Ministry of Transport

Auckland Road Pricing
Charging Mechanisms

Author: Rod James
Checker: James Date
Approver: Andrew Body
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Hyder Consulting (NZ) Ltd
88-793-064
Level 3, City Chambers, 142 Featherston Street, PO Box 10-602, Wellington, New Zealand
Tel: +64 4 472 4007  Fax: +64 4 472 4008  www.hyderconsulting.com
Contents

1 Executive summary ................................................................. 2
  1.1 Process .............................................................................. 2
  1.2 Congestion scheme issues ................................................. 3
  1.3 Revenue scheme issues .................................................... 3
  1.4 Low-cost alternative revenue scheme ................................ 3
  1.5 Congestion (Area) scheme - Summary ............................ 4
  1.6 Revenue (Cordon) scheme - Summary ............................ 4
  1.7 Cost estimates ................................................................ 5

2 Introduction .............................................................................. 6

3 Report structure .................................................................... 7

4 Project background .................................................................. 8
  4.1 Project objectives ........................................................... 8
  4.2 Project outputs ............................................................... 8

5 Stage one – Core inputs .......................................................... 10
  5.1 Review of previous ARPES reports and charging mechanisms 10
  5.2 Development of current schemes ...................................... 15
  5.3 Current scheme concepts, details and principles ................ 16
  5.4 International experience and technologies ........................ 19
  5.5 TSP systems, standards and parameters ............................ 32

6 Stage two – Candidate solutions ............................................. 36
  6.1 Candidate solutions and technologies ............................... 36
  6.2 Scheme requirements ...................................................... 36
  6.3 Technology options ........................................................ 40
  6.4 Candidate technologies .................................................. 54
  6.5 Alternative revenue scheme ............................................. 54
  6.6 Model inputs ................................................................. 57
  6.7 Travel choices and equity ................................................. 59
  6.8 Privacy ........................................................................... 59

7 Stage three - Assessment of solutions ..................................... 61
  7.1 Fitness for purpose .......................................................... 61
  7.2 Risks and mitigation ....................................................... 62
  7.3 Capital and operating costs .............................................. 62
  7.4 Alignment with TSP ......................................................... 63
  7.5 Procurement issues ......................................................... 63
  7.6 Lessons from international review ................................... 65
7.7 Evaluation against scheme requirements ......................................................... 66
7.8 Streetscape ........................................................................................................ 71
7.9 Conclusions and recommendation ................................................................. 72

8 Stage four – Cost / analysis reporting............................................................... 75

8.1 Concept (DSRC/ANPR) system design............................................................... 75
8.2 Congestion (Area) scheme - Summary ............................................................... 84
8.3 Revenue (Cordon) scheme - Summary ............................................................... 85
8.4 Base cost schedule / model .............................................................................. 86
8.5 Comparison with other systems ...................................................................... 90

9 Summary and recommendations ....................................................................... 93

9.1 Congestion scheme issues .............................................................................. 93
9.2 Revenue scheme issues .................................................................................. 94
9.3 Low-cost alternative revenue scheme ............................................................... 94
9.4 Congestion (Area) scheme - Summary ............................................................. 94
9.5 Revenue (Cordon) scheme - Summary ............................................................. 95

Appendix A ............................................................................................................ 97

Assessment of prime technology options against functional requirements .......... 97

Appendix B ............................................................................................................ 123

Cost model............................................................................................................ 123
# Executive summary

This report addresses the requirements of this workstream, to supplement and enhance the evaluation carried out for the Auckland Road Pricing Evaluation Study (ARPES) in 2005/06, and ensure defensible advice on the costs associated with the technology choices.

The process followed through this assessment and report builds from the results of the last study and further international research, and has been coordinated with other workstreams to provide a compatible outcome.

## Process

This report and assessment has been based on a staged process that has included developing core inputs from other previous and current work, leading to a detailed definition of the current scheme concepts and requirements.

From this base a series of candidate systems and technologies have been developed, including a primary and sub technologies. These have then been assessed against the defined requirements through an evaluation framework that included costs, fitness for purpose, procurement issues, and alignment with NZ requirements.

The level of detail has been targeted at providing a sound basis for answering fundamental questions on the particular options identified, and to support decision makers in assessing the most suitable overall package.

Some of the primary drivers for evaluation of the two main scheme concepts have included:

- The revenue-focused scheme’s strong focus on cost control
- The congestion-focused scheme’s focus on ensuring cost-effective collection, and provision of options to address social and economic impacts.
- Capital cost of the schemes
- Future expansion and integration plans
- Policy and legislative structures and constraints
- Scheme approach (e.g. enforcement or collection)
- Operational cost and cost effectiveness
- Proportions of casual and regular users
- Payment security
- Reliability and accuracy of technologies
- Alignment with proven technologies
- Alignment with well supported standards
1.2 Congestion scheme issues

Based on the evaluation, of the congestion scheme, a system providing a combination of a DSRC system with an ANPR enforcement facility has been identified as the most suitable option, key factors include:

- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

1.3 Revenue scheme issues

Based on the evaluation of the revenue scheme, a system using a DSRC tag based solution with an ANPR enforcement facility has also been identified as the most suitable option, key factors again include:

- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

1.4 Low-cost alternative revenue scheme

From the evaluation of reduced cost options the only option that was considered to provide some potential was Parking Levies, applied to the entire area, but with exemptions for residents. By removing the requirement to capture all vehicles (as for the earlier study) the potential of this solution does improve, reducing overall costs and improving net revenue.
The extent and structure of a parking levy would need to be examined in greater detail in order to consider the most appropriate package. However, a basic evaluation of potential costs and revenues has been provided.

1.5 Congestion (Area) scheme - Summary

The selection of a DSRC system for the Area options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined area. This type of system also offers the potential to provide more flexible charging variations, and an improved ability to differentiate vehicle types and functions.

A DSRC system also provides improved opportunities to address exemptions through special status OBUs, and the use of OBUs reduces the enforcement task by efficiently processing payments from a large proportion of passing vehicles.

DSRC systems are now being used increasingly for free flow tolling and the technology is relatively common and available. It provides high levels of reliability and protection against tampering, installation is relatively straightforward and fraudulent duplication of OBUs extremely difficult.

To operate successfully these systems do require trained local support, and the maintenance of roadside equipment and management of OBUs contribute significantly to the system’s reliability.

Overall a DSRC system will provide the potential for more versatile and efficient payment methods and structures to suit individuals. The requirement for users to fit OBUs will present some inconvenience. OBU transactions linked to smartcard payments and accounts provide a high degree of reliability and ability to ensure payment, with significantly lower operating costs due to automated collection and enforcement.

1.6 Revenue (Cordon) scheme - Summary

Cordon schemes generally involve charging vehicles that cross a defined boundary line, with the aim of reducing congestion on routes leading into and through the cordoned area. Charges can be fixed at a single known rate (for any given vehicle type) with only one payment required per day, or varied by time, actual or expected level of congestion, or across toll points so that it would cost more to cross the cordon at toll points where congestion is higher.

Cordon schemes provide a greater degree of flexibility and are also suited to more advanced technology systems (providing opportunities to vary charges across a defined boundary).

The selection of a DSRC system for the Cordon options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined boundaries. This type of system also offers the potential to
provide more flexible charging variations, and an improved ability to
differentiate vehicle types and functions.

With suitable levels of maintenance and support a DSRC system provides
improved opportunities to address exemptions, high levels of reliability and
security, and the potential for a wider choice of payment methods and
structures to suit individuals. The requirement for users to fit OBUs will
present some inconvenience, but OBU transactions linked to smart card
payments and accounts provide a high degree of reliability and ability to
ensure payment, with significantly lower operating costs due to automated
collection and enforcement.

Overall a DSRC solution will improve the level of charges collected through
a cordon scheme, reduce operating costs, and provide for more flexible
options for future expansion and the management of special status users
and vehicles.

1.7 Cost estimates

A cost model has been developed based on the identified solutions and
used to provide inputs to the financial model, and also to provide a ‘top
down’ comparison process based approach of the financial model.

The cost model developed includes the following components:

- Common Factors
- OBU Costing
- Operational Costs – Revenue and Congestion
- Back Office Capital costs
- Typical Site installations – 2 lane, 4 lane, and 6 lane
- Road side equipment capital costs
- Overall Summary

<table>
<thead>
<tr>
<th>Overall Summary</th>
<th>Revenue</th>
<th>Congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside Capex</td>
<td>$23,191,176</td>
<td>$34,381,295</td>
</tr>
<tr>
<td>Back Office Capex</td>
<td>$33,633,558</td>
<td>$52,601,990</td>
</tr>
<tr>
<td>Total Capex</td>
<td>$56,824,734</td>
<td>$86,983,285</td>
</tr>
<tr>
<td>Annual Opex</td>
<td>$10,649,493</td>
<td>$12,156,314</td>
</tr>
<tr>
<td>Estimated Cost per Transaction</td>
<td>$0.24</td>
<td>$0.43</td>
</tr>
<tr>
<td>Estimated Annual Revenue</td>
<td>$132,550,236</td>
<td>$169,314,600</td>
</tr>
<tr>
<td>Estimated Opex as a %age of Revenue</td>
<td>8.03%</td>
<td>7.18%</td>
</tr>
</tbody>
</table>
2 Introduction

Hyder Consulting (NZ) Ltd (Hyder) is pleased to present this report to the Ministry of Transport for the Auckland Road Pricing Evaluation, Charging Mechanisms workstream.

This report addresses the requirements of this workstream, to supplement and enhance the evaluation carried out for the Auckland Road Pricing Evaluation Study (ARPES) in 2005/06, and ensure defensible advice on the costs associated with the technology choices.

The process followed through this assessment and report builds from the results of the last study and further international research, and has been coordinated with other workstreams to provide a compatible outcome.
3 Report structure

This report is based on four principal stages:

1. Developing core inputs – a review of previous studies, current New Zealand environment, international benchmarking, direction from other current work on the ARPES project, and defining the current scheme concepts.

2. Development of candidate systems and technologies – identifying a range of system and technology options for the two scheme types, including related sub technologies to address required specialist adaptations (e.g. to facilitate improved travel and equity solutions).

3. Assessment of candidate systems against the requirements of the defined schemes, and related adaptations – this includes an evaluation framework around the key scheme requirements, costs, and assessment of options in terms of their fitness for purpose, procurement issues, alignment with NZ requirements, and a risk and mitigation review.

4. Cost and analysis reporting – a detailed cost and risk schedule considering a range of scenarios and identifying a preferred option for both schemes; and a detailed report of the full assessment process.

The following diagram sets out the primary elements of work, and related stages.

Figure 1: Approach Overview
4 Project background

4.1 Project objectives

The main purpose of this assessment is to build on the previous 2005-06 Auckland Road Pricing Evaluation Study, and to provide direction on the suitability of charging mechanisms and technology choices to assist the broader evaluation process. The report provides an evaluation of the primary issues, leading to the identification and costing of a solution best suited to the requirements of each scheme.

The level of detail has been targeted at providing a sound basis for answering fundamental questions on the particular options identified, and to support decision makers in assessing the most suitable overall package.

In addition to providing the basis for the evaluation and selection process, this study provides an estimate of the capital and operating costs associated with the preferred solutions for both schemes, providing inputs to the financial modelling.

4.2 Project outputs

The general requirements of this stream of work are to supplement and enhance the evaluation carried out for the Auckland Road Pricing Evaluation Study in 2005/06, and provide the basis for advice on the costs associated with the charging mechanisms and technology choices.

The report sets out the charging mechanism options and provides an analysis of these, and the system and technology options, including the following:

1. Scheme and system descriptions; representations of the functional design concepts, and key system elements driving capital and operating costs.

2. Primary transaction/volume related aspects of the system options, and key transaction related estimates developed from the transport model outputs.

3. A review of international system examples, technology applications and trends, including current systems, developing technologies, international benchmarking of operating costs, and relevance to New Zealand.

4. Specific and structured consideration of the fitness for purpose of identified charging mechanisms and technologies, including compatibility with the Toll Systems Project.

5. Capital and operating costs for each system option, including identified technology driven components and operating costs, advice on costs associated with different payment options, in a form suitable
to inform the broader financial model, and assist in evaluating alternative options.

6 Assessment of procurement and implementation timeframes.
7 Structured assessment of risks and related mitigation strategies.

Some of the primary drivers for evaluation of the two main scheme concepts include:

- The revenue-focused scheme has a strong focus on cost control, and potential for a lower-technology approach in the immediate term.
- The congestion-focused scheme, while also focused on ensuring cost-effective collection, requires consideration of technology-driven ‘fixes’ to some of the real or perceived social and economic impacts.
5 Stage one – Core inputs

5.1 Review of previous ARPES reports and charging mechanisms

The following is a summary of the previous schemes developed for the 2005/06 Auckland Road Pricing Evaluation Study and the results of the consultation on these options conducted in 2006.

The 2005/06 study developed 5 conceptual charging approaches and conducted an evaluation of these schemes to assess the feasibility, desirability and potential impacts of general road pricing principles in the Auckland environment.

The following section briefly summarises the 5 approaches examined through this previous study.

5.1.1 Scheme 1 – Single cordon charges

The Cordon scheme involved establishing a boundary around the Auckland isthmus, the majority of the cordon located through harbour areas, including two main land based boundary zones and five bridges. This cordon was defined by the following boundaries, with a total of 16 crossing points.

- Boundary Zone A – Avondale to Green Bay. Following a line east of Portage Road, with approximately eight crossing points.
- Boundary Zone B – Otahuhu / Westfield. Following a line from Mangere Inlet (west) to Otahuhu Creek (east), with three crossing points.
- Five Bridges The remainder of the cordon crosses five main bridges.
- Under this scheme charges would be applied to vehicles entering the cordon between 6am and 10am Monday to Friday using a combined DSRC/ANPR facility. These charges would be applied only once per vehicle per day.
Figure 2: Isthmus cordon scheme map

5.1.2 Scheme 2 - Double cordon charges

The Double cordon scheme involved establishing two cordons, an inner cordon and an outer cordon, around the Auckland isthmus and Central City.

The inner cordon placed a boundary around the central Auckland area from the harbour to the north, and following a line immediately to the north of St Lukes Road and Remuera Road in the south. This boundary creates a total of 34 crossing/toll points.

The outer cordon established a boundary around the Auckland isthmus, again with the majority of the cordon located through harbour areas, including two main land based boundary zones and five bridges. This outer cordon is defined by the following boundaries, with a total of 16 crossing points.

- Boundary Zone A – Avondale to Onehunga. Following a line that runs roughly close to SH20.
- Boundary Zone B – Otahuhu / Westfield. Following a line from Mangere Inlet (west) to Otahuhu Creek (east), with three crossing points.
- Five Bridges The remainder of the cordon crosses five main bridges.

Charges would be applied to vehicles entering either cordon between 6am and 10am Monday to Friday using a combined DSRC/ANPR facility. There would be a fee for going into each cordon. These charges would be applied only once per vehicle per day.
5.1.3 Scheme 3 - Area charges

The area charge option involved placing a boundary around the central Auckland area from the harbour to the north, and following a line immediately to the north of St Lukes Road and Remuera Road in the south. Charges would be applied to vehicles entering or moving within the area between 6am and 10am Monday to Friday using a combined DSRC/ANPR facility. These charges would be applied only once per vehicle per day.
5.1.4 Scheme 4 - Strategic/arterial network charges

The concept for this option was to implement a distance based charge (or similar “sector” based alternative) on the following sections of the Auckland strategic network.

- SH1 from a northern boundary at the interchange with Greville Rd and the Albany Expressway to a southern boundary at the Hingaia Road Interchange
- All of SH16 from the interchange with SH18 in the north to Central Motorway Junction in the south
- SH20 from the interchange with SH20A in the south to its planned interchange with SH16 to the North.

Charges would be applied to vehicles using the designated sections between 6am and 10am Monday to Friday using a combined DSRC/ANPR facility. These charges would be capped at a level similar to other options for an average trip.
5.1.5 Scheme 5 - Parking charges

For the parking option, charge zones would be applied to the central commercial areas of Auckland City, Newmarket, Manukau City, Henderson and Takapuna.

The parking scheme would use coupons, with provision for private operators to opt out of this scheme in favour of a higher flat rate fee per space available.

5.1.6 Previous technology choices

The recommended technology choices at the conclusion of this earlier stage were based on a limited evaluation exercise, the technologies recommended chosen solely for the purposes of estimating capital and operating costs for the original study.
For the strategic network, cordon and area scheme options, the recommended choice of technology was a combination of a DSRC Transponder facility with ANPR facilities for enforcement and as a payment option for infrequent users. This choice of technology reflected a desire to encourage users to choose the lower operating costs of DSRC technology, but acknowledged the need to provide a non-DSRC based option for infrequent users, or those travelling through the region.

For the parking option a coupon based scheme was assumed, and costed such that it could be assessed alongside other road pricing alternatives, including cordon charges, area charges and strategic network tolls.

5.2 Development of current schemes

Following the completion of the previous study a process of consultation was undertaken that identified a range of issues relating to the impacts and effects of the options considered.

These included:

- Passenger transport – the need to provide a real and viable alternative in a low density environment, and for this to be in place prior to introduction of road pricing not funded progressively from road pricing revenues
- Provision of a (free) ring road and viable alternative north-south route to SH1
- Impacts on commercial/retail areas, particularly in central Auckland
- Affordability and social inequity – charges are regressive, i.e. a single charging structure disadvantages lower income households
- Exemptions sought for particular groups, particularly motorcycles and taxis but also those considered to be socially disadvantaged/vulnerable (cross-over with revenue treatment)
- Treatment of the revenue (hypothecation) – where and how it can be used, including to reduce existing charges such as Fuel Excise Duty and/or RUC
- Road pricing seen as a “last resort” option after all other alternatives exhausted, e.g. staggered education start times, traffic engineering solutions, incentives for freight to move to rail or travel outside peak hours (limited discussion on “complementarity” of some of these solutions)
- Paying for roads twice / charging for roads which are currently a free good
- Need to be clearer about the social/economic impact of the “do minimum” –there are social, economic and environmental impacts associated with the rising vehicle usage and congestion in Auckland not withstanding any congestion charging response
- Equity from a regional (spatial) and socio-economic group level – i.e. making it clear which parts of the region or groups are more affected than others, who pays and who benefits.
The current stage of the Auckland Road Pricing evaluation concentrates on how to better respond to these issues, focussing particularly on the detail of economic impacts and the Public Transport (PT) alternatives.

5.3 Current scheme concepts, details and principles

As a basis for the current study two schemes, one focused on optimising ‘Revenue’ and one ‘Congestion reduction’ have been developed. These schemes are designed to highlight how these different approaches might address the different issues highlighted through the consultation process. The two scheme concepts that are being considered (the revenue and congestion schemes) have been developed as two separate approaches, each with its own set of principles and objectives. The following table sets out the characteristics and principles of each. The congestion-focused scheme, while also focused on ensuring cost-effective collection, requires consideration of technology-driven ‘fixes’ to some of the real or perceived social and economic impacts.

<table>
<thead>
<tr>
<th>Table 2 Scheme descriptions and base assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Scheme Description / Characteristics</strong></td>
</tr>
<tr>
<td><strong>Type of Scheme</strong></td>
</tr>
<tr>
<td><strong>Area</strong> – charge to enter and/or travel within the boundaries.</td>
</tr>
<tr>
<td><strong>Boundaries</strong></td>
</tr>
<tr>
<td><strong>Time of Day</strong></td>
</tr>
<tr>
<td><strong>Days of week</strong></td>
</tr>
<tr>
<td><strong>Vehicles Included</strong></td>
</tr>
<tr>
<td><strong>Exemptions / Discounts</strong></td>
</tr>
<tr>
<td><strong>Charge Regime</strong></td>
</tr>
<tr>
<td><strong>Maximum charge per day</strong></td>
</tr>
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</table>
## Charging Mechanisms

### Auckland Road Pricing

<table>
<thead>
<tr>
<th>Number of toll points</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other relevant descriptors</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim is to make a meaningful difference to congestion levels – consideration of appropriate alternatives (e.g. passenger transport, other options) is important</td>
<td>The aim of this scheme is to minimise diversion impact (and social impacts), but to deliver revenue to improve Auckland’s transport networks.</td>
<td></td>
</tr>
</tbody>
</table>

### Objectives/Principles

<table>
<thead>
<tr>
<th>Costs</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>A technology solution that maximises net revenue would be valued, but the primary objective is to manage congestion</td>
<td>The technology solution must maximise net revenues</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Options for mitigation of social impacts/ providing exemptions</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>The possibility of using the technology solution to provide for mitigation options such as ‘mobility vouchers’ would be seen as an advantage Ability to provide non-charged options for transport disadvantaged to be provided</td>
<td>Not a priority – the $3 charge is envisaged as being sufficiently low to not require a focus on mitigation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Payment Options</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance of convenience, cost and ‘message to road users that they are paying to use in peak periods’ to be considered</td>
<td>Convenience for users is important, but overall aim must first be to keep the operating costs of the system low</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inter-relationship with TSP</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not an absolute requirement, but departure from TSP operating model will need to be justified</td>
<td>Not an absolute requirement, but departure from TSP operating model will need to be justified</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Enforcement</th>
<th>Congestion Scheme</th>
<th>Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system</td>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system, but balance of capital and operating cost will need to be considered to ensure that net revenue is maximised</td>
<td></td>
</tr>
</tbody>
</table>

Figures 6 and 7 below illustrate the layout of these schemes. Locations of boundary and internal charge/check points have been assessed based on a review of aerial surveys, lane configurations, and optimising coverage.
Figure 6: Revenue Scheme

Figure 7: Congestion Scheme
5.4 International experience and technologies

As a basis for the evaluation of suitable charging mechanisms and technologies a review of international applications and trends in urban road pricing has been undertaken, including current systems, developing technologies, and international experience relating to key cost elements.

The following section provides a review of the charging systems, mechanisms and technologies from a range of example road pricing applications, and key characteristics and factors that led to their development.

5.4.1 Road pricing approaches used in urban areas

Based on current systems in operation and others that have been given detailed consideration, there is a range of road pricing scheme options available. Two of the most common are Area and Cordon based, which are the basis of the two options currently being considered for Auckland. These and other approaches are described briefly below, as context for the subsequent consideration of technology issues.

Area licensing schemes

Area schemes apply charges to trips made within a defined area during a defined time period. Users who wish to use (or keep) their vehicles within a defined area during a defined time period need to purchase and display a special permit, or to register the vehicle registration number in a computer database (e.g. the London congestion charging scheme).

A key advantage for these types of pricing mechanisms is that for a small, simple scheme it can be relatively easy for the public to understand and relatively straightforward to implement. However, charges are applied on a daily basis for access to the defined area, rather than on a per trip basis reducing the potential impact on peak demand. These schemes also suffer from limitations on flexibility (e.g. varying charges across time periods).

Cordon charging schemes

Cordon charging schemes are the most commonly proposed form of electronic road pricing (e.g. Singapore ERP scheme and Stockholm Congestion Tax). These involve setting up a cordon of charging points around a defined boundary, road users are then charged (usually electronically) each time they cross the cordon. A key benefit of cordon pricing is that each individual trip made into the defined area during the...
time of operation can be identified and potentially charged, with these charges varied by the time, direction or location of crossing.

Multi-cordon and zone-based charging schemes

Similar to simple cordon charging, multi-cordon schemes operate by charging users each time they cross defined boundaries, but typically have two or more concentric cordons. Use of multiple cordons or zone-based charges can give a finer level of influence over travel patterns since the charging points can more closely reflect the problem traffic movements that the scheme is seeking to address. The proposed Manchester Congestion Charging scheme is based on a double cordon system with different charges to cross the outer boundary of the city, and the inner cordon which applies a separate charge for crossing into the central city area.

Distance-based charging schemes

Charges under these schemes are applied directly on the basis of distance travelled (e.g. on a toll road where distance travelled between toll plazas or segments provides the basis for the charge).

While distance-based charging schemes have been considered for planned national road user charging systems, and have been implemented on some countries for heavy vehicle charging (e.g. Germany) no distance based systems have yet been developed for urban road pricing/congestion charging schemes.

Distance–based charging is attractive in that it charges directly for travel in the problem areas. It is therefore the logical end-point in a process of creating denser and denser networks of charging zones, and correspondingly should theoretically be even better at influencing demand than multi-cordon or zone-based charging schemes. However, the technology required is currently considered more complex and costly to implement.

Access control schemes

Access control schemes or 'Electronic Gateways' are used in several cities in Italy to reduce congestion. These schemes differ from other charging schemes with per-trip charging not generally applied, with complex local access rights and short term exemptions applied for local businesses and residents. Access control schemes are attractive in providing more user acceptance in the local urban centre, providing flexibility for occasional users.
5.4.2 Example schemes

Led by the introduction of the Singapore ERP system in 1998 several large scale congestion charging and road pricing schemes have been developed in recent years, with several others at advanced stages of development. The following brief summaries set out some of the key aspects and issues relating to these schemes including:

- Singapore
- London
- Stockholm
- Italy (e.g. Florence, Rome, Pisa)
- Hong Kong
- Manchester

More detailed technical aspects of these systems are also referred to through the later sections of this report considering technology choices and selections.

Singapore

The current Singapore ERP scheme that has been in operation since 1998 is specifically designed to manage congestion, with revenue generation almost incidental to the implementation of the charge. The scheme operates as a cordon with a series of related point charges on key feeder routes to the city centre.

Figure 8: Singapore ETC

This system has been introduced against a background and history of strong policies aimed at managing congestion. In 1972 the import duty on motor vehicles was raised from 30 to 45 percent and registration fee equal to 25 percent of a vehicle’s market value was introduced. In 1975 this
special registration fee was increased to 55 percent and an Area Licensing Scheme (ALS) introduced that required cars entering the central business district (CBD) during the morning rush hours to pay three Singapore dollars per day (more than double the bus fare for those commuting in from outside). Drivers were originally exempted from this charge if there were at least four people in the vehicle.

As a result of these measures average traffic volumes were cut by more than 50 percent and average traffic speeds in the CBD doubled to 36 km per hour.

This 1975 scheme was essentially a manual system, with the vehicle owner required to purchase a sticker and place it in the windshield. Enforcement officials checked vehicles entering the CBD at booths and checkpoints.

This scheme was superseded in 1998 by a fully electronic system using multi-lane fully free flow dedicated short range communications (DSRC) technology. The current system uses a proprietary 2.45 GHz technology, combined with a fast debit smartcard payment system and ANPR camera enforcement.

The system’s reported reliability indicates that less than 0.05% of all transactions are lost, and the combination of a strong local rule obedience culture, with the potential loss of expensive vehicle ownership rights helping to achieve a high degree of compliance.

Singapore’s use of debit smartcards for payment has ensured a high degree of privacy, and is currently unique among operating road pricing systems. Motorists can acquire the debit card from their bank, and top up the balance at ATMs. This means that the ERP system has no need to record information on the passing vehicle, unless there is no transponder or there are insufficient funds on the debit card to perform the transaction.

The current scheme uses average speed for each individual route, as a surrogate for congestion. If speeds are too high, there is assumed to be too much suppression of traffic and the ERP charge is lowered. If the speeds are lower than the targets, there is too much congestion and the ERP charge on that route is increased. As a result, the ERP charges vary on each leg of the strategic road network, and these are reviewed on a 6 monthly basis.

Key aspects of the Singapore Scheme include:

- Primarily a congestion charging scheme
- Implemented to replace an existing manual system and in conjunction with other fleet controls and related measures
- High level of compliance from culture
Manual system replaced as expensive to operate, unwieldy and not optimal in economic terms
Conversion from the previous daily charge to variable Cordon Charging has proved more effective at pinpointing and relieving congestion
DSRC-based system with smartcard payment delivers cost effective reliability and privacy
Mandatory professional installation of DSRC units is a key factor in system reliability and efficiency
DSRC/Smart card units and installation relatively expensive
Tightly controlled vehicle fleet improves cost effectiveness of the solution
Mixed and variable charge zones and arterial charging are possible (ability to identify time location and direction of crossing is a key factor in this flexibility)

London

The UK currently has two operational congestion charging schemes (London and Durham) and is currently developing plans for the introduction of additional schemes in other cities, the furthest advanced being Manchester. The Durham scheme is a very simple toll charge manually collected for entering the small central ancient district of the town, and has been effective in reducing traffic.

The London Congestion Charge is one of the best known systems currently in operation. It is operated as an area charge, imposing a flat fee for motorists travelling within those parts of London designated as the Congestion Charge Zone. The main objectives of this charge are to reduce congestion, and to raise funds for investment in London's transport system. A payment of £8 is required for each day a chargeable vehicle enters or travels within the zone between 7 am and 6 pm; a substantial fine is imposed for non-payment.
The zone came into operation in parts of Central London in February 2003 and it was extended into parts of West London in February 2007. Although not the first scheme of its kind in the United Kingdom, it was the largest when it was introduced, and it remains one of the largest in the world.

More recently an additional charge for some categories of vehicle has been developed (to be introduced in October 2008), imposing an additional £25 charge on vehicles emitting over 120g/km of Co2. (linked to a vehicle’s registration class)

The primary technology that is used for the London system is an ANPR camera system. This is essentially an enforcement system and is not used directly to collect charges. Drivers are required to pay the daily charge through a range of channels including retail outlets, web sites, telephone and SMS. ANPR camera records are used to check against the list of subscribed users for the day. The system captures each number plate on average 3.5 times, with over 1 million images to be sorted and reconciled every weekday. 60% of the plate images are discarded, as these are associated with exempt and discounted vehicles.

Some of the key drivers for the London system’s design included:

- need to implement a reliable system quickly
- a potentially large user base and high proportion of infrequent users
- legislative/timing constraints around more advanced technologies
- desire to highlight daily payment and so increase the impact of the charge on demand

Key aspects of the London Scheme include:
- Simple all day charge area scheme
- Need to implement quickly
- Desire to highlight daily payments
- Easy to install and implement, generally successful operation
- At £5 and £8 achieved congestion relief objectives
- Flat charge applied to cars and goods vehicles; 60% of vehicles identified are exempt/discount (motorcycle, public transport, taxi, special)
- ANPR-based system
- System operations cost high, 46% of revenue
- Switch to DSRC or mixed DSRC/ANPR planned

Stockholm

The Stockholm congestion tax is a traffic congestion and environmental tax imposed on most vehicles in Stockholm (Sweden). This scheme was initially implemented as a trial between January and July 2006, followed by a referendum in September 2006. The scheme was subsequently implemented on a permanent basis in August 2007.
The primary purpose of the congestion tax is to reduce traffic congestion and improve environmental conditions in central Stockholm. The funds collected are used money for new transport infrastructure in and around Stockholm.

The Stockholm system operates as a cordon, similar to the Singapore ERP, with charges varied according by time of day.

The technology used for the initial trial was based on a combination of DSRC tags, using the European 5.8GHz standard, and ANPR for non-tag equipped vehicles.

The Stockholm system also incorporates some specific concessions for bypass traffic. Bounded by water, there are no suitable bypasses, and the strategic road network is used instead as a free bypass.

Since the scheme has been made permanent the use of the original DSRC system has been reduced, and now only operates for vehicles wishing to benefit from the special concessions, the majority of traffic making payment through the ANPR based account and billing systems. Reasons for this change included:

- Higher than expected levels of reliability and accuracy from the ANPR system (85-90% depending on conditions) through use of front and rear plate matching
- Problems with the legal status of DSRC based transactions
- Key aspects of the Stockholm scheme include:
  - Need to provide effective through route concessions
  - Natural geographic barriers limited required check points
  - Single Cordon DSRC/ANPR based scheme
  - Free bypass/through routes provided
  - Time period variation of charge
  - Problems with DRSC legislation
- The Stockholm scheme has an exemption for non-Swedish registered vehicles, due to difficulty of enforcement.

**Italy**

Italy has implemented a series of “Electronic Gateways” in several of its major cities. The “Electronic Gateway” is a form of congestion charging by regulation, that allows residents and key businesses and services free access to the city centre, while requiring all other vehicles to either register for access or bypass the designated area. It is strictly an access control system which employs bypasses, park-and-ride together with bus services and public transport from the edges of the zones to support access into the historic centres of these cities.

Access is monitored using a combination ANPR and DSRC system, similar to that used in Stockholm, and in wider free-flow tolling systems. The DSRC tags used are the standard Italian “Telepass” devices used on the majority of Italian motorways. Users are able to identify their existing Telepass device to be used for the specific access control zone.

Access conditions are different in each city, including some with multiple zones, and a range of temporary local variations and short term access rights linked to particular local characteristics. Examples include, temporary access provided free to specific patrons or patients of medical facilities and businesses. These are administered by the respective organisations through a secure on-line facility. (e.g. patients who are referred to a medical facility in the CBD can be granted an exemption for the day of their appointment). Any vehicle without a right of access is fined by the local police.

Electronic Gateways are currently employed in Rome, Florence, Bologna, Sienna, Pisa, Peruglia, Torino and Padua. Cities such as Rome, Florence, Bologna and Torino are divided into sub-access zones and access is
provided to one or multiple zones depending on the location of the business in the access control area.

Using the same technology employed on the national toll road network, the system has been easy to implement and has a high degree of reliability (over 99.95%). ANPR is necessary for those vehicles not equipped with Telepass units and the performance of this system is reported at between 70% and 84%.

Key aspects of the Italian schemes include:

- Multiple zones used by some systems
- Multiple DSRC/ANPR facilities in narrow street environments
- Design of system not considered intrusive in historic cities
- Large number of exemptions managed

**Hong Kong**

Hong Kong has recently competed a detailed evaluation of congestion charging options for the city, including development of an extensive conceptual system design and business case evaluation.

Following evaluation of several options, a multiple cordon based system was identified as being most suitable for the Hong Kong situation, and a system designed to suit the requirements of this approach, and the specific challenges of the Hong Kong environment.

The system developed is based on a combination of DSRC, ANPR and smart card payment facilities, utilizing the widely used (in Hong Kong) “Octopus” card. This system assumes the use of hybrid 5.8Ghz DSRC tags (based on the current CEN standard) that will have the facility to interface with the Octopus card directly.

This scheme is similar in many ways to the Singapore ERP, combining the benefits of an existing common e-payment network with a well develop open road tolling technology for maximum efficiency.
The DSRC based system was also identified as providing options for more variable charging (e.g. multiple cordon combinations) in real time.

Key aspects of the Hong Kong scheme include:
- Use of an established e-payment facility
- Multi-cordon changing variations
- Alignment with well established e-toll standards

Manchester

Manchester is currently in the process of developing a large scale congestion charging scheme based on a double cordon arrangement. As part of this process a detailed system design has been developed, along with a detailed business case.

Figure 11: Manchester charging scheme

The system that has been developed for Manchester is based on a combination of DSRC, ANPR technologies, using European standard 5.8Ghz DSRC tags and an ANPR enforcement system, similar in operation to the original Stockholm system, and a wide range of free flow tolling facilities.

The DSRC based system was also identified as providing options for more variable charging (e.g. multiple cordon combinations) in real time, and a more flexible basis for targeted concessions and discounts.

Key aspects of the Manchester scheme include:
- Combined DSRC and ANPR systems
- Multi-cordon changing variations
- Alignment with well established e-toll standards
- Developing a basis for targeted concessions and discounts
5.4.3 Future technologies and options

Although the majority of systems currently in operation, or at an advanced stage of development, have been based on combinations or variations of DSRC and/or ANPR based technologies, several other options are developing and have been evaluated in some detail for use as alternatives. These include current and potential future alternatives such as:

- Global Navigational Satellite Systems (GNSS) or “GPS” technologies
- “Sticker based” Radio-Frequency Identification (RFID)
- Developing 5.9Ghz “Vehicle Infrastructure Integration” technologies
- Micro or “Pico” Cell technologies

GNSS technologies are currently used as a basis for several road user charging applications, such as the German and Swiss heavy vehicle charging schemes, and provide the potential for distance and location based charging variations. Evaluations of this technology for urban road pricing applications has, to date, found that it is not yet cost effective, due mainly to the costs of units, although these are reducing.

RFID systems are used as the basis for several large free-flow tolling applications (particularly in the USA). These devices are generally less expensive than the more widely used 5.8Ghz standard tags, (around 1/3) but at the expense of lower accuracy and data capacity levels.

The USA’s VII program is currently developing a range of applications based on 5.9Ghz technology. This is expected to provide the basis for a suite of vehicle safety related systems into the future, and has the potential to provide an advanced high capacity base technology for tolling.

Micro or Pico cell technology uses mobile phone technology and deploys additional ‘cells’ in urban areas which are considerably smaller than a standard mobile phone ‘cell’. A mobile phone ‘cell’ is an area around a transmitter that a mobile phone can operate in. By deploying micro or pico cells, it is possible to more accurately determine the position of a phone and its user. This is another emerging technology with potential as a basis for urban road charging, although still at a relatively early development stage.

These options are addressed in greater detail through the later technology evaluation sections.

5.4.4 Summary of key factors

The systems considered through the previous section provide an insight into the key factors and issues that combine to drive the selection of the most suitable system design. These include:

- Purpose of system
- Capital cost of the scheme
- Future expansion and integration plans
- City geography and infrastructure required to implement the scheme
- Policy and legislative structures and constraints
- Scheme approach (e.g. enforcement or collection)
- Operational cost and cost effectiveness
- Optimisation of revenue collection
- Proportions of casual and regular users
- Payment security concerns
- Reliability and accuracy of technologies
- Alignment with proven technologies
- Alignment with well supported standards
- User understanding and acceptance
- Ability to provide flexibility and variation in charging and concessions
- Cost and flexibility of payment options
- Desire to highlight or simplify payment processes
- Level of foreign vehicles and ability to enforce

Most of the existing urban charging schemes in operation, or at advanced stages of development, are based on ANPR or DSRC technologies and, in a variety of forms and combinations. These have proved to be effective and reliable, with reliability rates of over 99.5%, and an ability to manage more advanced charging variations, according to different points and time of day.

In all schemes, effective enforcement is a critical factor, and number plate recognition technology is used in most cases as the base technology, to capture vehicles without DSRC tags or without accounts.

Several aspects of scheme design are linked to the availability and/or reliability of other related systems and services. In many cases the reliability of data in the motor vehicle registry is a critical element, in others reliance on other e-payment networks is key, and others the support of related enforcement mechanisms and penalties (e.g. Singapore).

The individual and combined analysis of existing international examples of road charging schemes indicates the following:

- ANPR and DSRC are both proven in urban conditions.
- ANPR is simple to design, operate and use by motorists. However it is restrictive on charging approach, increases labour related operating costs, and limits future flexibility and system expansion.
- DSRC offers a wider range of charging capabilities, is flexible in application, has higher capital costs, but is cheaper to operate with reasonable levels of regular users.
5.5 TSP systems, standards and parameters

The New Zealand Toll Systems Project (TSP) is now at a relatively advanced stage of development, with contracts let for the delivery of the main roadside equipment, and work on the Transport Registry Centre’s operations underway. Specific National technology standards have also been confirmed for the critical vehicle to roadside interface, and related data structures.

The compatibility of any proposed road pricing solution for Auckland with the technology options and operating principles of TSP will be a critical element in the evaluation of options; in order to optimise costs, and to ensure full interoperability and greater simplicity in terms of the public’s understanding of electronic fee collection in New Zealand.

This section provides an overview of the current status of the Toll Systems Project, its planned operation and technologies, focusing particularly on those elements that are likely to have a direct bearing on any candidate options for an Auckland Road Pricing solution; including:

- Current operations concepts and plans
- Legal and Policy assumptions and directions
- Contract structures related to the procurement and operation of the systems
- System and technology capacity issues and potential to meet likely road pricing demands
- System and technology lifecycle programs
- The interrelationships between these and other aspects of the TSP
- Systems Standards

5.5.1 Current operations concepts and plans

The Toll Systems Project has progressed during the past 12 to 18 months to deliver a fully functioning free flow toll system for the ALPURT motorway, that is also the foundation for a broader national centralised system that can be applied to any future toll or charging facility in New Zealand. The system is now at an advanced stage of development with both roadside and back office systems under construction, and detailed operational processes assigned.

Kapsch TafficCom (KTC) have been contracted to provide a roadside system comprising a 5.8Ghz tag facility, ANPR camera systems, vehicle classification and verification facilities. This contract also extends to assisting Land Transport NZ’s Transport Registry Centre (TRC) to develop a functioning back office that will be operated from their centre at Palmerston North.
The main toll operations for ALPURT are due to be commissioned in mid to late 2008 for the road opening in January 2009. Roadside systems will record all vehicles passing the single toll point in each direction, and process transaction records that will be passed directly through to the TRC operations centre.

TRC will manage and operate the payment and account management functions, receiving the developed transactions from the ALPURT systems, and processing payments and charges for account holders, casual and commercial users.

Initially the ALPURT toll system will be operated using only the ANPR facilities, users will establish accounts based on their vehicle number, or pay tolls as a casual user within a defined period. Kiosk payment facilities will also be provided for those users wishing to pay with cash.

5.5.2 Legal and policy assumptions and directions

The development of the toll systems project has included a detailed evaluation of policy and legislative issues, with a particular focus on the requirements of the LTMA and other related legislation.

Key aspects that have influenced the design of planned operations include:

- The need to provide a payment option that does not record any personal information of the person paying the toll. i.e. cash payment
- The management of any access, or reference, to the motor vehicle registry
- Approaches to processing violations and debt collection
- Processes relating to exempt vehicles
- Ability to impose appropriate charges and pass on administration costs
- Driver / owner responsibilities
- Processes and procedures relating to key evidential devices (e.g. cameras)

5.5.3 Contract structures related to the procurement and operation of the systems

The roadside systems and core elements of the back office are being provided by KTC, with some back office systems being modified and enhanced to coordinate with TRC facilities.

Once the system is fully commissioned this supply contract will migrate to a detailed 5 year maintenance and support contract, under which KTC will provide a defined level of support linked to a package of KPIs defined through the current contract.
This contract also includes a requirement for ongoing improvements, upgrades, and expansion linked to a series of defined principles.

The operation of the back office account and payments systems by TRC will be contracted on per transaction basis, with TRC receiving a defined service fee per transaction, and linked to CPI escalation.

5.5.4 System and technology capacity issues and potential to meet likely road pricing demands

The system currently being completed has been designed to provide sufficient capacity for the forecast ALPURT transaction volumes over the next 5 years. However, many of the components of the system have significant spare capacity, due to the fact that this system is developed from a base designed from the broader free-flow tolling industry. The system that KTC are providing is essentially a modified version of their core free-flow package that is designed to accommodate a significantly higher level of transitions.

One area that would need to be developed and extended is the issuing and management of DSRC tags (not included in the current phase).

TSP has been developed, from its first inception, to provide the basis of a national tolling system, capable of supporting multiple toll and charging facilities. This philosophy has remained within the current system design, with many of the key capacity elements incorporating spare capacity, or an ability to be readily expanded.

In terms of technical capacity, the TSP system is capable of expanding to meet the requirements of an Auckland Road Pricing application; however an expansion of this scale would be likely to require an expansion of TRC’s operating resources and development of an Auckland based tag management facility.

5.5.5 System and technology lifecycle programs

The current system that is being developed for ALPURT has an initial 5 year contract period. This will then be reviewed, and either extended, upgraded or superseded by another system.

The current system and technologies have been designed with the majority of core technical facilities either replaced or upgraded on a 7year cycle.

5.5.6 Standards

New Zealand has recently developed a National standard for DSRC toll/charging technology, based mainly on alignment with the current
Australian standard used for free-flow tolling, which in turn was based on the European standard.

This standard (NZS 6907 2007) was confirmed in November 2007, and is based on 5.8Ghz frequency, with defined roadside to vehicle protocols and data structures closely aligned with those used in Australia.

This standard aligns New Zealand with a strong market for DSRC tags, with at least 3 current suppliers operating in a competitive market in Australia.

5.5.7 Summary

In summary:

- TSP has been established as a foundation for future charging systems in New Zealand
- The capacity and flexibility of the system currently being commissioned has the ability to meet the needs of an Auckland Road Pricing application
- Application to an urban road pricing scheme would require some changes or additions to current legislation.
6 Stage two – Candidate solutions

6.1 Candidate solutions and technologies

This stage considers the different charging mechanisms and associated technology options for each scheme, and provides the basis for the selection of an appropriate solution package.

Options are developed for each scheme type, drawn from international examples and variations developed to address the specific requirements of the Auckland system.

Key inputs to this process have been the transport modelling figures, to provide direction on scale and user mix, consideration of travel choice and equity enhancing options, and the ability of charging solutions to provide for these measures.

The following section considers the key requirements of the two schemes (Congestion and Revenue) in terms of their alignment with potential candidate technologies.

![]()  

6.2 Scheme requirements

As described in earlier sections, the two scheme concepts that are being considered under the current stage (the revenue and congestion schemes) have been developed as two separate approaches, each with its own set of principles and objectives.

The following table sets out the characteristics and principles of each of the schemes, and develops these further to identify key scheme requirements that candidate technologies will need to address.
### Table 3 Scheme Requirements

<table>
<thead>
<tr>
<th>General Scheme Description / Characteristics</th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Scheme</strong></td>
<td><strong>Area</strong> – charge to enter and/or travel within the boundaries.</td>
<td><strong>Cordon</strong> – with a charge in both directions.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Requires ability to monitor at least a proportion of internal traffic movements, in addition to those crossing boundary.</td>
<td>Requires ability to monitor vehicles moving in both directions and identify by direction</td>
</tr>
<tr>
<td><strong>Boundaries</strong></td>
<td>Based on the Area Charge zone boundaries from the first ARPES study – small area tightly focussed on the CBD.</td>
<td>Based on the Area Charge zone boundaries from the first ARPES study – small cordon tightly focussed on the CBD.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Relatively high number of boundary points with majority located in urban street environments. Several sections of major highway/motorway crossing the area.</td>
<td>Relatively high number of boundary points with majority located in urban street environments. Several major highway/motorway crossing points.</td>
</tr>
<tr>
<td><strong>Time of Day</strong></td>
<td>6-10am</td>
<td>24 hours a day.</td>
</tr>
<tr>
<td><strong>Days of week</strong></td>
<td>5 days per week</td>
<td>7 days per week</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Ability to accurately determine internal movement times may lead to some disputes.</td>
<td>Requires full time operation and high system reliability</td>
</tr>
<tr>
<td><strong>Vehicles Included</strong></td>
<td>Buses receive a 100% discount. All other vehicles are charged (motorbikes, taxis &amp; trucks pay charge).</td>
<td>Buses receive a 100% discount. All other vehicles are charged (motorbikes, taxis &amp; trucks pay charge).</td>
</tr>
<tr>
<td><strong>Exemptions / Discounts</strong></td>
<td>To be considered during study.</td>
<td>To be considered during study.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Need to develop robust procedure or technology solution to identify qualifying exempt vehicles (e.g. only scheduled services, including or excluding tour buses, additional exemptions or concessions planned).</td>
<td></td>
</tr>
<tr>
<td><strong>Charge Regime</strong></td>
<td>Charge level of $6 per trip. Maximum of $6 per day. (i.e. pay once and you have paid for the day).</td>
<td>$3 per trip charge Maximum $3 charge per day (i.e. pay once and it covers multiple entries and exits).</td>
</tr>
<tr>
<td><strong>Maximum charge per day</strong></td>
<td>$6 per day</td>
<td>$3 per day</td>
</tr>
</tbody>
</table>
## General Scheme Description / Characteristics

<table>
<thead>
<tr>
<th>Related requirements and issues</th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement to match and consolidate trips.</td>
<td>70 Points / 238 Lanes</td>
<td>Requirement to match and consolidate trips.</td>
</tr>
<tr>
<td>Real time or post matching will impact on technology choices</td>
<td>40 Points / 122 Lanes</td>
<td>Real time or post matching will impact on technology choices</td>
</tr>
<tr>
<td>Lower single charge level may affect business case (if processing multiple “transactions” for each $3 charge)</td>
<td></td>
<td>Lower single charge level may affect business case (if processing multiple “transactions” for each $3 charge)</td>
</tr>
</tbody>
</table>

### Number of toll points
- 70 Points / 238 Lanes
- 40 Points / 122 Lanes

### Related requirements and issues
- Additional internal points and potential mobile enforcement levels need to be balanced with cost and deterrent effect
- Relatively high number but majority are likely to be smaller installations

### Other relevant descriptors
- Aim is to make a meaningful difference to congestion levels – consideration of appropriate alternatives (eg passenger transport, other options) is important
- The aim of this scheme is to minimise diversion impact (and social impacts), but to deliver revenue to improve Auckland’s transport networks.

### Related requirements and issues
- Need for visible compliance monitoring and appropriate penalties
- Need to optimise revenue collection through efficiency of operations and reliability / accuracy of collection processes.
### Objectives/Principles

<table>
<thead>
<tr>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs</strong></td>
<td>The technology solution must maximise net revenues</td>
</tr>
<tr>
<td>A technology solution that maximises net revenue would be valued, but the primary objective is to manage congestion</td>
<td></td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Need to optimise revenue collection through efficiency of operations and reliability / accuracy of collection processes.</td>
</tr>
<tr>
<td>Need for visible compliance monitoring and appropriate penalties</td>
<td></td>
</tr>
<tr>
<td>Options for mitigation of social impacts/ providing exemptions</td>
<td>Not a priority – the $3 charge is envisaged as being sufficiently low to not require a focus on mitigation</td>
</tr>
<tr>
<td>The possibility of using the technology solution to provide for mitigation options such as 'mobility vouchers' would be seen as an advantage</td>
<td></td>
</tr>
<tr>
<td>Ability to provide non-charged options for transport disadvantaged to be provided</td>
<td></td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Requirement for versatility reduced</td>
</tr>
<tr>
<td>Need for system that is capable of providing versatile concessions and exemption options</td>
<td></td>
</tr>
<tr>
<td>Payment Options</td>
<td>Convenience for users is important, but overall aim must first be to keep the rating costs of the system low</td>
</tr>
<tr>
<td>Balance of convenience, cost and 'message to road users that they are paying to use in peak periods' to be considered</td>
<td></td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Reduced cost a priority</td>
</tr>
<tr>
<td>A system that alerts users to each payment, but is not unduly inconvenient or expensive to operate</td>
<td></td>
</tr>
<tr>
<td>Inter-relationship with TSP</td>
<td>Not an absolute requirement, but departure from TSP operating model will need to be justified</td>
</tr>
<tr>
<td>Not an absolute requirement, but departure from TSP operating model will need to be justified</td>
<td></td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Consideration of alignment with TSP where possible</td>
</tr>
<tr>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system</td>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system, but balance of capital and operating cost will need to be considered to ensure that net revenue is maximised</td>
</tr>
<tr>
<td>Enforcement</td>
<td></td>
</tr>
</tbody>
</table>
6.3 Technology options

6.3.1 Functional requirements

The basic function of any congestion charging or Road Pricing system, and its supporting technologies, is to collect payment from users within the framework of the scheme’s rules. This framework can vary significantly depending on particular local conditions, strategic, legal and policy requirements, and the nature of the outcomes that the scheme seeks to achieve.

As these types of facilities have evolved in recent years the capabilities and/or limitations of the technologies available have often played a major role in shaping functional design; as the capabilities of technology have increased, the flexibility of charging schemes to more directly address the key transport objectives has improved. In the same way that some technology limitations have (and still do) restrict some desirable scheme functions, the rapidly developing capabilities of new technologies can also offer options that may previously have not been considered.

Whatever system or technology solutions are adopted, the collection of payment from users within the framework of the scheme must include consideration of the following nine core functional requirements.

1. **Informing** – providing adequate information to users and potential users (often defined by legislation).
2. **Detection** – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle crossing a cordon or moving within an area zone).
3. **Identification** – Identification of the user, vehicle, or in some cases numbered account.
4. **Classification** – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.
5. **Verification** – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.
6 **Payment** – pre and post use collection of payment from users based on verified use.

7 **Enforcement** – providing the means to identify and prosecute violators, and/or pursue violators for payment of charges and/or fines.

8 **Exemptions** – providing the facility to manage a range of exemptions and discounts within the context of the scheme.

9 **System Reliability and Accuracy** – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

This base functional framework has been used through several of the later sections to consider and compare the functional capabilities and operation of candidate technologies against the requirements of the congestion and revenue schemes.

The following is a summary of the potential candidate technologies for both schemes, based on consideration of a combination of currently operating systems, developing new technologies and standards.

1 **Paper Based Systems** - Paper-based systems essentially require that road users, who wish to use (or keep) their vehicles within a defined area during a defined time period, purchase and display a supplementary licence or permit. This usually takes the form of a paper licence that can be displayed on the windscreen or dashboard of the vehicle.

2 **Manual Toll Facilities** - Manual toll facilities, toll booths or plazas essentially comprise payment points at which drivers pay a charge using cash, vouchers, charge cards or smart cards.

3 **DSRC Schemes (with ANPR enforcement)** - Dedicated Short Range Communication (DSRC) is the most common form of primary electronic road pricing technology in general use, and is the standard on most free flow tolled facilities. The technology is based on the use of on-board vehicle units (OBUs), sometimes referred to as transponders, which communicate with gantry mounted equipment at defined charge or check points. These units can also incorporate a smart card facility for payment.

4 **Vehicle Positioning Systems (GNSS) e.g. GPS, Galileo** - Vehicle Positioning (e.g. GPS) Systems use a satellite location systems (generally GPS) to determine the vehicle’s position and measure location and distance travelled for the purposes of charging and access control.

5 **Image Based or ANPR Only Systems** - Image Based Tolling/Automatic Number Plate Recognition (ANPR) Technology is based on images taken of vehicle number plates and processed through recognition software to identify the vehicle.

6 **RFID “sticker” systems** - using small electronic tags placed in the windscreen and identified by roadside equipment.
Combinations - The majority of current road charging systems, including toll roads and urban charging and access schemes, use a combination of technologies to manage the collection and enforcement process. By using a combination of technologies these systems are able to apply the most suitable technology to specific tasks and achieve an optimum system overall. One of the most common combinations is the use of DSRC OBUs as the primary payment and identification technology, and ANPR technology for enforcement and casual user transactions.

In addition to these primary systems there are several related sub systems for which a range of technology options exist, including:

1. Vehicle classification systems (e.g. laser, video, digital loop, axle detection treadles)
2. Telecommunications, Roadside and Centralised Control Facilities (e.g. in unit, controller based processing)
3. Automation of Operations (e.g. payment and enforcement processing, account setup and management)
4. Secondary enforcement systems (e.g. scene image capture, mobile and portable enforcement)
5. Payment systems
6. DSRC Systems (tag and reader options including a range of frequencies and packages)
7. ITS Integration
8. On-Board Unit (OBU) distribution facilities (e.g. vending machines and agents)

Appendix A sets out the candidate primary technologies, including a brief description of each and a summary of how core functions are addressed by each. The following section provides a summary of this assessment.

6.3.2 Paper-based systems

Paper-based systems essentially require that road users, who wish to use (or keep) their vehicles within a defined area during a defined time period, purchase and display a supplementary licence or permit. This usually takes the form of a paper licence that can be displayed on the windscreen or dashboard of the vehicle.

There are two main options available for implementing paper-based schemes;

- entry permit schemes – where vehicles need to display a valid licence sticker to enter (or leave) a defined area (the restricted zone)
- “true” area licensing schemes - Where vehicles need to display a valid licence to travel or park within a defined area
The distribution of permits or licences is usually managed through a combination of existing retail outlets, and other system operator channels such as vending machines, web and phone based mail order.

Examples

Singapore’s Area Licensing Scheme (ALS), operated from 1975 until 1998 required car drivers entering the CBD during the morning peak to pay three Singapore dollars per day (with exemptions for vehicles carrying four or more people. This was managed using a paper based (sticker) system, stickers being purchased for each day and placed on the inside of the windscreen. Under this system drivers were able to travel into and around the priced area several times in a day without having to pay multiple charges. Enforcement of the system was addressed using checkpoints where officials inspected each vehicle to ensure a valid license was displayed.

- Parking Management Schemes – use a range of paper based systems to collect and enforce the payment of parking charges, based on time of day, length of stay, location and vehicle class. Examples include:
- Pay and Display – used in most developed cities across the world; this system requires vehicles to display a valid ticket that is dispensed via roadside vending machines. With advances in technology these devices are now provided with live communications connections that enable them to manage variable charges by time of day, parking location and class; as well as providing a range of payment facilities including SMS-Text, credit, debit and smart cards.
- “Coupon” or “Voucher” parking – common in many urban centres in the UK, US and Europe, this type of system requires that parked vehicle display a valid coupon or voucher for the zone, time period or class of vehicle. These systems are generally used in areas where restrictions apply to a relatively large area, and where parking durations are longer. It operates in a similar way to ‘Pay and Display’ but removes the need for on site payment and issuing machines. Instead coupons are made available though retail outlets and/or mail.

6.3.3 Manual toll facilities

Manual toll facilities, toll booths or plazas have been used around the world for many years and essentially comprise payment points at which drivers pay a charge using cash, vouchers, charge cards or smart cards. Due to the amount of space required for conventional toll booths in dense urban road networks, the congestion (worsening) impact caused by the need to slow down or stop to pay, and the
associated negative public perceptions, this method is generally not considered appropriate for urban road pricing. The development of automated payment machines has helped to reduced the costs of manual collection, but these variations on a manual system still operate in much the same way, with similar problems.

**Durham City road user charge scheme**

One of (if not the only) “manual” based congestion charge schemes currently in operation is the Durham City scheme implemented in 2002, which uses a system of bollard gates and “manual” payment machines.

Drivers are required to pay the designated charge when exiting the city centre zone before the bollard gate will open. These gates are also manned by an official, and drivers unable to pay are allowed to pass but incur a fine.

**On-street equipment and environment**

The street based equipment required for a manual system would be significant, and include potentially charging booths, additional lanes to increase throughput, and gates at all entry points. There would be a need for sufficient space to install the required equipment and access to power, communications.

For a small and restricted application such as Durham City this has been possible as the scheme is designed to restrict traffic to a minimum, and so requires the processing of relatively low volumes. For a more extensive central city environment the impact of toll booths and the related infrastructure would have a major impact on the urban environment.

**6.3.4 Image based tolling/automatic number plate recognition (ANPR) technology**

ANPR technology is commonly used on most electronic tolling facilities around the world, both in free-flow and toll lane based situations, although most often as an enforcement back up to DSRC or GNSS technology.

ANPR is based on images taken of vehicle number plates and processed through recognition software to identify the vehicle. Some systems can use front and/or rear located cameras to capture the images and so improve identification rates. Once identified the required charge or permit checking processes are undertaken in a similar way to other systems.
A key issue with ANPR facilities is the level of reliability of the plate reads. Even the best systems in current use are capable of read rates of around 95% in good conditions, but this can reduce as a result of problems such as light reflections in the image, dirty or damaged plates. This leads to the need for manual checking of those that cannot be automatically read and can add significantly to processing costs.

London example

The London Congestion Charge is the only facility that currently relies entirely on ANPR on a large scale, and it is worth noting that the London Scheme is an area licensing scheme with the ANPR system effectively used here as an enforcement system.

Stockholm has also moved to a high level of ANPR based transactions since the scheme became permanent, but still retains its DSRC facilities for some types of transactions.

Several other toll facilities provide ANPR only account options to users, but most with additional fees to cover the increased overall cost of processing these types of transactions (in comparison to their alternative DSRC based accounts).

The London scheme being an “area” charge system also requires ANPR stations within the designated zone, at fixed locations and on mobile enforcement units.

On-street equipment and environment

The street based equipment required for an ANPR system includes pole and/or gantry mounted cameras and illumination devices. In some cases these are combined into one unit and depending on the overall system design there may be a requirement for additional cameras (front and rear), classification devices, and independent verification counters.

Figure 12 Typical camera and illumination devices

In addition to the camera mountings some form of system controller is required in the vicinity of each installation. This controller is similar to a traffic signal controller, requiring full power and communication connections via a purpose designed base unit, connected via ducting to each camera.
location. Again depending on the nature of the system the communications connections may need to be to a dedicated or leased fibre-optic network, with power supplies supported by UPS facilities. The location of camera sites around the network is generally flexible, and the impact of the pole and/or gantry supports adapted to the local environment.

Figure 13 Typical camera installations

6.3.5 **DSRC free flow toll using transponders and gantries**

Dedicated Short Range Communication (DSRC) is the most common form of primary electronic road pricing technology in general use, and is the standard on most free flow tolled facilities.

The technology is based on board vehicle units (OBUs), sometimes referred to as transponders, which communicate with gantry mounted equipment at defined charge or check points. The roadside equipment identifies and verifies each vehicle’s OBU, and depending on the type of system, either processes a charge from its designated account or confirms its rights of access.

Combinations of toll points can be used to facilitate distance based charging systems, special charging conditions for particular entry and exit points or times.

In most Multi-Lane Free Flow systems the DSRC system also acts to locate the vehicle within its detection zone using an array of DSRC transceivers.

The enforcement of this type of scheme is generally addressed using roadside enforcement cameras and Automatic Number Plate Recognition (ANPR) technology (described below).

There are a range of different DSRC systems in use (and under development). Some use infrared communications; this technology has not been deployed widely in higher speed applications, and is not generally considered an open standard. Most are based on microwave communication; the most common systems currently in use are based on a 5.8GHz frequency, using the European CEN-278 standard. This standard is
now well developed and delivers robust and secure OBU devices that have an average (battery) life of around 5 years.

The next generation 5.9GHz systems being developed mainly in USA to address a wider spectrum of ITS applications will provide longer range communication and multiple channels. Although not currently in use on any operational charging system, these devices (OBUs) are planned to become standard installations in all new vehicles within the next decade.

Another frequency system used in Singapore and some Hong Kong toll facilities is 2.45Ghz. This is not an open standard but is used by several toll operators.

Once established, DSRC systems can be expanded relatively easily onto other routes or across adjacent areas through the deployment of additional toll or check points. However, expanding these types of systems to cover much wider areas is less cost effective, as the numbers of toll points to provide effective coverage can increase significantly.

On-street equipment and environment

The street based facilities required for a DSRC system would include a range of equipment including:

- pole and/or gantry mounted transceivers
- in most cases ANPR cameras and illumination devices
- vehicle classification devices
- independent verification devices
- roadside control cabinets.

The location and street environments will include both multi-lane highway and urban situations.

In the urban environment some street layouts may require local modifications to improve the operation of the system; for example to provide localized separation of traffic from opposing direction streams, and assist in reducing the need for full gantries in street situations. The transceiver/classifier units are generally mounted separately from the cameras to allow the cameras to pick up vehicles in the detection zone, although technologies are available to combine all functions to one location.

A further variation in some arrangements is the use of front and rear cameras, which may require an additional camera support structure.
As for an ANPR system, some form of system controller would also be required in the vicinity of each installation, requiring full power and communication connections via a purpose designed base unit and connected via ducting to each location.
The issues of urban streetscape “clutter” can be seen as a problem with this technology, although through good design this can be kept to a minimum, as illustrated by the Italian access control systems and recent London DSRC trials.

Figure 17 Italian Access Control Systems
In multi-lane situations an array of transceivers and classifiers will be required, generally mounted on purpose built gantries or potentially on existing structures. The following are examples of existing multi-lane facilities combining transceivers (ETC RX/TX), detection and classification units, and video capture.

**6.3.6 GNSS (e.g. GPS) systems**

Internationally, road authorities have been exploring and implementing GNSS which do not require on-road infrastructure to assign a position to a vehicle. Instead, these systems use a satellite location system (generally GPS) to determine the vehicle’s position and measure location and distance travelled for the purposes of charging and access control. These systems offer greater flexibility for authorities to vary
Charging Mechanisms

Auckland Road Pricing

Although GNSS technologies are an effective means of tracking vehicle position, the information they gather and store needs to be communicated to central systems on a regular basis, and as such GNSS units are generally combined with other technologies (digital maps, wide area communications, and short range GPRS communications) to charge and enforce the system. Other additional features required for this type of system include enforcement check points (fixed and mobile) and depending on the focus of the system these can be extensive.

The current cost of units has been a major factor in these systems only being used for major heavy vehicle application to date, but these are reducing and, once established, GNSS based systems have the advantages of wide coverage and far fewer check points than other technologies. It is expected that on-board GNSS units will become standard features in new vehicles within 10 years, and this migration is a specifically identified strategy for the European Union.

On-street equipment and environment

GNSS based system require far less on-street equipment than other systems, with the primary function of the street based facilities being backup enforcement at selected check points. Fixed on street checkpoints are most likely to use similar DSRC and ANPR technologies described in the previous section, and require a series of pole or gantry mounted devices.

The check points will be similar to ANPR and DSRC facilities, with the functions depending on the structure of the system. Devices required may include DSRC transceivers, ANPR cameras and vehicle classifiers, with similar controller requirements to the systems already described.

These fixed enforcement stations will most likely be supported by mobile units that will reduce the number of locations required. The location of these sites around the network would be relatively flexible, and the impact of the pole and/or gantry supports adapted to the local environment.

GNSS examples

GNSS type technology is in use on several wide area heavy vehicle road user charging facilities, including systems in Germany and Switzerland. Internationally, GNSS-based systems have been introduced (e.g. Germany) or considered (United Kingdom) as technology solutions for the introduction of distance-based charging, primarily for heavy vehicles. The German model is now beginning to demonstrate that the technology is moving towards being ‘proven’ – but only for a distance-based charge. Nowhere in the world has GNSS yet been used for a more contained urban
congestion charging scheme – primarily because of difficulties in managing the urban environment (with its canyon effect) and because the higher costs of in-vehicle units is prohibitive in smaller areas. In an urban area the costs of the scheme would also be likely to rise dramatically due to the need for “repeater” units to overcome the canyon effects and generally improve boundary accuracy.

6.3.7 RFID “sticker” systems

Lower cost windscreens stickers incorporating RFID tags are used as the basis for several electronic toll systems (particularly in the USA). These systems operate in a similar way to other DSRC systems, but with all power drawn from the roadside equipment and a more limited data capacity.

These systems have some limitations in comparison with the previous DSRC systems described, including:

- Reduced data sets supported (such as emission class, License plate, vehicle chassis number addition to the serial number ID)
- Reduced tamper and move detection
- No current standardised protocol (e.g. CEN / ISO DSRC)
- Single vendor support both on tags and readers
- Limited ability to provide read/write function at high speed
- Interference from GSM cell phone systems
- Limited ability to identify location across multiple lanes

The limitations of this technology mean that it is most often used for lane constrained tolling applications where vehicles can be slowed and channelled.

6.3.8 Combination systems

The majority of current road charging systems, including toll roads and urban charging and access schemes, use a combination of technologies to manage the collection and enforcement process.

By using a combination of technologies these systems are able to apply the most suitable technology to specific tasks and achieve an optimum system overall.
One of the most common combinations is the use of DSRC OBUs as the primary payment and identification technology, and ANPR technology for enforcement and casual user transactions. This combination allows operators to benefit from the higher accuracy and lower operating costs of DSRC, while overcoming the DSRC limitations of casual user management and enforcement with ANPR. This package also limits the use of the less accurate and more operations cost hungry ANPR technology to a reduced number of transactions.

Other example combinations include the main current deployments of GNSS on the German and Swiss Truck Toll systems, which use GNSS to address the distanced and location based elements, DSRC to provide the necessary local roadside communication, and ANPR as a the base enforcement technology.

The following table provides a summary of the key elements and issues.

Table 4: Functional requirements and characteristics

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Informing</td>
<td>Combination of fixed signage, public media and VMS where variable charging is used. Ability to also provide information through OBUs on charge levels and account balance.</td>
<td>Manual detection devices for semi automated lanes</td>
<td>Though detection device (laser, Loop, Video)</td>
<td>Short range communications and/or detection device (laser, Loop, Video)</td>
<td></td>
</tr>
<tr>
<td>Detection</td>
<td>Manual</td>
<td>Manual and detection devices for semi automated lanes</td>
<td>Though detection device (laser, Loop, Video)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>Manual</td>
<td>Manual</td>
<td>Vehicle Plate</td>
<td>OBU</td>
<td>OBU</td>
</tr>
<tr>
<td>Classification</td>
<td>Manual</td>
<td>Manual and detection devices for semi automated lanes</td>
<td>Though detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
</tr>
<tr>
<td>Verification</td>
<td>Manual</td>
<td>Manual and some cross checks with detection devices for semi automated lanes</td>
<td>Plate number against account records and classification measures</td>
<td>OBU against account records and classification measures</td>
<td></td>
</tr>
<tr>
<td>Payment</td>
<td>Retail outlets and vending machines using cash or card payment</td>
<td>At booth cash or card payments (some pre-purchased voucher options)</td>
<td>Pre or post pay accounts or licenses based on plate number</td>
<td>Pre or post pay accounts based on OBU. Some with smartcards directly linked to the OBU</td>
<td></td>
</tr>
<tr>
<td>Enforcement</td>
<td>Manual</td>
<td>Manual</td>
<td>License plate through the motor vehicle registry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exemptions</td>
<td>Manual (paper based)</td>
<td>Manual (paper based)</td>
<td>Linked to registration</td>
<td>Linked to OBU</td>
<td></td>
</tr>
<tr>
<td>Reliability &amp; Accuracy</td>
<td>High manual component leads to high cost</td>
<td>Traffic delays, and high manual component leads to high cost</td>
<td>ANPR read rate 85-90%. Increased costs from manual checking and data handling</td>
<td>DSRC read rate 99.7% reduced costs of processing and data handling</td>
<td>Proven heavy vehicle systems but units still expensive</td>
</tr>
</tbody>
</table>
6.4 Candidate technologies

6.4.1 First stage assessment

The first stage assessment of these options against the broad requirements of both schemes removes both paper-based and manual tolling, concluding that these types of facilities would present difficulties in terms of traffic disruption and limitations on any future ability to vary charges by time of day and level of congestion.

GNSS was identified as technically possible, but not cost-effective currently.

The conclusion of the first level assessment was that the only feasible candidate options for implementation were DSRC, ANPR or a combination system.

The following Table sets out a summary of this first stage technology assessment.

<table>
<thead>
<tr>
<th>Scheme type and technology</th>
<th>Paper-Based System</th>
<th>Manual Toll-Plazas</th>
<th>ANPR</th>
<th>DSRC</th>
<th>Vehicle Positioning GNSS Systems (GPS, Galileo)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Congestion (Area)</strong></td>
<td>Not Recommended due to cost of operations and the scale of enforcement that would be required.</td>
<td>Not Applicable due to significant disruption to traffic.</td>
<td>Potential Option to be evaluated in greater detail.</td>
<td>Potential Option to be evaluated in greater detail.</td>
<td>Technically possible, but not cost-effective currently.</td>
</tr>
<tr>
<td><strong>Revenue (Cordon)</strong></td>
<td>Not recommended. Due to the scale of the system, the large number of cordon points and feasibility of enforcement.</td>
<td>Not Recommended. Location and delays from charging points, traffic and safety issues would outweigh any benefits.</td>
<td>Potential Option to be evaluated in greater detail.</td>
<td>Best Current Option. Similar to the model adopted for Singapore. Infrequent user issues would need to be resolved.</td>
<td>Technically possible, but not cost-effective currently. Issue of infrequent users would need to be addressed. Costs would need to be balanced with greater ability to differentiate charges by time/location.</td>
</tr>
</tbody>
</table>

6.5 Alternative revenue scheme

As part of the development of candidate options, a specific requirement of this study is to consider a lower cost (lower level technical) solution for the revenue scheme.
As described through earlier sections, the principles that are most important for the revenue scheme include:

- Minimise diversion impact (and social impacts), but to deliver revenue to improve Auckland’s transport networks.
- Adopt a technology solution to maximise net revenues
- Seek to deliver convenience for users, but overall aim to keep the costs of the system low
- The scheme must be capable of automatic enforcement to ensure integrity of the system, but the balance of capital and operating cost will need to considered to ensure that net revenue is maximised

A group of “low-technology” alternatives have been identified for consideration in terms of their suitability. They include:

- RFID “Sticker” tags – small lower cost tags (approximately 1/3 of a standard 5.8Ghz tags) that are read by high powered roadside transceivers, used to identify a vehicle.
- Daily paper based permit systems – windscreen tickets or stickers/cards that are required each day, and enforced through random enforcement checks at the cordon boundary.
- Period based passes – windscreen tickets or stickers/cards that are valid for a set period (e.g. weekly or monthly) enforced through random enforcement checks at the cordon boundary.
- Parking levies on non residents of the cordoned zone – application of a parking levy across the area, with exemptions for residents

The following table considers these options against some of the primary revenue scheme requirements.

Table 6 Low technology / cost options evaluation

<table>
<thead>
<tr>
<th>Low Technology/Cost Options Evaluation</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Scheme</strong></td>
<td>Cordon – with a charge in both directions.</td>
</tr>
<tr>
<td><strong>Time of Day</strong></td>
<td>24 hours a day.</td>
</tr>
<tr>
<td><strong>Days of week</strong></td>
<td>7 days per week</td>
</tr>
<tr>
<td><strong>Key objectives</strong></td>
<td>Minimise diversion impact (and social impacts), but maximise revenue. Convenience for users at low cost Maintain integrity of the system, but balance capital and operating cost</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Requires ability to monitor vehicles moving in both directions and identify by direction. 24 / 7 operation would require optimising of enforcement to maximise potential revenue.</td>
</tr>
</tbody>
</table>
## Low Technology/Cost Options Evaluation

<table>
<thead>
<tr>
<th>Revenue Scheme (Cordon)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RFID “Sticker” tags</strong></td>
<td>These types of systems have lower tag and roadside equipment costs than a system based on the 5.8Ghz units. However this saving is at expense of overall reduced accuracy, reliability and security. The systems also suffer from interference problems in areas where GSM cell phone systems are operating. While the costs of these types of tags are around 1/3 of the price of a 5.8Ghz system, all are proprietary systems that would lock in the system to one supplier. In order to offer a feasible lower cost option, such a system would need to operate without any ANPR enforcement, and therefore would need to provide a suitable facility for casual or infrequent users. At around $10 per tag, it would be difficult to provide such an option for single trips.</td>
</tr>
<tr>
<td><strong>Daily Permits</strong></td>
<td>This option would involve providing books of daily permits through retail agents and a program of enforcement designed to optimise compliance. The 24/7 operation of the revenue scheme would inevitably limit effectiveness, but by targeting peak periods and routes this could be mitigated. One of the key factors that limit the viability of this type of solution for the revenue scheme is the level of manual enforcement that would be required. In order to ensure a suitable level of revenue, and a level of compliance to maintain scheme credibility, the costs would be significant and reduce overall net revenue.</td>
</tr>
<tr>
<td><strong>Period Permits</strong></td>
<td>This option would involve providing period permits through retail agents and a program of enforcement designed to optimise compliance. As for the daily permits, the 24/7 operation would limit effectiveness, but could be mitigated through targeting of peak periods and routes. As for the previous permit option, one of the key limiting factors would be the level of manual enforcement that would be required, reducing overall net revenue to unacceptable levels.</td>
</tr>
<tr>
<td><strong>Parking Levies</strong></td>
<td>Parking levy options were examined as part of the earlier Auckland Road Pricing study, and at that stage they were found to be ineffective in delivering suitable congestion impacts. However, when considered as a means of addressing a revenue collection task, a parking levy scheme may be more effective. The key problem with such a scheme would be the administration of exemptions, the costs of which may outweigh the revenue collected, along with potential abuse of any related systems.</td>
</tr>
</tbody>
</table>

Of the options reviewed as alternatives for the revenue scheme the only option that is considered suitable for further consideration in the Parking...
Levy. This has been examined in more detail through the later assessment sections 7 and 8.

6.6 Model inputs

The transportation modelling carried out as part of the wider evaluation study provided the traffic and trip purpose figures for the two schemes. The figures summarised below are drawn from the 2016 model and have provide relevant inputs to the evaluation of options and the development of costs for the identified solution for each scheme.
### Table 7: Model inputs
The following table provides figures by trip purpose

<table>
<thead>
<tr>
<th>Revenue Scheme</th>
<th>Item</th>
<th>Description</th>
<th>Veh trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Trips 7-9am</td>
<td>Vehicle trips entering the scheme</td>
<td>79029</td>
</tr>
<tr>
<td></td>
<td>Charged Trips 7-9am</td>
<td>Vehicle trips incurring a charge</td>
<td>77029</td>
</tr>
<tr>
<td></td>
<td>Total Trips 24 hours</td>
<td>Vehicle trips entering the scheme</td>
<td>588000</td>
</tr>
<tr>
<td></td>
<td>Charged Trips 24 hours</td>
<td>Vehicle trips incurring a charge</td>
<td>121383</td>
</tr>
<tr>
<td></td>
<td>Total network trips 7-9am</td>
<td>ARC modelled area</td>
<td>438742</td>
</tr>
<tr>
<td></td>
<td>Total network trips 24 hrs</td>
<td>ARC modelled area</td>
<td>3264000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Congestion Scheme</th>
<th>Item</th>
<th>Description</th>
<th>Veh trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Trips 7-9am</td>
<td>Vehicle trips entering the scheme</td>
<td>66125</td>
</tr>
<tr>
<td></td>
<td>Charged Trips 7-9am</td>
<td>Vehicle trips incurring a charge</td>
<td>66125</td>
</tr>
<tr>
<td></td>
<td>Total Trips 6-10am</td>
<td>Vehicle trips entering the scheme</td>
<td>105366</td>
</tr>
<tr>
<td></td>
<td>Charged Trips 6-10am</td>
<td>Vehicle trips incurring a charge</td>
<td>105366</td>
</tr>
<tr>
<td></td>
<td>Total network trips 7-9am</td>
<td>ARC modelled area</td>
<td>403158</td>
</tr>
<tr>
<td></td>
<td>Total network trips 24 hrs</td>
<td>ARC modelled area</td>
<td>3275000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No Pricing Scheme</th>
<th>Item</th>
<th>Description</th>
<th>Veh trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total network trips 7-9am</td>
<td>ARC modelled area</td>
<td>446157</td>
</tr>
<tr>
<td></td>
<td>Total network trips 24 hrs</td>
<td>ARC modelled area</td>
<td>3318000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AM to daily (AHTS2006)</th>
<th>Purp</th>
<th>%SumOfTrips in AM</th>
<th>SumOfTrips</th>
<th>AM SumOfTrips</th>
<th>% in AM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Home based work trips</td>
<td>0.603</td>
<td>320558</td>
<td>193338</td>
<td>0.603</td>
</tr>
<tr>
<td></td>
<td>Home based education</td>
<td>0.796</td>
<td>114347</td>
<td>91021</td>
<td>0.796</td>
</tr>
<tr>
<td></td>
<td>Home based shopping</td>
<td>0.097</td>
<td>89513</td>
<td>8699</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td>HBSo</td>
<td>0.061</td>
<td>54673</td>
<td>3319</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td>Home based other</td>
<td>0.214</td>
<td>215996</td>
<td>46125</td>
<td>0.214</td>
</tr>
<tr>
<td></td>
<td>Home based bus</td>
<td>0.388</td>
<td>44954</td>
<td>17429</td>
<td>0.388</td>
</tr>
<tr>
<td></td>
<td>Home based other</td>
<td>0.321</td>
<td>519482</td>
<td>166592</td>
<td>0.321</td>
</tr>
<tr>
<td></td>
<td>Non Home based</td>
<td>0.129</td>
<td>610605</td>
<td>78692</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td></td>
<td>1450645</td>
<td>438622</td>
<td>0.302</td>
</tr>
<tr>
<td></td>
<td>All non-escort trips</td>
<td>2295478</td>
<td>564030</td>
<td>0.246</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All escort trips</td>
<td>450397</td>
<td>104348</td>
<td>0.232</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All trips</td>
<td>2745875</td>
<td>668378</td>
<td>0.243</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ARPES</th>
<th>Area boundary</th>
<th>Revenue Scheme</th>
<th>AM model</th>
<th>Daily charged</th>
<th>Revenue $3 cap/day</th>
<th>Annual 24/7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AM model</td>
<td></td>
<td>42509</td>
<td>70481</td>
<td>211443</td>
<td>54975082</td>
</tr>
<tr>
<td></td>
<td>Home based work</td>
<td></td>
<td>2529</td>
<td>7886</td>
<td>23658</td>
<td>7097547</td>
</tr>
<tr>
<td></td>
<td>Non home based</td>
<td></td>
<td>1015</td>
<td>7876</td>
<td>23627</td>
<td>7088215</td>
</tr>
<tr>
<td></td>
<td>Serve</td>
<td></td>
<td>3295</td>
<td>7111</td>
<td>21333</td>
<td>6400009</td>
</tr>
<tr>
<td></td>
<td>Ext</td>
<td></td>
<td>2167</td>
<td>5703</td>
<td>17108</td>
<td>5132368</td>
</tr>
<tr>
<td></td>
<td>CV</td>
<td></td>
<td>16579</td>
<td>8246</td>
<td>24739</td>
<td>6432158</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td></td>
<td>68094</td>
<td>107303</td>
<td>321909</td>
<td>87125379</td>
</tr>
</tbody>
</table>
6.7 Travel choices and equity

Work is currently being developed to examine the options and impacts of improving travel choices and enhancing equity through the road pricing schemes. The scope of this assessment and options available have some relevance to the charging mechanisms and technologies evaluation, in particular the feasibility of developing and delivering specific options reliably, cost effectively, and through methods that are understandable to the public.

Key considerations of the travel choices and equity work include:

- A Revenue Scheme is likely to impact (albeit at a lower level) on a larger overall number of trips than a Congestion Scheme
- A Congestion Scheme is likely to lend itself more easily to a range of targeted exemptions
- The social impacts of each of the representative schemes
- Experiences in other cities where road pricing has been implemented
- How road pricing will impact on specific groups

In considering the potential charging mechanisms and technologies for each scheme, a key consideration has been to effectively coordinate the charging mechanisms development, and evaluation, with potential measures developed as options to improve travel choices and enhance equity.

This has included assessing the ability of systems and technologies to facilitate targeted discounts and exemptions, and potentially to interface with wider passenger transport fare collection systems to provide, potentially, a common “transport” currency that can be used across multiple electronic fee collection systems for multiple transport purposes. Multi-modal transport charging mechanisms based on converging electronic fee collection systems and technologies have the potential to revolutionise travel demand management packages, and are increasingly being identified as a core element of congestion charging initiatives.

A primary objective of charging mechanisms will be to identify a system that provides an open architecture at the highest level to ensure flexibility for future schemes.

6.8 Privacy

Section 51(3) of the Land Transport Management Act 2003 requires that at least one of the methods of payment available for paying a toll/charge must be a method that does not record personal information in relation to the person paying the toll/charge.
Furthermore, in addition to the requirements of section 51(3) of the LTMA, the operator of a charging scheme will also be required to adhere to the requirements of the Privacy Act 1993.

In particular, the Privacy Principles require that an Agency use personal information only for the purpose for which it was gathered. The operator will also have to adhere to limits over the length of time information should be retained, the manner in which it is collected, from whom it is collected, the accuracy of the information and the security around its storage. The operator will collect personal information about users solely for the purpose of facilitating the electronic payment of road pricing charges by way of an account, or for enforcing the collection of unpaid charges.

The Toll Systems Project has considered the issue of privacy in detail, and developed methods for accommodating this requirement that are also applicable to road pricing schemes.
Stage three - Assessment of solutions

The main requirements of the two schemes defined through earlier sections combine with a series of additional factors to form the basis for the overall evaluation.

These factors or selection criteria are summarised through the following sub sections under 6 categories:

- Fitness for purpose
- Risks and mitigation
- Capital and operating costs
- Alignment with TSP
- Procurement issues
- Lessons from international review

7.1 Fitness for purpose

7.1.1 Congestion Scheme (Area)

From a “fitness for purpose” perspective, the main requirements of the congestion scheme can be summarised as follows:

- Ability to monitor at least a proportion of internal traffic movements, in addition to those crossing boundary.
- Operate a Relatively high number of boundary points with majority located in urban street environments
- Address urban street and highway environments
- Ability to identify qualifying exempt vehicles and provide for a range of account and special purpose concession schemes
- Requirement to match and consolidate trips (for some categories in real time)
- Need for visible and credible compliance monitoring and appropriate penalties
- Providing charging mechanisms that meet public expectations of complexity and fairness

7.1.2 Revenue (Cordon)

From a “fitness for purpose” perspective, the main requirements of the revenue scheme can be summarised as follows:

- Requires ability to monitor vehicles moving in both directions and identify by direction
• Need to manage a relatively high number of boundary points with majority located in urban street environments.
• Address urban street and highway environments
• Requires full time operation and high system reliability
• Ability to identify qualifying exempt vehicles and provide for a range of account and special purpose concession schemes
• Requirement to match and consolidate trips.
• Lower single charge level may affect business case (if processing multiple "transactions" for each $3 charge)
• Additional internal points and potential mobile enforcement levels need to be balanced with cost and deterrent effect
• Need to optimise revenue collection through efficiency of operations and reliability / accuracy of collection processes
• Providing charging mechanisms that meet public expectations of complexity and fairness

7.2 Risks and mitigation

Across both schemes key risk areas relating to the charging mechanisms and technologies include:

• Level of accuracy and reliability of the technology and systems
• Credibility of monitoring and enforcement
• System operational costs
• Public resistance
• System maintenance and support

Mitigations strategies for these, and other risk factors, have been considered through the more detailed development of the concept designs that have provided the basis for cost estimating.

These include appropriate levels of system support, redundancy, cost effective management of public interfaces, and technology choices that provide suitable levels of reliability and efficiency.

7.3 Capital and operating costs

The primary considerations around capital and operating costs are to provide a complete package, balancing the following:

• Up front capital investment in the system
• Realistic replacement costs and profiles for the main system elements
• Day to day operating costs to deliver a suitable level of service
Key aspects of these considerations have been in the balance of technology levels to operating costs. In this area factors that have been critical to the evaluation include:

- Proportions and levels of casual / regular users forecast
- Assessments of critical high volume operations processes
- Forecast technology developments and cost profiles.

7.4 Alignment with TSP

As referred to through earlier sections, the New Zealand Toll Systems Project is now at a relatively advanced stage of development, with specific technology standards confirmed and systems being established.

The compatibility of any proposed road pricing solution for Auckland with the technology options and operating principles of TSP will be a critical element in the evaluation of options; in order to ensure full interoperability and greater simplicity in terms of the public's understanding of electronic fee collection in New Zealand.

7.5 Procurement issues

In considering the most suitable charging mechanisms and technologies, the procurement of systems and services is a key consideration. Depending on the type of system selected, a range of options exist.

Most existing free-flow electronic toll collection operations comprise four basic components. The following diagram illustrates the key processes involved.

Figure 20: Key processes of electronic free-flow toll collection

Four basic components
In most current systems the majority of these functions are combined into one single operations division (either public or private), this single toll systems operation addressing all functions from roadside through to customer and transaction management.

The following diagram illustrates how these key functions are generally structured when combined as one single operation, and broadly defines those elements that fall within the descriptions of back-office, front-office and roadside facilities.

Figure 21: Representation of key system elements (drawn from TSP concept designs)

As more free-flow electronic charging facilities are being developed in major cities the benefits of sharing some of these services has becoming more apparent, and examples are emerging where some operators are contracting aspects of the toll collection process from each other, and the wider market.

When considering the potential for shared or outsourced services some key aspects that need to be considered include:

- Grouping functions into packages that can be readily defined, with clear boundaries to other functions or packages
- Developing packages that match existing or developing service markets
- Developing packages that provide potential for improved efficiencies
- Improving simplicity for users

A further development of the shared services model that is emerging, particularly in Europe, is the “service provider model”. This model effectively provides an alternative “front-office” service to customers and operators.
An evolution of this model where this customer facing front office function is wholly outsourced to multiple service providers is being pursued as a basis for several developing urban congestion charging schemes. The concept being proposed in these cases is based around 3 specific market segments providing services that suit their particular abilities and experience to deliver, over-all, a more efficient package.

- Roadside systems and services – contracted and provided by specialist providers (e.g. Kapsch, Q-Free)
- Account management and “retail” customer facing services – contracted and provided by multiple specialist providers
- Toll operator (Government or Private) interface management – “Contracted” from, or provided by the central operator.
- This model basically allows the operator to retain overall control and management, while extracting maximum efficiency from relatively strong markets in the roadside systems and customer management markets.

### 7.6 Lessons from international review

Based on the earlier assessment of international system, the following considerations were identified as issues to be considered.

- Purpose of system
- Capital cost of the scheme
- Future expansion and integration plans
- City geography and infrastructure required to implement the scheme
- Policy and legislative structures and constraints
- Scheme approach (e.g enforcement or collection)
- Operational cost and cost effectiveness
- Optimisation of revenue collection
- Proportions of casual and regular users
- Payment security concerns
- Reliability and accuracy of technologies
- Alignment with proven technologies
- Alignment with well supported standards
- User understanding and acceptance
- Ability to provide flexibility and variation in charging and concessions
- Cost and flexibility of payment options
- Desire to highlight or simplify payment processes
- Level of foreign vehicles and ability to enforce
These have been included within the consideration of suitable solutions for the two Auckland schemes.

7.7 Evaluation against scheme requirements

This second stage assessment considers a DSRC and ANPR solution against the main scheme requirements identified. This evaluation is set out in the following table.

Table 8: General scheme / system evaluation

<table>
<thead>
<tr>
<th>General Scheme / System Evaluation</th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Scheme</strong></td>
<td><strong>Area</strong> – charge to enter and/or travel within the boundaries.</td>
<td><strong>Cordon</strong> – with a charge in both directions.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Requires ability to monitor at least a proportion of internal traffic movements, in addition to those crossing boundary.</td>
<td>Requires ability to monitor vehicles moving in both directions and identify by direction.</td>
</tr>
<tr>
<td><strong>ANPR Assessment</strong></td>
<td>Suitable system - increased volume of plates recorded increases operating costs</td>
<td>Suitable system - increased volume of plates recorded increases operating costs.</td>
</tr>
<tr>
<td><strong>DSRC Assessment</strong></td>
<td>Suitable system - increased volume of vehicles recorded improves benefits from cost efficiencies, but with additional capital costs</td>
<td>Suitable system - increased volume of plates recorded increases operating costs.</td>
</tr>
<tr>
<td><strong>Boundaries</strong></td>
<td>Based on the Area Charge zone boundaries from the first ARPES study – small area tightly focussed on the CBD.</td>
<td>Based on the Area Charge zone boundaries from the first ARPES study – small cordon tightly focussed on the CBD.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Relatively high number of boundary points with majority located in urban street environments. Several section of major highway/motorway crossing the area.</td>
<td>Relatively high number of boundary points with majority located in urban street environments. Several major highway/motorway crossing points.</td>
</tr>
<tr>
<td><strong>ANPR Assessment</strong></td>
<td>Suitable system - reduced cost per lane reduces overall capital costs</td>
<td>Suitable system - reduced cost per lane reduces overall capital costs.</td>
</tr>
<tr>
<td><strong>DSRC Assessment</strong></td>
<td>Suitable system - higher per lane costs increases overall capital costs</td>
<td>Suitable system - higher per lane costs increases overall capital costs.</td>
</tr>
</tbody>
</table>
### General Scheme / System Evaluation

<table>
<thead>
<tr>
<th>Related requirements and issues</th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Day</td>
<td>6-10am</td>
<td>24 hours a day.</td>
</tr>
<tr>
<td>Days of week</td>
<td>5 days per week</td>
<td>7 days per week</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANPR Assessment</th>
<th>Suitable system - Limited ability to process in real time</th>
<th>Suitable system - Limited ability to process in real time</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSRC Assessment</td>
<td>Suitable system - Improved ability to process in real time</td>
<td>Suitable system - Improved ability to process in real time</td>
</tr>
</tbody>
</table>

| Vehicles Included              | Buses receive a 100% discount. All other vehicles are charged (motorbikes, taxis & trucks pay charge). | Buses receive a 100% discount. All other vehicles are charged (motorbikes, taxis & trucks pay charge). |

| Exemptions / Discounts         | None identified at this stage but expected that travel choices and equity measures will require flexibility for a range of special concessions |

<table>
<thead>
<tr>
<th>Related requirements and issues</th>
<th>Relatively high number but majority are likely to be smaller installations</th>
<th>Additional internal points and potential mobile enforcement levels need to be balanced with cost and deterrent effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANPR Assessment</td>
<td>Limited system - Reduced opportunity to provide for future more complex concessions and user incentives. (e.g. those linked to PT use, multi trip incentives)</td>
<td>This is linked in part to problems in processing and matching high volumes of ANPR transactions, particularly in real time. Other issues include the limited ability of these systems to integrate with PT and other payment systems.</td>
</tr>
<tr>
<td>DSRC Assessment</td>
<td>Suitable system - Improved ability to provide for complex concessions</td>
<td>Suitable system - Improved ability to provide for complex concessions</td>
</tr>
</tbody>
</table>

| Charge Regime                  | Charge level of $6 per trip. Maximum of $6 per day. (i.e. pay once and you have paid for the day). | $3 per trip charge. Maximum $3 charge per day (i.e. pay once and it covers multiple entries and exits). |
| Maximum charge per day         | $6 per day                                                               | $3 per day |

| Related requirements and issues | Requirement to match and consolidate trips. Real time or post matching will impact on technology choices | Requirement to match and consolidate trips. Real time or post matching will impact on technology choices |
## General Scheme / System Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower single charge level may affect business case (if processing multiple “transactions” for each $3 charge)</td>
</tr>
<tr>
<td><strong>ANPR</strong></td>
<td><strong>Limited system - Reduced opportunity to match trips in real time</strong>&lt;br&gt;This is linked in part to problems in processing and matching high volumes of ANPR transactions, particularly in real time. Other issues include increased overall processing cost and risk of errors.</td>
<td></td>
</tr>
<tr>
<td><strong>DSRC</strong></td>
<td>Suitable system - Improved ability to match trips in real time</td>
<td>Suitable system - Improved ability to match trips in real time</td>
</tr>
<tr>
<td><strong>Number of toll points</strong></td>
<td>70 Points / 238 Lanes</td>
<td>40 Points / 122 Lanes</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Relatively high number but majority are likely to be smaller installations</td>
<td>Additional internal points and potential mobile enforcement levels need to be balanced with cost and deterrent effect</td>
</tr>
<tr>
<td><strong>ANPR</strong></td>
<td>Suitable system - increased volume of plates recorded increases operating costs</td>
<td>Suitable system - increased volume of plates recorded increases operating costs</td>
</tr>
<tr>
<td><strong>DSRC</strong></td>
<td>Suitable system - increased volume of vehicles recorded improves benefits from cost efficiencies, but with additional capital costs</td>
<td>Suitable system - increased volume of plates recorded increases operating costs</td>
</tr>
<tr>
<td><strong>Other relevant descriptors</strong></td>
<td>Aim is to make a meaningful difference to congestion levels – consideration of appropriate alternatives (e.g. passenger transport, other options) is important</td>
<td>The aim of this scheme is to minimise diversion impact (and social impacts), but to deliver revenue to improve Auckland’s transport networks.</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td>Need for visible compliance monitoring and appropriate penalties</td>
<td>Need to optimise revenue collection through efficiency of operations and reliability / accuracy of collection processes.</td>
</tr>
<tr>
<td><strong>ANPR</strong></td>
<td>Suitable system - ANPR being the main enforcement base for most systems</td>
<td>Suitable system - ANPR being the main enforcement base for most systems</td>
</tr>
<tr>
<td><strong>DSRC</strong></td>
<td>Suitable system - ANPR being the main enforcement base for most systems</td>
<td>Suitable system - ANPR being the main enforcement base for most systems</td>
</tr>
</tbody>
</table>
## General Scheme / System Evaluation

<table>
<thead>
<tr>
<th>Costs</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A technology solution that maximises net revenue would be valued, but the primary objective is to manage congestion</td>
<td>The technology solution must maximise net revenues</td>
</tr>
</tbody>
</table>

### Related requirements and issues

**ANPR Assessment**
- Suitable system - Higher operating costs reduce net revenue

**DSRC Assessment**
- Suitable system - More efficient operations reduces costs and increases net revenue

### Options for mitigation of social impacts / providing exemptions

<table>
<thead>
<tr>
<th>Related requirements and issues</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The possibility of using the technology solution to provide for mitigation options such as ‘mobility vouchers’ would be seen as an advantage</td>
<td>Not a priority – the $3 charge is envisaged as being sufficiently low to not require a focus on mitigation</td>
</tr>
<tr>
<td>Ability to provide non-charged options for transport disadvantaged to be provided</td>
<td></td>
</tr>
</tbody>
</table>

**ANPR Assessment**
- Limited system - Reduced opportunity to provide for future more complex concessions and user incentives. (e.g. those linked to PT use, multi trip incentives). This is linked in part to problems in processing and matching high volumes of ANPR transactions, particularly in real time. Other issues include the limited ability of these systems to integrate with PT and other payment systems.

**DSRC Assessment**
- Suitable system - Improved ability to provide for complex concessions

### Payment Options

<table>
<thead>
<tr>
<th>Related requirements and issues</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A system that alerts users to each payment, but is not unduly inconvenient or expensive to operate</td>
<td>Reduced cost a priority</td>
</tr>
</tbody>
</table>

**ANPR Assessment**
- Very limited ability to provide this facility. Examples include text payment options, but these involve external systems, can be delayed, and are not linked directly to charge locations.
## General Scheme / System Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Congestion Scheme (Area)</th>
<th>Revenue Scheme (Cordon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DSRC Assessment</strong></td>
<td><em>Suitable system - Improved ability to provide several feedback alerts</em></td>
<td><em>Suitable system - Improved ability to provide several feedback alerts</em></td>
</tr>
<tr>
<td><strong>Inter-relationship with TSP</strong></td>
<td>Not an absolute requirement, but departure from TSP operating model will need to be justified</td>
<td></td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td><em>Consideration of alignment with TSP where possible</em></td>
<td></td>
</tr>
<tr>
<td><strong>ANPR Assessment</strong></td>
<td><em>Compatible system - TSP incorporates both ANPR and DSRC capability</em></td>
<td><em>Compatible system - TSP incorporates both ANPR and DSRC capability</em></td>
</tr>
<tr>
<td><strong>DSRC Assessment</strong></td>
<td><em>Compatible system - TSP incorporates both ANPR and DSRC capability</em></td>
<td><em>Compatible system - TSP incorporates both ANPR and DSRC capability</em></td>
</tr>
<tr>
<td><strong>Enforcement</strong></td>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system</td>
<td>Scheme must be capable of automatic enforcement to ensure integrity of the system, but balance of capital and operating cost will need to be considered to ensure that net revenue is maximised</td>
</tr>
<tr>
<td><strong>Related requirements and issues</strong></td>
<td><em>Important that compliance and enforcement is visible and credible</em></td>
<td><em>An appropriate level of enforcement balanced with penalties to optimise operational cost</em></td>
</tr>
<tr>
<td><strong>ANPR Assessment</strong></td>
<td><em>Suitable system - ANPR being the main enforcement base for most systems</em></td>
<td><em>Suitable system - ANPR being the main enforcement base for most systems</em></td>
</tr>
<tr>
<td><strong>DSRC Assessment</strong></td>
<td><em>Suitable system - ANPR being the main enforcement base for most systems</em></td>
<td><em>Suitable system - ANPR being the main enforcement base for most systems</em></td>
</tr>
</tbody>
</table>
7.8 Streetscape

With any type of scheme in an urban environment, there are perceived issues of additional equipment, or clutter in the street environment.

The figure below shows some of the innovative designs that have been used internationally to address this issue.

On the more major state highway type routes where there are already gantries and large road signs the equipment that would be deployed for a congestion charging scheme is less of an impact.

Figure 22: London and Stockholm installations

For the installations on more local routes, some additional design and construction funding would need to be allowed for in addressing the issue of streetscape and minimising the impact of such equipment.

The preliminary designs assume approximately 30 of these internal sites in Auckland, of which only some would be in areas where this impact minimisation would be required.

Every attempt would be made to use existing structures where possible and to keep structures away from sensitive areas.
7.9 Conclusions and recommendation

7.9.1 Congestion scheme

Based on this assessment against the main evaluation criteria for the congestion scheme, a system providing a combination of a DSRC system with an ANPR enforcement facility has been identified as the most suitable option, key factors include:

- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

7.9.2 Revenue scheme

Based on this assessment against the main evaluation criteria for the revenue scheme, a system using a DSRC tag based solution with an ANPR enforcement facility has also been identified as the most suitable option, key factors again include:

- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

7.9.3 Low-cost alternative revenue scheme

Any lower cost alternative for the Revenue scheme will still be required to address the core requirements, but would be expected to trade off the level of delivery of some against the primary objective to optimise/maximise potential revenue.
From the earlier assessment RFID “Sticker” tags were considered unsuitable, as they would still require a significant capital costs and would be unable to (alone) deliver a feasible and enforceable system.

The only other option that was considered to provide some potential was Parking Levies, applied to the entire area, but with exemptions for residents. By removing the requirement to capture all vehicles (as for the earlier study) the potential of this solution does improve, reducing overall costs and improving net revenue.

As the alternative is primarily focused on revenue collection and not congestion reduction, the results identified from the earlier study are also less relevant.

The potential scenario would be to apply a levy on all parking facilities, and properties with parking facilities, across the area. Total costs incurred would only relate to the development and application, administration and audit of the levy, as no enforcement would be required. A key problem with the previous (study) scheme was the administration and costs of enforcement.

A brief assessment of the potential costs and revenues from such a scheme is summarised below.

Parking levy option

The extent and structure of a parking levy would need to be examined in greater detail in order to consider the most appropriate package. However, for the purposes of considering the potential for such a scheme, the following scenarios have been developed.

Based on the Auckland CBD only, the number of parking spaces has been assumed (based on a 2004 survey) as follows.

Figure 23: Number of long-stay parking spaces Auckland CBD

<table>
<thead>
<tr>
<th>Long stay (&gt;4hrs) - Central area parking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Privately operated public car parks</td>
</tr>
<tr>
<td>On-street car parks</td>
</tr>
<tr>
<td>Council operated public car parks</td>
</tr>
<tr>
<td>Private residential car parks</td>
</tr>
<tr>
<td>Private non-residential car parks</td>
</tr>
</tbody>
</table>

Assuming that long stay spaces only would be subject to a levy, a total of 38045 spaces would be subject to the levy. This total has also been factored up to match the level of estimated revenue scheme trips charged (approximately a 3 fold increase), with revenue and cost estimates developed for both scenarios.
The levy scheme has been assumed that would include the following:

- Privately operated public parking spaces, on street and council operated parking spaces – An annual charge would be made based on the number of long-stay spaces operated.
- Private residential and non residential spaces - An annual charge would be made based on the number of spaces, with exemption for residents.

Costs to operate this scheme would include:

1. Setup of the system and related processes
2. Resident exemption process
3. Audit processes (for parking buildings and private parking facilities)
4. Communications, administration and management

Estimated revenue has been developed based on a simple $3 per working day per space; assumed 50 weeks per year, summarised in the following table.

<table>
<thead>
<tr>
<th>Estimated Costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup costs</td>
<td>$250,000</td>
</tr>
<tr>
<td>Operational costs</td>
<td></td>
</tr>
<tr>
<td>Administration (annual)</td>
<td>$220,000</td>
</tr>
<tr>
<td>Audit (annual)</td>
<td>$180,000</td>
</tr>
<tr>
<td>Exemptions management (annual)</td>
<td>$130,000</td>
</tr>
<tr>
<td>Estimated spaces charged (CBD only)</td>
<td>38045</td>
</tr>
<tr>
<td>Estimated spaces charged (Expanded to match estimated revenue scheme charged trips)</td>
<td>121383</td>
</tr>
<tr>
<td>Estimated revenue (CBD Only)</td>
<td>$28,533,750</td>
</tr>
<tr>
<td>Estimated revenue (Matched to revenue trips)</td>
<td>$91,037,250</td>
</tr>
<tr>
<td>Estimated net revenue (CBD Only)</td>
<td>$28,003,750</td>
</tr>
<tr>
<td>Estimated net revenue (Matched to revenue trips)</td>
<td>$90,507,250</td>
</tr>
</tbody>
</table>
8 Stage four – Cost / analysis reporting

8.1 Concept (DSRC/ANPR) system design

The concept designs for the two schemes include the technology option of combining DSRC with an ANPR enforcement facility. This concept design has been developed primarily to provide a basis for estimating costs in each case.

The various elements developed to provide a basis for a DSRC/ANPR system are described below under three main categories;

- On Road facilities
- Back Office
- Operations

This system design is based on a combined DSRC/ANPR system, under which a range of users and potential payment structures would be established. The following diagram sets out the main system concepts.

Figure 24: System concepts

The system will use multiple charge points located to match the required scheme requirements. Each of these points will be equipped to record each vehicle passing and to generate a transaction record based on data generated from a package of technologies and measures. The recorded roadside transactions are then passed to the back office for processing against a range of account and payment structures.
This back office operation will in turn manage the overall scheme requirements, set the relevant charge levels and rules, and manage all payment accounts, related payment products and enforcement. The back office facility will be combined with a range of front office processes, dealing with direct customer contact related to the management of accounts, direct payments and general enquiries.

Users will be provided with a package of payment options designed to address the requirements of defined user groups, and to improve overall system efficiencies. These will include on board unit (OBU) and number-plate based accounts, commercial accounts, a series of products designed for casual users, and specific options for managing special status users.

8.1.1 Roadside charge points

Each charge/check point will be developed with the ability to collect a defined package of data from each vehicle passing, and facilities to process this data to provide predefined transaction records.

Although the vehicles passing each point will include a range of vehicle and user categories, at the time of passing each will be subject to the same series of checks and data collection processes, with all other variations being addressed through subsequent processing.

In each case the data collected will be processed through a series of checks and validations in order to generate the appropriate transaction record, along with any required enforcement data where required.

The processing of base transaction data at the roadside, and packaging to defined transaction record types will contribute to improving processing efficiency and minimising communications costs and risks.

Basic roadside facilities

Each roadside installation will be equipped with an integrated suite of technologies, including:

- Transceivers to communicate with vehicle based OBUs
- Front and rear cameras to capture vehicle plates/images
- Detection/classification devices
- Digital detection loops for independent verification
- Roadside processor(s)
As vehicles pass these points, six specific processes will be performed to develop the basic vehicle passing data for each event. All of these processes are performed simultaneously, or within fractions of a second, as the vehicle passes at full speed.

The first two processes are the detection alert and response of the OBU if one is fitted to the vehicle.
The transceiver systems at the roadside continually transmit alert signals to any OBU in the immediate vicinity, which act as a trigger to OBUs to transmit a response containing its unique identification and other related data (for the purposes of the Manchester system this is likely to include the vehicle registration and vehicle class).

This data will be passed to the base roadside transaction record. In the event that no OBU is detected the vehicle passing will be recorded as a non-OBU transaction.

The third roadside process formally registers the vehicle passing and classifies the vehicle based on the defined scheme classification system. For the Manchester system the technologies used will be dependant on the selected roadside equipment provider, but will deliver a system capable of generating a detailed vehicle profile that can subsequently be used as part of any required enforcement evidence.
The fourth process captures an image of the vehicle’s front number-plate and an image of the vehicle. The plate image is also immediately processed by optical character recognition (OCR) to provide a record of the plate number.

**Figure 29: Front plate read and scene image capture**

The fifth process records the vehicle passing through an independent digital loop system, to provide a basis for verification and audit. This system records the vehicle presence and class, and the data generated is processed separately from the other base transaction information.

**Figure 30: Independent verification**
The sixth and final process captures an image of the vehicles rear number-plate and the image immediately processed by OCR to provide a record of the plate number.

Figure 31: Rear plate read

The data collected for each vehicle passing is then subjected to a series of checks and validations, (e.g. matching front and rear plate records, checking recorded OBU and plate data against account databases and assessing inconsistencies with classification data) before being processed into one of several predefined transaction record types.

These will include confirmed OBU account transactions, confirmed plate based account transactions, pre-paid casual user transactions, those that are potential post-pay casual transactions or violations, and a range of other combinations.

These roadside transaction records are then communicated to the back office processing centre, along with any associated enforcement records. This will be done using a batch processing approach, with backup storage maintained at roadside pending confirmed receipt.

Other roadside related processing functions will include the regular updating of locally held account status databases, used to check valid account transactions and identify hot listed vehicles.

8.1.2 Users and products

Users will be provided with a package of account and payment options designed to address the requirements of defined user groups, and to optimise overall system efficiencies.
The management of accounts and payment options will include the use of incentives to encourage the use of OBU account based payments, as the most efficient and reliable payment alternative. Conversely payments by cash and in person will be managed to a minimum, through the provision of incentives and alternative “cash” options such as pre-paid cards and automated 0800 payment options.

The OBU technology proposed will include simple 5.8GHz DSRC units, with the potential to introduce units in the future that incorporate a card based facility. This would be used to provide additional payment options and account versatility, including the use of pre-paid cards for user convenience and for vehicles used by multiple drivers. This design variation also provides flexibility for future technology migrations, and for the possible integration of road user charging system with broader transport payment facilities both locally and nationally.

The functional design has been developed to address the following user categories with a combination of account and payment options.

1. Regular users – OBU accounts/cards
2. Semi-regular users – Number-Plate based accounts
3. Casual users – Pre-pay and Post-pay options
4. Fully exempt users – OBU/Card combinations
5. Short term, condition based and trip specific exempt users - OBU/Card combinations
6. Commercial/Fleet users – Post pay OBU accounts/cards
7. Multi driver vehicles and convenience user – Pre-pay OBU cards and pre-pay value cards

The following figure illustrates these seven basic user categories and the basic payment options available for each.
8.1.3 Back and front office

The back-office and front office systems will provide the basis for the overall operation of the charging scheme. Front-office facilities will provide for the management of the overall scheme requirements, set the relevant charge levels and rules, and manage all payment accounts, related payment products and enforcement. Related front-office processes will address all direct customer contact related to the management of accounts, direct payments and general enquiries.

Data collected for each vehicle passing is processed at the roadside into one of several predefined transaction record types, before being communicated to the back office processing centre using a batch processing approach, with backup storage maintained at roadside pending confirmed receipt. These transactions are received by back office systems and processed against a range of current and temporary accounts.

In addition to account setup, management and transaction processing, the back and front office facilities also provide several other core functions, as illustrated by the following diagram of core services.
8.1.4 Further systems issues

The system proposed would be based on current NZ industry standard OBU communications technologies to take advantage of the benefits this provides in terms of cost and security of supply.

The system described would involve some additional processing complexity to deal with the specific requirements of some schemes. For example, the requirement to charge only once per day under an Area or Cordon scheme would require the system to recognise OBUs that have already paid, and treat these as “exempt” for the remainder of that period.

Enforcement of this system would be through a secondary ANPR and image capture system. Any vehicle passing a charge point that does not complete a valid payment (this may include insufficient funds or incorrect class of payment) would be recorded as a violation, and an image and plate read recorded. These would then be used to pursue payment form the registered owner of the vehicle.
8.1.5 Cost estimate structure

The basic functional design of the DSRC/ANPR solution comprises a system of boundary charging and enforcement sites, and in the case of an Area scheme, a series of internal check points. These will be equipped for vehicle detection, vehicle classification, DSRC processing, and ANPR image capture. The number and location of these toll points is based on the defined boundaries of each scheme and assessment of the access points, as well as the key routes and intersection within the Area option. For an Area scheme these fixed facilities would also be supported by mobile enforcement units operating within the defined area.

From evaluation of the defined charge points, four generic toll point facilities have been developed as the basis for the scheme designs and costing, and used within the wider cost model to generate an overall scheme cost;

1 Pole Site – comprising pole mounted equipment and applied generally to streets with a single lane in each direction where physical separation of traffic is possible.

2 2 to 3 Lane Gantry – comprising a gantry or mast-arm arrangement across a 2 to 3 lane sections where no lane separation is possible or is not cost effective.

3 Full Motorway Gantry – comprising a full gantry across a multi lane limited access road.

Each site will provide the ability to detect and classify all passing vehicles, communicate with DSRC based OBUs and collect and process license plate images from vehicles that fail to complete a valid payment response.

A key component of the overall charging system will be the back office facility. This facility will need to be established to process all of the DSRC transactions and ANPR checking of any that are incomplete, all violations and enforcement systems, and the processes required to set up, assign and manage contracts, bills and payments for account holders.

Alongside the main back office systems OBU distribution and contract management will also be required to provide OBUs to the public through outlets and to manage the ongoing maintenance and operation of this part of the system. A payment and account management facility will also need to be established to deal with all the financial transactions, and a customer service operation to service user enquiries and manage the task of informing and educating the public on the operation and use of the scheme.

8.2 Congestion (Area) scheme - Summary

The selection of a DSRC system for the Area options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined area. This type of system also offers the potential to provide
more flexible charging variations, and an improved ability to differentiate vehicle types and functions.

A DSRC system also provides improved opportunities to address exemptions through special status OBUs, and the use of OBUs reduces the enforcement task by efficiently processing payments from a large proportion of passing vehicles.

DSRC systems are now being used increasingly for free flow tolling and the technology is relatively common and available. It provides high levels of reliability and protection against tampering, installation is relatively straightforward and fraudulent duplication of OBUs extremely difficult.

To operate successfully these systems do require trained local support, and the maintenance of roadside equipment and management of OBUs contribute significantly to the system’s reliability.

Overall a DSRC system will provide the potential for more versatile and efficient payment methods and structures to suit individuals. The requirement for users to fit OBUs will present some inconvenience. OBU transactions linked to smartcard payments and accounts provide a high degree of reliability and ability to ensure payment, with significantly lower operating costs due to automated collection and enforcement.

8.3 Revenue (Cordon) scheme - Summary

Cordon schemes generally involve charging vehicles that cross a defined boundary line, with the aim of reducing congestion on routes leading into and through the cordoned area. Charges can be fixed at a single known rate (for any given vehicle type) with only one payment required per day, or varied by time, actual or expected level of congestion, or across toll points so that it would cost more to cross the cordon at toll points where congestion is higher.

Cordon schemes provide a greater degree of flexibility and are also suited to more advanced technology systems (providing opportunities to vary charges across a defined boundary).

The selection of a DSRC system for the Cordon options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined boundaries. This type of system also offers the potential to provide more flexible charging variations, and an improved ability to differentiate vehicle types and functions.

With suitable levels of maintenance and support a DSRC system provides improved opportunities to address exemptions, high levels of reliability and security, and the potential for a wider choice of payment methods and structures to suit individuals. The requirement for users to fit OBUs will present some inconvenience, but OBU transactions linked to smart card payments and accounts provide a high degree of reliability and ability to
ensure payment, with significantly lower operating costs due to automated collection and enforcement.

Overall a DSRC solution will improve the level of charges collected through a cordon scheme, reduce operating costs, and provide for more flexible options for future expansion and the management of special status users and vehicles.

8.4 Base cost schedule / model

A cost model has been developed based on the identified solutions and used to provide inputs to the financial model, and also to provide a ‘top down’ check to the ‘bottom up’ process based approach of the financial model.

The cost model was made up of the following parts. These are illustrated by the figure below which shows the build up of these costs:

- Common Factors
- OBU Costing
- Operational Costs – Revenue and Congestion
- Back Office Capital costs
- Typical Site installations – 2 lane, 4 lane, and 6 lane
- Road side equipment capital costs
- Overall Summary

8.4.1 Key inputs

The cost model structure relies on the following key inputs:

- Transaction volumes
- Schedule of sites – site type, and site specific costs
- Total number of lanes covered

From these key inputs, a number of factors and assumptions are used to generate the total capital costs, and operating costs per year.
8.4.2 Common factors

The factors worksheet was used to contain all common factors that were used to generate the capital and operating costs such as:

- Number of chargeable trips
- Number of OBU’s
- Typical roadside maintenance costs

8.4.3 OBU costs

The OBU cost section of the cost model used the chargeable trip data, an assumed failure rate of 3% and an assumed profile of battery failure based on international experience. From this starting point, a profile of OBU’s was costed over a 20 year period based on:

- Number of OBU’s supplied
- Number of OBU’s in operation
- Number of OBU failures
- Number of OBU’s battery expired

From these quantities, the OBU cost, postage and recycling costs were used to generate a cost profile.
The average OBU costs per year over the 20 year period was used to generate the operational costs related to this payment option.

### Operational costs – revenue and congestion

The financial model works on a process base to create a bottom up estimation of Operational costs for each scheme. The purpose of the input model was to generate the top down approach to staffing and operating a charging scheme.

The operational costs were generated by taking the fixed overheads for staffing a call centre and a typical staffing structure. Total number of staff drove the yearly operating costs for each scheme.

Also included in the yearly operating costs were extra overheads, such as:

- Economic compliance
- Staff training
- Consultancy
- Operational reviews
- Insurance
- Costs of different payment options

Roadside maintenance costs were calculated based on a technicians hourly rate to do maintenance tasks and calculated for each scheme on a per lane basis.

The total of all these inputs provided an approximate yearly operating cost to reconcile against the financial model.

<table>
<thead>
<tr>
<th>Operational Costs – Revenue Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staffing and Payment Options costs</td>
</tr>
<tr>
<td>Maintenance</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational Costs – Congestion Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staffing and Payment Options costs</td>
</tr>
<tr>
<td>Maintenance</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

### Back office capital costs

The back office capital costs worksheet included the following one off cost items:
- Development and set up of “Back Office Systems” (BOS) processes
- Payment and account management facility
- Customer service facility
- Communications infrastructure
- Commissioning
- Purchase of OBU’s

The summary results for the back office for both the Revenue and Congestion Schemes are shown in the figures below:

Table 12: Back Office Capital Costs - Revenue

<table>
<thead>
<tr>
<th>Back Office Costs - Revenue Schemes (Cordon)</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development and set up of “Back Office Systems” (BOS) processes</td>
<td>1</td>
<td>$18,963,840</td>
<td>$18,963,840</td>
</tr>
<tr>
<td>Payment and account management facility</td>
<td>1</td>
<td>$423,300</td>
<td>$423,300</td>
</tr>
<tr>
<td>Customer service facility</td>
<td>1</td>
<td>$253,980</td>
<td>$253,980</td>
</tr>
<tr>
<td>Communications infrastructure</td>
<td>1</td>
<td>$338,640</td>
<td>$338,640</td>
</tr>
<tr>
<td>Design &amp; integration of toll points</td>
<td>40</td>
<td>$253,980</td>
<td>$10,159,200</td>
</tr>
<tr>
<td>Commissioning</td>
<td>1</td>
<td>$338,640</td>
<td>$338,640</td>
</tr>
<tr>
<td>Transponders standard</td>
<td>121,383</td>
<td>26</td>
<td>$3,155,958</td>
</tr>
</tbody>
</table>

$33,633,558

Table 13: Back Office Capital Costs - Congestion

<table>
<thead>
<tr>
<th>Back Office Costs - Congestion Scheme (Area)</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development and set up of “Back Office Systems” (BOS) processes</td>
<td>1</td>
<td>$33,864,000</td>
<td>$33,864,000</td>
</tr>
<tr>
<td>Payment and account management facility</td>
<td>1</td>
<td>$846,600</td>
<td>$846,600</td>
</tr>
<tr>
<td>Customer service facility</td>
<td>1</td>
<td>$507,960</td>
<td>$507,960</td>
</tr>
<tr>
<td>Communications infrastructure</td>
<td>1</td>
<td>$677,280</td>
<td>$677,280</td>
</tr>
<tr>
<td>Design &amp; integration of toll points</td>
<td>40</td>
<td>$253,980</td>
<td>$10,159,200</td>
</tr>
<tr>
<td>Mobile and fixed check points</td>
<td>40</td>
<td>$84,660</td>
<td>$3,386,400</td>
</tr>
<tr>
<td>Commissioning</td>
<td>1</td>
<td>$338,640</td>
<td>$338,640</td>
</tr>
<tr>
<td>Transponders standard</td>
<td>108,535</td>
<td>26</td>
<td>$2,821,910</td>
</tr>
</tbody>
</table>

$52,601,990

8.4.6 Typical site installations

Three costing worksheets were generated for typical site installations:
- 2 lane
- 4 lane
- 6 lane

The 2 lane sites were based on typical pole type installations, whereas the 4 lane and 6 lane were gantry type installations. The majority of internal sites for the Congestion (Area) scheme were assumed to be of the pole type as the sites would generally be on smaller local roads or slip roads/junctions to larger roads.

The site costings included civil works, mechanical and electrical equipment, and the independent verification system.
Table 14: Typical site installation costs - Capital

<table>
<thead>
<tr>
<th>Typical site costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Lane Site</td>
<td>$258,237</td>
</tr>
<tr>
<td>Four Lane Site</td>
<td>$946,837</td>
</tr>
<tr>
<td>Six Lane Site</td>
<td>$1,561,532</td>
</tr>
</tbody>
</table>

8.4.7 Roadside capital costs

The roadside capital costs for each of the two schemes were generated from the work into the location of the charging points and the total number of vehicle lanes counted for each scheme.

The typical site costings were used as described above to generate a cost for each site.

Table 15: Roadside capital costs

<table>
<thead>
<tr>
<th>Roadside capital costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion</td>
<td>$34,381,295</td>
</tr>
<tr>
<td>Revenue</td>
<td>$23,191,176</td>
</tr>
</tbody>
</table>

8.4.8 Overall summary

A copy of the cost model can be found in Appendix B. The headline figures generated by the processes and costs described above are shown in the table below:

Table 16: Key figures from cost model

<table>
<thead>
<tr>
<th>Overall Summary</th>
<th>Revenue</th>
<th>Congestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside Capex</td>
<td>$23,191,176</td>
<td>$34,381,295</td>
</tr>
<tr>
<td>Back Office Capex</td>
<td>$33,633,558</td>
<td>$52,601,990</td>
</tr>
<tr>
<td>Total Capex</td>
<td>$56,824,734</td>
<td>$86,983,285</td>
</tr>
<tr>
<td>Annual Opex</td>
<td>$10,649,493</td>
<td>$12,156,314</td>
</tr>
<tr>
<td>Estimated Cost per Transaction</td>
<td>$0.24</td>
<td>$0.43</td>
</tr>
<tr>
<td>Estimated Annual Revenue</td>
<td>$132,550,236</td>
<td>$169,314,600</td>
</tr>
<tr>
<td>Estimated Opex as a %age of Revenue</td>
<td>8.03%</td>
<td>7.18%</td>
</tr>
</tbody>
</table>

8.5 Comparison with other systems

In order to provide context for these figures, the following section briefly summarises a range of international examples, providing an indication of two key measures:

1. Operations costs per transaction, and;
2. Operations costs as a proportion of revenue.
For the purpose of this assessment, toll collection operating costs have been measured as the cost to collect tolls, including staff and processing, violation enforcements, administration and management.

The comparisons provided have been based on assessments of the toll/charging facilities listed in the following table. These facilities include toll systems from the USA, Europe, UK Australia and Asia.

Given the commercially sensitive nature of much of the information used, specific figures have not been quoted for particular facilities, and the list below is simply an alphabetically ordered list of those included.

### Table 17: Sample facilities

<table>
<thead>
<tr>
<th>Sample Facilities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria Motorway Tolls (full open road tolling)</td>
<td></td>
</tr>
<tr>
<td>Dublin West-link (Cash &amp; ETC lanes)</td>
<td></td>
</tr>
<tr>
<td>E-470 Denver (Cash &amp; ETC lanes)</td>
<td></td>
</tr>
<tr>
<td>Germany Truck Toll System (GPS Tolling)</td>
<td></td>
</tr>
<tr>
<td>Italy Motorway Tolls (Cash &amp; ETC lanes)</td>
<td></td>
</tr>
<tr>
<td>London CC, TfL, London (Number plate based system)</td>
<td></td>
</tr>
<tr>
<td>M6 Toll Road - UK (Cash &amp; ETC lanes)</td>
<td></td>
</tr>
<tr>
<td>Melbourne City-Link (full open road tolling) Est Range - Low and High</td>
<td></td>
</tr>
<tr>
<td>Norway (Average non-cordon toll systems)</td>
<td></td>
</tr>
<tr>
<td>Norway (Average cordon toll systems) Full ETC</td>
<td></td>
</tr>
<tr>
<td>Norway (Bergen Cordon System) Full ETC</td>
<td></td>
</tr>
<tr>
<td>Norway (Gjesdal Cordon System) Full ETC</td>
<td></td>
</tr>
<tr>
<td>Norway (Tonsberg Cordon System) Full ETC</td>
<td></td>
</tr>
<tr>
<td>Orange County – Foothills-East &amp; San Joaquin toll roads (Cash &amp; FasTrak ETC)</td>
<td></td>
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<tr>
<td>Pennsylvania Toll Roads (Cash &amp; FasTrak ETC)</td>
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<tr>
<td>Queensland Motorways Estimate (With and without capital)</td>
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<tr>
<td>San Francisco, Bay Area - Seven bridges (Cash &amp; ETC lanes)</td>
<td></td>
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<tr>
<td>Singapore ERP system (full open road tolling)</td>
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<tr>
<td>SR 91 Expressway, Orange County (full ETC)</td>
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<tr>
<td>Sydney Cross-City Tunnel (full open road tolling) Estimated Range Low and High</td>
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<tr>
<td>Sydney M2 Motorway (Cash &amp; ETC lanes) Est Range Low and High</td>
<td></td>
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<tr>
<td>Tobin Bridge Boston &amp; Massachusetts Turnpike (manual, auto-coin and ETC)</td>
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</tbody>
</table>
8.5.1 Cost/transaction

The following figure sets out the average cost per transaction, for the range of toll facilities included, and indicates the relative position of the calculated industry average, and estimated average for existing MLFF systems.

Figure 35: Average cost per transaction

<table>
<thead>
<tr>
<th>Cost/Transaction NZ$</th>
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<tbody>
<tr>
<td>$2.44</td>
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<td>$2.05</td>
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<tr>
<td>$1.89</td>
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<tr>
<td>$0.15</td>
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<tr>
<td>$0.84</td>
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</tbody>
</table>

8.5.2 Operating cost as proportion of revenue

The following figure sets out operating costs as a proportion of revenue for the range of toll facilities included, and indicates the relative position of a calculated industry average, and estimated average for existing MLFF systems.

Figure 36: Operating cost as a proportion of revenue
Summary and recommendations

This report and assessment has been based on a staged process that has included developing core inputs from other previous and current work, leading to a detailed definition of the current scheme concepts and requirements.

From this base a series of candidate systems and technologies have been developed, including a primary and sub technologies. These have then been assessed against the defined requirements through an evaluation framework that included costs, fitness for purpose, procurement issues, and alignment with NZ requirements.

The level of detail has been targeted at providing a sound basis for answering fundamental questions on the particular options identified, and to support decision makers in assessing the most suitable overall package.

Some of the primary drivers for evaluation of the two main scheme concepts have included:

- The revenue-focused scheme’s strong focus on cost control
- The congestion-focused scheme’s focus on ensuring cost-effective collection, and provision of options to address social and economic impacts.
- Capital cost of the schemes
- Future expansion and integration plans
- Policy and legislative structures and constraints
- Scheme approach (e.g. enforcement or collection)
- Operational cost and cost effectiveness
- Proportions of casual and regular users
- Payment security
- Reliability and accuracy of technologies
- Alignment with proven technologies
- Alignment with well supported standards
- User understanding and acceptance
- Cost and flexibility of payment options

9.1 Congestion scheme issues

Based on the evaluation, of the congestion scheme, a system providing a combination of a DSRC system with an ANPR enforcement facility has been identified as the most suitable option, key factors include:
- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

9.2 Revenue scheme issues

Based on the evaluation of the revenue scheme, a system using a DSRC tag based solution with an ANPR enforcement facility has also been identified as the most suitable option, key factors again include:

- High proportions of regular users, and expected high take-up rates for DSRC payment, increasing the cost effectiveness of a DSRC solution and reducing overall operating costs
- Expected reducing future capital costs
- Improved overall system reliability and accuracy leading to higher net revenue for both schemes
- Improved convenience and security for users
- Alignment with TSP solution
- Future flexibility and reliability

9.3 Low-cost alternative revenue scheme

From the evaluation of reduced cost options the only option that was considered to provide some potential was Parking Levies, applied to the entire area, but with exemptions for residents. By removing the requirement to capture all vehicles (as for the earlier study) the potential of this solution does improve, reducing overall costs and improving net revenue.

The extent and structure of a parking levy would need to be examined in greater detail in order to consider the most appropriate package. However, a basic evaluation of potential costs and revenues has been provided.

9.4 Congestion (Area) scheme - Summary

The selection of a DSRC system for the Area options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined area. This type of system also offers the potential to provide more flexible charging variations, and an improved ability to differentiate vehicle types and functions.
A DSRC system also provides improved opportunities to address exemptions through special status OBUs, and the use of OBUs reduces the enforcement task by efficiently processing payments from a large proportion of passing vehicles.

DSRC systems are now being used increasingly for free flow tolling and the technology is relatively common and available. It provides high levels of reliability and protection against tampering, installation is relatively straightforward and fraudulent duplication of OBUs extremely difficult.

To operate successfully these systems do require trained local support, and the maintenance of roadside equipment and management of OBUs contribute significantly to the system’s reliability.

Overall a DSRC system will provide the potential for more versatile and efficient payment methods and structures to suit individuals. The requirement for users to fit OBUs will present some inconvenience. OBU transactions linked to smartcard payments and accounts provide a high degree of reliability and ability to ensure payment, with significantly lower operating costs due to automated collection and enforcement.

9.5 Revenue (Cordon) scheme - Summary

Cordon schemes generally involve charging vehicles that cross a defined boundary line, with the aim of reducing congestion on routes leading into and through the cordoned area. Charges can be fixed at a single known rate (for any given vehicle type) with only one payment required per day, or varied by time, actual or expected level of congestion, or across toll points so that it would cost more to cross the cordon at toll points where congestion is higher.

Cordon schemes provide a greater degree of flexibility and are also suited to more advanced technology systems (providing opportunities to vary charges across a defined boundary).

The selection of a DSRC system for the Cordon options provides a flexible and reliable system that can effectively charge all vehicles moving across the defined boundaries. This type of system also offers the potential to provide more flexible charging variations, and an improved ability to differentiate vehicle types and functions.

With suitable levels of maintenance and support a DSRC system provides improved opportunities to address exemptions, high levels of reliability and security, and the potential for a wider choice of payment methods and structures to suit individuals. The requirement for users to fit OBUs will present some inconvenience, but OBU transactions linked to smart card payments and accounts provide a high degree of reliability and ability to ensure payment, with significantly lower operating costs due to automated collection and enforcement.

Overall a DSRC solution will improve the level of charges collected through a cordon scheme, reduce operating costs, and provide for more flexible options for future expansion and the management of special status users and vehicles.
Appendix A

Assessment of prime technology options against functional requirements
This appendix sets out the candidate primary technologies, including a brief description of each and a summary of how core functions are addressed by each.

9.5.1 Paper-based systems

Paper-based systems essentially require that road users, who wish to use (or keep) their vehicles within a defined area during a defined time period, purchase and display a supplementary licence or permit. This usually takes the form of a paper licence that can be displayed on the windscreen or dashboard of the vehicle.

There are two main options available for implementing paper-based schemes;

- entry permit schemes – where vehicles need to display a valid licence sticker to enter (or leave) a defined area (the restricted zone)
- “true” area licensing schemes - Where vehicles need to display a valid licence to travel or park within a defined area

The distribution of permits or licences is usually managed through a combination of existing retail outlets, and other system operator channels such as vending machines, web and phone based mail order.

Examples

**Singapore's Area Licensing Scheme (ALS)**, operated from 1975 until 1998 required car drivers entering the CBD during the morning peak to pay three Singapore dollars per day (with exemptions for vehicles carrying four or more people. This was managed using a paper based (sticker) system, stickers being purchased for each day and placed on the inside of the windscreen. Under this system drivers were able to travel into and around the priced area several times in a day without having to pay multiple charges. Enforcement of the system was addressed using checkpoints where officials inspected each vehicle to ensure a valid license was displayed.

- **Parking Management Schemes** – use a range of paper based systems to collect and enforce the payment of parking charges, based on time of day, length of stay, location and vehicle class. Examples include:
  - **Pay and Display** – used in most developed cities across the world; this system requires vehicles to display a valid ticket that is dispensed via roadside vending machines. With advances in technology these devices are now provided with live communications connections that enable them to manage variable charges by time of day, parking location and class; as well as providing a range of payment facilities including SMS-Text, credit, debit and smart cards.
  - **“Coupon” or “Voucher” parking** – common in many urban centres in the UK, US and Europe, this type of system requires that parked
vehicle display a valid coupon or voucher for the zone, time period or class of vehicle. These systems are generally used in areas where restrictions apply to a relatively large area, and where parking durations are longer. It operates in a similar way to ‘Pay and Display’ but removes the need for on site payment and issuing machines. Instead coupons are made available though retail outlets and/or mail.

Summary comparison with functional requirements

Considering this type of system against the functional framework described above provides a base level assessment of its key strengths and weaknesses, and those of the current technologies used.

1 Informing – providing adequate information to users and potential users (often defined by legislation)

For on street parking applications providing adequate information to users is generally addressed simply though signs and instructions on the payment machines. In areas where no vending devices are used (e.g. coupon and voucher parking) roadside signs provide information on the restrictions and often where permits can be purchased.

For moving vehicle schemes signage is also the main method of informing drivers of the restrictions, and as these types of schemes are generally unsuitable for variable pricing scenarios, the use of VMS would be unlikely.

In most cases information would also be promoted through public media to improve public understanding and acceptance of the systems.

2 Detection – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle entering a zone).

In the case of parking schemes detection is simply a case of wardens recognising that a vehicle is parked in a particular zone. Devices are also available to detect vehicle presence and alert wardens when a vehicle has exceeded time restrictions.

For moving vehicle schemes (such as the Singapore ALS) detection of vehicles is again a manual function, although the use of simple vehicle detection systems may also be used to alert officials of vehicles approaching a check point.

3 Identification – Identification of the user, vehicle, or in some cases numbered account.

The identification of parked vehicles is again a manual process carried out by wardens, and is based purely on the license plate of the vehicle. If fines issues are not paid the owner of the vehicle is pursued using the motor vehicle registry. In some cases clamping or towing a vehicle effectively removes the identification issue, as the owner/driver must then make contact with the enforcement agent to pay any fine and recover the vehicle.

4 Classification – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.
With paper based parking or area licence schemes the classification of the vehicle is a manual task carried out by wardens or check-point officials. The classification can therefore be easily aligned with vehicle license based classification systems.

5 **Verification** – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.

For this type of system the need to cross-check and provide backup enforcement information is reduced to simple procedures followed by wardens to complete violation tickets correctly; recording time and location of violation etc, and retaining any required evidential information.

6 **Payment** – pre and post use collection of payment from users based on verified use.

Payment for paper based schemes is generally made through retail outlets where licenses or permits are purchased, or at vending machines. This provides for a range of customer payment options, including cash, charge cards and cheque. In some instances SMS payments are also provided for通过 vending machines.

7 **Enforcement** – providing the means to identify and prosecute violators, and/or pursue violators for payment of charges and/or fines.

Enforcement processes for this type of system are based on issuing violation tickets against the vehicle license plate, similar to regular parking offences, with a system of fines, debt collection and prosecution processes in place to pursue these. A key point of evidence in this situation is the paperwork filled out by the warden, who is the primary means of proving the identity and location of the vehicle.

8 **Exemptions** – providing the facility to manage a range of exemptions within the context of the scheme.

Exemptions are relatively simple to manage within a paper based scheme, as the checking of permits and licences is done manually. Exemptions are generally based on additional special vehicle permits displayed in the windshield.

9 **System Reliability and Accuracy** – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

The use of manual processes, while improving some elements of accuracy also leads to increased cost, and while common for parking enforcement, their use with moving vehicle systems increases delays and is not cost effective. Also the collection of revenues through external retailers and vending machines can be expensive and have high levels of revenue leakage.
9.5.2 Manual toll facilities

Manual toll facilities, toll booths or plazas have been used around the world for many years and essentially comprise payment points at which drivers pay a charge using cash, vouchers, charge cards or smart cards. Due to the amount of space required for conventional toll booths in dense urban road networks, the congestion (worsening) impact caused by the need to slow down or stop to pay, and the associated negative public perceptions, this method is generally not considered appropriate for urban road pricing. The development of automated payment machines has helped to reduced the costs of manual collection, but these variations on a manual system still operate in much the same way, with similar problems.

Durham City road user charge scheme

One of (if not the only) “manual” based congestion charge schemes currently in operation is the Durham City scheme implemented in 2002, which uses a system of bollard gates and “manual” payment machines.

Drivers are required to pay the designated charge when exiting the city centre zone before the bollard gate will open. These gates are also manned by an official, and drivers unable to pay are allowed to pass but incur a fine.

On-street equipment and environment

The street based equipment required for a manual system would be significant, and include potentially charging booths, additional lanes to increase throughput, and gates at all entry points. There would be a need for sufficient space to install the required equipment and access to power, communications.

For a small and restricted application such as Durham City this has been possible as the scheme is designed to restrict traffic to a minimum, and so requires the processing of relatively low volumes. For a more extensive central city environment the impact of toll booths and the related infrastructure would have a major impact on the urban environment.

Summary comparison with functional requirements

Considering this type of system against the functional framework described above provides a base level assessment of its key strengths and weaknesses, and those of the current technologies used.

1 Informing – providing adequate information to users and potential users (often defined by legislation).
As with paper based scheme, for manual charging systems providing adequate information to users is generally addressed simply through signs placed before the entry to the zone and/or instructions on payment machines. In most cases information would also be promoted through public media to improve public understanding and acceptance of the systems.

2 **Detection** – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle entering a zone).

In the case of manual facilities detection is simply a case of toll booth operators recognising that a vehicle is at the booth, for automated lanes a range of detection equipment can be used to register the presence of a vehicle.

3 **Identification** – Identification of the vehicle, user, or in some cases numbered account.

The identification of vehicles in most manual toll situations is not required, as post enforcement is not necessary. However the Durham example illustrates that in some circumstances violation fines may need to be issues, and in this case the vehicle license plate will be the main form of identification, recorded by the attending official.

4 **Classification** – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.

In manual toll situations classification of the vehicle is done by the toll both operators. Where automated toll machines are used a range of technologies are available to check the vehicle class. The capability and accuracy of automated classification technologies is an issue that needs to be considered when developing the classification payment structure, as the ability to measure some class specific characteristics is limited.

5 **Verification** – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.

For manual systems verification systems are generally focused on the task of matching revenue to recorded traffic, due to the high instance of cash leakage and fraud.

6 **Payment** – pre and post use collection of payment from users based on verified use.

For manual systems most payment will be made at the time of use, although some systems include pre-purchased vouchers. Post payment is not an option. With a manual system customers payment options can include cash, charge cards, and in some cases accounts.

7 **Enforcement** – providing the means to identify and prosecute violators, and/or pursue violators for payment of charges and/or fines.

Not generally required for manual systems as each vehicle is checked before passing.

8 **Exemptions** – providing the facility to manage a range of exemptions within the context of the scheme.
Exemptions are relatively simple to manage with a manual toll facility, as the checking of permits and licences is done manually. Exemptions are generally based on special vehicle permits displayed in the windscreen.

9 System Reliability and Accuracy – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

The use of manual processes, while improving some elements of accuracy also leads to increased cost, their use increases delays and is not cost effective. Also the collection of revenues can be expensive and have high levels of leakage.

9.5.3 Image based tolling/Automatic Number Plate Recognition (ANPR) technology

ANPR technology is commonly used on most electronic tolling facilities around the world, both in free-flow and toll lane based situations, although most often as an enforcement back up to DSRC or GNSS technology.

ANPR is based on images taken of vehicle number plates and processed through recognition software to identify the vehicle. Some systems can use front and/or rear located cameras to capture the images and so improve identification rates. Once identified the required charge or permit checking processes are undertaken in a similar way to other systems.

A key issue with ANPR facilities is the level of reliability of the plate reads. Even the best systems in current use are capable of read rates of around 95% in good conditions, but this can reduce as a result of problems such as light reflections in the image, dirty or damaged plates. This leads to the need for manual checking of those that cannot be automatically read and can add significantly to processing costs.

London example

The London Congestion Charge is the only facility that currently relies entirely on ANPR on a large scale, and it is worth noting that the London Scheme is an area licensing scheme with the ANPR system effectively used here as an enforcement system.

Stockholm has also moved to a high level of ANPR based transactions since the scheme became permanent, but still retains its DSRC facilities for some types of transactions.

Several other toll facilities provide ANPR only account options to users, but most with additional fees to cover the increased overall cost of processing these types of transactions (in comparison to their alternative DSRC based accounts).
The London scheme being an “area” charge system also requires ANPR stations within the designated zone, at fixed locations and on mobile enforcement units.

On-street equipment and environment

The street based equipment required for an ANPR system includes pole and/or gantry mounted cameras and illumination devices. In some cases these are combined into one unit and depending on the overall system design there may be a requirement for additional cameras (front and rear), classification devices, and independent verification counters.

In addition to the camera mountings some form of system controller is required in the vicinity of each installation. This controller is similar to a traffic signal controller, requiring full power and communication connections via a purpose designed base unit, connected via ducting to each camera location. Again depending on the nature of the system the communications connections may need to be to a dedicated or leased fibre-optic network, with power supplies supported by UPS facilities. The location of camera sites around the network is generally flexible, and the impact of the pole and/or gantry supports adapted to the local environment.

Summary comparison with functional requirements

Considering this type of system against the functional framework described above provides a base level assessment of its key strengths and weaknesses, and those of the current technologies used.
1 Informing – providing adequate information to users and potential users (often defined by legislation).

As with other systems, providing adequate information to users is generally addressed through signs placed before the entry to the zone and/or instructions at payment points. In most cases information would also be promoted through public media to improve public understanding and acceptance of the systems.

2 Detection – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle entering a zone).

For ANPR systems, in most cases the detection of a vehicle entering the zone is addressed using a separate system such as magnetic loops or lasers. This detection is then matched to the identification process for timing of the transaction.

3 Identification – Identification of the vehicle, user, or in some cases numbered account.

The identification function is the primary role of the ANPR system, the cameras taking an image of the vehicle plate and processing this through recognition software. Once successfully read the plate number is then checked against account or permit records. (In the case of the Italian Access Control schemes plate records are used widely for temporary permit holders).

4 Classification – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.

The classification function of vehicles under an ANPR system is generally addressed using a secondary technology based on some physical measures, such as lasers or digital loops. However The ANPR read can also be used to check the class of the vehicle from registry records and cross-checked with the physical measures.

5 Verification – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.

With most ANPR systems a series of verification checks are carried out at each vehicle passing, including matching plate number against account records and classification measures to confirm the validity of the transaction, and determining the need for retention of any enforcement records. A secondary verification system is also generally provided (for audit and monitoring purposes) to measure traffic and transaction rates, and matching these to revenue collection.

6 Payment – pre and post use collection of payment from users based on verified use.

The collection of payment for ANPR based systems is addressed through a variety of means. In most cases payment is made through pre or post pay accounts or licenses based on the plate number. Others, such as the Italian Access control schemes require payment for some permits annually, these are managed completely separately from the recording of vehicle movements.
Taking the London system as an example, payment can be using a full range of payment methods, including cash and charge cards through retail agents, by phone using credit card, and by SMS through the system operator.

7 Enforcement – providing the means to identify and prosecute violators, and/or pursue violators for payment of charges and/or fines.

The most common form of enforcement used in most free flow toll systems is based on ANPR technology. Where ANPR is also the primary source of vehicle and transaction identification additional backup ANPR and/or video enforcement systems can be provided. The license plates of offending vehicles provide the evidence of the event and a means of pursuing violators through the motor vehicle registry.

8 Exemptions – providing the facility to manage a range of exemptions within the context of the scheme.

ANPR systems provide the facility to manage a wide range of exemptions. As each vehicle can be identified individually the plate number can be linked to special exemptions based on the vehicle registration or account status. The Italian Access Control systems illustrate this with special exemption being provided by day and time for users of particular services within the designated zones.

9 System Reliability and Accuracy – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

ANPR systems have been in use on toll roads and congestion charging schemes for many years, but mainly as an enforcement facility. The main problems with ANPR systems arise from their ability to overcome physical constraints on the ability to read plates (common examples include light reflections, dirty or damaged plates, and the variety of angles and mounting positions that need to be addressed). Where plates cannot be read automatically manual checking is required which increases costs and processing time. The move to free-flow charging facilitated by ANPR also introduces some additional complexities and costs, including the need for more robust violations procedures, a range of payment options including agents etc, all of which increase complexity and cost.

9.5.4 DSRC free flow toll using transponders and gantries

Dedicated Short Range Communication (DSRC) is the most common form of primary electronic road pricing technology in general use, and is the standard on most free flow tolled facilities.

The technology is based on board vehicle units (OBUs), sometimes referred to as transponders, which communicate with gantry mounted equipment at defined charge or check points. The roadside equipment identifies and verifies each vehicle’s OBU, and depending on the type of
system, either processes a charge from its designated account or confirms its rights of access.

Combinations of toll points can be used to facilitate distance based charging systems, special charging conditions for particular entry and exit points or times.

In most Multi-Lane Free Flow systems the DSRC system also acts to locate the vehicle within its detection zone using an array of DSRC transceivers.

The enforcement of this type of scheme is generally addressed using roadside enforcement cameras and Automatic Number Plate Recognition (ANPR) technology (described below).

There are a range of different DSRC systems in use (and under development). Some use infrared communications; this technology has not been deployed widely in higher speed applications, and is not generally considered an open standard. Most are based on microwave communication; the most common systems currently in use are based on a 5.8GHz frequency, using the European CEN-278 standard. This standard is now well developed and delivers robust and secure OBU devices that have an average (battery) life of around 5 years.

The next generation 5.9GHz systems being developed mainly in USA to address a wider spectrum of ITS applications will provide longer range communication and multiple channels. Although not currently in use on any operational charging system, these devices (OBUs) are planned to become standard installations in all new vehicles within the next decade.

Another frequency system used in Singapore and some Hong Kong toll facilities is 2.45Ghz. This is not an open standard but is used by several toll operators.

Once established, DSRC systems can be expanded relatively easily onto other routes or across adjacent areas through the deployment of additional toll or check points. However, expanding these types of systems to cover much wider areas is less cost effective, as the numbers of toll points to provide effective coverage can increase significantly.

On-street equipment and environment

The street based facilities required for a DSRC system would include a range of equipment including:

- pole and/or gantry mounted transceivers
- in most cases ANPR cameras and illumination devices
- vehicle classification devices
- independent verification devices
- roadside control cabinets.

The location and street environments will include both multi-lane highway and urban situations.

In the urban environment some street layouts may require local modifications to improve the operation of the system; for example to
provide localized separation of traffic from opposing direction streams, and assist in reducing the need for full gantries in street situations. The transceiver/classifier units are generally mounted separately from the cameras to allow the cameras to pick up vehicles in the detection zone, although technologies are available to combine all functions to one location.

A further variation in some arrangements is the use of front and rear cameras, which may require an additional camera support structure.

A further variation in some arrangements is the use of front and rear cameras, which may require an additional camera support structure.

Italy Access Zone System Florence

Typical street based DSRC installation Pisa Italy
As for an ANPR system, some form of system controller would also be required in the vicinity of each installation, requiring full power and communication connections via a purpose designed base unit and connected via ducting to each location.

Typical roadside controllers

The issues of urban street-scape “clutter” can be seen as a problem with this technology, although through good design this can be kept to a minimum, as illustrated by the Italian access control systems and recent London DSRC trials.

Italian Access Control Systems
London DSRC Trial

In multi-lane situations an array of transceivers and classifiers will be required, generally mounted on purpose built gantries or potentially on existing structures. The following are examples of existing multi-lane facilities combining transceivers (ETC RX/TX), detection and classification units, and video capture.

Singapore ERP
Where multi-lane facilities are to be installed in two directions, the relative location of gantries also requires consideration, as a degree of separation is required between some equipment. The following diagram illustrates a typical layout.
Summary comparison with functional requirements

Considering this type of system against the functional framework described above provides a base level assessment of its key strengths and weaknesses, and those of the current technologies used.

1  Informing – providing adequate information to users and potential users (often defined by legislation).

For this type of system signage is also the main method of informing drivers of the restrictions, with VMS likely to be used for situations where variable charges are applied. In most cases information would also be promoted through public media to improve public understanding and acceptance of the systems. Some OBUs also include the ability to provide information on charge levels and account balance through displays or audible signals to confirm transaction or for low account balance warning.

2  Detection – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle entering a zone).

Although most DSRC systems do provide an “echo” based location function for multilane applications, in most cases the detection of a vehicle entering the zone is addressed using a separate system, using loops or lasers. This detection is then matched to the identification process for timing of the transaction, and linking to possible future enforcement evidence.

3  Identification – Identification of the vehicle, user, or in some cases numbered account.

The identification function is the primary role of the DSRC system, the OBU having a unique number that is identified by the transceiver and its associated systems, and through the account structures to the vehicle or account holder.

There are a range of scheme variations that use this type of technology, using the OBU to identify vehicles movements to confirm access or process payments for use, matching and processing transactions by time location and distance.

The correct operation of the system does depend to a degree on the users placing and treatment of the OBU. In most cases it is necessary to ensure that the OBU is placed in the correct orientation on the windscreen of the vehicle. This can lead to problems as some users fail to use the OBU correctly and this can lead to read failure and subsequently disputes or additional operational processes to correct.
4 Classification – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.

The classification of vehicles under a DSRC system is generally addressed using a secondary technology based on some physical measures, such as lasers, digital loops or stereoscopic video. However, the DSRC OBU will often include information on the class of the vehicle that will be cross-checked with these physical measures. In some cases, the class information from the OBU is fixed, and in others, it is selected by the user.

5 Verification – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.

With most DSRC systems, a series of verification checks are carried out at each vehicle passing, including matching OBU information against account records and classification measures to confirm the validity of the transaction, and determining the need for retention of any enforcement records. A secondary verification system is also generally provided (for audit and monitoring purposes) to measure traffic and transaction rates, and matching these to revenue collection.

6 Payment – pre and post use collection of payment from users based on verified use.

The collection of payments for DSRC based systems is addressed through a variety of means. In most cases, payment is managed through pre or post pay accounts, the DSRC OBUs being used as remote identifiers of transactions against these accounts. Others, such as Singapore, offer the ability to make payment through smartcards directly linked to the OBU. The Italian Access Control facilities use DSRC units to simply check the validity of user’s rights of access, payments for annual permits being handled completely separately.

DSRC account based payments generally require account holders to provide a valid bank account or credit card from which top-ups are drawn, these being the primary payment options for users. However, other options are provided with some DSRC applications such as the purchase of prepaid OBUs from retail outlets that allow customers to pay using cash or other charge card alternatives.

An issue to consider with this type of system is the cost and use of the OBU. In most systems, the initial cost of the OBU is recovered from the user in the form of a deposit or minimum balance requirement, and any replacements required due to misuse are covered by this fee.

7 Enforcement – providing the means to prosecute violators, and/or pursue violators for payment of charges and/or fines.
In most instances DSRC systems provide for unrestricted free-flow of traffic. This requires that some form of enforcement facility is provided to ensure that violators of the system (users without valid OBUs, those with default accounts, or incorrect class etc). The most common form of enforcement used is based on a system of cameras and ANPR technology. These cameras capture images of the license plates of offending vehicles to provide evidence of the event and a means of pursuing violators through the motor vehicle registry.

A common issue with DSRC systems (as referred to under identification above) is the misuse of OBUs that lead to “false” infringement or casual user processing. These can result in significant additional work for back office staff and inconvenience to users, and reduce the operational and cost benefits of OBU based transactions.

Exemptions – providing the facility to manage a range of exemptions within the context of the scheme.

DSRC based systems provide the facility to manage a wide range of exemptions. As each OBU can be programmed with an individual and unique identification number, these can be linked to special exemptions or conditions for almost any scenario. The Italian Access Control systems illustrate this with special exemption being provided by day and time for users of particular services within the designated zones. As with regular payments, the use of OBU based exemption systems requires the proper use of the OBU. The fraudulent use of exemption OBUs can be an issue, and this is generally dealt with by cross matching ANPR information.

System Reliability and Accuracy – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

DSRC systems have been in use on toll routes and congestion charging schemes for many years, and as such the technology is now well developed and has evolved to a high level of accuracy. These systems are proved to provide a cost effective solution, the processing and management costs of the system being lower than most other alternatives.

Key issues include, as mentioned above, the correct use of the OBU, regular monitoring and maintenance of systems and management of the OBU inventory to address battery life limitations.
9.5.5 GNSS (e.g. GPS) systems

Internationally, road authorities have been exploring and implementing GNSS which do not require on-road infrastructure to assign a position to a vehicle. Instead, these systems use a satellite location systems (generally GPS) to determine the vehicle’s position and measure location and distance travelled for the purposes of charging and access control. These systems offer greater flexibility for authorities to vary charges to influence more aspects of travel and transport choice.

Although GNSS technologies are an effective means of tracking vehicle position, the information they gather and store needs to be communicated to central systems on a regular basis, and as such GNSS units are generally combined with other technologies (digital maps, wide area communications, and short range GPRS communications) to charge and enforce the system. Other additional features required for this type of system include enforcement check points (fixed and mobile) and depending on the focus of the system these can be extensive.

The current cost of units has been a major factor in these systems only being used for major heavy vehicle application to date, but these are reducing and, once established, GNSS based systems have the advantages of wide coverage and far fewer check points than other technologies. It is expected that on-board GNSS units will become standard features in new vehicles within 10 years, and this migration is a specifically identified strategy for the European Union.

On-street equipment and environment

GNSS based system require far less on-street equipment than other sytems, with the primary function of the street based facilities being backup enforcement at selected check points. Fixed on street checkpoints are most likely to use similar DSRC and ANPR technologies described in the previous section, and require a series of pole or gantry mounted devices.

The check points will be similar to ANPR and DSRC facilities, with the functions depending on the structure of the system. Devices required may include DSRC transceivers, ANPR cameras and vehicle classifiers, with similar controller requirements to the systems already described.

These fixed enforcement stations will most likely be supported by mobile units that will reduce the number of locations required. The location of these sites around the network would be relatively flexible, and the impact of the pole and/or gantry supports adapted to the local environment.
GNSS examples

GNSS type technology is in use on several wide area heavy vehicle road user charging facilities, including systems in Germany and Switzerland. Internationally, GNSS-based systems have been introduced (e.g. Germany) or considered (United Kingdom) as technology solutions for the introduction of distance-based charging, primarily for heavy vehicles. The German model is now beginning to demonstrate that the technology is moving towards being ‘proven’ – but only for a distance-based charge. Nowhere in the world has GNSS yet been used for a more contained urban congestion charging scheme – primarily because of difficulties in managing the urban environment (with its canyon effect) and because the higher costs of in-vehicle units is prohibitive in smaller areas. In an urban area the costs of the scheme would also be likely to rise dramatically due to the need for “repeater” units to overcome the canyon effects and generally improve boundary accuracy.

Summary comparison with functional requirements

Considering this type of system against the functional framework described above provides a base level assessment of its key strengths and weaknesses, and those of the current technologies used.

1 Informing – providing adequate information to users and potential users (often defined by legislation).

For this type of system signage would again be the main method of informing drivers of the restrictions, with VMS likely to be used for situations where variable charges are applied. In most cases information would also be promoted through public media to improve public understanding and acceptance of the systems. The multi system GNSS/DSRC OBUs would also include the ability to provide information on charge levels and account balance.

2 Detection – detecting, and in some cases measuring, each individual instance of use (e.g. vehicle entering a zone).

As mentioned above, GNSS devices alone cannot be used to address the detection function, in current operational systems the OBUs used combine with either DSRC or cell phone technologies to communicate with ground based detection sites, and to transfer GNSS data to roadside and back office systems. Other boundary trigger technologies can also be used to detect vehicles passing boundary or check points.

3 Identification – Identification of the vehicle, user, or in some cases numbered account.

The identification function is provided by the OBU having a unique number that is identified through the roadside communications and associated systems, and through the account structures to the vehicle or account holder. A key aspect of GNSS systems in the continual
tracking of units to determine distance and location, and generally this is done within the OBU, data then being transferred on a regular basis through roadside communications. As it is the unit that records the movements of the vehicle, the identification is only necessary at these defined communication points.

4 Classification – measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.

The classification function of vehicles under a GNSS system is generally addressed using a combination of programmed OBU class and some secondary technology based on physical measures, such as lasers, digital loops or stereoscopic video. In some cases the class information from the OBU is able to be selected by the user, particularly heavy vehicle systems where the loading and unloading of trailer units can vary the class of a vehicle using the same OBU. This also increases the need for closer checking through enforcement systems.

5 Verification – cross checking processes and secondary means of detection, to assist in confirming transactions, reducing processing costs and providing a backup for potential enforcement.

With most GNSS systems a series of verification checks are carried out through roadside enforcement stations, including matching OBU information against account records and classification measures to confirm the validity of transactions, and determining the need for retention of any enforcement records.

Classification checking is of particular relevance in the current heavy vehicle systems operating.

6 Payment – pre and post use collection of payment from users based on verified use.

The collection of payment for GNSS based systems is addressed through a variety of means. In most cases payment is managed through pre or post pay accounts. The OBUs being used as remote identifiers of distance based transactions against these accounts. Some systems offer the ability to make payment through smartcards directly linked to the OBU.

Account based payments generally require account holders to provide a valid bank account or credit card from which top-ups are drawn, these being the primary payment options for users. However, other options are provided such as the purchase of prepaid OBUs that allow customers to pay using cash or other charge card alternatives.

An issue to consider with this type of system is the cost and use of the OBU. In most systems the initial cost (or at least part cost) of the OBU will is recovered from the user in the form of a deposit or minimum balance requirement, and any replacements required due to misuse are covered by this fee.

7 Enforcement – providing the means to identify and prosecute violators, and/or pursue violators for payment of charges and/or fines.
GNSS systems provide for unrestricted free-flow of traffic and the ability to charge by distance and location over a wide area. This requires that some form of enforcement facility is provided to ensure that violators of the system (users without valid OBUs, those with default accounts, or incorrect class etc). The most common form of enforcement used is based on a system of cameras and ANPR technology. These cameras capture images of the license plates of offending vehicles to provide evidence of the event and a means of pursuing violators through the motor vehicle registry.

These enforcement points also need to check OBU data against class and account status, and all of these functions must also be provided within mobile enforcement units in order for an effective system to be established.

8 Exemptions – providing the facility to manage a range of exemptions within the context of the scheme.

GNSS based systems provide the facility to manage a wide range of exemptions, as each OBU can be programmed with an individual and unique identification number, these can be linked to special exemptions or conditions. The fraudulent use of exception OBUs is not a major issue due to the complexity of the units, and this can be further reduced by cross matching ANPR information.

9 System Reliability and Accuracy – providing all of the above through cost effective systems and technologies that can meet the required levels of reliability and accuracy, minimise revenue leakage and fraud.

GNSS systems have only recently been implemented as the primary technology of a toll system, and these only for heavy vehicles. The main reason for this limited deployment at this stage is the cost of units. However the base GNSS technology is well developed and supplemented with widely used DSRC systems the overall reliability and accuracy is good. There have been some documented problems with the early applications of the German system, but these have now been addressed and the system is working well. The key issue still to be addressed is the ability of this type of system to operate in a dense urban area and as a system that operates across the entire vehicle fleet.

9.5.6 RFID “sticker” systems

Lower cost windscreen stickers incorporating RFID tags are used as the basis for several electronic toll systems (particularly in the USA). These systems operate in a similar way to other DSRC systems, but with all power drawn from the roadside equipment and a more limited data capacity.

These systems have some limitations in comparison with the previous DSRC systems described, including:
- Reduced data sets supported (such as emission class, License plate, vehicle chassis number addition to the serial number ID)
- Reduced tamper and move detection
- No current standardised protocol (e.g CEN / ISO DSRC)
- Single vendor support both on tags and readers
- Limited ability to provide read/write function at high speed
- Interference from GSM cell phone systems
- Limited ability to identify location across multiple lanes

The limitations of this technology mean that it is most often used for lane constrained tolling applications where vehicles can be slowed and channelled.

9.5.7 Combination systems

The majority of current road charging systems, including toll roads and urban charging and access schemes, use a combination of technologies to manage the collection and enforcement process.

By using a combination of technologies these systems are able to apply the most suitable technology to specific tasks and achieve an optimum system overall.

One of the most common combinations is the use of DSRC OBUs as the primary payment and identification technology, and ANPR technology for enforcement and casual user transactions. This combination allows operators to benefit from the higher accuracy and lower operating costs of DSRC, while overcoming the DSRC limitations of casual user management and enforcement with ANPR. This package also limits the use of the less accurate and more operations cost hungry ANPR technology to a reduced number of transactions.

Other example combinations include the main current deployments of GNSS on the German and Swiss Truck Toll systems, which use GNSS to address the distanced and location based elements, DSRC to provide the necessary local roadside communication, and ANPR as a the base enforcement technology.

The following table provides a summary of the key elements and issues.
## Functional requirements/technology characteristics

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<tbody>
<tr>
<td><strong>Informing</strong></td>
<td>Combination of fixed signage, public media and VMS where variable charging is used</td>
<td>Combination of fixed signage, public media and VMS where variable charging is used</td>
<td>Though detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
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</tr>
<tr>
<td><strong>Detection</strong></td>
<td>Manual</td>
<td>Manual and detection devices for semi automated lanes</td>
<td>Though detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
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</tr>
<tr>
<td><strong>Identification</strong></td>
<td>Manual</td>
<td>Manual</td>
<td>Vehicle Plate</td>
<td>OBU</td>
<td>OBU</td>
</tr>
<tr>
<td><strong>Classification</strong></td>
<td>Manual</td>
<td>Manual and detection devices for semi automated lanes</td>
<td>Though detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
<td>Though OBU and detection device (laser, Loop, Video)</td>
</tr>
<tr>
<td><strong>Verification</strong></td>
<td>Manual</td>
<td>Manual and some cross checks with detection devices for semi automated lanes</td>
<td>Plate number against account records</td>
<td>OBU against account records and classification measures</td>
<td>OBU against account records and classification measures</td>
</tr>
<tr>
<td><strong>Payment</strong></td>
<td>Retail outlets and vending machines using cash or card payment</td>
<td>At booth cash or card payments (some pre-purchased voucher options)</td>
<td>Pre or post pay accounts or licenses based on plate number</td>
<td>Pre or post pay accounts based on OBU. Some with smartcards directly linked to the OBU</td>
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</tr>
<tr>
<td><strong>Enforcement</strong></td>
<td>Manual</td>
<td>Manual</td>
<td>License plate through the motor vehicle registry</td>
<td></td>
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<tr>
<td><strong>Exemptions</strong></td>
<td>Manual (paper based)</td>
<td>Manual (paper based)</td>
<td>Linked to registration</td>
<td>Linked to OBU</td>
<td></td>
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<tr>
<td><strong>Reliability &amp; Accuracy</strong></td>
<td>High manual component leads to high cost</td>
<td>Traffic delays, and high manual component leads to high cost</td>
<td>ANPR read rate 85-90%. Increased costs from manual checking and data handling</td>
<td>DSRC read rate 99.7%. Reduced costs of processing and data handling</td>
<td>Proven heavy vehicle systems but units still expensive</td>
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