COMMENT ON: DRAFT REPORT. REVIEW OF FARES FOR METRO AND OUTER METRO BUS SERVICES.

PREAMBLE

- I was the Project Leader of the SE Queensland integrated ticketing project, responsible for conceiving a solution for fare and ticketing integration, designing the PT system, preparing technical specifications, going to tender, awarding a contract and implementing a fully integrated fare system and finally, converting that system to an ETS.
- Brisbane went to tender a full twelve months behind Sydney. Brisbane has now had an integrated ETS since 2004. Sydney is still at least three years away, but is more likely light years away, if this IPART Draft Report influences the future approach to fare setting.
- The original Sydney ETS contract, now terminated, was awarded to an ERG consortium. At the time, ERG was a world leader in smartcard technology, with successful projects in many parts of the world. What they were asked to do in Sydney was beyond them, and it is a moot point as to who bears responsibility.
- The Sydney problems standing in the way of an integrated ETS are still there.

OBJECTIVES OF THE DRAFT REPORT

- In the introduction to this study, it was stated that "any decision made by IPART should facilitate the planned electronic ticketing system".
- This central caveat to the study has been virtually ignored in the Draft Report.

OVERVIEW OF DRAFT REPORT

- As a treatise on PT fare setting , dependent upon public funding, the report expounds a rationale which is well amplified.
- As a report which meets the key requirement of facilitating an ETS, it is irrelevant, since what is proposed is unworkable. Worse, it takes the integrated ETS objective further in the wrong direction.

THE DICHOTOMY OF GOVERNMENT TRANSPORT POLICY AND INDEPENDENT FARE SETTING.

- If the Government wishes to pursue public transport goals, within which fare and ticketing strategy forms a key part, then it cannot be beholden to an independent fare setting authority which is not locked into the broader goals, and lacks the expertise to operate outside its established areas of competency and capability.
- The mindset of IPART of clearly demonstrated by two short excerpts from the Draft Report. [i] "How we set fares" [based on economic theory around efficient costs and external benefits etc]. That is to say, that since IPART has the charter, things will be done *"their way"*, based on the economic concepts and disciplines they have always used. [ii] [the report] *"establishes a fare structure that a future e-ticketing provider must work within"*.
- Therein lies the problem. They are saying we are going to set fares ***our way*** and the e-ticketing provider will just have to live with it. This is why Sydney does not have an integrated fare ETS, and never will, unless this mindset is completely jettisoned in favour of technical expertise and a grasp of the practical realities as to how a fares framework and ticketing technology can be merged together. The report as it stands, will take Sydney down the same ERG track all over again. It will have learned nothing.

PRIMARY LOGIC OF FARE CALCULATION IN DRAFT REPORT.

- The Draft Report comes down in favour of a distance-based fare structure.
- It supports this solution with the statement that "there is no evidence that the current distance-based structure of most fares will not be workable under an integrated e-ticketing regime"

- It is highly surprising, [incomprehensible] that the researchers did not explore this belief with the two short listed e-ticketing consortia. Had they done so, they would have established that this assumption was **wrong. Uninformed. Wrong.**
- Continued support for distance- based methodology will only frustrate fare integration and cripple the ETS objective. Contrary to the Draft Report, there is a mountain of evidence that this is so.

PROBLEMS WITH DISTANCE-BASED METHODOLOGIES FOR FARE INTEGRATION AND ETS

- A distance based methodology could work in an environment where [i] there is a single operator involved, and [ii] where the routes are roughly linear.
- However, in Sydney, we have the opposite of that. We have multiple operators. We have multiple modes. We have thousands upon thousands of circuitous routes.
- Since the IPART decision "must facilitate" an integrated ETS, we cannot accept this report. It does not "facilitate". It frustrates.
- It is not possible to look at the way forward, without deeply and intimately understanding two things.[i] What is necessary to achieve integration; and [ii] what are the limits of the technology, both hardware and software which will make an ETS deliverable. It is a recipe for total disaster, for IPART to misapprehend that software could be developed for any fare model it wished.[the "provider must work within" kind of language]. It cannot. ERG couldn't do it.
- ETS systems and their supporting software are like any other systems, whether they be Doctors' surgery appointments, on-line airline bookings, supermarket checkout prices or passport border control. That is, they are designed to perform certain functions within defined and limited parameters, and do not contain a kind of "all things for anyone" capability.
- Until someone takes control of this, and sets the bar at "the art of what's possible" , then Sydney will not get an integrated ETS.

SOME BRIEF EXAMPLES OF ISSUES TO BE RESOLVED FOR FARE INTEGRATION AND NON WORKABILITY OF DISTANCE-BASED METHODOLOGY.

- Example 1. [i] Rail travel from Belmore to Strathfield is 18.47 km and costs $4.oo [Attachment 1].Bus travel for the same origin/destination is about 6km [Attachment 2] and costs $3.20, ie three Sections [Attachment 3]. Under an integrated system, there must be only one standard fare. The distance-based formula of Rail could not be adopted in this situation.
- Example 2.Bus travel from Seaforth to Castlecrag .[Attachment 4] This journey requires three changes of route. The distance travelled on bus would be easily 20-25kms. The actual distance between Seaforth Cres and Edinburgh Rd is about 2-3 kms. Under a distance-based regime, what distance is to be calculated?. Is it as per rail in Example 1 ,i.e distance travelled.? We know it cannot be, since such calculation produces an anomalous outcome with bus, and cannot be used.
- Example 3. Continue to refer to Attachment 4. The journey here is from Woodland St Sth, Balgowlah, to Upper Beach St Balgowlah. To avoid interchanges and broken journey, Route 132 via Clontarf is chosen. The distance travelled, is further than Seaforth to Spit Junction. The actual distance between origin and destination is less than 1km. Under a distance-based regime, what fare is to be charged?
- Example 4. Compare the cost of travel from [a]Woolwich Wharf to Town Hall, [bus]; and [b]Rhodes to Town Hall [rail]. Refer attachments 5 and 6. Rhodes is approximately twice the distance from Town Hall than Woolwich Wharf, yet the fare from Rhodes is cheaper;[$4,- Attachment 7, versus $4.20 for six sections. Both would claim to employ a "distance-based regime". How can this be so?
- The simple fact is that under an integrated ETS, it will not be possible to deploy a distance-based model. It is unworkable. Undeliverable.

- Now, consider ETS technology and how it works. It is pointless for IPART to imagine an ETS provider can "work within" some fares framework for which no technology exists. Rather, it is necessary for IPART to "work within" what is technically possible.
- All ETS bus systems, whoever the provider, are the same. Diagrammatic examples are provided for ERG [Attachment 8] and Cubic [Attachment 9].
- Route data are loaded into the Depot computer and linked to the on-board console by wireless lan. However, for a distance-based calculation, each bus will only have access to route data pertaining to its depot's operations. The Sydney Bus Depot locations are shown in Attachment 10. A bus from one depot, say Brookvale, does not have access to route data from another, say Waverly.
- The distance to be calculated is based on a marker reading at each stop, determined by GPS, and the odometer readings between each marker. That is, each kilometre travelled will be aggregated into the fare calculation. This technology is best explained by Silvester Prakasam, in his article in the "journal of the institution of engineers, Singapore,vol.44,issue 2 2004.[Attachment11]
- What IPART needs to understand, and accept, is that this *is the technology of ETS*. There is no other. No ETS provider has system software to accommodate a multiplicity of fare calculation methodologies and a multiplicity of business rules, as ERG was asked to do. Clearly, the Sydney fare system taken as a whole, is full of countless anomalies. Hundreds and hundreds of thousands. Without trying hard, I have illustrated only four.
- In an integrated system, there **cannot be anomalies.** The fare from Point A to Point B must be the same, whatever the mode and whoever the carrier. Standardised. Not "harmonised". Standardised.
- A distance-based regime, as recommended by IPART in this study, simply cannot work. From a system wide perspective, it is riddled with anomalies. Further, there is **no** system software which can calculate the actual distance travelled, from anywhere to anywhere in the system, utilising different transport modes and operators, all using separate rationales for calculating distance, as illustrated by the examples.
- Whereas the solution seems daunting, in reality it is not. It has two underpinning precursors.[i] Fares must be standardised. [ii] The calculation method must be zonal. The world-wide, and Australian examples of zonal ETS systems are numerous. They work.
- I will not expand this response by going into the detail, as to how [i] and [ii] above, can be achieved. Suffice to say that little of the methodology as set out in this draft report would be utilised, although the actual fare outcomes would not be very different.

SUMMARY

1. The study recommendations are required to facilitate an integrated ETS. They do not do this, and therefore must be rejected.
2. The study proposes a "distance-based regime", which, if applied system –wide as it must be for an integrated ETS, is unworkable and undeliverable.
3. If NSW transport authorities wish to have an integrated system supported by an ETS, then either PT fares must be removed from IPART [working to its existing charter]; or the IPART charter must change to achieve PT goals, and the necessary expertise introduced.

R Lutherborrow

ATTACHMENT 1

CityRail

Fare calculator

Fare options for Belmore to Strathfield (18.47km)

Type	Adult	Child	Student*	Pensioner*	Half Fare*
Single	$4.00	$2.00	$2.00	$2.00	$2.00
Return	$8.00	$4.00	$4.00	$2.50	$4.00
Off-peak return	$5.60	$2.80	N/A	N/A	N/A
7 Day RailPass	$32.00	$16.00	$16.00	$16.00	N/A
14 Day RailPass	$64.00	$32.00	$32.00	$32.00	N/A
30 Day FlexiPass	$125.00	$62.50	$62.50	$62.50	N/A
90 Day FlexiPass	$355.00	$177.50	$177.50	$177.50	N/A
180 Day FlexiPass	$669.00	$334.50	$334.50	$334.50	N/A
365 Day FlexiPass	$1,314.00	$657.00	$657.00	$657.00	N/A

Create your own custom FlexiPass

Select the number of days you would like to travel.

Number of days: 28 (Must be between 28 and 366) Calculate

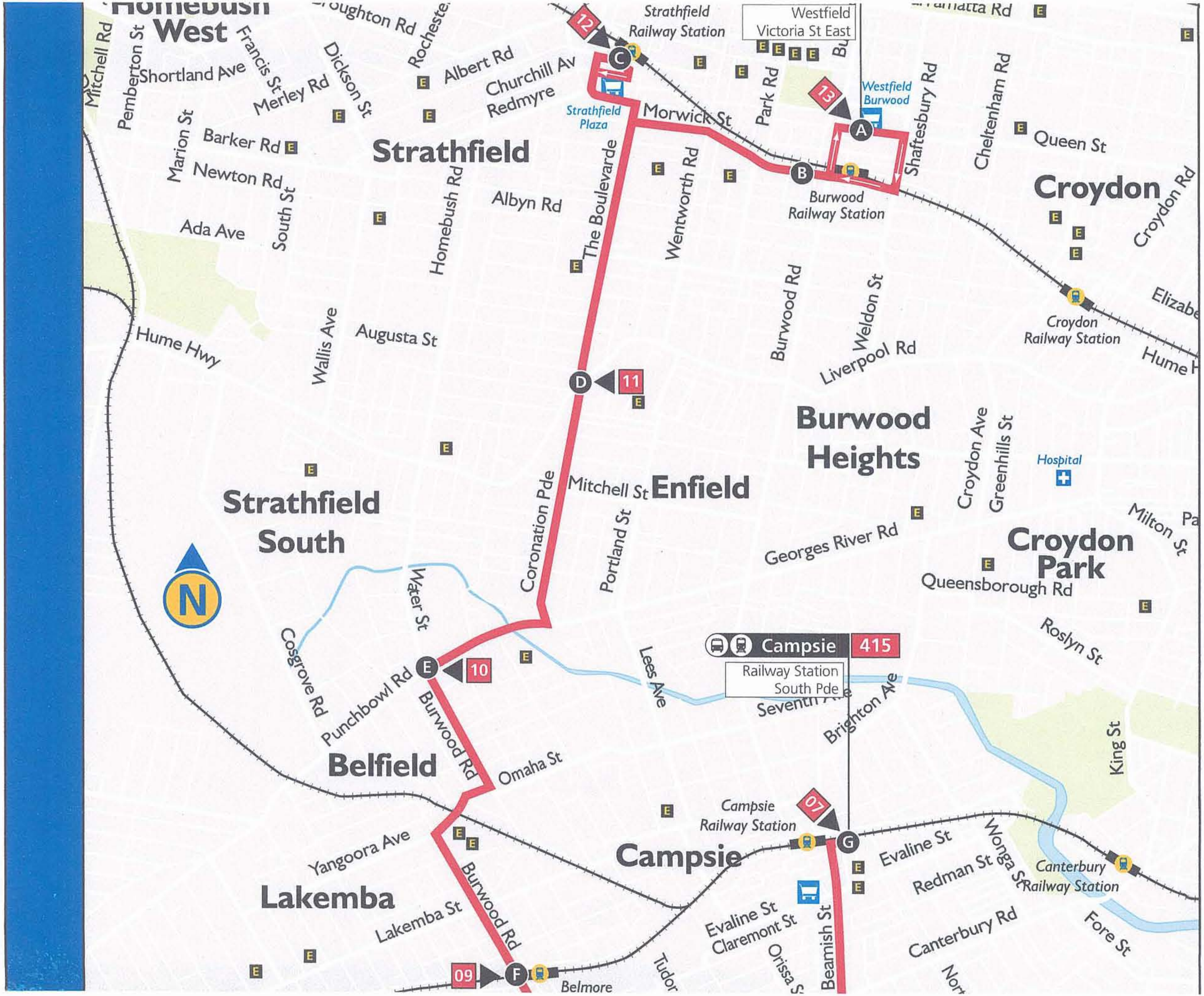
	Adult	Child	Student*	Pensioner*	Half Fare*
28 Day FlexiPass	$117.00	$58.50	$58.50	$58.50	N/A

- Prices include GST.
- * indicates entitlement card must be held.
- N/A indicates this fare type cannot be purchased.
- Fares are calculated via the shortest possible route of travel between the two locations.
- When a longer route of travel exists, break of journey on RailPass and FlexiPass ticket is permitted only on the shortest or other CityRail-approved route of travel.
- Prices to Green Square, Mascot, Domestic Airport and International Airport are inclusive of a station access fee.
- All traffic carried subject to the Transport Administration Act (109) 1988.

Compare driving costs

The costs to drive from **Belmore** to **Strathfield** by car would be:

ATTACH 2



Homebush West
Strathfield Railway Station
Westfield Victoria St East
Strathfield Plaza
Westfield Burwood
Burwood Railway Station
Croydon Railway Station
Strathfield
Croydon
Burwood Heights
Enfield
Strathfield South
Croydon Park
Belfield
Lakemba
Campsie
Campsie Railway Station
Canterbury Railway Station
Campsie 415
Railway Station South Pde
Hospital
Mitchell Rd
Pemberton St
Shortland Ave
Francis St
Dickson St
Merley Rd
Albert Rd
Churchill Av
Redmyre
Marion St
Barker Rd
Newton Rd
South St
Ada Ave
Homebush Rd
Albyn Rd
The Boulevarde
Morwick St
Park Rd
Wentworth Rd
Shaftesbury Rd
Cheltenham Rd
Queen St
Croydon Rd
Hume Hwy
Wallis Ave
Augusta St
Burwood Rd
Weldon St
Liverpool Rd
Croydon Ave
Greenhills St
Milton St
Coronation Pde
Mitchell St
Portland St
Georges River Rd
Queensborough Rd
Roslyn St
Water St
Cosgrove Rd
Punchbowl Rd
Lees Ave
Seventh Ave
Brighton Ave
King St
Omaha St
Yangoora Ave
Lakemba St
Evaline St
Claremont St
Redman St
Wonga St
Beamish St
Orissa St
Canterbury Rd
Fore St
Tudor
Belmore
A
B
C
D
E
F
G
07
09
10
11
12
13
N

ATTACH 3

NSW GOVERNMENT

131500.com.au Transport Info
Information for people on the move

Home » Fares and Passes » Sydney Buses Single

Sydney Buses Single Fares

3-step fare finder
There are 5 single bus ticket prices based on the distance travelled. Use the route map, and follow the steps to identify your single ticket.

Step 1
View route maps or refer to the maps in the printed timetables.

Step 2
Using the map, count the number of sections your jouney will take (including your starting section).

Step 3
Once you know the number of sections in your journey, refer to the following table for the cost of your fare.

	Adult	Concession
1 to 2 sections	$1.90	$0.90
3 to 5 sections	$3.20	$1.60
6 to 9 sections	$4.20	$2.10
10 to 15 sections	$5.00	$2.50
16 + sections	$6.10	$3.00

Fares valid 4 January 2009 (includes GST).

Ideal usage: Occasional travel.

Purchase single tickets from:

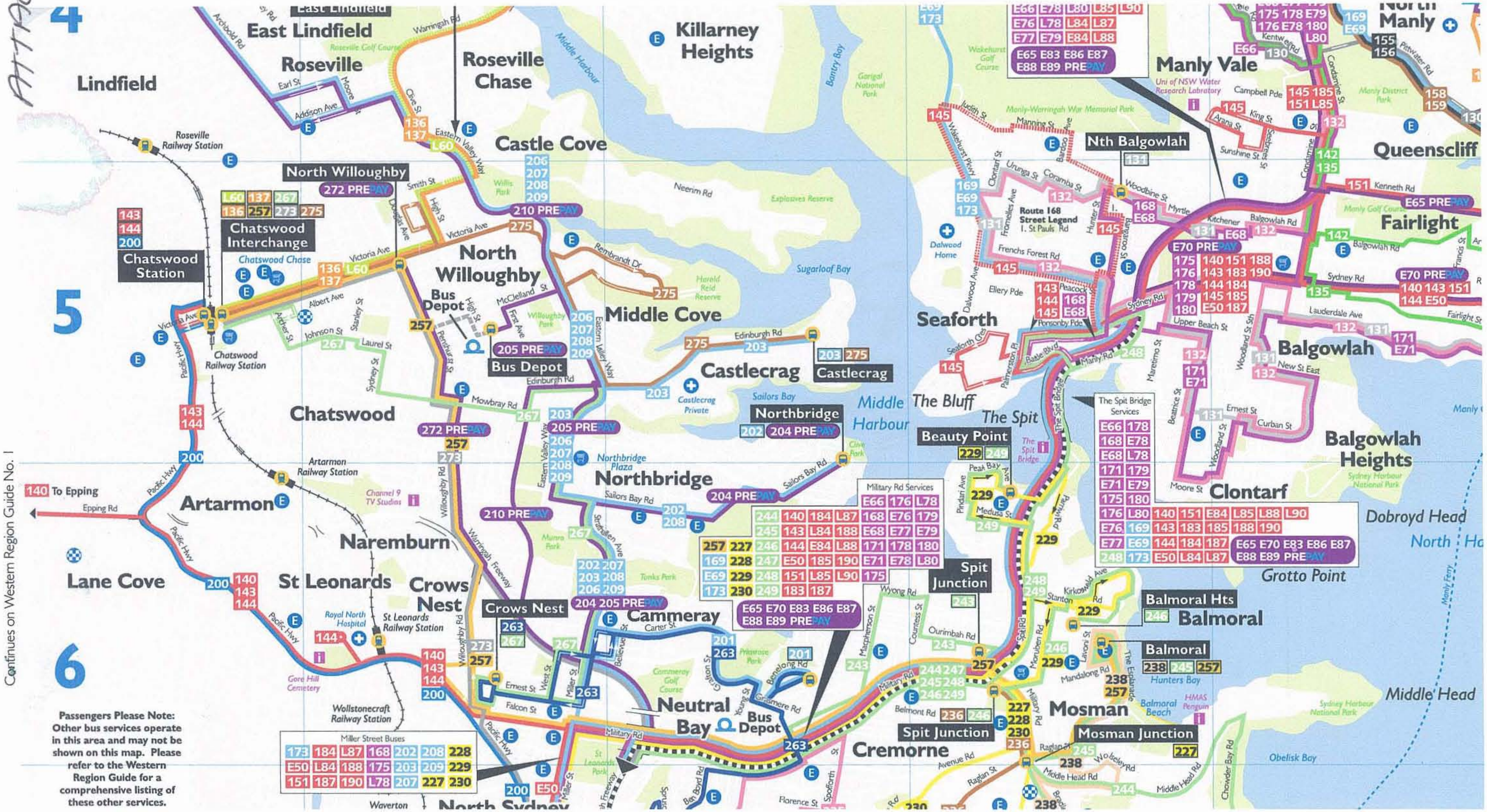
- Bus driver (excluding Prepay Only bus services)
- Sydney Buses TransitShops
- Selected ticket agents (look for Sydney Buses flag)
- Ticket vending machines at:
  - Wynyard (Carrington St entrance)
  - Bondi Junction Interchange

Late Breaking News

- HSC Transport Advice
- Cabarita Wharf closure 7 & 8 November
- Parramatta River tidal restrictions advice for November 2009
- Cremorne Point Wharf closure off-peak
- New MetroBus 20
- Emergency EnergyAustralia roadworks near QVB affect bus services
- Off-peak Manly Ferry Timetable Changes

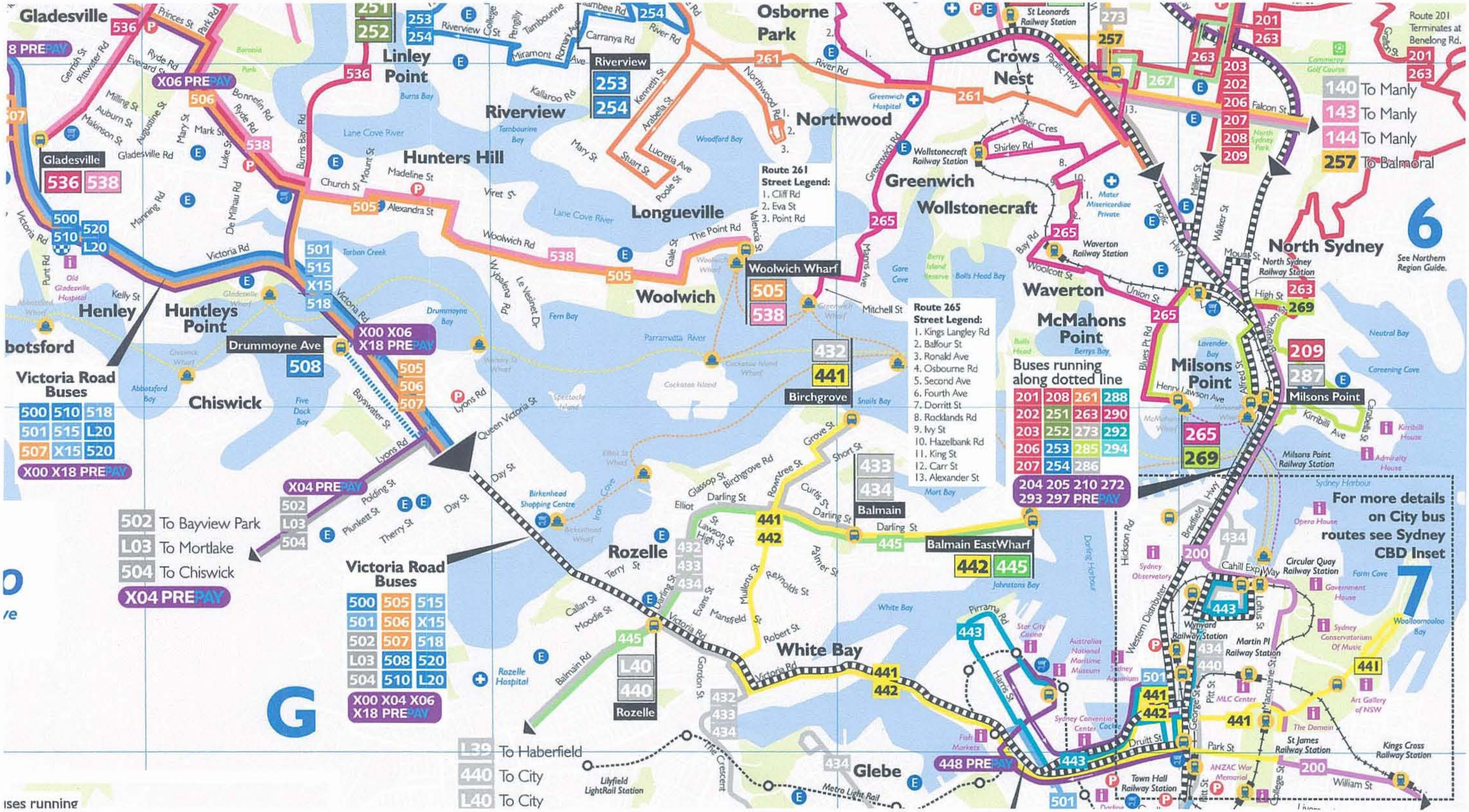
Top

ATTACH 4



Continues on Western Region Guide No. 1

PTTDCA 5



Continue

Guide No. 4

ATTACH 6

Eastwood Station
Denistone East
Denistone
Denistone Railway Station
Denistone West
West Ryde
West Ryde Station
Melrose Park
Meadowbank
Meadowbank Railway Station
Meadowbank Wharf
Ryde
North Ryde
East Ryde
Lane Cove West
Chatswood West
Boronia Park
Gladesville
Bus Depot
Linley Point
Hunters Hill
Putney
Rhodes
Rhodes Railway Station
Concord Hospital
Concord
Homebush Bay
Newington
Sydney Olympic Park Wharf
Olympic Park
Olympic Park Railway Station
Tennyson
Breakfast Point
Abbotsford
Henley
Huntleys Point
Chiswick
Drummoyne Ave
Victoria Road Buses
Mars Rd
Sager Place
Street Legend:
1. Sam Johnson Wy
2. Orion Rd
3. Sirius Rd
For Route information in this area, refer to Southern Region Guide.
460 To Five Dock
X00 PREPAY
X06 PREPAY
X18 PREPAY
297 PREPAY
293 297 PREPAY
X00 X18 PREPAY
X00 X06 X18 PREPAY

ATTACH 7

Rhodes to Town Hall

	Adult	Child	Student*	Pensioner*	Half fare*
Single	$ 4.00	$ 2.00	$ 2.00	$ 2.00	$ 2.00
Return	$ 8.00	$ 4.00	$ 4.00	$ 2.50	$ 4.00
Off Peak Return	$ 5.60	$ 2.80	N/A	N/A	N/A
7 Day RailPass	$ 32.00	$ 16.00	$ 16.00	$ 16.00	N/A
FlexiPass Fares					
30 days	$ 125.00	$ 62.50	$ 62.50	$ 62.50	N/A
90 days	$ 355.00	$ 177.50	$ 177.50	$ 177.50	N/A
180 days	$ 669.00	$ 334.50	$ 334.50	$ 334.50	N/A
365 days	$ 1,314.00	$ 657.00	$ 657.00	$ 657.00	N/A
	$117.00	$58.50	$58.50	$58.50	

28 Calc

* indicates Entitlement Card must be held.

To calculate a Flexipass fare for an alternate number of days, enter the days above, and click calculate. Result figures will appear in the columns above.

CityHopper	Peak	Off-peak
Adult	10.40	8.00
Child	5.20	4.00

Note

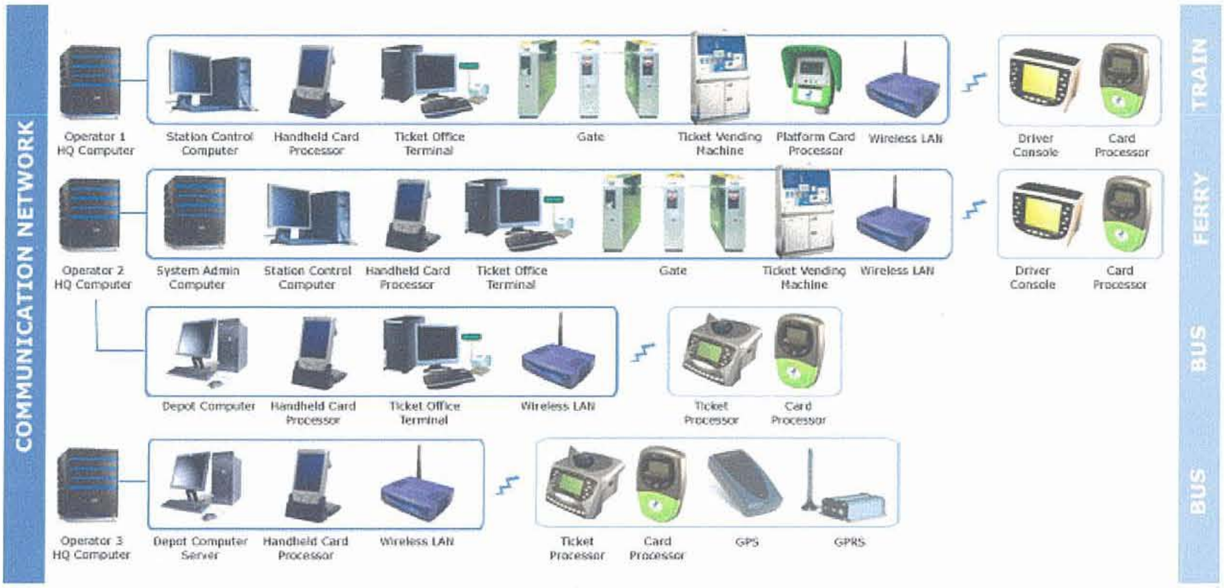
- All prices include GST
- N/A indicates this product fare type cannot be purchased.
- All fares are calculated via the shortest possible route of travel between the two locations.
- When a longer route of travel exists between two locations, break of journey on RailPass and FlexiPass ticket is permitted only on the shortest or other CityRail-approved route of travel.
- Prices to Green Square, Mascot, Domestic and International stations are inclusive of a station access fee.
- For further information, contact your local CityRail station, or call Transport InfoLine on 131 500.
- ALL TRAFFIC CARRIED SUBJECT TO THE TRANSPORT ADMINISTRATION ACT (109) 1988

Print

ATTACH 8

SOLUTIONS - FRONT OFFICE

The Front Office is made up of hardware devices that are used to issue tickets and/or validate smart cards. Also (optional) software applications are available that allow to sell products and/or manage customer enquiries.



Back Office

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ATTACH 9

CUBIC
For a world on the move™

Depot Computer

FEATURES & BENEFITS

- Integrated operator console for depot control, monitoring and administration
  - Manage data between central system and bus equipment
  - Communications via a dedicated network
  - Upload transactions and equipment status
  - Download software updates, fare tables, hotlists, Autoload lists to the bus equipment via wireless LAN
- Simple and secure operations of depot level equipment
  - Release the farebox cashbox via an infrared probing event
  - Track farebox cashbox cycles, receiver/vault cashbox cycles and mobile safe cycles
  - Convert the XML-formatted lock codes received from the central system to binary for use by the infrared probe
  - Monitor the UPS
- User-friendly interfaces
  - Simple graphical user interface for operator
  - Standard PC, keyboard and mouse
  - 432mm (17in) monitor
  - Printer for local and network reports

The Depot Computer is a personal computer (PC) based system designed for depot control, monitoring and administration. Residing in the Depot Operations Center at each bus garage, the main function of the Depot Computer is to store and forward files between the central system and the bus equipment.

The Depot Computer communicates with the central system via a dedicated network to upload transactions and equipment status and download configuration data including software updates, fare tables, hotlists and Autoload lists.

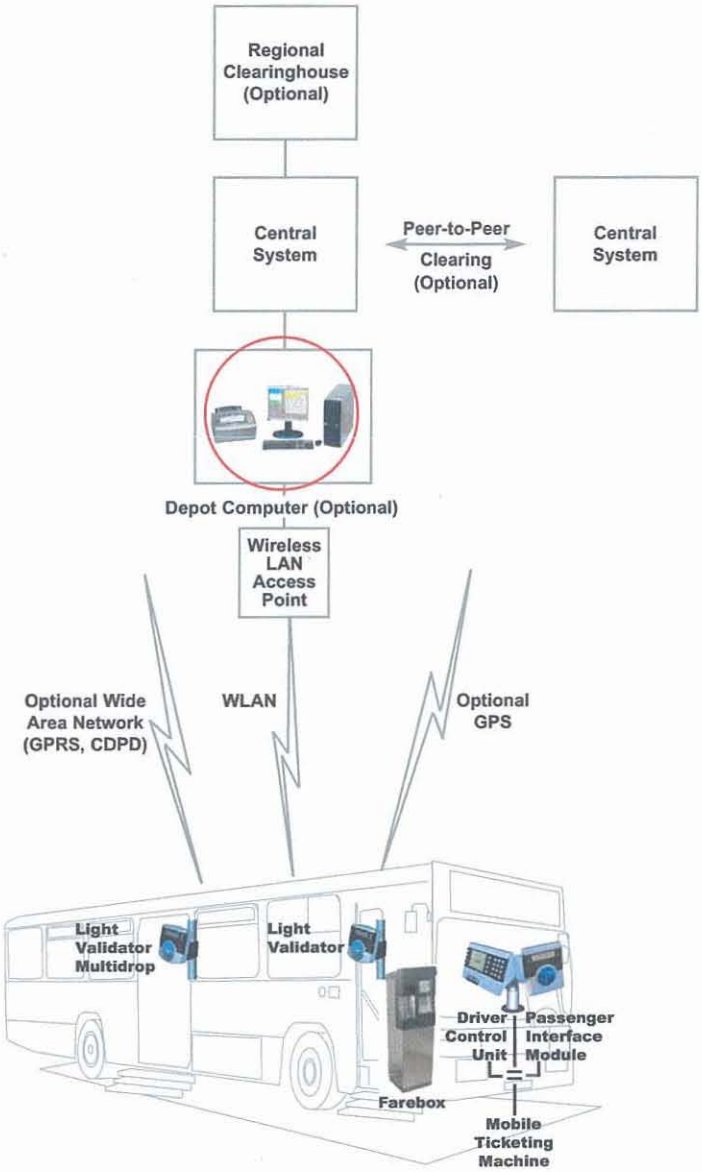
The depot operator console consists of a commercial-off-the-shelf PC, keyboard, mouse, super video graphics adapter (SVGA) monitor, laser printer and Uninterruptible Power System (UPS). Screen selection is menu-driven from either the mouse or keyboard.

In addition to providing an interface to the system, the Depot Computer controls the depot level equipment, performs daily operations and diagnostics, displays table data and device status information, monitors the power supply, maintains an activity and message log, and stores and/or routes data.

Four Reasons to Choose Cubic for Your Fare Collection Needs

- Quality
- Reliability
- Innovation
- Customer Focus

Depot Computer



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Cubic Transportation Systems Limited
European Headquarters
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Salfords, Redhill, Surrey, RH1 5LA UK
+44-1737-782200 • FAX +44-1737-789759

Cubic Nordic
Branch of Cubic Transportation Systems Limited
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Cubic Transportation Systems (Deutschland) GmbH
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Cubic Transportation Systems (Australia) Pty Limited
3/11 Palmer Place
Murarrie, QLD, 4078 Australia
+61-7-3907-3900 • FAX +61-7-3907-3986

CUBIC
www.cubic.com

SPECIFICATIONS

Physical

- Dimensions: Height 445mm (17.5in) [Computer], 253mm (10in) [Printer], 376mm (14.8in) [Monitor]; Width 165mm (6.5in) [Computer], 415mm (16.3in) [Printer], 402mm (15.8in) [Monitor]; Depth 445mm (17.5in) [Computer], 486mm (19in) [Printer], 208mm (8.2in) [Monitor]
- Weight: approximately 30kg (65lbs)
- Material: high impact plastic
- Voltage: 115 or 230 VAC, 60 Hz
- Power Dissipation: 682W Max

Capacity

- Processor: Pentium® P4 3.7 GHz CPU
- Operating System: Windows® 2000
- Memory: 512 MB RAM [Computer]; 1 MB RAM, 32 KB ROM [Printer]

External Interfaces

- USB Version 2.0 (6, 1 for printer)
- Ethernet with RJ45 connector (2)
- Serial port with DB-9 connector (2)
- Parallel port with DB-25 connector (1)
- Digital I/O board, 4 EIA-232 ports each with a DB-25M connector
- VGA output (1, for monitor)
- Wireless Access Point: 802.11b Cisco

Environmental

- Storage Temperature: 0°C to +40°C (+32°F to +104°F)
- Operating Temperature: +10°C to +32.5°C (+50°F to +90.5°F)
- Relative Humidity: 20% to 80%
- Vibration: Not Rated
- Shock: Not Rated
- Ingress Protection: Not Rated
- Immunity: EN55024 [Monitor]
- Emissions: EN61000-3-2, EN55024, FCC Part 15, Class B, CE [Printer]; FCC Part 15, Class B [Monitor]
- Flammability: Not Rated

User Interfaces

- Operator Interface: 432mm (17in) SVGA monitor, standard PC, keyboard and mouse, microphone and headset jacks
- Patron Interface: N/A
- Media Issuance: N/A
- Media Acceptance: N/A

DATA-EU-DC-121605

ATTACH 10

New South Wales Government Directory

State Transit Authority of NSW

Sydney Buses

Telephone:	(02) 9245 5777
Fax:	(02) 9245 5710
Street Address:	Level 1, 219-241 Cleveland Street, STRAWBERRY HILLS NSW 2012
Postal Address:	PO BOX 2557, STRAWBERRY HILLS NSW 2012
Website:	http://www.131500.info
Website:	http://www.sydneybuses.nsw.gov.au

Local Units

- Brookvale Bus Depot
- Burwood Bus Depot
- Kingsgrove Bus Depot
- Leichhardt Bus Depot
- Mona Vale Bus Depot
- North Sydney Bus Depot
- Port Botany Bus Depot
- Randwick Bus Depot
- Ryde Bus Depot
- Waverley Bus Depot
- Willoughby Bus Depot

SYSTEM OVERVIEW OF THE BUS TICKETING SYSTEM

Figure 1 provides the system overview of the CSC based on-board Bus Ticketing System. The system consists of the following:

1. <u>Two Bus Entry Processors (BEP)</u>

The BEPs encode sufficient information of entry on the ticket so that the appropriate fare due can be calculated when passengers alight from the bus. They also display the remaining value on the ticket to passengers. They are placed near the entry doors for processing CSC based tickets when passengers board the bus.

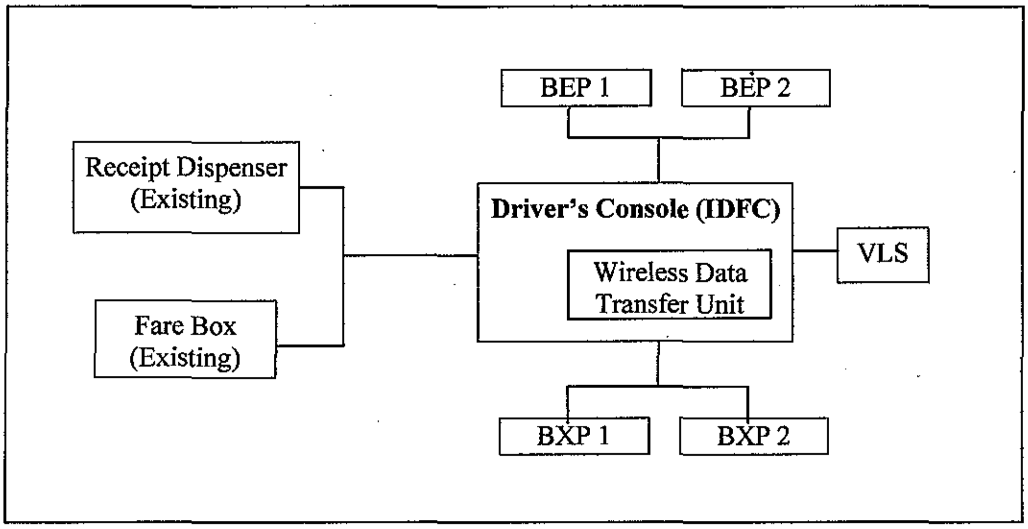

Figure 1: CSC Based On-Board Bus Ticketing System

2. <u>Two Bus Exit Processors (BXP)</u>

The BXPs read the boarding information on the tickets, calculate and deduct the appropriate fare. These processors also display remaining value on the ticket to passengers. They are placed near the exit doors for processing CSC based tickets when passengers alight from the bus.

3. <u>Vehicle Location System (VLS)</u>

The VLS determines the location of the bus through its interface with the GPS receiver, bus odometer and door opening/closing signal. It then provides information of the fare stage to the driver's console to determine the fare stage for fare calculation.

4. <u>Fare box</u>

The fare box is used to collect cash fares. It was part of an existing system used for magnetic tickets and integrated into the CSC system.

5. <u>Receipt Dispenser</u>

The receipt dispenser is used to dispense receipt for payment of cash fares. It was also part of the magnetic ticketing system and was integrated into the CSC system.

6. Driver's console

The driver's console is termed the Integrated Driver Fare Console (IDFC). This console is the brain of the on-board bus ticketing system. It stores information such as the fare stage and fare tables. It also provides this information to the BEP and BXP and updates them each time there is a fare stage or table change. The console provides the driver an interface to the ticketing system for driver's login/logout, issuing cash fare receipt, cancelling of boarding for passenger who boarded the wrong bus and updating of fare stage when the VLS is out of service. The console also has a wireless data transfer unit for automatic transfer of data from the bus to the depot computer when the bus returns to depot.

SYSTEM OVERVIEW OF THE VEHICLE LOCATION SYSTEM

The main function of the VLS is to determine the location of the bus and provide fare stage information to the IDFC. The VLS uses a combination of GPS, gyroscope, odometer and door switches to determine position and compares this with route data to report the bus position.

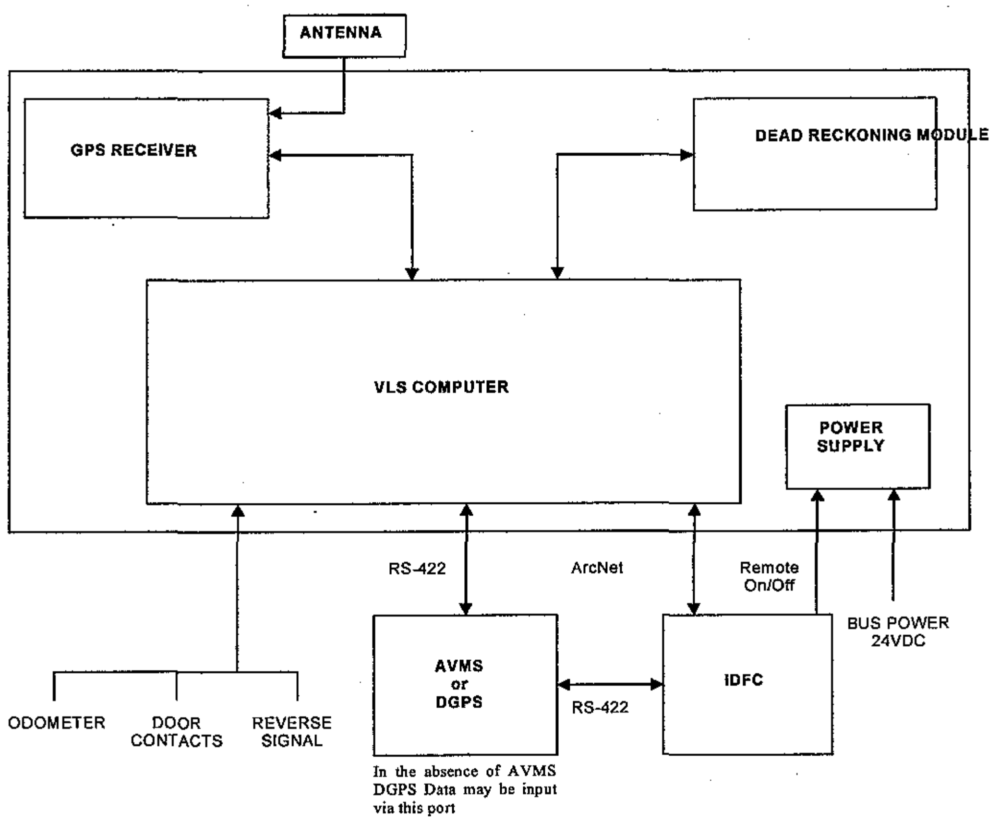

Figure 2: System Diagram of the VLS

Other than providing location information, the VLS will also interface with the bus operator's Automatic Vehicle Management System (AVMS) to provide real-time location information. Figure 2 shows the system diagram of the VLS. The VLS consists of the following components:

1. Main computer

The main computer incorporates the microprocessor, memory and all electronics that are required to perform position calculation. It has a volatile memories that has a minimum of 100 hours of memory retention when the power supply is removed.

2. Communication ports

There are four types of ports on the VLS. There is the IDFC Local Area Network (LAN) port that operates using Transmission Commission Protocol (TCP) running over Attached Resource Computer network (ARCnet), the RS-422 AVMS port, the bus signal port that interfaces to the odometer, door switches and reverse signal on the bus and the power port that taps power from the 24VDC bus power supply.

3. Dead reckoning module

The dead reckoning module includes a gyroscope for bearing information. This module derives position from the gyroscope and bus signals when no GPS signal is available.

4. GPS module

The GPS module gathers information via satellite to calculate position and also provide accurate current time. The module has 8 channels, DGPS capability and position precision of less than ± 100m (2drms). Its hot time to first fix (TTF) is less than 60 seconds and cold TTFF is less than 15 minutes.

5. Antenna

The antenna for the GPS module connects via a connector to the VLS enclosure. The antenna (if roof mounted) does not exceed a height of 5 cm and is designed to be sufficiently robust to prevent damage by low vegetation or bus wash brushes.

6. Power supply

The power supply incorporates appropriate circuitry to handle voltage variations and transients. It accepts a remote on/off signal from the IDFC.

LOCATION DETERMINATION AND FARE CALCULATION

In order to determine the fare that a passenger should pay, the bus system have to first know its position with respect to the bus route every time a passenger entry or exit process their CSC at the BEP and BXP respectively. The VLS provides this information by making use of a series of other information such as GPS co-ordinates and information bus route, bus stop location and input from odometer and dead reckoning module.

In CSC based system, for every bus service route that is operated by a bus operator, a bus service table is defined in the system. Table 1 shows a simplified bus service table used in the system. In every bus service table there is a series of markers. They represent the locations the bus will pass through if it is running the particular service route. On a separate table, each of these markers has a GPS co-ordinate assigned to it. The table can define up to 30,000 markers although currently only about 7000 markers are used for the all the bus services in the whole of Singapore. There are close to 300 bus services in Singapore.

Table 1: A Simplified Bus Service Table

Service Number: 170 Scheme: Aircon Trunk					
Direction: Outbound					
Marker ID	Active Markers *	Distance to next marker (in metres)	Stage no. (of Stop)	Half-Stage	Stop ID
1044	S	290	1		1234A
10115	W	380			
10176	W	442			
1476	S	280	1	√	1235A
...	...	...			
2431	S	505	22		6137C
...	...	...			
Direction: Inbound					
Marker ID	Active Markers	Distance to next marker (in metres)	Stage no. (of Stop)	Half-Stage	Stop ID
3250	S	299	1		6790Z
4346	S	404	1	√	6789Z
...	...	...	...		...
2431	S	389	16		6137C
...	...	...	...		...
3275	S	551	25		1247Z
10446	W	393			
...	...	...	...		...

* S – (Bus) Stops, W – Way-points

The bus service table indicates whether a marker is a bus stop or a way-point. A way-point is a location along a bus service route that is not a bus stop. Based on the marker information, the VLS determines where the bus is along a service route by comparing the GPS co-ordinates received by its GPS module and the information provided in the bus service table. If the reading is within the radius of certainty to a marker, then the VLS can confirm that the bus is at that marker. The radius of certainty is a system parameter that is set to 20 metres. If there is no match all the time as the bus may be somewhere between two markers, the VLS have to wait a while before trying again.

If a marker on the bus service table is a bus stop, other information such as bus stop ID and stage number are also included in the bus service table. Every bus stop along a bus service route has been assigned a stage number. The assignment of stage number is based on distance between two consecutive bus stops.

For fare calculation, the bus ticketing system makes use of the stage numbers assigned to the boarding and alighting bus stop. The stage difference or stages travelled will determine the fare to be charged.