table 2 outlines the various views of supporters and opponents of the New York proposals. The proposal did not go to a vote at the State Assembly because the majority (Democrat) made it clear it would be rejected. Federal funding was withdrawn and the project was shelved.

Since that date, a new plan has emerged called MoveNY[61], which intends to "normalise" tolls in New York, by introducing tolls on the East River Bridges, but reducing tolls on more distant crossings. The proposal is

[60] 67% of commuting in New York City is not by private car. Source: Institute for Quality Communities, University of Oklahoma, using census data. http://iqc.ou.edu/2013/10/22/the-latest-bike-walk-and-transit-usage-data/
[61] More details at http://iheartmoveny.org/

designed to replicate many of the benefits of the Bloomberg scheme in reducing congestion and to raise revenue for public transport. To date, it does not have the support of the current Mayor of New York.

Table 2 - New York congestion pricing attitudes

Position		Views of congestion pricing supporters	Views of congestion pricing opponents
Opinions on Societal impacts		**Reduces traffic congestion** **Funds better mass transit** **Reduces air pollution** **Furthers the goals of sustainability, urban quality of life.** Reasonably discourages often-unnecessary driving.	**Congestion pricing targets "working person" driving to work, medical appointments, etc.** Pricing represents social engineering by Manhattan-based elites. Little impact on Manhattan traffic (trucks and taxis seen as main cause of congestion in central business district). Revenue will be diverted from the MTA which cannot be trusted to use new revenue effectively.
Individual level impacts (evaluated both for oneself and others)	Impact on transit riders	Funds better public transport. Public transport improvements will absorb increased ridership from drivers switching.	Public transport will be more crowded. Public transport is not and will not be a viable alternative Value of travel time savings (if any) not worth the $8 fee.
	Impact on auto users	Drivers will have reasonable public transport alternatives. Drivers benefit by reduced traffic congestion.	

2.4.1.6. Lessons for Auckland

New York is very different from Auckland, but in many ways it had circumstances that should have made it easier to implement congestion pricing. The key lessons are common with some other schemes:

- Do not underestimate the power of lobbying groups to undermine a scheme concept, develop strategies to explain how they will benefit and to develop policies to counters claims of negative impacts (such as claims that parking near the cordon will be crowded).
- Persuade drivers they benefit from the charge. New York did not communicate travel time savings, or the planned investment in fixing New York's roads.

2.4.2. Manchester

2.4.2.1. Proposed system map

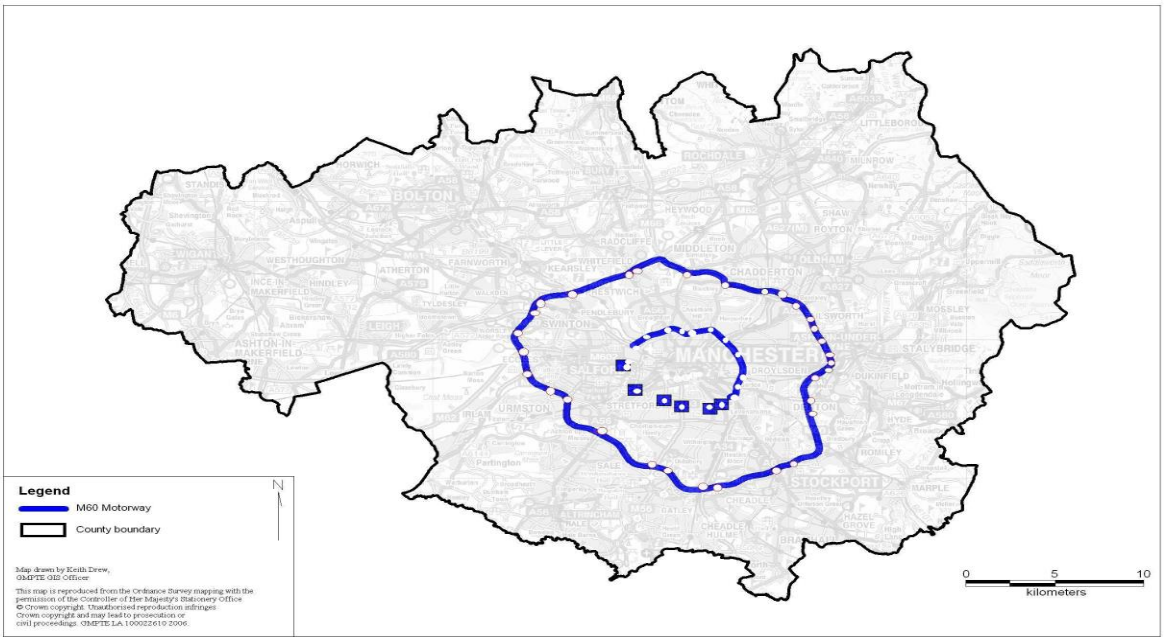

Figure 21 - Manchester congestion charge double cordon proposal

2.4.2.2. Proposed scheme concept

Type of scheme	Double cordon
Vehicles charged	All vehicles except buses, taxis, emergency vehicles, those with disability plates, people with registered health appointments and specified low income workers
Charging times	0700-0930 inbound, 1600-1830 outbound
Charging technology	Detection based system using DSRC, with declaration based system using ANPR, and pilot GNSS system
Use of net revenues	Fund public transport improvements
Range of charge rates	NZ$1.76-NZ$3.52 per crossing, up to a cap of NZ$10.57

2.4.2.3. Background and Relevance

Greater Manchester has a population of around 2.8 million and around a 50% mode share for public transport trips to central Manchester. Manchester developed a congestion charging scheme, for peak time operation only, based on a double cordon, as part of a package of major improvements to public transport under the auspices of a central government fund to incentivise adoption of road pricing by cities. Manchester's scheme would have significantly reduced travel times, but this was not well communicated to the public, as the primary narrative was around what the revenue was to be spent on. This contributed to a referendum vote where nearly 80% rejected the proposal.

2.4.2.4. Proposal development

The UK Government set up the Transport Innovation Fund in 2006, promising significant funding for local transport projects for cities that developed programmes of demand management and complementary capital investment. Manchester had long developed a series of transport proposals that had struggled to receive funding. Greater Manchester's ten local authorities (operated under the auspices of the then Greater Manchester Passenger Transport Executive GMPTE) agreed in 2006 to investigate options for congestion charging to support wider goals around economic development and agglomeration in central Manchester. A key concern was labour market connectivity and the need for a higher catchment area of population to be able to easily commute to employment centres in the region, particularly the centre. To support this, Manchester needed to ease congestion at peak times, and significantly improve public transport infrastructure to improve travel times between residential and key employment areas.

2.4.2.5. Option development

Using traditional transport and traffic modelling tools, indicating journey time decay rates due to congestion, GMPTE demonstrated that congestion would choke growth in the city centre. A strategic transport demand model, based on forecasting growth related to land use was applied to a transport assignment model (SATURN) to identify where congestion would be most severe, by link. The marginal economic cost of congestion was identified for each link, so that the cost of each additional vehicle trip at peak times per road segment (based on values of time used by the Department for Transport (DfT) by type of trip) could be identified. These were then aggregated into zones to assist in the development of congestion charge options.

It was clear that full network pricing would be optimal, but it was decided that this would not be feasible or cost effective, so a range of options were considered including cordon/area charges and motorway/arterial only charges. All were mapped against the marginal economic costs of congestion by zone, and the preferred option was selected. The proposed scheme would have cost NZ$250m upfront (2007 prices) including traffic management measures, with annual operating costs estimated at around NZ$71m.[62] It included a tag and beacon system of prepaid accounts, with ANPR cameras for enforcement and the use of occasional user products. A GNSS pilot was also included, whereby a small number of users could pay by distance after crossing each cordon up to a capped amount.

Central government was willing to grant £1.5b upfront to improve transport infrastructure, with another £1.2b as a loan to be repaid over time by the congestion charge. The intention was for the system to be operational by 2013, in parallel with the completion of most of the proposed public transport improvements.

2.4.2.6. Public engagement and referendum

Public engagement was low key for the first year or so of the proposal's development. The major city newspaper was broadly supportive, believing that the congestion charge, if designed well would be worth it for the city to gain a large investment in improved public transport. After DfT approved the package in principle, the core proposal was taken forward for more formal political consultation with the ten local authorities that comprise greater Manchester.

The concept of a referendum for the transport package (including the congestion charge) did not exist at the inception. However, three of Manchester's ten local authorities were sceptical of the congestion charge and political differences resulted in agreement that the only way the package could proceed was to hold a referendum to seek public support.

[62] These prices ***exclude*** risk contingency and 30% optimism bias as per UK Government guidelines.

The referendum question was "Do you agree with the Transport Innovation Fund proposals?" That question itself generated negative publicity, because it appeared to be concealing the congestion charging proposals, giving the impression the authorities wanted to hide their intent from the public. Bizarrely, GMPTE as project sponsor only maintained a consultation campaign during the referendum period, as campaigns became organised on both sides of the argument. Information was misinterpreted and the main newspaper printed a map on its front page mistakenly misrepresenting the location of the cordons. Internal polling indicated that many did not understand the scheme, with around a third surveyed believing they would be charged for driving around the ring roads that formed the cordons (which was false). Many did not understand the charge only applied at peak times and only in one direction, as many simply looked at London's scheme and that was seen as the reference point.

Furthermore, there was little communication of benefits to road users. Travel time savings were not publicised well, and there was no publicity for the NZ$175m in road improvements that would be funded, just the money on public transport. This may have been because GMPTE, as the project sponsor, was a public transport authority, with no responsible for roads or traffic congestion mnagement. Its institutional incentives were on delivering public transport improvements, not reducing traffic congestion. Those campaigning for a "yes" vote in the referendum were focused on selling the benefits of spending on transport improvements, not on what charging would mean for those who pay.

The "no" campaign had a much more direct and simple message. It was able to take advantage of the lack of communication of benefits of charging to simply claim it was wrong to pay more to drive in order to get transport improvements that it believed "should be funded anyway". The final result of the referendum in December 2008 was 78.8% voting "No" with 21.2% voting "Yes". The banking crisis emerged months before the referendum, raising concerns that the economic and employment outlook was bleak, increasing the reluctance to support a new charge, along with resentment that the policy looked like an imposition from central government to get funding for transport, at the same time as the banks were being "bailed out" by central government.

Manchester has not seriously considered congestion pricing since 2008, the recently elected Mayor claimed "scepticism" over its merits. If it were to be reconsidered, network charging may be considered in preference to a cordon scheme, because of concern of the boundary effects.[63]

2.4.2.7. Lessons for Auckland

Manchester demonstrated a wider economic case for charging beyond simple travel time savings, by assessing how it could improve labour market connectivity and support agglomeration. This significantly enhanced the economic case for the scheme.

Mistakes made in Manchester were in part due to governance limitation. A public transport agency that was institutionally focused on delivering public transport improvements, proved poor at explaining the benefits of congestion charging and communicating to road users. There was a strong need for simple clear messages about the charging scheme, where and when it would work, how it would work, and a need to re-emphasise this and the difference it would make to travel times. This was not done well.

Today, Manchester says it would be highly unlikely to adopt a cordon approach given the technological advanced that could enable network charging. The cordon lacked flexibility when applied to residential areas, as it placed people different sides of a line they would think is arbitrary. Distance/ time/location

[63] Source: Interview with Transport for Greater Manchester.

charging is also seen in Manchester as being closer to the increasing experience people have with on-demand transport, such as Uber.

2.4.3. Edinburgh

2.4.3.1. Proposal map

Figure 22 - Edinburgh congestion charge double cordon proposal

2.4.3.2. Charging Concept

Type of scheme	Double-cordon
Vehicles charged	All vehicles except buses
Charging times	0700-1830 inner cordon, 0700-1000 outer cordon
Charging technology	ANPR
Use of net revenues	¾ on public transport (buses, trams, and regional rail); ¼ on road improvements
Range of charge rates	NZ$3.50 (2005) for crossing either or both cordons

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2.4.3.3. Background and relevance

Edinburgh has a population of 1.4 million and endured substantial growth in traffic and congestion in the 1990s. 42% of commutes in Edinburgh are by car.[64] When first proposed in 1999, there was relatively positive support for congestion charging in Edinburgh, but as the scheme was developed that support was overturned to a 3 to 1 vote against congestion charging in a referendum in 2005. The key lesson from Edinburgh is to maintain momentum and to focus on strategic engagement with those who would be expected to benefit from the policy, and not to let opponents gain the media narrative.

2.4.3.4. Development of proposal

In 1999, a draft transport strategy for Edinburgh ("Transport Choices") proposed a congestion charge. At the time, a Loughborough University study of public views on the idea measured 60% support and 30% opposition. In 2000, UK Government legislation gave local authorities the power to introduce congestion charging on their roads and in the years through to 2005, Edinburgh engaged in market research, regional consultation, concept introduction, detailed design, and public inquiry, with the intention and expectation that continued monitoring of public opinion would enable a scheme to be developed and introduced with public consent. In 2001, options had narrowed to an inner city cordon or an outer cordon, and it was decided to proceed with a double cordon design. The proposal would've had a £2 (NZ$3.50) charge for inbound traffic across either cordon (but no additional charge for crossing both). The purpose of this approach to charging was to increase public acceptability.

Both cordons were to be enforced with ANPR cameras, with no other charging technology. The scheme would be used to support expenditure on public transport and road improvements, most notably a new tram scheme for the city. However, the messages around reducing congestion, reducing emissions and raising revenue to improve transport became increasingly inconsistent. In 2003 Edinburgh undertook more extensive public consultation, but found that there remained broad support, especially within Edinburgh city itself. However, it became clear that as more details were released, opposition was growing in outer suburbs and scepticism increased as to the objectives behind the scheme (it was seen increasingly as a new tax).

2.4.3.5. Failure to win support

Public support for the scheme consistently fell through each phase of development. In 2005, the plan was soundly rejected in a referendum by city residents with 74% of those who voted rejecting the council's plan out of a turnout of 69%. A Loughborough University study found that media coverage over the policy was predominantly negative (see Figure 23). [65] Key issues raised as to why people were opposed included:

- Concern over local impacts of traffic diversion;
- Scepticism that congestion was sufficiently severe a problem;
- Belief that alternatives would not be good enough;
- Belief that motorists are taxed enough already;
- Concern it would price the poor off the roads to benefit the rich.

It can be argued that there was no lack of public consultation in Edinburgh, yet communications did not sustain initial support for the scheme. General scepticism grew as the project proceeded. Concerns emerged that the project would suppress growth in the city centre, as shoppers would drive to destinations outside Edinburgh. Residents located at the periphery of the city believed the scheme would penalise

[64] 2010. Source: Edinburgh draft Local Transport Strategy 2014, data extracted from Scottish Household Survey.
[65] https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/2756/3/Paper_to_Transport_Policy_-_final_submission_7-05_-_to_IR_4-07.pdf

them, as many considered themselves low income. Many commuters did not believe that planned public transport improvements would give them a viable alternative. Statistics provided by Edinburgh City Council about the effects were not trusted, as increasingly people believed it was a scheme to raise revenue rather than manage congestion.

The current Scottish government and Edinburgh City Council are both opposed to congestion charging.

Figure 2. A graph of the text units in newspaper articles between January 2000 and June 2003

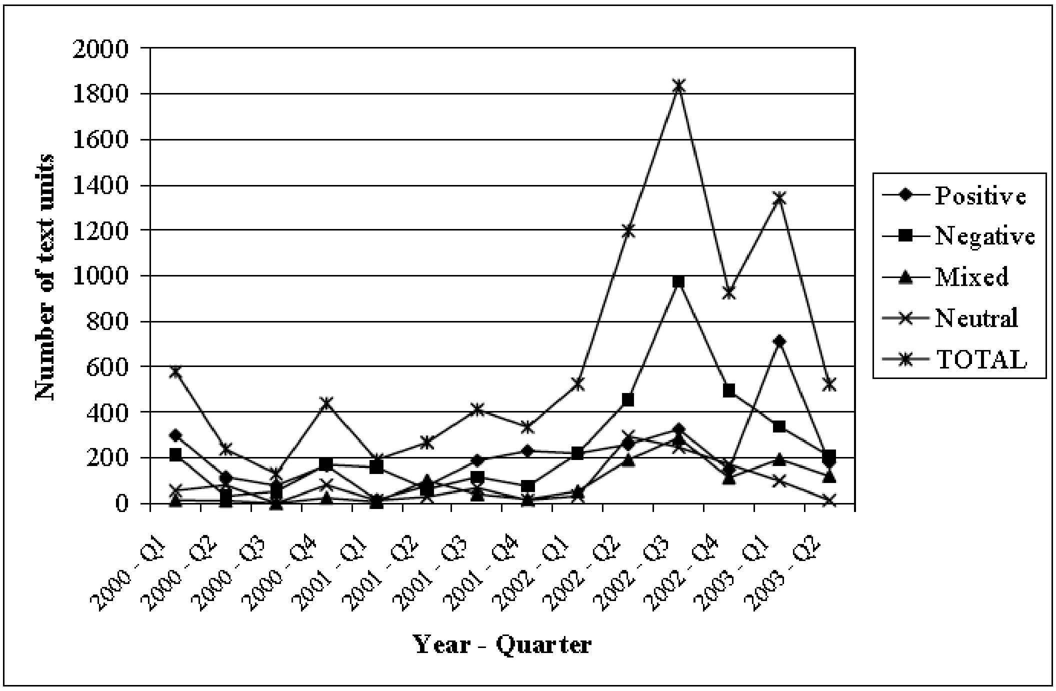

Figure 23 - Edinburgh congestion charge newspaper coverage analysis

2.4.3.6. Lessons for Auckland

The Edinburgh scheme provides the following lessons for Auckland:

- Momentum can be lost if focus on objectives and the benefits to those paying the charge are blurred. Edinburgh spent six years developing a simple concept, but increasingly failed to communicate effectively why it was developing the policy.
- Ensure the media and public narrative does not get dominated by the views of opponents. An effective strategic engagement plan that works with the media and the public to understand the purpose and intent in the scheme is critical. This includes strategic engagement and open debate on critical issues by leaders of the scheme and not relying on consultation alone to reflect public sentiment.
- The value of a single team responsible for leading, driving and implementing the scheme, to guide communications, policy and demonstrate a unified voice on the design to the public.

2.4.4. Copenhagen

2.4.4.1. Proposal map

Figure 24 - Proposed Copenhagen congestion pricing cordon scheme

2.4.4.2. Proposed scheme concept

Type of scheme	Area charge
Vehicles charged	All except buses and emergency vehicles
Charging times	Not finalised
Charging technology	ANPR
Use of net revenues	Fund public transport improvements
Range of charge rates	NZ$3.16 daily fee when entering city centre during morning and evening peaks; NZ$1.27 daily fee when entering city centre during rest of the day with no charge at night

2.4.4.3. Background and relevance

With a metropolitan area of just over 2 million inhabitants, Copenhagen has a high mode share for cycling (33% of all trips[66], 45% of commuting trips) and another 33% of trips in Copenhagen are by public transport or foot. In Copenhagen itself, there was a significant initial support for congestion pricing, which was followed by the government elected in 2011 including the implementation of congestion pricing in Copenhagen as a manifesto pledge. However, despite strong political support in a city with very high mode shares for alternatives to the private car, opposition emerged due to concerns over the boundary effects of the cordon proposal that ultimately saw it abandoned.

2.4.4.4. Development of concept

In 2005, the Copenhagen City Council adopted the *2004 Transport and Environmental Action Plan* which contained an action plan to help clarify how congestion problems in the metropolitan region could be solved. The *Forum of Municipalities*, a grouping of 16 municipalities near Copenhagen, commissioned a study in 2006 to consider congestion pricing for Copenhagen, which concluded that a charge could reduce congestion and raise money for other modes.

In 2006, the *Forum of Municipalities* suggested using the London congestion pricing model by setting up a boundary around the city centre. All those entering the centre would be charged a daily fee 25 DKK NZ$3.16) during morning and evening rush hour, 10 DKK (NZ$1.27) during the rest of the day, and having no charge for entering the city centre in the night. This was modelled to reduce traffic by 23% within the cordon and 4% across metropolitan Copenhagen.[67] The bigger political interest was that it was forecast to generate 2.2 billion Danish Kroner (NZ$450m) per annum. Leftwing and environmentalist parties were strongly supportive saying the revenue could help reduce public transport fares and improve service. Rightwing parties were split, with one claiming motorists are already too heavy taxed and that a cordon would place a barrier across the city, another claiming it would be fairer to introduce network based road pricing. However, in 2011, the centre-left coalition won the national elections, including in its policies the introduction of congestion charging to Copenhagen.

2.4.4.5. Opposition

The Copenhagen Post was in favour of the concept, but argued that the key point was to debate where the cordon boundaries would be and started to argue in favour of full network pricing as the Social Liberal Party said there should be a study of this option.[68] Opposition developed further out of concerns as to the local impacts of the cordon location on residents and businesses, with the Social Liberal Party claiming cordons are "obsolete". As the national government had also pledged to introduce GNSS based road pricing for heavy vehicles, this seemed to gain some support. However, the key factor that saw the policy suspended was new modelling that suggested the likely revenues from the scheme would be less than half of that previously forecast. The government decided to commission a new study on congestion in Copenhagen, to consider the "full range of alternatives" so that road pricing would only be considered "as a last resort" after all other measures had been tried. After the congestion pricing scheme was halted, the government promised to spend a billion kroner to cut ticket prices and raise public transport standards nationwide. Debate on congestion pricing has since stalled as it seems the primary political interest in the policy was its potential to generate new revenue.

[66] See http://www.epomm.eu/tems/result_city.phtml for European city modal splits for all trips
[67] Source: http://www.traengsel.dk/upload/traengsel/dokumenter/congestion%20charging%20in%20gca.pdf
[68] Source: http://roadpricing.blogspot.com/2011/10/copenhagen-congestion-charge-looks.html

2.4.4.6. Lessons for Auckland

There are many reasons for the failure of the Copenhagen scheme that are relevant to Auckland:

- Insufficient analysis of options before advancing a preferred choice. The proposed cordon based solution was pursued without investigating other alternatives such as GNSS based network pricing. Momentum built up around that option to address the shortcomings of the cordon, which blurred debate about the merits of introducing road pricing;
- Lack of agreement on border of the cordon. Local authorities challenged the proposed borders as leading to overwhelming diversion of traffic on their local roads. They also insisted upon further improvement of public transport before implementation of a congestion charge. These boundary issues were not adequately addressed, creating a constituency of opposition;
- Failure to communicate benefits to those who would pay. There was little discussion about how this would benefit those paying to use the roads, and it was unclear how the use of money to reduce public transport fares would benefit them as well;
- Governance. Despite strong central government support, the need to get support from multiple local authorities ultimately undermined the ability to implement the scheme; and
- Revenue was too important. Although the scheme was primarily sold as reducing traffic, it was clear that politically the raising of a lot of revenue to pay for complementary public transport measures was critical. When revenue appeared to be much lower than expected, the political impetus to proceed has been eroded.

2.4.5. Netherlands

2.4.5.1. Proposed (latest) scheme concept

Type of scheme	Full network pricing
Vehicles charged	All vehicles
Charging times	All periods with peak charging in congested areas
Charging technology	GNSS
Use of net revenues	Replace existing revenues, support land transport expenditure
Range of charge rates	Distance, weight, time of day, location and emissions rating

2.4.5.2. Background and relevance

77% of commuting by distance in the Netherlands is undertaken by car[69], although only 38% of trips in Amsterdam are by car.[70] The Netherlands has a highly developed public transport network, and its cities have some of the highest mode shares in the world for cycling (with a 22% mode share for cycling in

[69] Source: p 9. Transport and Mobility 2016, Statistics Netherlands, The Hague, 2016.
[70] http://www.epomm.eu/tems/result_city.phtml

Amsterdam). Yet despite having apparently a high standard of alternative modal choices, it has been unable to implement congestion pricing. The Netherlands has attempted five times to introduce some form of road pricing, on each occasion to address congestion. However, in each case either the political momentum stalled or it failed to gain sufficient public confidence that congestion pricing would benefit them.

2.4.5.3. Development and cancellation of proposals

Congestion has long been a key concern for transport policy makers and road users in the Netherlands, not least because of the population and vehicle density in this relatively small country. A report in the Netherlands Times in 2015[71] noted that traffic data company INRIX reported the Netherlands having the second highest levels of congestion in Europe. As a result, early plans for road pricing focused on seeking to address congestion. The planned schemes are in summary:

1990 **Rekening Rijden** (I): Cabinet announced it would implement multiple cordons around major cities (e.g. Amsterdam, Rotterdam, The Hague, and Utrecht), intended to charge for entering urban areas. Proposal abandoned in 1991 due to widespread public opposition, opposition from provincial and local authorities affected, opposition party campaign against proposal. As an alternative, fuel tax and registration fees were raised as an attempt to restrict traffic growth nationally.

1992 **Spitsvignet**: Proposal for a peak time only toll on motorways and similar major highways, to manage congestion. Trials were conducted, but political support waned and a change of government in 1994 saw the proposal cancelled.

1994 **Rekening Rijden** (II): Newly elected government proposed AM peak cordons around Amsterdam, Rotterdam, The Hague, and Utrecht. Would operate 0700-0900, intention was to be operational by 2001. Advanced in electronic tolling technology encouraged interest in the scheme, but opposition emerged due to concerns that alternative modes were inadequate. Public opposition grew further as the cost of the scheme was seen to be prohibitive (due to the high cost of the gantries and associated technology at the time for a large number of charging points). By the late 1990s, media and motoring association opposition had developed so that the proposal was quietly dropped in 2001.

2001 **Kilometerheffing**: Proof of capability through technical trials in several countries, and the introduction of GPS assisted heavy vehicle charging in Switzerland saw a new proposal that replaced cordon and tolling concepts with distance based charging. The Dutch Government announced it would introduce legislation to allow for distance charging by 2003, with a system to start being operational in 2004 (but not operational on all vehicles until 2006). The intention was to replace existing vehicle registration and sales taxes with a flat charge by location and time of day, with evolution to congestion pricing at a later date.

The proposal received significant opposition from the Dutch automobile association, the general public and employer groups, who were concerned about the costs of the scheme (a Ministry of Finance report indicated the implementation cost would be in the billions of Euros for 6 million OBUs) and unconvinced it would deliver promised benefits to road users. At the subsequent general election, the new coalition government abandoned the proposal in favour of new road building to relieve congestion.

2005 **Anders Betalen voor Mobiliteit**: Advocates of road pricing decided that a new focus had to be on stakeholder engagement and public acceptability. The government consented to the formation of the National Platform for Paying Differently for Mobility to produce a report on options, including representatives of government agencies and interest groups in transport and society. It concluded that

[71] http://nltimes.nl/2015/08/25/belgium-netherlands-worst-traffic-europe-rotterdam-scores-badly

nationwide distance charging to replace existing charges would be fair and effective in reducing congestion, and improving economic efficiency. The newly elected government in 2006 decided to focus on developing the proposal further rather than implementing it quickly. It stated that legislation would be introduced in 2009 for implementation by 2018. One of the key policy parameters was that road pricing would only be implemented once operating costs could be assured to cost no more than 5% of gross revenues. However, in 2010 the government fell and the new coalition decided to not proceed with the legislation or policy. Reasons cited included the scale of the project, difficulties in communicating to motorists that there would be winners and losers, and ongoing concern over the likely scale of administrative costs.

2.4.5.4. Current status

There is no agreement on proceeding with road pricing in the Netherlands, but some political parties advocate it to manage congestion. For now, the Netherlands is observing the newly introduced heavy vehicle RUC system introduced in Belgium in 2016 and there is some debate about introduce heavy vehicle RUC as a first step.

2.4.5.5. Key lessons for Auckland

The Netherlands first sought to implement urban congestion pricing, but then expanded to seek to introduce national road pricing primarily to address congestion. Although the political, geographic and transport context of the Netherlands is very different from Auckland, there are still some core lessons to be learnt from the Dutch attempts to radically reform road charging.

1. Maintain project scope and momentum: Long lead times for project development and implementation risk a loss of political support and the development of opposition as momentum wanes. The last attempt lost momentum as it focused on trying to build support over many years, but political priorities changed and the focus on delivery was eroded. Long timeframes give opponents and sceptics more time and ways to intervene in the process to stall project development. Focus on what can be delivered in a relatively short time frame.

2. Avoid excessive specificity in design detail to reduce the risk of cost inflation. The Netherlands sought to develop systems to meet bespoke policy and operational requirements developed by the public sector that were not on the market and expensive to develop for the Netherlands alone. Avoid excessive costs by developing specifications that are output not input driven, and seek to build a system with simplicity, but scalability.

2.4.6. Helsinki

2.4.6.1. One proposed concept map

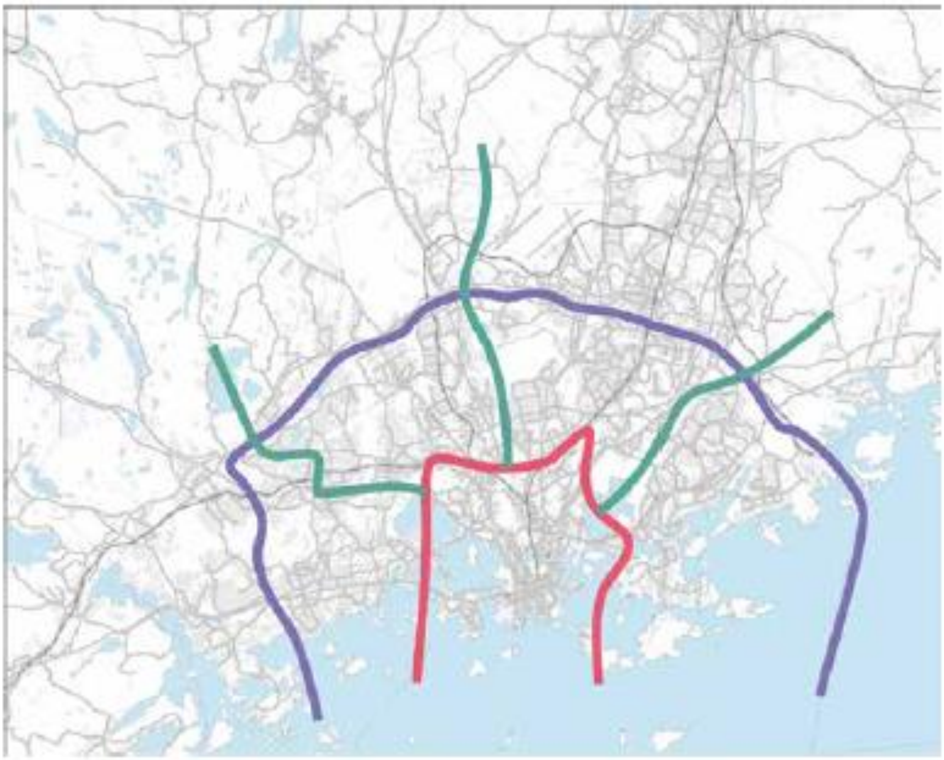

Figure 25 - Helsinki congestion pricing gate-zone proposal[72]

2.4.6.2. Proposed scheme concept

Type of scheme	Full network pricing, initially flat rate
Vehicles charged	Cars only
Charging times	24/7
Charging technology	GNSS based on board units
Use of net revenues	Fund National transport infrastructure company
Range of charge rates	Average 500-600 Euros per annum based on CO2 emissions and vehicle usage

2.4.6.3. Background and Relevance

Helsinki has a metropolitan population of around 1.4 million. The mode share for morning peak trips to the city centre by public transport is 74%, although for crosstown routes it is 21%.[73] According to Inrix, 14% of peak driving is spent in congestion with the average 24.9 hours spent in congestion in 2016.[74]

[72] Study on Road Pricing, 14 March 2016, HSL, Helsinki.

Initial focus of studies in Helsinki was to reduce congestion on major corridors and to encourage mode and travel time shift. However, the most recent policy proposals were part of a package of reforms to improve the efficiency of the supply and management of land transport infrastructure. Road pricing was proposed to provide a legally dedicated source of revenue for a national transport company and provide a future platform for congestion pricing, but the policy was suspended due to public opposition. The proposals were seen as unfair and few motorists appeared to believe that they would benefit from the proposal.

2.4.6.4. Studies, debate and policy development

Helsinki had undertaken two studies of congestion pricing following the success seen in Stockholm.[75] The key objectives were to encourage mode and travel time shift. Three approaches were modelled: a single cordon, multiple cordons and a multiple zone based system (illustrated in Figure 25). These studies found that the multiple zone based system appeared to have greatest merit and found that it could reduce peak period traffic volumes by between 10 and 30% on major radial and ring routes in metropolitan Helsinki. The 2016 report[76] also found that while central Helsinki and adjacent municipalities would benefit from a multi-zone congestion pricing system, local employment and service hubs along ring roads would likely be negatively affected (because it would cost more to service the CBD from those locations), and that the benefits of interpeak pricing were not exceeded by the costs. It also indicated that although a full network pricing approach would be able to address these disparities, the high investment costs meant it was only suitable to be implemented as part of a national programme. This finding helped to influence national policy on road pricing.

2.4.6.5. National road pricing

Parallel to the debate on congestion pricing in Helsinki, a 2014 report found that fixed taxation of motor vehicles (a sales tax on new vehicles, and annual registration taxes) should be replaced by distance charging, both for economic efficiency and environmental reasons, and that there should more widespread reform of the management and supply of roads in Finland. In late 2016, the Finnish government announced it would create a new national transport infrastructure company, to be responsible initially for roads, and then subsequently railways and waterways. The company was described as follows:

The company would fund its operation with customer fees collected from road users and moderate borrowing. The revenue from customer fees would be ploughed directly back to transport network maintenance and development.[77]

The reform of motoring taxation would provide such customer fees. In January 2017 it was announced that various fixed taxes on motoring would be reduced significantly or abolished, along with a modest cut in fuel tax. Two options would be available for car owners, in both cases all of the revenue collected would be dedicated to the new state transport infrastructure company[78]:

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[73] Source: HSL Helsinki Region Transport Annual Report 2015.
[74] http://inrix.com/scorecard/#
[75] Summary available at http://www.epomm.eu/newsletter/v2/content/2015/0415/doc/RUMA_I_summary.pdf
[76] https://www.hsl.fi/sites/default/files/uploads/ajoneuvoliikenteen_hinnoitteluselvitys_2016_en.pdf
[77] https://www.lvm.fi/documents/20181/937315/5-2017+Transport+network+development+%E2%80%93+The+transport+network+company.pdf/4694fe9e-d286-4184-8aab-3a77fe104867
[78] https://www.lvm.fi/documents/20181/937315/7-2017+Transport+network+development+%E2%80%93+Customer+fees+for+motorists.pdf/62642834-d644-479a-99f2-3324248f315b

The users could choose between a flat-rate customer fee (for example a monthly or an annual fee) or, in a later phase, billing based on driving distances offered by a service operator. Vehicle tracking would not be required for flat-rate billing.

To enable per-kilometre rates, the vehicle would have to be tracked to know whether it is driving on a road maintained by the company or a municipal/private road. Even in that case, the monitoring would focus on the vehicle and the driving distances rather than tracking a certain person.

The citizens' protection of privacy would be safeguarded. A tracking system would only be deployed if the devices used were secure and the protection of privacy could be ensured.

Those who choose to pay by actual distance would be expected to install a GNSS on-board unit.

2.4.6.6. Policy suspended

Following the announcement of the policy, opposition emerged from several sources. A major concern was that the elimination of the car tax and vehicle registration fees, and modest reduction in fuel tax, was primarily regressive in impact. Those seen as benefiting the most would be the wealthy, because they more frequently buy new cars (and so pay car tax), whereas those buying second hand cars in Finland do not pay that tax. There was also criticism that it was going to be too costly to equip all vehicles with GNSS OBUs and that heavy vehicles were excluded.[79] The Finnish government is now reconsidering how to progress national transport funding and charging reform.

2.4.6.7. Lessons for Auckland

In Finland, a possible programme for Helsinki congestion pricing was suspended in favour of a reform of national road charging, but primarily for infrastructure funding purposes. Because that reform was handled poorly (primarily because the package of offsetting tax cuts were seen as unfair), progress on implementing national road pricing, and Helsinki congestion pricing have both been suspended. Reverting to a national reform programme means delaying and deferring the introduction of congestion pricing.

Finland also failed to convince road users of the benefits of replacing existing taxes to fund a new transport infrastructure company. Finland's policy objectives and priorities changed several times over several years, so that when the new policy was announced, the media and the public appeared unclear over the objectives of the scheme. The urgency of clear, consistent and simple communications as to why a road pricing proposal is being advanced and the benefits to those participating remains a common lesson across many schemes internationally.

[79] The Government could not, under EU law, reduce fixed charges on heavy vehicles sufficiently to offset heavy vehicle charges.

2.5. Pilot programme

2.5.1. Portland, Oregon

2.5.1.1. Pilot zone maps

Figure 26 - Oregon Road User Fee Pilot Program Portland pricing zones

2.5.1.2. Pilot concept

Type of scheme	Full network charge based on distance, time of day and location
Vehicles charged	Cars only
Charging times	24/7, with peak charges
Charging technology	GNSS based on board units
Use of net revenues	State Constitution requires all such revenues collected to be used on roads
Range of charge rates	Option 1: NZ$0.01/km for all distance travelled in Oregon at all times Option 2: NZ$0.086/km peak in Portland only, NZ$0.043/km off peak in Portland and at all times elsewhere in Oregon.

2.5.1.3. Background and relevance

Oregon has not introduced a congestion pricing scheme, but operated a pilot of distance based road charging for light vehicles in 2006/2007 that included a subset paying a simulated distance based congestion charge for driving in Portland during peak hours by distance (with an offsetting lower off peak price and credits for fuel tax). The purposes of the pilot were to:

- Demonstrate the concept of charging users by distance paid at fuelling stations in exchange for refunds of gas tax was technically and administrative feasible; and

- Demonstrate the feasibility of such a system for collecting congestion charges.

2.5.1.4. Description of scheme

299 volunteers chose to have a GNSS OBU installed in their cars and the pilot started April 2006. For the first two months, volunteers operated as a control, and from June 2006 all were charged NZ$0.01/km paid at filling stations in exchange for a refund of gas tax. From September 2006, one third of volunteers chose to pay the congestion pricing option whereby they would pay NZ$0.086/km to drive distance in metropolitan Portland between 0700-0900 and 1600-1800 weekdays, but NZ$0.004/km for any other distance driven in Portland (or elsewhere in Oregon). In effect, volunteers chose either to pay a flat distance charge regardless of time of day or location (in Oregon), or to pay a higher charge in Portland at peak times, but a lower charge for all other distance travelled in the state.

The pilot cost NZ$4.1m (including four years of development and preparation, one year of operation and a subsequent evaluation period). Full details of the pilot have been published by the Oregon Department of Transportation.[80]

2.5.1.5. Outcome

The pilot demonstrated the technical and administrative feasibility of implementing distance based road pricing, which would be paid at the pump with corresponding refunds of fuel tax, and the technical feasibility of charging difference varying location by zone using GPS technology. The pilot was established at a relatively low cost and included measures to protect privacy (with 82% of volunteers having "no concern" over privacy, although to some extent volunteering to participate in a pilot involving GPS technology involves an element of self-selecting).

What was most significant and relevant to Auckland is that volunteers who chose to switch to the congestion pricing option reduced their peak period distance travelled by an average of 22%, compared to their previous usage (2.4km on average).[81] Although none experienced the benefits of congestion pricing (because congestion cannot be reduced for a small sample of road users in a pilot), it showed the potential effectiveness of congestion pricing, *by distance,* and time of day.

The pilot also showed the value of holding such a demonstration to build public acceptability. 93% of volunteers expressed satisfaction at how the trial functioned and their experience of the charging system.

The programme ultimately saw Oregon implement a subsequent pilot for car owners to opt into paying by distance in exchange for fuel tax credits, which operates today with around 1000 users (OReGO).[82]

[80] Oregon's Mileage Fee Concept and Road User Fee Pilot Program - Final Report, November 2007, Oregon Department of Transportation. Available at http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf
[81] Those within "four block" of public transport reduced their distance driven on average by another 1.2km per day.
[82] http://www.myorego.org/about/

However, it was decided to not proceed further with congestion pricing, because the policy priority was to implement a system to replace fuel tax as a means of raising revenue to pay for road infrastructure. Inclusion of congestion pricing at this stage was seen to be a competing (and more controversial) objective that could undermine a policy of revenue replacement. [83]

2.5.1.6. Lessons for Auckland

Operating a trial or pilot does not, *in itself*, mean that public acceptability issues can be addressed. The Oregon pilot was predominantly focused on developing a new way of raising revenue to fund roads on a statewide basis. The congestion management element was secondary and did not proceed because it was easier to gain political and public acceptability for providing an *option* for how to pay the roads based on a flat distance charge, than to also incorporate a congestion pricing element. For Auckland, Oregon is an example of how to operate such a demonstration or pilot, but does not offer any compelling lessons in how to implement a congestion pricing programme. However, the behaviour change response from the pilot is of minor interest suggesting that if offered a choice of peak and off-peak charging.

[83] A subsequent study was undertaken on congestion pricing in Portland that resulted in the implementation of a parking management pilot project.

3. Review of previous reports on road pricing in Auckland

- Previous core findings that road pricing could significantly reduce congestion and raise revenue in Auckland remain sound.
- Technology options have widened, and capital and operating costs have reduced for all options.
- Net benefits to road users after paying charges are negative in all options evaluated to date, but this does not take into account the use of revenues or the diverse values of time of different road users.
- Large cordon and area charge options have considerable economic and social impacts associated with the location of the boundaries. Almost all international schemes have much smaller cordon or area zones.
- Motorway only charges have not been applied elsewhere and modelling indicates considerable negative impacts on the local road network (i.e. parallel corridors). Their utility may be limited to targeting congestion on specific roads.
- A small CBD cordon or area charge could be a low-risk and publicly acceptable first step given the findings of ATAP, but this would not have a significant impact on congestion across Auckland.

3.1. Summary of reports

Four major reports were commissioned over the past 15 years to review the merits and options for road pricing in Auckland:

2006: The Auckland Road Pricing Evaluation Study (ARPES) was commissioned by the Ministry of Transport, following from the 2004 Auckland Joint Officials Group on transport in Auckland. It considered, in some detail, five options to manage congestion and raise revenue for transport purposes. Based on international experience, technology and costs at the time it concluded that there could be considerable merits in introducing road pricing for both purposes. However, both modelling results and the public consultation process identified shortcomings to all the options, particularly around either local economic and social impacts, or traffic impacts. A key concern for all options was the impact on access in the absence of suitable alternatives.

2008: The Auckland Road Pricing Study (ARPS), also commissioned by the Ministry of Transport, followed on from ARPES and reported in 2008. It delivered a more detailed evaluation on a short list of two options (one identified as a "congestion" scheme, one as a "revenue" scheme") set forth in ARPES. This study included assessment of public consultation on ARPES and sought to respond to issues raised during that consultation process.

2014: The Future Auckland Transport Funding (FATF) report commissioned by Auckland Council and reported in 2014. It focused on options to raise additional revenue for transport in Auckland, comparing increasing rates and fuel tax to a motorway only charge. The analysis concentrated on appraising the impacts of funding options on transport investment and the consequential benefits from those improvements, with demand impacts of a second order.

2016: The Auckland Transport Alignment Project (ATAP) report was jointly commissioned by central and local government and reported in 2016. It considered pricing within the context of wider strategic measures to manage the growth of transport demand in Auckland. It recommended that steps be taking to implement "smarter transport pricing" over the following ten years. It noted that a whole of network pricing system would offer the greatest potential to improve conditions on the road network and give better price signals as to future investment. It also enables pricing to minimise distortions at charging boundaries or points, such as diversion of traffic.

3.2. Review of ARPES

ARPES was the most comprehensive and thorough of the four studies that have been reviewed. This section reviews the objectives, evaluation framework, and results of ARPES and their applicability to current conditions.

3.2.1. Objectives of ARPES

ARPES considered how road pricing could contribute to achieving objectives around reducing congestion and generating revenue for future capital and operating spending for transport in Auckland. It sought to establish[84]:

- How much various proposed schemes would reduce congestion at peak times;
- What the positive and negative social, economic and environmental impacts of the schemes would be, and the extent to which the negative impacts could be mitigated;
- Whether there is a financial business case for each of the schemes, and assuming there is, how much net revenue might be generated over time;
- Whether the schemes would be technically feasible to implement;
- Whether the schemes would be acceptable to the public; and
- Whether the schemes would be consistent with central and regional government policies and development strategies.

These objectives remain broadly sound, although an additional element that should be considered in future studies of road charging schemes is the scalability and flexibility of any scheme options. As demonstrated in Singapore and Stockholm (and attempted in London), schemes may be implemented on a limited basis and later expanded in geographical scope and time of operation, and more granular variations in pricing based on vehicle type, time of day and location may be introduced. Options that are more scalable and flexible allow greater scope for adjustment to reflect changing conditions, to refine performance, or to reduce negative impacts, whereas other options may be seen as "dead ends" in policy terms. For example, a cordon scheme that allows for different charges at each crossing point may offer greater flexibility than an area charge.

3.2.2. Evaluation framework of ARPES

The ARPES evaluation framework, depicted in Figure 27 below, sought to consider the social, economic and environmental impacts of scheme options across a number of metrics.

Social impacts:

- Non-financial social cost of congestion, which in theory should be reduced by any charging option;

[84] ARPES Executive Summary, paragraph 11, pg.2.

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- Impact on total number of trips taken (i.e. is access to employment and education adversely affected); and
- Direct financial impacts of charging on households, with distribution by location, demographics, and household type.

Economic impact:

- Benefit/cost assessment based on travel time savings and monetary costs to users, with a further iteration based on the financial costs of scheme implementation and operation, costs to mitigate negative impacts and benefits of such mitigation;
- Impacts on business trips, in terms of both number of trips and costs; and
- Wider economic impacts (partially dependent on what is done with any net revenues).

1. Social, economic and environmental impact assessment

(including equity and efficiency dimensions)

2. Evaluate scheme against NZTS objectives:

- Assisting economic development
- Assisting safety and personal security
- Improving access and mobility
- Protecting and promoting public health
- Ensuring environmental sustainability

3. Identify and assess:

- revenue potential
- demand management
- social distributional effects
- consistency with Akld Regional Policy Statement land-use policies
- privacy issues
- technical feasibility/ implementation issues (including establishment and operating costs, enforcement)
- administrative simplicity
- public acceptability
- legislative implications

4. Identify and assess mitigation proposals

(e.g. additional public transport services, discounts/exemptions from potential charges)

5. Re-assess 1-3 in light of mitigation proposals

Figure 27 - Auckland Road Pricing Evaluation Framework

Environmental impact:

- Reductions in VKT, which are assumed to imply reductions in average discharges of emissions and runoff from roads;
- Reductions in particulate matter; and
- Changes in local road amenity from reduced traffic.

3.2.3. Review of evaluation framework and methodologies

ARPES sought to use the travel time savings of the scheme options as an input to BCR using the standard NZTA Economic Evaluation Model approach. The economic evaluation was based on transport impacts derived from modelling traffic with the Auckland Regional Transport (ART) model. This report does not contain a comprehensive peer review of the economic evaluation (which was carried out separately by NZIER in association with ARPES), but a number of points are worthy of note in considering the overall net benefits of urban road pricing to reduce congestion. Further details of our assessment of the economic analysis are contained in Appendix T by Ian Wallis Associates.

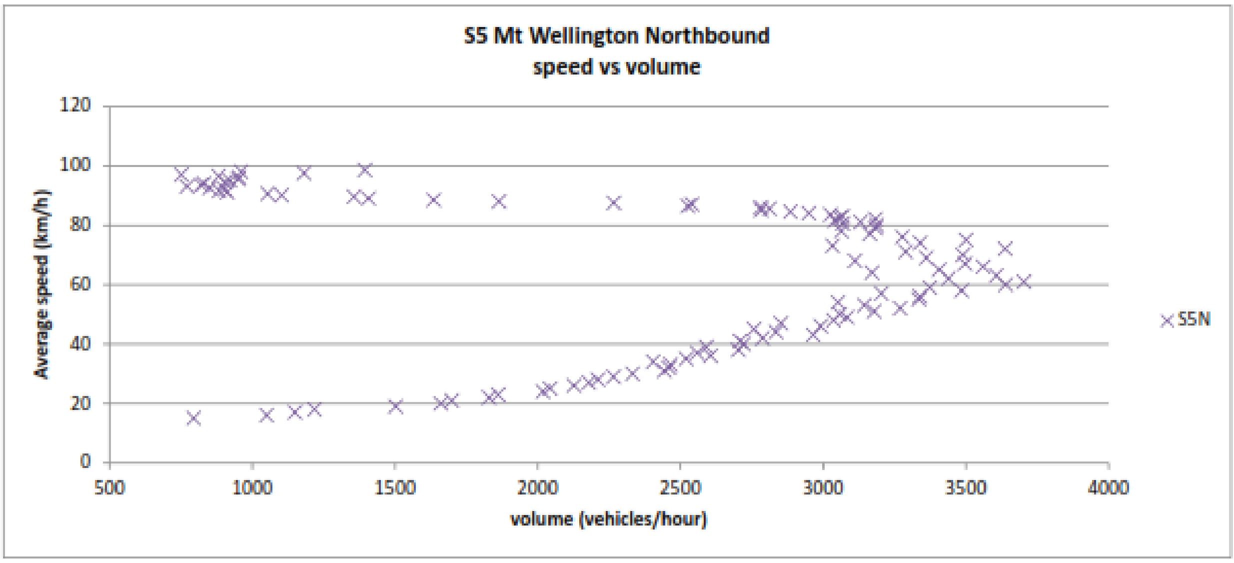
The modelling undertaken had several limitations, some of which may be addressed with current and forthcoming updates to the modelling suite.

1. Lack of segmentation of road users: Car users are treated as a single group, whereas they are likely to have a wide range of values of time, dependent on income and trip purpose. Those with a higher value of time gain greater benefits from congestion reduction (and have a higher willingness to pay for travel time savings). Conversely, those who are less willing or able to pay may be more willing to mode shift or time shift, but also may be more vulnerable to seeing their ability to access activities such as employment and education restricted by charging. Identification of the geographies and trip patterns particularly affected would enable mitigation measures to be better targeted. In aggregate terms, if the demand responses (and the value of benefits) of car users better reflected a segmentation of those users, the benefits calculated when modelling the ARPES options would increase, and the economic impact of road pricing options would improve. It is understood that the refresh of the ART model will incorporate such improvements, which would better enable it to identify the net benefits of road pricing options.

2. Limitations of ability to identify hyper-congestion on the network: At times of peak congestion, the numbers of vehicles passing an individual point may reduce considerably below capacity. This is best highlighted in the speed flow curve seen in Figure 28. The effect of this on the evaluation is that a strategic model may not be able to identify locations where charging may result in increased traffic count numbers *because easing congestion increases throughput* (so traffic count figures increase). This may indicate that the benefits of pricing are underestimated when relieving parts of the network that are severely congested. This cannot be addressed at the strategic modelling level, but for the purposes of further evaluation of a preferred option (and refining pricing) it might be addressed by modelling demand impacts on individual road links.

3. Underestimation of benefits of major infrastructure projects: There is some evidence that the benefits identified by ART models for major projects are significantly lower than those calculated by localised traffic models for such projects. This impact, which has not been clearly assessed, may also mean that the benefits identified in ARPES could have been underestimated.

Figure 4.6 Average speed vs flow – Southern motorway



Source: Consultant analysis/NZ Transport Agency

Figure 28 - Depiction of capacity/speed flow relationship

The evaluation of economic impacts is also limited by its ability to identify exactly what behavioural responses mean for users. Modelling can identify reductions in the number of trips by car and increases in trips by other modes, and assumptions can be made that this represents modal shift. However, it cannot identify what happens when a reduction in car trips is *not* offset by increases in trips by other modes, or what trips have been priced off. This is a particularly difficulty, as it relies on models inferring preferences around willingness to pay to drive vs. public transport, vs. travel time (and other inputs into trip decision making) as well as the value of the trip to the road user. More importantly, longer term decisions about housing, employment and discretionary trip patterns, which are informed by factors such as travel times and the costs of travel options, are much more difficult to evaluate. Evidence provided in the interview with Stockholm indicated that the initial impact of introducing pricing was that a proportion of road users perceived that the trip by car was no longer worth undertaking for the price imposed on it, but that the impact of *subsequently* increasing prices (or introducing them on a related corridor) was lower than modelled.

Experience in the UK with modelling economic impacts of congestion charging in Manchester indicated that the main beneficiaries of a peak time congestion charging scheme would be business users of the road network (such as freight, commercial vehicle traffic including traded services, business trips by car and employment). Those users, in aggregate, were modelled as gaining more in travel time savings than they would pay in charges. By contrast, non-business trips (leisure, those accessing health, education and other purposes) paid more than they gained in benefits.

The ARPES evaluation of impacts on business appears at least questionable in this context.[85] In several instances, the scheme options all appear to *increase* trip times for business, which is counter-intuitive given the overall impacts, are to reduce trip times. Figure 29 below illustrates this, as it appears that business trips experience increased trip times as well as road charges. It is not clear why this is the case.

[85] See Table 10, Executive Summary, ARPES.

- The increase in average ***trip costs*** (including the charges) varies considerably. The Single Cordon and Double Cordon scheme increases are 5.5% and 7.4% respectively, while the Strategic Network Charging scheme increase is higher at 7.8%. However, the Area charge results in an increase of 18.3%, driven partly by the incidence of road charges, and partly by the increase in trip time.

Figure 29 - Extract from ARPES on business impacts

The Area Charge scheme is earlier noted as *reducing* VKT on congested roads from 20% of all trips to 14%. With the exception of the Strategic Network option (which increases net congestion by shifting traffic onto the local network), all options reduce average travel times. Given that transport network result, the assessment of business impacts in ARPES would appear to underestimate the benefits for business. Given growth in traffic and GDP since ARPES, it is likely that the net economic impacts of road pricing for business in Auckland, assuming pricing significantly improves the performance of the network, would be positive. As noted by NZIER[86], the evaluation does not consider the impacts of trip reliability, which tends to be valued highly by business, particularly in the transport and services sectors. As a key element in building public acceptability for road pricing will come from the economic impacts on business, it is important to provide robust evidence on the range and scale of those impacts. ARPES falls short in doing this.

Wider economic benefits are generally not reflected in ARPES. A key policy driver for proposals for congestion charging in Manchester was to increase the available labour market for employers, both by reducing travel times (so increasing the number of households that were within commuting times that potential employees would see as reasonable) and by using net revenues to enhance access by other modes. Increasing the available labour market gives both employers and employees more choices for available labour and employment opportunities respectively. Significant reductions in congestion may enable greater productivity for individual businesses (e.g. a plumber may be able to operate across a wider area if travel times are sufficiently reduced) as well as increase competition, reducing costs to consumers and opportunities for the most productive businesses. Again, this benefit is not included in the ARPES evaluation.

On social impacts, ARPES indicates a negative view, primarily based on treating road pricing as an imposition of cost that is not offset by sufficient benefits. In the absence of any consideration of the use of net revenues, this remains a valid concern. However, it is problematic to look at road pricing impacts in isolation from the use of net revenue collected from road users. If revenues are used to benefit those paying by some other means (either by road improvements or offsetting reductions in other taxes they may pay), it is more likely that the net benefits will be greater than the costs. NZIER also noted that road pricing is perceived in ARPES to be regressive, in that those paying (or priced off the network) are those with the lowest value of time and lowest incomes. This assumption is not supported (or contradicted) by any evidence included in the study. As NZIER suggests, it could be that road pricing could particularly impact those on higher incomes (and the design of the scheme would contribute to this), and that benefits could also accrue to those on lower incomes that do not pay (e.g. bus users that experience reduced travel times). ARPES did not explore extensively the distributional impacts, so evaluation of any future scheme options should consider the incidence of road pricing costs and benefits by user group, income and geography.

[86] ARPES Peer Review, Final Report to Ministry of Transport, May 2006.

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Given these limitations it is clear that the social impact analysis is unnecessarily negative and presumptive, and that any future analysis should focus on the critical elements of social impact such as:

- Is a scheme going to introduce a barrier to accessing employment for those on low incomes?
- Is a scheme going to benefit those on lower incomes, due to impacts on the transport network that benefit them?
- What are the distributional impacts of the costs congestion and trip reliability? This includes the wider economic impacts of congestion on employment and housing choices for those on lower incomes.
- How can the use of net revenues be used to improve overall access to employment and education for those impacted by a pricing scheme? Could net revenues be used to reduce other costs of car ownership and usage at other times?

The environmental impacts of road pricing are assumed to be a function of VKT, with all options except the Strategic Network charge (because of the increased congestion on the local road network) seen as delivering benefits from reduced emissions because of reduced levels of traffic. Further improvements may be seen to result from more efficient traffic flow reducing overall fuel consumption and resulting emissions. Since ARPES, through the regular turnover of the vehicle fleet, noxious emissions per vehicle are likely to have decreased slightly. As vehicle efficiency continues to grow, and especially as the numbers of low emission vehicles (e.g. hybrids and electric vehicles) increase, the environmental benefits can be expected to reduce over time.

The evaluation of the charging options against NZTS objectives is not specifically applicable under current policy settings. However, the qualitative assessment of improving access and mobility is at least questionable as it appears to be primarily based on increasing total numbers of passenger transport trips with no mention of a reduction in private car trips or reconciliation of the latter with the former. It is possible that access is *reduced* if the price to travel is increased beyond that which is acceptable to the road user and no reasonable alternative is available (because the alternative is too expensive in terms of price or travel time penalty). Careful scheme design and evolution of scheme development, including the use of net revenues, may address such issues.

3.2.4. Mitigations

A number of mitigation measures were outlined in ARPES, namely:

- The application of discounts and exemptions;
- Public transport improvements (particularly increased frequencies, new routes and demand responsive services);
- Road improvements;
- Traffic management measures;
- Active mode infrastructure improvements; and
- Transfer payments to specific categories of users.

The applicability of discounts and exemptions seems reasonable, although the claim that commercial vehicles contribute "roughly equal" to congestion appears incorrect if counting heavy vehicles. Both the proportion of road space occupied and the acceleration rates of heavy vehicles indicate (as reflected in Singapore's scheme) that they create 2 to 3 times the per VKT congestion costs of light vehicles. Transport related mitigation measures should be designed to reflect the scheme option, which appears to have been done at a high level in ARPES. The identification of groups for specific transfer payments (e.g. disabled, health appointments and those in transition to work) should be undertaken with particular care.

3.2.5. ARPES option identification and analysis

ARPES considered five scheme options in detail and rejected two options for consideration at that time. It establishes taxonomy between road pricing schemes that charge either for:

1. Travel into, across or within a defined area; or

2. Travel on specific roads.

Both of these categories involve charging for crossing a specific point, rather than charging for the use of roads more generally.

ARPES rejected two options for detailed appraisal:

- Toll lanes; and
- Full network pricing.

Review of the five scheme options as well as the two rejected options is described in detail in Appendix A

3.2.6. ARPES findings and key conclusions

Although Auckland has grown considerably since ARPES, the findings around the options considered remain largely valid. The key change since 2006 is that the cost of implementing such systems is likely to have declined. ARPES recommended installing both DSRC (tag and beacon) and ANPR systems for all of the options considered (excluding the parking levy), but ANPR technology is now sufficiently advanced as to call into question the need for DSRC at all. New Zealand and the UK have both successfully introduced toll roads with very high levels of accuracy in identifying number plates using ANPR alone. This should result in lower capital costs for on-road infrastructure, and no need to distribute or manage an inventory of vehicle tags. ARPES did not consider if any options could be scalable or enable future expansion of charging beyond the schemes considered, whereas there may be merits in taking a staged approach as has applied in Singapore, by adding charging locations over time.

None of the schemes evaluated in detail are without significant negative impacts. Either they create serious boundary effects (the single and double cordon proposals in particular) or they worsen congestion by diverting traffic (strategic network charge). Cordons can reduce congestion, but only that generated by vehicles crossing the boundary. Because they do not charge those moving within them, they do not capture many vehicles that contribute to congestion. Elsewhere, successful cordons have been small enough that most of the traffic circulating within the cordon is likely to have crossed it as well, and sufficiently small to minimise boundary effects.

The area charge option would have merit for an area where congestion is spread evenly across the zone, but the proposed area in ARPES does not appear to have that characteristic, and would capture traffic movements within residential areas, which may raise different concerns around charging uncongested trips.

The Strategic Network charge option is likely to worsen congestion on local roads, a situation that could only be addressed by either charging those roads (making it closer to a full network charge), expanding capacity on those roads, or having minimal charges on the motorways (undermining their effectiveness in reducing congestion on the motorways).

The full network pricing option was ruled out in ARPES because, at the time, it was seen as technologically too risky. This is now less of a consideration, and future experience in GNSS road pricing is likely to further reduce the risks involved. Full network pricing could significantly reduce congestion in Auckland, have a major impact on travel time reliability and encourage modal shift. At present, however, only Singapore is actively moving to implement such a system to manage congestion, and it has been operating some form of urban congestion charging since 1975. The implementation of such a solution would take time and be at considerable cost.

3.3. Review of ARPS

ARPS was a follow-up study from ARPES intended to address concerns raised by public consultation in ARPES by better assessing the economic, social and environmental consequences of two specific options selected from ARPES. These concerns included the viability of public transport as an alternative for those subjected to road pricing, the impacts of road pricing on commercial and retail areas and the impacts on low income households. One of the options given further review was primarily focused on reducing congestion and the other on raising revenue through road pricing.

3.3.1. Objectives of ARPS

ARPS sought to refine the work undertaken in ARPES by taking two schemes and undertaking deeper analysis of them. For each scheme, it looked at transport network impacts, household impacts, economic impacts, environmental impacts, land use and equity impacts. The core purpose of the work was to determine if either scheme could be designed with sufficient mitigation provided to address the major concerns of the public and stakeholders about introducing road pricing in Auckland. A detailed review of the two schemes is contained in Appendix B. A review of the economic analysis in the report is contained in Appendix T.

3.3.2. Evaluation tools

The main elements of analysis for ARPS were:

- Effectiveness in addressing the core objective (e.g. congestion reduction) as measured by car trips generated, percentage of the network that is defined as congested, average network speeds and mode shares;
- Performance against wider NZTS objectives; and
- Ability to address issues raised in consultation (e.g. alternatives, equity, affordability, impacts on businesses and retail).

3.3.3. Conclusions from ARPS

The methodology used to select the ARPS options appears to be largely based on finding options where those subject to the charge would be best able to find public transport alternatives. For the purposes of finding an *initial* charging scheme in Auckland, that appears generally sound. Nevertheless, it is important to note than in a metropolitan area such as Auckland, it is unlikely to be economically viable or practical to provide all users of the road network with public transport alternatives for all trips.

ARPS gave little indication that road users would change travel by *time of day* under the congestion reduction scheme. It found that 8-14% of households affected would change mode, 2-5% would change the number of trips undertaken and 8-13% would pay, but there was little indication that any might change travel time (a factor difficult to model, but a likely consequence given experience elsewhere).

The ARPS "congestion scheme" option indicated that an option could be designed at a location where many of the trips subject to a charge could reasonably transfer onto public transport. The denser the land use and level of activity, the easier it is to develop viable alternatives to private motoring to that area.

The analysis undertaken of business and household costs appears sound. This calculates that, for those paying, the benefits they gain from travel time savings are still lower on average than the cost to users of paying the charge. This remains an issue with a charging tool that is inherently blunt (as the analysis indicated that many would pay with very limited travel time savings and some that would not pay also obtain benefits from reduced congestion on routes approaching the scheme location).

Furthermore, although an area charge may have a significant *initial* impact on congestion, charging a vehicle *once* regardless of *how far* or *how frequently* it is used within the charging area has severe limitations. For example, if taxis were to be charged, they would be more likely to absorb the cost of operating during peak hours among multiple trips. Experience in London suggests that although the area charge may have had a significant initial impact, growth in demand means that unless the charge is increased significantly over time, congestion benefits are not sustained, as any that do pay to drive in the area have no incentive to limit vehicle use, and do not adequately face the costs they impose upon other road users from that use.

It therefore appears that the congestion reduction scheme from ARPS has considerable limitations, in terms of flexibility, equity and in scalability to enable charging to be refined further over time. Although it would certainly have a valuable impact on congestion upon introduction, it may face barriers in public acceptability because it is relatively blunt. In particular, the effects upon those undertaking trips that commence or terminate not far within the southern boundary of the charging area may be perceived as excessive. Incorporating predominantly residential areas within a charging zone may be seen as necessary to capture a higher proportion of congestion, but it also risks calls for residents' discounts (a 90% residents' discount applies in London) or exemptions, which would undermine the effectiveness and equity of the scheme.

3.4. Review of FATF

The FATF report was focused on assessing options to raise revenue to fund the Auckland Plan Transport Network. Much of the analysis in FATF focused on the impacts not of charging in itself, but of increased supply of roads and public transport funded by revenue from charging.

One option considered was to increase rates and fuel tax, which is not considered further in this report. The other option was a motorway-only charge assessed at a level designed to generate revenue, whilst minimising diversion onto parallel local roads. An underlying assumption was that for most motorists a modest motorway charge was worth the travel time savings, so they would not divert to parallel routes.

3.4.1. Objectives

The purpose of FATF was to provide an evidence base to justify additional capital and operating expenditure on transport in Auckland, and possible options to address the funding shortfall between that spending and the status quo. It did not seek to investigate charging as a tool to manage congestion, although the analysis noted that in association with raising revenue, it could also have a positive impact on congestion and modal choices for transport users in Auckland. In effect, the road pricing schemes in this report were designed as taxation options first and transport management tools second.

3.4.2. Evaluation tools

The report indicated that detailed assessment of "economic, social and affordability impacts" was a "critical element" in decision making. It considered the scale and extent to which households would pay the new charge, with some assessment of what proportion of lower income households would pay. On economic assessment, the report developed benefit cost ratios of the revenue raising options *including* the benefits from the proposed spending on transport network improvements, blurring the distinction between the economic benefits of the transport spending and the revenue raising options. This is different from the approaches used by other reports (and used internationally for appraisal of other schemes).

3.4.3. Identification of charging options

Several options considered in earlier reports were ruled out from the beginning, including the use of toll lanes, a double cordon, parking levies, an area charge (as in ARPS) and full network charging. The report does not make clear why these other options were rejected, but it appears likely to be due to higher implementation costs (i.e. due to the number of charging points) or lower revenue generation potential (as with toll lanes).

Two cordon schemes and two variations on motorway charging were considered initially. The two cordons considered were:

- Single Cordon scheme from ARPES; and
- the inner cordon only of the double cordon scheme from ARPES.

In addition, two variations of a "motorway user charge" were considered:

- A distance-based charge; and
- A motorway access charge, which would charge a flat rate each time a motorist accessed the motorway network.

Both cordons were ruled out of further consideration. The inner cordon was seen as raising concerns of "community impacts, complexity and fairness"[87]. The key issues were related to boundary effects of the cordon location and the fairness of charging only those crossing the cordon but not those travelling from within it to the CBD. The outer cordon was seen to have less community impact (although the scale of this is not clear), but because it would clearly place a boundary between much employment in the Southdown, Penrose and Mt. Wellington area and lower income households in South Auckland, it was seen as placing a burden on those who had fewer alternatives and a lower ability to pay.

The two variations of motorway user charges that were considered in FATF had a much greater geographical scope than the Strategic Network scheme proposed in the ARPES. A distance based charge option was rejected as "complex" and "unfair"[88]. The motorway access charge option, which was intended to operate from 0600-2000 weekdays and 0600-1900 on weekends and public holidays, was carried forward for further analysis.

[87] p 30, Funding Auckland's Transport Future, two pathways, alternative funding for transport, 2014.
[88] p 31, Funding Auckland's Transport Future, two pathways, alternative funding for transport, 2014.

A detailed review of the motorway user charge option is contained in Appendix A.

3.4.4. Conclusions from FATF

Fundamentally, the analysis in FATF is focused not on options to address congestion, but on charging options with minimal administrative and operating costs to maximise revenue. The motorway user charge approach sets a flat fee for use of any part of the motorway network regardless of how congested it is (even with a peak option of higher charges, it has higher charges *across* the network). This does not target congestion and is likely to mean some parts of the network are more underutilised (as traffic diverts onto parallel roads that may be less safe and develop congestion issues), yet the busiest parts of the motorway network would see little sustainable improvement in congested conditions.

The report concludes that a motorway user charge would have net positive impacts on Auckland because it would encourage behaviour change that could reduce congestion and increase use of other transport modes. This contrasts with the conclusion of ARPES on the Strategic Network charge scheme, that a similar scheme would significantly worsen congestion on parallel local roads. The FATF scheme mitigates this effect by charging substantially less, and only charging for each time a vehicle accesses the motorway network. That may not reflect how much of the motorway network it uses, and thus creates an equity issue in itself.

From a wider strategic perspective, promoting a motorway user charge primarily to raise revenue is likely to have greater challenges for public acceptability than any form of road pricing designed to reduce congestion. It is likely to have the same level of resistance as other forms of new or increased taxation, with similar debates about the incidence of such taxes. If the intention is to introduce road pricing in Auckland to address congestion, the risk is that previous reports advancing road pricing purely to make money from road users will blur those objectives.

3.5. Review of ATAP Demand Management Report

The ATAP process was intended to bring both central and local government together on a set of priorities for spending and management of transport in Auckland over the next thirty years. It prioritised three key strategic objectives:

- Make better use of existing networks;
- Target investment to the most significant challenges; and
- Maximise new opportunities to influence travel demand.

Road pricing falls under the third of these objectives, but is also relevant in encouraging the first and helping inform the second. One of the recommendations of ATAP was "[E]arly establishment of a dedicated project to progress smarter transport pricing, with a view to implementation within the next 10 years"[89].

3.5.1. Objectives

The core policy objectives for ATAP were to:

- Support economic growth and increased productivity by improving access to employment/labour;

[89] cite

- Improve congestion results, particularly travel time and reliability in the peak period and ensure congestion does not become widespread during working hours;
- Improve public transport mode share, where it will address congestion; and
- Ensure any increases in financial costs of using the transport system deliver net benefits to users.

To achieve those objectives it examined two major options, one to increase supply, the other to make better use of existing capacity through technology and pricing.

3.5.2. Identification of charging options

The ATAP Demand Management Pricing Report developed options based on the following factors:

- desire that schemes should improve the operation of the transport network through managing demand, rather than maximising revenue;
- desire to incentivise a change of time/mode of travel rather than removing trips;
- the need to keep schemes relatively simple at early stages of investigation; and
- the need for an assessment of schemes which covers a broad range of scenarios including:
    - small to large geographical/network coverage, and
    - with and without good public transport alternatives.

Three options emerged as meriting further analysis:

- A CBD only cordon, much more tightly concentrated around the Auckland CBD compared to options considered in ARPES. It notably does not include charging through traffic on the motorways;
- A motorway only charge, focused on reducing congestion by charging by trip, not distance; and
- Full network pricing based on charging by distance, varying by time of day. Charges under this scheme would be offset partly by removal of light RUC and fuel excise duty.

The purpose of considering these options was to enable a comparison between significantly different options. The selection of these three options seems fair given that:

- A CBD only cordon had not been subject to significant evaluation before and seems to have fewer negative characteristics compared to the larger cordons examined previously (but has a lower impact);
- There has been considerable debate about motorway charging as an option, largely led by Auckland local government; and
- Full network pricing had been ruled out in previous studies, but the enabling technology is now technically viable and the likely benefits (and ability to minimise negative impacts) make it theoretically compelling.

3.5.3. Evaluation Methodology

All three options were considered according to how they would affect:

- Access to employment and labour by car within a 30 minute trip in the AM peak (and by 45 minutes by public transport);
- Proportion of travel time in severe congestion in the AM peak and interpeak;
- Proportion of freight travel time in severe congestion in the AM peak and interpeak;
- Average vehicle occupancy;
- Proportion of total AM peak trips made by public transport;
- Proportion of vehicular trips over 9km made by public transport in the AM peak;
- Increase in financial cost per trip compared to travel time and vehicle operating cost savings (excluding use of revenue); and
- Value for money (including value of revenue).

The three charging options from ATAP are reviewed in more detail in Appendix A.

3.5.4. Conclusions from ATAP

ATAP appears to offer two options for future Auckland road pricing, both of which could appear on a timeline for development of pricing. A CBD-only cordon appears to be a useful first step that would achieve reductions in congestion for the CBD by encouraging modal shift, and prove the concept to road users as being easy to use and effective. However, it may also be seen as step towards much wider network pricing, which is identified for the first time as having the potential to make a step change difference in the performance of the transport network in Auckland. A further review of the ATAP analysis is contained in Appendix T.

3.6. Key changes since the reports were produced

Since these reports were published Auckland has continued to grow, as has transport demand and the public transport and roads networks. In respect to road pricing, advances in technological capability, refinements to modelling tools, and additional global experience give reason to reconsider some of the earlier findings, particularly in terms of cost and risk.

3.6.1. Advancements in GNSS

The key advancement has been the much more widespread application of GNSS-based technologies for road pricing internationally. In Europe, five countries now use such systems to charge heavy vehicles by distance and location.[90] In the United States, Oregon is operating a live pilot programme to charge light vehicles by distance and location (albeit on a small scale). Other US states (most recently California) have held trials of a range of technologies to charge by distance. In New Zealand, the Road User Charge system has been updated by allowing for certified service providers to offer technology-based options to measure

[90] Germany, Slovakia, Hungary, Belgium and Russia. Switzerland is arguably a sixth country, but the GNSS element is still a backup to the core tachograph based system.

road use. As a result a growing percentage of heavy vehicles now pay RUC using electronic distance recording with a GNSS component (albeit on a prepaid and distance, not location and time-of-day basis).

The prevalence of such technology for charging has considerably lowered the costs involved. The latest units now cost around NZ$180 and can be installed by vehicle owners themselves. Its use for urban road charging remains confined to heavy vehicles to date, with the most sophisticated application being in Belgium, where heavy vehicles are charged for using all roads in Brussels, but with a lower price for the use of motorways compared to other streets. Singapore is applying GNSS technology for the next evolution of its Electronic Road Pricing system from 2020.

3.6.2. Advancements in ANPR

In 2006, the use of DSRC technology was widespread with free flow tolling and also applied for some urban road charging systems. Today, New Zealand has successfully deployed ANPR technology for free flow tolling on three State Highways, and the relative merits of DSRC compared to ANPR have reduced considerably. The main issue with ANPR in 2006 was that the reliability of number plate recognition systems as that time was around 85% at best. This meant staff had to manually inspect images of vehicles not identified. They would then be able to identify most of the remainder, but the chance of missing a vehicle was sufficiently high as to make ANPR alone insufficiently reliable for linking a series of chargeable events (e.g. passing multiple cordon points or charging points on a motorway).

These conditions have changed considerably, with ANPR now being reliably used on toll roads in New Zealand and the UK as the *sole* free flow charging technology for those roads, achieving levels of reliability in automatically reading number plates of above 95%. This means that ANPR alone may suffice for any charging system, without DSRC being needed for greater accuracy and reliability in identifying vehicles.

3.7. Summary conclusions from past reports

The analysis of previous reports indicates that cordon/area charges, whilst having some merit, are likely to have too many negative impacts to be applied outside the CBD in the first instance. A cordon around the Auckland CBD would have merit for more detailed investigation. It would not have a significant impact on region-wide congestion, but would have a worthwhile impact on congestion approaching the CBD and have minimal distortions or negative impacts on residents and businesses around its periphery. It could be implemented using ANPR technology, not require any in-vehicle equipment, and would be easy for users to understand.

The option of charging the motorways has been examined in three out of the four studies and, in terms of managing congestion, has been found wanting. It is likely to result in changes in route rather than travel times or mode, so that the local road network is likely to suffer from increased congestion, reducing amenity for local residents and businesses. A flat motorway user charge may usefully dissuade inefficient use of motorways for short trips, but is unlikely to promote modal shift for those who may better use public transport for longer trips. The only way that motorway charging's negative impacts could be mitigated whilst sustaining congestion improvements on the motorways would be to significantly increase capacity on the parallel local network. It is far from clear that this is desirable on a large scale across Auckland, given wider policy objectives expressed in the ATAP reports.

Full network pricing is clearly the option with the greatest potential to efficiently target congestion, but would require a longer lead time to introduce because of the need to test a system and deploy hundreds of thousands of OBUs across Auckland vehicles to be effective. It is likely to face much greater public resistance without a trial to prove that road pricing can effectively reduce congestion and not simply be used as a means to raise additional revenue. It is important that the first scheme that is implemented can demonstrate a reduction in congestion as well as providing options for road users to change behaviour (such as mode, time of day or route) to minimise charges and be scalable for expansion if successful. A CBD cordon and a CBD area charge would both meet those tests, as could targeted charging on key corridors, corridor based charges (motorways and parallel routes) may also do this.

Since the earlier ARPES and ARPS reports, the capabilities of ANPR technologies have improved considerably, rendering options to use DSRC technology (in addition to ANPR, which is needed for enforcement in any case) unlikely to be value for money. Consequently, the capital costs of introducing such a scheme should now be lower in real terms compared to the estimates in ARPES.

However, an alternative GNSS based option could be developed at a subsequent stage for regular users, to be charged by distance, which would vary according to the zone their vehicle is in, and the congestion levels of that road (some roads may have no charge) as a precursor to network charging. Such an approach would combine the provision of a low technology option for visitors (which is easy to understand), and a high technology option for regular users that allows for much more refined charging.

4. Technology options for pricing systems

- Since the ARPES and ARPS reports, ANPR technology has lowered in cost and become much more reliable. ANPR technology is already proven in New Zealand for tolling, and can be easily applied for point-based congestion pricing. ANPR is essential for any urban road pricing system for enforcement.
- Advances in ANPR reliability have rendered DSRC effectively obsolete for new urban road pricing systems.
- GNSS systems are technically feasible for full network road pricing, but not proven in operation for such a system charging by distance, time and location. Singapore will pioneer this application in an urban congestion pricing context from 2020, and London may follow.
- Development of a GNSS solution will take considerably more time and expense than an ANPR solution, because:
  - ANPR is required in any case for enforcement, and
  - GNSS would also require hundreds of thousands of on-board units to be supplied to road users, and managed.
- Smartphones do not provide an urban road pricing system solution in themselves, but can provide a user-friendly channel for payment and account management.
- Vehicle telematics are unlikely to provide an option for urban road pricing in New Zealand within the next ten years.
- ANPR technology offers the fastest deployment and lowest cost for a demonstration, pilot, and initial urban road pricing system.

4.1. Introduction

The purpose of this chapter is to review technologies used to identify and measure the chargeable events undertaken by vehicles in an urban road pricing scheme.

Technology is the enabler of an urban road pricing programme. Technology must be applied to achieve the policy, strategic objectives and specific goals established for a programme, but technology also sets the limitations on how these can be realised. A programme's strategic objectives should inform the overarching design and architecture of the entire project. The specific programme goals will outline the technological needs of the road charge system and help to identify the technology options that support them.

The technology used in a programme should provide flexibility and scalability to evolve with the scheme over time. Evidence of technological evolution can be found in the current RUC system in New Zealand, the Congestion Charge in London, the Stockholm congestion tax, or ERP in Singapore. All of these cases involve the evolution of scheme design over time in response to new technology advances and policy refinement.

It is also valuable to recognise that technologies *not* selected for a system—perhaps dismissed as immature or too expensive/infeasible—may also evolve over time. Shifts in existing technology and emergence of new technology may disrupt or possibly displace the original technology used in a programme.

In urban road pricing, the main technology trends in recent years are threefold:

1. increasing use of ANPR,
2. the emergence of Global Navigation Satellite Systems (GNSS), and

3. increasing interest in using smartphones.

ANPR technology is significantly advancing in its capabilities, functionality, accuracy and lowering of costs. Where ANPR was previously paired with Dedicated Short Range Communications (DSRC or tag and beacon technology), ANPR is now displacing the usage of DSRC, which now provides little more than unnecessary duplication of technology and doubling of costs. Earlier ARPS and ARPES reports recommended DSRC, but ANPR systems have advanced sufficiently since those reports to render DSRC redundant for any new system.

The second trend is the emergence of GNSS On Board Units for road charging that are increasingly smaller and more cost effective. However, they have yet to be proven for full network urban road pricing.

Smartphones have dramatically changed our lives since the introduction of the iPhone in 2007. As smartphones have gained a large market share worldwide, the idea of using smartphones that contain GNSS technology for urban road pricing has been raised. Several attempts to use smartphones for road pricing have occurred to date in the USA. However, trials in the US states of Minnesota, Oregon, California and Washington indicate serious shortcomings in usage of smartphones as the primary technology for road pricing. The tests, however, also suggest smartphones are outstanding personal interface devices for account management, payment and reporting, when matched with primary vehicle identification technologies such as ANPR.

4.2. Summary application of technology for urban road pricing

Any urban road pricing system technology must support pricing of vehicles based on four core parameters:

1. time of day,
2. location,
3. vehicle type, and
4. an observation or measure of chargeable events (either a point crossed or distance travelled).

The operating model for a charging system either involves a vehicle's chargeable activity being "detected" by the charging system or being "declared" either by equipment related to the vehicle or by the vehicle user. A system may use both detection and declaration. A detection-based system charges vehicles only when the system identifies their presence or chargeable event. A declaration-based system charges either when a vehicle has its chargeable events declared to the system (by measuring usage with an in-vehicle device) or if a vehicle user pre-purchases a charging product (whether or not the chargeable event occurs). Most systems operate on a detection basis. GNSS systems operate on a declaration basis, and the London Congestion Charge operates on both (some users have accounts and pay when detected, others prepay for a trip, but do not get refunded if the vehicles does not undertake the trip). Table 3 below summarises the technologies used for all currently operational urban congestion pricing schemes.

System	Current Technology	Future Technology	Comments
Singapore	DSRC (2.4Ghz) in ERP scheme	GNSS	Transitioning to GNSS based system starting 2020. Was paper based with ALS/RPS from 1975-1998. ANPR for enforcement.
London	ANPR	ANPR (GNSS proposed)	ANPR used for congestion charging, low-emission zone enforcement and proposed ultra-low emission zone. GNSS proposed for full network charging in Mayor's draft Transport Strategy.
Stockholm	ANPR	ANPR	2006 Pilot and Lidingö exemption used DSRC. DSRC abandoned for full scheme because not considered legal evidence under tax law, and ANPR sufficiently reliable. DSRC retained for Lidingö exemption to ensure high reliability for exemption, but removed in 2015 when bypass to Lidingö opened.
Gothenburg	ANPR	ANPR	
Dubai	DSRC (915MHz)	DSRC	ANPR for enforcement.
Milan	ANPR	ANPR	Initially an emissions charge.
Oslo and Bergen	DSRC and ANPR	DSRC and ANPR	ANPR option available for those without accounts. DSRC used a primary measure for charging through accounts.
Tehran	ANPR	ANPR	

Table 3 - Technologies used in congestion pricing schemes

4.3. Overview of main technology options for urban road charging

4.3.1. Dedicated Short Range Communications (DSRC)

DSRC (or “tag-and-beacon”) technology was first used for road charging in Norway in 1986 for the Bergen toll ring. The system involves a vehicle identifier ("tag") installed to a vehicle windscreen so that a beacon can detect the vehicle. Using data contained in the electronics built into the tag, the system can identify the vehicle for billing purposes in a back office system. The system requires gantries to mount antennas (the beacons), and an ANPR system for enforcement. DSRC is a highly accurate and reliable means of identifying vehicles, generally achieving reliability levels of over 99%. Singapore, Dubai, Oslo and Bergen all use this technology for their free-flow urban road pricing systems. However, all of these systems are at least ten years old, and Singapore's is an expensive, bespoke system. It is planning to replace this with a GNSS system supported by ANPR. DSRC is not used in New Zealand, and compared to modern ANPR systems, DSRC no longer offers sufficient advantages in terms of reliability, accuracy and operating costs to justify its inclusion in a new urban road pricing system. The added cost of tags, beacons, gantries, roadside support cabinets and communications would not only increase the budget, but also add significant time to any implementation, without offering significant technological benefits.

4.3.1.1. Costs

DSRC tag-based systems' costs are a combination of the tag costs and the roadside equipment. DSRC tag inventory management and renewal costs must also be considered. The price of tags, readers and beacons to support them depend on the selected technology platform and site conditions. Tags can range from NZ$1.50 to NZ$30 each, readers from NZ$4,500 to NZ$14,000, and gantries/beacon poles with associated equipment from the low hundreds of thousands into the millions, depending on site conditions.

Due to the relatively high costs and insignificant benefits, DSRC is not considered a suitable technology for further consideration in this report.

4.3.2. Automatic Number Plate Recognition (ANPR)

ANPR is video image processing of number plates, including converting images of number plate alpha-numeric sequences into digital information. This information is then used to identify a vehicle to match against accounts, charging products paid and vehicle owners. ANPR is an essential element of any urban road pricing system for enforcement purposes.

Initially, ANPR was a vital supplement to DSRC technology for capturing incomplete transactions, non-working tags, and violations of unequipped vehicles. However, as ANPR technology has improved significantly, it has become sufficiently reliable by itself to replace DSRC systems. There have been two main areas of technology improvements to ANPR:

1. Better image processing techniques (algorithms) to read the number plate and record vehicle characteristics from a given image;
2. Increases in memory speed and size have greatly increased speeds that a digital camera can capture an image.

The increases in memory speed and size allow multiple images to be captured and compared, in order to select the "best" image for image interpretation by the processing algorithms. Moreover, fast processing power allows the camera controls to automatically adjust aperture and processing for light, glare or blooming effects of headlights or reflection for each image. Finally, these systems now also use other visually captured information, such as the model vehicle and colour, to provide an "electronic fingerprint" of the vehicle, allowing vehicles to be positively identified even when a perfect read of the number plate cannot be made.

The number of cameras needed to cover a given roadway is also decreasing. Many new cameras can handle the entire video capture and interpretation to produce the number plate read of two or three vehicles visible in multiple lanes simultaneously.

ANPR is already deployed as the sole detection technology for free flow toll roads in New Zealand. It is already demonstrated and working to a high level of accuracy (over 98%) in New Zealand.

Figure 30 - London ANPR infrastructure

Today, London, Stockholm, Gothenburg, Milan and Tehran all use ANPR as the sole charging technology.

In Germany, the latest generation of ANPR cameras are on single vertical towers located on the road verge for enforcement, not requiring the more costly roadway-wide gantry installations.

ANPR would be the simplest, easiest, and most cost-efficient option for an urban road pricing system in Auckland. Unless some form of in-vehicle system (such as GNSS) were made compulsory, and enforcement means were enacted to ensure vehicles were universally equipped, ANPR would needed in any case for enforcement.

The key limitation of ANPR systems is the cost per charging point, which renders it expensive to deploy for network wide road pricing. However, the number of charging points needed varies with the design of the scheme, so a scheme can be designed to require fewer charging points and thus cost less, with the key trade-off being to balance cost with the precision/bluntness and scale of the charging scheme overall.

Although ANPR technology is used today for tolling in New Zealand, it is envisaged that adding a congestion pricing scheme would necessitate a change in the back-office capabilities of the software and hardware used for the existing tolling system. First, the volume of the daily transactions from an urban road pricing system could exceed the capacity of the existing system. Second, the existing back-office software and hardware may not be compatible with the functionality and capabilities of the newest ANPR cameras and related technology (given the NZTA tolling system has been in place for around a decade). The assessment of the existing back office facilities, hardware and software were beyond the scope of this report, but would be a necessary step in any future plans to proceed with a congestion pricing scheme in Auckland.

Figure 31 - Gothenburg ANPR gantry

4.3.2.1. Costs

ANPR video-based systems' costs are a combination of the video or camera costs and the roadside equipment.

The following costs are indicative costs for worldwide supply of video-based systems. The costs assume a mounting structure such as a gantry or a cantilevered arm across the lanes. While the camera units can be mounted on existing structures, the details for such mountings may or may not fit the charging area or zone boundaries. As such, the costs included below may be conservative: they do not include site-specific mounting and structure design; and it is assumed there is reasonable access to electricity and communications infrastructure.

The below costs are for relative comparative purposes of this initial report. More details and breakdown of each of the above costs for ANPR image capture systems on a generic two-lane, plus two shoulder road segment or other configurations can be provided for system-wide road charging configurations of an agreed urban road charge design and configuration.

Table 4 - High-level Costs of ANPR Video Image Capture Systems

	Type of Technology	Price (NZ$)
1	Camera, low light, DVD definition	$1000 to $2000 ea.
2	Housing, mounting per camera	$375 ea. to $500 ea.
3	Cost of a 2-lane, 2-shoulder Gantry*	Approximately $1,200,000 ea.

* A gantry may not be needed for city street camera mounting in dense urban areas—poles on buildings may be used, which cost substantially less.

4.3.3. Global Navigation System by Satellite (GNSS)

GNSS systems employ on-board units (OBUs) that can determine their location based on receiving satellite signals. GNSS has the key advantage of not being tied to on-road infrastructure and so can apply pricing that includes consumption of road use by distance (or time) and distinguish road use by time and location. This provides unrivalled flexibility in charging scheme design.

GNSS OBUs are self-contained systems. They typically contain cellular communications technology and internal sensors to augment the location based services, computer processing and memory to compute a vehicles location in near real time. Cellular data communications may transmit either individual charging events or an aggregation of chargeable event data to a centralised processing system. To enable full network pricing, with variation by region, GNSS OBUs must be used with map-matching in the vehicle or back office to charge by location and time of day. To facilitate this, Geographical Information Systems and digital maps must be kept up to date about chargeable routes and charging rates. These can be dynamically updated while the system is operational.

GNSS based charging systems exist in six countries in Europe[91] charging heavy vehicles mainly on motorways and highways based on distance, vehicle type and road type. The latest systems in Belgium and Hungary have OBUs that can be self-installed by drivers.

[91] Switzerland, Germany, Slovakia, Hungary, Belgium and Russia.

GNSS is also used in New Zealand for the collection of RUC from some heavy vehicles (eRUC). The next generation Singapore ERP system for urban system will be GNSS based and will advise of ERP rates by route and provide real-time traffic information. Singapore LTA believes that these value-added services will help spread traffic demand and provide better information on the availability of other modes. The system will also provide a means for billing for on-road parking. A system diagram of the new system is shown below in Figure 32.

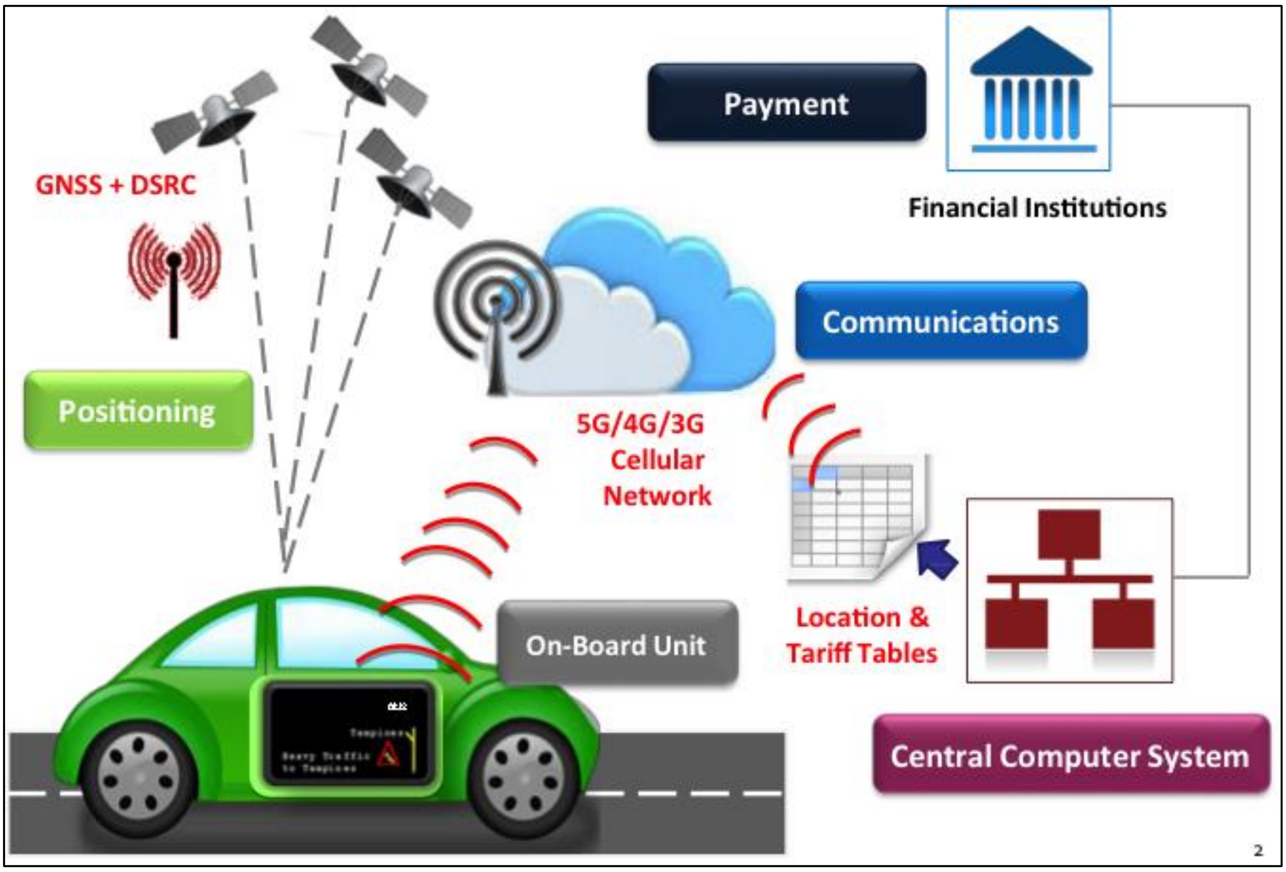

Figure 32 - proposed Singapore GNSS road pricing concept of operations

The public often perceives GNSS as more intrusive than ANPR raising privacy concerns. GNSS is often related with invasive government "tracking." If GNSS is to be used, the communications around this central point of privacy will need to be addressed. Previous reports have identified some limitation in the availability of GNSS signals in New Zealand that may affect the ability to use such technology for charging purposes. Further details on how these issues may be addressed are contained in Appendix S.

Unless GNSS units are mandatory on all vehicles and this mandate is enforced in some way, ANPR systems are still needed for enforcement with GNSS systems.

4.3.3.1. GNSS and eRUC

In New Zealand, the existence of eRUC systems could provide a platform that could be developed for congestion pricing in Auckland. If a point-based charging system were to be adopted, using ANPR as the core platform, eRUC systems could be used to charge eRUC-equipped vehicles to support the following options:

- Charging for crossing charging points on a similar basis to vehicles that are not equipped (by simply accumulating the congestion charge as part of the eRUC account). The purpose of this is to reduce transaction costs for users; or
- Charging for crossing charging points, *not* for crossing the point per se, but by charging distance accumulated after crossing the charging point at a specific location and time; or
- Charging based on distance that varies by location and time that is not necessarily related to any charging points (effectively having a parallel charging system).

Over time, such a system could allow for evolution of a point-based charging system using ANPR to a full network pricing system, although this would require most vehicles in Auckland to be equipped with an eRUC type system that would enable distance, location and time based charging.

There are some issues that would need to be addressed to enable this.

- The technical requirements for eRUC service providers would need to be reviewed and updated to ensure they could enable location based charging that could vary by individual road segment, time of day, day or the week (in addition to existing RUC charging elements of distance, vehicle type/configuration, gross vehicle weight), and move from prepayment to postpayment of distance;
- The paper-based RUC system would need to be phased out, so that all RUC-liable vehicles are on a GNSS platform that is capable of full network pricing;
- Non-RUC liable vehicles (petrol powered cars predominantly) would have to be transitioned to the same platform;
- The future of fuel duty would need to be examined if petrol powered vehicles are transitioned to an eRUC type platform.

For congestion pricing in Auckland, it may be challenging to justify on an economic basis or to the public, a transition away from existing charging systems purely to meet the needs of demand management in Auckland. There may be other policy reasons to embark on such reforms, but these are outside the scope of this report. Nevertheless, given the likely advantages of full network pricing, there are merits in considering how this may be developed and whether and how the existing eRUC platform could be adapted and used to support congestion pricing in Auckland.

4.3.3.2. Cost

GNSS-based systems costs are a combination of the on-board unit costs and the following enforcement sub-system necessary for a complete installation:

- Vehicle detection and classification systems
- ANPR system for enforcement or occasional (unequipped) users

In many GNSS-based systems, a mobile enforcement platform (mobile ANPR units, housed in vans) is used both as an augmentation to the fixed ANPR gantry sites, and also as a substitute for a fixed enforcement sites should the fixed site need maintenance or repair of a subsystem component. The following costs are current estimated costs for the GNSS technology.

Table 5 - High-level Costs of GNSS-based Systems

	Type of Tag-based Technology	Price of GNSS Units NZ$
1	GNSS on-board unit	$180 to $250 each

4.3.3.3. Challenge of GNSS charging on a regional basis

Since 2009 New Zealand enabled the development of eRUC as a more technologically advanced option of measuring distance travelled on public roads for RUC.

However, although the technical feasibility of charging by time, distance and location is now proven (although not applied in a highly disaggregated time/location basis in an urban environment), there is one significant barrier to its implementation.

Such a system would require a significant number of vehicles in Auckland to be equipped with OBUs to measure the distance travelled by time of day and location, and the cost of equipment to do that for each vehicle is likely to be around at least NZ$180 per device.[92] In addition, there is the need to manage and maintain such equipment, including renewals and to manage any breakages. The logistics of supplying, installing and testing such a large number of OBUs in advance of deployment, primarily for private vehicles, are considerable and has not been replicated on that scale anywhere. Furthermore, there may be considerable public concern around privacy from such a system. Although privacy protection can be robustly designed into any such system, misperceptions about how the technology works can mean that a narrative about "spy in the sky" or "tracking the public" can quickly gain credence, raising concerns that the scheme is a Trojan horse for mass scale government surveillance. Having privacy as a core principle in the design and development of policy can help ease concerns.

Those motorists not equipped with a GNSS OBU could be faced with two options. Either a fine for using charged roads at specific periods (making the OBU and account compulsory), or a secondary scheme for occasional users (e.g. a day pass or trip pass). Given Auckland's location between two regions, and having the country's largest airport and port, a lot of traffic is generated by visiting vehicles. A secondary scheme, which by necessity would need to be based on identifying vehicles by number plate, would need to be established and designed to fairly capture occasional users, without creating unnecessary distortions.

4.3.4. Other technologies

Three emerging technologies for urban road charging are:

1. In-vehicle telematics
2. Usage-based insurance devices
3. Smartphone road charging applications

<u>In-Vehicle Telematics</u>

No jurisdiction currently uses in-vehicle telematics for urban road charging.

[92] Units supplied for Belgian and Hungarian distance and location based charging schemes are around €80-€135.

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In-vehicle telematics, or native automobile manufacturer telematics, are electronic systems in vehicles that include wireless communications to transmit data to/from on-board vehicle computers to a supplier's system. Vehicle manufacturers often have unique brands for their GM's OnStar, Ford's Sync, Nissan's Carwings, and Toyota's Entune. As Connected Vehicle technologies emerge, in-vehicle telematics systems are becoming more sophisticated, including enhanced location information.

Figure 33 - Illustration of in vehicle telematics

Telematics has the prospect of supporting urban road pricing in the future, but is dependent upon the proportion of vehicles with such systems increasing over time, the technical capabilities of such systems, and the willingness of telematics providers to support the development of applications for road pricing systems. It is theoretically possible for in-vehicle telematics to replicate the types of data provided by GNSS on-board units, but the IT design of telematics systems prevents location data being used for charging purposes in an efficient manner.

Moreover, international experience in using in-vehicle telematics systems to support urban road charging is embryonic. It is possible to support urban road charging from in-vehicle telematics by allowing third parties to access vehicle data such as odometer values. Measurement of distance travelled in this manner was offered in the recently completed California Road Charge Pilot Program.

It is likely to be many years before a sufficient percentage of New Zealand's vehicle fleet is embedded with telematics that may be useful for road pricing applications, and the current IT architecture of vehicles prevents location data from being used efficiently. For this reason, in-vehicle telematics cannot be recommended at this time.

4.3.4.1. Costs

Telematics systems are already built into individual vehicles. However, to be useful for road charging purposes, applications need to be developed, tested and released onto the telematics platform. Since there are multiple manufacturers with distinct and different in-vehicle telematics interfaces, the application will need to be modified, tested and released for each in-vehicle telematics system in the market at the time of the implementation.

The vehicles existing network interfaces to a cloud address to forward transactions for processing is assumed in these figures. Additionally, there may be costs for access to the telematics system, which are typically borne by the vehicle owner (if the owner chooses to subscribe to the telematics services).

Table 6 - High-level Costs of In-vehicle telematics application per vehicle manufacturer

	Type of Technology	Price (NZ$)
1	Application development and testing*	$150,000 to $500,000 ea.

Note * - An application development and testing would be necessary for each major manufacturer's telematics platform.

Smartphones

Another variant to the above technological advancement is the use of smartphones (or cellular-equipped tablet computers) with applications to link a vehicle to the phone and identify and measure chargeable events to be communicated to the back-office system. Since 2009, GNSS technology has been a common sub-component of smartphones.

Most smartphone applications for road charging are triggered by using the GNSS capabilities of the phone to mark geo-fencing of charging points.

However, smartphones do not eliminate the need for an ANPR system to identify and verify that vehicles have undertaken chargeable events to correlate to declarations made by a smartphone application. In this sense, the sole purpose of smartphones is to provide a new user interface and either alert or automated declaration application for users of an urban road pricing scheme, for point based charging only.

Smartphones alone cannot be used for urban road pricing, because they need to be correlated to a specific vehicle and because they cannot be relied upon to provide a sufficiently accurate positioning system to reliably distinguish between whether a vehicle is one or another side of a charging point. This can only be done by having a smartphone application linked to a vehicle directly or by number plate, and the ANPR system used to identify the vehicle so it can be checked against transactions undertaken using the smartphone application.

Smartphone applications for tolling already exist in the United States and have been developed in Australia, but in all cases they rely on vehicles being declared crossing charging points on major highways (where there is little risk of diverting from the charging point).

Smartphones can offer a user-friendly user interface and feedback system for an ANPR-based charging scheme. The application could alert drivers of an impending charge zone and offer alternatives, such as public transport or park-and-ride services outside the zone. The smartphone application could also offer mobility-as-a-service options for ticketing and payment of those public transport services in a single application. Should the driver continue into the zone, the driver could be alerted to the charge. The smartphone application could provide feedback, recordkeeping of trips, costs on a weekly or monthly basis, and total charges to date over customised timeframes. For business trip purposes, the smart phone can also provide the user with receipts for travel and charges.

4.3.4.2. Costs

Smartphone applications, just like in-vehicle telematics applications, would require the development of application software for installation on all main smartphone operating systems. The development, testing and release of an applications program to install and operate the urban road charging on the two major smartphone operating systems would be a cost.

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There would be further costs to develop the technical systems integration between the smartphone application provider's systems and the back office/billing systems of the scheme. These costs are not provided. However, depending on the business model used to implement congestion pricing (and for the charging of other urban transport services), there may be commercial opportunities for the open market to develop such applications.

Table 7 - High-level Costs of Smartphone application

	Type of Technology	Price (NZ$)
1	Application customisation, testing and approval per operating system	$75,000 to $150,000

4.4. Conclusions

- Any urban road pricing system requires ANPR for enforcement or to charge vehicles that do not have any other equipment or system installed to identify them to a road pricing system.
- Given the necessity of having such a system, ANPR appears to be the most expedient and cost effective near-term solution for any point based urban road pricing scheme.
- There appears to be no further merit in considering DSRC, given New Zealand conditions and the capabilities of modern ANPR systems.
- GNSS has considerable merit as the only current technology capable of implementing a full network pricing system. Existing eRUC service providers may offer a platform to develop this, which could be used to offer another option to the ANPR system for eRUC users, but the cost to implement GNSS for vehicles not using such systems (i.e. most vehicles in Auckland) is likely to be high and the timeframes for implementation much longer than an ANPR based system.
- Smartphone applications may add an interface and the potential for value added service for users with a system based on ANPR. It might also support Mobility-as-a-Service integration with public transport and other services, such as parking. However, smartphone applications do not offer a stand-alone solution for urban road charging.

5. Functional elements of demand management based road pricing systems

- Key functions are user services, charge processing, enforcement and back office administration.
- User services functions can be open to competitive supply (as is the case already in New Zealand with eRUC).
- Charge processing functions include both monopoly and competitive elements.

5.1. Key functions

This chapter provides an overview of the key system elements of demand management based road pricing as well as an explanation of the distinctions between tolling (a more common form of direct user-pays road pricing) and congestion pricing. This does not include the wider legal and policy framework within which a charging system operates

5.2. Key Functional Elements of a Congestion Pricing System

At the technical level, there are four major functional elements to a congestion pricing system:

5.2.1. User Services/Account Management

This element includes all services required to manage users, including responding to all user queries and creating, modifying, and closing user accounts. It includes the operation of possible channels by which users access and pay for their accounts (retail, phone, online, postal); payment means (direct debit, credit and debit cards, bank transfer, cash, cheques); and complaint and dispute management functions. This element also includes verification of users' identities in relation to accounts and processes and systems to verify eligibility for any discounts or exemptions. Finally, User Services/Account Management also includes the supply, installation, maintenance and replacement of any on-board systems on vehicles (if required), including the interface between such equipment, (including communications (if required)) and the back office systems to support these processes.

5.2.2. Charge Processing

This element includes all components in the process by which a chargeable event (any usage of the road network that is chargeable) is detected and verified. This process starts with the vehicle either being detected having undertaken a chargeable event (or series of such events) or having declared that it will undertake such events (such as prepaying for future travel) and detection to verify this if necessary. This chargeable event data includes identification of the vehicle type, and the location and time when the chargeable event occurred. All of these data points are collected for the specific vehicle and are typically processed in a batch (and taking into account any cap or vehicle/user specific discount or exemption) to calculate the charge and engage the payment systems to collect the charge, or (if no account or relevant payment is made within a specific threshold of time) engage compliance and enforcement systems.

5.2.3. Compliance and Enforcement Systems

This element includes all components needed for the detection of non-compliant vehicles[93], managing compliance issues, pursuing debt recovery, pursuing prosecutions/fines and appeals against prosecutions or debt. This element includes both violations (the establishment, policing, charging and prosecuting of failures to pay) and debt recovery (recovering unpaid charges), which may be undertaken separately. This element also includes identification and pursuit of fraud and tampering with any in vehicle charging equipment.

5.2.4. Accounting and Management

Accounting and Management includes a wide range of administrative matters including institutional arrangements and relationships, charge setting, charge products, the management and distribution of gross revenues, asset management, and contract management.

Figure 34 below is a more detailed depiction of these key components of a charging system.

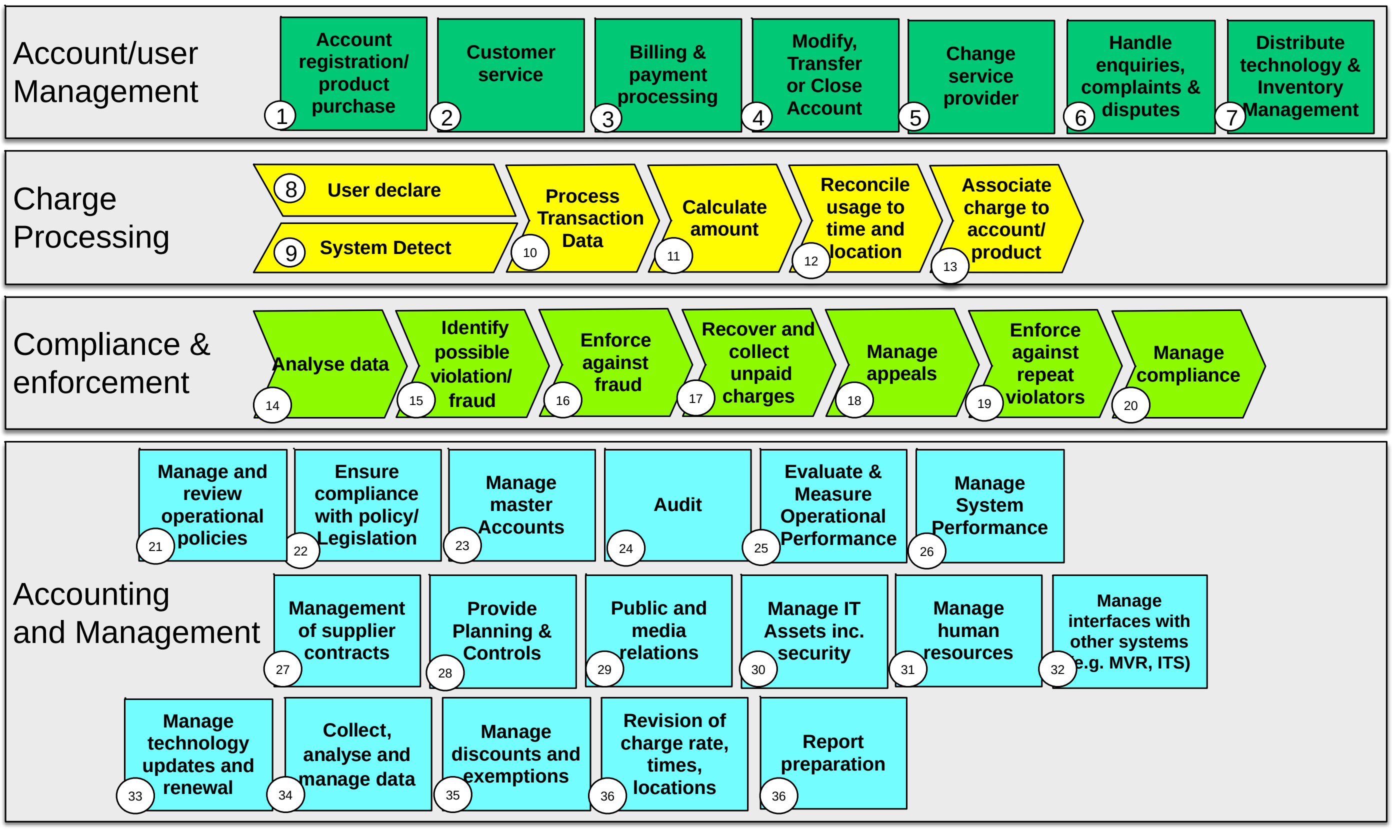

Figure 34 - Road pricing system Major Elements with Key Functions and Processes

5.3. Differences Between Congestion pricing and Tolling

Charging vehicles directly for using roads is not new, as tolling has been around for centuries. The main limitation on tolling has been that, until the 1990s, technology always required vehicles to stop to pay the toll. Although charges based on prepayment of time and distance had also been developed (such as the

[93] Defined here as vehicles for which a charge has not been paid for a chargeable event within the required threshold period (e.g. in London it is 48 hours).

vignette systems in Europe and New Zealand's RUC system), these could not differentiate by location and required prepayment of anticipated road use (whether defining usage as time or distance).

The advent of modern information technology (IT) and communications technologies initially allowed vehicles to be identified with electronic tags that could be read by radio-communications beacons as they passed particular points, eliminating the need to slow or stop to collect tolls. Further technology development enabled the use of Automatic Number Plate Recognition (ANPR) technology enabling toll enforcement and more recently, collection simply by the electronic character recognition of number plates. The first fully electronic free flow toll road was opened in Toronto in 1997 with the ETR-407, allowing toll collection at highway speeds with no lane separation. Subsequently, Melbourne CityLink pioneered electronic free-flow tolling in 1999 for Australia, and similar technologies have also been applied to urban congestion charging schemes in Singapore in 1998, London in 2003, Stockholm in 2007 and subsequently in other cities.

It was the introduction of such systems that enabled charging to be introduced on *existing* roads without interrupting the flow of traffic, so that the material technical differences between free flow tolls and congestion pricing were low. The key difference is the greater need to apply enforcement on existing roads, and for congestion pricing to be designed to take into account the legacy road network conditions, rather than applying tolls to a road that is being designed and built in parallel to the toll system.

Furthermore, as toll roads are designed primarily to attract road users to pay for a premium service over the untolled alternative (and to charge to raise revenue to cover the long run capital and maintenance costs of the road), the value proposition to road users is quite different to congestion pricing. Toll road users are paying for travel time savings compared to the alternative route, but still have a choice of route. Tolls are set at rates to recover infrastructure costs, although a few have peak and off peak charges to manage capacity. Congestion pricing is not based on infrastructure costs and in most cases there is not an alternative route for vehicles that would be charged (excluding routes designed to bypass areas/cordons).

The free flow technologies enabled charges to vary by individual point, including the time the charge is levied and vary the price by that time (as happens in Singapore).

However, the key limitation remains that point based charging can only be undertaken when and where it was financially viable to install and operate the necessary equipment to charge on specific roads. Charging still required gantries or beacons to be located at specific points on a network, limiting charging only to roads with high volumes of traffic over relatively short distances or networks with few entry/exit points. Although it could allow tolling to be delivered so that charge rates could be set based on distance between charging points (as is done in Portugal), it did not offer the flexibility to charge across a wide network with lower densities of traffic due to associated high capital and operational costs.

The availability of GPS technology and continued improvements in IT hardware, software and mobile communications systems enabled road charging to be extended beyond those roads where it was economically feasible to install roadside charging infrastructure, to measure the road use of individual vehicles. Such systems have enabled charging by distance varying by many factors, including vehicle type, location, and time of day. This flexibility comes from the fact that the primary technology for charging vehicles, GPS or GNSS, is in the vehicle, not at the roadside. The key trade-off is that with such systems, vehicles need to be equipped with on board units to measure chargeable events

5.4. Description of elements

5.4.1. Account and user management

These functions are those that involve a direct relationship with users and the general public more widely.

1. Account registration/product purchase: The process by which a user opens an account for a vehicle, or purchases a non-account based product for that vehicle.

2. Customer service: The processes by which users and potential users interact with customer service staff for assistance (e.g. in person, phone, online)

3. Billing & payment processing: The processes of billing for accounts, and management of payments for accounts or non-account based products.

4. Modify, transfer or close account: Processes for users to change any of the details on accounts, such as vehicle or personal contact details, or to close an account.

5. Change service provider: Management of the process by which users may transfer vehicles from an account of one provider to another (in the context of systems with more than one service provider).

6. Handle enquiries, complaints & disputes: Processes to respond to account holders, non-account users and the general public for enquiries, complaints or disputes, including formal dispute management procedures.

7. Distribute technology and inventory management: For systems with on-board units or in-vehicle tags, processes for the distribution, management, collection, replacement and disposal of such units, and managing the inventory of such devices correlated against vehicles and accounts.

5.4.2. Charge processing

These processes arise from vehicles undertaking chargeable events and users interacting with the system to pay for such events.

8. User declare: Under such a system, the user is expected to declare the future or past event of the vehicle undertaking a chargeable activity (e.g. declaring entry into an area or prepurchase of a pass for a period or a number of trips). Under user declaration, the vehicle may not necessarily undertake the chargeable activity, but the declaration means that it would not be subject to enforcement if it did (and would not get a refund if it did not). Users may declare manually, have technology that assists in declaration (by alerting the user of the need to declare) or does so automatically. Systems based on GNSS measurement of distance are effectively automatically declaring chargeable events.

9. System detect: Under such a system, a charge is made when the charging system detects that a vehicle has undertake a chargeable event (or series of such events). Under system detect, the user is expected either to have an account which bills (or deducts) the chargeable amount, or is billed directly from the charge. Systems typically detect users by roadside infrastructure (such as ANPR cameras). All systems have a detect element for enforcement, but may not necessarily do so for measuring and collecting charges.

10. Process transaction data: The process by which the charging system collects data from declarations or system detection to either associate the vehicle with a declared charge, or associate the vehicle with an identified chargeable event. This includes the classification of the vehicle.

11. Calculate amount: For the specified vehicle type, calculation of the amount due based on chargeable events, time of day of each event, location of each event and inclusion of any applicable discount or exemption based on vehicle (or user) classification.

12. Reconcile usage to time and location: Reconciling data collected as part of the enforcement system to confirm usage based on time and location, against any payments made or products purchased.

13. Associate charge to account/product: Association of data identifying a vehicle undertaking a chargeable event to the account and/or products obtained for the vehicle, to ensure that the vehicle is considered compliant and a charge is appropriately collected.

5.4.3. Compliance and enforcement

All processes under this category are for the identification of the status of all vehicles interacting with the system and clarification if a vehicle is compliance, non-compliant or of questionable status). Compliance and enforcement includes the gathering of intelligence around user behaviour and trends, as well as handling appeals and disputes with alleged violators.

14. Analyse data: Vehicles identified as not having accounts and not having paid non-account based products are analysed. Those that should be exempt are screened out and others are identified for further processing. Wider analysis is undertaken to determine if there are any patterns of non-compliance, evasion or avoidance that are appearing, by different vehicle category. This may include behaviours based on ignorance rather than deliberate attempts to evade the system.

15. Identify possible violation/fraud: Vehicles that have neither an account nor have paid an occasional use product are immediately grey-listed as being possible violators. There may be reasons for non-payment that are legitimate (e.g. vehicle reported stolen), or exemptions. Those identified as clear violators become black-listed. Fraud may be more complex, such as unauthorised use of accounts, stolen number plates or concealed number plates.

16. Enforce against fraud: Once fraud has been identified, and the fraudulent party identified, this process means the taking of legal action against the fraudulent party. Steps may also be taken to prevent future similar fraud by identifying processes or procedures that may reduce the risk of such fraud.

17. Recover and collect unpaid charges: If a registered vehicle owner does not pay a charge, this process represents the steps taken to enforce unpaid charges including application of any administrative fees and fines. This includes both the punitive and the debt collection elements of enforcement.

18. Manage appeals: Road users subject to a violation notice may appeal the notice for a range of reasons (e.g. mistaken identity of number plate, vehicle had been sold, stolen or some mistake at the account management end).

19. Enforce against repeat violators: Persistent violators may not pay fines or charges, so processes to escalate action against them are required. This may parallel processes for enforcement against persistent violators of safety regulations.

20. Manage compliance: A compliance and enforcement strategy is focused first on ensuring road users know what they have to do to be compliant and making compliance as easy as possible, rather than focusing on identifying and penalising non-compliance.

5.4.4. Accounting and management

21. Manage and review operational policies: Ongoing feedback from system performance and all operational procedures as to whether there should be refinements or other amendments to operational policies, including those for compliance and enforcement.

22. Ensure compliance with policy/legislation: Management of the entire system to ensure it remains within the parameters of the law and is being operated according to the policy that is its foundation.

23. Manage master accounts: Management of the account that all gross revenues are placed, and management of parallel accounts for costs. This may also include distribution of net revenues for the stated purpose.

24. Audit: Processes to audit financial and operational performance against reported statistics.

25. Evaluate and measure operational performance: The system is subject to regular monitoring of its performance across a range of Key Performance Indicators. This is reported and used to assist in managing contracts with suppliers and to refine the operation of the system.

26. Manage system performance: The evaluation and measurement of performance is used to manage the performance of the system and the performance of third party suppliers.

27. Management of supplier contracts: Contracts with third party suppliers (system maintenance, retail outlets, account managers) are managed, including retendering when required, contract variations and terminations.

28. Provide planning and controls: Overall management planning for expected change (e.g. suppliers, technology updates, variations on the system, suspension of charging points for operational reasons) and controls on how change is managed. This also includes longer term planning for any expansion or revision of the scheme.

29. Public and media relations: The release of information to the public about the scheme, including ongoing publicity, information about changes and media relations about performance and key measures (e.g. impacts on congestion, net revenues).

30. Manage I.T. assets including security: The ongoing management of the system's IT assets, including databases and ensuring the security of such systems and data from attack.

31. Manage human resources: Management of the hiring, performance appraisal, dismissal and contracting of human resources to support the scheme, including all elements of remuneration and conditions.

32. Manage interfaces with other systems: Charging systems must interface with the motor vehicle register, but may also require interface with any tolling or other charging systems. Ensuring reliable access to those databases and systems to enable charging and enforcement is a critical function.

33. Manage technology updates and renewal: Part of the asset management function and performance management function is to manage renewals and updates of technology within any of the systems. This may be done before the end of the depreciated life of an asset if there is a worthwhile performance/cost advantage to be gained.

34. Collect, analyse and manage data: The scheme will gather a lot of data around traffic, usage, payments, queries and various interactions with the system. This element includes processes to classify, analyse and manage that data to inform the scheme's management, but also overall policy.

35. Manage discounts and exemptions: Some road users may have discounts or exemptions from the scheme. Processes to record these, which may include the need to apply for such a discount or exemption, are included here. This also includes processes to identify fraudulent application of such discounts and exemptions.

36. Revision of charge rates, time and location: Periodically, charge rates will be revised to reflect various factors such as inflation, demand and performance. Charging points and periods may also be amended. This element includes processes to identify the basis for these and to inform policy decisions on such revisions.

37. Report preparation: The scheme will be subject to regular reports on various aspects of performance (financial, transport, customer service, enforcement). This element comprises the tasks to prepare these regular updates.

6. Operational models and delivery programme for pricing systems

- Important to choose a delivery option based on experience, risk transfer and interest in provision of competitive service delivery.
- Most operating systems have chosen to outsource supply, maintenance and operations of their pricing systems, but there is merit in considering a more open market approach that allows more than one customer service provider.

6.1. Operational and delivery models

This section provides a detailed review of the following issues associated with procurement and delivery model:

- Elements of Procurement and Delivery,
- Delivery Approaches,
- Contracting Approaches,

6.1.1. Elements of Procurement and Delivery

One of the most complex issues associated with the implementation of a road pricing system is how to procure and deliver it. Procurement and delivery affect nearly every other aspect of the programme: schedule, capital and operating costs, the relationship of users to the charge, the functions that would remain with the contracting authority, the system's flexibility and scalability, the level of specificity required for design and contracts, and trade-offs that may need further assessment as key policy dimensions of the scheme get finalised. In addition, the initial procurement decision affects not only the initial installation and delivery of the scheme, but also the longer-term operations, costs, modifications or updates to the system.

In all cases procurement and delivery involve the acquisition of equipment, systems and software integration, and operation for the intended purpose of charging vehicles to manage congestion and collect revenue (and the associated components of customer services, customer relations, compliance and enforcement). Procurement of charging systems is fundamentally different from most undertaken by road controlling authorities. Unlike construction projects or related services acquired by highway authorities, a charging system is not passive infrastructure, but rather the supply of a service involving direct interfaces with numerous end users (or customers) – in effect, a transaction for a purchased service (in this case, legal authorisation to use the charged network). Creating an urban road pricing system means establishing a customer relationship with charged road users that includes establishment, payment and management of accounts or bills. Additionally, it also includes customer relations, handling of customer queries, collection and management of revenue. This goes well beyond the types of interactions that highway authorities traditionally have with road users, although it does have some correlation with the toll collection and RUC collection activities of NZTA. In this section, we distinguish between two separate but overlapping dimensions to the procurement and delivery of an urban road pricing system.

1. The **delivery approach** looks at a high level, how a system is procured and delivered to establish and operate a road user charge. It goes beyond simple procurement of the equipment and systems to include how it will be operated, how change may be managed and ultimately how renewal and replacement may be procured. It may also include the financing of the

equipment and systems, their maintenance and the operation of all of the interrelated elements described in Section 5.

2. **Contracting/payment options** means the various payment arrangements possible between the government and the firms/consortia that would provide systems and services for charging. These options are directly influenced by the delivery approach, but there are some options for contracting that have different legal, commercial and financial implications.

There is a wide range of factors that influence the procurement/delivery approach taken when acquiring an urban road pricing scheme described below. All of these issues should be considered when designing the procurement process and developing a contracting approach. Some of these issues have emerged due to lessons learned from poor contract design. These include the following issues by category:

Delivery approach

- **Lack of experience with some procurement models.**Insufficient experience of similar procurements may mean there is either a higher cost of undertaking the procurement or a higher risk of excessive price, particularly with contracting authorities with little experience of similar contracts or services.
- **Management of cost.** This issue includes ensuring cost effective delivery and operation, whilst managing risks of delayed delivery and poor performance. Different delivery options can impact price.
- **The roles of public and private finance** to support delivery of the system and associated infrastructure, and how that finance is accessed and supported.
- **Level of required flexibility**. This includes how easily a change in policy can be enabled in a cost- effective way; the longer the period of the contract, the more important that it include flexibility to update technologies, performance goals, and other factors.
- **Ways of managing payments and revenue**, including the cash flow for financing and/or funding the system.
- **How best to manage and transfer risk** (influencing capital and operating cost, delivery time and successful implementation), including the extent to which risks ought to and can effectively be transferred to the private sector. Some key risks (including public reputation and relations) cannot, *de facto*, be transferred, even if there is some *de jure* transfer. It is important to determine what elements are more likely to be better managed by the private sector.
- **Interest in the competitive delivery of end user services** and the scope for competitive operations. This can range from choice in payment outlets through to offering of competitive account services. This may be determined based on the scale and scope of operations, and the contracting arrangements to incentivise service providers. Even when capital project delivery is managed by a single contractor, end user services may be provided by a range of competing providers.
- **Timescales for delivery**. Shorter timescales may limit delivery options, and also add risks to implementation and related costs.
- **Capabilities, roles and responsibilities of the contracting authority** (commercial, legal, contractual and technical). If some similar functions are already carried out, this may be taken into account in designing the organisational and delivery framework.
- **Incentives for entities with their roles and responsibilities.**Given the objective is maximising net revenue collection, the delivery approach and organisational framework should have the right incentives to manage risk, cost and performance;

- **Scale of the proposed system and number of users**, this influences the level of market interest from contractors and how the contracting authority might promote interest at the early stages of procurement.
- **Risks and costs of having one vs. multiple contractors**. Some earlier contracting authorities have preferred procuring charging services from a single integrated service provider consortium, paying a price premium for ensuring effective delivery. As technologies, systems and experience has grown, the risk profile has changed, enabling more cost efficient solutions and procurement approaches to be explored.
- **Interest in using charging as a platform to offer other services** to users, and the impact that a proposed procurement and delivery approach may have on the market for such services (including existing service providers).
- **Interdependencies with other policy initiatives** or infrastructure projects, including use of ITS systems for other regulatory purposes.
- **Legal limitation on procurement options**. There may be specific provisions limiting procurement and delivery options. Legal authority to stop vehicles and issue penalties tends to be retained within the public sector, although some elements of enforcement (e.g. audit and intelligence of violations) may be contracted out.

Contracting issues

- **Management and ownership of data.** Access to data about system performance is important to monitor and audit contract performance. In addition, the ability for account holders and the contracting authority to access data from accounts, is important not only to protect account holders, but also to enable the transfer of accounts from a poorly performing operator to a new one. This is relevant both in a model of competitive delivery conditions of transfer between suppliers or in cases of transfer of contracts between single suppliers. Charging systems generate a vast amount of traffic and user data, when contracting with service providers the contracting authority should seriously consider holding full access to user data.
- **Monitoring of performance and quality of service**. Contracts need to allow the contracting authority to accurately monitor contractor performance throughout the lifetime of the project. This issue includes having effective incentives even in the context of a single supplier procurement or in-house provision by a government entity.
- **Complexity and clarity of proposed system scope and definition**. Contracts need to comprehensive, precise, and clear. Uncertainty creating "scope creep" may increase costs and delay delivery. The clearer the proposed scope (and policy), the easier it is to manage cost and encourage market participation by potential suppliers.

All of these issues may be considered in selecting proposed procurement, delivery and contracting approaches.

For Auckland, a key consideration may be that start-up and operation of the charging system can only happen after the opening of a related piece of infrastructure (e.g. City Rail Link).

The key elements that need to be agreed for delivery and operation of an urban road pricing system are:

- **Identification of target vehicles and any need to classify vehicles** for the purpose of differentiated charging: Unless all vehicles are being charged at the same rate, there will need to be a system to identify different vehicles either by physically profiling them at charging points, registering number plates or another form of identification. This includes identifying heavy from light vehicles (if charging is intended to reflect road space occupancy as in Singapore) and identifying vehicles eligible for discounts or exemptions (which may be best done by number plates kept as a database of vehicles registered for such concessions).

- **Identification of charging points or the charged road network**: The locations of charging points, including direction of travel, is an essential element of any system, including the identification of the charged network (i.e., the points on the network beyond which a vehicle is subject to a charge, because there is no alternative route).
- **Identification of charging periods**: It is assumed that congestion pricing does not operate at all times or on every day of the week. Decisions need to be made on when it operates and whether there are different periods of charging by charging point or direction of travel.
- **Scheme management**: An agency needs to be selected or created to have overall responsibility for the charging scheme. The management agency would be ultimately responsible for all operations, including application of the charging policy, customer account and relationship management, and collection and processing of payments. This also includes any contractual relationships with third party suppliers, concessions or service providers that may undertake some of those functions.
- **Role of the Motor Vehicle Register**: For any successful urban road pricing scheme, there needs to be regular access to the motor vehicle register to access details of vehicle owners and to enable both account management and enforcement. It is likely that any congestion pricing scheme for Auckland will require a review of the capacity and capability of existing systems to provide data for such a system to operate on a daily basis.
- **Compliance and enforcement**: There are two elements to enforcement. First, is the issuing of fines to vehicles that are non-compliant with the scheme, either by not paying or by paying incorrectly or fraudulently claiming a discount or exemption. Second, is debt collection of unpaid charges, either for those with accounts that have gone into deficit or for those who are also non-compliant. Clarity of roles and responsibilities around compliance and enforcement is critical.

6.1.2. Delivery Approaches

The delivery approaches available vary depending upon the extent to which the contracting authority wishes to finance, own, operate and manage the elements of the charging system, and how much competition is sought or possible in service delivery.

Internationally, there are four broad delivery approaches in delivering road pricing systems:

1. **In-house ownership and operation**: The responsible agency procures equipment or a system that it owns, manages and operates the scheme. It will typically expect the initial supplier to be contracted to maintain the system for a set period.
2. **In-house ownership, outsourced management and operations**: The responsible agency procures and owns the system, but outsources the maintenance, management and operations to a third party.
3. **Single supplier PPP**: The responsible agency contracts the design, delivery and operation (and perhaps finance) of the system to one entity responsibility for the provision of charging services as a concession for a set period of years.

4. **Open system of certified service providers**: The authority develops a series of output-based specifications allowing a number of suppliers to offer charging services to users against those specifications). A single contracted supplier is still needed for necessary on-road infrastructure and associated systems for compliance.

Delivery Approach 1: In-House ownership and operations

An example of in house ownership of a road charging system is the RUC system in New Zealand (for the NZTA operated paper based system) which franchises out payment options and retail outlets for RUC licences, but owns and maintains its own database of RUC paying vehicles and manages the revenue for the system. Singapore's LTA also uses this approach, and has developed over 40 years' experience in managing and operating urban road charging systems.

This approach is perhaps familiar to most highway authorities, but given the need to engage in complex systems integration, it may also retain most risks with the contracting authority, including technical risks and risks of costs not being effectively or efficiently managed. This approach retains a maximum level of flexibility, as the contracting authority is responsible for operations. A key limitation on the practicability of this approach is the capabilities of the contracting authority. Without sufficient technical understanding, it may not satisfactory deliver a system. Without the right commercial capabilities, customer relations' orientation, and performance incentives, it may not be able to maintain adequate pressure on capital and operating costs. In addition, there may be limitations to the extent to which a government contracting authority can introduce competitive tensions, innovations, operational cost savings, and challenges to operating practices and systems.

Delivery Approach 2: In-House ownership, outsourced management and operations

A variation on the first approach is to own the system, but contract out the operations and management of the system to the supplier. This is the approach that has been used in London and Stockholm. In these cases the installation and operation of the schemes were contracted to a single provider, which was also responsible for managing the delivery and operations of the system. However, in both cases the responsible agency still "owned" the system and had responsibility for decisions on changes to policy and operations (although provisions for variances existed in the contracts with the provider.

The primary advantage of this approach is that the responsible agency transfers the risk of performance and customer service to the contracted provider, and uses its capabilities and experience to operate and manage the system through key performance indicators. The main limitation is that reliance on a single provider for all services does not remove the risk to the responsible agency of poor performance (it will be blamed for any poor judgment or poor service by its contractor as it is seen as ultimately responsible). The contractual arrangements to maintain a high degree of policy and operational flexibility and discretion under this option can be expensive and complex. In both London and Stockholm's cases, the responsible agencies have been increasingly bringing more and more operations under their control, in part to better manage costs. In London, cost savings during a contract period were difficult to achieve. It took contract re-tenders to create a better commercial environment to realise cost savings.

Delivery Approach 3: Public-Private Partnership

Single supplier PPP procurement has been common for toll systems in many jurisdictions and heavy vehicle charging schemes in Europe. These systems have generally involved a public tender resulting in selection of a consortium to finance, design, install and operate an integrated charging system for a set number of years. Initial expressions of interest are received, supplier consortia get pre-qualified and shortlisted, before undertaking full tender bids to be responsible for full system delivery and operation. Such contracts are typically regarded as high value for bidders, because they guarantee recurrent revenue over many years.

The contracting authority may use a contract delivery partner. A simpler procurement document can be prepared and a delivery partner with suitable experience can be selected. Both the delivery partner and the contracting authority can work together to define the road pricing system and its operational standards. The delivery partner can then procure the urban road pricing system, install and commission it. The contracting authority can test and accept the system. After system acceptance, the delivery partner can operate and maintain the system according to the agreed key performance indicators developed between the parties.

In both cases above, the costs of system delivery are born by the supply and operations consortium – often referred to as the PPP contractor. Delivery risks are also transferred to it, on the basis that most or all payment for delivery does not commence until the system is operational and collecting revenue according to either the specifications developed by the contracting authority or developed jointly between the contracting authority and the delivery partner. In exchange for bearing the financing costs and risks of deployment, the supply and operations consortium has an exclusive concession for several years to collect revenue (and is paid for providing charging services and recovers its investment in financing and building the system). The primary advantage of this approach has been to put the risks of delivery entirely on one contracted party/consortium. It also provided a financial advantage to governments by transferring the financing cost to the private sector (and off public sector balance sheets) and spreading the capital costs across the term of the contract.

However, it has the key limitation of any monopoly delivery of services, in that quality of service must be defined by contract, and the scope for innovation is within the consortium delivering the PPP contract, rather than being market driven during operations. For urban road pricing, there is a tension between providing sufficient certainty of revenues and costs for the concessionaire and the desirability of having flexibility and scalability for the concession. Given these constraints, no urban road pricing system to date has adopted this approach.

Delivery Approach 4: Open System

An example of an open system is seen in New Zealand with its introduction of the eRUC system, which authorised the entry of certified service providers to collect RUC to a specific standard. In this case, a certification process is established, based on output specifications in relation to revenue collection and user services. Suppliers interested in providing these services (these suppliers typically also offer other telematics services to heavy vehicle operators) obtain certification and establish the processes for the revenue collected through accounts provided to the contracting authority. In Hungary, this approach has been extended further with its open system of certification. Suppliers of the charging service become certified to measure and aggregate chargeable event data, and collect payment for those services. The number of service providers may not be limited to maximise competition.

A separate contract is undertaken (using delivery approaches 1 or 2) to procure the natural monopoly infrastructure, its maintenance and operation. This includes the provision of on-road infrastructure, communications and related back-office infrastructure and databases for compliance, enforcement and audit purposes. That contracted provider is also responsible for the systems integration with multiple customer service providers.

The key advantage of this approach is it introduces a competitive dimension to service delivery and puts a premium on customer service. It also has the advantage of putting the technology risk and its refresh into the hands of private companies who can better manage the risks. However, it may need a different approach of certification and delivery of any “occasional user” product that does not need on-board equipment (as has been done in Hungary). It may also offer opportunities for customer service providers that may provide additional value added services, either related to transport and motoring (such as public transport ticketing, parking and breakdown services) or unrelated (e.g. utility based services). The growth in providers of Mobility as a Service may offer opportunities here.

The disadvantage is with schemes that may not have a market big enough to generate sufficient interest to have multiple providers, and the higher sense of uncertainty about the reliability and accuracy of certified service providers particularly when introducing a new and controversial policy. eRUC has already attracted two customer service providers in New Zealand competing with the traditional paper-based RUC system.

6.1.3. Contracting Approaches

Within the delivery models outlined above, then can be several approaches to contracting with suppliers. Although some of these approaches have not been used in heavy vehicle charge systems, they are included here for completeness. This sub-section provides a brief summary of these options:

- **“Contracted delivery” contract**: The contracted entity supplies the equipment, software and systems, and is paid on the successful handover of the tested system. The risk around operations remains entirely with the contracting authority or may in a separate contract be transferred to an operations contractor. A new contracted delivery contract would be sought when the system needs renewal due to technology refresh.
- **“Contracted operations” contract**: The contracted operations entity is paid on a regular basis for the successful operation of the system based upon technical reliability and service quality standards. This contractor bids on the basis that the delivery contract is successful, but takes the risk of operating a system that it was not involved in delivering. This contract may be for the operational lifecycle of the key system elements, or for part of that period to incentivise the operating contractor to seek contract renewal.
- **“Target cost to complete” contract**: The contractor bids a single price for the delivery of the system, through testing and into operations, and would be paid on the successful introduction of the system and may also be paid on the basis of target costs, on a regular, formulaic basis to operate the system for a set period before it is handed over to the contracting authority. This period may be short, to allow procurement of a separate contractor to operate and manage the system, or it may be longer—perhaps lasting for the stated operational life of the key system elements. The operational payments would be based on the quoted target cost of the contractor for the delivery of services. This operational contract may continue for the lifecycle of the system or for a subset of that time to incentivise good performance and permit a different operator to be contracted.
- **Milestones and service payment contract**: The contractor is paid during the setup period according to milestones based on delivering certain value (e.g. systems or components that are tested as fully functional). Once the system is operational, the contractor is paid for the delivery of charging services based on a number of metrics including system availability, reliability and quality of service. The service payment contract may be for the lifecycle of the system, or a subset of that period to incentivise performance and permit a different operator to be contracted.
- **Unitary charge payment contract on delivery and operations**: This is the typical approach for a PPP (Public Private Partnership) on a DBFO (Design-Build-Finance-Operate) basis. The contractor is paid on a unitary charge only when the system is in full operation, which incorporates payment for capital and operating costs, based on multiple metrics of revenue collected, quality of service, reliability and other targeted measures. These contracts are typically of a length intended to recovering the initial financing costs of the system through the

unitary charge, although they may be limited to incentivise performance for renewal. At the termination of the contract, the contracting authority owns the system.

- **Transaction charge contract**: For a certified open system, the contracting authority pays certified service providers a set amount per account/user for delivering the charging service, but certified service providers may also charge end users for the charging service based on convenience or packaging it with value added services. The number of providers does not limit this contracting model, although depending on market conditions, fees offered to service providers may vary to incentivise early market entry. Often in the open system approach, some elements (e.g. supply of compliance/enforcement systems) would need to be procured on the basis of one of the other contracting approaches above.

In most cases, contracting authorities with a PPP approach pay a unitary charge based on delivery and on-going operations. Those adopting the open system approach have taken different approaches to incentivise market entry.

In earlier implementation of some road charging systems, the preference of contracting authorities was to adopt the PPP approach, with unitary charge payment on delivery and operations. In such cases, contracting authorities' priorities were to manage risk of implementation, use private finance to pay for the capital costs of the system (rather than public funding) and provide incentives for suppliers and operators to efficiently manage capital and operating costs. This approach resulted in several road charging systems being successfully introduced, but with such systems being owned and operated by a single PPP contractor, with the monopolistic characteristics that such service provision generates (e.g. Germany and Czech Republic). This includes the costs of seeking to replace that provider once the concession period ends, as the concessionaire may hold the account details and own the equipment used to charge hundreds of thousands of users.

However, as technology and experience have progressed, the risks of implementation have dropped significantly and are typically a matter of efficient delivery of user services during the introduction, and having an effective pilot of the proposed system before introduction.

The delivery approach to the eRUC system is an example of providing a more open platform to enable multiple providers to offer user services and charging services, enabling not only competition in service quality and price, but also facilitating the bundling of charging with other services.

Contracting approaches for open platform systems with certified service providers differ from the unitary charge payment PPP approach, in that they are designed to ensure minimum levels of service and emphasise the auditability and reliability of data for revenue collection. These approaches make provision for the transfer of account and charging data to another provider if it closes for any reason. There are specific risks and issues that need to be addressed in the certification and contract process for such systems, depending on the scope of the applicable policy. It also allows bundling of other value added services to enrich the customer experience. These value added services can promote greater integration with parking and public transport that may enable mobility as a service.

6.2. Governance and institutional implications

It is critical that any development of an urban road pricing scheme should consider the governance and institutional arrangements for the procurement and operation of a scheme. Such arrangements provide a framework within which policy, procurement, programme management and deployment are delivered.

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Traditionally, many transport policy or operational agencies do not hold the institutional knowledge or culture that is consistent with the delivery of a road pricing system. A road pricing system establishes a direct customer-provider relationship between road users and the road provider (and the supplier of the charging service itself, which may be an agent of either the road user or the road provider, depending on the procurement model adopted). This is much closer to the commercial model of infrastructure delivery seen in other parts of the transport sector, including how commercial road users operate themselves.

Traditionally, road controlling authorities have been dominated by engineering imperatives, in that they provide infrastructure that road users then use, with little formal relationship between user and provider. Nationally collected motoring taxes establish only a limited relationship.

Urban road pricing creates such a relationship, and with it are expectations of customer service, of responsiveness to queries, complaints and issues in paying it. However, it also creates expectations of levels of service in terms of traffic flow and reduced congestion.

As the charge establishes a new relationship between users and the provision of the road, consideration may be given to reviewing institutional arrangement to ensure that the right type of agency with the correct powers, capabilities and incentives is responsible for the scheme. The key roles and responsibilities should be identified for a responsible entity, and the options for such an entity (including the creation of a new one, or transfer or creation of new powers for an existing one).

6.2.1. Powers

The operation of an urban congestion pricing system will require a responsible agency to have a range of powers that enable it to respond flexibly to a wide range of operational and policy imperatives. Some of these matters may traditionally be seen as matters for legislation or regulation, but for a road pricing scheme to be responsive, some such powers may be better placed directly of an agency, with appropriate regulatory oversight. These powers should include:

- Definition of chargeable events;
- Establishing, revising and abolishing the location, time of operation and schedules of rates for each charging location;
- Establishing, revising and abolishing discounts and exemptions, including the definitions, processes and criteria for applications, penalties for fraud;
- Suspension of operation of the scheme entirely or at specific times and locations for operational or other policy purposes (e.g. road closures, special events);
- Discretion around the issuance of penalties, including waivers;
- Management of net revenues;
- Procurement of infrastructure and services related to charging;
- Definition of charging products;
- Management of any relationships with other charges, taxes;
- Management of relationships with other road controlling authorities and public transport service providers;

- Relationship with inter-related traffic management systems (whether through ownership and operations, or contract);
- Ownership of aggregate data collected through scheme operation.

6.2.2. Capabilities

The responsible agency should have the institutional capabilities to carry out its functions, including management and operational experience with large scale customer service and billing systems. Entities with some parallel functions include telecommunications and energy utilities, which have significant capacity not only to manage customer relations, but also address queries, complaints and supply of customer information. The responsible agency should be capable of specifying, procuring and managing the testing, commissioning and implementation of a charging scheme, most importantly including the functions of communicating with the public, user groups and the media about how the scheme will operate and what it means for them.

In addition to supporting the development and implementation of a pricing scheme, the responsible agency needs to be responsible for informing the public about the scheme, communicating its purpose and establish a clear understanding about when, where and how it operates and what users need to do to be compliant.

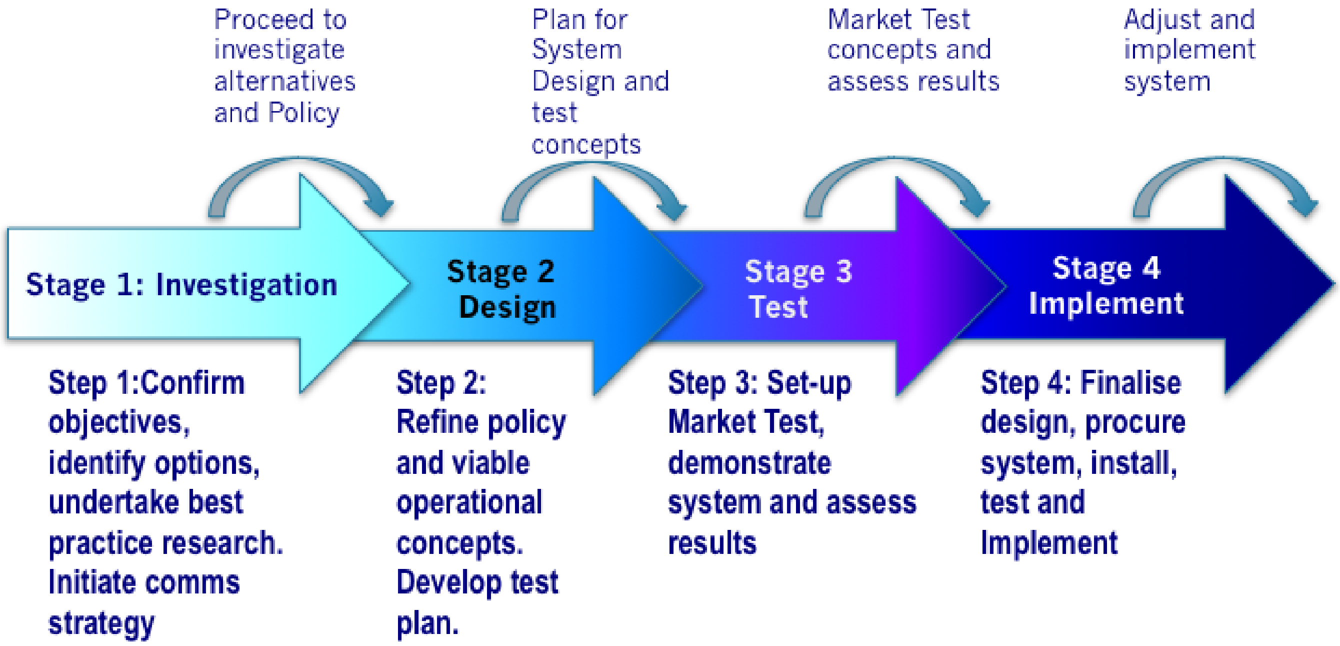
6.2.3. Incentives

The responsible agency should be incentivised to ensure users of the road pricing scheme receive a high quality of service, not only when they interact with the scheme but also in using the charged roads. If a road pricing scheme is intended to reduce congestion, improve trip reliability and travel times, the responsible agency should also have the right incentives to ensure the policies and operation of the road charging scheme support this. The responsible agency should also have the right incentives to ensure other operational elements of managing the charged road network do not undermine the objective of improving congestion.

6.3. Indicative programme for delivery of urban road charging system

Once strategic policy objectives and an outline road pricing concept is developed, there are four main phases in development of such a programme to implementation; these are illustrated in Figure 35 below.

Figure 35 - Four Stages of the Implementation Process



Stage 1 - Investigation: The first programme step is to set the overall policy objectives of the programme, and to identify and assess the options to achieve those objectives based on best practices evolving in the delivery of similar schemes. Options at a policy and operational concept level are identified and considered, in the context of best practice elsewhere. These should be appraised and those that appear to have greatest merit are taken to the design stage. This stage of the programme is primarily a policy, communications and technical option development activity. This should also include demand, traffic, revenue and cost modelling.

Stage 2 – Design: The shortlisted options for policy, operational concepts and system design are developed in more detail, with specific concepts to be taken further for assessment in the market test stage. When a refined operational concept and set of policies are decided, a public consultation process should test them against a wider audience, both of prospective users and the general public (including key lobby groups) to help build a wider consensus around congestion pricing. Caution should be taken to not engage the wider public until a sound, conceptual basis in developed, but one should always lead and build public engagement and communications upon the overarching objectives of the programme/project. This stage of the programme is more technical and communications focused, but still with much policy activity and is also likely to be the stage at which legislation may be initially developed.

Stage 3 – Test: As suggested by the success in Stockholm and Oregon, a demonstration and/or pilot of the operational concepts should be considered (although it is not essential). The purpose of demonstration testing is twofold: to prove the technology and operational concepts and to expose a small number of users to both the concept and its possible implementation. A pilot test provides a robust assessment of the system to measure and evaluate both the acceptance of the various operational concepts and the overall approach being taken. This assessment is the key ingredient in refining and modifying the operational concepts before advancing to procurement, installation and implementation. The results of this testing phase are used to finalise the concept for procurement and implementation. This stage is technical and communications led, but also is a significant increase in early procurement activity.

Stage 4 –Implementation: Supplier/s are selected and the system is installed and the user community is made aware of the inauguration of the charge and what they need to do to pay and be compliant with it (and the consequences of not doing so). As part of the implementation, integrated system testing will be undertaken to ensure that all vendor systems are working effectively, efficiently and appropriately communicating and interacting with each other. This stage in the programme is a combination of communications (making users aware of what they need to know) and technical audit, to ensure installation and testing is on schedule and successful.

These stages should take approximately 3 to 4 years. While some vendors may seek to accelerate this, the proposed timeframe is reasonable, based on successful programmes elsewhere to effectively communicate and engage users, and ensure the successful testing and implementation of the system. The time line also recognises sufficient time for suppliers to make necessary modifications of their equipment, software and systems when shortcomings in operations or performance are identified in testing.

Table 8- Workstreams based on other Programmes and Worldwide Best Practices

Stage of the Programme >	Investigation	Design	Test	Implementation
Policy	Shortlist preferred options that affect design and legislation	Finalise compliance and enforcement approach for legislation	Refine policy based on trial feedback.	Finalise charge schedule, policy, discounts/exemptions
Communications and Engagement	Prepare communications plan, manage communications, and begin media outreach. Baseline surveys and interviews	Engage full formal consultation with stakeholders. Recruit demonstration or pilot participants. Attitudinal surveys. Prepare and distribute information	Pro-active communications during demonstration or pilot. Participant surveys and wider public engagement	Continue media engagement and report findings through greater public engagement. Briefings to decision makers. Comprehensive report on user attitudes
Business Case	Initial review of baseline business case. Demand, revenue and cost modelling	Undertake full financial and economic appraisal	Refine business case with revised costs from testing, demand and policy inputs	Post-procurement revision of financial appraisal and establish further cost reductions through incremental improvements
Institutional arrangements	Identify and assess options for appropriate institutional arrangements	Revise recommendations based on finalised enforcement approach. Pass necessary legislation	Create transitional arrangements for changes in responsibilities	Monitor operations of new institutional arrangements. Perform independent evaluation and reviews to target further efficiencies and cost savings over time
Programme Management	Prepare Programme Strategic Plan and establish programme budgets. Coordinate and manage workstreams,	Coordinate and prepare deliverables for test stage. Create test plan and evaluation plan.	Monitor demonstration or pilot and reporting of outcomes through evaluation criteria. Measure acceptability and	Monitor implementation and reporting of workstreams. Participate in and help market the system to users and the public.

Review of international road pricing schemes, previous reports and technologies

Stage of the Programme >	Investigation	Design	Test	Implementation
	provide interface with management and Ministers.		refine operational procedures.	
Risk management	Identify programme risks, likelihood, impacts, responsibilities and mitigation strategy	Implement and review programme risk strategy for design stage	Implement and review programme risk strategy for test stage	Implement and review programme risk strategy for implementation
Procurement	Assess and identify preferred procurement approaches, set up vendor engagement plan. Develop contract approaches	Commence vendor engagement, set up demonstration or pilot. Finalise contract approaches and evaluation of each system element.	Conduct demonstration or pilot and collect and report on evaluation data. Prepare for tender/s.	Undertake procurement and sign contracts for delivery.
Complementary Measures	Develop options for complementary measures for traffic management, public transport and scheme concessions	Finalise costs and delivery plans for complementary measures according to type	Deliver infrastructure and service based measures in advance of operation of pricing scheme	Confirm operation of all complementary measures
Delivery	Consider delivery assurance approaches	Select approach including personnel or delivery partner	Engage with likely vendors, using input from demonstration or pilot, develop monitoring and auditing approach	Monitor installation, testing and system inauguration. Report on readiness of implementation and system integration.
Estimated Timeframe	12 to 16 months	12 to 16 months	9 to 18 months	6 to 12 months

7. Key lessons for Auckland

- Let policy lead technological choices, even if technological choices may provide limits around what is achievable on a step-by-step basis.
- Focus on designing a scheme that can be easily implemented, that will demonstrate clear, sustainable results, without constraining options for scalability and flexibility to evolve further.
- Do not seek to develop the perfect solution as the first scheme that is introduced. Complexity risks greater confusion, suspicion and opposition from the public, who may not accept too much of a change from the start.
- Seek to balance the desirability of simplicity and ease of understanding with targeting congestion where and when it occurs. The blunter the scheme, the more the concerns about fairness and need to mitigate equity issues.
- Clarity on use of revenues is critical to building public acceptability; it helps for at least some of the net revenues to be applied to roads (e.g. Stockholm, London).
- Lead the public communications narrative as to the purpose of the proposal and emphasise its benefits to road users.
- Flood the public with information and seek to have answers to as many questions as possible, even if it includes matters that are under study. The more you can be seen to be able to answer issues and concerns, the more confidence the public will have over the proposal.
- Demonstrations and pilots can be valuable in building public confidence by focusing public attention on a real-life application of technology to engage their opinions on various policy and user options. They can also build institutional knowledge and awareness of policy and design issues, and reduce the risks around deployment.

7.1. Key themes

The main lessons to be learned from international experience in developing and implementing congestion pricing systems can be categorised into three main themes:

- Policy (including scheme design);
- Public acceptability;
- Delivery.
- Complementary measures

7.2. Policy

Lessons in policy come within a range of elements including:

7.2.1. Start with an achievable scheme that targets a problem and evolve

For a scheme to be understood and accepted by the public, it should be sufficiently easy to understand so that the public knows how to be compliant and how to avoid having to pay (i.e. change route, change time of travel or change mode). London, Stockholm, Gothenburg, Dubai and Milan are all relatively simple schemes, as was Singapore with its original ALS. However, it is also important that the scheme is not so blunt that it is seen as charging road users on routes and at times that are not congested. Gothenburg's scheme is relatively blunt, and has chosen a scheme where the cordon crosses residential areas and roads that are not heavily congested at peak times, which has undermined public acceptability and created local economic and social issues that it is seeking to address (separating a suburban shopping centre from residential areas on uncongested roads). Singapore is the most sophisticated, but is too complex in its current form to implement in one step. Singapore evolved from its simple cordon scheme to a far more disaggregated scheme over several years, as users understood how it worked and its purpose. Although Auckland should develop a scheme that is relatively easy to understand, it should not sacrifice achieving objectives and minimising negative impacts for the sake of simplicity. Schemes that are excessively simple and so have blunt impacts on congestion, but also blunt negative impacts are less likely to be acceptable than those with more refinement in design.

7.2.2. Demand modelling has limitations but is useful for designing the first set of rates

All schemes internationally saw demand responses to the introduction of congestion pricing that were within the range forecast by demand modellers (typically 15-20% reductions in traffic). In all cases, this is for charges introduced on cordons or area charges or corridors approaching the central city. This means not only reductions in the number of charged vehicles, but also improvements in traffic speeds. Auckland should have some confidence that effective demand modelling can forecast what will happen to traffic levels for any point based system design. However, *subsequent* increases in charge rates tend not to have a similar level of elasticity of demand, as reported by Stockholm. This is attributed to the profile of road users that choose to pay having a higher value of time and lower demand elasticity than those that have been priced off of the network already.

Furthermore, in both Stockholm and Gothenburg it was observed that demand models cannot identify when road users choose to change departure times for trips because of peak/offpeak pricing. In both Stockholm and Gothenburg, overall traffic flows have smoothed across the peak/offpeak period suggesting a higher demand response in the peaks, but there is no way that has been identified to reliably measure what proportion of peak trips shifted to the offpeak, and the proportion of offpeak travel that has been suppressed from travelling at all. Trip diaries are considered unreliable by Stockholm as memories of regular trips are poor, and models are poor at identifying when road users choose to travel less frequently.

No scheme designer has developed models that can effectively forecast the specific impact of highly refined road pricing schedules for network road pricing. Strategic demand models can estimate total impact on vehicle kilometres travelled, but cannot identify the proportion of road users that may time shift, route shift or not travel at all.

7.2.3. Charge rates should be adjusted to reflect target levels of service

Most pricing schemes adjust prices irregularly. London has only ever increased prices four times over 14 years, Stockholm once in 10 years. However, Singapore adjusts prices every three months, to reflect network performance and this includes decreases in prices if traffic speeds are above a set level. This helps ensure that charge rates are not too high for the travel time savings obtained and so do not price away economically valuable trips, but also means that a minimum standard of network performance in assured. In no other system is network performance managed so actively through pricing. In addition to helping to optimise prices to manage congestion, it also helps build public acceptability. Not only are those paying the charge effectively guaranteed a minimum level of service, but also by reducing charges it dispels concerns that the scheme exists primarily to generate revenue. For Auckland, having a process and methodology to revise charge rates to reflect network conditions could have positive economic, social and public acceptability impacts.

7.2.4. Different charges by time of day helps spread demand

Experience in Singapore, Stockholm and Gothenburg indicates that having a graduated series of steps in charges up to a peak rate (and down again) helps to spread demand. Gothenburg reported that the charging scheme has spread demand to a "fairly even level" during charging hours. Stockholm reported that the charge had a traffic smoothing effect, but that demand modelling cannot capture when trips are made at different times of day. Trip diaries are also not reliable, as most motorists do not remember their trips patterns for more than a few weeks. It can only be assumed and managed by trial and error that differential time of day pricing can spread trips by time of day.

7.2.5. Area charges are relatively blunt

Only one operating scheme is an area charge (London). The primary reason it is an area charge is because the technology to implement ANPR based charging at the time it was introduced was relatively unreliable (at best 70% of vehicle number plates would be accurately identified). No other electronic free flow road charging scheme or toll road had solely used ANPR as a charging technology before London. To reliably capture vehicles, sufficient charging points were placed so that the average vehicle driving into the zone would pass 2.5 points per trip. Because it charges for any movement within an area, it can only charge for movement by interval. In London it is one charge for an entire day, this is a poor disincentive for traffic that may make one trip (e.g. delivery vehicles) because it is the same price for one trip as it would be to circulate for an entire day. This is one reason why removal of exemptions for taxis in London would be ineffective, as a one-off payment of the congestion charge could be spread among multiple jobs. It would be possible to charge by smaller intervals to capture regular circulation, but the smaller the interval, the higher the number of charging points needed in the area to capture circulation and the lower the area charge would have to be to avoid a high volume user accumulating a very high charge for circulating across multiple time intervals.

As area charges by definition charge at a flat rate, the only ways to *vary* charges by time of day would be to either to require all vehicles in the area after an interval to pay a particular rate, even if they had circulated in the area one minute beforehand charged at a different rate, or combine a flat rate with differential charging for crossing the cordon around the area. Both would add considerable complexity and create issues of equity.

7.2.6. Conventional economic appraisal is not favourable to congestion pricing schemes

Economic appraisal of both the Stockholm and Gothenburg schemes indicated that the net benefits to those paying the charges are much lower than the amount that they are paying including the social benefits from reduced externalities (€288m and €51m p.a. respectively[94]). This appraisal suggests that these charging schemes are, in effect, revenue collection systems. One explanation is that the value of time for road users may be underestimated, particularly for some types of trips at peak times, and that trip reliability also is undervalued. However, it is also likely that the scheme designs capture many trips that receive little travel time saving (because some of the cordon charging points are not congested without a charge).

Revision of appraisal methodology to take into account segmentation of road users based on value of time (and revaluing the value of trip reliability) may help address this, but more fundamentally, developing a design that only targets congested segments of road at times they are congested is likely to increase the proportion of road users paying the charge that are benefiting from travel time savings. One should be cautious trying to compare economic evaluation across jurisdictions (because of different assumptions such as discount rates and values of time). Another way to ensure a favourable economic appraisal is to use net revenues collected for a purpose that clearly has a high benefit/cost ratio, so that the revenue generated from the scheme is spent on generating net economic benefits. However, it is important to ensure this source of benefits is transparently separate from the scheme's congestion impacts in and of itself.

[94] Sources: Jonas Eliasson, The Stockholm congestion charges: an overview, KTH Royal Institute of Technology, CTS Working Paper 2014:7 and Jens West, Maria Börjesson The Gothenburg Congestion charges: CBA and equity, KTH Royal Institute of Technology, CTS Working Paper 2016:17

Distributional impacts of the benefits of any scheme funded by pricing scheme revenue may also be relevant.

7.2.7. Take care in applying discounts and exemptions

Discounts and exemptions are effective tools to mitigate negative impacts upon road users that are not the subject of the scheme (for demand management) or which would otherwise experience excessively negative impacts from the scheme. However, discounts and exemptions add costs to any scheme, as they add administrative complexity in reliably identifying eligible vehicles and ensuring details are accurate for such vehicles if circumstances change. Measures also need to be taken to minimise fraudulent claims for discounts and exemptions. Discounts and exemptions reduce scheme revenue and can reduce the effectiveness in managing congestion. Emergency vehicles are universally exempt as are cars used by those with disabled parking permits. Buses are exempt in all schemes except Singapore because there is no demand response expected from them. However, London has a long list of discounts and exemptions, which due to the relatively low proportion of private car traffic in the charging zone, means that half of traffic circulating in central London does not pay. This has undermined the effectiveness of the scheme in managing congestion. It will be important for Auckland to be strict about applying discounts and exemptions to maintain scheme credibility and minimise financial impacts.

7.2.8. Use of revenue is important in delivering benefits and public acceptability

Most charging schemes have net revenues dedicated for transport capital and operating expenditure in the cities concerned. The efficient use of such revenues can help offset a negative economic appraisal, if the benefits from the demand response of the charge are outweighed by the charges collected. The use of net revenues to improve local transport can also assist in improving local roads (Stockholm), improve alternatives to driving (London) or offset reductions in other taxes (Singapore). However, the use of net revenues in Gothenburg has undermined public acceptability, primarily because the main projects being funded will not be open until 2020 or beyond, and there has been extensive National Audit Office criticism of the economic value of the largest project. In Edinburgh and Manchester, proposals to use almost all net revenues to fund major public transport projects were not supported, in part because sentiment from those who would pay the charge saw no benefit to them from those projects. In the Netherlands and Finland, projects were to introduce charges to correspond to reductions in registration and sales taxes of vehicles, but public opposition arose because of concerns that this would not be enough to offset the new charges or that the cuts in taxes would unduly benefit the rich (cutting sales tax on new cars).

7.2.9. No schemes to date have had to address serious distributional impacts

The schemes introduced to date have almost all focused on congested inner city locations, with a high level of public transport provision, so that few negative distributional impacts have been observed. Distributional analysis of Gothenburg indicates its congestion tax is regressive, largely because low-income individuals are highly car dependent to access employment (and may be less likely to have access to suitable alternative transport modes) and higher income users are more likely to have company cars (for which they do not have to pay the congestion tax themselves). Given many who pay the Gothenburg scheme are not gaining significant travel time-savings, this suggests the scheme charges many users excessively for congestion management purposes.

Care will need to be taken in Auckland to design a scheme that minimises such regressive impacts, but international experience on scheme design does not offer example of how to effectively mitigate this beyond improved alternative choices (which are relevant) or highly targeted congestion pricing by location and time.

7.3. Public acceptability

7.3.1. The importance of public support

It is not easy to develop public support to pay more to use the roads. Road users may believe that they "already pay" for the roads through existing motoring taxes, and if there is no direct relationship between paying for a road and improvements to the road or a new road (as with tolls), there is likely to be scepticism as to the value of paying more at the times roads are the busiest.

When congestion pricing has been advanced in many cities, some of the public reactions have included scepticism that it will reduce congestion ("I have to drive at that time, nobody does this for fun"), scepticism that the political objectives are to reduce congestion (rather than raise revenue) and extensive unfamiliarity with the concept. Lack of understanding and familiarity with congestion pricing can mean that the public speculates as to the purpose, impacts and how such a system would work (or not work) for them.

The single biggest factor that has halted development of urban congestion pricing schemes internationally has been a lack of public acceptability. Schemes in Manchester, Edinburgh, Helsinki, the Netherlands, Copenhagen and New York were all abandoned because of public opposition, whether expressed by referendum (Manchester and Edinburgh) or the erosion of political will (Helsinki, the Netherlands, Copenhagen and New York). Even schemes with an apparent political mandate to proceed (Copenhagen) or strong political champion (New York) were vulnerable to being blocked by organised opposition that proved too difficult to address.

Schemes that have succeeded have done so because policy, design and communications with the public were in synergy so that those who would be likely to pay the charge and the general public more widely *accepted* the merits of the proposal and were willing, on balance, to agree to it proceeding. Policy and design are addressed elsewhere in this chapter. Described below are the key elements to having a successful communications and strategic engagement strategy for congestion pricing.

7.3.2. A political champion is helpful, but not sufficient

In London, Ken Livingstone was the political champion for the congestion charge, which helped tremendously in delivering political momentum for the scheme, because he was elected on the promise of implementing it. A political champion can provide leadership on policy and communications, and the imperative to advance the project against stakeholder concerns or opposition. Political champions, in the form of political parties, promoted both the Stockholm and Gothenburg schemes. However, in New York, Mayor Bloomberg was the political champion for its proposed cordon scheme, but this was insufficient to advance the project because he did not have the legal authority to impose the charge (it required state legislative approval which was not forthcoming). In Copenhagen, the government was elected with a manifesto promise to introduce a congestion charge, but extensive criticism from the opposition and local concerns undermined momentum and the scheme was shelved. In both Edinburgh and Manchester, there was no major political champion empowered to implement the scheme.

7.3.3. Develop a strategic engagement strategy

London ensured the acceptability and success of its scheme by having a comprehensive strategic engagement strategy that included engagement with key stakeholders in business, community, the transport sector and with road user groups. It hired a professional communications firm to develop a strategy through all of the stages of the congestion charging programme, from the decision by the Mayor to proceed with the scheme, through consultation on scheme policy details (including location of the charge, discounts and exemptions), to installation and commissioning of the scheme. It was focused on getting support from stakeholders and *leading the narrative* on the congestion charge in the media and with the public.

7.3.4. Sell the problem of congestion and the solution

Core to public acceptability of any congestion pricing scheme is that the public need to believe the problem is serious enough to warrant the solution. In Singapore, London and Stockholm this was done successfully, as the seriousness of congestion at peak times in the areas proposed for charging was demonstrable. To sell congestion pricing as a solution, it is important to outline that the traditional alternatives are either not feasible (e.g. widening roads in central London) or have been exhausted (e.g. high density provision of public transport), and that pricing has had success elsewhere in moderating demand for road space at peak times Part of building acceptability about pricing being a solution is demonstrating to the public that the problem of congestion is understood and that the objective of the proposal is to address this.

7.3.5. Provide as much information as possible to lead the narrative

Congestion pricing is a highly unfamiliar concept in New Zealand. Media coverage to date already refers to it as tolls, which have a range of connotations in New Zealand, including toll booths (as once seen on the Auckland Harbour Bridge), charges that apply 24/7 and the operations of toll roads seen in Australia (some of which get heavily congested). It is critical that terminology, purpose and understanding of congestion pricing are consistent, clear and easy to understand. It should be made clear that congestion pricing is *not* tolls, as it is not charging for road use simply to pay for infrastructure.

London and Stockholm both ensured that as schemes were being developed and cities prepared for their introduction that there was no shortage of material provided to stakeholders, residents of affected areas, the media and the general public about the charging schemes. TfL's view is that by doing so, it ensured that speculation about elements of the scheme were minimised and that only factual information would be published by the media. Part of this strategy is to reduce the credibility of opponents who may wish to spread misinformation. The more information that is provided, the more difficult it is to claim the scheme has been developed "in secret" and that there is a contrary agenda. By contrast, Gothenburg provided minimal information to the public resulting in ongoing public opposition to the scheme. Neither Edinburgh, nor Manchester provided sufficient information. The Manchester Evening News published on its front page an incorrect geographical depiction of the scheme. In-house surveys undertaken during the referendum campaign in Manchester found a third of respondents thought they would be charged on the roads that formed the boundary of the cordons (they would not have been).

7.3.6. Treat communications like a political campaign

Opposition campaigns for road pricing schemes can develop quickly and gain momentum based on a series of simple messages regardless of their accuracy. This is what happened in Edinburgh and Manchester. Strategic engagement about congestion pricing is not like any conventional marketing programme for a product and is unlike the communications activities traditionally undertaken by transport authorities. Those who treated it as an extension of conventional transport public relations (as in announcements about new train services) found their approach wanting (e.g. Manchester, Edinburgh and New York).

7.3.7. Communicate benefits to those who will pay

A core group that needs to be convinced of the merits of any scheme is those who would be subject to pay the charge. First, strategic engagement needs to make it clear who *will* pay, which means not only types of vehicles, but there being a clear understanding of *where* there will be a charge and *when*. Beyond this, the scheme promoter should communicate the benefits to those paying, which should have three key elements; travel time savings, travel time reliability and the value of the use of net revenues (see 7.2.8 above). In both Edinburgh and Manchester, there was a failure to communicate to those who would pay why they would benefit from the congestion pricing proposals. In the case of Manchester, the emphasis was the declared value of the public transport projects that would be funded by the scheme, which gave the impression that the scheme was about raising revenue (for projects that would not directly benefit those paying), rather than easing congestion.

7.3.8. Use strategic engagement to consult on what you want to know

Consultation about congestion pricing should be used as an opportunity to ask the public questions about issues that the responsible authority wants feedback about. Transport Department Hong Kong most recently did this, by specifically seeking feedback about privacy, indicators to measure effectiveness of congestion pricing and what complimentary measures should be prioritised. It also sought feedback on the basic elements of the concept, such as the location of charging points, the type of charging scheme (cordon vs. area charging), charging period and discounts/exemptions. Directing issues for feedback helps to increase the value of consultation and can help the responsible authority decide on policy matters informed by actual views rather than assumptions. For example, consultation on discounts and exemptions in Hong Kong produced considerable feedback that these should be minimised, because submitters thought it was unfair to grant concessions to some road users that would reduce the effectiveness of the overall scheme.

7.3.9. Privacy is an issue, but is likely to be exaggerated

As any road pricing system involves identification of the location of vehicles at specific times, it has the potential to raise privacy concerns. Early implementations of congestion pricing saw some sensitivity to privacy as an issue, with both Singapore and London conscious of the need to protect individual privacy (and building options to do so into design). However, privacy is much more likely to be a concern for proposals for GNSS based systems than others. Privacy issues tend to get raised by opponents along with other issues as a reason to fear road pricing, primarily out of concern that government or companies will "track movements". Detailed design should seek to develop ways to address privacy concerns, but it is important that language used around technology avoids claiming that systems "track" people. It may be helpful to communicate that road pricing systems exist to identify and measure chargeable events and that if these events are paid for, there is no need to keep details about when and where vehicles undertook those events.

7.4. Complementary measures

7.4.1. Public transport and active transport modes are important enablers

Core to successful congestion pricing schemes internationally has been the availability of adequate capacity and quality of public transport to enable a segment of car users to change mode of travel at peak times. Schemes in Singapore, London and Stockholm have all implemented improvements to public transport capacity and frequency in advance of introducing charging schemes. Although all cities already had well developed public transport infrastructure, modelling indicated that there could be a shift in demand from car to public transport, so all introduced more frequent bus services, and in some cases new bus routes to cope with the change in demand. This proved to be a success, indeed Stockholm reported that the additional capacity provided was excessive and was progressively reduced in coming months.

It is difficult to prove the extent to which increased public transport patronage is due to the congestion pricing schemes, rather than improvements in service frequency and quality.[95] Proposed schemes in Edinburgh, Manchester, New York and Copenhagen were also to have improvements to public transport to manage additional demand. Gothenburg had relatively little improvements to public transport provided because it was considered that there was sufficient spare capacity in the network to meet forecast additional demand.

7.4.2. Traffic management and road improvements can support a charging scheme

Congestion pricing schemes may include bypass routes for vehicles that do not wish (or need) to enter a charged zone or cross the cordon. Such routes may experience increases in traffic, as vehicles that may have driven multiple routes across the charging zone are incentivised to follow the bypass route. In advance of introduction of a charge, measures should be considered to ensure the capacity of the bypass or orbital route (and in particular intersections or junctions) is adequate to manage increased demand. If a scheme is designed to enable free use of a route to bypass one or more charging points, road improvements may need to be made to ensure new bottlenecks are not caused by changes in route selection.

7.4.3. Take care in designing a scheme that is reliant on offsetting tax cuts

Reducing other motoring taxes in exchange for the introduction of congestion pricing has only occurred to date in Singapore, although both Finland and the Netherlands planned such a measure in exchange for the introduction of nationwide road charging schemes as the first stage towards implementing urban congestion pricing. In all cases, the tax cuts applied were to apply generally and were primarily focused on fixed annual or sales taxes, rather than taxes on consumption (such as fuel).

7.5. Delivery

7.5.1. Maintain momentum

If there is considerable political support and sufficient political acceptance for the concept of congestion pricing, it is important for project momentum to be maintained to ensure there is steady progress. For Hong Kong, the Netherlands and Edinburgh, lengthy periods of investigation and scheme development were followed by changes in the political environment and public mood for the proposals. If momentum is lost in detail or progress appears to be stalled, there is opportunity for opponents to seek to undermine the programme and delay it or spread misinformation about it. In the case of Hong Kong, a loss of momentum saw concerns over congestion wane as an economic slowdown reduced pressure from business and the public to address congestion. In Edinburgh considerable public support for the concept of congestion charging was undermined by lengthy development periods, slowing momentum and giving time for opponents to develop arguments against the scheme.

7.5.2. Demonstration or pilot can build capability and public acceptability

Trials have been used to demonstrate technical capability of scheme options, but have also been used to prove the demand suppression/congestion relieving impact of a scheme (the Stockholm plot) and to obtain feedback on options for users and direct public debate and discussion towards an operating (simulated) scheme (e.g. Oregon). For responsible authorities with little experience of demand management based road pricing, it can provide an opportunity to test interfaces between customer service, account

[95] Moshe Givoni, Re-assessing the results of the London Congestion Charging scheme, University of Oxford, 2010.

management, roadside infrastructure and other agency functions, and test design concepts. It can also be useful in demonstrating to the public how a system may work in real life, obtain feedback about design and customer interface options and focus media and public debate on a functional system rather than an idea. Experiences of demonstrations or pilots in road pricing mostly see volunteer participants leave a scheme more convinced of its merits than when they started participating. This can help build public acceptability and show commitment to involving the public in policy and system design.

7.5.3. Provide sufficient customer service capacity for all users to get a high standard of service

London paid for a backup call centre to be in operation in case the main one would fall over on the day the congestion charge was introduced. This was to ensure that nobody could complain that they could not get queries answered or make payments for the congestion charge based on sitting on the phone in a queue. It is important to build public confidence in any scheme by ensuring there is sufficient capacity to provide quick responses to queries or to set up or pay any accounts or bills.

7.5.4. Own the data

Be wary of suppliers that want to hold system data as proprietary. Regardless of the procurement or contract model, responsible authorities should contract on the basis that all data generated by a congestion pricing system should be owned by the responsible authority. This not only makes it much easier to analyse performance of the system and better monitor costs, but it makes it much easier to change contractor or supplier of charging services.

7.5.5. Consider procurement models that allow competitive delivery

For responsible authorities with little experience of developing, operating and managing congestion pricing systems it may be tempting to agree to a single PPP to provide an end-to-end solution to supplying and operating such a system. However, these may be difficult to unwind after several years and restrict the provision of customer service (and scope for innovation in value added services) to one entity. It may also be difficult to ensure that the concessionaire does not take advantage of cost savings rather than pass them onto the public sector. Options that allow for open certification of customer service providers (as is the case with eRUC in New Zealand today) are worthy of consideration.

7.5.6. Promote compliance

To minimise operating costs, it is critical to encourage high levels of compliance by users. This is undertaking by promoting a clear understanding of what is required to be compliant and the penalties for failing to do so. Management of queries, complaints and challenges to fines can be a significant cost in the initial years of a scheme.

7.6. What should be done

- Design a scheme that will be effective in improving conditions for the location targeted, but don't promise it will be the "magic solution" in the first phase. Scalability is helpful, but don't let scaling it take over the narrative, focus on delivering a workable, acceptable, feasible scheme.
- Minimise complexity, but avoid being too blunt, balance between targeting bottlenecks and not creating worse impacts.
- Undertake demonstrations or pilots, primarily to provide a focus for the public to engage with proposals and policy options. Such demonstrations are less about technology and system risks

(although there is value in using trials to help identify and reduce these), but more about building public confidence and addressing public concerns.

- Provide clarity on use of revenues (whether new spending or offsetting cuts in other charges).
- Lead the narrative with the media and the public, swamp both with information and be pro-active about data and information.
- Accept the first year or two may not generate much net revenue as costs will be high in building public understanding and managing a high level of user interaction

7.7. What should not be done

- Do not let others lead the debate, particularly ensure you can avoid an organised campaign of opposition. Do not let an absence of information exist, because opponents will fill the vacuum.
- Avoid charging uncongested traffic. To maximise economic efficiency, charging should be focused when and where congestion is imposing significant delays (and therefore costs) on road users. This also will improve the public acceptability of charging.
- Do not lose momentum, maintain and manage a programme from option development to delivery.
- Do not seek to develop the best solution from day one. Make a meaningful difference to a location or small area for a set period of time to prove the concept, then expand or implement elsewhere.