Wellington Public Transport Spine Study

RAILWAY STATION TO HOSPITAL
International Review of Public Transport Systems

Appendices A, B and D

Appendix A

Glossary

Glossary

Service Quality	Qualitative components of passenger transport services affecting and influencing passengers e.g. riding comfort, aesthetics and cleanliness of buses and facilities. Other elements include convenience of using services (local or high frequency services) as well as ones accessibility to and from stops.
Service Frequency	Relates to the type of services provided and is a factor of stopping schedules, operation periods and route scheduling. As a result the terms high frequency, quality and local services are indicators of the type of service frequencies provided by operators and will vary according to location and city goals for public transport.
High Frequency	A high service frequency may offer selected stopping schedule (express / limited stops) compare to the local service stopping at all stops. A high service frequency also quality, frequency (travel time, reliability).
Bus (Service) *	Passenger services provided by buses; they include: - BUS RAPID TRANSIT (BRT) – Bus transit designed as an integrated system of distinct bus vehicles, mostly separate ROW (category B or A), preferential treatments at intersections, ITS, and other elements for greater efficiency. Its better performance and stronger image result in greater passenger attraction than regular bus. - BUS TRANSIT SYSTEM (BTS) – A bus service developed as a coordinated system with improvements in ROW separation, stops, vehicles, operations, passenger information, etc. for higher speed, reliability, and efficiency. - EXPRESS – Express transit service operated by buses. - LOCAL – Bus routes serving all stops, as distinguished from short-haul and express services.
Bus lane *	Traffic lane for dominant or exclusive use by buses. It may be: - CONTRAFLOW (CBL) – The same as a regular bus lane but with buses operating in the opposite direction from other traffic. - EXCLUSIVE (EBL) – Bus lanes (usually two) for bus use only, physically separated (by curbs or barriers) from other traffic. - REGULAR (RBL) – A lane on urban streets or freeways reserved for bus use only, separated from other lanes by pavement markings, signs, or rubber cones but not by fixed physical barriers.
Bus way *	A roadway reserved for buses only (ROW category A)
Capacity (Vehicle) *	(1) Static: total number of spaces or persons a vehicle can accommodate. (2) Dynamic: the maximum number of TUs, vehicles, spaces, or persons that can be transported on a transit line past a fixed point in one direction per unit of time (usually in one hour).
Guide way *	A travel way (rail track, guide beam, riding and guiding surfaces, and others) that physically guides vehicles specially designed to travel on it. Guide ways always require ROW category A except rail, which can be placed in any category (A, B, or C).
High Occupancy Vehicle (HOV) *	Vehicle of any type (automobile, van, bus or others) that carries at least a certain prescribed number of passengers (usually four). Concept used for reserved “HOV lanes.”

Level of Service (Loss) *	An overall measure of all service characteristics that affect users.
Light Rail Transit (LRT) *	A transit mode utilising predominantly ROW category B, sometimes A or C, on different network sections. Its electrically powered rail vehicles operate in one- to four-car TUs. The mode has a wide range of LOS and performance characteristics.
Metro *	A popular name for rail rapid transit systems.
Park-and-ride *	A mode of travel by bus and/or rail when passengers drive to a passenger transport station and park their automobiles in the station's park-and-ride lot
Personal Rapid Transit (PRT) *	A small passenger transport mode consisting of small-capacity (two to six spaces) cabin-type vehicles travelling automatically over an elaborate system of guide-ways; individuals or small acquainted groups would use a cabin to travel between origin and destination stations without stopping. Also called Urban Light Transit.
Passenger Transport Priority *	Physical devices or traffic regulation measures which separate or speed up transit vehicles over general traffic, e.g. bus priority, bus lanes.
Rapid Transit *	A generic class of electrically powered guided transit modes that operate exclusively on all or part of ROW to provide high speed, capacity, reliability, and safety.
Right-of-way (ROW) *	1) Strictly defined, a legally and physically separated strip of land for exclusive use by transit vehicles; crossings may be allowed, 2) Broadly defined, any path or way on which transit vehicles travel. Based on the latter definition, transit ROW are classified in three categories: - CATEGORY A – Fully controlled ROW without (or with fully protected) grade crossings or any legal access by other vehicles or persons; also called "grade-separated", "private", or "exclusive" ROW. It can be a tunnel, aerial, or at grade level. - CATEGORY B – ROW types that are longitudinally physically separated (by curbs, barriers, grade separation, etc.) from other traffic, but with grade crossings for vehicles and pedestrians, including regular street intersections. - CATEGORY C – Surface streets with mixed traffic. Transit may have preferential treatment, such as reserved but not physically separated lanes, or it may travel in general traffic lanes.
Transit *	Urban public transportation services with fixed routes and schedules, such as bus, trolleybus and rail services. Also called mass transit, mass transportation, or public transit, passenger transport or public transport.
Urban Light Transit (Ultra) *	Also called Personal Rapid Transit (PRT) – see above definition.

* The following definitions for Passenger Transport systems is sourced from Votic, V R, (2007) Urban Transit Systems and Technology, Wiley & Sons Canada, and amended as appropriate to the New Zealand terminologies and planning context.

Appendix B

Summary of Responses to Case Study Questions (by Mode)

Appendix B:

Summary of Responses to Case Study Questions and Modal Characteristics

1.0 Personal Rapid Transit (PRT)

Table 1 PRT Characteristics

Location	Urban Light Transit (ULTra) London Heathrow Airport Terminal 5	PRT, Masdar City	PRT, West Virginia
Vehicle Capacity	4	4-6	20
Peak Hour Capacity (pphpd)	480	500	1,500
Service Frequency	On demand	On demand	No more than five minutes
Capital Expenditure (per km)	NZ$9-NZ$20M	-	NZ$11.3M
Total Cost	-	-	-
Operating Expenditure (per vehicle per km)	-	-	-
Operating Speed (km/h)	40 km/h (operating and design top speed)	40km/h	50 km/h
Turning radii (m)	<10 m	-	9.1 m
Power Source	Battery	Lithium-Phosphate batteries	575V AC
Typical Spacing of Stops	3.8 km	1.2 km	2.6 km
Annual Patronage	500,000 (Anticipated)	310,000	2,250,000
Annual Passenger Kilometres	1,900,000 (Anticipated)	372,300 km	-
Hours of Operation	22 hours	6am-12am	-
Rides per day	-	-	-

Note: - Information not available

Table 2: PRT Summary Response to Questions

Questions	
1. Range of demand	Refer to Table 1
2. Key success factors	- Zero emission vehicles (environmentally friendly); - Energy efficient; - Low noise levels; - Journey time savings over shorter distances; - Short wait times; - Flexible infrastructure provided by turning radii and narrow width (2.1 m wide); - Relatively cheap construction; - Novelty factor leads to greater patronage; - Free or inexpensive to users.
3. Key constraints on capacity	- Capacity of each pod is relatively low (e.g. only four passengers Heathrow). - Unlikely to be suitable for large cities as it is not considered capable of handling large mass transit requirements. - Top speed of 40 km/h. - Although vehicles can recharge while sitting unused in stations, if this is not possible they must be taken out of the network to recharge.
4. Has the system achieved a high modal shift transfer and why?	- Yes, for example at Heathrow the system is expected to eliminate 50,000 bus journeys on roads PRT provides a faster and more direct alternative.
5. Highest passenger and /or vehicle through put capacity (pphpd)	Refer to Table 1.
6. Key factors for keeping transferring or modal interchanges passengers in system	- Replaces existing bus services or car movements; hence modal shift is anticipated to be maintained and increased as the line is extended to the other activities.
7. Does PT shape or respond to travel patterns (examples)?	- The PRT system responded to an existing demand for travel at Heathrow and West Virginia. - The PRT system is intended to shape travel demand at Masdar City.

8. What are the land use planning policies or strategies that support passenger transport system	- Promotes a sustainable transport system. - Policy to reduce environmental impact of transport system.
9. Describe key design issues	- Small vehicles, travelling on lightweight guideways which makes construction cheaper and integration into the existing urban fabric easier than for heavier infrastructure. - Guideways are approximately 2.1m (7 feet) wide, including the outer kerbs, and therefore relatively narrow. - The network does not release local pollution and noise levels are low. - The PRT system can only travel on pre-determined routes, segregated from other transport. - Generally requires grade separation. - Not suitable for large cities as it is not considered capable of handling large mass transit requirements or longer journeys. - The network is completely flat with vehicles using magnets imbedded in the track to position them. - The onboard batteries last for around 60 km (approximately 50 trips) before they need recharging. - Can be vulnerable to weather conditions e.g. snow.
10. Describe key operational issues	- Customers pick their destination by pressing a button on a touch screen before departing. - Empty vehicles charge themselves at battery points although they are available on demand. - Can only travel on a predetermined route. - Pod cars are activated by passengers using a touch screen interface. - Larger interchanges require docking areas for multiple PODs.
11. How have transport corridors been re-structured to support the use of high quality PT links?	- Segregated from other modes to maximise the efficiency of the system.
12. What is the typical spacing of stops	Refer to Table 1.
13. Describe the design characteristics of interchange locations and identify desirable	- Size of interchanges depends on demand. - Can dispatch up to 100-120 vehicles per hour with little or no waiting time. - If PRT is stops working for more than 15 minutes, an indicator light will signal this at affected stations.

attributes	
14. Explain how the PT services interact with traffic and discuss the good and bad characteristics of the design	- The PRT network is completely segregated from traffic. - The lightweight design on purpose built guideways can be customised to suit a variety of environments which makes the infrastructure relatively easy to construct in an existing built environment. - Raised infrastructure is visually intrusive, however, and requires additional land take.
15. How was the PT network acquired and discuss the procurement and governance models	- Can be privately or publicly owned and operated. - Often land is already owned or procured by government. - In some cases governments may provide funding assistance.
16. What was the range of capital costs for the total scheme and on a per kilometre basis?	Refer to Table 1.
17. What is the range of operational costs per route kilometere?	Refer to Table 1.

2.0 Bus Rapid Transit (BRT) Systems

Table 3 BRT Characteristics

Location	Adelaide	Brisbane	Cleveland	16th Street Mall Denver	Xiamen Elevated	Nantes Ligne 4	Rouen TEOR	Auckland Northern Busway
Vehicle Capacity	-	60-70	47 seated and 53 standing	115	88	150	110-115	60-75
Peak Hour Capacity (pphpd)	36,000	6,500 actual 12,000 capacity	1,000	5,500	7,900	2,200	1,770[1]	6,000 (future 18,750)
Service Frequency	5-15 minutes	From 24 seconds[2]	5 min	-	From 40 seconds	4 mins	5-8 mins	-
Capital Expenditure (per km)	NZ$10.5M	NZ$74M[3]	NZ$23.87M	NZ$62.1 M (Mall) NZ$2.5 M (LRT)	NZ$17.6M[4]	NZ$12.7M	NZ$8M	NZ$34.0M
Total Cost	-	-	-	-	-	NZ$88M[5]	NZ$188.9M	-
Operating Expenditure (per vehicle per km)	-	NZ$9.80[6] (all buses)	-		-	NZ$6.6[7]	NZ$7.50 (2006)[1]	-
Operating Speed (km/h)	100 km/h	29[8]	40 km	40	Ave 27 (Max 60)	21–23 km/h (design average speed - 23km/h)	Average speed 18-20 km/h	100 km/h (design), 80 km/h (normal)
Turning radii (m)	-	15-20	-	-	~50	12 m	25 m when optical guidance is in operation. (12 m otherwise)[9]	-

1 ETC Papers - LPT03iii (2011)
2 http://transporttextbook.com/?p=1136
3 http://www.atrf11.unisa.edu.au/Assets/Papers/ATRF11_0183_final.pdf $950 M for 16.5km in 2010 AU dollars, AU$57.58 M per km
4 BRT Line 1 only, assuming an investment of 3 billion Yuan over 32.6 km of busway (from a secondary source: http://bbs.xmfish.com/simple/?t3316391.html)
5 ETC Papers - LPT03iii (2011)
6 Acoording to the 2009-10 TransLink annual report, bus operator expenditure was AU$682.7 M over 90,000,000 service kilometres, or AU$7.58 per kilometre source: http://translink.com.au/resources/about-translink/reporting-and-publications/2009-10-annual-report.pdf
7 http://www.sputnicproject.eu/docs/equipment/Nantes%20Busway.pdf
8 http://www.chinabrt.org/en/cities/brisbane.aspx
9 http://ctcqyjs.cqjtu.com/upload/2010-06/10062311509554.pdf

Location	Adelaide	Brisbane	Cleveland	16th Street Mall Denver	Xiamen Elevated	Nantes Ligne 4	Rouen TEOR	Auckland Northern Busway
Power Source	-	Diesel, some CNG	Diesel-Electric Hybrid	Hybrid gas-electric	Diesel	Hybrid (LPG, Diesel)	Diesel	Diesel
Typical Spacing of Stops	6 km	1,500 m	400 m	120 million	900 m to 1300 m	500 m	500 m	800 m–1 km
Annual Patronage	8,000,000	35,000,000[10]	3,800,000	17,500,000	11,000,000	9,240,000[11]	11,966,000[12]	-
Annual Passenger Kilometres	-	~6,000,000,000 place kilometres (all buses 2009-10)	-	-	-	20,050,800	31,654,059	-
Hours of Operation	-	-	24 hours, daily	-	0550 to 2240	05:00 to 00:30 (02:30 on Saturdays)	06:00 to 02:00	-
Rides per day	-	-	12,000	-	-	-	-	-

Note: - Information not available

[10] South East Busway Extension Rochedale to Springwood Concept Design Study Report, Parsons Brinckerhoff. Entire network has an annual patronage of about 60,000,000 according to TransLink Annual Report 2009-10.
[11] ETC Papers - LPT03iii (2011)
[12] ETC Papers - LPT03iii (2011)

Table 4: BRT Summary Response to Questions

Questions	
1. Range of demand	Refer to Table 3.
2. Key success factors	- Improves transit system efficiency, via a dedicated corridor, with enhanced stops. - Priority treatments at intersection where BRT merges with general traffic (entry / exit gateways). - Improves passenger transport vehicles, marketing and branding to improve the image of public transport - Streetscape improvements, pedestrian provisions part of corridor revitalisation and economic development. - BRT stops and interchange facilities located for quick transfers, access to significant buildings, open spaces. - Seamless fare collection to reduce dwell / passenger delays. - Distinctive vehicles. - ITS (priority at junctions). - Quality stations and frequent service. - Integrated, easy to use ticketing alongside complementary bus and tram services.
3. Key constraints on capacity	- Fleet Size and Vehicle type – imposing constraints on the carrying capacity of vehicles operating on the BRT. - Access to the BRT Systems for Buses entering from general traffic lanes and the lack of priority at signals. - Capacity is constrained by the size of individual vehicles (articulated buses) and by traffic signal operations along the corridor. - Serves areas of contrasting population densities.
4. Has the system achieved a high modal shift transfer and why?	Yes, for example in Cleveland, Ohio – 58% increase in ridership via the introduction of the BRT replacing local bus services due to: - Faster average speeds over general traffic lanes at peak times. - A direct, high quality service with safe, visible and clean station stops. - Dedicated transit mall for pedestrians and buses only. - Connections with other modes of transport e.g. metro / subway and local feeder buses.
5. Highest passenger and /or vehicle through put capacity (pphpd)	Refer to Table 3.
6. Key factors for keeping transferring or modal interchanges passengers	- Quality Stations and multi-modal interchanges e.g. both BRT connected with metro interchanges. - Reliable and frequent services. - Safe pedestrian movements to and from facilities e.g. Xiamen Elevated BRT pedestrian over bridges between stations to adjoining

in system	sidewalks.
7. Does PT shape or respond to travel patterns (examples)?	The BRT systems have been designed and respond to existing transit demand and travel patterns within the city but are also linked to future revitalisation within and adjoining the BRT corridors.
8. What are the land use planning policies or strategies that support passenger transport system	- The City of Cleveland supported the economic revitalization of the corridor through an economic development plan, a zoning overlay district, design guidelines and various financial incentives. - Strategic influence from a national programme to develop a high quality bus concept (BHLS[13]) and local political will to provide high quality public transport in the city.
9. Describe key design issues	- Funding – influencing the design parameters e.g. giving recognition to financial contributions. - Spatial requirements / buffers zones between adjoining buildings, land use to support BRT, Stations, and Viaducts etc. - Flexibility in design to convert BRT to LRT / Metro for any future increased throughput capacity. - Urban Design e.g. design the full streetscape environment and interface with adjoining businesses. - Design of entry and exit points of BRT System.
10. Describe key operational issues	- Operational Speeds – a fully segregated BRT from general traffic / pedestrian environment can minimise operational issues vs. BRT systems operating within the general streetscape environment. - BRT Single Lanes / Station Design – during peak periods buses can queue on approach to the bus stations, hindering travel time reliability of buses unable to overtake buses at stations. - Traffic Signal Priority – a lack of traffic signal priority for buses entering / existing the BRT system, results in slower speeds than planned. - BusWay provides levels of operational flexibility that rail-based solutions would not have been able to provide: in the suburbs, the vehicles merge with general traffic for sections of the route. - Bottlenecks associated with fare collection and validations may remain, adversely impacting on journey times.
11. How have transport corridors been re-structured to support the use of high quality PT links?	- Xiamen Elevated BRT – has created a two tier transport corridor. With limited streetscape planting the at-grade street environment is harsh. With eight lanes of general traffic lanes and off-street parking the environment caters to rapid congestion free movement with less emphasis on slower forms of movement pedestrian. - Cleveland BRT – a key objective of the design has been to improve transit system efficiency and promote economic and community development growth within the corridor. With a strong emphasis on whole streetscape design with adjoining land uses, the project has sought to improve pedestrian linkages, incorporate public art in addition to the upgrading of the Euclid Avenue Corridor to Transit Street which supports up to 40 buses per hour during peak periods.

[13] http://ctcqyjs.cqjtu.com/upload/2010-06/10062311509554.pdf (English translation of case study on the BHLS concept)

12. What is the typical spacing of stops	Refer to Table 3.
13. Describe the design characteristics of interchange locations and identify desirable attributes	- Integration of BRT stations with metro / subway stations. - BRT stations allow buses to leave or enter the network, allowing greater connections to surrounding area. - Park-and-ride facilities for motorists to transfer to the public transport network.
14. Explain how the PT services interact with traffic and discuss the good and bad characteristics of the design	Elevated BRT - No integration with general traffic. At-grade BRT - Transit signal priority, but the benefit can be somewhat reduced by the high pedestrian movements and frequent number of cross streets. - Turning movements across the BRT lanes not allowed in most locations, which also helps BRT performance.
15. How was the PT network acquired and discuss the procurement and governance models	- Government funding was used to construct the O-Bahn and operated by TransAdelaide, a publicly owned corporation. - BRT networks have been implemented using Private-Public-Partnerships as well as being solely publicly funded.
16. What was the range of capital costs for the total scheme and on a per kilometre basis?	Refer to Table 3.
17. What is the range of operational costs per route kilometre?	Refer to Table 3.

3.0 Light Rapid Transit (LRT)

Table 5 LRT Characteristics

Location	Bremen BSAG	Bergen Bybanen	Freiburg	Karlsruhe	Edmonton, Alberta	Gold Coast Rapid Transit, Queensland	Ampang and Kelana Jaya Lines Kuala Lumpur	Hiawatha Line, Minneapolis	Portland Transit Mall	C Street Mall, San Diego	San Francisco	Canada Line (SkyTrain), Vancouver	Luas, Dublin	Phileas, Eindhoven	Rouen LRT	Downtown Seattle Transit Tunnel	Hong Kong Trams	Kagoshima Trams	St Kilda Road Trams
Vehicle Capacity	106 (tram)	220	205[14]	223 (100 seated)	160	Up to 309	414	186	4,000	532 (2 cars)	220	-	256 (red line) 358 (green line)	120 and 180 person models	178	200	115	80	85
Peak Hour Capacity (pphpd)	-	Phase 1 2,000[2]	-	Up to 40,000 (peak on busiest city centre section)[15]	5,000	2,000	30,000	4,800	-	15 trains, 4,000 riders	9,500	10,000–15,000	3,150[16]	1,000	-	3,600	4,600	3,200	10,000
Service Frequency	10 mins	5 minutes (peak) 10 minutes (off peak) 1 hour at night	7.5 min	45 second headways (peak on busiest section)	5–15 mins	7.5 minutes	3-4 mins	7-9 peak/p 10 mins headway 15 mins Sat/Sun	-	-	-	<2 mins	4–5 mins (15 mins at night)	10 min	Every 3 minutes (peak) and every 20 minutes (off peak)	7.5 M peak 10-15 M off peak/week end	90 seconds	5–6 minutes	30 seconds
Capital Expenditure (per km)	NZ$16.7M per km for 3.4km extension to new northern terminus completed in the 1990's [17]	NZ$ 46.4[18]	-	Conversions from heavy rail - $3.8m[19] (€2.3m) Street running – NZ$$29.4M (€17 million)	NZ$11.5M	NZD$31M[20] per km (estimated)	NZ$60M[21]	NZ$44.8M	-	NZ$25 M	NZ$28.6M (Embarcadero extension)	NZ$100 M (for Canada Line)	NZ$56.9M [22]	NZ$11.6M	NZ$50M (€32m)[2]	NZ$275 M (for Bus Tunnel)	-	-	NZ$13-19M[23]
Total Cost	NZ$56.6m	NZ$ 454.8M	-	-	NZ$254M	-	-	-	-	-	-	-	NZ$1,266 M	-	NZ$796M	-	-	-	-
Operating Expenditure (per vehicle per km)	Maximum of 70 km/h. Lower operational speed in city centre.	NZ $1.5m per km per annum (includes staff costs)[24]	-	-	70 km/h	N/A	-	NZ$1.6M	NZ$1.6 M	NZ$1.6 M	NZ$3.4M	-	Not known, however Luas operates without subsidy	-	-	NZ$1.9 M	NZ$4.23 per service kilometre	NZ$15/service km[25]	NZ$13.50

[14] http://bc.transport2000.ca/debate/opinions/ad_justification.html
[15] ttp://www.railforthevalley.com/news-articles/lrt-and-subway-construction-costs/
16 ETC Papers - LPT03iii (2011)
[17] http://www.railway-technology.com/projects/bremen/
[18] ETC Papers - LPT03iii (2011)
[19] http://www.tramtrain.org/en/index.html
[20] Assuming a cost of AU$949 million and 40 kilometres of route
[21] US $50 M per kilometre according to "CAI-Asia and Sustainable Urban Mobility in Asia (SUMA): Bus Rapid Transit Systems PUTRA" presentation
22 ETC Papers - LPT03iii (2011)
[23] The tram tracks on St Kilda Road have been in place for so long that it would not be useful to report the capital costs of building that part of the network. However, recent extensions on other parts of the Melbourne tram network allow an approximate capital cost for tram infrastructure to be estimated based on three recent extensions (see http://transporttextbook.com/?p=21). Adjusted for 2010 dollars, three extensions cost between AU$10 million and AU$15 million per kilometre.
[24] ETC Papers - LPT03iii (2011)
[25] Operational cost is 1,560,000,000 yen per year, excluding capital costs for infrastructure renewal. This converts to NZ$24.3 million per year, over an estimated 1,600,000 service kilometres per year. This translates to an operating cost of approximately NZ$15.20 per service kilometre.

Location	Bremen BSAG	Bergen Bybanen	Freiburg	Karlsruhe	Edmonton, Alberta	Gold Coast Rapid Transit, Queensland	Ampang and Kelana Jaya Lines Kuala Lumpur	Hiawatha Line, Minneapolis	Portland Transit Mall	C Street Mall, San Diego	San Francisco	Canada Line (SkyTrain), Vancouver	Luas, Dublin	Phileas, Eindhoven	Rouen LRT	Downtown Seattle Transit Tunnel	Hong Kong Trams	Kagoshima Trams	St Kilda Road Trams
Operating Speed (km/h)	-	Average speed: 28km/h (Maximum speed: 70 km/hr)	-	Innercity: 30-70 km/h Outskirts: 60-80 km/h	-	Up to 70 km/hr (vehicle maximum)	40 km/hr	25 km/h	-	-	-	-	50 km/h on city centre streets 70 km/hr elsewhere 26 km/hr[26]	25-30 km/h (average speed)	19 km/h (80km/h maximum)	-	~9 average 50 maximum	14–18	11 km/h (CBD) 14 km/h (St Kilda Rd)
Turning radii (m)	-	25 m		25 m	-	25m (vehicle minimum)	50	-	-	-	600 m	-	-	12.5 m	-	-	20–25m	15–20	16.8
Power Source	750v DC overhead supply system	Electric (overhead) 98% from hydro plants	Electric	Electric (DC + AC)	0.4 km	Overhead electric DC600V	Third rail		-	-		-	Electric (DC)	LPG Fuel/Battery	Electric	-	Overhead electric 550V DC	Overhead electric DC600V	Overhead electric DC600V
Typical Spacing of Stops		800 m	300 metres	-	-	400 metres	1 km	400 m	300 - 450 m	0.5 km	47.4 m (all lines)	500 m	700 m	300 m	500m	500 m	250 m	200–400 m	200 – 300 m
Annual Patronage	Over 267,000 people use the public transport network every day – 8 tramways and 46 bus lines (BSAG, 2011)[27]	Phase 1 8,580,000[28]	65.9million[29] (two thirds light rail)	-	-	18,250,000[30] (projected)	118,990,000[31]	10.5 million	-	-	-	290,000	27,400,000[32] (network)	9,405,000 (network)	15 million[33](network)	-	83,950,000	10,200,000	182,700,000[34] (all trams)
Annual Passenger Kilometres		42,805,331[35]		133 m[1] (network)	-	N/A	-	-	-	-	-	-	143,850,000 km (network)	-	-	-	-	1,600,000 service km	24,600,000[2] service kilometres
Hours of Operation				-	-	-	0600 to midnight	-	-	-	-	-	-	-	0500 to 2330	-	05:30 to 00:30	6 am – 10.30 pm (7 days)	-
Rides per day				-	-	-	-	-	-	-	-	-	-	-	-	-	-		-

Note: - Information not available

26 http://kfarr.com/2007/11/23/light-rail-smackdown-dublins-luas-vs-sf-munis-t-third/
27 http://www.bsag.de/eng/4587.php (2011)
28 ETC Papers - LPT03iii (2011)
29 F. Fitzroy and I. Smith, Public transport demand in Freiburg: why did patronage double in a decade (1998)
30 The patronage is expected to reach 50,000 passengers per day (source: http://www.railexpress.com.au/archive/2011/may/may-11th-2011/top-stories/goldlinq-win-gold-coast-rapid-transit-bid)
31 326,000 average per day in FY 08/09 source: http://www.utusan.com.my/utusan/info.asp?y=2008&dt=0709&pub=Utusan_Malaysia&sec=Kota&pg=wk_04.htm
32 ETC Papers - LPT03iii (2011)
33 http://www.metrotram.it/index.php?vmcity=ROUEN&vmsys=lrt&ind=0&num=2&lang=eng
34 http://yarratrams.com/about-us/who-we-are/facts-figures/
35 ETC Papers - LPT03iii (2011)

Table 6: LRT Summary Response to Questions Patronage and Travel Patterns

Questions	
1. Range of demand	Refer to Table 4.
2. Key success factors	– Can be fully segregated (elevated or tunnelled) from general traffic / pedestrian environment and thus can minimise operational issues, congestion. – Is topographically suited to hilly and steep terrain. – Ridership projections lower than reality with some systems exceeding projects by >50% in the first year of operation – Can offer the ability and operate LRT as a zero emission schemes, with sustaining policies and strategies long term. – LRT stops can be convenient spaced allowing short walks to most destinations. – Can relatively easily incorporate flexibility and adaptability into plans.
3. Key constraints on capacity	– Street / tunnel and block configurations can impose constraints on vehicle length (carrying capacity) e.g. <400 m limits the size of LRT to 2-3 cars only. – At-grade intersections – no right-of-way or priority applies to LRT. There is the need to maintain all traffic and pedestrian movements which can result in extended headways for LRT. – Shared space with other non-LRT vehicles impacting on LRT throughput. – Infrastructure e.g. platforms configured for two or three cars only.
4. Has the system achieved a high modal shift transfer and why?	– Generally yes. For example, In Freiburg the total public transport demand increased by 70% between 1997 to 2006 as a result of investment and policies which support passenger transport. – Projected ridership lower than reality with most systems exceeding projects by >50% in the first year of operation.
5. Highest passenger and /or vehicle through put capacity	Refer to Table 4.
6. Key factors for keeping transferring or modal interchanges passengers in system	- LRT developed as a network encouraging onward journeys by passenger transport. - LRT connections with high frequency bus services, using timed transfers. - Fully integrated network of timetabling across all passenger transport modes e.g. regional and city services. - Seamless ticketing e.g. Seattle's ORCA Cards (One Regional Card for All) which automatically calculates fares / transfers on PT modes. - Transfer receipts valid up to 2.5 hours. - Interchanges and transfers designed to be as seamless as possible e.g. short walking distances, cross-platforms transfers

	- High quality design and infrastructure for pedestrians and cyclists accessing and arriving at stops and stations. - High quality pedestrian streetscape and transit mall environment with initiatives to encourage ease of movement e.g. Fare Free Zones
7. Does PT shape or respond to travel patterns (examples)?	- LRT systems reviewed have: o Supported compact land use development on corridors and around stations e.g. Transit Planning Zones within District Plans. o Preserved historical towns and pedestrian “car free” environments o Respond to existing and / or new travel patterns to reduce congestion levels and vehicle km’s travelled o Create economic stimulus through new forms of urban development e.g. TOD. - Service planning is an on-going process, with timetabling and performance evaluated and modified to respond to changes in demand and changing community needs
8. What are the land use planning policies or strategies that support passenger transport system	– Zoning and Development Controls – stipulate development around stations to serve existing as well as new urban centres with planning controls designed to enable intensification around stations e.g. Muni LRT, San Francisco, USA –“Transit First” prioritises development of public transit, walking, cycling and other alternative modes. Parking policies and facilities are located and designed to encourage passenger transit use. – Project and Design Frameworks for infrastructure – Passenger transport is an integral part of projects and designed at the start of projects rather than incorporated at later stages or at the end. For example in Edmonton, Alberta, Canada, this approach to planning ensured that the areas around LRT Stations have the highest densities, but acknowledges that development densities will vary as they respond to local projected growth conditions. – Revised Parking Controls – restructuring of the parking policies to restrict the growth of parking spaces in the downtown area e.g Portland Oregon – Inter-government agency programmes funding of development and sustainable communities initiatives e.g. housing, mixed use activity around stations. e.g. Hiawatha Line, Minneapolis, USA – the Metropolitan Council promotes medium and higher density housing and mixed use development. Several stations on the LRT route are designated as “catalyst” stations with initial investment and TOD. As a result, Planners predicted areas surrounding the Hiawatha Line would attract 7,000 new housing units. In December 2010, the reality is 8,100 new housing units constructed with another 7,700 proposed by developers. – Taxation around TOD / Transit Stations - Land use and taxation policies to facilitate the appropriate use around stations, including where practical constraints on parking. – Legalisation Requirements – for example, Canada Line, Vancouver, BC, Canada – Translink required by law to support the Liveable Regional Strategic Plan, which promotes, compact and sustainable communities with a diverse transport choice. Higher density development is an instrumental component of the plan with many areas along the Expo and Canada Line redeveloped / earmarked for higher development densities.
9. Describe key design issues	– Spatial constraints to accommodate either surface at-grade, underground and / or evaluated structures, interchanges and stations etc. – Funding and investments of alignment:

	o to enable a comprehensive design that can support and is flexible to future changes e.g. growth, technology o relocation of services e.g. gas, water and communications o relocation / comprehension of access to buildings, parking abutting proposed alignments - Streetscape / Transit Mall Design – integration with existing historical character, incorporation of art and public spaces for pedestrians - Block typologies and street layouts can impose constraints on LRT Fleet length, blocking intersections and pedestrian access to platforms / stations. - Construction – ability to re-route traffic and retain the reliability of existing passenger transport patronage during construction. - Emergencies / Breakdowns – co-ordination and quick responses especially if tunnels are shared e.g. bus / rail tunnels. - Noise - the Norwegian system has laid rubber jackets within selected corridors to reduce noise within the CBD. - Traffic Signal Priority – to improve reliability of LRT and improve safety for all road users.
10. Describe key operational issues	- LRT systems operating within the general streetscape environment and the requirement to stop at intersections. – Fleet Size and capacity of train sets to meet peak demands. – Poorly integrated service planning, timetabling can reduce the effectiveness and performance of passenger services and reduce community and political support – Streetscape / Transit Mall Design – inefficient movement of space for LRT and buses, well located stops and information, use of colour and themes for LRT and bus groupings inadequate public spaces for pedestrians and retail frontages. – Poorly located corridors and pedestrian accessibility to stations outside CBDs can negatively affect both community and political support. - Long operating hours (weekday and weekend) are seen as attractive and an easy alternative to cars e.g. hop on and off. - Reduced dwell times, transfers between modes and station spacing are critical to competiveness of LRT over other modes of transport. - Traffic Signal Priority – installing of automatic stops and signal priority for LRT entering / existing intersections / tunnels
11. How have transport corridors been re-structured to support the use of high quality PT links?	– Revitalisation of areas e.g. redevelopment and reconstruction of buildings and infrastructure resulting from earthquake demand. – Historical centres / CBD and downtown areas better supported by higher carrying capacity modes vs private cars resulting in exclusive right-of-ways “car-free environments” – Corridor widening to accommodate LRT alignments e.g. exclusive rights of way, grade separated. – Additional Bus services to accommodate the increased patronage arsing from LRT and the wider appeal of passenger transport services. – Bus Operations – service planning and routes redesigned to coordinate LRT patrons and their connecting movements. – Fare restructuring to allow for seamless transfers and/or and fare free transfers / zones.

12. What is the typical spacing of stops	The range of spacing on average is between 400 m to 1.0 km, subject to one or a combination of the following factors: – Station location at-grade or underground. – Block typologies and street layouts. – distance between higher density areas within the corridor e.g. stations more closely spaced within CBD downtown areas
13. Describe the design characteristics of interchange locations and identify desirable attributes	Design Principles – The LRT system should be recognisable and easy to locate in the streetscape. – Interchanges between modes should be legible and easily accessed, within line of sight where possible. – Station and interchange locations should be designed to be appropriate for the location, safe and accessible for all ages including those with disabilities. – Integrated provision for bike lockers at stations and the provision of commuter parking in outlying areas e.g. Norway, USA. – Information available for all users e.g. viable message signs with automatic voice. Station staff available onsite for assistance. – Local Police stations including public and private retail services are also an integral part of interchange /station designs. At-grade configurations: – Located in the medium on key arterial routes (up to six lanes wide). – Pedestrian access to stations at-grade crossings, with signal phasing favouring pedestrians over other vehicle movements. Underground configurations: • Tunnel connections integrated with buildings, cross-platform movements and connections to surface landmarks, key intersections for ease of access.
14. Explain how the PT services interact with traffic and discuss the good and bad characteristics of the design	• LRT generally receives preferential priority treatments when operating at-grade. • LRT is segregated from general traffic e.g. medium strip and/or elevated with sections of the route either double tracked or with right-of-ways where spatial constraints exist. • Marking of LRT Lanes at intersections easily distinguishable from all other pedestrian and general road markings. • General traffic is limited and dispersed to the edge of the downtown, with priority in downtown areas for passenger transport and pedestrian movement • Parking and delivery controls applied on vehicles accessing transit malls and car-free zones e.g. Freiburg, Portland Transit Mall.

15. How was the PT network acquired and discuss the procurement and governance models	• Partnerships between Central, Regional and Local Government Authorities e.g. Bergen Bybanen Norway, Hiawatha Line, Minneapolis and Gold Coast LRT are examples with funding provided by various government bodies. Types of government funding mechanics include increased rates, tendering of LRT operations to private parties or funding from revenue earned form fuel taxes and/or tolling of roads. A recent example within the Asia Pacific region is the proposed The Gold Coast Rapid Transit between the Queensland Government, Gold Coast City Council, the Commonwealth of Australia and GoldLinQ all made an investment/equity of AU$949 million (NZ$1,243) to the project: o Commonwealth Government - AU$365 million (NZ$478 m) o Queensland Government - AU$464 million (NZ$607.8 m) o Gold Coast City Council - AU$120 million (NZ$157 m) – Design and Build contracts for all or sections of the LRT alignment. – Establishment of Government LRT Agency – responsible for part of all of the planning, construction of LRT infrastructure and rolling stock e.g. Bergen Bybanen, Norway. Such agencies may also operate the services e.g. Sound Transit, Seattle – Private ventures, which develop 100% of LRT infrastructure, rolling stock and operation. However this recently has resulted in government bail outs due to financial difficulties e.g. Malaysian Government purchase of the Kelana Jaya LRT line – LRT Operations – contracted to private operators for an agreed period e.g. Bergen Bybanen Norway. – Transit Malls – partnership between government and mall developers.
16. What was the range of capital costs for the total scheme and on a per kilometre basis?	Refer to Table 4.
17. What is the range of operational costs per route kilometre?	Refer to Table 4.

4.0 Mass Rapid Transit (MRT)

Table 7 MRT Characteristics

Location	North East Line, Singapore	Mumbai Metro Lines I II and III	Airport Express, Hong Kong	Line D, Lyon Metro
Vehicle Capacity	1,920 based on six train set (six passenger/m^2)	1100 (four car unit)	-	500 (2 car) – 250 per car
Peak Hour Capacity (pphpd)	-	15,000-25,000	80,000	24,000
Service Frequency	90 seconds	3–5 mins	2-3 minutes on main lines	2- minutes
Capital Expenditure (per km)	NZD$2.2M	NZ$65M[36]	-	-
Total Cost	-	-	-	-
Operating Expenditure (per vehicle per km)	-	33 average[37] 80 top speed	-	-
Operating Speed (km/h)	100 km/h (design), 90 km/h (normal)	100	80-130 km/h	75 km/h
Turning radii (m)	-	-	-	100 m
Power Source	1,500V from the DC overhead line	25 kV, 50 Hz AC through overhead catenary	1500V DC	750V DC Third Rail
Typical Spacing of Stops	-	1 km	-	750 m
Annual Patronage	137,970,000 trips	-	1,298,700,000	258,504,680 (Total network)
Annual Passenger Kilometres	2,759,400,000 km	-	-	-
Hours of Operation	-	-	-	5am- 12:20am
Rides per day	-	-	-	-

Note: - Information not available

[36] http://articles.economictimes.indiatimes.com/2010-05-18/news/28491695_1_mmrda-projects-versova-andheri-ghatkopar-line
[37] http://www.mmrdamumbai.org/

Table 8: MRT Summary Response to Questions

Questions	
1. Range of demand	Refer to Table 7
2. Key success factors	- Fully segregated e.g. underground and / or grade-separated from general traffic / pedestrians - Known to be frequent, reliable and clean. - Can and has helped shape the existing and redeveloped urban form around corridors
3. Key constraints on capacity	- Rolling Stock – capacity of vehicle types - Headway – delays resulting from capacity of vehicles, circulation on platforms. - Spatial underground challenges for alignments, with respect to services, sea levels, building pilings and existing and future MRT lines and stations.
4. Has the system achieved a high modal shift transfer and why?	- Yes, for example travel savings on the Mumbai Metro. The Metro Line I is expected to cut passenger travelling time by one hour making it an attractive alternative to car travel. While the system will support a large model demand, the system alone is unlikely to sufficiently meet the city's growing demand for accessibility
5. Highest passenger and /or vehicle through put capacity (pphpd)	Refer to Table 7
6. Key factors for keeping transferring or modal interchanges passengers in system	- MRT provides a faster service compared with travelling by car. - Connecting with high frequency bus or other services. - Integrated timetabling. - Integrated ticketing. - Short walk distances (to other modes). - Good and safe design of stations.
7. Does PT shape or respond to travel patterns (examples)?	For densely populated cities like Mumbai passenger transport is essential to maintaining a well connected and accessible place. The proposed metro lines respond to existing and future travel patterns.
8. What are the land use planning policies or strategies that support passenger transport system	- In Singapore, the Land Transport White Paper, 2006 set the vision for all transport modes. - Integrating the Metro into the TCL system has created a passenger transport system that provides a comprehensive network across the city. The Metro itself serves the inner city area, allowing mass transit along key routes at high speeds, while tram and bus services create additional links between stations and out into the suburbs.

9. Describe key design issues	- In the early days of the NEL's operation there were issues related to the design of the trains, namely people leaning on the automatic stop buttons. This was remedied by the installation of plastic covers being placed over the buttons to prevent this. - Underground, however there are some above ground sections.
10. Describe key operational issues	- Passenger carrying capacity of existing metro in some instances is well over capacity and imposes safety issues on operators - A single ticketing system is used across the entire public transport network (e.g. in Lyon), making it easy to change between modes. - Safety, cleanliness, ease of use and reliability are all features of the MTR which have led it to being held in high regard.
11. How have transport corridors been re-structured to support the use of high quality PT links?	- Metro systems are designed to be fully segregated from general traffic and can have elevated and underground tunnel sections.
12. What is the typical spacing of stops	Refer to Table 7
13. Describe the design characteristics of interchange locations and identify desirable attributes	- Passengers can be protected from falling onto the tracks by the train's innovative sliding platform screen doors. - Lift access, tactile flooring, wide fare gates, a communications system and a quality passenger information system are featured in all stations ensuring that they are accessible. - Can act as civil defence shelters.
14. Explain how the PT services interact with traffic and discuss the good and bad characteristics of the design	- MRT is fully segregated from general traffic.
15. How was the PT network acquired and discuss the procurement and governance models	- Mumbai Metro Line II – Japanese funding through International cooperation - Mumbai Metro Line I and III funding will be via PPP model. However due to huge capital costs associated with the construction of Metro III this line is not seen as a viable PPP model - The Metro de Lyon was constructed by the Transport en Commun Lyonnais in the 1970's, the public transport agency in Lyon. - The MTR Corporation was established by the Hong Kong government in 1975 as a state-owned enterprise with the purpose of setting up the MTR system. - In order to foster competition, the license to operate along Singapore's NEL was given to the newly established Singapore Bus Services (SBS).

16. What was the range of capital costs for the total scheme and on a per kilometre basis?	Refer to Table 7
17. What is the range of operational costs per route kilometre?	Refer to Table 7

Appendix D

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Appendix D References

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