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Congestion Pricing Options for Auckland: *analysis of distributional effects*

Prepared for

The Congestion Question

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Executive Summary

Background

This report provides an input to *The Congestion Question* (TCQ) project, a joint project between central government and Auckland Council to investigate whether to introduce congestion pricing in Auckland. Phase I examined the emerging congestion problem, whether there were technical barriers to implementation and reviewed international examples. It concluded that congestion pricing shows considerable potential for tackling Auckland's congestion problems.

This study aims to support the project Steering Group to deliver a social assessment required as part of the Phase II evaluation of a short-list of options.

This study is not a cost benefit analysis (CBA); it does not address the full set of costs and benefits that would be included in a CBA. However, it examines the way in which the financial costs of congestion charging would be distributed across the region, particularly amongst households by income category (low, medium and high), as supplementary information to accompany a CBA.

Impacts of Overseas Schemes

A review of international literature undertaken to examine the distributional impacts of congestion charges suggests:

- Higher income households tend to face higher costs because they tend to drive more, are more likely to drive to areas (such as city centres) which are charged, and are less responsive to price increases so they tend to pay the charge rather than reduce trips.

- Low income households tend to face higher costs as a percentage of income, so the impacts on these households may be greater. They are also more likely to take actions to avoid charges than high income households. This includes shifting mode (to PT or active modes) and overall trip suppression.

- The distributional impact of the use of additional revenues raised by the charge is important to an overall understanding of impacts. This is beyond scope for this study.

New Zealand Studies

Several studies have examined potential impacts of road or congestion pricing in New Zealand. Recent analysis by MRCagney (MRC) suggests most types of households would experience increases in the financial costs of travel, offset to varying degrees by benefits related to faster or more reliable travel, or improved accessibility. The estimated scale of these financial impacts is on the order of 1% of household income. MRC suggests lower-income households and households with children are likely to experience the largest financial impacts relative to their incomes. This principally reflects variations in household incomes, rather than variations in the financial costs of the scheme.

Options for Analysis

For this study we examine the impacts of five different congestion charge designs. The geographic limits are shown in Figure ES1.

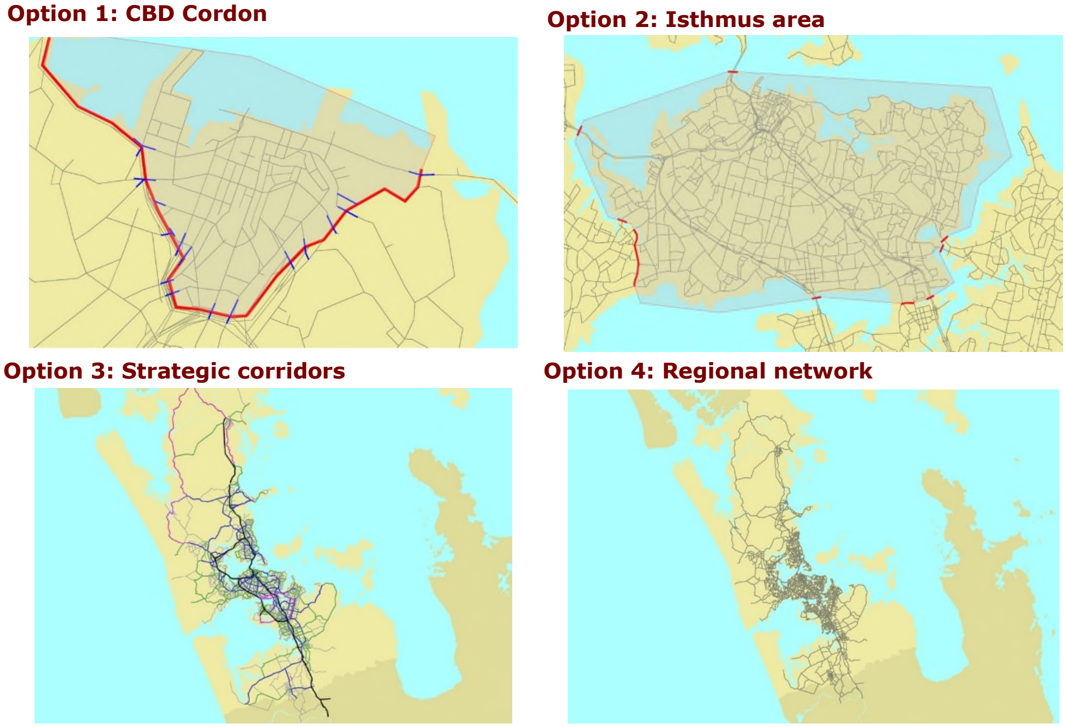
Two cordon charges would charge a fixed amount for entering the charge area:

1. A cordon charge for the central business district (CBD). This is the area bounded by State Highway 1 (SH1) and SH16 from Grafton to the Port.
2. An area charge for the whole of the isthmus north of Otahuhu and bounded by the Harbour Bridge to the north and New Lynn to the west.

Two corridor/network charges would charge an amount per kilometre within the charging area:

3. A corridor charge in main arterial routes in the city
4. A network charge covering the whole of the regional network
5. A combined CBD Cordon (option 1) and corridor (option 3) charge.

Figure ES1 Geographical boundaries for congestion charging options



Source: Auckland Transport

The pricing assumptions are shown in Table ES1. The charges are assumed to operate at AM and PM peaks. This would mean those entering cordon areas would face a cost of entry in the morning and of departure in the afternoon/evening. For the corridor and network options the charges apply to every kilometre driven in the charging area during these time periods.

Table ES1: Price assumptions for congestion charging options

Charge design	Charge rate
Cordon charges	$2.30/cordon crossing
Corridor/network charges	$0.12/km

Source: Auckland Transport

Methodology

For analysis, we undertake the following steps:

- The options are used to specify runs for the Auckland Forecasting Centre's Macro Strategic Model (MSM). These are used to produce outputs for a base case (no congestion charge) and the charging options. MSM estimates some impacts of congestion charging (particularly route and mode changes) but does not fully capture trip suppression or trip chaining responses.

- The MSM outputs are in the form of origin-destination matrices, including trip numbers and trip costs.

- These trips are distributed to households within the trip origin areas using:
    - Trip rates for different household types taken from the Ministry of Transport's Household Travel Survey (HTS); and
    - Statistics NZ census data on household numbers by type and location.

- Price elasticities are applied to modelled household private vehicle trips and costs to estimate the total travel demand response, including impacts on mode choice that are measured by MSM.

- A difference analysis is undertaken between the base case and the options, of the trip rates and costs, by location and household type. The analysis focuses on changes in travel (or trip) costs as a percentage of household income.

The business analysis is more straightforward. We assume, as a first approximation, that there is no price response beyond that measured by MSM. Rather businesses will generally choose to pay the charge. We estimate impacts for business in aggregate based on modelled employer business trips and freight trips.

Results of Analysis

Liability to the Charge

Different numbers of households pay a charge under the different schemes, reflecting their location and trip routes relative to the charged area.

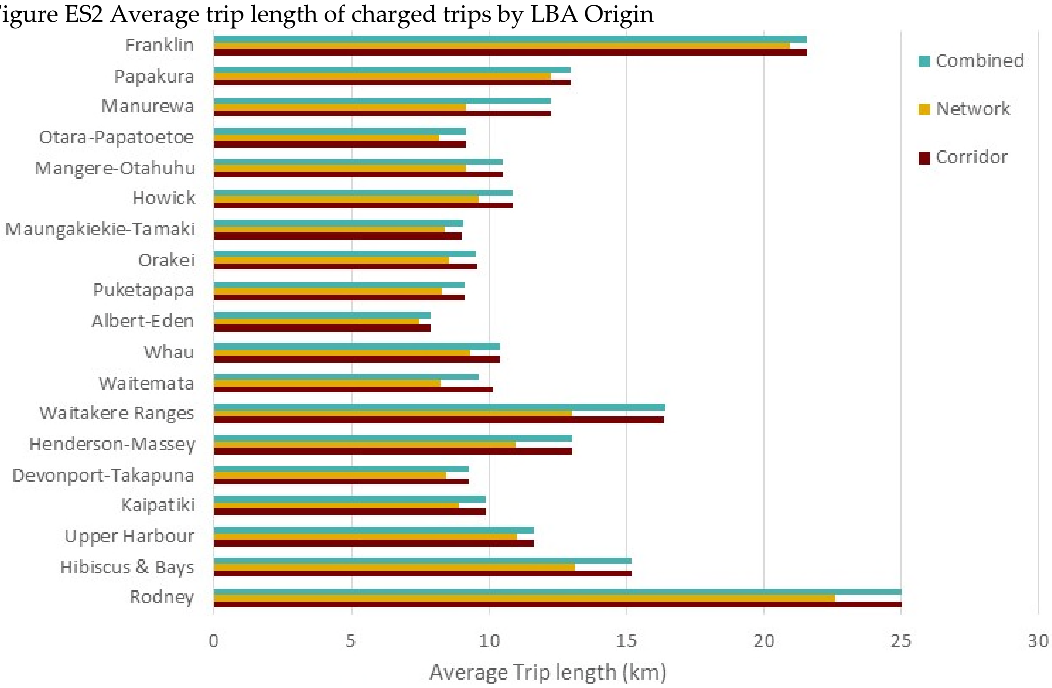
Table ES2 shows the percentage of trips which would face the charge under the different options. These are the base case trips which, if they do not shift (mode, time or route) or are not avoided, will pay the charge. The percentage of trips affected will differ significantly across the city. For example, the CBD Cordon only covers 3% of trips across Auckland as a whole, but rises to 6% for trips originating in Orakei. The network option charges 74% of trips on average, ranging between 57% (Franklin) and 81% (Manurewa and Otara-Papatoetoe). The Isthmus area charge only covers 35% of trips, but 8% of trips from Maungakiekie-Tamaki.

Table ES2 Percentage of trips facing the congestion charge

LBA	CBD Cordon	Isthmus area	Corridor	Network	Combined
Auckland Region	3%	35%	59%	74%	59%

Three of the charge options (corridor, network and combined) levy on a per km basis. Figure ES2 shows the average kilometres charged, per charged trip for the different LBA origins. The highest charged trip lengths are for Franklin and Rodney.

Figure ES2 Average trip length of charged trips by LBA Origin



Changes in Trips

Table ES3 shows the changes in numbers of trips for Auckland as a whole as a result of the congestion charge. This includes trips that have shifted to PT, those that have changed the time of the trip and those which are supressed completely. The CBD cordon charge has a small average effect reflecting the small percentage of trips that it affects (Table ES2).

Table ES3 Changes in car trips from the base case (household and business)

Income group	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	0.8%	12.9%	7.8%	12.0%	8.8%
Medium	0.7%	12.5%	7.2%	11.2%	8.2%
High	0.6%	9.9%	6.6%	10.0%	7.4%
All households	0.7%	11.7%	7.2%	11.0%	8.1%

Table ES4 shows the changes in PT trips relative to PT trips in the base case. These are smaller in percentage terms than for percentage reductions in car trips In absolute terms they are even smaller, because the number of PT trips is smaller to start with.

Table ES4 Changes in PT trips from the base case (household and business)

Income group	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	0.5%	3.3%	0.9%	1.4%	1.6%
Medium	0.5%	3.2%	0.9%	1.4%	1.6%
High	0.4%	2.8%	0.9%	1.3%	1.4%
All households	0.5%	3.1%	0.9%	1.4%	1.5%

Average Household Cost Increases

Table ES5 shows average increases in costs across all household types. The costs are the sum of costs across all trip types (to work or education and other trips) and modes (car and PT). Cost increases are greater for high income households than for low.

Table ES5 Option comparison: cost increases per household per annum

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	-$1	$156	$121	$482	$137
Medium	$1	$220	$157	$592	$178
High	$5	$230	$178	$630	$200

Costs are highest for the network option, partly because it is assumed there is a $200/annum cost of in-vehicle technology required to operate the scheme. Costs are lowest for the CBD cordon charge. The isthmus area scheme has the second highest costs, with the corridor and combined options in between.

Table ES6 shows weighted average costs as a percentage of income across all household types. All options have higher proportional costs for low income households. The lowest cost option is the CBD cordon. The network option has the highest costs.

Table ES6 Option comparison: costs as a percentage of income

Income level	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	0.00%	0.52%	0.41%	1.61%	0.46%
Medium	0.00%	0.28%	0.20%	0.76%	0.23%
High	0.00%	0.15%	0.11%	0.40%	0.13%

Impacts on Low Income Households

Table ES7 shows the average cost increases as a percentage of annual income for low income households, by LBA. For the network charge, costs are estimated to be as high as 2.1% of household income in Rodney. The CBD cordon charge has impacts estimated to be no higher than 0.02% of annual income and a financial benefit of close to 0.1% of income for Waitemata households, because people who choose not to make CBD-bound trips as a result of the congestion charge will also avoid fuel and parking charges.

Table ES7 Option comparison: cost increases per low income household per annum (% of annual income)

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	0.02%	0.15%	0.69%	2.06%	0.72%
Hibiscus & Bays	0.02%	0.09%	0.49%	1.69%	0.53%
Upper Harbour	0.02%	0.19%	0.59%	1.79%	0.65%
Kaipatiki	-0.02%	0.21%	0.37%	1.59%	0.43%
Devonport-Takapuna	-0.01%	0.18%	0.32%	1.51%	0.37%
Henderson-Massey	0.01%	0.32%	0.48%	1.64%	0.54%
Waitakere Ranges	0.02%	0.39%	0.23%	1.68%	0.32%
Waitemata	-0.08%	0.48%	0.23%	1.22%	0.25%
Whau	-0.02%	0.93%	0.25%	1.46%	0.32%
Albert-Eden	-0.03%	0.72%	0.16%	1.26%	0.19%
Puketapapa	-0.01%	1.19%	0.26%	1.49%	0.28%
Orakei	-0.04%	1.00%	0.20%	1.42%	0.27%
Maungakiekie-Tamaki	-0.02%	1.50%	0.39%	1.68%	0.47%
Howick	0.01%	0.38%	0.42%	1.66%	0.46%
Mangere-Otahuhu	0.01%	0.49%	0.44%	1.72%	0.47%
Otara-Papatoetoe	0.01%	0.30%	0.48%	1.69%	0.51%
Manurewa	0.00%	0.13%	0.33%	1.63%	0.34%
Papakura	0.00%	0.10%	0.58%	1.90%	0.58%
Franklin	0.00%	0.09%	0.66%	1.76%	0.66%
Auckland	0.00%	0.52%	0.41%	1.61%	0.46%

Business Impacts

The impacts on business are estimated to be generally positive. This is because of the inclusion of impacts of travel time savings in the analysis. This reflects the fact that business trips experience savings in 'on the clock' time that offset the added financial cost of the tolls.

Conclusions

Trip Numbers

The introduction of congestion charging is expected to result in a reduction in car trips and an increase in PT trips. The reduction in car trips will include the shifts to PT, shifts in the time of the trip away from the peak periods which are charged and some overall trip suppression.

The largest reductions in car trips, at over 12% on average, are estimated to result from the isthmus area and network charge options. The corridor and combined options also have significant effects, whereas the CBD cordon is expected to result in a less than 1% reduction in trips.

All options result in increases in PT trips, with the isthmus area option having the greatest estimated effect (2.8% increase in PT trips). The corridor and CBD cordon charges are expected to increase PT trips by less than 1%.

Costs and their Distribution

The estimated financial costs of the schemes are higher for high income households, because they use more transport and are more likely to continue to take trips in the charged period and to pay the charge. However, as a percentage of annual income, costs are greater for low income households. This result is consistent with the international literature.

On average for Auckland households, as a percentage of household income, the scale of costs is between close to zero (the CBD cordon) and approximately 0.7% (the Network option). However, for low income households, average costs increase for the network charge to 1.6% of annual income.

With the exception of the isthmus area charge, the schemes are expected to reduce costs for employer business and freight travel.

1 Introduction

1.1 Background

1.1.1 The Congestion Question Project

This report provides an input to *The Congestion Question* (TCQ) project. Formerly known as the Auckland Smarter Transport Pricing Project, TCQ is a joint project between the Government and Auckland Council to investigate whether to introduce congestion pricing in Auckland.

An initial Phase I of the TCQ project examined the emerging congestion problem, whether there were technical barriers to implementation and reviewed international examples. It concluded that congestion pricing shows considerable potential for tackling Auckland's congestion problems. It suggested that work continued into Phase II, including more detailed analysis of charging options.

The project's Terms of Reference state that consideration must be given to economic, social and environmental effects. This study aims to support the Steering Group to deliver the social assessment required as part of the Phase II evaluation of a short-list of options.

1.1.2 Distribution of Impacts

The costs of congestion in Auckland are estimated to be significant, including those relating to travel time for industry, commuters and others.[1]

Efficiency Analysis

Congestion pricing is motivated largely by economic efficiency concerns. This is that, if roads are to be used to provide the greatest benefits for the community, people should only use them when the benefits of doing so outweigh the costs. Congestion pricing addresses this by applying tolls to reflect the "externality" that arises when an additional vehicle affects the driving conditions faced by other road users, reducing their speed and increasing journey time.[2] In principle, the optimal toll should be set equal to the marginal external costs of an additional vehicle, which varies significantly by time and location.[3]

Because the marginal costs of road use are not easily calculated, congestion charging may use a simpler basis for pricing, in which the marginal external costs are not carefully calculated. However, it is still assumed that road use efficiency is improved relative to un-priced use.

Cost benefit analysis usually focuses on economic efficiency in the aggregate and does not concern itself with distributional effects. However, the NZ Treasury states:[4]

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[1] Leung *et al* (2017)
[2] Newbery (1990)
[3] See Yang *et al* (2018) as an example.
[4] NZ Treasury (2015) Guide to Social Cost Benefit Analysis. p47

"Welfare economics has long recognised that … the benefit that a poor person derives from another dollar of income, and therefore from another dollar of expenditure, may be higher than the benefit derived by a rich person. Basing a CBA on the concept of 'willingness to pay' therefore reflects the existing distribution of income or wealth, which may be considered to be inequitable. It is almost inevitable, therefore, that public sector projects have distributional consequences which some people will consider undesirable."

This study is not a CBA; it does not address the full set of costs and benefits that would be included in a CBA. However, it examines the way in which the financial costs of congestion charging would be distributed. This is to provide supplementary information to accompany a CBA.

Distributional Effects

The social assessment is tasked with addressing the equity or fairness aspects of congestion charging, ie whether the imposition of a charge has costs which are distributed differently across the community, by income group, household type, or geographic area. This might include lower income households facing higher relative costs or being more likely to avoid trips, with consequent impacts on employment or other opportunities.

Having impacts which differ is expected, but knowing about these impacts can provide useful information to help refine charging designs or the development of complementary policies to address the effects.

1.2 Social Impacts: International Literature Review

MRCagney (MRC) reviewed a selection of literature on the equity impacts of road pricing, concluding that studies have not come to clear conclusions on the direction of distributional effects by income, but that effects vary with specific design and location, and with the use of revenues.[5] The International Transport Forum (ITF) expert group, meeting recently in Auckland, concluded that the distributional impacts of road pricing are generally modest, but depending on the design (particularly cordon location), pricing can have a significant impact on some vulnerable households and individuals.[6]

Below we include a brief review of some of the same studies, plus some more recent literature.

1.2.1 Cost Incidence Relative to Income

Analysts examining the impacts of congestion charging in Paris conclude that the distributional impacts depend primarily on whether the costs of road pricing are measured in absolute terms or as a percentage of income (relative terms). In relative terms, road pricing is always more detrimental to low-income individuals, meaning that road pricing is regressive.[7] This seems to be a consistent finding across other studies.

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[5] MRCagney (2018)

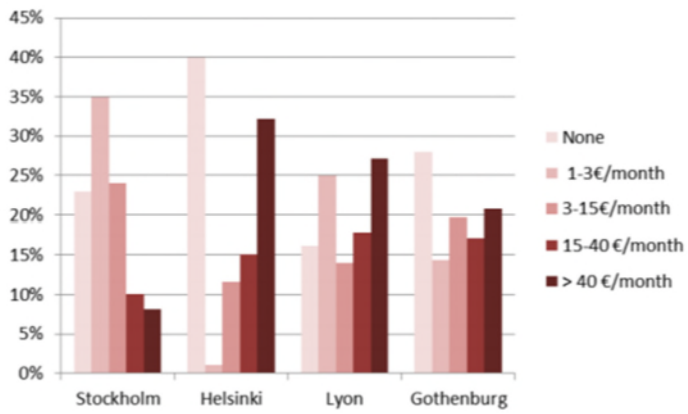
[6] Perkins *et al* (2018)

[7] Bureau & Glachant (2008)

For example, Santos & Rojey model the impact of a cordon toll in three English towns,[8] suggesting that it can be progressive, regressive, or neutral depending on where low-income people live and where and how they travel to work.[9] But their definition is simply whether the charge is likely to place higher costs on low (regressive) or high (progressive) income households or individuals, rather than taking account of cost to income ratios.

Consistent with this, Eliasson notes from studies in two Swedish cities, Helsinki and Lyon, that high income groups tend to pay more than low income groups (Figure 1),[10] but that even if the poor pay less than the rich, they actually pay more relative to their income. From his study of the original trial of congestion charging in Stockholm, Eliasson suggests the impacts were greatest on higher-income road users because they have a higher share of working trips and tend to choose car travel over public transport.[11]

Figure 1 Share of population who pay various amounts in tolls



Source: Eliasson (2016)

1.2.2 Differences in Response

In addition to differences in the direct impacts of charging itself, there are differences in the responses to charging.

Santos & Rojey suggest that, if the majority of drivers entering the charge area come from households with incomes above average, it can be expected that, once the scheme is implemented, these drivers will continue to cross the cordon and will be prepared to pay the charge.[12] On average in such a case, richer people will pay the toll and poorer

[8] Cambridge, Northampton and Bedford

[9] Santos & Rojey (2004)

[10] In Gothenburg and Helsinki, the highest income group pay less than the middle groups. In Helsinki it is because the highest income group tend to live and work more centrally, and hence drive shorter distances on average. In Gothenburg, it is because company cars are exempt from congestion charges (according to Swedish tax law), and high income groups have access to company cars to a much larger extent.

[11] Eliasson (undated)

[12] Santos & Rojey (2004)

people will not. And this is consistent with price elasticities of demand, varying by income, as discussed in Section 2.6.3.

A study of the impacts of the Madrid scheme suggest the costs particularly affect unskilled and lower income individuals living in the south of the city, who would reduce their use of tolled roads and have to find new arrangements for these trips, eg switch to PT, spend double the time travelling or stay at home.[13]

Transport options, so charges can be avoided, appears to be significant in reducing impacts.[14] The Sydney Harbour Bridge and Tunnel had peak charging introduced in 2009, of A$4 in the morning peak, compared to A$3 in the inter-peak. Up to 3.9% of low-income households were estimated to have a "high financial impact" because of a lack of choices as to how and when to travel.[15] Introducing travel choices reduces the impacts, eg toll routes operating in parallel to free routes that offer slower travel times can benefit both high-income and low-income users and routes with different prices can be a more progressive design than tolling all routes equivalently.[16]

Bureau & Glachant noted that, when tolls lead to a small reduction in traffic density, low-income motorists lose more (in absolute terms) than wealthier motorists.[17] The reverse is true with larger reductions in traffic, but only because low-income commuters switch to PT, which mitigates disbenefits from pricing.

1.2.3 Compensating Benefits of Reductions in Traffic Density and Other Impacts

The full impacts of congestion charging, and the distribution of impacts, is affected by the related impacts on traffic density and of other effects, such as changes to air quality.

Several studies include theoretical and pre-introduction (ex-ante) analyses which suggest all road tolls have disbenefits for road users,[18] but that disbenefits are lower for users with high value of travel time who benefit from lower traffic density (high value of time is generally correlated to high income),[19] but higher disbenefits for those with low values of time.[20]

Anable and Goodwin suggest that the distributional impacts of congestion pricing miss important elements if concentrating only on costs in comparison to income.[21] A more detailed analysis would include effects that include impacts on pollution. This will be affected by the geographical location of residents living near a road which will include people of different incomes and car use patterns. They conclude that "*Statistically, the type of disaggregation of the population by those who gain benefits and those who suffer losses demands a complex pattern of joint distributions by economic, social, travel and*

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[13] Di Ciommo and Lucas (2014)
[14] Perkins *et al* (2018)
[15] D'Artagnan Consulting (2018)
[16] De Palma & Lindsey (2004)
[17] Bureau & Glachant (2008)
[18] Net benefits accrue as a result of the benefits of revenue use
[19] Bureau & Glachant (2008)
[20] Arnott et al (1994)
[21] Anable and Goodwin (2018)

geographical variables which stands in danger of being intractable to carry out and complex to understand."

These wider impacts are also relevant to Eliasson's analysis of citizens' perspectives on the fairness of congestion charging. Depending on individuals' views of procedural fairness, equity, environmental issues and so on, congestion pricing can be viewed as more or less "fair" in an abstract sense, regardless of its more direct "consumer" effects.[22] He suggests it is hard to find much support for the view that congestion pricing is unfair, as long as its purpose is to correct prices and allocate scarce resources. This is consistent with the recent conclusions from the ITF meeting in Auckland that "*The primary objective of road pricing should be to cut congestion and manage demand for the use of private vehicles. Other forms of taxation that cost less to administer are recommended if the objective is simply to raise revenue*."[23]

1.2.4 The Importance of Revenue Use for Understanding Total Impacts

Many studies include revenue redistribution to address equity issues, with the redistribution being highly significant in protecting low-income and other vulnerable households.[24]

Swedish researchers suggest the two most important factors for the net impact of congestion pricing are: (1) the initial travel (commuting) patterns and (2) how revenues are used. Differences in these factors dwarf differences in others such as the value of time.[25] A study of a trial with congestion charging in Stockholm concluded that all road users face disbenefits because savings in travel times do not compensate for the increase in travelling costs, and it is only when the income from congestion charging is used to benefit the community through investments in traffic infrastructure or in other ways, that any net socioeconomic benefit is created.[26] The need to consider the distributional effects of revenue use is a point also raised by Anable and Goodwin.[27]

The collection and use of revenue is out of scope for this analysis, but we acknowledge the shortcomings of the study accordingly.

1.2.5 Social Impacts on Vulnerable Households

Other studies examined a wider set of effects, eg on factors that affect social inclusion (or exclusion), particularly for vulnerable groups such as low income households, the elderly, people with disabilities, women (eg due to security fears when using other modes), ethnic minority groups (if language / cultural barriers make use of other modes difficult) and people without access to public transport.[28]

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[22] Eliasson (2016)
[23] Perkins *et al* (2018)
[24] Bureau & Glachant (2008); De Palma and Lindsey (2004); Eliasson and Mattsson (2006); Fridstrøm *et al* (2000); Safirova *et al* (2006); Raub *et al* (2013)
[25] Eliasson & Mattsson (2006)
[26] Transek (2006)
[27] Anable and Goodwin (2018)
[28] Bonsall & Kelly (2005)

A recent analysis of the extension of the London congestion charge, the Western Extension Zone (WEZ), examined the frequency of visits to friends and family before and after its implementation.[29] The research performed difference-in-difference analysis,[30] and observed large and statistically significant reductions in visits as a result of the WEZ, including a reduction of around 20 visits a year to friends and of around 100 visits a year for those acting as an informal carer. Because the changes occurred in such a small time-frame (10 months), they concluded that the WEZ was likely to be the main driver of these reductions. This level of effect would not be expected from the proposed Auckland schemes, because the proposals are for morning peak pricing only (whereas the London scheme operates for 11 hours per day) and because the proposed prices are significantly less than the London prices.[31]

1.2.6 Offsetting impacts on land values and rents

Some studies have considered whether the costs of congestion charges would result in changes to land values which might modify the costs considered here. This is because the costs of congestion charges and the benefits of reduce congestion, would be expected to change the demand for living in certain locations in a city because of the changes to the costs of travel. For property owners, any net costs of a scheme might result in reductions in land values, although the financial impacts might not be seen for several years when the owners exit that (local) housing market. For rental markets, the impacts might flow through more quickly at the time rents are re-set. However, any downward movement in rents (and property prices) might be muted because of stickiness in downward price movements.

Despite the theory, there is mixed empirical evidence of such price responses. In London, two studies found that house prices increased more rapidly just inside the congestion charging zone, relative to similar areas just outside the zone.[32] The authors interpret this as the effect of improved amenities – reduced traffic congestion and improved air quality – rather than the direct financial impact of the toll. A separate analysis found no impact on office rents.[33]

1.2.7 Conclusions

The literature suggests the following impacts of congestion or road charging relevant to a social assessment.

- The impacts on different income groups differ widely in absolute terms, depending on designs and the location of households (and their trip destinations) by income. For example, there are many examples where higher income households face greater costs because they tend to drive more and are greater users of cars than PT.

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[29] Munford (2017)
[30] See Schiff *et al* (2017) for a description
[31] It imposed a daily cost of £8 for driving within the zone between 7am and 6pm; the price has recently been increased to £11.50
[32] Zhang and Shing (2006); Tang (2016)
[33] Schlaffer (2015)

- Charging schemes tend to be regressive in the sense that the costs of charges paid are greater for low income households as a percentage of income than they are for higher income households.

- Low income householders are more likely to take actions to avoid charges than high income householders. This includes shifting mode (to PT or active modes) and overall trip suppression. This means the overall impacts depend significantly on the supply of transport options so that people can realistically avoid the charge.

- The distributional impact of the use of additional revenues raised is important to an overall understanding of impacts. This is beyond scope for this study.

1.3 Social Impacts: NZ Studies

A number of New Zealand studies have examined potential impacts of road or congestion pricing.

1.3.1 Auckland Congestion Pricing Studies

MRC note that there have been three previous attempts to evaluate the equity impacts of road pricing in the Auckland context:

- The 2006 Auckland Road Pricing Evaluation Study (ARPES);
- The 2008 Auckland Road Pricing Study (ARPS); and
- The 2014 Funding Auckland's Transport Future (FATF).

Both ARPES and ARPS were led by the Ministry of Transport (MoT), whereas FATF was initiated by Auckland Council. The Auckland Transport Alignment Project (ATAP) did not assess distributional impacts of road pricing, but noted the issue as an area that would require more detailed assessment before progressing towards implementation.

Auckland Road Pricing Evaluation Study (2006)

ARPES evaluated five schemes: a single cordon charge, a double cordon charge, an area charge, a motorway ('strategic network') toll, and a parking levy. Schemes were developed and assessed only to an indicative level.

Auckland Road Pricing Study (2008)

In 2008, ARPS provided a more detailed assessment of:

- an area charging scheme that applied to the city centre and inner isthmus areas, including the motorway corridors through this area; and

- a cordon charge designed mainly to raise revenue, rather than improve transport network performance.

The analysis estimated that:

- 19-32% of households will be directly impacted;
- 8-14% of households will change travel mode;

- 2-5% will change the number of trips undertaken; and
- 8-13% of households will pay the congestion charge.

The most commonly impacted household types are couples and multi-family or non-family households, particularly those with working age adults and/or in the higher quintile groups. Less commonly affected are households containing older singles and older couples. The greatest impacts are on:

- households living within the congestion scheme boundary; and/or
- those working and travelling during the morning peak period.

In contrast, the lowest impacts are on:

- households less likely to be living within the scheme boundary – poorer households, family households; and/or
- households where one or more adult members are less likely to be working within the charging area – family households, older households.

Funding Auckland's Transport Future Study (2014)

The FATF study was initiated by Auckland Council to investigate alternative options for raising additional revenue to fund transport infrastructure in Auckland. It considered three options: (1) raising rates and fuel taxes, (2) introducing a flat per-kilometre charge on the city's motorways, and (3) introducing a variable motorway charge that was higher at peak times. Unlike previous studies, FATF did assume that additional revenues would be spent on increasing transport network capacity. The reported equity impacts therefore reflect the impact of both road pricing *and* additional transport expenditure.

The study focused on financial impacts rather than overall changes in welfare;[34] no consideration was given to costs of avoided trips.[35]

Results generally showed that the schemes involving motorway charges would have low impacts on most households, with added costs of less than 1% of after-tax household income for close to 90% of households. Low-income households (those in the bottom 20% of income within each category) with or without children were found to pay less than the average household in dollar terms. However, they make up a disproportionate share of the households that experience very high impacts relative to incomes.

Supporting qualitative research suggested that the low-income households would not be able to absorb congestion charges (or fuel tax / rates increases) and would have to make changes to lifestyle or travel patterns to mitigate costs. In the short run, this would serve to increase financial stress on households. In the long run, these households would consider changing home locations, reducing to one car, or increasing reliance on public transport.

[34] Changes in public transport and car travel time were assessed using transport modelling but results were not incorporated into the analysis of household impacts.

[35] Market Economics (2014a)

A companion study on impacts on businesses suggested motorway tolling is expected to lead to net benefits for businesses, as the monetary value of travel time savings generally exceeds the cost of tolls.[36] Positive impacts were found to be largest for firms that provide mobile services to households, construction firms, and transport firms. In contrast, the retail sector may be negatively affected if people forego some shopping trips.

1.3.2 MR Cagney Report

MRCagney (MRC) recently produced a report for the NZ Transport Agency on the *Social and Distributional Impacts of Time and Space-based Road Pricing*.[37] It outlined a general framework to analyse the social and distributional impacts of road pricing, and applied it to two hypothetical case studies in Auckland and Wellington.

MRC identified three general principles to guide impact assessment.

1. Road pricing will have different impacts on specific households (or individuals). If it is not possible to measure outcomes at the household (or individual) level, then analysis should group households based on characteristics that affect:
    - Their exposure to the impacts of pricing – relevant characteristics include location, household composition, employment status, and car ownership;
    - Their ability to bear the financial costs of pricing – household income, or disposable income, is a particularly relevant characteristic; and
    - Their ability to respond to pricing, eg by changing their transport behaviours – this will reflect location and travel needs.

2. When considering the distributional impacts of road pricing, it is important to consider multiple ways in which impacts may be distributed:
    - Vertical distribution of impacts, or impacts on households with different abilities to pay or mitigate the costs; and
    - Horizontal distribution of impacts, or impacts on similar households that live in different places and who therefore may be exposed to a different degree.

3. Road pricing will have both financial and non-financial impacts on households. Multiple impact measures are therefore needed to capture different categories of impacts, and to address the possibility that households will incur a mix of costs and benefits.

For Auckland, the analysis suggests most types of households would experience increases in the financial costs of travel, offset to varying degrees by benefits related to faster or more reliable travel, or improved accessibility. The estimated scale of these financial impacts is on the order of 1% of household income, which is in line with previous studies and is roughly comparable to the estimated social cost of traffic congestion in Auckland.

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[36] Market Economics (2014b)

[37] MRCagney (2018)

Lower-income households are likely to experience the largest financial impacts relative to their incomes. This principally reflects variations in household incomes, rather than variations in the financial costs of the scheme. Similarly, households with children, especially single-parent families, are likely to experience larger financial impacts relative to their incomes than other household types. This reflects the fact that children contribute to household travel – they need to be transported to school and play activities, and they induce retail trips – without contributing to household incomes

1.3.3 Social Exclusion

Rose *et al* examine the impacts of transport related social exclusion, which occurs "*when transport is routinely so difficult, unsafe, or costly that people forego opportunities for employment, education, and/or social participation.*"[38]

They build on previous work which has analysed the potential effects of vehicle emissions policy in New Zealand, and specifically the impacts of policy measures which would result in fewer low price vehicles available for purchase in New Zealand, eg if replacing a failing one.[39] The effects of congestion pricing are not expected to be as significant because they are smaller weekly price increases as opposed to one-off large purchases. However, the vulnerable groups are expected to be similar.

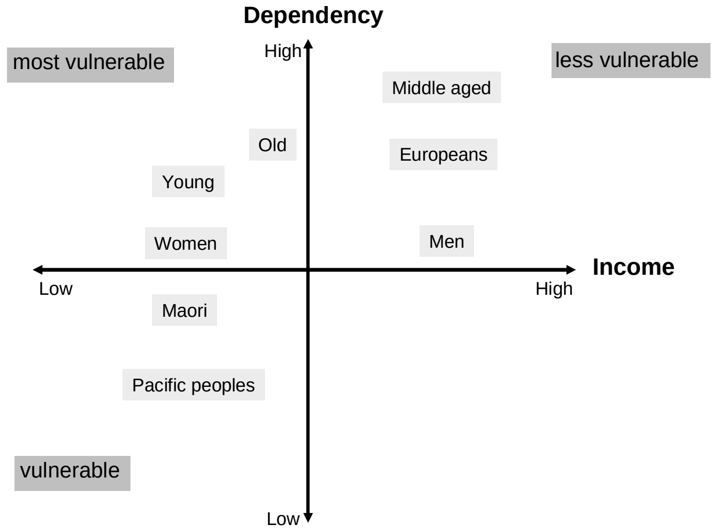
Those most at risk were low income households and those who rely on vehicles for their ongoing participation in work and other activities. This included (Figure 2):

- young and old people, particularly of Maori and Pacific descent;
- solo parents, who have particularly low average household incomes and relatively high daily living costs;
- large families, related to the lower levels of disposable income and the number of people affected by a loss of vehicle;
- people with disabilities because of lower incomes and difficulties in accessing other transport means.

[38] Rose *et al* (2009)

[39] Denne *et al* (2005)

Figure 2 Communities at Risk

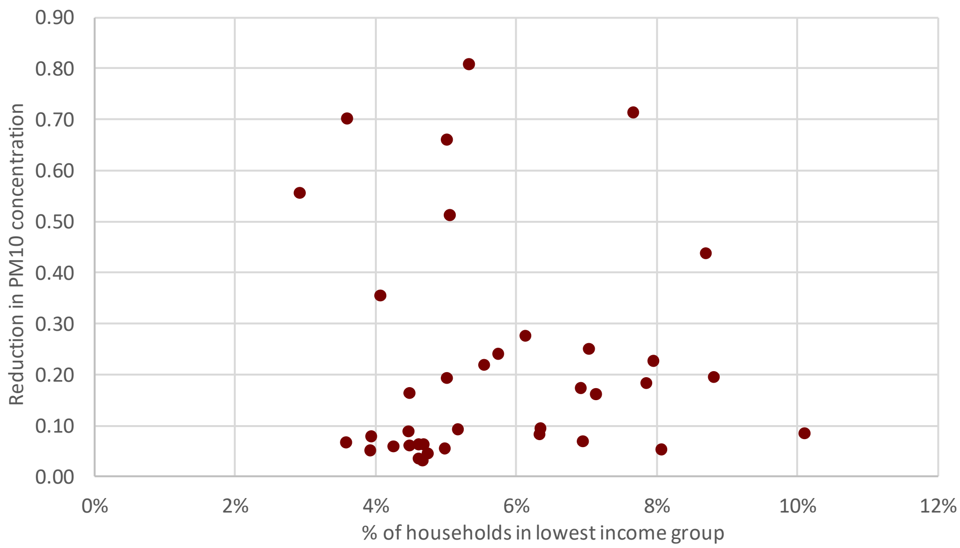


Source: Denne *et al* (2005)

1.3.4 Interaction of Environmental Impacts and Vulnerable Households

The wider environmental impacts of road pricing in Auckland[40] were considered in an analysis of possible air pollution policy measures.[41] Air quality benefits of $1 to $9 million per annum were estimated (depending on the approach to valuation of premature deaths). The PM_{10} reductions varied by location (census area unit), but there is no correlation between the location of modelled reductions and of low-income households (Figure 3).

Figure 3 Relationship between PM_{10} concentration reduction and low-income households



Source: 2013 income data by census area unit (and six income groups) from StatsNZ; PM_{10} reductions data taken from analysis by Denne and Atkins (2015)

[40] Based on assumptions in Ministry of Transport (2008). This assumes road pricing applies to a central Auckland area including the CBD & Port, estimated to result in an approximate 10% reduction in traffic and approximate 5% increase in public transportation service requirements.

[41] Denne and Atkins (2015)

1.3.5 Offsetting impacts on land values and rents

While road pricing has not been implemented in Auckland, a mid-2000s increase in Accommodation Supplement payments in central Auckland provides a 'test case' for whether rents adjust in response to a spatially-targeted shock to low-income households' incomes. Hyslop and Rea (2016) evaluate the change and find no evidence that the more generous payment led to an increase in rents in central Auckland. Based on that experience, we suggest that rent adjustment should be considered a hypothetical – albeit possible – impact of a congestion charging scheme.

2 Analysis

2.1 Congestion Charging Scenarios for this Study

For this study we examine the impacts of five different congestion charge designs. The geographic limits are shown in Figure 4.

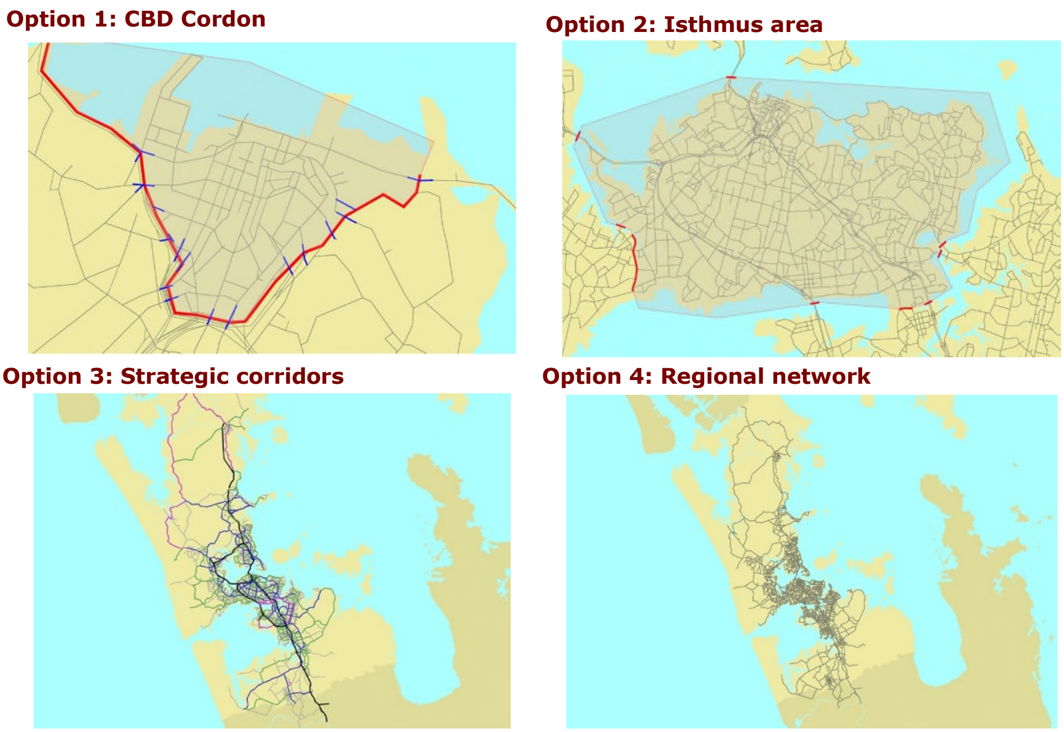
Two cordon charges would charge a fixed amount for entering the charge area:

6. A cordon charge for the central business district (CBD). This is the area bounded by State Highway 1 (SH1) and SH16 from Grafton to the Port.
7. An area charge for the whole of the isthmus north of Otahuhu and bounded by the Harbour Bridge to the north and New Lynn to the west.

Two corridor/network charges would charge an amount per kilometre within the charging area:

8. A corridor charge in main arterial routes in the city
9. A network charge covering the whole of the regional network
10. A combined CBD Cordon and corridor charge.

Figure 4 Geographical boundaries for congestion charging options



Source: Auckland Transport

The pricing assumptions are shown in Table 1. The charges are assumed to operate at AM and PM peaks. This would mean those entering cordon areas would face a cost of entry in the morning and of departure in the afternoon/evening. For the corridor and network options the charges apply to every kilometre driven in the charging area during these time periods.

Table 1 Price assumptions for congestion charging options

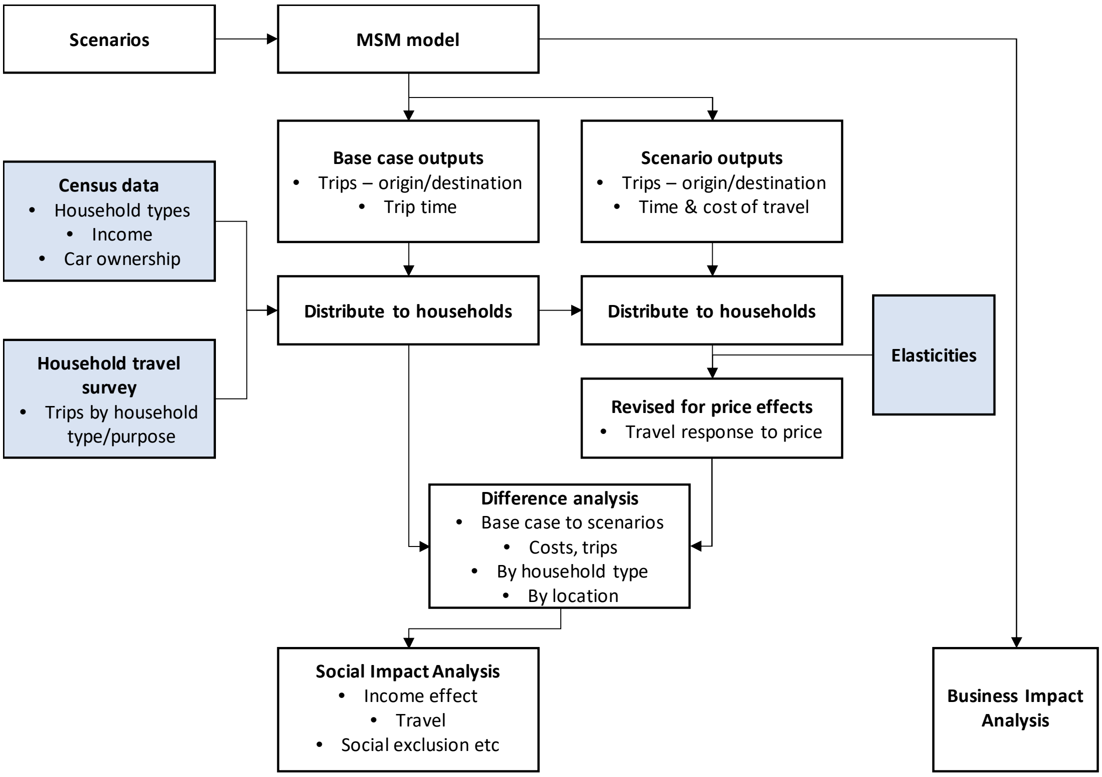
Charge design	Charge rate
Cordon charges	$2.30/cordon crossing
Corridor/network charges	$0.12/km

Source: Auckland Transport

2.2 Analytical Approach

Figure 5 provides an overview of the approach taken to analysis.

Figure 5 Overview of approach



The steps are as follows for the household analysis:

- The scenarios (charge options) are defined as noted in Section 2.1.
- These are used to specify runs for the Auckland Forecasting Centre's Macro Strategic Model (MSM). These are used to produce outputs for a base case (no congestion charge) and the charging options. MSM estimates some impacts of congestion charging (particularly route and mode changes) but does not fully capture trip suppression or trip chaining responses.
- The MSM outputs are inputs to the analysis described in this report. The outputs are in the form of origin-destination matrices, including trip numbers and trip costs.
- These trips are distributed to households within the trip origin areas using:

- Trip rates for different household types taken from MoT's Household Travel Survey (HTS); and
- Statistics NZ census data on household numbers by type and location.

- Elasticities are applied to modelled household private vehicle trips to estimate the total travel demand response, including impacts on mode choice that are measured by MSM.

- A difference analysis is undertaken between the base case and the options, of the trip rates and costs, by location and household type.

The business analysis is undertaken more simply. We assume, as a first approximation, that there is no price response beyond that measured by MSM. Rather businesses will generally choose to pay the charge. We estimate impacts for business in aggregate based on modelled employer business trips and freight trips.

Below we explain the different elements in more detail.

2.3 Macro Strategic Model

MSM is a detailed transport model which simulates traffic flows on the basis of least cost journeys between specified origin-destination pairs. It uses approximately 600 separate geographical zones across the Auckland region, each of which is both an origin and a destination. MSM produces matrices for trips between each pair, including trip numbers and costs.

MSM provides an initial estimate of the response to the congestion charge by estimating changes in:

- trip mode from car use to public transport (PT);
- trip route to avoid or to reduce the charge faced;
- time of trip;[42] and
- destination, in some circumstances.

However, MSM assumes that the total number of trips does not change in response to congestion charges. In reality, congestion charges will cause some people to avoid some trips, either by choosing not to travel or by chaining trips to multiple destinations together. These effects are estimated in this study by applying price elasticities to the results from MSM.

MSM produces results for trips with different purposes and modes (which apply to all purposes), as shown in Table 2. Because the terms discretionary and o-discretionary are

[42] MSM models five time periods: the AM peak period, the interpeak period, the school peak, the PM peak period, and the off-peak period (evenings and early mornings). It does not model finer-grained changes in departure times, eg people who choose to leave 15 minutes earlier or later to avoid the 'peak of the peak'. Some models of congestion pricing suggest that these finer-grained responses are likely to enhance the efficiency of congestion pricing while mitigating distributional impacts.

not necessarily descriptive of the different purposes, we use the following category names:

- travel to work or education;
- other (household) trips; and
- employment-based.

Table 2 Trip purposes and modes in MSM

	Non-discretionary	Discretionary	Employment-based
Trip purposes	Travel to work Travel to education	Other trips, eg shopping	Trips for work purposes while at work Freight trips
Mode	Car travel Public transport (PT) Heavy commercial vehicle (for freight trips)		

The outputs shown in Table 3 are produced by MSM for each purpose. Trip length is used to estimate trip costs on the basis of fuel costs.

Table 3 Origin-Destination Matrix outputs from MSM

Base case car travel	Base case PT	Congestion charge car travel	Congestion charge PT
• Trip numbers • Average trip length • Parking costs	• Trip numbers • Average fare	• Trip numbers • Average trip length • Trip numbers facing the CC • Average CC paid • Parking costs	• Trip numbers • Average fare

2.4 Aggregation of Results

The roughly 600 MSM geographical areas are not the same as geographical areas defined for census purposes, eg meshblocks or area units, so some adjustment is required to combine the trip matrices with household data (counts of households by types and income bands) from Statistics NZ (StatsNZ). In addition, when census data are supplied at a disaggregated level, many are supressed for reasons of confidentiality. Given these constraints, the decision was made to undertake the analysis at a more aggregated geographic level, equivalent to Local Board areas (LBAs). There are 21 LBAs in Auckland (see map in Annex B); we discarded the Waiheke and Great Barrier areas[43] because congestion charging would not apply to any trips within or from these areas. Output data from MSM was reshaped into 19 x 19 origin:destination matrices containing data for purposes and modes as shown in Table 2, with details as shown in Table 3.

[43] The Waiheke LBA includes Waiheke Island, the islands of Rangitoto, Motutapu, Motokorea, Motuihe, Ponui, Rakino, and a number of smaller islands.

2.5 Distribution to Households

2.5.1 Approach

To understand the effects on households, the trip numbers and costs from MSM need to be allocated to different household types, defined by structure and income. MSM does not model travel at the household level so another method is required to allocate trips to household types. To do so, we have combined data from two sources:

- StatsNZ data on the numbers of households in each LBA in our chosen classifications (see below); and

- MoT Household Travel Survey (HTS) data, from which we calculated trip rates by household type.

StatsNZ household counts were multiplied by HTS trip rates to estimate the number of trips which originated in each LBA, by household type. The total trips from each LBA, based on this HTS-based analysis, was then compared to the total trips estimated from the same LBA by MSM. The HTS-based numbers were then adjusted so the total trips for each LBA was the same as that estimated by MSM. Different adjustment factors were used for each LBA, but the same adjustment factor was applied to all households in each LBA.

2.5.2 Defining Household Types

The first step was to identify the household types. The requirement was for them to:

- provide a useful basis for analysing socio-economic impacts;

- be based on descriptors used by StatsNZ so that household counts could be obtained for each household type for each LBA; and

- be compatible with descriptors used in the HTS so trip rates could be estimated for each household type.

MRC (2018) used econometric analysis of HTS data to identify household characteristics that are statistically significant predictors of trip generation rates for households (and hence that could affect households' exposure to congestion charges).[44] Household size, employment status, and vehicle ownership were identified as the most important and statistically significant predictors of trip generation. Household income was also identified as statistically significant, but the estimated impact of a change in income on trip generation was so small that it was considered to be irrelevant in practice.

The earlier MRC analysis of congestion pricing was applied to Census Area Units (CAUs) and the definition of household types was constrained by availability of census data at that level. Confidentiality constraints meant only household composition was

[44] MRCagney (2018) see Appendix B.

used to define a set of nine household types,[45] under the assumption that household composition broadly reflected the household size, employment status, and vehicle ownership characteristics that were found to be predictors of trip generation rates.

Our analysis is applied to larger geographic areas, ie LBAs, so we were able to consider using more than one household characteristic to define household types. Based on the MRC econometric analysis, we initially defined a set of 22 household types given by all feasible combinations of:[46]

- Household size: 1, 2, 3, 4 or more people
- Number of employed people in the household: 0, 1, 2 or more
- Number of vehicles in the household: 0, 1 or more

For each of these 22 household types, we used HTS data to calculate average daily trips per household by car and PT modes (Table 4).

This involved combining HTS data for "trip legs" into trips and calculating the average number of trips taken per weekday by PT and car (combined) for each household type. While our analysis of congestion charging applies to travel during the morning peak only, our initial analysis of trip generation for the 22 household types used average trips per weekday as a measure of overall travel intensity for each household type. This was because of concerns about excessive "noise" in the HTS data if analysing only morning peak trips for a large number of candidate household types.

Many of the household types have similar trip generation rates. Using the results of *k*-means clustering as a guide,[47] we reduced the initial set of 22 household types to six broader groups, defined combinations of household size, employment, and vehicle ownership (shown in the first column of Table 4).

Given the small number of trips taken by households with no vehicles, and hence the low impacts of congestion charging on these households, it was decided to further reduce the number of household types to four by combining the three groups of household types with no vehicles into one household type. This led to our final specification of four household types:

1. All households with no vehicles.
2. Households with one or two people and one or more vehicles.
3. Households with three people and one or more vehicles.
4. Households with four or more people and one or more vehicles.

[45] Census data classifies household composition according to the relationship(s) among the people living in the household, eg "Family with adults only", "Family with children under 18 years old", "Person living along", etc.
[46] This is not 24 household types because households with only 1 person could not have 2 or more people employed
[47] k-means clustering divides a set of observations of a variable into k groups such that the sum of squared deviations of the observations in each group from the mean of each group is minimised.

Table 4 Initial set of household types and trip generation rates.

Group	Household size	Employed people	Vehicles	Total trips	Total households	Total household days	Trips per household day
1 person + 2 people, 0 vehicles							
1	1	0	0	110	36	45	2.4
1	1	1	0	49	13	20	2.5
1	2	0	0	80	10	16	5.0
1	2	1	0	60	11	15	4.0
1	2	2+	0	15	2	4	3.8
	Aggregate group			314	72	100	3.1
1 person + 2 people, 1+ vehicles							
2	1	0	1+	906	167	245	3.7
2	1	1	1+	1,594	253	401	4.0
2	2	0	1+	2,605	256	390	6.7
2	2	1	1+	3,588	362	600	6.0
2	2	2+	1+	7,024	609	979	7.2
	Aggregate group			15,717	1,647	2,615	6.0
3 people + 4 people, 0 workers + 1 workers, 0 vehicles							
3	3	0	0	84	14	18	4.7
3	3	1	0	40	5	8	5.0
3	4+	0	0	92	14	21	4.4
3	4+	1	0	52	9	16	3.3
	Aggregate group			268	42	63	4.3
3 people + 4 people, 2+ workers, 0 vehicles							
4	3	2+	0	37	4	5	7.4
4	4+	2+	0	58	6	9	6.4
	Aggregate group			95	10	14	6.8
3 people, 0, 1 or 2+ workers, 1+ vehicles							
5	3	0	1+	1,067	74	110	9.7
5	3	1	1+	3,029	241	388	7.8
5	3	2+	1+	6,152	382	627	9.8
	Aggregate group			10,248	697	1,125	9.1
4+ people, 0, 1, or 2+ workers, 1+ vehicles							
6	4+	0	1+	1910	89	143	13.4
6	4+	1	1+	9,016	404	652	13.8
6	4+	2+	1+	2,1672	864	1,433	15.1
	Aggregate group			32,598	1,357	2,228	14.6

For each of these four household types, we used HTS data to calculate trip generation rates for the morning peak period. We differentiated these trip generation rates by mode (car/ PT) and by trip purpose. We re-classified HTS trip purposes into two categories, consistent with MSM (see Table 2):

- Non-discretionary trips: Trips to work or education.

- Discretionary trips: Trips for shopping, personal business, medical, and social visits.

The resulting trip generation rates for the four household types, two modes, and two purposes are shown in Table 5. Households with no vehicles make some car trips; these predominantly reflect trips taken as passengers, eg ride-sharing or carpooling with others, rather than as drivers.

Table 5 morning peak trips per household per day by household type, mode, and purpose.

	To work or education		Other	
Household type	**Car**	**PT**	**Car**	**PT**
All with no vehicles	0.12	0.15	0.04	0.10
1 or 2 persons; 1+ vehicles	0.37	0.03	0.31	0.01
3 persons; 1+ vehicles	0.68	0.09	0.68	0.01
4 or more persons; 1+ vehicles	1.26	0.16	1.54	0.02

2.5.3 Combining Trip Rates with Household Numbers

Census data were obtained from StatsNZ for these individual household types. To do so we included income as an additional category. Household numbers were provided for each LBA, for each household type and for each of three income categories: low, medium and high, based on household incomes for the Auckland region as a whole.

Household size and composition affects available income and the income needs of households. To account for this, StatsNZ uses a modified income measure: Jensen equivalised household income. It is calculated by dividing household income by household size and adjusting for the number of children in the household.[48]

$$Jensen\ income = \frac{Total\ household\ income}{[a + (c * x) + (t * y)]^z / 2z}$$

Where a is the number of adults in household; c is the number of children in household; t is the sum of individual ages of children in household; and x, y, z are constants that standardise between children of different ages and households of different sizes.

The total numbers of households in the different categories are shown in Table 6. The Jensen-equivalent income groups were defined so that one third of households fell within each band. The numbers in Table 6 show that this was broadly achieved. Some households (1.5%) could not be classified and were ignored in the analysis.[49]

[48] See Appendix 2 in Statistics New Zealand (2013)

[49] These were marked “Not elsewhere included” in the dataset provided by StatsNZ and are a combination of residuals, such as ‘not stated’, ‘response outside scope’, ‘response unidentifiable’, ‘refused to answer’, and ‘don’t know’.

Table 6 Numbers of households by household type (Auckland total)

	Low	Medium	High	Total
Jensen-adjusted Income	$45,000 or less	$45,101 – $85,300	$85,301 or more	
All with no vehicles	20,760	4,692	1,731	27,183
1 or 2 persons; 1+ vehicles	57,342	58,275	57,228	172,845
3 persons; 1+ vehicles	17,253	20,112	30,093	67,458
4 or more persons; 1+ vehicles	32,223	45,984	40,719	118,926
Could not be classified	3,141	1,656	945	5,742
Total	**130,719**	**130,719**	**130,716**	**392,154**

Source: data from StatisticsNZ

For analysis, the numbers of households were updated to expected household numbers in 2028, the assumed year for analysis. Tables were produced for each of the 19 LBAs and the household numbers were scaled to meet the new totals, while assuming the proportion in each household category and income group did not change in each LBA. The revised numbers are shown in Table 7 the balance between income groups has change reflecting different growth rates by LBA, ie there is greater expected growth in LBAs with a higher percentage of low income households so the balance has shifted towards more low income households.

Table 7 Numbers of households by household type (Auckland total – 2028 assumptions)

	Low	Medium	High	Total
Jensen-adjusted Income	$45,000 or less	$45,101 – $85,300	$85,301 or more	
All with no vehicles	38,866	8,187	2,823	49,877
1 or 2 persons; 1+ vehicles	102,809	102,317	95,115	300,241
3 persons; 1+ vehicles	30,932	35,356	49,658	115,946
4 or more persons; 1+ vehicles	57,834	79,454	64,755	202,042
Total	**230,441**	**225,314**	**212,351**	**668,106**

Source: modified from Table 6

These numbers (at the LBA level) were combined with the trip rates (Table 5) to produce an estimate of trips by household type, purpose, mode and LBA. They were then scaled so that the total trips by origin (LBA), mode and purpose were the same as those estimated by MSM for 2028.

2.6 Elasticities

Responses to congestion charging will include:[50]

- No change in behaviour, ie people with high value trips continue to make them;
- Changing route to avoid the charge or to pay a lower one, including through changing trip destination (or origin) and through trip-chaining (combine

[50] MRCagney (in press)

multiple trips to avoid multiple tolls);

- Changing departure time to times of day when congestion (and road pricing) is lower;

- Changing transport mode from car to PT; and

- Avoiding making trips, including through changing employment or moving house.

The responses will vary with the reasons for the trips and the characteristics of the people. MSM estimates some changes to trips following the introduction of a congestion charge. As noted above, these are changes in:

- trip mode from car use to public transport (PT);
- trip route to avoid or to reduce the charge faced;
- time of departure; and
- destination, in some circumstances.

However, MSM does not include any additional price response, eg total trip suppression. We estimate these effects using elasticities.

2.6.1 The Need for Elasticities in this Analysis

MSM currently simulates a response to congestion charging in the form of a shift in journey routes, modes, and, to a degree, time of departure. It does not change the total number of trips. However, all of these responses are likely to occur. To ensure these effects are taken into account, we have added an elasticity response to the analysis. Elasticities will be applied to the trip rates produced as outputs from MSM.

Our interest is in elasticities which can be applied to trip rates which we differentiate by household type and trip purpose. We discuss elasticities in more detail in Annex A, including those which have been derived from studies of:

- Fuel price changes;
- Toll roads; and
- Congestion charges.

2.6.2 Elasticity Values from Congestion Charge Studies

There are sufficient elasticity values derived from studies of congestion charges that we have used these as the basis for our numbers. The elasticities estimated differ by scheme and with the base costs assumed. The base cost matters as the elasticity is measuring the price difference relative to a starting cost. A selection of values is given in Table 8 for the main international charging schemes.

The Swedish studies have measured peak time elasticities in addition to all charged time, ie when a charge applies to a longer period of the day. The Swedish and London studies have been based on changes relative to initial fuel costs or to fuel costs plus parking or time. For Singapore, elasticities have been calculated from periods when charge rates have changed. Elasticities for Milan have been calculated for a base cost of zero. This is possible because they (along with all the other studies) are calculated as arc elasticities (see Annex A for definition).

Table 8 Elasticity values for congestion charging schemes

Location	Base costs	Peak Elasticity	All charged time
Stockholm	Fuel cost x 1.2[a]	-0.67 (-0.28)[b]	-1.57 (-2.49)[b]
Gothenburg	Fuel cost x 1.2	-0.53 (-0.16)[b]	-1.18 (-0.85)[b]
London	Fuel cost		-0.47
	Fuel + parking		-0.72
	Fuel + cost of time		-0.68
Milan: Petrol Euro 1 & 2	Zero		-0.66
Petrol Euro 0, Diesel	Zero		-0.44
Singapore	Previous toll price	-0.106	

[a] This is the per kilometre rate as applied by Swedish tax authorities for allowable expenses.
[b] Figures in brackets are long run elasticities, when differentiated from short run
Source: Börjesson (2017); Evans (2008); Croci and Ravazzi (2016); Olszewski and Xie (2005)

Because they provide peak elasticities, we have used the Swedish study values as the best generalised elasticity for this analysis. The average value for Stockholm and Gothenburg is -0.6. This is a measure of the change in traffic volume (vehicles/hour) in response to a change in cost measured as fuel cost times 1.2 (for a one-way trip) plus the congestion charge. A change in vehicles per hour across a cordon is equivalent to a change in the number of trips across the cordon. We also use this elasticity with per-km charging scenarios, on the assumption that the average-length trip in any origin-destination pair is reduced.

2.6.3 Elasticity Values by Household Type

Some studies have examined differences in price elasticities by household type and income, but only for fuel price elasticities (not for congestion charges). We examine the differences in elasticity from these studies to alter the average elasticity by household type and income.

Researchers at Imperial College, University of London found price elasticities of demand fell with increased income (Table 52).

Table 9 Price elasticities for income and expenditure quintiles

Quintile:	1st	2nd	3rd	4th	5th
Reported (pre-tax) income	-0.510	-0.513	-0.474	-0.454	-0.397

Source: Wadud *et al* (2010a)

These same researchers found price elasticities differing with car ownership and employment (Table 10). Elasticities are higher for multiple vehicle owners and for multiple-earner households.

Table 10 Impact of household type on price elasticity of demand for transport fuel (urban areas)

Car ownership	0 – 1 Earners	2+ earners
Single	-0.327	-0.421
Multiple	-0.482	-0.576

Source: Wadud *et al* (2010b)

We combine these values with the average elasticity value above to produce the elasticities used in this study as shown in Table 11. Following the Swedish example, we apply these to fuel costs times 1.2.

Table 11 Household-specific arc elasticities

Household type	Low Income	Medium Income	High Income
All households with no vehicles	-0.44	-0.41	-0.37
1 or 2 person households with 1+ vehicles	-0.65	-0.60	-0.54
3 person households with 1+ vehicles	-0.65	-0.60	-0.54
4 or more person households with 1+ vehicles	-0.65	-0.60	-0.54

To estimate these values:

- the general rate (-0.6) is applied to all medium income households with a vehicle;
- a lower elasticity is applied to households without a vehicle using the ratio between elasticities of multiple and single car ownership (single-earner) households from Table 10 (.327/.482 = .678 and .678 × -0.6 = -0.41));
- a higher elasticity is applied to low-income households using the ratio between the average elasticities of 1st and 2nd quintile incomes and 3rd quintile incomes from Table 9 (.512/.474 = 1.079 and 1.079 × -0.6 = -0.65);
- a lower elasticity is applied to high income households using the ratio between the average elasticities of 4th and 5th quintile incomes and 3rd quintile incomes from Table 9.

The general rate is applied to all households in sensitivity analysis.

2.6.4 Application of Elasticities

These elasticities (using the arc elasticity formula – see Annex A) are applied to the change in the financial costs of driving (fuel costs × 1.2) to estimate a change in the number of trips. The starting trip number is the number of trips in the base case that would pay the charge if there was no change of behaviour to avoid the charge.

2.7 Estimation of Differences

For each of the congestion charging scenarios, we estimate results as the change in trips (by purpose) and the change in costs for each LBA and household type relative to the base case.

The change in financial costs are the change in trip costs made up of fuel costs, parking costs and congestion charges. Where trips have shifted mode (from car to PT), we calculate the reduction in car trip costs and the increase in PT fares. We have not calculated:

- Costs of travel time (or benefits of travel time savings); or
- The losses in consumer wellbeing from trip suppression, ie the reduction in wellbeing from households changing trips to a less preferred option.

The reason for excluding these effects is because we are comparing costs against income as a measure of relative impact. If we were to include these non-financial wellbeing effects, the comparisons should be made against total current wellbeing, eg wellbeing reduction as a percentage of annual household wellbeing. We do not have data to undertake such an analysis.

2.8 Social Impacts

We compare the costs of the different options against mean household incomes.

We use separate values for all 19 LBAs. Values for Auckland as a whole are shown in Table 12 below.

Table 12 Mean income – Total Auckland

	Low	Medium	High
All households with no vehicles	$19,600	$56,000	$111,600
1 or 2 person households with 1+ vehicles	$25,100	$63,000	$136,800
3 person households with 1+ vehicles	$32,600	$75,000	$157,600
4 or more person households with 1+ vehicles	$43,900	$102,200	$187,300

2.9 Business Impacts

Our brief for this work means our focus for analysis is more on the impacts on households than on businesses. However, we would expect congestion pricing to result in financial benefits for business travel and freight. These trips are 'on the clock' and hence reduced congestion will translate directly into cost savings for businesses or customers.

For completeness, we therefore estimate the impacts on businesses using MSM outputs for employer business (EB) trips and heavy commercial vehicle (HCV or freight) trips. We do not apply elasticities to estimate trip suppression effects, as we assume that most business and freight trips will not be deterred by the cost of a congestion charge.

Our analysis focuses on the financial impacts of the congestion charge on business in the aggregate, broken down by local board area. We do not separate out impacts for different types of businesses, eg by size or industry, although this could be done in a future stage of work.

2.9.1 Identifying business trips

We used MSM outputs to identify impacts on employer business and freight trips.

In the model, 'employer business' trips refer to trips that people take for business reasons. This should include, for instance, staff travelling to attend meetings, tradespeople visiting job sites, and so on. EB trips can be taken by either car or public transport, and hence MSM predicts that some of these trips will shift mode in response to congestion pricing.

For EB trips, we used MSM outputs for the base case and each of the congestion pricing options to quantify the change in the number of AM peak trips taken by each mode.

Freight trips, by contrast, are deliveries and movements of goods in HCVs. These trips are assumed to have a fixed set of origins and destinations, and cannot shift mode.

We therefore assumed that there would be no change in the number of freight trips as a result of congestion pricing.

2.9.2 Calculating toll, fuel, parking, and PT fare cost impacts

We calculated the direct financial costs incurred for business travel using MSM matrices for congestion charges paid, distance travelled, parking costs at destinations (if any), and public transport fares. Total costs incurred to travel were estimated for the do-minimum scenario and each option, and then compared.

These costs may change due to mode shift (for EB trips), other changes to demand that are modelled within MSM, or changes to routes to take advantage of congestion pricing. As noted above, we did not apply elasticities to business travel and hence it was not necessary to estimate trip suppression impacts.

Default MSM outputs do not include cost and travel time matrices for freight trips. We therefore assumed that distances travelled and tolls paid would be similar for freight trips and employer business trips.

2.9.3 Calculating value of travel time savings

Congestion pricing is also likely to result in financial savings for businesses as less time will be spent travelling 'on the clock'. We valued these savings using MSM outputs for changes in journey time for EB trips combined with estimates of the value of travel time savings for EB and freight trips.

MSM outputs provide information on the change in journey times resulting from general decongestion, which is expected to speed up business travel. Journey times were estimated for the base case and each option, and then compared.

This approach is likely to under-estimate travel time savings for business trips as MSM does not capture the full impact of decongestion from trip suppression. We have not re-run MSM to remove trips that were estimated to be suppressed or re-timed to other periods based on the elasticity analysis.

Table 13 summarises the assumptions made about value of travel time savings. We note that people making business or freight trips tend to value travel time savings more highly than people making other types of trips. As a result, congestion pricing is likely to have a larger impact on mode shift and trip suppression for household travel relative to business travel.

Table 13: Value of travel time savings assumptions

Mode	Value of travel time savings	Notes
Employer business (EB)	$35.06 per hour	EEM Table A4.1(b) provides a base (2002) value of $23.85/person-hr, which we update to 2017 values using the benefit update factor of 1.47 from Table A12.2 (If vehicle occupancy of 1.2-1.4 is factored in, this would rise to somewhere in the range of $42-50/vehicle-hr, which is similar to the value of $48/hr used in MSM.)
Freight (HCV)	$68.28 per hour	As for EB, starting with $23.85/person-hr times 1.47. (With vehicle occupancy of 1.1, this would rise to $38/hr, close to the value of $38 used in MSM.) EEM Table A4.2 provides base (2002) values of $17.10/hr and $28.10/hr for freight and vehicle time for HCV1 and HCV2 vehicles, respectively. We average these and update them to 2017 values using the above benefit update factor.

EEM = Economic Evaluation Manual (NZ Transport Agency 2018)

As noted above, default MSM outputs do not include cost and travel time matrices for freight trips. We therefore assumed that journey times would be similar for freight trips and employer business trips.

2.9.4 Summing up impacts

To conclude, we summed up the above financial impacts at a local board level, and for Auckland as a whole. To calculate total financial impacts on businesses, we summed together increases in tolls with any modelled changes in fuel, fare, and parking costs, and modelled reductions in the cost of business and freight travel time.

3 Household Impacts

3.1 Base Case

Household trips in the base case total 821,250 across the 19 LBAs; these are one-way trips per morning peak. For analysis we assume that every trip in the morning peak has a corresponding return trip in the evening peak. The household trip rates as an average for the Auckland region are shown in Table 14. These are different from the trip rates in Table 5 because we have scaled the number of trips so the totals are equal to the trip numbers estimated by MSM for each LBA origin.

Table 14 Trips per household per day (morning peak)

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	0.09	0.10	0.11	0.26	0.26	0.25
1 or 2 person with 1+ vehicles	0.28	0.28	0.29	0.05	0.05	0.05
3 person with 1+ vehicles	0.50	0.51	0.52	0.17	0.17	0.17
4 or more person with 1+ vehicles	0.89	0.91	0.96	0.28	0.29	0.29
Other trips						
All with no vehicles	0.03	0.03	0.03	0.17	0.15	0.12
1 or 2 person with 1+ vehicles	0.23	0.23	0.24	0.01	0.01	0.01
3 person with 1+ vehicles	0.49	0.50	0.51	0.03	0.03	0.03
4 or more person with 1+ vehicles	1.09	1.11	1.17	0.04	0.04	0.04

Table 15 shows average costs for trips per household per year. These include the costs of fuel, parking and congestion charges. The following patterns emerge:

- Costs of trips to work/education by car and PT are highest for high income households;
- Costs of other trips by car are highest for high income households, but costs by PT are highest for low income households.

Table 15 Trip costs per household per year (morning peak)

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$170	$189	$206	$535	$574	$602
1 or 2 person with 1+ vehicles	$487	$488	$506	$99	$98	$101
3 person with 1+ vehicles	$872	$872	$903	$318	$318	$326
4 or more person with 1+ vehicles	$1,561	$1,586	$1,666	$517	$527	$548
Other trips						
All with no vehicles	$39	$43	$46	$299	$260	$229
1 or 2 person with 1+ vehicles	$324	$325	$331	$21	$21	$20
3 person with 1+ vehicles	$692	$688	$694	$51	$51	$48
4 or more person with 1+ vehicles	$1,564	$1,556	$1,585	$67	$65	$61

Average costs vary significantly by LBA. Table 16 shows the differences in costs for car trips to work or education for Waitemata and Franklin.

Table 16 Costs of car trips to work or education by household per year (morning peak) for two LBAs

	Waitemata			Franklin		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$105	$105	$105	$259	$259	$259
1 or 2 person with 1+ vehicles	$315	$315	$315	$772	$772	$772
3 person with 1+ vehicles	$583	$583	$583	$1,431	$1,431	$1,431
4 or more person with 1+ vehicles	$1,080	$1,080	$1,080	$2,652	$2,652	$2,652

3.2 Charge Options

The different options (or scenarios) for analysis were described briefly in Section 2.1. Table 17 shows, for Auckland as a whole and for the individual LBAs, the percentage of trips which would face the charge under the different options. These are the base case trips which, if they do not shift (mode, time or route) or are not avoided, will pay the charge.

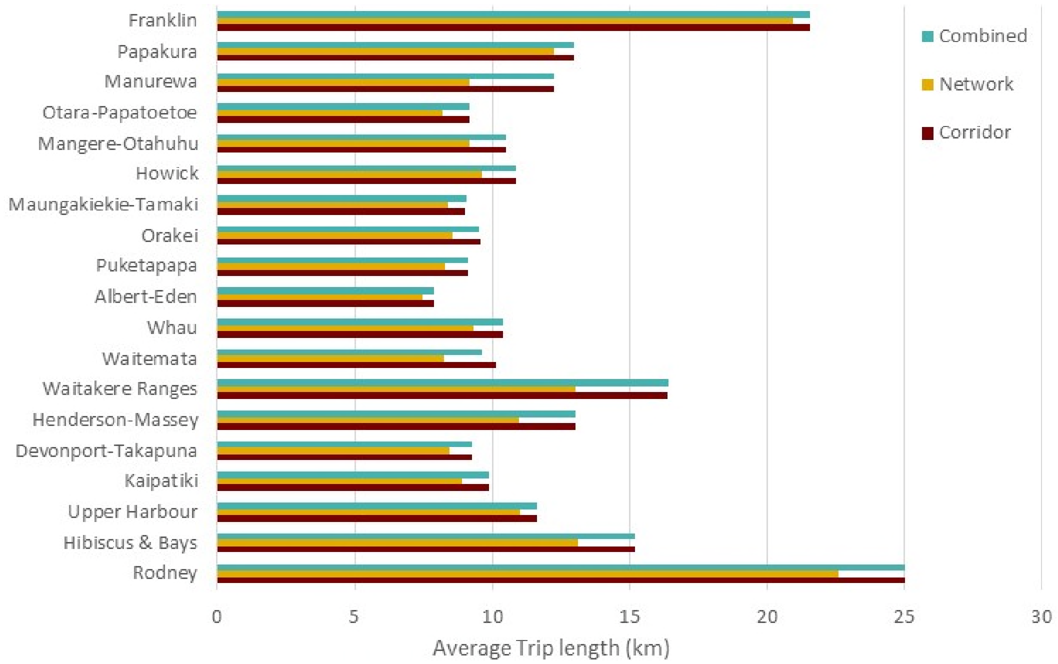
The CBD Cordon only covers 3% of trips across Auckland as a whole, but rises to 6% for trips originating in Orakei. The network option charges 74% of trips on average, ranging between 57% (Franklin) and 81% (Manurewa and Otara-Papatoetoe). The Isthmus area charge only covers 35% of trips, but 8% of trips from Maungakiekie-Tamaki.

Table 17 Percentage of trips facing the congestion charge

LBA	CBD Cordon	Isthmus area	Corridor	Network	Combined
Auckland Region	3%	35%	59%	74%	59%
Rodney	2%	9%	51%	63%	51%
Hibiscus & Bays	2%	6%	55%	73%	55%
Upper Harbour	3%	10%	70%	78%	70%
Kaipatiki	4%	14%	63%	78%	63%
Devonport-Takapuna	3%	13%	59%	71%	59%
Henderson-Massey	4%	19%	57%	75%	57%
Waitakere Ranges	5%	25%	43%	75%	43%
Waitemata	5%	72%	50%	69%	53%
Whau	5%	61%	57%	74%	57%
Albert-Eden	3%	78%	69%	77%	69%
Puketapapa	2%	78%	60%	77%	60%
Orakei	6%	80%	58%	73%	58%
Maungakiekie-Tamaki	5%	83%	70%	80%	69%
Howick	2%	18%	59%	76%	59%
Mangere-Otahuhu	1%	25%	60%	76%	60%
Otara-Papatoetoe	1%	13%	64%	81%	64%
Manurewa	0%	6%	47%	81%	47%
Papakura	0%	4%	68%	77%	68%
Franklin	0%	4%	52%	57%	52%

Three of the charge options (corridor, network and combined) levy on a per km basis. Figure 6 shows the average kilometres charged, per charged trip for the different LBA origins. The highest charged trip lengths are for Franklin and Rodney.

Figure 6 Average trip length of charged trips by LBA Origin



3.3 Option 1: CBD Cordon

Table 18 shows the estimated morning peak trip changes across Auckland as a whole, by household type. There are reductions in car trips, particularly for trips to work or education, but increases in PT trips. Reductions in car trips and increases in PT trips are expected to be greater for low income households than for high income households. Car trip reductions (and PT increases) are also greater for larger households, although elasticities do not differ based on household size (see Table 11).

Table 18 Changes in peak trip numbers (% of base case) total Auckland

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-0.7%	-0.5%	-0.3%	0.2%	0.2%	0.1%
1 or 2 person with 1+ vehicles	-1.0%	-1.0%	-0.8%	0.5%	0.5%	0.4%
3 person with 1+ vehicles	-1.2%	-1.1%	-0.9%	0.5%	0.5%	0.5%
4 or more person with 1+ vehicles	-1.4%	-1.2%	-1.0%	0.6%	0.6%	0.5%
Other trips						
All with no vehicles	-0.4%	-0.2%	-0.1%	0.0%	0.0%	-0.1%
1 or 2 person with 1+ vehicles	-0.5%	-0.5%	-0.4%	0.2%	0.2%	0.1%
3 person with 1+ vehicles	-0.6%	-0.5%	-0.4%	0.3%	0.3%	0.1%
4 or more person with 1+ vehicles	-0.7%	-0.6%	-0.4%	0.5%	0.4%	0.2%

Table 19 shows the results of using a uniform (-0.6) elasticity. The same pattern of higher car trip reductions for low income households is evident.

Table 19 Changes in peak trip numbers (% of base case) total Auckland (uniform elasticity)

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-0.9%	-0.6%	-0.4%	0.3%	0.2%	0.2%
1 or 2 person with 1+ vehicles	-1.0%	-1.0%	-0.9%	0.5%	0.5%	0.4%
3 person with 1+ vehicles	-1.1%	-1.1%	-1.0%	0.5%	0.5%	0.5%
4 or more person with 1+ vehicles	-1.3%	-1.2%	-1.1%	0.6%	0.6%	0.5%
Other trips						
All with no vehicles	-0.5%	-0.3%	-0.2%	0.0%	0.0%	-0.1%
1 or 2 person with 1+ vehicles	-0.5%	-0.5%	-0.4%	0.2%	0.2%	0.1%
3 person with 1+ vehicles	-0.5%	-0.5%	-0.5%	0.3%	0.3%	0.1%
4 or more person with 1+ vehicles	-0.6%	-0.6%	-0.5%	0.5%	0.4%	0.2%

Table 20 shows the change in costs per household (using variable elasticities). On average the costs are very small as a percentage of income.

Table 20 Change in trip costs – Total Auckland

	Costs ($/hh/year)			% of mean income		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$4	$4	$3	0.02%	0.01%	0.00%
1 or 2 person with 1+ vehicles	$0	$1	$2	0.00%	0.00%	0.00%
3 person with 1+ vehicles	$0	$2	$4	0.00%	0.00%	0.00%
4 or more person with 1+ vehicles	-$2	$2	$8	0.00%	0.00%	0.00%
Other trips						
All with no vehicles	$1	$1	$0	0.01%	0.00%	0.00%
1 or 2 person with 1+ vehicles	$0	$0	$1	0.00%	0.00%	0.00%
3 person with 1+ vehicles	-$1	$0	$1	0.00%	0.00%	0.00%
4 or more person with 1+ vehicles	-$4	-$2	$2	-0.01%	0.00%	0.00%

Table 21 shows the changes in costs by LBA. Some LBAs are showing reductions in costs, because of the reduced costs of fuel and parking when trips are avoided. This is particularly so for households in or close to the CBD: Waitemata, Albert-Eden, Orakei, Whau and Maungakiekie-Tamaki (see Annex B for map).

On the face of it, this might suggest that households in these areas should *already* be avoiding some trips. However, this does not take account of other costs and benefits, including the value of time and the wellbeing losses from avoiding trips or changing modes. If we added these non-financial impacts, we would expect all to show net costs.

Table 21 Change in average household costs – by LBA and income group – CBD Cordon

	Costs ($/hh/year)			% of Income		
	Low	Medium	High	Low	Medium	High
Rodney	$6	$9	$10	0.02%	0.01%	0.01%
Hibiscus & Bays	$6	$10	$11	0.02%	0.01%	0.01%
Upper Harbour	$5	$8	$11	0.02%	0.01%	0.01%
Kaipatiki	-$5	-$2	$2	-0.02%	0.00%	0.00%
Devonport-Takapuna	-$3	-$1	$3	-0.01%	0.00%	0.00%
Henderson-Massey	$3	$7	$10	0.01%	0.01%	0.01%
Waitakere Ranges	$7	$12	$16	0.02%	0.01%	0.01%
Waitemata	-$27	-$28	-$21	-0.08%	-0.03%	-0.01%
Whau	-$5	-$1	$4	-0.02%	0.00%	0.00%
Albert-Eden	-$10	-$10	-$7	-0.03%	-0.01%	0.00%
Puketapapa	-$3	-$3	-$1	-0.01%	0.00%	0.00%
Orakei	-$13	-$12	-$5	-0.04%	-0.02%	0.00%
Maungakiekie-Tamaki	-$6	-$3	$3	-0.02%	0.00%	0.00%
Howick	$4	$7	$8	0.01%	0.01%	0.01%
Mangere-Otahuhu	$3	$5	$7	0.01%	0.01%	0.00%
Otara-Papatoetoe	$3	$5	$6	0.01%	0.01%	0.00%
Manurewa	$1	$2	$2	0.00%	0.00%	0.00%
Papakura	$1	$1	$2	0.00%	0.00%	0.00%
Franklin	$1	$1	$2	0.00%	0.00%	0.00%
Auckland region	-$1	$1	$5	0.00%	0.00%	0.00%

3.4 Option 2: Isthmus Area

Table 22 shows the estimated morning peak trip changes across Auckland as a whole, by household type. The changes in trips are much more significant than for the CBD cordon option. Low income households are expected to reduce car trips and increase PT trips more than high income households.

Table 22 Changes in morning peak trip numbers (% of base case) total Auckland

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-7.4%	-4.8%	-2.9%	2.0%	1.5%	0.9%
1 or 2 person with 1+ vehicles	-12.8%	-11.9%	-9.4%	2.7%	2.6%	2.2%
3 person with 1+ vehicles	-12.9%	-12.6%	-10.8%	2.7%	2.8%	2.4%
4 or more person with 1+ vehicles	-14.7%	-13.9%	-11.2%	3.1%	3.0%	2.5%
Other trips						
All with no vehicles	-7.9%	-5.1%	-3.0%	1.2%	1.0%	0.7%
1 or 2 person with 1+ vehicles	-13.7%	-12.6%	-9.6%	5.3%	5.2%	4.6%
3 person with 1+ vehicles	-13.7%	-13.4%	-11.1%	5.0%	5.2%	4.9%
4 or more person with 1+ vehicles	-15.7%	-15.0%	-11.6%	5.4%	5.5%	5.1%

The changes in trip numbers differ significantly by location. For example, in the Franklin LBA, congestion charges are less significant as a percentage of costs households and hence trip numbers reduce by no more than 0.5% across all household types. Closer-in suburbs show more significant trip changes, including an approximately 40% reduction in car trips for some household types and trip purposes in the Albert-Eden LBA (Table 23).

Table 23 Changes in trip numbers (% of base case) – morning peak – Albert-Eden

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-27.1%	-25.5%	-23.4%	6.6%	0.0%	0.0%
1 or 2 person with 1+ vehicles	-37.3%	-35.0%	-32.1%	7.0%	7.0%	7.0%
3 person with 1+ vehicles	-37.3%	-35.0%	-32.1%	7.0%	7.0%	7.0%
4 or more person with 1+ vehicles	-37.3%	-35.0%	-32.1%	7.0%	7.0%	7.0%
Other trips						
All with no vehicles	-30.2%	-28.5%	-26.2%	4.4%	4.2%	3.8%
1 or 2 person with 1+ vehicles	-41.1%	-38.6%	-35.6%	13.6%	13.6%	13.6%
3 person with 1+ vehicles	-41.1%	-38.6%	-35.6%	13.6%	13.6%	13.6%
4 or more person with 1+ vehicles	-41.1%	-38.6%	-35.6%	13.6%	13.6%	13.6%

Table 24 shows the change in costs for Auckland households on average. The costs are more significant than for the CBD cordon and are highest, as a percentage of income, for low income households.

Table 24 Change in trip costs – Total Auckland

	Costs/hh/year			% of mean income		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$29	$24	$20	0.15%	0.04%	0.02%
1 or 2 person with 1+ vehicles	$49	$55	$57	0.20%	0.09%	0.04%
3 person with 1+ vehicles	$91	$105	$116	0.28%	0.14%	0.07%
4 or more person with 1+ vehicles	$174	$205	$221	0.40%	0.20%	0.12%
Other trips						
All with no vehicles	$17	$14	$10	0.09%	0.02%	0.01%
1 or 2 person with 1+ vehicles	$36	$40	$41	0.14%	0.06%	0.03%
3 person with 1+ vehicles	$75	$87	$96	0.23%	0.12%	0.06%
4 or more person with 1+ vehicles	$178	$210	$225	0.41%	0.21%	0.12%

Table 25 shows the changes in average household costs by LBA. These costs combine all trip purposes and modes.

The highest average costs per household are for the areas where the greatest percentage of trips face the charge (Table 17).

Table 25 Change in average household costs – by LBA and income group - Isthmus area

	Costs ($/hh/year)			% of Income		
	Low	Medium	High	Low	Medium	High
Rodney	$45	$61	$67	0.15%	0.08%	0.04%
Hibiscus & Bays	$27	$37	$38	0.09%	0.05%	0.03%
Upper Harbour	$53	$71	$86	0.19%	0.09%	0.05%
Kaipatiki	$64	$83	$90	0.21%	0.10%	0.06%
Devonport-Takapuna	$52	$69	$88	0.18%	0.09%	0.05%
Henderson-Massey	$91	$119	$126	0.32%	0.16%	0.08%
Waitakere Ranges	$126	$164	$172	0.39%	0.20%	0.11%
Waitemata	$158	$225	$253	0.48%	0.26%	0.17%
Whau	$302	$379	$395	0.93%	0.45%	0.26%
Albert-Eden	$217	$310	$338	0.72%	0.40%	0.23%
Puketapapa	$356	$565	$650	1.19%	0.73%	0.41%
Orakei	$302	$456	$514	1.00%	0.58%	0.33%
Maungakiekie-Tamaki	$467	$614	$687	1.50%	0.75%	0.42%
Howick	$116	$154	$160	0.38%	0.20%	0.11%
Mangere-Otahuhu	$139	$191	$225	0.49%	0.25%	0.14%
Otara-Papatoetoe	$96	$126	$128	0.30%	0.16%	0.09%
Manurewa	$41	$56	$56	0.13%	0.07%	0.04%
Papakura	$25	$33	$38	0.10%	0.05%	0.02%
Franklin	$19	$27	$38	0.09%	0.04%	0.02%
Auckland region	$156	$220	$230	0.52%	0.28%	0.15%

3.5 Option 3: Corridor

Table 26 shows the estimated morning peak trip changes across Auckland as a whole, by household type. As with the isthmus area option, low income households are expected to reduce car trips and increase PT trips more than high income households.

Table 26 Changes in morning peak trip numbers (% of base case) total Auckland

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-7.4%	-4.8%	-2.9%	2.0%	1.5%	0.9%
1 or 2 person with 1+ vehicles	-12.8%	-11.9%	-9.4%	2.7%	2.6%	2.2%
3 person with 1+ vehicles	-12.9%	-12.6%	-10.8%	2.7%	2.8%	2.4%
4 or more person with 1+ vehicles	-14.7%	-13.9%	-11.2%	3.1%	3.0%	2.5%
Other trips						
All with no vehicles	-7.9%	-5.1%	-3.0%	1.2%	1.0%	0.7%
1 or 2 person with 1+ vehicles	-13.7%	-12.6%	-9.6%	5.3%	5.2%	4.6%
3 person with 1+ vehicles	-13.7%	-13.4%	-11.1%	5.0%	5.2%	4.9%
4 or more person with 1+ vehicles	-15.7%	-15.0%	-11.6%	5.4%	5.5%	5.1%

Table 27 shows the change in costs for Auckland households on average. As with the isthmus area option, costs are highest, as a percentage of income, for low income households.

Table 27 Change in trip costs, morning peak – Total Auckland

	Costs/hh/year			% of mean income		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$29	$24	$20	0.15%	0.04%	0.02%
1 or 2 person with 1+ vehicles	$49	$55	$57	0.20%	0.09%	0.04%
3 person with 1+ vehicles	$91	$105	$116	0.28%	0.14%	0.07%
4 or more person with 1+ vehicles	$174	$205	$221	0.40%	0.20%	0.12%
Other trips						
All with no vehicles	$17	$14	$10	0.09%	0.02%	0.01%
1 or 2 person with 1+ vehicles	$36	$40	$41	0.14%	0.06%	0.03%
3 person with 1+ vehicles	$75	$87	$96	0.23%	0.12%	0.06%
4 or more person with 1+ vehicles	$178	$210	$225	0.41%	0.21%	0.12%

Table 28 shows the changes in costs by LBA. The average costs are affected both by the percentage of trips charged (Table 17) and the average length of trips (Figure 6).

Table 28 Change in average household costs – by LBA and income group - Corridor

	Costs ($/hh/year)			% of Income		
	Low	Medium	High	Low	Medium	High
Rodney	$207	$274	$302	0.69%	0.36%	0.19%
Hibiscus & Bays	$148	$201	$199	0.49%	0.25%	0.14%
Upper Harbour	$168	$219	$258	0.59%	0.28%	0.16%
Kaipatiki	$111	$139	$142	0.37%	0.17%	0.09%
Devonport-Takapuna	$90	$118	$145	0.32%	0.16%	0.09%
Henderson-Massey	$136	$175	$180	0.48%	0.23%	0.12%
Waitakere Ranges	$74	$95	$98	0.23%	0.12%	0.06%
Waitemata	$75	$96	$97	0.23%	0.11%	0.06%
Whau	$79	$98	$99	0.25%	0.12%	0.07%
Albert-Eden	$49	$68	$71	0.16%	0.09%	0.05%
Puketapapa	$77	$118	$132	0.26%	0.15%	0.08%
Orakei	$60	$87	$95	0.20%	0.11%	0.06%
Maungakiekie-Tamaki	$123	$158	$171	0.39%	0.19%	0.10%
Howick	$131	$171	$173	0.42%	0.22%	0.11%
Mangere-Otahuhu	$124	$166	$190	0.44%	0.22%	0.12%
Otara-Papatoetoe	$151	$194	$192	0.48%	0.24%	0.13%
Manurewa	$103	$139	$136	0.33%	0.18%	0.09%
Papakura	$152	$199	$225	0.58%	0.29%	0.15%
Franklin	$139	$198	$272	0.66%	0.29%	0.17%
Auckland region	$121	$157	$178	0.41%	0.20%	0.11%

3.6 Option 4: Network

Table 29 shows the estimated morning peak trip changes across Auckland as a whole, by household type. The network option has a more significant impact on total trip numbers than the other options. As with other options, low income households are expected to reduce car trips and increase PT trips more than high income households.

Table 29 Changes in morning peak trip numbers (% of base case) total Auckland

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-9.4%	-8.3%	-7.2%	1.3%	1.2%	1.2%
1 or 2 person with 1+ vehicles	-13.8%	-12.7%	-11.4%	1.2%	1.3%	1.2%
3 person with 1+ vehicles	-13.9%	-12.9%	-11.5%	1.3%	1.3%	1.2%
4 or more person with 1+ vehicles	-14.0%	-12.9%	-11.6%	1.3%	1.3%	1.2%
Other trips						
All with no vehicles	-8.4%	-7.2%	-6.0%	1.0%	0.9%	0.7%
1 or 2 person with 1+ vehicles	-12.5%	-11.5%	-10.2%	1.8%	1.8%	1.9%
3 person with 1+ vehicles	-12.7%	-11.8%	-10.5%	1.8%	1.8%	1.9%
4 or more person with 1+ vehicles	-12.9%	-11.9%	-10.5%	1.7%	1.8%	2.0%

Table 30 shows the change in costs for Auckland households on average. As with other options, the costs are highest, as a percentage of income, for low income households.

Table 30 Change in trip costs – Total Auckland

	Costs/hh/year			% of mean income		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$33	$40	$47	0.17%	0.07%	0.04%
1 or 2 person with 1+ vehicles	$61	$64	$73	0.24%	0.10%	0.05%
3 person with 1+ vehicles	$106	$111	$127	0.32%	0.15%	0.08%
4 or more person with 1+ vehicles	$176	$195	$231	0.40%	0.19%	0.12%
Other trips						
All with no vehicles	$11	$11	$11	0.05%	0.02%	0.01%
1 or 2 person with 1+ vehicles	$38	$41	$46	0.15%	0.06%	0.03%
3 person with 1+ vehicles	$79	$83	$95	0.24%	0.11%	0.06%
4 or more person with 1+ vehicles	$164	$180	$214	0.37%	0.18%	0.11%

The network charge includes a cost per vehicle of $200 per annum for in-vehicle technology.[51] This was added to household costs using estimates of vehicle numbers per household.[52] This is the cost of systems required to track the physical location of vehicles and their charge liability. These costs are not included in Table 30 because it is not possible to allocate the costs between trip purpose. However, they are included in total cost estimates in Table 31 which shows the changes in costs by LBA.

The costs of the network charge are considerably more than that of the other options, largely because of this technology cost. But it also reflects the higher percentage of trips which face the charge (Table 17).

[51] Auckland Transport estimate.

[52] 1 or 2 persons: 1.674 vehicles/hh; 3 persons: 2.06/hh; 4+ persons:2.316/hh (data from MoT Household Travel Survey)

Table 31 Change in average household costs – by LBA and income group - Network

	Costs ($/hh/year)			% of Income		
	Low	Medium	High	Low	Medium	High
Rodney	$619	$745	$789	2.06%	0.98%	0.50%
Hibiscus & Bays	$510	$647	$649	1.69%	0.82%	0.44%
Upper Harbour	$505	$628	$698	1.79%	0.82%	0.43%
Kaipatiki	$484	$579	$590	1.59%	0.71%	0.37%
Devonport-Takapuna	$431	$509	$564	1.51%	0.69%	0.34%
Henderson-Massey	$467	$597	$613	1.64%	0.78%	0.41%
Waitakere Ranges	$539	$626	$635	1.68%	0.76%	0.40%
Waitemata	$400	$486	$493	1.22%	0.57%	0.33%
Whau	$470	$556	$563	1.46%	0.66%	0.37%
Albert-Eden	$381	$469	$480	1.26%	0.61%	0.33%
Puketapapa	$446	$565	$598	1.49%	0.73%	0.38%
Orakei	$426	$518	$536	1.42%	0.66%	0.34%
Maungakiekie-Tamaki	$523	$601	$625	1.68%	0.73%	0.38%
Howick	$511	$617	$622	1.66%	0.79%	0.41%
Mangere-Otahuhu	$488	$605	$654	1.72%	0.80%	0.40%
Otara-Papatoetoe	$537	$647	$644	1.69%	0.81%	0.44%
Manurewa	$511	$622	$618	1.63%	0.79%	0.41%
Papakura	$503	$618	$673	1.90%	0.92%	0.44%
Franklin	$375	$547	$724	1.76%	0.80%	0.46%
Auckland region	$482	$592	$630	1.61%	0.76%	0.40%

3.7 Option 5: Combined Option

Table 32 shows the estimated morning peak trip changes across Auckland as a whole, by household type. As with other options, low income households are expected to reduce car trips and increase PT trips more than high income households.

Table 32 Changes in morning peak trip numbers (% of base case) total Auckland

	Car trips			PT trips		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	-7.2%	-6.3%	-5.4%	1.3%	1.4%	1.4%
1 or 2 person with 1+ vehicles	-10.6%	-9.8%	-8.8%	1.4%	1.5%	1.4%
3 person with 1+ vehicles	-10.7%	-9.9%	-8.9%	1.5%	1.5%	1.4%
4 or more person with 1+ vehicles	-11.0%	-10.0%	-9.0%	1.6%	1.6%	1.4%
Other trips						
All with no vehicles	-6.0%	-5.1%	-4.3%	0.8%	0.8%	0.7%
1 or 2 person with 1+ vehicles	-8.7%	-8.1%	-7.1%	1.6%	1.6%	1.6%
3 person with 1+ vehicles	-8.9%	-8.2%	-7.3%	1.7%	1.7%	1.6%
4 or more person with 1+ vehicles	-9.0%	-8.2%	-7.3%	1.8%	1.7%	1.7%

Table 33 shows the change in costs for Auckland households on average. As with the other options, the costs are highest, as a percentage of income, for low income households.

Table 33 Change in trip costs, morning peak – Total Auckland

	Costs/hh/year			% of mean income		
	Low	Medium	High	Low	Medium	High
Trips to work or education						
All with no vehicles	$31	$36	$41	0.16%	0.06%	0.04%
1 or 2 person with 1+ vehicles	$51	$54	$61	0.20%	0.09%	0.04%
3 person with 1+ vehicles	$91	$96	$108	0.28%	0.13%	0.07%
4 or more person with 1+ vehicles	$155	$169	$198	0.35%	0.17%	0.11%
Other trips						
All with no vehicles	$10	$10	$10	0.05%	0.02%	0.01%
1 or 2 person with 1+ vehicles	$30	$32	$37	0.12%	0.05%	0.03%
3 person with 1+ vehicles	$64	$67	$76	0.20%	0.09%	0.05%
4 or more person with 1+ vehicles	$136	$146	$172	0.31%	0.14%	0.09%

Table 34 shows the changes in costs by LBA. The highest costs are for Rodney, reflecting the length of trips facing the charge (Figure 6).

Table 34 Change in average household costs – by LBA and income group – Combined option

	Costs ($/hh/year)			% of Income		
	Low	Medium	High	Low	Medium	High
Rodney	$216	$286	$315	0.72%	0.38%	0.20%
Hibiscus & Bays	$160	$217	$215	0.53%	0.27%	0.15%
Upper Harbour	$183	$239	$282	0.65%	0.31%	0.17%
Kaipatiki	$132	$165	$170	0.43%	0.20%	0.11%
Devonport-Takapuna	$104	$136	$168	0.37%	0.19%	0.10%
Henderson-Massey	$153	$197	$204	0.54%	0.26%	0.14%
Waitakere Ranges	$103	$131	$135	0.32%	0.16%	0.09%
Waitemata	$81	$106	$109	0.25%	0.12%	0.07%
Whau	$105	$129	$132	0.32%	0.15%	0.09%
Albert-Eden	$57	$78	$82	0.19%	0.10%	0.06%
Puketapapa	$84	$128	$143	0.28%	0.16%	0.09%
Orakei	$82	$121	$132	0.27%	0.15%	0.08%
Maungakiekie-Tamaki	$146	$187	$204	0.47%	0.23%	0.12%
Howick	$143	$187	$189	0.46%	0.24%	0.12%
Mangere-Otahuhu	$133	$179	$204	0.47%	0.24%	0.13%
Otara-Papatoetoe	$161	$207	$205	0.51%	0.26%	0.14%
Manurewa	$105	$142	$139	0.34%	0.18%	0.09%
Papakura	$154	$200	$227	0.58%	0.30%	0.15%
Franklin	$141	$201	$275	0.66%	0.29%	0.18%
Auckland region	$137	$178	$200	0.46%	0.23%	0.13%

3.8 Option Comparisons

3.8.1 Changes in Trips

Reflecting the percentage of trips which face the charge (Table 17), Table 35 shows the estimated change in car trips, relative to the base case, resulting from the different options. The Isthmus area and Network charge options are estimated to reduce car trips by more than 12% on average across the region. The corridor and combined options by 8-9% and the CBD cordon by less than 1%.

The Isthmus area charge has a high impact relative to liability to the charge because the cost is relatively high for those facing the charge (see Section 3.4).

Table 35 Option comparison: changes in car trip numbers by LBA (% of base)

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Auckland region	-0.8%	-12.9%	-7.9%	-12.1%	-8.9%
Rodney	-0.2%	-1.0%	-6.5%	-9.4%	-6.7%
Hibiscus & Bays	-0.4%	-0.8%	-8.0%	-12.4%	-8.6%
Upper Harbour	-0.5%	-1.7%	-10.1%	-12.9%	-11.0%
Kaipatiki	-1.1%	-3.2%	-8.4%	-12.7%	-9.8%
Devonport-Takapuna	-1.0%	-2.8%	-8.6%	-11.6%	-9.9%
Henderson-Massey	-0.9%	-4.1%	-8.8%	-13.1%	-9.8%
Waitakere Ranges	-1.1%	-5.5%	-3.8%	-11.3%	-5.1%
Waitemata	-2.8%	-33.9%	-9.0%	-14.3%	-11.2%
Whau	-1.4%	-23.7%	-6.7%	-11.8%	-8.6%
Albert-Eden	-1.1%	-37.0%	-9.7%	-13.4%	-11.2%
Puketapapa	-0.4%	-34.1%	-7.5%	-12.5%	-8.0%
Orakei	-1.7%	-34.1%	-6.4%	-11.1%	-8.7%
Maungakiekie-Tamaki	-1.1%	-33.4%	-9.0%	-12.6%	-10.5%
Howick	-0.4%	-4.4%	-7.6%	-11.4%	-8.2%
Mangere-Otahuhu	-0.3%	-6.9%	-7.9%	-12.4%	-8.4%
Otara-Papatoetoe	-0.3%	-3.0%	-8.9%	-13.0%	-9.5%
Manurewa	-0.1%	-1.1%	-5.6%	-12.7%	-5.8%
Papakura	0.0%	-0.6%	-9.1%	-12.9%	-9.2%
Franklin	0.0%	-0.4%	-5.7%	-8.1%	-5.8%

Table 36 shows the same analysis for PT trips. In this case, the options result largely in increases in PT trips. The Isthmus area option is estimated to result in an overall 2.6% increase in PT trips. The Network and Combined options are estimated to increase PT trips by 1.3% and 1.5% respectively. The corridor and CBD cordon charges are expected to increase PT trips by less than 1%.

Table 36 Option comparison: changes in PT trip numbers by LBA (% of base)

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	0.2%	-0.1%	0.1%	-0.4%	0.5%
Hibiscus & Bays	0.4%	-0.4%	-0.4%	0.1%	0.1%
Upper Harbour	0.2%	0.3%	0.7%	1.1%	1.0%
Kaipatiki	0.6%	-0.3%	0.3%	0.8%	0.9%
Devonport-Takapuna	0.5%	-0.6%	0.2%	0.6%	0.7%
Henderson-Massey	0.1%	0.6%	0.9%	1.3%	1.1%
Waitakere Ranges	0.2%	0.7%	0.3%	1.3%	0.5%
Waitemata	1.4%	5.9%	1.3%	1.7%	2.8%
Whau	0.3%	4.8%	0.7%	1.3%	1.1%
Albert-Eden	0.7%	7.4%	1.6%	1.9%	2.4%
Puketapapa	0.5%	7.2%	1.2%	1.8%	1.8%
Orakei	0.7%	5.8%	1.0%	1.6%	1.8%
Maungakiekie-Tamaki	0.2%	6.5%	1.0%	1.4%	1.3%
Howick	0.3%	0.7%	0.9%	1.4%	1.4%
Mangere-Otahuhu	0.0%	2.2%	2.1%	2.7%	2.5%
Otara-Papatoetoe	0.0%	1.2%	1.2%	1.6%	1.4%
Manurewa	0.1%	0.8%	0.9%	1.3%	1.1%
Papakura	0.1%	0.6%	0.5%	1.0%	0.7%
Franklin	0.0%	0.6%	1.4%	1.1%	1.6%
Total	0.4%	2.8%	0.9%	1.3%	1.5%

3.8.2 Average Household Cost Increases

Table 37 shows average increases in costs across all household types. The costs are the sum of costs across all trip types (to work or education and other trips) and modes (car and PT). Cost increases are greater for high income households than for low.

Table 37 Option comparison: cost increases per household per annum

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	-$1	$156	$121	$482	$137
Medium	$1	$220	$157	$592	$178
High	$5	$230	$178	$630	$200

Costs are highest for the network option, partly reflecting the $200/annum assumed cost of in-vehicle technology required to operate the scheme. Costs are lowest for the CBD cordon charge. The Isthmus area scheme has the second highest costs, with the corridor and combined options in between. The Isthmus area option has relatively high costs for those facing the charge (see Section 3.4).

Table 38 shows weighted average costs as a percentage of income across all household types. All options have higher proportional costs for low income households. The lowest cost option is the CBD cordon. The network option has the highest costs.

Table 38 Option comparison: costs as a percentage of income

Income level	CBD Cordon	Isthmus area	Corridor	Network	Combined
Low	0.00%	0.52%	0.41%	1.61%	0.46%
Medium	0.00%	0.28%	0.20%	0.76%	0.23%
High	0.00%	0.15%	0.11%	0.40%	0.13%

Table 39 shows the average annual increase in costs per household across the different options. The geographical differences in costs reflects the different location of the charged area relative to trip origins.

Table 40 shows these cost increases as a percentage of annual income. They range from small positive impacts (where fuel and parking costs are reduced) to cost increases averaging close to 1% of annual income (network option for Rodney and Papakura).

Table 39 Option comparison: household average increase in costs

Trip origin LBA	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	$8	$57	$259	$714	$270
Hibiscus & Bays	$9	$33	$179	$591	$193
Upper Harbour	$8	$73	$222	$625	$242
Kaipatiki	-$2	$78	$129	$546	$154
Devonport-Takapuna	$1	$76	$127	$523	$147
Henderson-Massey	$6	$111	$162	$555	$183
Waitakere Ranges	$12	$155	$90	$603	$124
Waitemata	-$27	$198	$86	$447	$95
Whau	-$2	$351	$90	$522	$120
Albert-Eden	-$9	$281	$62	$438	$71
Puketapapa	-$2	$529	$110	$539	$119
Orakei	-$10	$431	$82	$497	$113
Maungakiekie-Tamaki	-$2	$601	$153	$588	$182
Howick	$6	$145	$160	$587	$174
Mangere-Otahuhu	$5	$191	$164	$593	$177
Otara-Papatoetoe	$5	$115	$177	$603	$189
Manurewa	$2	$51	$127	$587	$130
Papakura	$1	$31	$183	$576	$184
Franklin	$1	$30	$215	$578	$217

3.8.3 Impacts on Low Income Households

Table 41 shows the average cost increases as a percentage of annual income for low income households, by LBA. In comparison to the average effects per household (Table 40), the impacts on low income households are more significant. For the network charge costs are estimated to be as high as 2.1% of household income in Rodney. The CBD cordon charge has impacts estimated to be no higher than 0.02% of annual income and a benefit of close to 0.1% of income for Waitemata households.

Table 40 Option comparison: household average increase in costs (% of annual income)

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	0.01%	0.07%	0.31%	0.84%	0.32%
Hibiscus & Bays	0.01%	0.04%	0.24%	0.79%	0.26%
Upper Harbour	0.01%	0.07%	0.22%	0.62%	0.24%
Kaipatiki	0.00%	0.09%	0.15%	0.64%	0.18%
Devonport-Takapuna	0.00%	0.07%	0.11%	0.46%	0.13%
Henderson-Massey	0.01%	0.14%	0.20%	0.68%	0.22%
Waitakere Ranges	0.01%	0.17%	0.10%	0.64%	0.13%
Waitemata	-0.04%	0.28%	0.12%	0.64%	0.13%
Whau	0.00%	0.45%	0.12%	0.67%	0.15%
Albert-Eden	-0.01%	0.37%	0.08%	0.58%	0.09%
Puketapapa	0.00%	0.59%	0.12%	0.60%	0.13%
Orakei	-0.01%	0.47%	0.09%	0.54%	0.12%
Maungakiekie-Tamaki	0.00%	0.61%	0.15%	0.59%	0.18%
Howick	0.01%	0.16%	0.18%	0.66%	0.20%
Mangere-Otahuhu	0.01%	0.19%	0.17%	0.60%	0.18%
Otara-Papatoetoe	0.01%	0.15%	0.23%	0.79%	0.25%
Manurewa	0.00%	0.06%	0.14%	0.67%	0.15%
Papakura	0.00%	0.05%	0.27%	0.86%	0.27%
Franklin	0.00%	0.03%	0.23%	0.61%	0.23%
Auckland	0.00%	0.23%	0.17%	0.65%	0.20%

Table 41 Option comparison: cost increases per low income household per annum (% of annual income)

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	0.02%	0.15%	0.69%	2.06%	0.72%
Hibiscus & Bays	0.02%	0.09%	0.49%	1.69%	0.53%
Upper Harbour	0.02%	0.19%	0.59%	1.79%	0.65%
Kaipatiki	-0.02%	0.21%	0.37%	1.59%	0.43%
Devonport-Takapuna	-0.01%	0.18%	0.32%	1.51%	0.37%
Henderson-Massey	0.01%	0.32%	0.48%	1.64%	0.54%
Waitakere Ranges	0.02%	0.39%	0.23%	1.68%	0.32%
Waitemata	-0.08%	0.48%	0.23%	1.22%	0.25%
Whau	-0.02%	0.93%	0.25%	1.46%	0.32%
Albert-Eden	-0.03%	0.72%	0.16%	1.26%	0.19%
Puketapapa	-0.01%	1.19%	0.26%	1.49%	0.28%
Orakei	-0.04%	1.00%	0.20%	1.42%	0.27%
Maungakiekie-Tamaki	-0.02%	1.50%	0.39%	1.68%	0.47%
Howick	0.01%	0.38%	0.42%	1.66%	0.46%
Mangere-Otahuhu	0.01%	0.49%	0.44%	1.72%	0.47%
Otara-Papatoetoe	0.01%	0.30%	0.48%	1.69%	0.51%
Manurewa	0.00%	0.13%	0.33%	1.63%	0.34%
Papakura	0.00%	0.10%	0.58%	1.90%	0.58%
Franklin	0.00%	0.09%	0.66%	1.76%	0.66%
Auckland	0.00%	0.52%	0.41%	1.61%	0.46%

4 Business Impacts

In this section we analyse the impacts of the congestion charges on business.

4.1 Base Case

Table 42 shows the employment-based and freight trips per morning peak from each origin LBA and in total.

Table 42 Base case trips per morning peak

Origin LBA	Car	PT	HCV	Total
Rodney	1,904	14	2,024	3,943
Hibiscus & Bays	1,995	48	1,120	3,162
Upper Harbour	2,690	151	1,938	4,779
Kaipatiki	2,060	73	940	3,073
Devonport-Takapuna	1,681	190	535	2,405
Henderson-Massey	2,542	143	1,878	4,563
Waitakere Ranges	881	11	404	1,295
Waitemata	9,169	1,045	1,656	11,870
Whau	2,568	84	699	3,350
Albert-Eden	4,855	161	790	5,806
Puketapapa	1,879	26	839	2,745
Orakei	4,032	63	840	4,935
Maungakiekie-Tamaki	8,203	189	5,653	14,046
Howick	7,750	137	2,996	10,883
Mangere-Otahuhu	3,911	129	4,101	8,141
Otara-Papatoetoe	4,289	163	3,091	7,543
Manurewa	2,928	39	1,458	4,425
Papakura	2,950	39	2,198	5,186
Franklin	4,118	32	2,139	6,289
Auckland Total	70,404	2,736	35,300	108,441

The base case costs as annual trip costs by LBA are shown in Table 43. Unlike household costs, we have included a cost of travel time for business, because this time is 'on the clock' and hence equivalent to a financial cost. The estimated costs of travel time dominate the direct financial costs of fuel, parking, and PT fares.

4.2 Impact of Options

Table 44 shows the impacts of the options on costs as a percentage of base case costs. In most LBAs, under most options, costs are expected to reduce, due to modelled reductions in travel time. The exception is the isthmus area charge, which is expected to result in net increases in costs for business travel.

Table 44 also shows the absolute value for Auckland region as a whole. It ranges from an estimated $4 million cost for this isthmus area scheme to a $10 million benefit of the combined scheme.

Table 43 Base case annual travel costs for business ($ million)

Origin LBA	Fuel	Parking	PT fares	Cost of travel time	Total cost
Rodney	$11.1	$0.8	$0.0	$54.1	$66.1
Hibiscus & Bays	$6.6	$0.9	$0.1	$34.9	$42.5
Upper Harbour	$7.2	$1.5	$0.4	$43.0	$52.1
Kaipatiki	$4.7	$1.7	$0.1	$30.4	$36.9
Devonport-Takapuna	$3.7	$1.5	$0.4	$27.7	$33.3
Henderson-Massey	$7.7	$2.4	$0.3	$52.3	$62.8
Waitakere Ranges	$2.7	$0.7	$0.0	$17.1	$20.5
Waitemata	$9.6	$20.9	$1.5	$67.3	$99.3
Whau	$4.3	$3.6	$0.1	$31.6	$39.6
Albert-Eden	$5.2	$7.3	$0.2	$35.8	$48.6
Puketapapa	$2.8	$1.3	$0.0	$19.1	$23.3
Orakei	$5.0	$6.3	$0.1	$36.4	$47.7
Maungakiekie-Tamaki	$14.9	$11.1	$0.3	$108.4	$134.7
Howick	$13.4	$2.1	$0.3	$96.4	$112.2
Mangere-Otahuhu	$9.6	$1.3	$0.3	$57.2	$68.3
Otara-Papatoetoe	$8.5	$1.2	$0.3	$56.4	$66.3
Manurewa	$5.0	$0.6	$0.1	$32.4	$38.1
Papakura	$6.5	$0.6	$0.1	$42.6	$49.8
Franklin	$13.4	$0.7	$0.1	$70.7	$84.9
Auckland Total	$141.9	$66.5	$4.8	$913.7	$1,126.8

Table 44 Option comparison: change in costs as % of base costs

	CBD Cordon	Isthmus area	Corridor	Network	Combined
Rodney	0.0%	0.4%	1.3%	1.3%	1.4%
Hibiscus & Bays	-0.1%	0.7%	1.3%	1.4%	1.4%
Upper Harbour	-0.4%	-1.2%	-0.7%	-0.6%	-1.1%
Kaipatiki	-1.2%	-1.7%	-1.0%	-0.9%	-1.8%
Devonport-Takapuna	-1.3%	-1.1%	-1.0%	-0.9%	-1.9%
Henderson-Massey	-0.5%	-2.1%	-2.2%	-2.0%	-2.8%
Waitakere Ranges	-0.4%	-1.1%	-1.2%	-1.2%	-1.6%
Waitemata	-0.5%	3.3%	-0.3%	0.0%	-0.8%
Whau	-1.1%	-1.0%	-1.3%	-1.7%	-2.6%
Albert-Eden	-0.1%	2.8%	-0.4%	-0.5%	-0.6%
Puketapapa	-0.3%	2.1%	-2.2%	-2.7%	-2.6%
Orakei	-1.0%	1.9%	-0.3%	-0.6%	-1.7%
Maungakiekie-Tamaki	-0.7%	3.6%	0.0%	-0.2%	-0.9%
Howick	-0.1%	-1.0%	-1.3%	-1.4%	-1.3%
Mangere-Otahuhu	-0.1%	-1.1%	0.3%	-0.1%	0.0%
Otara-Papatoetoe	0.0%	-1.2%	-1.5%	-1.6%	-1.6%
Manurewa	0.0%	-0.9%	-0.7%	-0.5%	-0.7%
Papakura	-0.2%	-0.3%	-0.6%	-0.3%	-0.6%
Franklin	0.0%	-0.2%	0.4%	0.4%	0.5%
Auckland	-0.4%	0.4%	-0.5%	-0.5%	-0.9%
$ million	-$4.3	$4.4	-$5.5	-$5.8	-$9.8

5 Conclusions

The quantitative results in Section 3 show the expected effects of congestion charging on household costs relative to income, and in Section 4 we analyse the costs to business. In this section we expand on these impacts by discussing the expected effects at the household level, building on the discussion of possible impacts in Section 2. We discuss this in terms of the demand response, effects on income and expenditure, and on social exclusion.

5.1 Demand Response

The introduction of congestion charging is expected to result in a reduction in car trips and an increase in PT trips. The reduction in car trips will include the shifts to PT, shifts in the time of the trip away from the peak periods which are charged and some overall trip suppression.

The largest reductions in car trips, at over 12% on average, are estimated to result from the Isthmus area and Network charge options. The corridor and combined options also have significant effects, whereas the CBD cordon is expected to result in a less than 1% reduction in trips.

The options result in increases in PT trips, with the Isthmus area option having the greatest estimated effect (2.8% increase in PT trips). The corridor and CBD cordon charges are expected to increase PT trips by less than 1%.

5.2 Costs and their Distribution

The estimated financial costs of the schemes are higher for high income households, because they use more transport and are more likely to continue to take trips in the charged period and to pay the charge. However, as a percentage of annual income, costs are greater for low income households. This result is consistent with the international literature.

On average for Auckland households, as a percentage of household income, the scale of costs is between close to zero (the CBD cordon) and approximately 0.7% (the Network option) (Table 40). However, for low income households, average costs increase for the network charge to 1.6% of annual income (Table 38).

With the exception of the isthmus area charge, the schemes are expected to reduce costs for employer business and freight travel. This reflects the fact that business trips experience savings in 'on the clock' time that offset the added financial cost of the tolls. Businesses may in turn pass on some of these savings to consumers (as lower costs) or workers (as higher incomes). For instance, a tradesperson who saves twenty minutes in traffic *en route* to visit a customer may be able to charge a lower amount to that customer.

5.3 Income and Expenditure

In addition to reductions in demand for transport, increases in costs of transport have impacts on demand for other goods also. Specifically, when there is an increase in transport costs, less will be spent on other items, and when there is a reduction in transport use because of the higher costs, this adds to available household income which is subsequently spent on other items. In Annex C we set out differences in expenditure patterns between income deciles and we include cross-price elasticities which suggest increases in the price of transport leads to increases in demand for other goods, particularly household operations,[53] housing and food.

Thus, some of the effects of the congestion charge will be a redistribution of costs within household budgets. On the assumption that households behave rationally in their current expenditure, this shift in expenditure patterns will result in a reduction in wellbeing. They will be spending on something they prefer less, giving up transport (or what transport enables) in favour of other household goods and services.

5.4 Social Exclusion

Congestion charging might result in increased social exclusion if, as a result, people forego opportunities for employment, education, and/or social participation. The impacts are limited because the charge applies at morning and evening peaks only, so many social interactions are unaffected, unlike the impacts in London discussed above (Section 1.2.5). There may be impacts on total employment, although the modelling does not enable us to identify this as oppose to shifts in the location of employment.

Rather than speculate on these impacts, we have limited our assessment to the changes in trip numbers, modal shifts and costs.

5.5 Business Impacts

The impacts on business are estimated to be generally positive. This is because of the inclusion of impacts of travel time savings in the analysis.

[53] The household operation group includes expenditure on furniture, domestic fuel and power, floor coverings, home appliances and household services such as telecommunications.

6 References

Anable J and Goodwin P (2018) *Assessing the Net Overall Distributive Effect of a Congestion Charge.* International Transport Forum Discussion Papers, OECD Publishing, Paris.

Arnott R, De Palma A and Lindsey R (1994). The welfare effects of congestion tolls with heterogeneous commuters. *Journal of Transport Economics and Policy* 28(2):139–161.

Baumol WJ and Oates WE (1988) *The theory of environmental policy*. 2nd Ed. Cambridge.

Bonsall P and Kelly C (2005). Road user charging and social exclusion: The impact of congestion charges on at-risk groups. *Transport Policy* 12(5): 406–418.

Börjesson M (2017) *Long-term effects of the Swedish congestion charges*. Paper presented to the International Transport Forum Roundtable on Social Impacts of Time and Space-Based Road Pricing. 30 November – 1 December, Auckland.

Bureau B and Glachant M (2008). Distributional effects of road pricing: Assessment of nine scenarios for Paris. *Transportation Research Part A: Policy and Practice*, 42(7): 994–1007.

Croci E (2016) Urban road pricing: a comparative study on the experiences of London, Stockholm and Milan. *Transportation Research Procedia*, 14: 253–262.

Croci E and Ravazzi A (2016) *Urban Road Pricing: A Comparative Study on the Experiences of London, Stockholm and Milan*. Working Paper No 85. IEFE - The Center for Research on Energy and Environmental Economics and Policy at Bocconi University.

D'Artagnan Consulting (2018) *Review of international road pricing initiatives, previous reports and technologies for demand management purposes.* Report for Ministry of Transport.

Denne T and Atkins S (2015) *Policies to Reduce Harmful Emissions from Vehicles: Costs and Benefits*. Report for Ministry of Transport. Covec Ltd. Auckland.

Denne T, Colegrave F, Vuletich S, Fisher G and O'Brien M (2005) *Vehicle Fleet Emission Screening Programme. Social and Economic Impact Assessment Phase I*. Report for the Ministry of Transport. Covec Ltd. Auckland.

De Palma A and Lindsey R (2004). Congestion pricing with heterogeneous travelers: A general-equilibrium welfare analysis. Networks and Spatial Economics, 4(2), 135–160.

Di Ciommo F and Lucas K (2014) Evaluating the equity effects of road-pricing in the European urban context - The Madrid Metropolitan Area', *Applied Geography*, 54: 74-82. doi: 10.1016/j.apgeog.2014.07.015

Eliasson J (undated) *Cost-benefit analysis of the Stockholm congestion charging system*. Accessed (October 2018) from: http://siteresources.worldbank.org/INTTRANSPORT/Resources/StockholmcongestionCBAEliassonn.pdf

Eliasson J (2016) *Is Congestion Pricing Fair? Consumer and Citizen Perspectives on Equity Effects.* International Transport Forum Discussion Paper 2016-13.

Eliasson J and Mattsson L-G (2006). Equity effects of congestion pricing: quantitative methodology and a case study for Stockholm. Transportation Research Part A: Policy and Practice, 40(7), 602–620.

Evans R (2008) *Demand Elasticities for Car Trips to Central London as revealed by the Central London Congestion Charge*. Transport for London Policy Analysis Division.

Fridstrøm L, Minken H, Moilanen P, Shepherd S and Vold A (2000). *Economic and equity effects of marginal cost pricing in transport*. AFFORD Deliverable A 2.

Goodwin P, Dargay J and Hanly M (2004) Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review. *Transport Reviews*, 24(3): 275–292.

Hanly M, Dargay J and Goodwin P (2002) Review of Income and Price Elasticities in the Demand for Road Traffic. ESRC Transport Studies Unit publication 2002/13. University of London Centre for Transport Studies.

Harding M (2014) *Personal Tax Treatment of Company Cars and Commuting Expenses: Estimating the Fiscal and Environmental Costs.* OECD Taxation Working Papers No 20. OECD Publishing. http://dx.doi.org/10.1787/5jz14cg1s7vl-en

Hyslop D and Rea D (2016) *Does the accommodation supplement increase spending on rents?* Phase 1 results of the Auckland Accommodation Supplement Study. Ministry of Social Development.

Kayser HA (2000) Gasoline demand and car choice: estimating gasoline demand using household information. Energy Economics, 22: 331-348.

Kennedy D and Wallis I (2007) Impacts of fuel price changes on New Zealand transport. Land Transport New Zealand Research Report 331.

Leung C, Destremau K, Pambudi D and Bealing M (2017) *Benefits from Auckland road decongestion*. NZIER report to the Employers and Manufacturers Association, Infrastructure New Zealand, Auckland International Airport Ltd, Ports of Auckland Ltd, National Road Carriers Association.

Market Economics (2014a) Analysis of the affordability and social impacts of alternative transport funding mechanisms for Auckland households. Auckland.

Market Economics (2014b) *Analysis of the impacts of alternative transport funding mechanisms on Auckland businesses*. Auckland.

Matas A and Raymond J-L (2003) Demand Elasticity on Tolled Motorways. Journal of Transportation and Statistics, 6(2): 91-108.

Mattioli G, Wadud Z and Lucas K (2018) Vulnerability to fuel price increases in the UK: A household level analysis. *Transportation Research Part A* 113: 227–242.

Ministry of Transport (2006) Tackling Congestion in Auckland. Auckland Road Pricing Evaluation Study. Summary Report.

Ministry of Transport (2008) Auckland Road Pricing Study 2008 Report no: WL00062-1

MRCagney (2018) Social and Distributional Impacts of Time and Space-based Road Pricing. Final Draft Report for NZ Transport Agency.

Munford LA (2017) The impact of congestion charging on social capital. *Transp Res Part A Policy Pract* 97: 192–208. doi: 10.1016/j.tra.2017.01.018

Newbery DM (1990) Pricing and Congestion: Economic Principles Relevant to Pricing Roads. *Oxford Review of Economic Policy*, 6(2): 22–38.

NZ Transport Agency (2018) *Economic Evaluation Manual*.

NZ Treasury (2015) *Guide to Social Cost Benefit Analysis*.

Olszewski P and Xie L (2005) Modelling the effects of road pricing on traffic in Singapore. Transportation Research Part A 39: 755–772.

Perkins S Wagner N and Leung J (2018) The Social Impacts of Road Pricing. Summary and Conclusions. International Transport Forum Discussion Papers, OECD Publishing, Paris.

Raub KR, Scholz AB and Liedtke GT (2013). Impacts of road user charges on individual welfare—A pre-inauguration exploration for Germany. *Case Studies on Transport Policy*, 1(1), 46–52.

Rose E, Witten K and McCreanor T (2009) Transport related social exclusion in New Zealand: evidence and challenges. *Kōtuitui: New Zealand Journal of Social Sciences Online*, 4: 191–203.

Safirova E, Houde S, Lipman DA, Harrington W and Baglino A (2006). *Congestion Pricing and Land Use Change: Long-Term Economic and Land-Use Effects*. Resources for the Future Discussion Paper RFF DP 06-37.

Santos G and Rojey L (2004). Distributional impacts of road pricing: The truth behind the myth. *Transportation*, 31(1), 21–42.

Schiff A, Wright L and Denne T (2017) *Ex-post evaluation of transport interventions using causal inference methods*. NZ Transport Agency research report 630. 154pp.

Schlaffer M (2015) *The Effects of the Congestion Charge on Office Rents in London.* Master Thesis STREEM. Vrije Universiteit Amsterdam. http://www.ubvu.vu.nl/pub/fulltext/scripties/27_2534568_0.pdf

Statistics New Zealand (2013) *Rental affordability 1998–2012: Regional distributions*. An experimental paper.

Tang CK (2016) *Traffic Externalities and Housing Prices: Evidence from the London Congestion Charge*. SERC Discussion Paper 205. http://www.spatialeconomics.ac.uk/textonly/SERC/publications/download/sercdp0205.pdf

Transek (2006) *Cost-benefit analysis of the Stockholm Trial*.

Wadud Z, Graham DJ and Noland RB (2009) Modelling fuel demand for different socio-economic groups. Applied Energy, 86(12): 2740-2749.

Wadud Z, Graham DJ and Noland RB (2010a) Gasoline demand with heterogeneity in household responses. *Energy Journal*, 31(1): 47-74.

Wadud Z, Noland RB and Graham DJ (2010b) A semiparametric model of household gasoline demand. *Energy Economics*, 32(1): 93–101.

Yang J, Purevjav A-O and Li S (2018) The Marginal Cost of Traffic Congestion and Road Pricing: Evidence from a Natural Experiment in Beijing. Available at SSRN: https://ssrn.com/abstract=2948619 or http://dx.doi.org/10.2139/ssrn.2948619

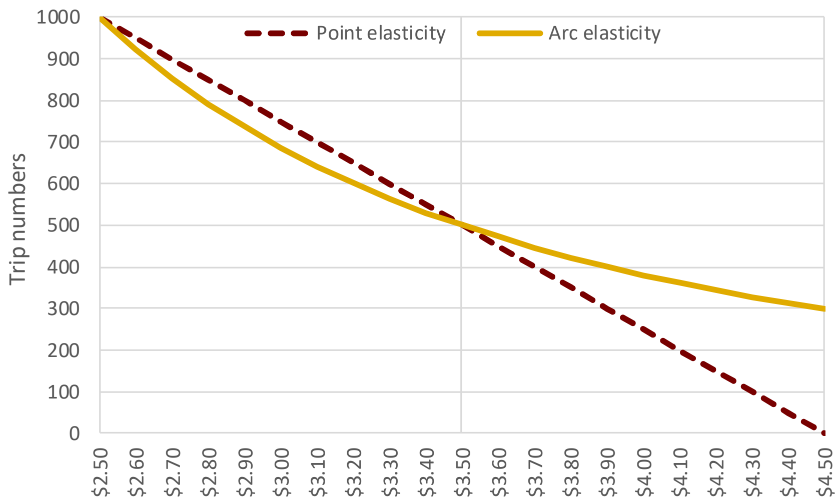
Zhang Y and Shing AF (2006) *The London Congestion Charge and Property Prices: an Evaluation of the Impact on Property Prices Inside and Outside the Zone*. Munich Personal RePEc Archive (MPRA) Paper No. 4050. https://mpra.ub.uni-muenchen.de/4050/1/MPRA_paper_4050.pdf

Annex A: Elasticities

The Role of Elasticities

Price elasticities of demand are used to estimate how much the demand for a good or service changes with a change in price. In this case, we are examining how trip rates (eg vehicles per hour) change as a result of imposing a congestion charge on top of the current costs of travel. Elasticities are generally expressed as a percentage change in quantity in response to a 1% change in price, eg a price elasticity of -0.5 means that demand (eg trips) will reduce by 0.5% if price increases by 1%. Such a simple (point)[54] elasticity definition can produce sensible results for small price changes, but where there are large changes estimated demand can fall to zero or negative. This occurs because the simple point elasticity produces a straight-line change in demand in response to price change. An alternative approach is to use an arc elasticity which, from the same input data, produces a curved demand curve with a diminishing marginal response. This is illustrated in Figure 7. Both approaches result in a 50% reduction in trips (from 1,000 to 500) with a price (or cost) change from $2.50 to $3.50 per trip. But the arc elasticity is a curve which never reaches zero with increased price, but the point elasticity predicts zero trips if the price increases to $4.50. In this analysis we use an arc elasticity approach and the examples taken from the literature have all been developed as arc elasticities. The methodologies are explained in more detail below (*Elasticity Equations)*.

Figure 7 Implications of elasticity type for the shape of the demand curve



Elasticity Values

A number of studies have analysed and estimated price elasticities of demand in the transport sector. This includes demand responses to:

- Fuel price changes;
- Toll roads; and
- Congestion charges.

[54] It is referred to as a point elasticity because it measures change relative to a single point on the demand curve, eg the current number of trips

The literature suggests that price elasticities of fuel price increases are much lower than for congestion charges, suggesting people react quite differently. And toll roads are different from congestion charges, in that they are generally avoidable by taking other roads, even to the same destination. Because of this, we have limited our analysis to studies of congestion pricing.

Elasticities have been developed for , and to those . This includes those analysing the main road pricing schemes in Europe, those in London, Stockholm and Milan. In New Zealand, elasticities have been developed in response to costs of travel in the form of changes to fuel prices. We examine the different values below.

New Zealand Transport Elasticities

Kennedy and Wallis summarised elasticity values from New Zealand and international studies (including their own) as they apply to traffic volume and fuel consumption (Table 45).

Table 45 Short run (SR) and long run (LR) elasticity estimates

Source of results	VKT/Traffic Vol.		Consumption		Notes
	SR	LR	SR	LR	
This study	-0.20 to -0.25	-0.35	-0.15	-0.20+	Traffic figures relate to 2002-06; consumption figures relate to 1974-2006
Other NZ studies			-0.1	-0.15	
Australian studies	-0.1	-0.25	-0.1	-0.15	Some studies indicate much higher LR consumption elasticities
International studies:					
US/Canada	-0.15	-0.3	-0.2	-1.0	
UK			-0.1	-0.5	
Europe average			-0.3	-0.9	

Source: Kennedy and Wallis (2007)

Table 46 shows elasticities for car traffic volume based on an analysis of data from January 2003 to June 2006.

Table 46 Car traffic volume elasticities for the period from January 2003 to June 2006 (1)

Data Set	Short-run effect (0-1 year)	Interim effect (1-2 years)	Medium-run effect (0-2 years)
Urban Off-Peak	-0.27*** (±0.08)	-0.09’ (±0.10)	-0.36*** (±0.13)
Urban Peak	-0.10** (±0.07)	-0.18*** (±0.09)	-0.29*** (±0.12)
Urban Peak – Reliable Sites(2)	-0.09*** (±0.05)	-0.15*** (±0.06)	-0.24*** (±0.08)

(1) Significance of results denoted ***0.1%, **1%, *5%, ‘10%. The coefficient is shown at the top of each cell and the 95% margin of error is shown in brackets.
(2) This dataset excludes sites with high proportion of missing data (includes most Auckland sites).
Source: Kennedy and Wallis (2007)

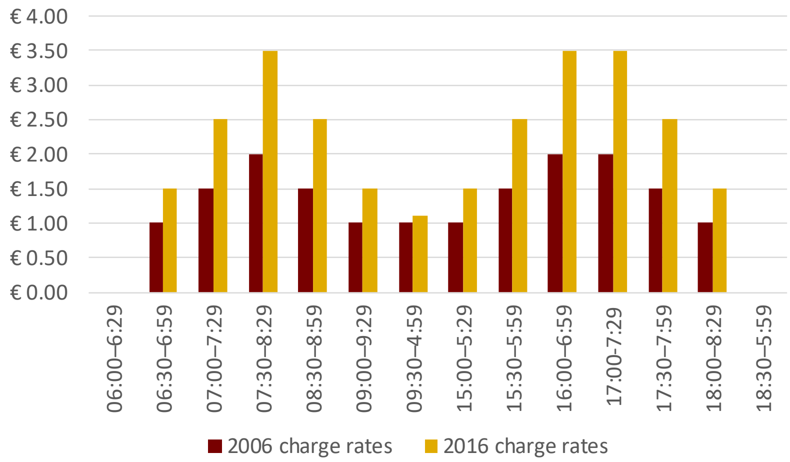
Sweden

Börjesson (2017) develops price elasticities based on the experience with two congestion charge systems in Sweden.

- The Stockholm system was introduced in 2006 and has time-varying charges between 6.30 am and 6.30 pm on weekdays. In 2016 this was extended to a heavily congested motorway (the Essinge bypass) which links the south and north of Stockholm. The charge was €1-€2 between 2006 and 2015, but were increased in 2016 by 75% in the peak and 10% off-peak (Figure 8). The maximum daily charge changed in 2016 from €6 to €10. The elasticity analysis was based on the period from 2006 to 2014.

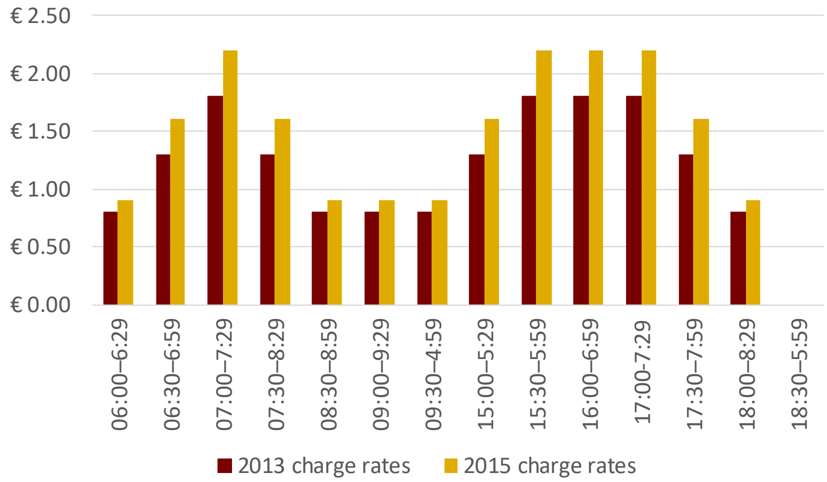
- Gothenburg has lower congestion levels, and it occurs mainly to the north of the city centre where a cordon has been established. Vehicles are charged when crossing the cordon in both directions. Starting in 2013, charges are time-varying and apply on weekdays; they were increased in 2015 (Figure 9).

Figure 8 Congestion charges in inner city Stockholm - 2006 and 2016



Source: data from Börjesson (2017)

Figure 9 Congestion charges in Gothenburg - 2013 and 2015



Source: data from Börjesson (2017)

The elasticities are calculated by analysing the relationship between a change in travel (vehicles per hour), adjusted for external factors (employment, relative car ownership and fuel price) and an increase in the average price of travel. The average price of travel was based on the driving cost per kilometre assumed by Sweden's tax authorities. This was €0.15/km in 2006 (equivalent to NZ$0.29 in 2006)[55] for the Stockhom analysis and €0.185/km in 2013 (equivalent to NZ$0.30 in 2013)[56] for the Gothenburg analysis.[57] The kilometre rates for taxation purposes in Sweden are largely based on fuel costs; the calculation is 1.2 times the estimated fuel cost (Harding 2014).

Stockholm

After adjusting for external factors affecting trip rates, the estimated price elasticity of demand in Stockholm was estimated initially for the whole time during which the congestion charge applies. It is -1.57 in 2006, the year the congestion charge started, increasing to -2.49 in 2014. Börjesson suggests that, with time it is more difficult to isolate the impact of the congestion charge from other factors and that the calculations are unreliable beyond that date. These elasticities are for private vehicles, excluding company cars and taxis (31% of the traffic in 2006) and light and heavy trucks (18%). Without excluding these vehicles, the elasticities were -0.87 in 2006, increasing to -1.24 in 2014.

The elasticities are summarised in Table 47, along with those for Gothenburg (discussed below). The short-run elasticity is that calculated in the first year of introduction of the charge. The long-run is that in 2014 for Stockholm (eight years after introduction) and 2015 in Gothenburg (two years after introduction).

Table 47 Arc price elasticities of demand for trips affected by congestion charging in Sweden

	Short run	Long run
Private vehicles		
Stockholm	-1.57	-2.49
Gothenburg	-1.18	-0.85
All vehicles		
Stockholm	-0.87	-1.24
Gothenburg	-0.69	-0.52

Source: Börjesson (2017)

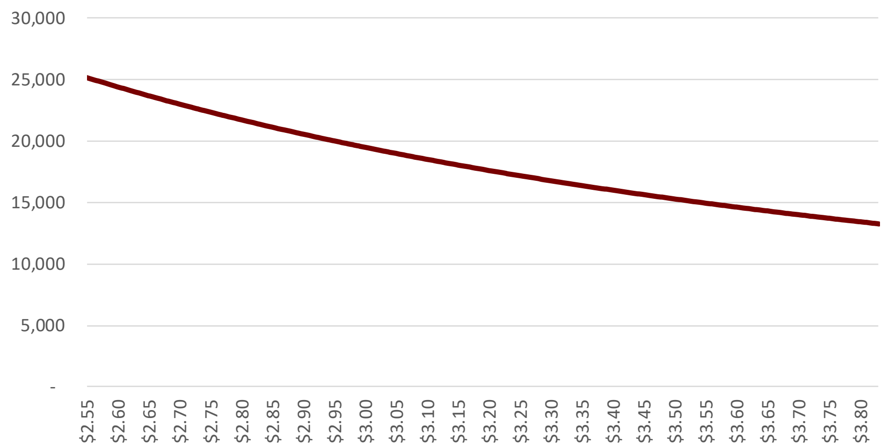
These are arc elasticities derived using a log formula. This is important to remember, ie the effect of applying a congestion charge of €1.28 on top of an average trip cost of €2.55 (17km at €0.15/km) is a 50.2% increase and this might imply a 79% reduction in travel (50.2% x -1.59). Traffic volume would be estimated to fall from 25,140 vehicles per hour to 5,357veh/hr, whereas it actually reduced to 13,287veh/hour.

It leads to a curved profile of changes in traffic volumes with price, with reducing marginal impacts, as illustrated in Figure 10.

[55] Using exchange rate of NZ$1:€0.5169 for 2006 (Reserve Bank of NZ exchange rates data)
[56] Using exchange rate of NZ$1:€0.6177 for 2013 (Reserve Bank of NZ exchange rates data)
[57] The NZ IRD equivalent rates are NZ$0.77/km for up to 14,000 km per year and $0.26/km thereafter. https://www.ird.govt.nz/business-income-tax/expenses/mileage-rates/emp-deductions-allowances-mileage.html

The assumed starting trip cost is important to the calculation. If the assumed trip cost is €0.20/km rather than €0.15/km, the elasticity is calculated from a smaller percentage change in trip cost (€1.28 is 38% of the starting trip cost of €3.40) and the calculated elasticity rises to -2.00. The base trip cost is calculated differently in MSM.

Figure 10 Application of elasticities to travel in 2006



Gothenburg

Börjesson (2017) also calculates elasticities for Gothenburg for 2013 to 2015 (Table 47). She finds that the elasticities fall in size over time, rather than increase, as in Stockholm. She suggests the differences might be driven by differences in city structures and transport systems. Gothenburg is smaller and less dense than Stockholm, and most work places are located outside the city centre. The public transport share is lower in Gothenburg, such that there are fewer transport alternatives. In addition, Börjesson speculates that increases in travel times in Stockholm from 2006 to 2015 (possibly reflecting construction work) might increase price elasticity, although the explanation for this is unclear.

Peak elasticities

Börjesson (2017) calculates price elasticities for peak travel, rather than for the whole period over which the congestion charge applies. These were calculated at the time of first introduction of the charge and for when the charges were increased (2016 in Stockholm and 2015 in Gothenburg) (Table 48). In both Stockholm and Gothenburg the price increase elasticity is lower. Börjesson suggests some explanations, the most likely of which is that the most price-sensitive users (and most flexible in terms of mode, destination and time of day) are already priced off the road at its first introduction and are no longer on the road when charges are later increased. Hence, the drivers that found it least costly to adapt have already done so prior to the increase.

Table 48 Price elasticities of demand for trips affected by peak time congestion charging in Sweden

	First introduction	Price increases
Stockholm	-0.67	-0.28
Gothenburg	-0.53	-0.16

Source: Börjesson (2017)

For application to Auckland, the peak time price elasticities, at first introduction, are likely to be the most relevant. Care will be needed to apply these to base costs of travel estimated in an equivalent way (1.2 times fuel costs in Sweden).

London

In London, arc elasticities were calculated for the London congestion zone, including the central charging zone (CCZ) and the western extension zone (WEZ). The CCZ charge was introduced in February 2003 at a rate of £5 per day, increasing to £8 in July 2005. In February 2007 the £8 charge was also applied to the WEZ, accompanied by a reduction in the charging hours, from 0700 – 1830 hours to 0700 – 1800 hours.[58]

The results are shown for different price changes in Table 49. The elasticities differ with the basis for the calculation, ie whether they are estimated from base costs of fuel only, or also including parking costs or the costs of time. They also differ as the charge level is increased.

Table 49 Arc price elasticities for London congestion zones (chargeable car trips only)

Base costs	CCZ £0 - £5	CCZ £5 - £8	CCZ £0 - £8	WEZ £0 - £8
Fuel costs	-0.55	-0.16	-0.47	-0.42
Fuel costs + parking costs	-0.89	-0.25	-0.72	
Fuel costs + costs of time (£10.80 per hour)	-0.68	-0.58	-0.67	-1.92

Source: Evans (2008)

Milan

Milan introduced a cordon pricing scheme called *Ecopass* in 2008. It was a charge on vehicles entering the city centre and was levied in proportion to a vehicle's small particulate (PM_{10}) exhaust emissions (lower emitting vehicles were exempt). It was levied between 7.30 am to 7.30 pm Monday to Friday. In January 2012, *Ecopass* was replaced by a flat fee congestion charge scheme, called "Area C".[59]

Arc elasticities were calculated for passenger vehicles based on data to 2011, the last year of *Ecopass* (Table 50). These are calculated as the change in vehicle numbers entering the cordon area in response to price. The price change was calculated using a zero base, ie it did not measure changes in price on top of other trip costs.

Table 50 Long-run arc elasticities for Milan

Vehicle class	Emissions	Charge	Elasticity
Petrol Euro 1 and Euro 2	≤ 10 mg/km	€ 2	-0.66
Petrol Euro 0 Diesel cars Euro 1, 2, 3 (and 4 without particulate filter) Diesel commercial vehicles Euro 4 without particulate filter Diesel commercial vehicles Euro 3	> 10 mg/km ≤ 100 mg/km	€ 5	-0.46

Source: Croci and Ravazzi (2016)

[58] Evans (2008)

[59] Croci and Ravazzi (2016)

There was no sign of a reduction in elasticity over time (Croci 2016). This is a slightly different type of elasticity in that many vehicles are not charged, so the elasticities would be expected to be lower than elsewhere. In addition, vehicle owners have an additional response option of changing vehicle to a less emitting type, thus reducing the potential demand response.

Singapore

Singapore has had road pricing since 1975, starting with a manual, coupon-based scheme. An Electronic Road Pricing system (ERP) system was introduced in 1998. The charge is deducted automatically from a pre-paid smart card when a vehicle passes under ERP gantries which form a cordon around the central area Restricted Zone (RZ), and on selected expressway segments and arterial roads. The central area charges apply on working days from 7:30 am to 7:00 pm, with a free entry period from 10:00 am to 12:00 noon. On other roads charges apply only during the morning peak period (7:30 – 9:30 am).[60] Prices change by time of day and are varied also in response to congestion levels. Arc elasticities have been produced (Table 51).

Table 51 Elasticity by vehicle type for morning peak

Vehicle category	Restricted zone	Expressways
Cars	-0.106	-0.195
Motorcycles	-0.040	-0.134
Taxis	-0.015	-0.112
LGVs	-0.023	-0.044
HGVs and buses	-0.007	-0.109
All vehicles	-0.069	-0.151

Source: Olszewski and Xie (2005)

Elasticities by Household Type

The elasticities discussed here relate total transport demand to congestion price. For the model development, our interest is also in elasticities which differ with household type or income. UK researchers have suggested that price elasticities will be negatively related to income, ie as income increases, the price elasticity of demand will fall with respect to fuel price.[61]

Using US data, researchers at Imperial College, University of London found price elasticities of demand fell with increased income and expenditure (Table 52).

Table 52 Price elasticities for income and expenditure quintiles

Quintile:	1st	2nd	3rd	4th	5th
Reported (pre-tax) income	-0.510	-0.513	-0.474	-0.454	-0.397
Expenditure	-0.596	-0.517	-0.484	-0.454	-0.334
Expenditure (from West and Williams 2004)	-0.724	-0.689	-0.549	-0.448	-0.180

Source: Wadud *et al* (2010a)

[60] Olszewski and Xie (2005

[61] Hanly *et al* (2002); Goodwin *et al* (2004)

These same researchers found price elasticities differing with household location (urban/rural), car ownership and employment (Table 53). Elasticities are higher in urban areas, for multiple vehicle owners and for multiple-earner households.

Table 53 Impact of household type on price elasticity

Location	Car ownership	Earners	Elasticity
Urban	Single	0 – 1	-0.327
	Single	2+	-0.421
	Multiple	0 – 1	-0.482
	Multiple	2+	-0.576
Rural	Single	0 – 1	-0.016
	Single	2+	-0.110
	Multiple	0 – 1	-0.171
	Multiple	2+	-0.265

Source: Wadud *et al* (2010b)

Similar results were produced by Kayser, who found rural households and those with no public transport available have lower price elasticities than those in urban areas and with access to public transport.[62]

Mattioli *et* al developed price elasticities of demand for fuel for different household types (Table 54), using categories shown in Figure 11. Low income high cost (LIHC) households have the lowest price response, suggesting that "*households in car-related economic stress, who already spend a disproportionate share of income on motoring, will increase expenditure even more if faced with a fuel price spike, further eroding disposable income.*" A similar response might be expected to CP.

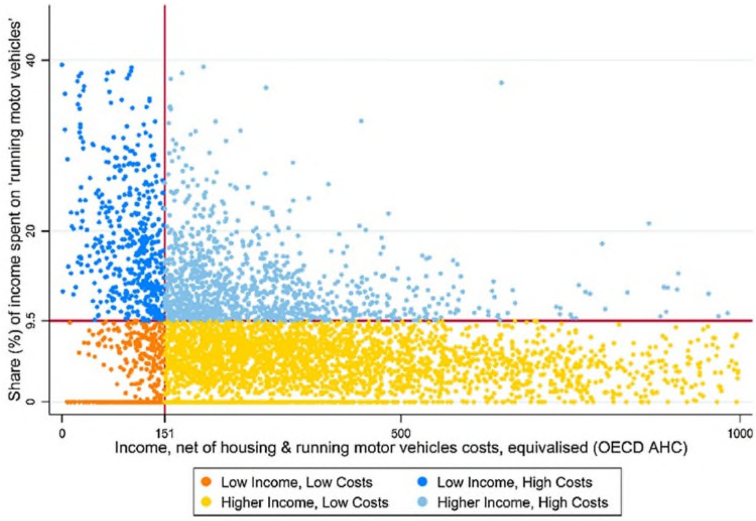
Table 54 Price elasticities by household type

Household type	Price elasticity
Low income low cost (LILC)	-0.980
Low income high cost (LIHC)	-0.341
High income low cost (HILC)	-0.568
High income high cost (HIHC)	-0.415

Source: Mattioli *et al* (2018)

[62] Kayser (2000)

Figure 11 Income (£/week) and cost (% of income spent on vehicles) categories used in analysis



AHC = after housing costs
Source: Mattioli *et al* (2018)

Elasticity Equations

Care needs to be taken in interpreting elasticities because of the different approaches to calculation. In this Annex we briefly describe the different approaches.

Point elasticity

An elasticity can be quantified most simply as the ratio of the percentage change in one variable to the percentage change in another variable. For example, imagine a road price of $1 per trip is introduced such that the average costs of a trip increases from $2.50 to $3.50, and that as a result the average number of vehicles per hour down a road changes from 1,000 to 500. The elasticity can be calculated as:

$$\varepsilon = \frac{\%\Delta D}{\%\Delta C}$$

Where: ε = price elasticity of demand
%ΔD = % change in demand for travel
%ΔC = % change in cost

Using the numbers above, a 40% increase in cost (1/2.5) leads to a 50% reduction in demand for travel (500/1000), and an elasticity of -1.25. By implication, a 20% increase in cost would lead to a 25% reduction in travel and so on. This form of elasticity is a point elasticity as it measures the elasticity of the change from a single point (current demand).

However, this simple specification of an elasticity assumes a straight-line response to cost and when extended to larger changes in cost the demand falls to zero or negative. For example, using the above formula, if cost increased to $4.50/trip, an 80% increase, demand would fall by 100%, ie to zero.

Arc elasticity

An alternative specification of the price elasticity is as an arc elasticity, which is estimated as the slope at the halfway point between two prices:

$$\varepsilon = \frac{\frac{D_1 - D_0}{0.5 \times (D_1 + D_0)}}{\frac{C_1 - C_0}{0.5 \times (C_1 + C_0)}}$$

Where: D = demand for travel in time periods before (D_0) and after the price increase (D_1)

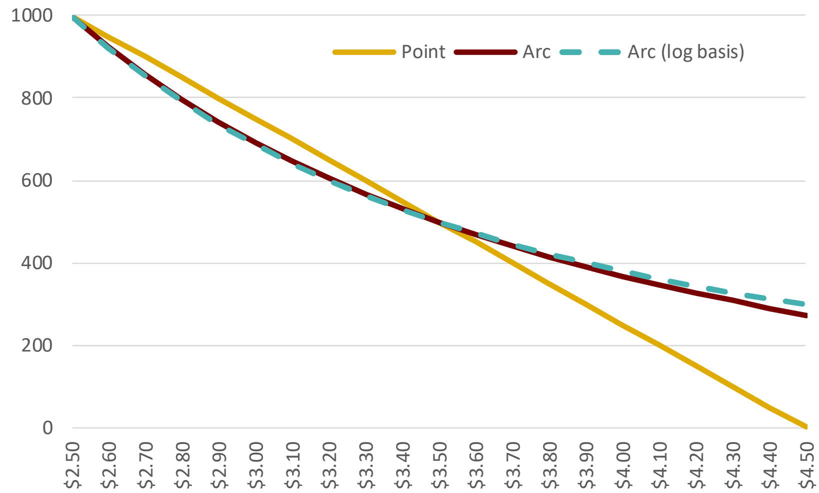
C = Cost of travel before (C_0) and after the cost increase (C_1)

It can also be calculated using a log formula, which is effectively measuring the average between very small changes in price:

$$\varepsilon = \frac{Log_e(D_1) - Log_e(D_0)}{Log_e(C_1) - Log_e(C_0)}$$

Using the same input assumptions as above, the arc elasticity is estimated as -2.00 (or -2.06 using the log formula). The implications of the different approaches are shown in Figure 12;[63] they produce similar results for small changes in price, but if larger price changes are assumed, the implications are more significant.

Figure 12 Implications of different elasticity formulae



The elasticities are solved for known ε and unknown D_1 using the following equations.

Point elasticity

$$D_1 = D_0 \times (1 + (\epsilon \times \%\Delta C))$$

Arc Elasticity – Averaging formula

$$D_1 = D_0 \times \frac{1 + 0.5 \times \epsilon \times p}{1 - 0.5 \times \epsilon \times p}$$

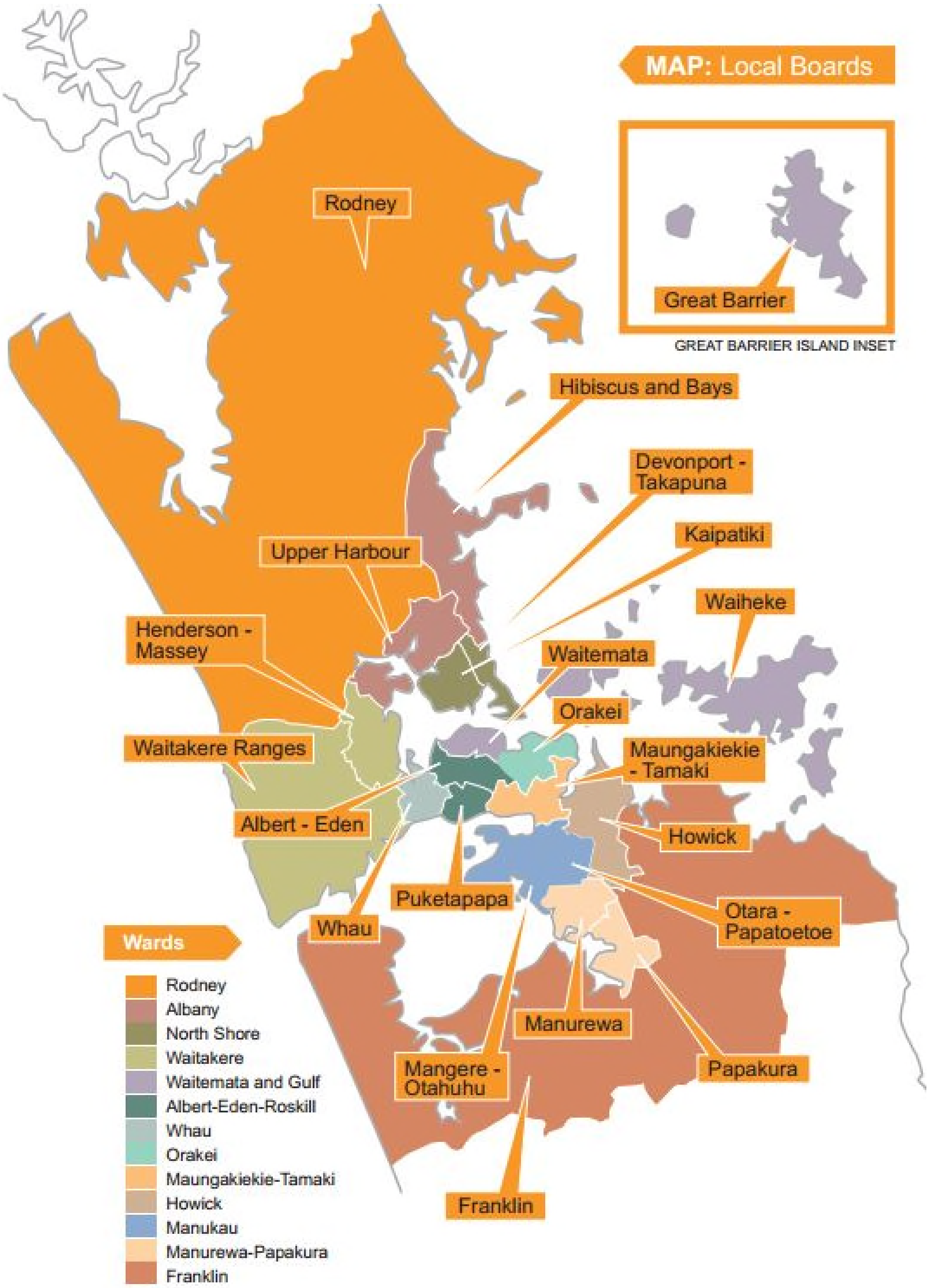
Where:

$$p = \frac{C_1 - C_0}{0.5 \times (C_0 + C_1)}$$

Arc Elasticity – Log formula

$$D_1 = D_0 \times \left(\frac{C_1}{C_0}\right)^{\varepsilon}$$

Annex B: Local Board Areas



Source: http://www.greaterauckland.org.nz/wp-content/uploads/2013/10/Auckland-Council-Wards-and-Local-Boards.jpg

Annex C: Household Expenditure Effects

Table 55 shows the average weekly household expenditure in 2016 on individual classes of goods, by income decile. Table 56 shows the same data as percentages of total expenditure by decile; the lowest income decile group spends 12% of their income on transport compared to 15% for the highest decile. Housing and household utilities (eg energy costs) are the highest costs, at 32% of decile one expenditure and 24% of decile 10.

Table 55 Average 2016 weekly household expenditure by income group (deciles)

	Decile									
Expenditure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Food	$104	$105	$135	$160	$204	$211	$245	$269	$306	$400
Alcohol, tobacco and illicit drugs	$11	$11	$18	$23	$26	$31	$35	$43	$45	$62
Clothing and footwear	$10	$12	$14	$19	$27	$30	$38	$49	$67	$103
Housing and household utilities	$175	$177	$225	$267	$293	$288	$313	$359	$460	$673
Household contents and services	$26	$22	$28	$33	$40	$41	$51	$62	$68	$102
Health	$20	$22	$29	$32	$34	$30	$39	$31	$66	$74
Transport	$65	$75	$107	$155	$162	$185	$206	$233	$281	$428
Communication	$22	$24	$29	$31	$34	$37	$41	$42	$42	$51
Recreation and culture	$42	$52	$66	$79	$91	$107	$118	$137	$167	$293
Education	$9	$5	$16	$12	$12	$13	$28	$26	$28	$67
Misc goods and services	$46	$52	$60	$73	$93	$91	$127	$144	$175	$256
Other expenditure	$29	$28	$45	$66	$107	$121	$157	$218	$231	$418
Sales, trade-ins and refunds	-$12	-$22	-$26	-$85	-$21	-$22	-$28	-$79	-$59	-$82
Total	$547	$563	$747	$862	$1,102	$1,162	$1,369	$1,532	$1,876	$2,845

Source: Statistics NZ Household expenditure statistics: Year ended June 2016 (NZ.stat)

Table 56 Average weekly household expenditure by income group (deciles)

	Decile									
Expenditure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Food	19%	19%	18%	19%	19%	18%	18%	18%	16%	14%
Alcohol, tobacco and illicit drugs	2%	2%	2%	3%	2%	3%	3%	3%	2%	2%
Clothing and footwear	2%	2%	2%	2%	2%	3%	3%	3%	4%	4%
Housing and household utilities	32%	31%	30%	31%	27%	25%	23%	23%	25%	24%
Household contents and services	5%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Health	4%	4%	4%	4%	3%	3%	3%	2%	4%	3%
Transport	12%	13%	14%	18%	15%	16%	15%	15%	15%	15%
Communication	4%	4%	4%	4%	3%	3%	3%	3%	2%	2%
Recreation and culture	8%	9%	9%	9%	8%	9%	9%	9%	9%	10%
Education	2%	1%	2%	1%	1%	1%	2%	2%	1%	2%
Misc goods and services	8%	9%	8%	8%	8%	8%	9%	9%	9%	9%
Other expenditure	5%	5%	6%	8%	10%	10%	11%	14%	12%	15%
Sales, trade-ins and refunds	-2%	-4%	-3%	-10%	-2%	-2%	-2%	-5%	-3%	-3%

These are average expenditures. To estimate the effects of marginal changes in price, we use cross-price elasticities. Table 57 shows an example set for New Zealand. These suggest that, a 1% increase in the price of transport leads to a 0.745% reduction in transport demand (expenditure on transport), and a 0.167% increase in demand for food and so on. In this analysis, we use a price elasticity of demand for transport of -0.6; the positive elasticities for consumption of other goods would be similarly smaller, taking account of the reduced income to spend on these other items. We show a revised set of elasticities using a base of -0.6 for transport.

Table 57 Cross-price elasticity

Good	Elasticity	Revised elasticity (-0.6 base)
Food	0.167	0.134
Housing	0.149	0.120
Household Operations	0.185	0.149
Apparel	0.083	0.067
Transport	-0.745	-0.600
Tobacco & Alcohol	0.017	0.014
Other Goods	0.056	0.045
Other Services	0.088	0.071

Source: Adolf Stroombergen (Infometrics), personal communication