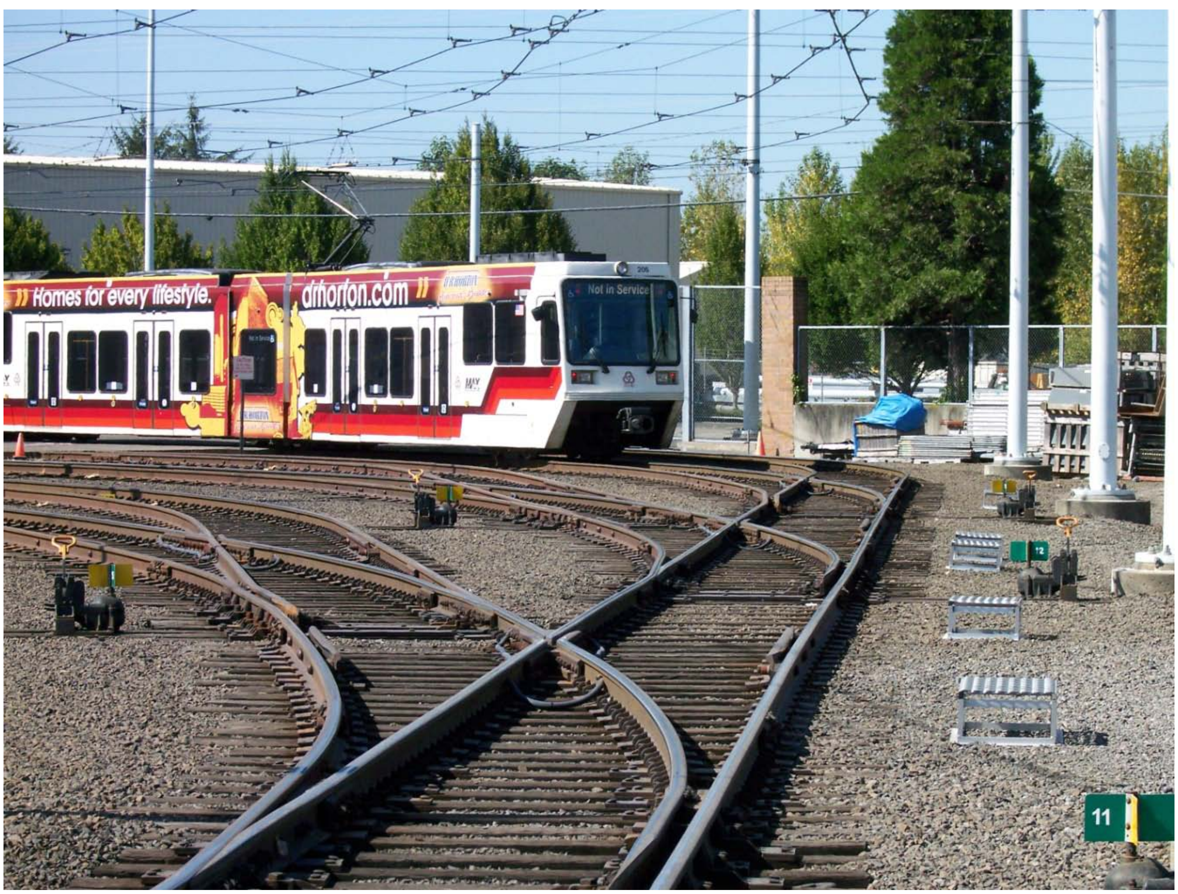
Tri-County Metropolitan Transportation District of Oregon

Light Rail Transit Fleet Management Plan

2013 - 2030

April 30, 2013
Revision 16 Draft



Revision History

Revision Number	Date	Approval	Comments
0	10/30/97	JG	Light Rail Fleet Analysis
1	4/1/98	JG	Original RFMP
2	6/1/99	JG	
3	10/15/99	JG	IMAX project
4	7/15/01	JG	
5	6/2/02	JG	
6	6/15/02	JG	Addendum
7	8/15/03	JG	
8	8/16/04	JG	
9	4/15/05	JG	
10	4/10/06	JG	I-205/Portland Mall Project
11	3/15/07	JG	Type 4 LRV details
12	7/30/08	JG	Milwaukie PE application revision
13	8/29/08	JG	CRC PE application revision
14	1/4/10	JG	Revision to address Milwaukie and CRC FEIS and PMOC comments
15	1/17/11	JG	Revision to address Milwaukie recalibration and PMOC comments
15 Final	6/21/11	JG	Additions for Preventive Maintenance Force Account Plan
16 Draft	4/30/13	JG	Update for CRC FFGA application

Cover photo: Track fan north of Ruby Main where connection to new west yard will be.

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1) Introduction

This plan documents characteristics of the light rail fleet and maintenance facilities as well as the process of forecasting TriMet's future fleet requirements. Also, the report projects the fleet's spare ratio in the overall context of an operations and maintenance program that meets or exceeds rail transit industry best practices. Tri-Met has and will continue to update this document periodically to reflect emerging trends in such key areas as ridership, service policies, and system expansion.

This plan update also includes TriMet's two light rail system extensions; the Portland-Milwaukie Light Rail (PMLR) Project currently under construction, and the Columbia River Crossing (CRC) Project that is a joint highway and transit project extending into Vancouver, Washington.

- **Milwaukie.** The Milwaukie extension will run from the south terminus of the Green and Yellow Lines on the Portland Mall 7.3 miles to a Park Ave. terminus south of Milwaukie. The line, designated as the Orange Line and scheduled to open in the Fall of 2015 to Park Ave. will require 14 LRVs initially and 18 LRVs in 2030, including spares, for 8.6-minute peak hour and 15-minute mid-day headways.

- **Columbia River Crossing (CRC).** The CRC extension is planned to run 2.8 miles from the north terminus of the Yellow Line at Expo Center to a terminus near Clark College in Vancouver, Washington. The extended Yellow Line, proposed to open in the Fall of 2019, initially requires 10 LRVs, including spares, to provide 7.5-minute peak hour and 15-minute mid-day headways. The planning horizon peak load forecast indicates that 19 LRVs, including spares, will be required to provide Yellow Line service in 2030 with 6-minute peak hour, 7.5-minute peak 2-hour and 15-minute mid-day headways.

Currently, TriMet has a fleet of 127 light rail vehicles (LRVs) for its MAX (Metropolitan Area Express) light rail system and 18 LRVs on order for the Milwaukie (Orange Line) extension. The fleet consists of 101 low floor cars and 26 high floor cars. A vehicle chronology follows:

- In 1986, a 26-vehicle fleet began serving passengers on a 15-mile line between Portland and Gresham.
- During 1997 and 1998, an additional 46 vehicles entered service in conjunction with an 18-mile system expansion to the West. These were North America's first low floor light rail vehicles.
- Prior to 1998 there were too few vehicles to keep pace with growing ridership. In response to these ridership trends and in consideration of the rare opportunity to purchase a small number of cars, TriMet's Board exercised an option (in the Westside vehicle contract) to purchase 6 additional vehicles put in service in 2000 and 2001.

- In 2000, 17 vehicles were ordered for the Interstate MAX, Yellow Line, opening.

- In 2002, 10 option vehicles were ordered for system ridership growth, 7 of those for Interstate MAX through 2020 as stated in the North Corridor FEIS.
- In 2006, 21 vehicles were ordered for the I-205/Portland Mall, Green Line extension. An option for 1 more vehicle was exercised in 2008.
- In 2012, 18 vehicles were ordered for the Portland to Milwaukie, Orange Line extension.

The light rail operating and maintenance program reflects industry best practices. Maintenance is conducted at two modern facilities, one, Ruby Junction, 13 miles east of Portland and the other, Elmonica, 10 miles to the west of Portland. Rather than conduct major vehicle overhauls at mid-life or periodically, TriMet follows the practice of progressive overhauls by subsystem as indicated by failure rate analysis for each subsystem.

This plan differs from the previous, June 2011, Revision 15 Final Plan in the following ways:

1. The Milwaukie extension is now under construction and scheduled to open in 2015, so it will be in operation when the proposed CRC extension is planned to open in 2019.

2. Some acronym definitions were added in Section 2.

3. All Figures and Tables that carry over into this revision were updated with current data.

4. In Section 5 the individual tables for the PMLR project were removed and a new MAX system table, Table 5.8, was added.

2) Definition of Terms and Acronyms

AWB - Average Weekday Boardings

Capacity … achievable – The portion of design capacity that reflects uneven loading of cars in a train and uneven passenger arrivals at stations upstream of the peak load point during the peak hour. For MAX this is 80% of design capacity or an average of 133 passengers per vehicle (266 per 2-car train) during the peak hour with standees at a density of 2.7 per square meter. This capacity is equivalent to a load factor of 2.1. This is TriMet's adopted loading standard for the peak hour.

Capacity … design (AW2) – The total number of seated and standing people a vehicle is designed to accommodate with some comfort as opposed to no comfort (crush load). Design capacity equals 166 passengers per vehicle (332 per 2-car train) with standees at a density of 4 per square meter. This capacity is equivalent to a load factor of 2.6.

Capacity … crush (AW3) – The total number of seated and standing people a vehicle is designed to accommodate with no comfort (crush load). As so defined crush capacity would equal 217 passengers per vehicle (434 per 2-car train) with standees at a density of 6 per square meter. This capacity would be equivalent to a load factor of 3.4. Historical manual counts have never recorded a 2-car train passenger load above 370 passengers even when holding a train until it was full after a special event.

Capacity … structural design (AW4) – The maximum passenger capacity of a vehicle used for calculating maximum loaded vehicle weight for structural analysis, with standees at 8 per square meter. This capacity would be equivalent to a load factor of 4.2.

CIP – Capital Improvement Program

CRC – Columbia River Crossing Project

Cycle time – The round trip travel time (run time in both directions) plus the layover times at both ends of the transit line.

Daybase train – A train that provides service most of the day and is in service generally between 16 and 20 hours per day.

Dwell time – The time a train spends stopped in the station waiting for passengers to board and a clear signal to proceed.

FFGA – Full Funding Grant Agreement

Forecast – Future passenger demand based on a mathematical model.

FTA – Federal Transit Administration

Gap train – A train with an assigned operator that waits at a designated location to fill a gap between scheduled trains that are off schedule creating an unacceptable gap in service.

Headway – The time interval between the passing of the front ends of trains moving along the same track in the same direction, usually expressed in minutes.

Life cycle – The length of time that it is economic to operate a vehicle. For light rail vehicles this is usually between 25 and 36 years.

Loading Standard - The maximum acceptable passenger load set by TriMet policy. TriMet's loading standard for an individual train equals 166 passengers per vehicle (332 per 2-car train) with standees at a density of 4 per square meter. This standard is equivalent to a load factor of 2.6. To achieve this standard for individual trains the standard for the peak hour is set lower to an average of 266 passengers per 2-car train.

Load factor – The number of sitting and standing passengers divided by the number of seats in a transit vehicle. A full-seated load has a load factor of 1. Load factor comparisons between different vehicles or transit systems are not valid because the ratio of areas for sitting and standing varies from vehicle to vehicle. The density of standees is a valid comparison of vehicle crowding.

LRV – Light Rail Vehicle

MAX – Metropolitan Area Express is the name of TriMet's light rail system

MDBF – Mean Distance Between Failures

OCC - Operations Command Center consists of Rail Central Control, Bus Dispatch, administrative staff and the equipment to support their activities

OSR – Operating Spare Ratio that equals the total active fleet minus the PVR divided by the PVR, (fleet-PVR)/PVR. The OSR is usually shown as a percentage.

Overhaul – The disassembly, inspection, repair or replacement and reassembly of all vehicle systems. Mid-life overhauls usually occur half way through the vehicle's life cycle.

PMLR – Portland -Milwaukie Light Rail Project, Orange MAX Line

PVR - Peak Vehicle Requirement is the number of vehicles needed to meet the expected passenger demand at the peak load points during the peak hour in the peak direction during a typical weekday and provide at least daybase headways elsewhere in the MAX system.

Passenger demand – The number of passengers and the time of day they desire to travel.

Peak tripper – A train that runs only during the peak periods to supplement the daybase trains when peak passenger demand is such that daybase trains alone cannot carry the loads. Trippers generally run from two to five hours at a time.

Progressive overhaul – The disassembly, inspection, repair or replacement and reassembly of only those vehicle systems that analysis of failure rates indicate is economically desirable.

Spare vehicle – Vehicles in the active fleet that are not needed during the peak periods for service and are therefore available for maintenance. If not scheduled for maintenance a spare can be used to replace a vehicle that fails in service.

Spare ratio – The number of spare vehicles divided by the PVR.

TC – Transit Center or passenger transfer station

Runtime – The one-way travel time from one end of a transit line to the other end.

3) The Existing System

a) TriMet Overview

The Tri-County Metropolitan Transportation District of Oregon, TriMet, was established by the State Legislature in 1969 to provide mass transit service to the more populous parts of Multnomah, Washington, and Clackamas counties (the Portland metropolitan area). The governing body of TriMet is a seven member board of directors, who are unpaid citizen volunteers appointed to four year terms by the governor and confirmed by the Oregon Senate.

The TriMet district covers about 530 square miles containing approximately 1.5 million people. TriMet's services as of September 2012 consist of:

- 104 peak light rail vehicles operating on 4 routes with 52 miles of right-of-way and 75 stations,
- 4 peak commuter rail vehicles operating on one 14.7-mile route with 5 stations.
- 498 peak buses operating on 79 routes with over 8,000 stops and over 1,000 shelters,
- 18 bus / train interchange transit centers and 57 park and ride lots providing about 10,000 parking spaces.

The light rail system is referred to as MAX, for Metropolitan Area Express. The 33-mile long, east to west, Blue Line was opened in stages during 1986, 1997 and 1998. The 5.6-mile Airport Extension Project, the Red Line, opened for revenue service in September of 2001. The 5.8-mile Interstate Ave. Extension Project, the Yellow Line, opened for revenue service in May of 2004. The 6.7-mile I-205/Portland Mall Extension Project, the Green Line, opened for revenue service in September of 2009. Figure 3.1 is a map of the system from September 2012 on. Each line runs between the following terminals:

- Blue – Government Center and Cleveland Ave.
- Red – Portland International Airport (PDX) and Beaverton Transit Center (BTC)
- Yellow – Expo Center and South Terminal just south of Portland State University (PSU)
- Green – Clackamas Town Center (CTC) and South Terminal / PSU

Current headways by line are as follows:

Blue – 15 minute daybase and 7 minute peak hour
Red – 15 minute daybase and peak hour
Yellow – 15 minute daybase and peak hour
Green – 15 minute daybase and peak hour

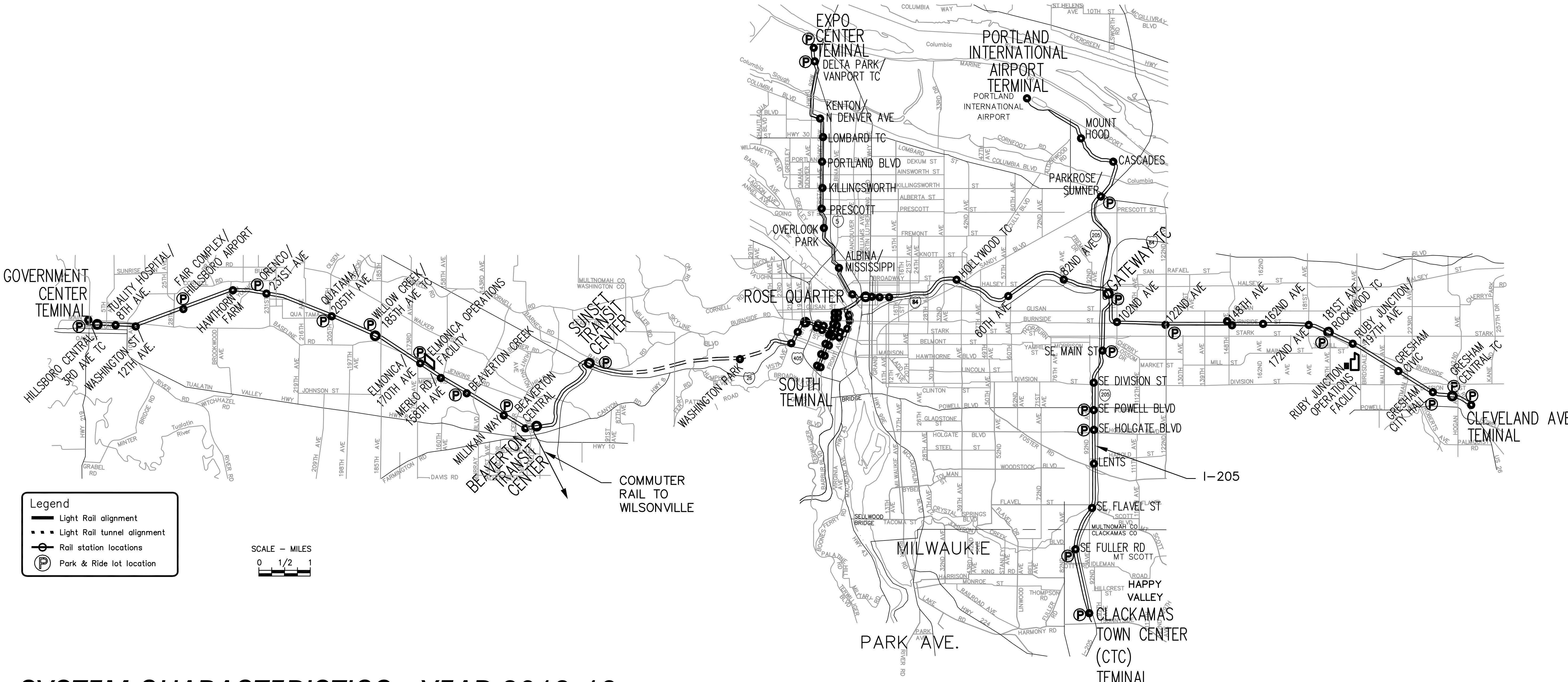
Blue Line headways include some Red Line trains that become Blue Line trains by running west to Hillsboro Government Center in the PM peak.

Combined or trunk headways along shared track are as follows:

Rose Quarter to Gateway - 5 minute daybase and 3 minute peak hour
Downtown east/west to BTC - 7.5 minute daybase and 5 minute peak hour
Downtown north/south – 7.5 minute daybase and peak hour

FIGURE 3.1

TRI-MET LIGHT RAIL SYSTEM



SYSTEM CHARACTERISTICS - YEAR 2012-13

- 52 ROUTE MILES, 4 LINES (BLUE, RED, YELLOW & GREEN)
- 127 LRV'S (26 TYPE 1, 52 TYPE 2, 27 TYPE 3, 22 TYE 4)
- 75 PASSENGER STATIONS, 107 PLATFORMS
- 3-15 MINUTE HEADWAYS IN PEAK PERIODS
- 51A.M., 52 P.M. TRAINS OPERATING IN PEAK PERIODS (42 MIDDAY)
- 120,000 TO 138,000 WEEKDAY PASSENGERS

TRI MET

Responsibility for the rail fleet is generally split between the Operations Division and the Capital Projects Division. Responsibility for design, procurement, and testing predominately rests with systems engineers within the Capital Projects Division. Operation and maintenance of the fleet is the responsibility of the Operations Division.

b) Light Rail Vehicles (LRV's)

The fleet consists of vehicles produced by two manufacturers: Bombardier and Siemens, referred to as Type 1 and Type 2, 3, 4 and 5, respectively. At the end of 2005 the fleet included 26 Type 1 LRVs, 52 Type 2 LRVs and 27 Type 3 LRVs. The I-205 / Portland Mall MAX project contract for 22 Type 4 vehicles resulted in these cars being available for service in 2009. The Portland to Milwaukie Light Rail (PMLR) project has a contract for 18 Type 5 LRVs that will be available for service in 2015, see Table 3.1.

Table 3.1 Fleet Size Chronology

Ordered	Available	Increase	Fleet Size	Notes
1982	1986	26	26	Original Eastside Purchase, cars 101-126 all active
1993	1997	8	34	Piggy-back Eastside order with Westside contract, cars 201-208, all active
1993	1997	2	36	Favorable price allowed an increased order, cars 209 & 210, both active
1993	1998	29	65	Original Westside Order, cars 211-239, all active
1995	1998	7	72	Expansion to accommodate Hillsboro Extension, cars 240-246, all active
1997	2000	6	78	Option allowed increased order to meet system growth, cars 247-252, all active
2000	2003-4	17	95	Interstate (North) MAX Line Order, cars 301-317, delivery 2003
2002	2004-5	10	105	Option allowed increased order to meet 2020 fleet size of 24 for Interstate, cars 318-327, delivery 2004-5
2006	2009	22	127	I-205/Portland Mall MAX Line Order, cars 401-422, delivery 2008-9
2012	2014-15	18	145	Portland to Milwaukie MAX Line Order, cars 521-538

With the introduction of the Type 2, 3, 4 and 5, low floor vehicles, all two-car consists must include at least one Type 2 or 3 vehicle or two Type 4 or 5 vehicles to insure accessibility for mobility devices. Type 1 vehicles have steps and cannot operate alone as the train would not be accessible to passengers requiring the use of mobility devices. Also, the system is designed to operate with trains of no more than two cars. (A two car train is roughly the length of one city block, thus when stopped at a platform cross-traffic can proceed unimpeded.)

Type 1 – Bombardier

The Bombardier vehicles were placed into service in September 1986. BN of Belgium designed the cars. Bombardier, the principal shareholder of BN, assembled TriMet's vehicles in Barre, Vermont. The cars are electrically propelled (DC drive) to a maximum design speed of 55 miles per hour, are constructed of corten steel, and have bi-directional operating capability. The cars seat 76 with a design capacity of 166 passengers with standees at 4 per square meter.

Type 2 and Type 3 – Siemens Duewag SD 660

The Siemens' vehicles entered service at various times between August 1997 and September 1998. Siemens Duewag of Germany designed the cars, with final assembly in Sacramento, California. They are designed with operator cabs at both ends to allow bi-directional operation. There is seating for 64 people and a design capacity of 166 passengers with standees at 4 per square meter. The 92-foot long cars are air-conditioned.

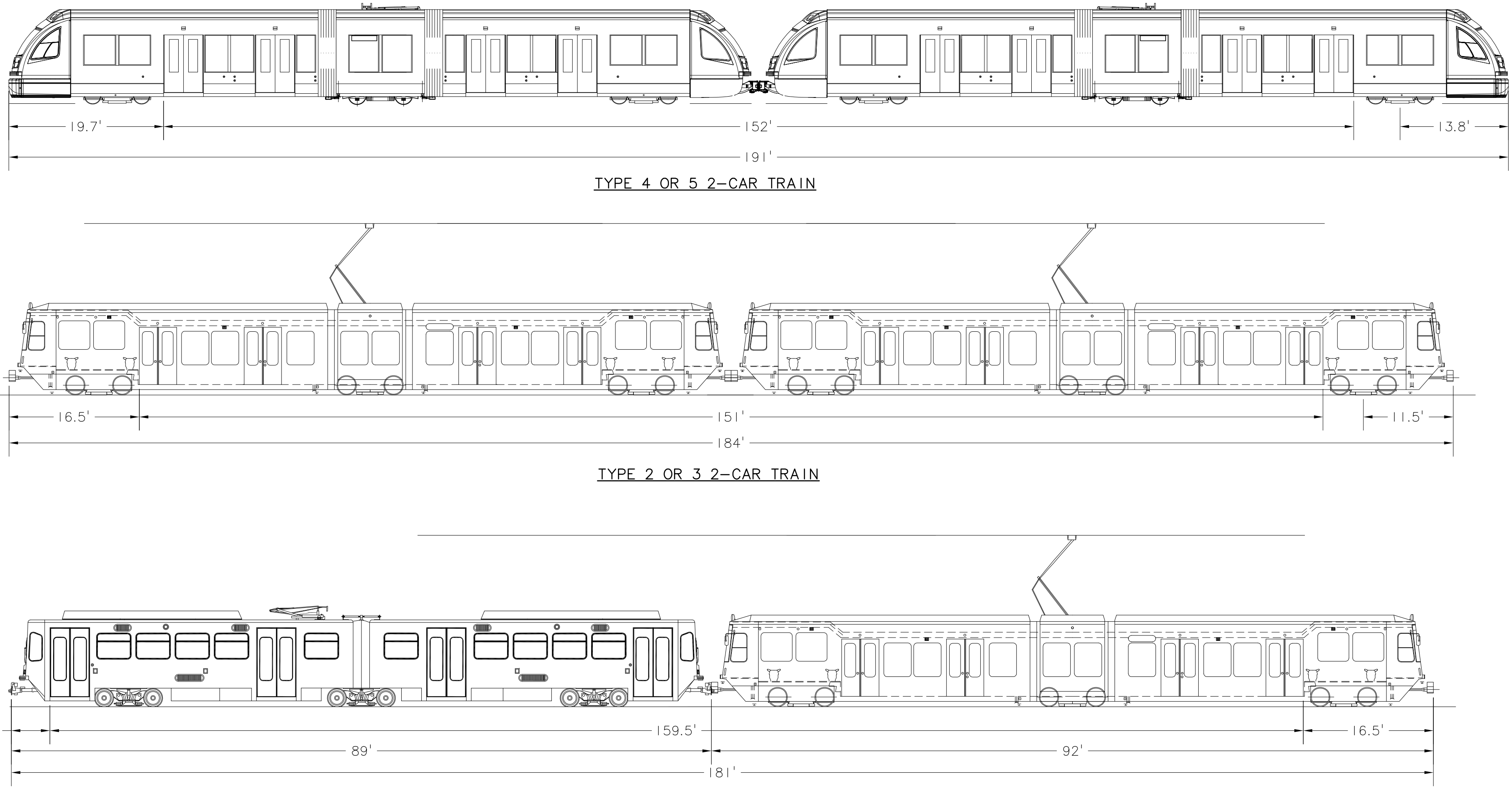
These are the first low floor light rail vehicles placed into service in North America. The cars are constructed of high tensile steel and designed for a top speed of 55 miles per hour with electric propulsion (AC drive). The cars are double articulated and can be operated in train sets of up to four, but are limited to two due to the length of MAX stations. These cars can be used in any combination of Type 1, Type 2 or Type 3 vehicles. Along with passenger/operator-activated bridgeplates on the center four doors, the low floor design allows full wheelchair access. The low floor section encompasses 70% of the vehicle, which is supported by a non-powered truck in the center articulation section.

Type 3's are the same as Type 2's with the following additions:
- Automatic passenger counters, APC's, for collecting better passenger load data for scheduling purposes
- Thermoking instead of Sutrak HVAC equipment.

Type 4 and 5 – Siemens S70

Type 4 and 5 vehicles are not backward compatible with the previous fleet in terms of the ability to train-line electrically with Type 1, 2 and 3 vehicles. Therefore, they are not able to run coupled together as trains with the existing Type 1, 2 or 3 vehicles in revenue service, see Figure 3.2 for all 2-car train consist configurations. Type 4 and 5 vehicles are mechanically compatible so that they may tow or be towed by a previous fleet vehicle. Type 4 and 5 vehicles are single-ended (have a control cab only at one end) which means they will be run as two-car trains, since the ends of the existing and planned lines do not have loops. Single-ended cars were selected because they have 5% greater passenger capacity. All vehicles will be capable of operating anywhere in the MAX system, so that the single-ended vehicles can be used where passenger loads and train congestion are greatest.

A schematic of the individual car types and lengths is shown in Figure 3.3.



NO.	DATE	BY CHK.	APPD.	REVISIONS

JG DESIGNED 01/07 DATE

JHM DRAWN 01/07 DATE

CHECKED DATE

APPROVED DATE

TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON

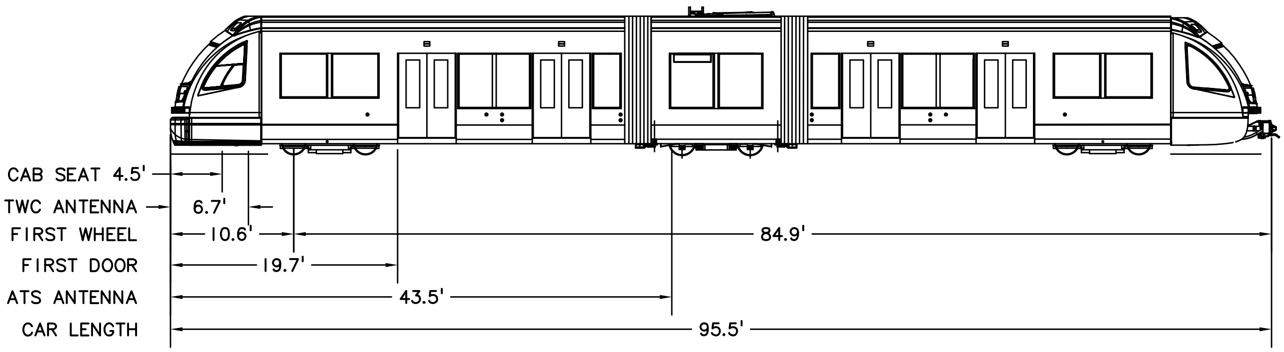
TRI MET

CAPITAL PROJECTS DIVISION
1800 SW FIRST AVE., SUITE 300
PORTLAND, OREGON 97201

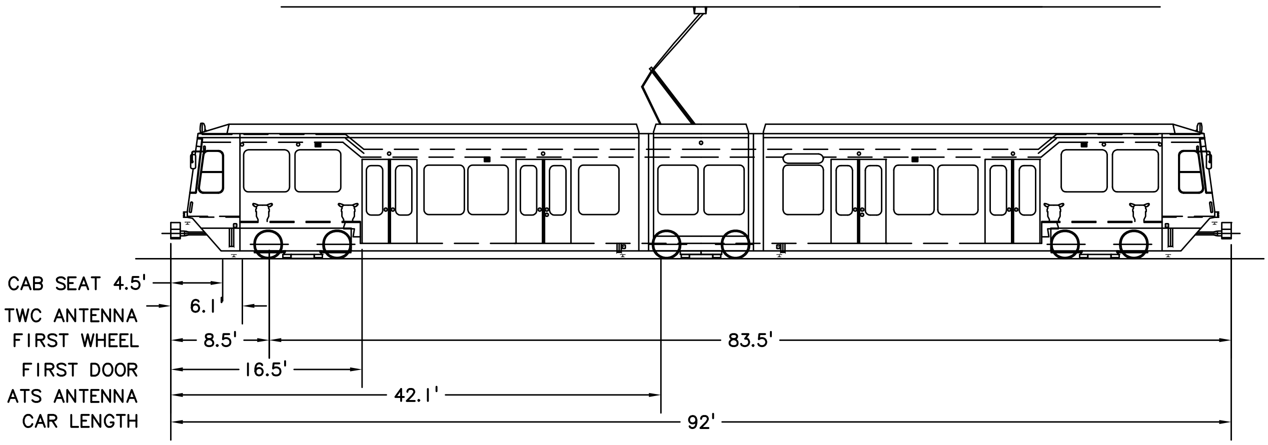
SUBMITTED: DATE: APPROVED: DATE:

FIGURE 3.2
REVENUE SERVICE 2-CAR CONFIGURATIONS

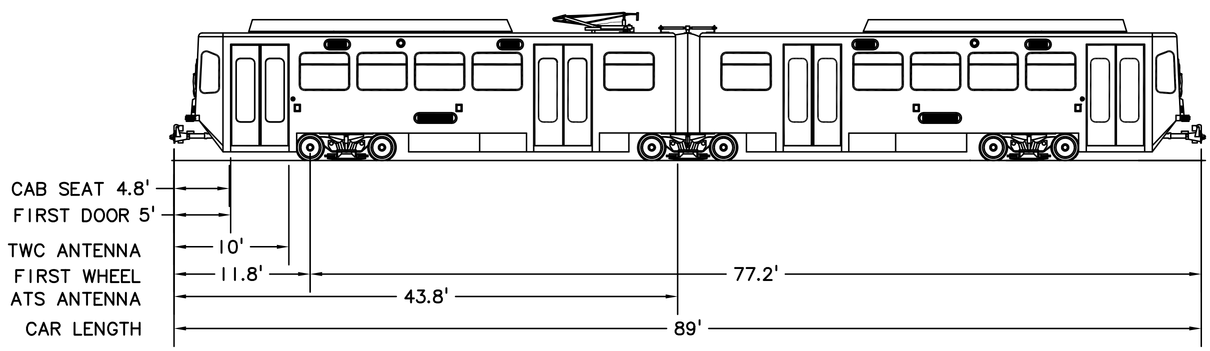
SCALE: NOT TO SCALE
DRAWING NO.: FIG 3.2 2-CAR CONFIG
CONTRACT NO.:
SHEET NO.:



TYPE 4 OR 5



TYPE 2 OR 3



TYPE 1

TRIMET CAPITAL PROJECTS DIVISION 1800 SW FIRST AVE, SUITE 300 PORTLAND, OREGON 97201			FIGURE 3.3 LRV CONFIGURATIONS	
DRAWN JHM	DESIGN JG	CHECKED JG	APPROVED: JG	DATE: APRIL 2013
SCALE: NOT TO SCALE	FILE NAME: FIG 3.4 LRV CONFIGS		CONTRACT NO:	SHEET NO: 1 OF 1

c) Maintenance Facilities

TriMet's Rail Operations Department has two operations and maintenance facilities. Ruby Junction is located two miles west of the eastern terminus in Gresham and Elmonica located in Beaverton seven miles east of the western terminus in Hillsboro. The two facilities operate as a unit with most specialized functions, such as central train control and heavy maintenance work, occurring at Ruby Junction.

Ruby Junction

This facility, opened in 1985, houses TriMet's light rail vehicle maintenance department. During 1995, remodeling prepared the facility to service the new low floor vehicles as well as house a new system-wide communication and control center, based on a fiber optic network (SONET) and supervisory control and data acquisition (SCADA) technology. For the Interstate MAX extension, Yellow Line, that opened in 2004 new storage tracks were added and a new building, Ruby South was built to house Maintenance of Way (MOW) and a new LRV body shop and paint booth. In 2015 the Operations Command Center (OCC) consisting of rail central control, bus dispatch and some rail operations staff will be relocating to TriMet's Center Street facility. A back up OCC of reduced size will remain at Ruby Junction.

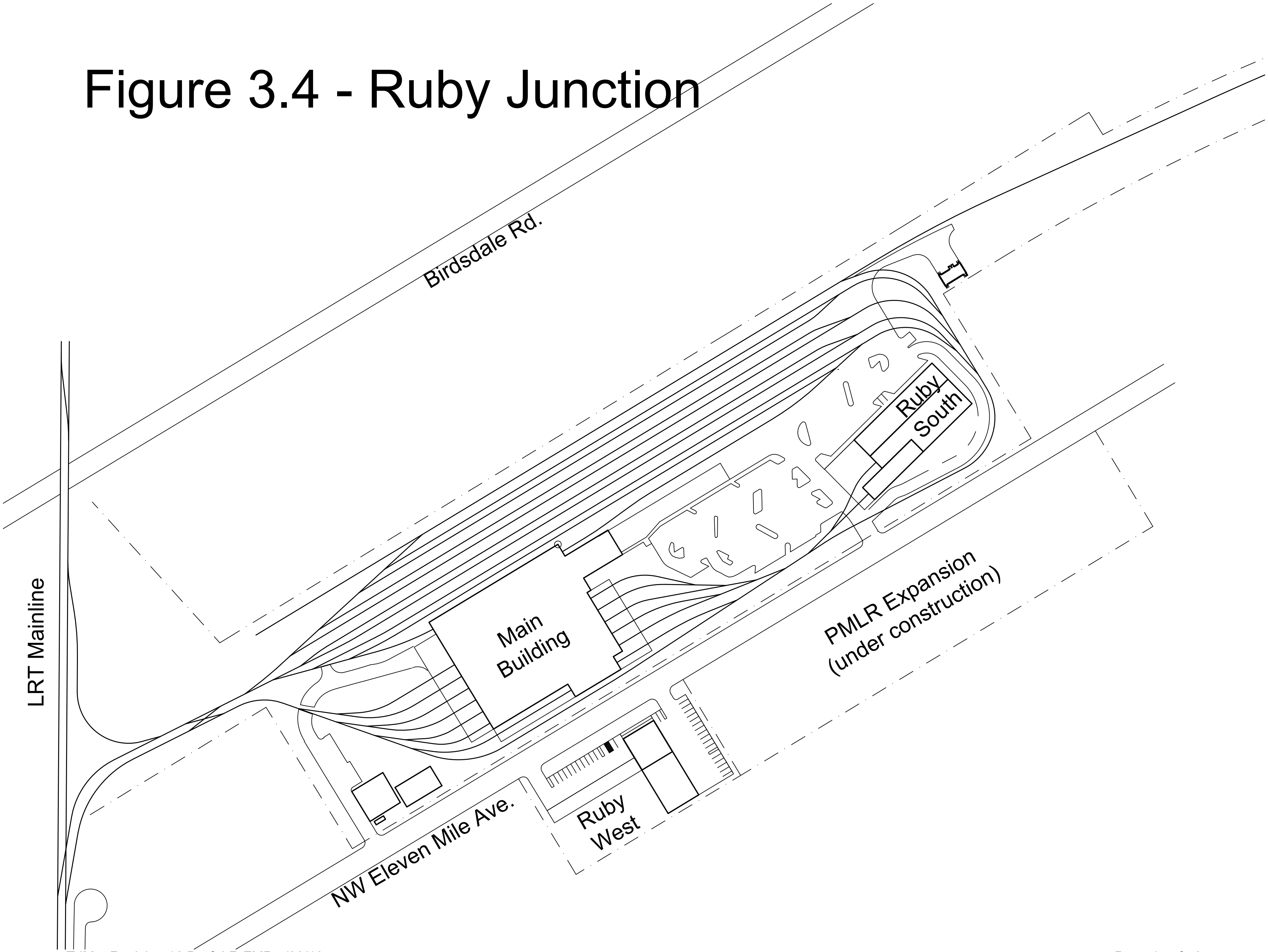
The 17-acre facility (see Figure 3.4) includes the following:

- Storage track for 67 vehicles, 20 additional spaces are under construction on 5.6 acres for 2015
- Ruby Main, a 112,000 square foot three story shop, operations and administrative building with 13 maintenance bays excluding the wash bay and the 2nd bay on the wheel truing track, a truck shop and two sets of in floor jacks
- Ruby West, a 9,500 square foot non-revenue vehicle (support vehicles) servicing shop and storage area
- Ruby South a satellite building with a 21,000 square foot footprint, containing paint and body bays, one flat track bay for interior car work, a metal fabrication area, some body parts storage, a Maintenance-of–Way (MOW) shop and offices, restrooms, lockers and a lunch room to accommodate 60 workers over 3 shifts.
- 161 employee and visitor parking spaces, 42 additional spaces are under construction for 2015
- A 6,700 square foot MOW shop and covered/open MOW storage

Elmonica

This facility was constructed in conjunction with the Westside project. To allow for testing and storage of new vehicles, the construction contract for this facility was one of the first completed, opening in 1996. The design was based on existing facilities in Europe, where low floor cars are commonly used.

Figure 3.4 - Ruby Junction



The 18-acre facility (see Figure 3.5) includes the following:

- Storage track for 53 vehicles
- A 70,000 square foot two story shop and operations building and 1,500 square foot storage building for LRV cleaning supplies
- A 6,000 square foot parts storage building (mostly MOW spare parts)
- 9 maintenance bays excluding the wash bay and the 2nd bay on the wheel truing track (six with access to the LRV roofs)
- A seven and a half ton overhead crane
- 97 parking spaces

Storage Yard Size vs. Fleet Size

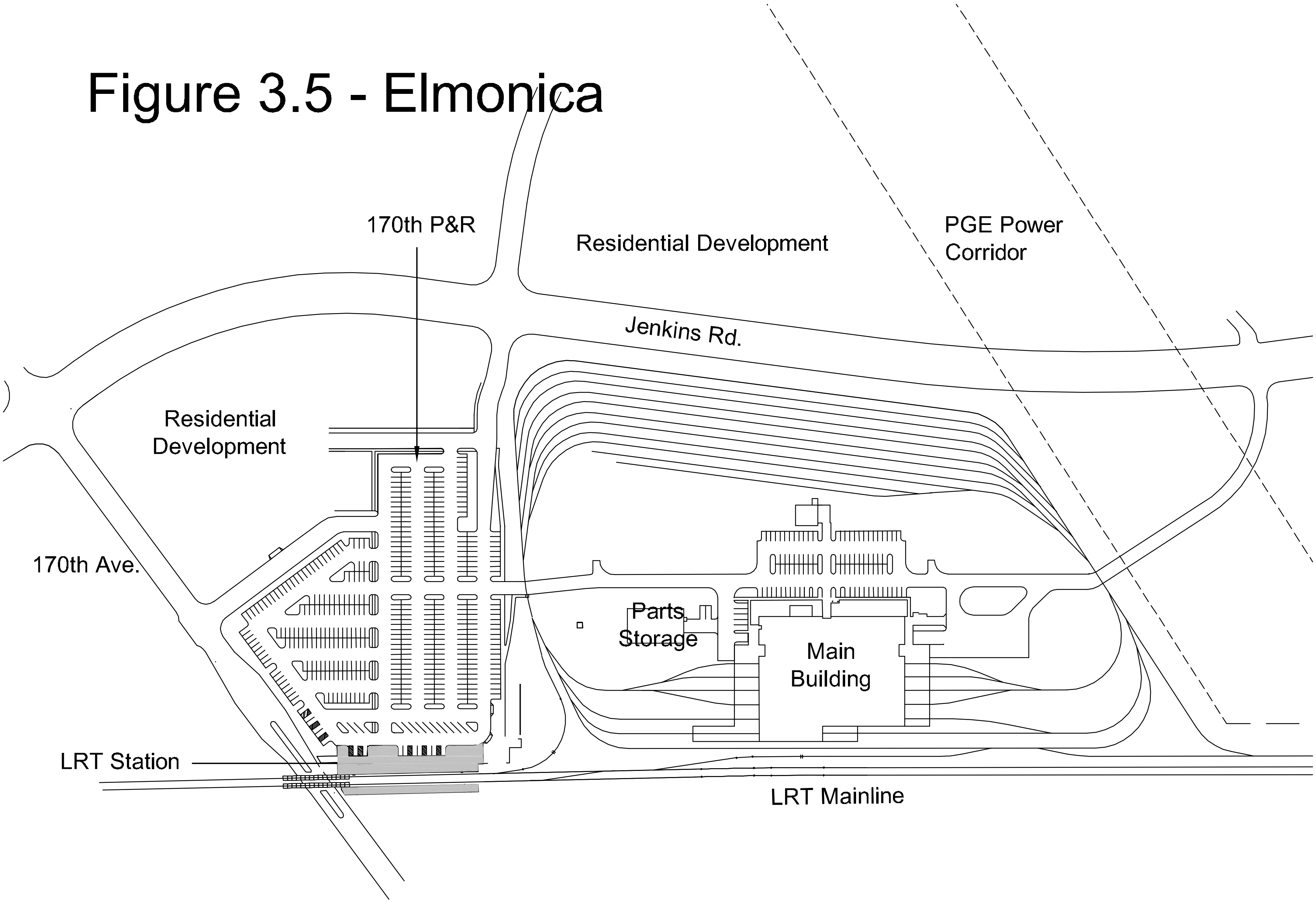
Since 1986 Tri-\Met has had a surplus of storage yard spaces to accommodate fleet size increases due to ridership growth. The I-205 / Portland Mall South Corridor MAX Green Line extension only added 5 spaces reducing the surplus to minus seven in 2009, see Table 3.2. The 2009 surplus of -7, although not ideal, is workable since 7 or more LRVs will be in some of the 26 available repair bays, not including wash bays.

Table 3.2

Storage Yard Size vs. Fleet Size

		2004	**2007**	**2009**	**2015**
Yard storage spaces	Ruby Junction	48	67	67	67
	Elmonica	42	42	48	53
Yellow/Orange Line additions:	at Ruby Junction	19			20
	at Elmonica		6		
Green Line additions	at Elmonica			5	
Total storage		**109**	**115**	**120**	**140**
	Existing LRV Fleet	78	105	105	127
	Yellow/Orange Line fleet additions	24			18
	Green Line fleet additions			22	
	System Growth fleet additions	3			
Total fleet		**105**	**105**	**127**	**145**
Surplus		4	10	-7	-5

Figure 3.5 - Elmonica



d) Service Design, Ridership and Fleet Size

In September of 2009 the MAX system evolved from a 3-route to a 4-route system. The four routes are identified by colors: the Green Line for the south corridor service to Clackamas Town Center, the Yellow Line for the north corridor service to Expo Center, the Red Line for Airport to Beaverton service via Downtown Portland and the Blue Line for Gresham to Hillsboro service via Downtown Portland. All four lines share the same right-of-way and tracks between Rose Quarter and the west end of the Steel Bridge, as shown in Figure 3.6 which is a time scaled diagram of the track plan and the MAX routes that use it. The north, east, south and west peak load points are also shown in Figure 3.6.

The MAX light rail system's service design is based on the use of daybase trains to provide the base service, 15-minute headways throughout the system. These 15-minute policy headways are provided for most of the service day until about 10:30 PM when there is a transition to 30-minute headways. As a supplement to the daybase trains, peak tripper trains are added during peak periods where peak passenger demand is such that daybase trains alone cannot carry the loads. Trains are mostly 2-car consists, but can be single cars if passenger demand permits. The downtown block length, tunnel station platform lengths and the station design criteria limit train length to a maximum of two cars.

Peak passenger demands are caused primarily by work trips and are greatest inbound, to downtown Portland, in the AM peak and outbound in the PM peak. As a result the Blue and Red lines have two peak load points, one east of downtown at Lloyd Center and one west of downtown at Goose Hollow. The Yellow Line's peak load point is north of Rose Quarter while the Green Line's peak load point is east of Lloyd Center. These are the points where most trains have their heaviest passenger loads and are used to apply TriMet's loading standards, detailed in Section 5.b, to estimate future peak vehicle requirements (PVR) and to monitor crowding that may require schedule or service adjustment.

The existing peak vehicle requirements (PVR) are shown in Table 3.3. Since April of 2004, TriMet has been receiving accurate passenger counts through the automatic passenger counters built into the newer light rail cars. TriMet continually monitors crowding on MAX and makes adjustments within our ability to shift capacity to alleviate it. A typical two-car (four section) MAX train can seat 128 people and carry 332, including standing passengers. When average daily peak passenger loads on a two-car train reach 266 passengers at the peak load point TriMet either adjusts that train's schedule or adjusts its leader's schedule or both. If schedule adjustments do not solve the problem another train may be added. TriMet makes these changes to accommodate and foster further ridership growth.

The light rail system's average weekday boardings (AWB) have been about 1,000 passengers per LRV since MAX opened in 1986, see the comparison of AWB vs. LRVs in Figure 3.7.

Figure 3.6

MAX Route Overlap on Time-Scaled Track Plan

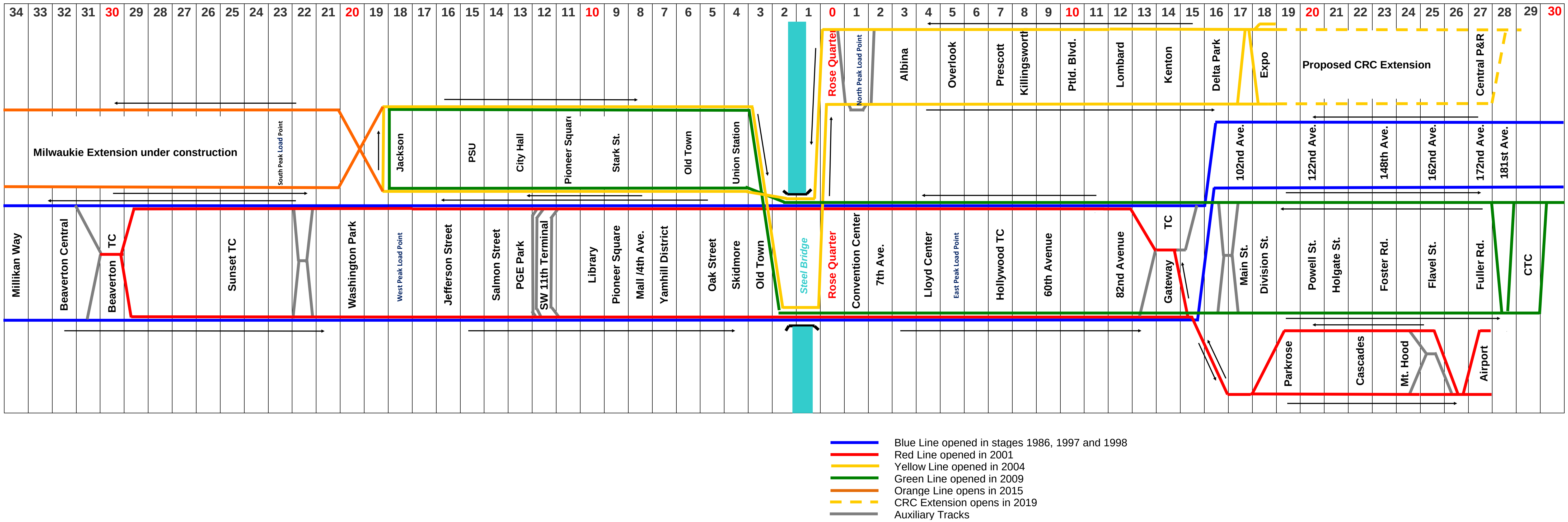
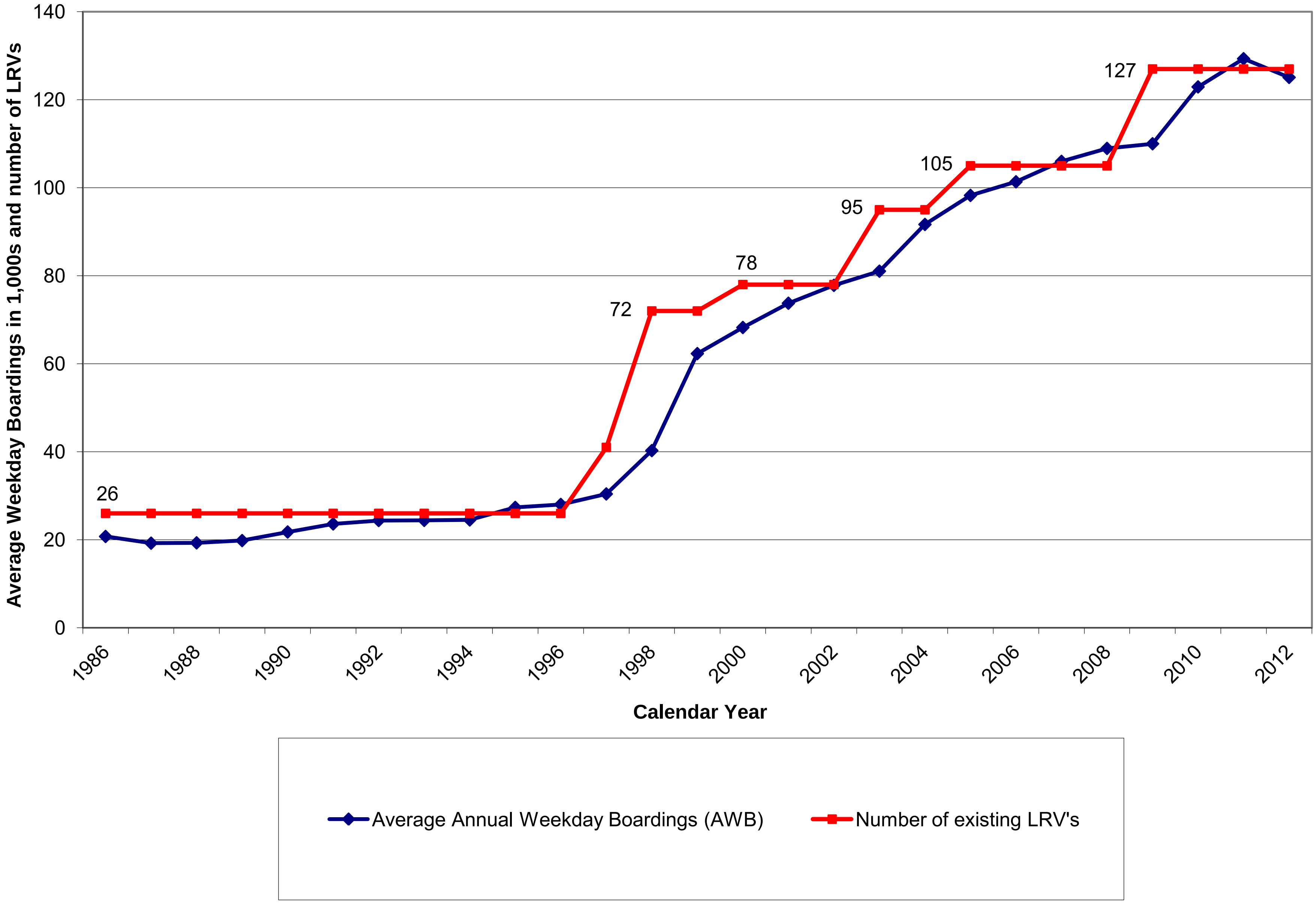


Table 3.3
2012-13 MAX Light Rail Peak Vehicle Requirements
based on the evaluation of APC data for individual trains

Fall of 2012	**Loads from Automatic Passenger Counters**						
MAX Line	East-West Gresham to Hillsboro		AirMAX: through routed to Beaverton TC		Interstate MAX: Expo to PSU	I-205: CTC to PSU	Total
Travel Times							
Adjusted Travel Time	96		58		34	46	
Round Trip Travel Time	192		116		68	91	
Daybase layover time: total for both ends (for operator break and schedule recovery)	38		34		22	29	
Travel time as a % of cycle time	83%		77%		76%	76%	
Daybase Cycle Time (round trip travel time + total layover time in minutes)	230		150		90	120	
Daybase							
Daybase Headway in minutes	15		15		15	15	
Number of trains required for daybase (Cycle time / headway) + 1 for Blue Line	**17**		**10**		**7**	**8**	**42**
Number of daybase trains passing the peak load point(s) in peak hour	4		4		4	4	
PM Peak Period: Peak Hour							
	East	West	East	West	North	East	
Peak Hour Volume from APCs	**1,287**	**1,641**	**571**	**673**	**631**	**752**	
Minimum number of 2-car trains required (forecast/266)	4.8	6.2	2.1	2.5	2.4	2.8	
Actual number of 2-car trains (2 Red Line trains continue to Gov. Ctr. In the PM peak)	6	6	4	6	4	4	
Achievable Capacity with standard average load, see Section 5.b	1,596	1,596	1,064	1,596	1,064	1,064	
Average Headway	10.0	6.0	15.0	10.0	10.0	15.0	
Number of peak hour trippers required past the peak load point(s)	**2**	**2**	**0**	**2**	**0**	**0**	**6**
PM Peak Period: Peak 2-Hours							
Peak 2-Hour Volume from APCs	**2,093**	**2,754**	**1,142**	**1,182**	**1157**	**1,421**	
Minimum number of 2-car trains required (forecast/266)	7.9	10.4	4.3	4.4	4.3	5.3	
Actual number of 2-car trains in peak hour	6	6	4	6	4	4	
Actual number of 2-car trains in peak 2-hours	12	12	8	10	8	8	
Average Headway	10.0	10.0	15.0	12.0	15.0	15.0	
Number of transition trippers required past the peak load point(s)	**2**	**2**	**0**	**0**	**0**	**0**	**4**
Fleet Size							
Total peak trains (daybase trains + peak trippers)	**25**			**12**	**7**	**8**	**52**
Peak Vehicle Requirement (PVR) = total peak trains x 2, except shuttle	50			24	14	16	104
Spares = Total Fleet minus PVR minus 2 Type 1s undergoing body rebuild							21
Active Fleet including spares							125
Total Fleet including Spares							127
Spare Ratio							20.2%
Notes: Achievable peak hour peak direction capacity per 2-car train averages 266 passengers per train at the peak load point.							

Figure 3.7
Weekday Ridership Growth vs. LRV Fleet Size



4) System and Service Expansion

a) Orange Line under construction opens 2015; PMLR Project

This is the second phase of the South Corridor Project; the first phase was the Green Line. The Orange Line extends light rail south from Downtown Portland to south of downtown Milwaukie at Park Ave., see Figure 4.1. The extension will operate as a through route with the North Corridor's Yellow Line, Interstate Ave. MAX. Revenue service on the Milwaukie extension is scheduled to begin in 2015, initially with 14 Type 5 LRVs (12 in service and 2 spares) to provide 10-minute peak hour and 15-minute mid-day policy headways. A fleet of 18 LRVs (14 in service and 4 spares) have been ordered to accommodate the estimated 2030 passenger demand of about 27,000 weekday boardings on this extension.

b) Columbia River Crossing (CRC) Planned Opening 2019

The Columbia River Crossing (CRC) project will extend the Yellow Line north from the Exposition Center station in Portland to a terminus near Clark College in Vancouver, Washington, see Figure 4.1. Revenue service on the CRC extension is planned to begin in 2019, initially with 10 LRVs (8 in service and 2 spares) to provide 7.5-minute peak hour and 15-minute mid-day headways. It was estimated that a fleet of 19 Type 5 LRVs (16 in service and 3 spares), will be needed to accommodate an average of about 19,000 weekday boardings on this extension in 2030. The large increase in trains is caused by the fact that trains added to the extension must also travel the length of the existing Yellow Line to shorten headways to 7.5 minutes for a full 2 hours in the peak periods to provide the needed passenger capacity, see Section 5 for calculations.

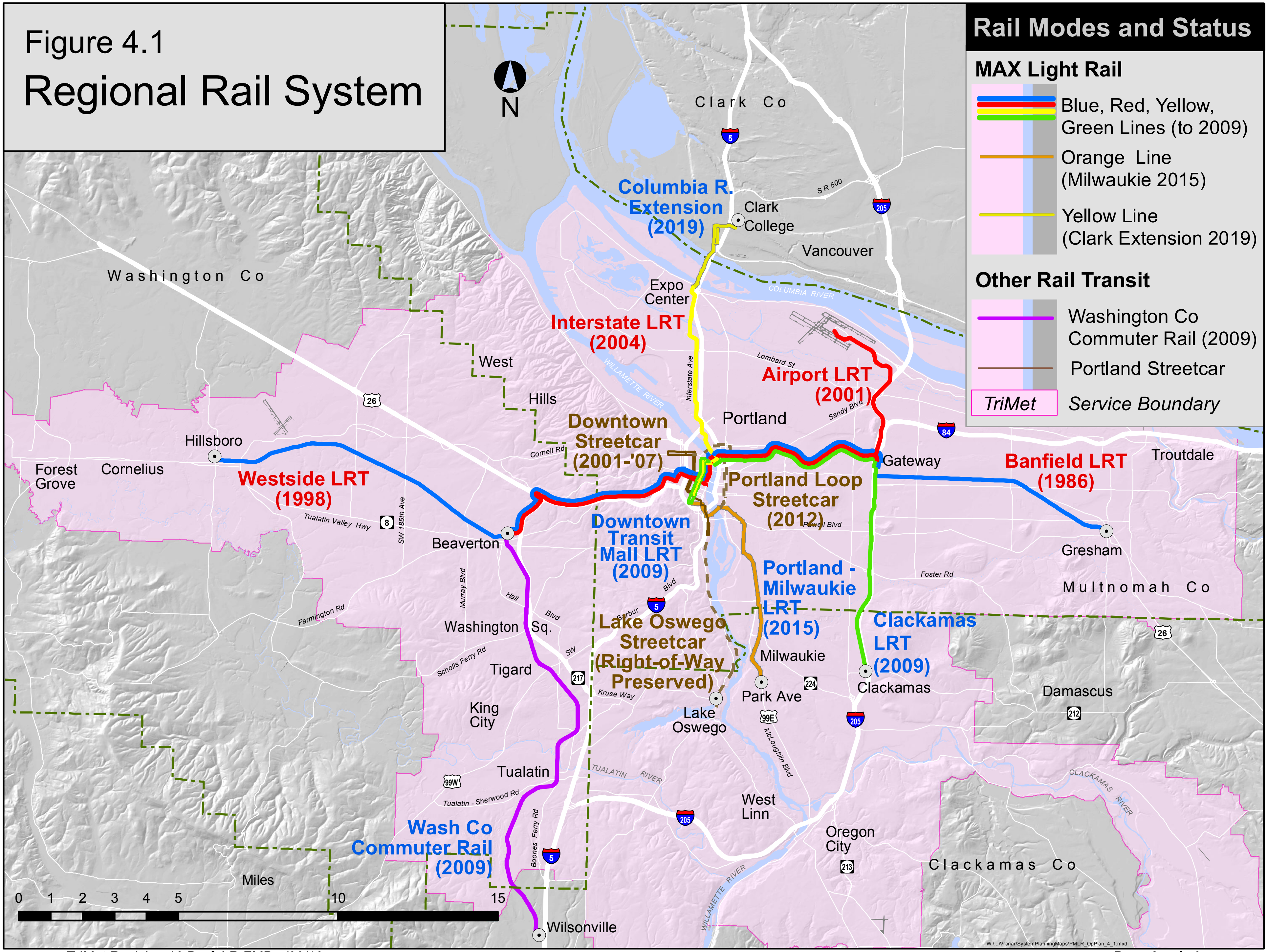
Type 5 vehicles will be compatible with Type 4 vehicles but not electrically compatible with Type 1, 2 and 3 vehicles. Therefore, they will not be able to run coupled together as trains with Type 1, 2 or 3 vehicles in revenue service. Type 5 vehicles will be single-ended like the Type 4 vehicles.

c) Green Line Service Improvements

Twenty-two LRVs were purchased for the Green Line within the FFGA. The 2025 passenger demand forecast indicated that 30 LRVs will be needed in the planning horizon year of 2025. This means TriMet needs to acquire 8 more LRVs prior to about 2025. TriMet will monitor actual ridership growth to determine when these 8 LRVs need to be acquired.

Figure 4.1

Regional Rail System



d) Operations and Maintenance Facility Expansion

Facility expansion for LRV storage and maintenance will be done at Ruby Junction for both projects. The expansion will occur in two phases: Phase 1 for the Milwaukie project is under construction in 2013 and 2014 while Phase 2 is planned to be built in 2015 and 2016 with CRC project funding.

Operation and Maintenance Facility additions for the Milwaukie fleet at Ruby Junction (Phase 1) on about 5.7 acres of land acquired with Milwaukie project funds include:

- LRV Storage
    - Construct the first phase of Ruby's west storage yard to a capacity of 20 spaces on 5 tracks (4 LRVs on each track).

- Maintenance Bays
    - Relocate the wash bay to make room for added maintenance bays.
    - Add 2 pit & platform bays on the west side of the main shop.

- Rail Control Improvements
    - Build a new Operations Command Center (OCC) on a more central TriMet site, Center St., to accommodate control room expansion, redundant equipment for reliability in emergencies and an overview display of greater height for acceptable readability.
    - Retain space for a scaled down back-up OCC at Ruby Junction.

- Parking and Parts Storage
    - Add about 42 parking spaces for the increase in workers.
    - Prepare outdoor storage area site for equipment that can be stored outside.
    - Retain one of the acquired existing buildings for indoor covered parts storage.

- Unit Repair Area
    - Expand the unit repair area on the 1st floor of the main shop through the relocation of administrative functions and parts storage to other floors or buildings.

Operation and Maintenance Facility additions for the CRC fleet at Ruby Junction (Phase 2) on about 4.8 acres of land acquired with CRC project funds will include:

- LRV Storage; 22 new spaces
    - Complete Ruby's west storage yard for a total capacity of 42 spaces on 7 tracks (6 LRVs on each track)

- Maintenance Bays; Complete the shop expansion by
    - Adding 3 pit & platform bays.
    - Adding 1 bay for a second wheel truing machine.

    - Adding 1 flat bay with jacks for truck work.

- Ruby Main Building Improvements
    - Finish the back up Operations Command Center (OCC) at Ruby.
    - Update locker and lunch rooms for additional operators and maintenance personnel.

- Parking and outdoor storage
    - Add about 52 parking spaces for the increase in workers.
    - Finish outdoor storage area for equipment that can be stored outside.

- Unit Repair Area
    - Retain an acquired existing shop building for MOW shop use.
    - Retain and adapt other acquired buildings for reuse.

A more detailed description and drawings of these improvements are contained in the "Operating and Maintenance Facilities Basis of Design Report for Entering Final Design" dated October 2010.

5) Demand for Revenue Vehicles

This Section is consistent with FTA guidance including the 1999 Hiram J. Walker Memo that outlined eight steps to calculate the demand for revenue vehicles. Those step numbers are shown in this section and in Section 8, Vehicle Demand and Supply Balance, to provide easy reference to the FTA guidance.

a) Passenger Demand Forecasts (Step 1)

Peak Passenger Loads. The Blue and Red Lines have two peak load points: Lloyd Center east of downtown and Goose Hollow (SE18th & Jefferson) west of downtown. The Green Line also passes Lloyd Center and serves that peak load point. The Yellow Line's peak load point is just north of Rose Quarter before it shares the right-of–way with the Blue, Red and Green Lines over the Steel Bridge and into downtown. The Milwaukie extension will have a new peak load point south of Tacoma while CRC is an extension of the Yellow Line and will share its peak load point, north of Rose Quarter.

2012 to 2030 actual, forecasted and interpolated PM peak direction passenger loads are shown in Table 5.1. Volumes were forecast for 2015 (Milwaukie model runs), 2018 (CRC FEIS model runs) and 2030 (CRC model runs in 2012) using the regional EMME2 travel demand model. CRC is now planned to open in 2019 so those load volumes are linear interpolations between 2018 and 2030. The Red, Green and Blue lines volumes are linear interpolations between actual 2012 counts and the 2030 forecast from the last CRC model run. This is also true for the Yellow line volumes between 2012 and 2018 using the 2030 baseline forecast.

PM peak passenger loads are used for fleet size forecasting because they are higher than AM peak passenger loads.

Table 5.1

PM Peak Direction Passenger Loads past the peak load points

	Milwaukie Orange Line **south** of Holgate		CRC Yellow Line **north** of Rose Quarter		Blue, Red and Green Lines **east** of Lloyd Center		Blue and Red Lines **west** of Goose Hollow	
	1-hour	2-hour	1-hour	2-hour	1-hour	2-hour	1-hour	2-hour
2012	0	0	**631**	**1,157**	**2,610**	**4,656**	**2,314**	**3,936**
2013	0	0	639	1,166	2,756	4,872	2,384	4,044
2014	0	0	647	1,175	2,902	5,088	2,454	4,152
2015	**1,239**	**2,354**	655	1,184	3,048	5,304	2,524	4,260
2016	1,266	2,374	663	1,193	3,194	5,520	2,594	4,368
2017	1,293	2,394	671	1,202	3,340	5,736	2,664	4,476
2018	1,320	2,414	679	1,211	3,486	5,952	2,734	4,584
2019	1,347	2,434	1,864	3,021	3,632	6,168	2,804	4,692
2020	1,374	2,454	1,926	3,118	3,778	6,384	2,874	4,800
2021	1,401	2,474	1,987	3,216	3,924	6,600	2,944	4,908
2022	1,428	2,494	2,049	3,313	4,070	6,816	3,014	5,016
2023	1,455	2,515	2,110	3,411	4,216	7,032	3,084	5,124
2024	1,482	2,534	2,172	3,508	4,362	7,248	3,154	5,232
2025	1,509	2,554	2,233	3,605	4,508	7,464	3,224	5,340
2026	1,536	2,574	2,295	3,703	4,654	7,680	3,294	5,448
2027	1,563	2,594	2,356	3,800	4,800	7,896	3,364	5,556
2028	1,590	2,614	2,418	3,898	4,946	8,112	3,434	5,664
2029	1,617	2,634	2,479	3,995	5,092	8,328	3,504	5,772
2030	**1,640**	**2,660**	**2,540**	**4,092**	**5,233**	**8,539**	**3,574**	**5,872**

Bold load amounts are from counts (in 2012) or forecasts (for 2015 and 2030). Other load amounts are from linear interpolations.

b) MAX Service Standards for Train Loading (Step 2)

In 1989, The TriMet Board of Directors adopted Service Standards for the design, evaluation and adjustment of transit service. The Service Standards do not apply to individual train trips but to average vehicle loads during each time period. This Service Standards document established the operating policies for headways as well as passenger loads. Headway is the time interval between train arrivals at stations. The minimum policy headways for light rail are:

- 10 minutes in the peak (7-9AM & 4-6PM)
- 15 minutes in the daybase (6-7AM & 9-4PM)
- 15 minutes in the evening (6-9:30PM)
- 30 minutes at night (9:30 PM -12 midnight)

The peak policy headway does not apply to the Red Line that averages 15-minute headways nearly the entire service day, seven days a week. This near uniform headway is a result of the line's more even demand levels due to a lower percentage of commuters and the bi-directional nature of travel patterns on the line during peak periods.

Due to the recent downturn in the economy and the resulting budget pressures the Green Line and Yellow Line are operating on 15-minute peak headways with 2-car trains, however the loading standards described below are being met.

The first eighteen years of operating experience taught TriMet that, in Portland, rider's crowding threshold is an average of 266 people per 2-car train during the peak hour in the peak direction. While some trains do carry the standard maximum passenger load of 332 or more riders, the average during the peak hour is 266, see Figure 5.1. This average is comparable to achievable capacity as defined in TCRP Report 13, "Rail Transit Capacity".

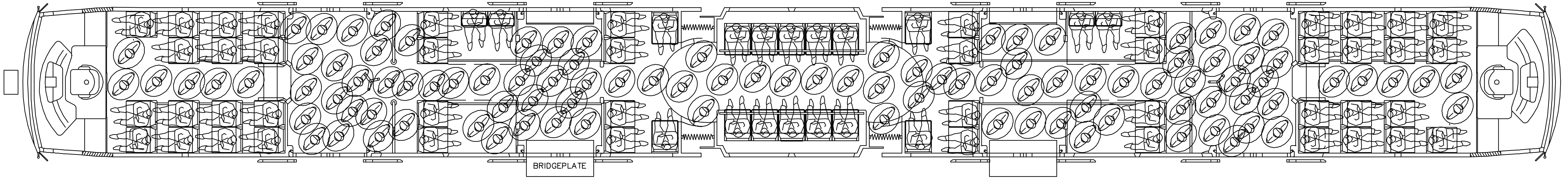
TriMet's loading standard is based on seated passengers plus standees at a peak hour average of 2.7 standees per square meter of standing floor area. This 2.7 average for the peak hour is very close to the 3.3 value suggested on page 5-27 and 28 of the TCRP Report 100 for the peak 15 minutes allowing for the peak hour factor, see Appendix A. Using load factors would result in a different standard for each LRV type.

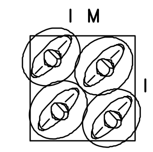
Type 4 and 5 LRVs have a slightly higher capacity than the Type 1, 2 and 3 LRVs, see table 5.2. However, since Type 4 and 5 LRVs make up only 27% of the fleet as of 2015 and due to increases in the demand from passengers who bring bicycles with them TriMet has elected to continue using the peak hour loading standard of 266 passengers per 2-car train.

Table 5.2

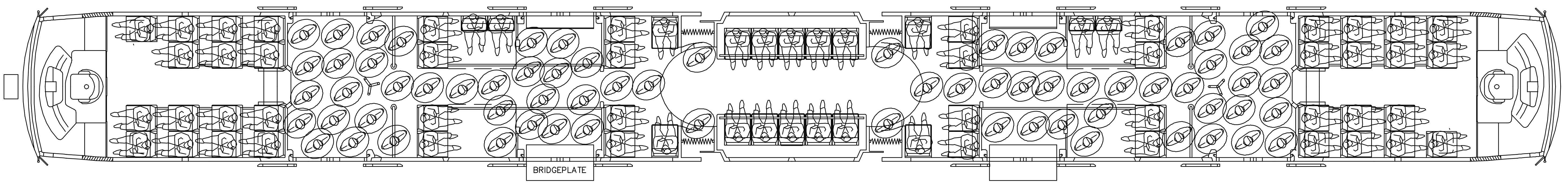
LRV Capacity

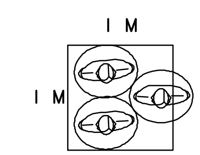
LRV Type	Design Capacity				Achievable Capacity	
	Seats per car	Standees per car	1-car train	2-car train	1-car Train	2-car Train
1	76	90	166	332	133	266
2 & 3	64	102	166	332	133	266
4 & 5	68	104	172	344	138	275



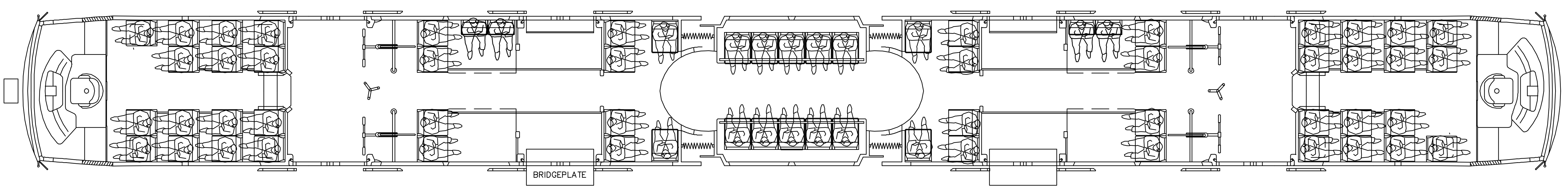


STANDARD MAXIMUM PASSENGER LOAD DURING PEAK HOUR (LOAD FACTOR OF 2.6)
166 = 64 SEATED + 102 STANDING AT 4 PER SQ. M.





STANDARD AVERAGE PASSENGER LOAD DURING PEAK HOUR (LOAD FACTOR OF 2.1)
133 = 64 SEATED + 69 STANDING AT 2.7 PER SQ. M.



64 SEATED: LOAD FACTOR OF 1.0

TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON

TRI MET — CAPITAL PROJECTS DIVISION, 710 NE HOLLADAY STREET, PORTLAND, OREGON 97232

FIGURE 5.1

MAX PASSENGER LOADING STANDARD

NO.	DATE	BY / CHK.	APPD.	REVISIONS

DESIGNED: JHM — DATE: 12/01
DRAWN — DATE
CHECKED — DATE
APPROVED — DATE

SUBMITTED: — DATE: — APPROVED: — DATE:

SCALE: NONE — DRAWING NO.: FIG 5.1 LFLRVCAP — CONTRACT NO.: — SHEET NO.: 21

R:\CAD_Admin\Operations\Figures\FIG 5.1 LFLRVCAP.dwg, 1/12/2011 2:13:33 PM, mcbridej

c) Run and Cycle Times by Line (Step 3)

Cycle time is the round trip travel time for a train and its operator on a particular line that accounts for travel time variations during peak and non-peak periods of the day. Cycle time includes the run times from one end of the line and back as well as schedule recovery and operator break time. Schedule recovery time is 10 percent of run time and operator break time is five minutes per hour. There is also a labor contract requirement for meal breaks that results in one additional daybase train on some lines. The run and cycle times for the MAX lines and the resulting daybase train requirements are shown in Table 5.3. TriMet's use of peak tripper trains results in a lower PVR than full cycle trains require, because a tripper train can serve the peak load point's passenger trips without making a full cycle. For CRC in 2030 the difference for through routed Yellow/Orange trains is 30 full cycle trains versus 23 trains (12 daybase trains plus 11 peak direction trippers). That is a 14-car reduction in the PVR for 2-car trains.

Table 5.3

MAX Run and Cycle Times

	2013 to 2030				2030	
MAX Line and Alignment	One-way Run Time	Round Trip Cycle Time	Daybase Headway in minutes	Number of Daybase Trains	Peak Hour & Direction Headway in minutes	Number of Peak Trains if Full Cycle
Blue Gov. Ctr. To Clev. Ave.	96	230	15	16	6	39
Red PDX to BTC	58	150	15	10	15	10
Green CTC to PSU	46	120	15	8	10	12
Yellow/Orange Expo Center To Park Ave.	58	150	15	10	Runs only until 2019	Runs only until 2019
Yellow/Orange Clark Col. To Park Ave.	67	180	15	12	6-north 8.6-south	30

d) Application of Loading Standards (Step 4)

Applying the 266 passenger 2-car train loading standard to the load data from Table 5.1 gives the minimum required number of trains that are needed in the peak direction past the peak load points. The minimum number of required trains in the peak hour is shown in Table 5.4. The minimum number of required trains in the peak two hours is shown in Table 5.5. Since many peak tripper trains do not make full cycles the 2-hour load must be examined to insure a smooth transition from the peak hour to the off-peak period.

The maximum headway can then be calculated by dividing the time period in minutes by the minimum number of trains required. Therefore, for CRC an average headway of 7.5 minutes is required in 2019 and 6 minutes in 2030 during the peak hour. During the 2-hour peak period an average headway of 10 minutes is required in 2019 and 7.5 minutes in 2030.

Table 5.4

Minimum Number of 2-car Trains
required past the peak load points in the peak hour

Year	Milwaukie Orange Line **south** of Holgate		CRC Yellow Line **north** of Rose Quarter		Blue, Red and Green Lines **east** of Lloyd Center		Blue and Red Lines **west** of Goose Hollow	
	1-hour load	Trains Required	1-hour load	Trains Required	1-hour load	Trains Required	1-hour load	Trains Required
2012	0	0	**631**	3	**2,610**	10	**2,314**	9
2013	0	0	639	3	2,756	11	2,384	9
2014	0	0	647	3	2,902	11	2,454	10
2015	**1,239**	5	655	3	3,048	12	2,524	10
2016	1,266	5	663	3	3,194	13	2,594	10
2017	1,293	5	671	3	3,340	13	2,664	11
2018	1,320	5	679	3	3,486	14	2,734	11
2019	1,347	6	1,864	8	3,632	14	2,804	11
2020	1,374	6	1,926	8	3,778	15	2,874	11
2021	1,401	6	1,987	8	3,924	15	2,944	12
2022	1,428	6	2,049	8	4,070	16	3,014	12
2023	1,455	6	2,110	8	4,216	16	3,084	12
2024	1,482	6	2,172	9	4,362	17	3,154	12
2025	1,509	6	2,233	9	4,508	17	3,224	13
2026	1,536	6	2,295	9	4,654	18	3,294	13
2027	1,563	6	2,356	9	4,800	19	3,364	13
2028	1,590	6	2,418	10	4,946	19	3,434	13
2029	1,617	7	2,479	10	5,092	20	3,504	14
2030	**1,640**	**7**	**2,540**	**10**	**5,233**	**20**	**3,574**	**14**

Note: See Section 3.d for an explanation of why 2-car trains are assumed.

Table 5.5

Minimum Number of 2-car Trains required past the peak load points in the peak 2-hours

Year	Milwaukie Orange Line **south** of Holgate		CRC Yellow Line **north** of Rose Quarter		Blue, Red and Green Lines **east** of Lloyd Center		Blue and Red Lines **west** of Goose Hollow	
	2-hour load	Trains Required	2-hour load	Trains Required	2-hour load	Trains Required	2-hour load	Trains Required
2012	0	0	**1,157**	5	**4,656**	18	**3,936**	15
2013	0	0	1,166	5	4,872	19	4,044	16
2014	0	0	1,175	5	5,088	20	4,152	16
2015	**2,354**	9	1,184	5	5,304	20	4,260	17
2016	2,374	9	1,193	5	5,520	21	4,368	17
2017	2,394	9	1,202	5	5,736	22	4,476	17
2018	2,414	10	1,211	5	5,952	23	4,584	18
2019	2,434	10	3,021	12	6,168	24	4,692	18
2020	2,454	10	3,118	12	6,384	24	4,800	19
2021	2,474	10	3,216	13	6,600	25	4,908	19
2022	2,494	10	3,313	13	6,816	26	5,016	19
2023	2,515	10	3,411	13	7,032	27	5,124	20
2024	2,534	10	3,508	14	7,248	28	5,232	20
2025	2,554	10	3,605	14	7,464	29	5,340	21
2026	2,574	10	3,703	14	7,680	29	5,448	21
2027	2,594	10	3,800	15	7,896	30	5,556	21
2028	2,614	10	3,898	15	8,112	31	5,664	22
2029	2,634	10	3,995	16	8,328	32	5,772	22
2030	**2,660**	**10**	**4,092**	**16**	**8,539**	**33**	**5,872**	**23**

Note: See Section 3.d for an explanation of why 2-car trains are assumed.

The calculations for number of peak tripper trains needed during the peak hour and transition periods to the daybase for each line are described in the next subsection. The marginal difference from the Baseline operation of the Yellow/Orange Line to operation of the CRC extension is also shown in the next subsection.

e) Peak Vehicle Requirements (Step 5)

Calculation of 2030 CRC PVR

The calculation of the PVRs for CRC in the planning horizon year of 2030 are shown in Table 5.6. The description of the PVR calculation that follows refers to the table, which has the rows, numbered for reference.

The table begins with travel times, step 3 in the FTA Guidance; used to determine the daybase cycle time, line 6. The number of daybase trains, line 9, are then calculated based on these cycle times and the daybase headways, line 8. TriMet's longest average daybase headway allowed by policy is 15 minutes. Daybase trains provide frequent service to all passengers whether they are peak direction or reverse direction commuters or are traveling on the extremities of the system. Only some of the daybase trains pass the peak load points in the peak direction during the peak hour, line 10.

Next the peak hour, peak direction demand is considered, FTA step 4. Line 13 the forecast passenger load for 2030, FTA step 1, comes from Metro's demand model. Line 14 divides the forecast by 266, the load standard for a 2-car train, FTA step 2. Line 15, the proposed number of trains, rounds up to a whole train or provides for the longest peak hour peak direction headway of 10 minutes allowed by policy. The number of peak hour trippers, line 18, is the proposed number of trains, line 15, minus the number of daybase trains passing the peak load point in the peak direction during the peak hour, line 10.

Next the peak period outside the peak hour is considered, lines 19-25. If peak period demand is great enough outside the peak hour trains may be added to smooth the transition between the daybase and the peak hour headways.

Next total peak trains, line 27, are calculated by adding up daybase trains, line 9, and peak trippers in the peak hour, line 18 and outside the peak hour, line 25. Then the PVR, line 28 and FTA step 5, is calculated by multiplying by 2 cars per train and accounting for any single car trains. Finally the Total Fleet with Spares, line 29, is calculated using TriMet's spare ratio target of 15 to 18 percent.

FTA step 6, TriMet does not currently use or plan to use gap trains.

The far right-hand column, CRC Marginal, shows the difference between the baseline and the build alternative car requirements for a through-routed Yellow/Orange Line. The total car requirement is 19 LRVs for CRC in 2030.

Table 5.6
2030 LRT Fleet Requirements for CRC Build with PMLR,
Hours and Miles based on Projected Travel Times and Proposed Headways

	Year 2030	Model Run made April 2012				
		CRC Build Clark Col. To Park Ave.		MAX No-build: Expo to Park Ave.		CRC Marginal
1	Travel Times					
2	Adjusted Travel Time	67		58		
3	Round Trip Travel Time	133		115		
4	Daybase layover time: total for both ends (for operator break and schedule recovery)	47		35		
5	Travel time as a % of cycle time	74%		77%		
6	**Daybase Cycle Time (round trip travel time + total layover time in minutes)**	180		150		
7	Daybase					
8	Daybase Headway in minutes	15		15		
9	**Number of trains required for daybase (Cycle time / headway)**	**12**		**10**		**2**
10	Number of daybase trains passing the peak load point(s) in peak hour	4		4		
11	Peak Hour Peak Direction					
12		North	South	North	South	
13	**Forecasted Peak Hour Volume from EMME2 travel demand model**	**2,540**	**1,640**	**769**	**1,640**	
14	Minimum number of 2-car trains required (forecast/266)	9.5	6.2	2.9	6.2	
15	Proposed number of 2-car trains (Policy max. headway of 10-min equals 6 trins per hour)	10	7	6	7	
16	Achievable Capacity	2,660	1,862	1,596	1,862	
17	Proposed Average Headway	6.0	8.6	10.0	8.6	
18	**Number of peak hour trippers required past the peak load point(s)**	**6**	**3**	**2**	**3**	**4**
19	Peak 2-Hours Peak Direction					
20	**Forecasted Peak 2-Hour Volume from EMME2 travel demand model**	**4,092**	**2,660**	**1,319**	**2,660**	
21	Minimum number of 2-car trains required (forecast/266)	15.4	10.0	5.0	10.0	
22	Proposed number of 2-car trains in peak hour	10	7	6	7	
23	Proposed number of 2-car trains in peak 2-hours	16	11	10	11	
24	Proposed Average Headway	7.5	10.9	12.0	10.9	
25	**Number of transition trippers required past the peak load point(s)**	**2**	**0**	**0**	**0**	**2**
26	Fleet Size					
27	**Total peak trains (daybase trains + peak trippers)**	**23**		**15**		**8**
28	Peak Vehicle Requirement (PVR) = total peak trains x 2	46		30		16
29	**Total Fleet with Spares = (PVR x 1.18 rounded up)**					**19**
	Notes: Achievable peak hour peak direction capacity per 2-car train averages 266 passengers per train at the peak load point.					
	CRC Project Fleet Spare ratio = 3/16					18.8%

2019 CRC PVR

The calculation of the PVR for the planned opening year, 2019, of the CRC project is shown in Table 5.7. This table is calculated in the same manner as the 2030 table was except that 2019 peak passenger loads are used as input. These loads were interpolated from the 2018 and 2030 demand model forecasts as shown earlier in Table 5.1.

Existing Line PVRs in 2030

The calculation results of the PVRs for the existing Lines are shown in Table 5.8 for 2030. For the MAX Lines that share common peak load points (East – Blue, Red & Green and West – Blue & Red) the proposed number of trains is based on the requirements shown in Tables 5.4 and 5.5. The demand model forecast underestimates the share of load that the Red Line will carry as evidenced by higher current Red Line loads shown in Table 3.3.

f) Gap or Ready Reserve Train Usage (Step 6)

After the introduction of Type 2 vehicles in October of 1997, TriMet did operate gap trains, when available, to mitigate the impact of more frequent mechanical failures which resulted in cars from the new fleet being taken out of service. As the Type 2 vehicles became more reliable the need for gap trains ended.

Table 5.7

2019 LRT Fleet Requirements for CRC Build with PMLR,

Hours and Miles based on Projected Travel Times and Proposed Headways

Year 2019-20					
	CRC Build Clark Col. To Park Ave.		Yellow/Orange Line 2015-18 Expo to Park Ave.		CRC Marginal
Travel Times					
Adjusted Travel Time	67		58		
Round Trip Travel Time	133		115		
Daybase layover time: total for both ends (for operator break and schedule recovery)	47		35		
Travel time as a % of cycle time	74%		77%		
Daybase Cycle Time (round trip travel time + total layover time in minutes)	180		150		
Daybase					
Daybase Headway in minutes	15		15		
Number of trains required for daybase (Cycle time / headway)	**12**		**10**		**2**
Number of daybase trains passing the peak load point(s) in peak hour	4		4		
Peak Hour Peak Direction					
	North	South	North	South	
Forecasted Peak Hour Volume from EMME2 travel demand model	**1,864**	**1,347**	**641**	**1,239**	
Minimum number of 2-car trains required (forecast/266)	7.0	5.1	2.4	4.7	
Proposed number of 2-car trains (Policy max. headway of 10-min equals 6 trins per hour)	7	6	6	6	
Achievable Capacity	1,862	1,596	1,596	1,596	
Proposed Average Headway	8.6	10.0	10.0	10.0	
Number of peak hour trippers required past the peak load point(s)	**3**	**2**	**2**	**2**	**1**
Peak 2-Hours Peak Direction					
Forecasted Peak 2-Hour Volume from EMME2 travel demand model	**3,021**	**2,434**	**971**	**2,354**	
Minimum number of 2-car trains required (forecast/266)	11.4	9.2	3.7	8.8	
Proposed number of 2-car trains in peak hour	7	6	6	6	
Proposed number of 2-car trains in peak 2-hours	12	10	10	10	
Proposed Average Headway	10.0	12.0	12.0	12.0	
Number of transition trippers required past the peak load point(s)	**1**	**0**	**0**	**0**	**1**
Fleet Size					
Total peak trains (daybase trains + peak trippers)	**18**		**14**		**4**
Peak Vehicle Requirement (PVR) = total peak trains x 2	36		28		8
Total Fleet with Spares = (PVR x 1.18 rounded up)					**10**
Notes: Achievable peak hour peak direction capacity per 2-car train averages 266 passengers per train at the peak load point.					
CRC Project Fleet Spare ratio = 2/8					25.0%

Table 5.8
2030 MAX System
Peak Vehicle Requirements

2030	Loads from CRC Demand Model Run in 2012							
MAX Line	East-West Gresham to Hillsboro		AirMAX: through routed to Beaverton TC		CRC/PMLR: Clark Col. to Park Ave.		I-205: CTC to PSU	Total
Travel Times								
Adjusted Travel Time	96		58		67		46	
Round Trip Travel Time	192		116		133		91	
Daybase layover time: total for both ends (for operator break and schedule recovery)	38		34		47		29	
Travel time as a % of cycle time	83%		77%		74%		76%	
Daybase Cycle Time (round trip travel time + total layover time in minutes)	230		150		180		120	
Daybase								
Daybase Headway in minutes	15		15		15		15	
Number of trains required for daybase (Cycle time / headway) + 1 for Blue Line	**17**		**10**		**12**		**8**	**47**
Number of daybase trains passing the peak load point(s) in peak hour	4		4		4		4	
PM Peak Hour Peak Direction								
	East	West	East	West	North	South	East	
Peak Hour Volume from Passenger Demand Model which assigns to ea. line by Freq.	**2,494**	**3,107**	**512**	**467**	**2,540**	**1,640**	**2,227**	
Minimum number of 2-car trains required (forecast/266)	9.4	11.7	1.9	1.8	9.5	6.2	8.4	
Proposed number of 2-car trains (20 east & 14 west past peak load points from Table 5.4)	10	10	4	4	10	7	6	
Achievable Capacity with standard average load, see Section 5.b	2,660	2,660	1,064	1,064	2,660	1,862	1,596	
Average Headway	6.0	6.0	15.0	15.0	6.0	8.6	10.0	
Number of peak hour trippers required past the peak load point(s)	**6**	**6**	**0**	**0**	**6**	**3**	**2**	**23**
PM Peak 2-Hours Peak Direction								
Peak 2-Hour Volume from Passenger Demand Model	**4,026**	**5,095**	**892**	**777**	**4,092**	**2,660**	**3,621**	
Minimum number of 2-car trains required (forecast/266)	15.1	19.2	3.4	2.9	15.4	10.0	13.6	
Proposed number of 2-car trains in peak hour	10	10	4	4	10	7	6	
Proposed number of trains in 2-hours (33 east & 23 west at peak load points from Table 5.5)	14	15	8	8	16	11	11	
Average Headway	8.6	8.0	15.0	15.0	7.5	10.9	10.9	
Number of transition trippers required past the peak load point(s)	**0**	**1**	**0**	**0**	**2**	**0**	**1**	**4**
Fleet Size								
Total peak trains (daybase trains + peak trippers)	**30**		**10**		**23**		**11**	**74**
Peak Vehicle Requirement (PVR) = total peak trains x 2, except shuttle	60		20		46		22	148
Total Fleet including Spares = (PVR x 1.18 rounded up)								175
Spare Ratio								18.2%

Notes: Achievable peak hour peak direction capacity per 2-car train averages 266 passengers per train at the peak load point.

6) Supply of Revenue Vehicles

a) Financial Constraints

TriMet carefully studies the capital and operating (financial) implications of expanding the fleet. This is done in the context of the Agency's overall financial planning process. Every year TriMet updates its five-year capital and operating financial forecasts. While financially sound, agency resources are scarce. The purchase of vehicles requires either federal funding assistance, the issue of TriMet long-term debt, or both. Equally important, operating costs are forecast so that local, continuing-revenue, sources will adequately meet any new continuing-expenditures. Funding for the fleet expansion for service in 2019 in this plan will come from the CRC Project. Funding for fleet expansions after 2019 will come from either the next Light Rail Project or bonding, see Section 8 for an estimate of when these fleet expansions will be needed.

b) Vehicle Purchasing Constraints

Like most light rail systems in the United States, TriMet vehicle specifications are unique to Portland. Thus, there are several "logistical" constraints to purchasing vehicles. First, purchase orders require a long (several years) lead-time to allow adequate time for the manufacture and transport of thousands of precision components, as well as the fabrication, assembly, and testing of the vehicles. Second, due to the long lead times, purchase orders of fewer than ten vehicles are uneconomical. For these reasons it is not possible to quickly purchase a few vehicles in response to an unexpected surge in ridership. On the contrary, large orders are placed years in advance for any project or extension. This inability to purchase a few vehicles at a time leads to interim spare ratios that are often higher than the transit agency desires.

c) Fleet Life Cycle

TriMet's anticipated replacement cycle for LRVs is 41 years for Type 1 LRVs and 36 years for all other LRV Types. The 26 Type 1 vehicles are due for replacement in 2027 prior to 2030; see Section 8, Vehicle Demand and Supply Balance, and the vehicle replacement schedule in Appendix B from TriMet's Capital Improvement Plan (CIP) for further details of timing. Type 1 LRVs are subject to a sale and leaseback arrangement that has penalties for early retirement. Type 1 vehicles are currently undergoing a full body rebuild after 18 to 27 years of service, this is the only body rebuild planned before retirement. To help maintain reliability these cars may be assigned to trains with shorter runs to reduce annual mileage. TriMet intends to maintain these vehicles via progressive overhauls until their retirement to assure a high level of in-service reliability and a reasonable resale value. If the possibility of resale looks doubtful during the last few years prior to retirement, then the deferral of some maintenance prior to sale for scrap will be considered.

7) Maintenance and Reliability

a) Maintenance Program Elements

TriMet's overall LRV maintenance program consists of seven distinct, but mutually supportive maintenance work programs: preventive maintenance, running repairs, component rebuild, progressive overhaul, scheduled maintenance, modifications (product improvements), and equipment engineering analysis and training. These seven work programs required about 127,000 labor hours per year for the 127-car fleet, or just less than 1,000 labor hours per year per vehicle.

<u>Preventive Maintenance (40% of total labor hours)</u>

Preventive Maintenance (PM) inspections, including correction of defects found, are performed on a consistent schedule based on mileage. PM inspections are scheduled at intervals of 4,500, 9,000, 13,500, 27,000, 40,500, and 81,000 miles, each mileage grouping accrues mileage independently from the other and is scheduled based on the mileage accrued since the completion of the last PM, each mileage interval is based on the specific needs of that system's components. Any periodic, scheduled inspection and maintenance tasks with intervals greater than 81,000 miles are performed under the Progressive Overhaul program.

The PM program content and intervals are based on manufacturer recommendations, refined through continuous analysis by equipment engineering staff, maintenance supervisors and technicians. Physical inspections of components and systematic data tracking of failures and repairs are continually analyzed to maximize both effectiveness and efficiency of the PM program. See Appendix C for a description of PM Inspections and their respective mileage intervals by LRV type. Items with a 0 for the mileage interval are no longer covered by technicians during PMs instead they are performed as running repairs when reported by operators or cleaners.

TriMet's goal is to complete at least 80 percent of PM inspections on time.

TriMet Preventive Maintenance Force Account Plan. TriMet's rail and facilities maintenance program includes work performed by TriMet's labor force and by contractors. By far the great majority of preventive maintenance is performed by TriMet's own labor forces as negotiated by the Working and Wage Agreement between Amalgamated Transit Union Division 757 and TriMet. Under the labor agreement work that is contracted out must meet criteria specified in the labor agreement. Contracted maintenance must also be pre-approved by the ATU. The justification for using force account work for preventive maintenance is the TriMet ATU labor agreement. Budgets for this work are shown in Appendix D.

Running Repairs (25% of total labor hours)

Running Repairs diagnose and correct defects on vehicles identified during revenue service and reported to LRV Maintenance by Transportation personnel. Vandalism and accident repairs are also classified under the Running Repairs program.

Component Rebuild (5% of total labor hours)

The component (or unit) rebuild program refers to repairable equipment removed and replaced on the vehicle. Such equipment components or subsystems are rotated through the component rebuild section of LRV Maintenance in appropriate cycles so as to maintain availability of rebuilt or repaired components to meet running repair requirements for removal and replacement of such components. This allows much faster return of defective vehicles to service. Component rebuild production and quality is under dedicated supervision, and is also supported by equipment engineering analysis and product improvement modifications at the component/subsystem level.

Progressive Overhaul (16% of total labor hours)

TriMet's LRV maintenance program seeks to keep current with the entire scope of vehicle maintenance requirements, and therefore seeks to avoid requirements for mid-life remanufacturing for its LRVs. Accordingly, long-cycle tasks (beyond the 81,000 PM program cycle) are also scheduled based on continuing fleet condition assessment and design of overhaul campaigns. Each overhaul campaign bundles multiple overhaul tasks which are now due, for simultaneous performance on each vehicle cycled through the campaign, for efficient overhaul program production. This progressive overhaul approach was recognized by USDOT in a 1995 report as best-practice in the rail transit industry, preferable to mid-life vehicle remanufacturing in terms of keeping the fleet continuously in service at a higher spare ratio and in minimizing fleet life-cycle total cost.

Scheduled Maintenance (14% of total labor hours)

Other scheduled maintenance tasks that are outside of preventive maintenance or progressive overhaul and are scheduled from time of completion, from measured wear limit or by seasonal requirements are captured under scheduled maintenance. Maintenance tasks such as wheel truing, car floor height adjustment and brake disc truing are examples of scheduled maintenance.

Modifications (product improvements are 1% of total labor hours)

Modifications are product improvements made to (1) increase vehicle reliability by decreasing failure and wear rates, (2) increase maintainability by easing or decreasing maintenance tasks, and (3) increase customer service by improving vehicle amenities or comfort.

Vehicle reliability and maintainability modifications are an ever-present element of the LRV maintenance program, and arise out of continuous analysis by equipment engineering staff, maintenance supervisors and technicians. Introduction of a new-type vehicle fleet to operate in train consists with existing vehicle types can also require considerable modifications to existing vehicle types, as was required for TriMet's Type 1 LRVs when the Type 2 LRVs were introduced. The new curved platforms on the Portland Transit Mall resulted in the addition of side view CCTV on the entire LRV fleet. Customer service modifications have include retrofitting air conditioning to the Type 1 LRVs, retrofitting CCTV surveillance to Type 1 and 2 LRVs, and modifying interior stanchions of Type 2 LRVs to increase bicycle boarding accommodations.

Equipment Engineering Analysis and Training (less than 1% of total labor hours)

Equipment engineering analysis and training functions are provided through a 4-member staff unit working in a team effort with maintenance supervisors and technicians, continuously analyzing failure data among component subsystems, refining maintenance techniques (e.g., procedures and training, including PM program effectiveness), and developing product improvement modifications.

The equipment engineering staff is dual-function, by also serving as LRV maintenance trainers. Training program elements include (1) initial training of apprentices from Tri-Met's maintenance helper classification to become LRV maintenance technicians (30-month program of classroom and on-the-job training), (2) technician recurrent training, and (3) training of technicians and apprentices on modifications, new or revised maintenance procedures, and new types of LRVs or maintenance equipment.

b) Train Failure Definitions and Actions

Train failures can require the use of spare vehicles to maintain scheduled service. The term relevant failure has been used to define which failures are used to calculate the mean distance between failures (MDBF).

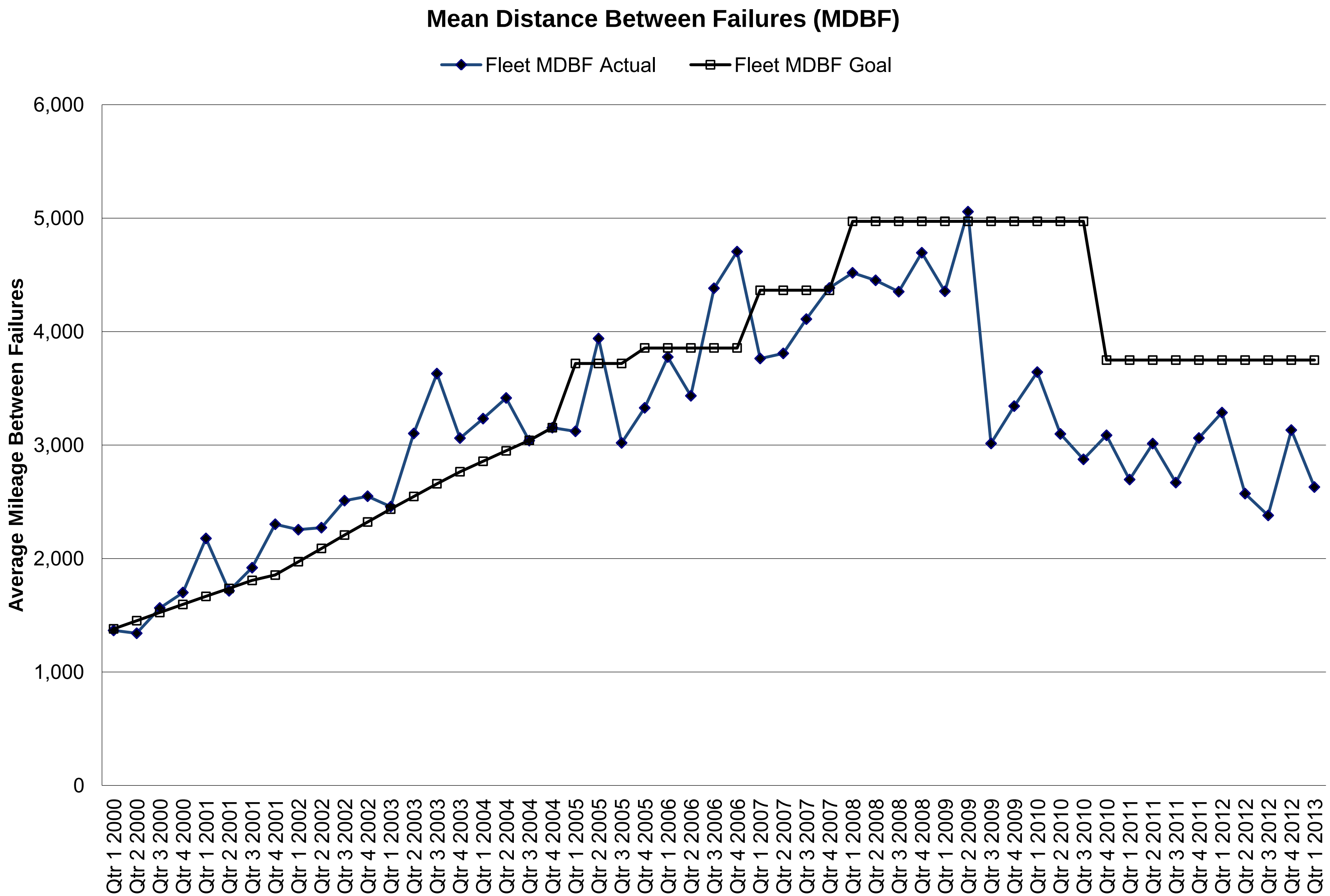
Relevant failures used in TriMet's traditional calculation of the mean distance between failures (MDBF) include any independent failure of an item which results in any of the following:

1. A four-minute or longer delay of revenue service.
2. Failure to enter revenue service at the scheduled time.
3. Need to remove a vehicle from revenue service.
4. Failure of the ventilation system.
5. Door and bridgeplate system failure that requires two or more doors or bridgeplates per car to be cutout.

Relevant failures varied between 7,500 miles and 25,000 miles between 2000 and 2004. Problems with the software's tracking of delays between 2004 and 2008 resulted in erratic data of little use for measuring trends in vehicle reliability.

In the year 2000, a new measure of vehicle reliability was developed, for more precision in measuring reliability, determining trends and meeting TriMet's goal of continuous improvement in LRV reliability. This service related failures measure is based on the number of times any symptom code is used to log in a repair on the pending worklist, see Appendix E for examples. There was much improvement in this measure of MDBF since 2001, from below 2,000 miles to above 4,000 miles. The MDBF for the past 12 years is shown in Figure 7.1. When new LRVs enter the fleet they tend to bring down the MDBF for some period of time as can be seen from the 3rd quarter of 2009 on.

Figure 7.1
Service Related Failures



8) Vehicle Demand and Supply Balance

a) Spare Vehicle Requirements (Step 7)

There are three purposes for vehicle spares:

- to allow for routinely scheduled, preventative maintenance work to be performed during day and swing shifts in service bays that would otherwise be vacant
- to replace vehicles that fail in peak revenue service
- to allow for progressive overhaul and vehicle modification campaigns that take more than 1 or 2 shifts per car to complete.

Prior to Green Line opening in September 2009 TriMet operated with an 18 percent spare ratio, 16 spare cars compared with 87 cars in PM peak service. Two Type 1 cars at a time were out of the active fleet of 103 undergoing mid-life body rebuilds. Since TriMet's fleet is fairly small a certain number of spares are not dedicated to a given category of work on a regular basis. With only 16 spares an entire car cannot be devoted to the smaller categories of work on a continuous basis. However on average: 5.6 cars were undergoing Preventive Maintenance, 3.36 cars were undergoing Running Repairs, 0.64 of a car was undergoing Component Rebuild, 3.52 cars were undergoing Progressive Overhaul, 2.08 cars were undergoing Scheduled Maintenance, 0.8 of a car was undergoing Modifications, and 0.16 of a car was involved in Equipment Engineering Analysis & Training.

Since Green Line opening in September 2009 TriMet has operated with a spare ratio of 20 or 21 percent. Two Type 1 cars at a time remain out of the active fleet of 127 undergoing mid-life body rebuilds. The Type 1 mid-life body rebuilds will be completed by the end of 2014 or early in 2015.

TriMet's long term goal is to operate with a spare ratio between 15 and 18 percent. This range allows TriMet to meet its service objectives in a cost effective manner. However, because small LRV orders are not economical and service increases for passenger load growth on existing lines are limited to an additional train every few years many LRVs must be acquired before they are required. This situation results in a spare ratio that fluctuates over time, higher just after LRV acquisitions and gradually declining as more LRVs are put in service.

b) Fleet Demand and Spare Ratio (Step 8)

The fleet size, at any given time, is governed by:

- The Peak Vehicle Requirement (PVR) required to serve the current passenger demands based on data from automatic passenger counters
- The Peak Vehicle Requirement (PVR) required to serve future passenger demands based on transportation demand modeling with assumptions on future population and employment growth
- Financial constraints

- Vehicle procurement constraints including minimum economical size of order and delivery schedule
- The spare ratio target of 15 to 18 percent for the planning horizon year

The anticipated fleet size requirements for MAX between 2013 and 2030 with both the Milwaukie extension and the CRC extension are summarized in Table 8.1. Based on the passenger demand model forecast for 2030 the fleet will total 175 cars. This includes new LRV deliveries available for peak service and spares in the following years:

- 2015 – 18 for Milwaukie
- 2019 – 19 for CRC
- 2025 – 11 for system growth (includes the 8 Green Line cars not delivered for 2009)
- 2027 – 26 replacement LRVs for Type 1 retirements

The operating spare ratio (OSR) is the number of spares (active fleet - the PVR) divided by the PVR. The spare ratio forecast which varies from 17 to 24 percent is shown in Table 8.1. A 17 percent spare ratio would be fairly close to the lowest spare ratios in the rail transit industry. Achieving spare ratios below 15 percent would force uneconomical and inflexible operating and maintenance practices such as:

- concentrating the vast majority of maintenance during off-peak periods leaving maintenance bays idle several hours twice daily
- forcing more swing and graveyard shift work at higher wages and lower productivity while increasing the need for more maintenance bays.

The future service increases shown in Table 8.1 are estimates of when service would be added based on passenger demand models that are updated often. Actual service implementation will be based on updated model forecasts and the evaluation of automatic passenger counter data from existing MAX service.

Table 8.1

LRV Demand Supply Balance

Year	PVR increase on Extensions		PVR increase on existing lines		PVR	LRV delivery	Active Fleet	Spares	OSR
	South	North	East	West					
2009		1	14	1 shuttle	103	22	125	22	21%
2010					103		125	22	21%
2011		Mall shuttle discontinued -1, west side peak tripper added +2			104		125	21	20%
2012					104		125	21	20%
2013					104		125	21	20%
2014			2		106		125	19	18%
2015	12			2	120	18	145	25	21%
2016					120		145	25	21%
2017			2		122		145	23	19%
2018					122		145	23	19%
2019	2	8			132	19	164	32	24%
2020					132		164	32	24%
2021		2	2		136		164	28	21%
2022				2	138		164	26	19%
2023					138		164	26	19%
2024		2			140		164	24	17%
2025			2		142	11	175	33	23%
2026		2			144		175	31	22%
2027					144	26*	175	31	22%
2028					144		175	31	22%
2029		2	2		148		175	27	18%
2030					148		175	27	18%

Two Type 1 LRVs, on a rotating basis, are out of the active fleet for body rebuilds until 2015. The entire 2009-2014 fleet totals 127 LRVs.

*****   In 2027 the 26 Type 1 LRVs are due for replacement.

Appendices

- A. TCRP Report 100 “TCQSM” 2nd Edition 2003 – Chapter 5 Rail Transit Capacity
- B. Capital Improvement Program (CIP) Replacement Table
- C. PM Inspections by LRV Type
- D. Preventive Maintenance Force Account Plan Budgets
- E. Service Related Failures MDBF Oct. Nov. & Dec. 2012

Appendix A

TCRP Report 100

Transit Capacity and Quality of Service Manual

2nd Edition

Part 5 Rail Transit Capacity

Chapter 4 Passenger Loading Levels

Pages 5-25 to 5-29

CHAPTER 4. PASSENGER LOADING LEVELS

INTRODUCTION

Establishing the loading level of rail transit is the final step in determining capacity. After the maximum train throughput has been calculated from the inverse of the sum of signaling separation time, dwell time, and operating margin, capacity is then based only on train length and loading level.

The existing loading levels on North American rail transit vary from the relaxed seating on many commuter rail lines to the denser loadings experienced on older subway and light rail systems. These loadings offer levels of passenger comfort that are inappropriate for new systems intended to compete with the automobile.

Loading levels vary widely by transit mode and system.

The next section reviews existing rail transit loading standards. The remainder of the chapter determines a range of loading standards that can be applied in specific circumstances for each mode.

LOADING STANDARDS

Most rail transit systems have loading standards for the peak-hour, peak-point location with more relaxed standards away from entry into the city center and for off-peak times. Exhibit 5-21 shows loading standards over the peak 15 minutes for selected heavy rail systems.

Mexico City's Metro is an exception and experiences loading that can exceed 1.8 ft^2/p (0.125 m^2/p).

Exhibit 5-21
Passenger Space on Selected North American Heavy Rail Systems During Peak 15 Minutes (1995)(R9)

System (City)	Passenger Space (based on gross floor space) (ft^2/p)	(m^2/p)
NYCT (New York)	4.0 into CBD	0.38 into CBD
CTA (Chicago)	7.0 into CBD	0.67 into CBD
SEPTA (Philadelphia)	8.0 into CBD	0.77 into CBD
MBTA (Boston)	5.0 into CBD	0.50 into CBD
BART (San Francisco)	5.75-9.0	0.53-0.83
WMATA (Washington)	5.0-12.0	0.50-1.11
MARTA (Atlanta)	6.75-7.5	0.63-0.71
TTC (Toronto)	4.5-6.0	0.42-0.56
STM (Montréal)	3.4-4.0	0.31-0.38

CBD: central business district

Care should be taken in comparing and applying the service standards with hourly average loadings. Service standards are usually based on the peak-within-the-peak—15 minutes or less. The difference between 15-minute and peak hour flows can be represented by a peak hour factor.

Service standards are usually based on peak-within-the-peak loads.

The peak hour factor for New York subway trunk routes averages 0.82. Outside New York, the peak-within-the-peak period tends to be more pronounced and the peak hour factor is lower. This is due in part to the long-established Manhattan program to stagger work hours and the natural tendency of passengers to avoid the most crowded period—particularly on lines that are close to capacity.

Peak hour diversity is lower in New York than in most other cities.

In addition to standards or policies for the maximum loading on peak-within-the-peak period trains and for standards based on minimum *policy* headways, at off-peak times some operators specify a maximum standing time. This is more often a goal rather than a specific standard—20 minutes is typical.

Maximum standing time policies.

Loading levels for commuter rail are unique and uniform. Although standing passengers may be accepted for short inner-city stretches or during times of service irregularities, the policy is to provide a seat for all passengers. Capacity is usually cited at 90 to 95% of the number of seats on the train.

SPACE REQUIREMENTS

The Batelle Institute[R8] provides details of the projected body space of passengers in various situations. The most useful of these for rail transit capacity are shown in Exhibit 5-22 for males:

Exhibit 5-22
Male Passenger Space Requirements[R8]

These are suggested minimum spaces.

Situation	Projected Area (ft^2)	Projected Area (m^2)
Standing	1.6-2.2	0.15-0.20
... with briefcase	2.7-3.2	0.25-0.30
... with daypack	3.2-3.8	0.30-0.35
... with suitcases	3.8-5.9	0.35-0.55
... with stroller	10.2-12.4	0.95-1.15
... with bicycle (horizontal)	17.2-20.4	1.60-1.90
Holding on to stanchion	2.7	0.25
Minimum seated space	2.7-3.2	0.25-0.30
Tight double seat	3.8 per person	0.35 per person
Comfortable seating	5.9 per person	0.55 per person
Wheelchair space (ADA)	10.0 (30 in x 48 in)	0.93 (0.76 m x 1.22 m)

NOTE: Stroller and bicycle dimensions based on review of manufacturer specifications.

Pushkarev et al.[R17] suggest *gross vehicle floor area* as a readily available measure of car occupancy, recommending the following standards for the peak hour:

- *Adequate*: 5.4 ft^2 (0.5 m^2) per passenger provides comfortable capacity.
- *Tolerable with difficulty*: 3.8 ft^2 (0.35 m^2) is the lower limit in North America with "some touching."
- *Totally intolerable*: 2.2 ft^2 (0.2 m^2) is the least amount of space that is occasionally accepted.

Commuter rail capacity is based on the number of seats, reduced by a peak hour factor. Commuter rail cars in North America are typically 86 ft (28 m) long and, with few exceptions, have seating for 114 to 185 passengers. The higher levels relate to bi-level or gallery cars and/or cars with 2+3 ("two-by-three") seating arrangements.

Wheeled mobility aid space provisions range from 5.9 to 12.9 ft^2 (0.55 to 1.2 m^2); the ADA uses a 30-in. by 48-in. (760-mm by 1220-mm) space. This space can include folding or jump seats. Provision must also be made for wheelchair maneuvering and for any requirements to carry strollers, baggage, and bicycles. More space is required for powered wheeled mobility aids and ones whose occupants have a greater leg extension, less for compact and sports chairs.

The capacity for existing systems should be based on actual loading levels of a comparable service. Actual levels on a specific system or line should be adjusted for any difference in car size and interior layout—particularly the number of seats.

Maximum, full, and crush loads.

Manufacturer-specified passenger loading—*total*, *maximum*, *full,* or *crush load*—does not necessarily represent a realistic occupancy level. Rather, it reflects applying a set criteria—such as 5 or occasionally 6 passengers per square meter (0.45 to 0.56 p/ft^2)—to the floor space remaining after seating space is deducted. In particular, *crush load* can represent the theoretical, and often unattainable, loading used to calculate vehicle structural strength or the minimum traction equipment performance.

Vehicle-Specific Calculations

Estimating the person capacity of a vehicle.

Detailed calculations of the person capacity of individual vehicles are not recommended. Given the wide range of peak hour occupancy that is dependent on policy decisions, elaborate determination of interior space usage is generally not practical. Reasonably accurate estimates of vehicle capacity are all that are needed. The following procedures offer a straightforward method.

The first step after obtaining the interior car dimensions is to determine the length of the car side free from doorways. Deducting the sum of the door widths, plus a setback allowance of 16 in. (0.40 m) per double door,[2] from the interior length gives the interior free wall length.

Seating can then be allocated to this length by dividing by the seat pitch:

- 27 in. (0.69 m) for transverse seating,[3] and
- 17 in. (0.43 m) for longitudinal seating.

The result, in lowest whole numbers,[4] should then be multiplied by 2 for longitudinal seating or by 3, 4, or 5, respectively for 2+1, 2+2, or 2+3 transverse seating. The result is the total number of seats. A more exact method would use the specific length between door setbacks. Articulated light rail vehicles should have the articulation width deducted. Four seats can be assigned to the articulation, if desired.

Seating area.

The floor space occupied by seats can then be calculated by multiplying transverse seats by 5.4 ft^2 (0.5 m^2) and longitudinal seats by 4.3 ft^2 (0.4 m^2). These areas make a small allowance for bulkhead seating but otherwise represent relatively tight and narrow urban transit seating. Add 10 to 20% for a higher quality, larger seat such as that found on BART.

Standing area.

The residual floor area can now be assigned to standing passengers. Light rail vehicles with step wells should have half the step well area deducted. Although prohibited by many systems, passengers will routinely stand on the middle step, squeezing into the car at stops if the doors are treadle operated.

Articulated light rail vehicles should have half the space within the articulation deducted as unavailable for standing passengers, even if the articulation is wider. Many passengers choose not to stand in this space.

Standing passengers can be assigned as follows:

- 2.15 ft^2/p (5 p/m^2), an uncomfortable near-crush load for North Americans with frequent body contact and inconvenience with packages and briefcases. Moving to and from doorways is extremely difficult.
- 3.2 ft^2/p (3.3 p/m^2) a reasonable service load with occasional body contact. Moving to and from doorways requires some effort.
- 5.4 ft^2/p (2.0 p/m^2),[5] a comfortable level without body contact, reasonably easy circulation, and similar space allocation as seated passengers.

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2 A lower set-back dimension of 12 in. (0.3 m) may be used if this permits an additional seat/row of seats between doorways.

3 Increase to 32 in. (0.8 m) for seats behind a bulkhead.

4 For more accurate results, the sidewall should be divided into the lengths between each set of doors (and, when appropriate, between the door and any articulation) and checked, or adjusted, to ensure that an integer of the seat pitch is used. This can be done by dividing the interior free wall length by the number of doorways plus one. The number of integer seat pitches in each space is then determined and used to calculate the total vehicle seating.

However, this approach can result in the seating changing radically with a small change in vehicle length, articulation length, or door width, any of which are sufficient to add or remove a row of seats between each set of doors. On a four-door car with 2+2 seating, this results in the seating adjusting up or down by 20 seats at a time—five rows of four seats. Simple calculations cannot substitute for a professional interior layout design that can optimize seating with a combination of transverse and longitudinal seats. Other design criteria can also be accommodated including the provision of wheelchair spaces and maximizing circulation space around doorways.

5 This upper level is a peak 15-minute occupancy level for standing passengers. Over the peak hour it corresponds closely to Pushkarev's[(R17)] and Jacobs'[(R12)] estimates of a U.S. rush hour loading average of 5.4 ft^2/p (0.5 m^2/p)—both seated and standing. It also corresponds to Pushkarev's and Batelle's[(R8)] recommendations for *adequate* or *comfortable* loading levels.

The middle level above is slightly relaxed from the often stated standard of four standing passengers per square meter. The so-called crush loads are frequently based on 5 or 6 passengers per square meter (0.45 to 0.56 p/ft²), the latter being more common in Europe. Asian standards for both maximum and crush loads reach 7 or 8 standing passengers per square meter (0.67 to 0.77 p/ft²). The resultant sum of seated and standing passengers provides a guide for the average peak 15-minute service loading level for the specific vehicle. Peak hour loading should be divided by the peak hour factor to get equivalent peak 15-minute loading levels. No specific allowance has been made for wheelchair, bicycle, stroller, or other wheeled device accommodation, or for reduced standing densities away from doorways. The above range of standing densities makes such small adjustments unnecessary. Cars intended for higher density loading should have a greater number of doors. Space inefficiencies at the extremities of a car are unavoidable unless the London Underground arrangement of doors at the very end of each car is adopted.

The above process can be expressed mathematically as:

Equation 5-6

$$C_c = \left[\frac{(L_c - 0.5L_a)W_c - 0.5D_n W_s D_w}{S_{sp}}\right] + N\left[\left(1 - \frac{S_a}{S_{sp}}\right)\left(\frac{L_c - L_a - D_n(D_w + 2S_b)}{S_w}\right)\right]$$

The articulated rail car schematic in Exhibit 5-23 shows the principal dimensions of this equation.

where:

- C_c = car capacity—peak 15 minutes (p/car);
- L_c = car interior length (ft, m);
- L_a = articulation length for light rail (ft, m);
- W_s = stepwell width (certain light rail only) (ft, m);
- W_c = car interior width (ft, m);
- S_{sp} = space per standing passenger (ft², m²):
  2.15 ft² (0.2 m²)—crush load,
  3.2 ft² (0.3 m²)—maximum schedule load, and
  5.4 ft² (0.5 m²)—comfortable standing load;
- N = seating arrangement:
  2 for longitudinal seating,
  3 for 2+1 transverse seating,
  4 for 2+2 transverse seating, and
  5 for 2+3 transverse seating;[6]
- S_a = area of single seat (ft², m²):
  5.4 ft² (0.5 m²) for transverse, and
  4.3 ft² (0.4 m²) for longitudinal;
- D_n = number of doorways;
- D_w = doorway width (ft, m);
- S_b = single setback allowance (ft, m):
  0.67 ft (0.2 m)— or less; and
- S_w = seat pitch (ft, m):
  2.25 ft (0.69 m) for transverse, and
  1.42 ft (0.43 m) for longitudinal.

6 2+3 seating is only possible on cars with width greater than 10 ft (3 m), and is not applicable to light rail or automated guideway transit.

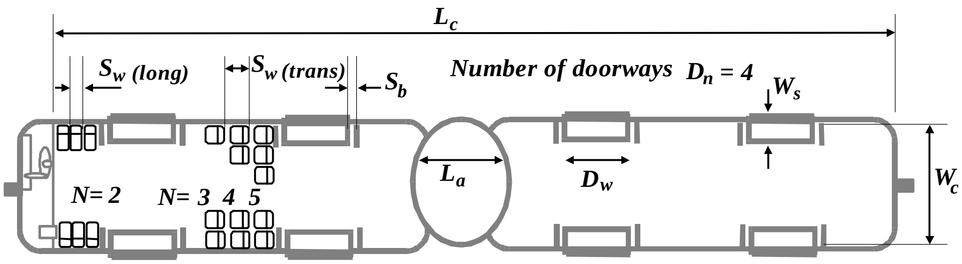

Exhibit 5-23
Schematic LRT Car Showing Dimensions(R15)

Default Method

A default method is to divide the gross floor area of a vehicle (exterior length multiplied by exterior width) by 5.4 ft² (0.5 m²) and use the resultant number of passengers as the average over the peak hour—without applying a peak hour factor. An average space over the peak hour of 5.4 ft² (0.5 m²) per passenger is the comfortable loading level on U.S. rail transit systems recommended in several reports and is close to the average loading on all trunk rail transit lines entering the CBD of U.S. cities.

LENGTH

Train length as a surrogate for capacity.

Another default method to approximate loading levels is to assign passengers per unit length. Applying Equation 5-6 to two typical light rail vehicles produces the loading levels in passengers per unit length shown in Exhibit 5-24. As would be expected, the wider and longer Baltimore car has proportionately higher loadings per meter of length. The almost generic Siemens-Düwag car used in nine systems (with some dimensional changes) has a range of 1.5 to 2.4 passengers per foot of car length (5.0 to 8.0 p/m length). The lower level of 1.5 passengers per foot length (5.0 p/m length)—with a standing space per passenger of 4.3 ft² (0.4 m²)—corresponds closely with the recommended *comfortable* loading of an average of 5.4 ft² (0.5 m²) per passenger.

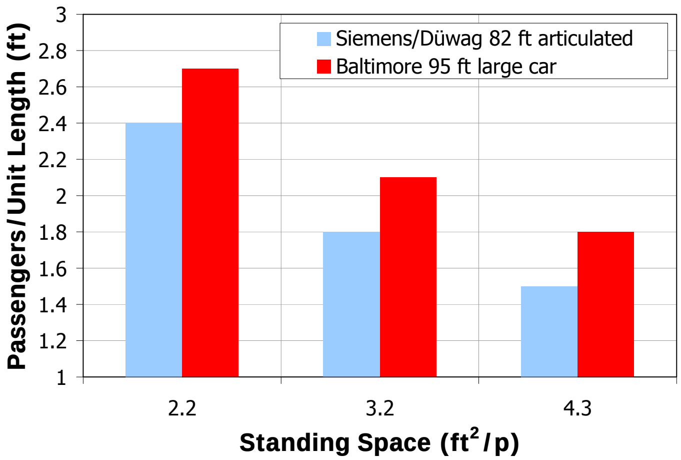

Exhibit 5-24
Linear Passenger Loading—Articulated LRVs(R15)

An alternative figure using metric units appears in Appendix A.

Applying Equation 5-6 to selected heavy rail cars produces the loading levels in passengers per unit length shown in Exhibit 5-25. As would be expected, the smaller and narrower cars in Vancouver and Chicago have lower loadings per unit length.

The more generic 75-ft (23-m) cars used in more than 12 U.S. and Canadian cities have a remarkably close data set for each of the three variations of door and seating configurations, with a range of 2.1 to 3.5 passengers per foot of car length (7.0 to 11.5 p/m of car length). The higher end of this range approaches that of crush loaded conditions.

APPENDIX B

Capital Improvement Program (CIP) Replacement Table

Light Rail Vehicle Replacements

LRVs have significantly longer life cycle than that of buses, with an expected useful life cycle of 36 and 41 years depending on type of LRV.

TABLE 2A. VEHICLES SYSTEMS - LIGHT RAIL VEHICLES

ITEM REQUIRED	PROJECT MANAGER	TOTAL FLEET	YEAR OF PURCHASE	ACTION NEEDED	FY NEEDED	CURRENT AGE FY14	OPTIMUM/ MINIMUM REPLACEMENT CYCLE[1]	COND.	2014	2015	2016	2017	2018	FY14-FY18 TOTAL
LIGHT RAIL VEHICLES	**Griffiths**													
Type 1 LRVs (Banfield LRT)		26	1986	Replace	2027	28	41	1	$0	$0	$0	$0	$0	$0
Type 2 LRVs (Westside LRT)		46	1998	Replace	2034	16	36	1	$0	$0	$0	$0	$0	$0
Type 2 LRVs (Airport MAX)		6	2000	Replace	2036	14	36	1	$0	$0	$0	$0	$0	$0
Type 3 LRVs (Interstate MAX)		27	2004	Replace	2040	10	36	1	$0	$0	$0	$0	$0	$0
Type 4 LRVs (I-205/Mall)		22	2009	Replace	2045	5	36	1	$0	$0	$0	$0	$0	$0
		127			**GRAND TOTAL VEHICLE SYSTEMS. . . .**				**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

Light Rail Vehicle Component Replacements

Table 2B			Estimated Replacements					Estimated Replacement Costs					
	Fleet		**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**	**FY14-FY18 Total**
Total Component Replacements	Type 1		179	172	240	188	214	$ 610,000	$ 680,500	$ 806,500	$ 615,500	$ 667,500	$ 3,380,000
	Type 2/3		1,150	1,037	590	603	539	$ 4,183,000	$ 3,554,210	$ 1,588,310	$ 1,472,310	$ 1,378,820	$ 12,176,650
	Type 4		175	242	176	115	94	$ 416,500	$ 631,000	$ 540,000	$ 282,500	$ 221,727	$ 2,091,727
	Total		1,504	1,451	1,006	906	847	$ 5,209,500	$ 4,865,710	$ 2,934,810	$ 2,370,310	$ 2,268,047	$ 17,648,377
	Assumed Maintenance Budget Baseline (3% inflation)							$ 1,701,170	$ 1,752,205	$ 1,804,771	$ 1,858,914	$ 1,914,682	$ 9,031,743
	Net Additional LRV Component Overhaul Total							**$ 3,508,330**	**$ 3,113,505**	**$ 1,130,039**	**$ 511,396**	**$ 353,365**	***$ 8,616,635***
		Car Count											Average
Per Car Averages	Type 1	26	6.88	6.62	9.23	7.23	8.23	$ 23,462	$ 26,173	$ 31,019	$ 23,673	$ 25,673	$ 26,000
	Type 2/3	79	14.56	13.13	7.47	7.63	6.82	$ 52,949	$ 44,990	$ 20,105	$ 18,637	$ 17,453	$ 30,827
	Type 4	22	7.95	11.00	8.00	5.23	4.27	$ 18,932	$ 28,682	$ 24,545	$ 12,841	$ 10,079	$ 19,016
	Average		*11.84*	*11.43*	*7.92*	*7.13*	*6.67*	*$ 41,020*	*$ 38,313*	*$ 23,109*	*$ 18,664*	*$ 17,859*	*$ 27,793*

APPENDIX C

PM Inspections by LRV Type

Appendix C Type 4 Tasks

ITEM	DESCRIPTION	Location	Frequency	N61	N62	N63	N64	N65	N66	N67	N68	N69	A-END	B-END	C	UpdateDate
LF120	TRUCK APPURTENANCES	Under Car	9.00	1	1	1	1	1	1	1	1	1				12/16/2009
LF122	TRACTION MOTOR	Under Car	81.00						1						---------	12/16/2009
LF125	GROUND BRUSH	Under Car	27.00	1			1			1						12/16/2009
LF130	TRANSMISSION OIL SAMPLE, OIL CHANGE, BREATHER CLEAN	Under Car	40.50					1				1			---------	12/16/2009
LF140	TRACK BRAKE	Under Car	9.00	1	1	1	1	1	1	1	1	1				12/16/2009
LF145	FRICTION BRAKE	Under Car	9.00	1	1	1	1	1	1	1	1	1				12/16/2009
LF147	CALIPER LUBRICATION	Under Car	0.00													12/16/2009
LF149	EHU FLUID LEVEL, ACCUMULATOR CHARGE, AND HANDPUMP	Under Car	27.00		1			1			1					12/16/2009
LF150	SANDING SYSTEM	Under Car	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF152	SANDING HEATER	Car Body and Interior	81.00			1									---------	12/16/2009
LF165	AUTOMATIC TRAIN STOP	Car Body and Interior	9.00	1	1	1	1	1	1	1	1	1				12/16/2009
LF170	PASSENGER SEATING	Car Body and Interior	0.00													12/16/2009
LF172	FLOORING	Car Body and Interior	0.00													12/16/2009
LF175	OPERATOR SEAT LUBRICATION	Car Body and Interior	45.50				1				1				---------	12/16/2009
LF180	CAB EQUIPMENT	Car Body and Interior	0.00													12/16/2009
LF185	WINDSHIELD WIPER WASHER	Car Body and Interior	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF190	COMMUNICATION SYSTEM	Car Body and Interior	27.00	1			1			1						12/16/2009
LF191	P.A. VOLUME ADJUSTMENT	Car Body and Interior	81.00									1				12/16/2009
LF197	EVENT RECORDER TEST	Car Body and Interior	40.50		1					1			---------		---------	12/16/2009
LF200	EMERGENCY EQUIPMENT	Car Body and Interior	40.50	1				1								12/16/2009
LF205	LIGHTING	Car Body and Interior	40.50			1				1						12/16/2009
LF210	CAB ELECTRICAL COMPARTMENTS	Car Body and Interior	40.50				1					1			---------	12/16/2009
LF211	CCTV TEST	Car Body and Interior	40.50					1				1		---------	---------	12/16/2009
LF212	INTERIOR ELECTRICAL COMPARTMENTS	Car Body and Interior	81.00		1											12/16/2009
LF215	DOORS OPERATION	Car Body and Interior	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF216	DOORS TIMING AND ADJUSTMENT	Car Body and Interior	81.00								1				---------	12/16/2009
LF220	DOOR LUBRICATION	Car Body and Interior	40.50			1				1					---------	12/16/2009
LF221	DOOR / BRIDGEPLATE SUMMARY	Car Body and Interior	40.50				1				1				---------	12/16/2009
LF225	BRIDGEPLATE OPERATION	Car Body and Interior	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF226	BRIDGEPLATE TIMING ADJUSTMENT	Car Body and Interior	81.00								1				---------	12/16/2009
LF230	BRIDGEPLATE LUBRICATION	Car Body and Interior	40.50				1				1				---------	12/16/2009
LF235	ELECTRICAL COUPLER CABLES & CONTACTS (B-END COUPLER)	Under Car	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF240	COUPLER	Under Car	13.50	1		1		1		1		1			---------	12/16/2009
LF245	COUPLER EXTENSIVE	Under Car	40.50	1					1						---------	12/16/2009
LF250	CARBODY	Car Body and Interior	40.50	1					1							12/16/2009
LF251	ARTICULATION	Car Body and Interior	81.00			1							----------	----------		12/16/2009
LF255	AUXILIARY INVERTER	Roof Top	40.50		1					1					---------	12/16/2009
LF260	EXTERIOR ELECTRICAL COMPARTMENTS	Roof Top	81.00						1							12/16/2009
LF265	DOWNLOAD VCU	Car Body and Interior	13.5	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF270	PROPULSION CONTAINER	Roof Top	27.00		1			1			1				---------	12/16/2009
LF275	HSCB	Roof Top	81.00					1					---------	---------		12/16/2009
LF290	KNIFE SWITCH	Roof Top	81.00						1				---------	---------		12/16/2009
LF300	HVAC	Roof Top	9.00	1	1	1	1	1	1	1	1	1			---------	12/16/2009
LF305	HVAC EXTENSIVE	Roof Top	81.00			1									---------	12/16/2009
LF315	PANTOGRAPH	Roof Top	9.00	1	1	1	1	1	1	1	1	1	---------	---------		12/16/2009
LF320	PANTOGRAPH EXTENSIVE + SURGE ARRESTOR	Roof Top	40.50	1					1				---------	---------		12/16/2009
LF325	BATTERIES	Roof Top	40.50			1			1				---------	---------		12/16/2009
LF213	SIDE VIEW CCTV	Car Body and Interior	9.00	1	1	1	1	1	1	1	1	1			---------	5/10/2010

Appendix C Type 3 Tasks

ITEM	Comp	DESCRIPTION	Location	Frequency	N20	N21	N22	N23	N24	N25	A-END	B-END	C	UpdateDate
LF 120	MIL120	Truck appurtenances	Under Car	9.00		1								11/15/2010
LF 122	MIL122	Traction motor cleaning (Power Down)	Under Car	81.00						1			---------	11/15/2010
LF 125	MIL125	Ground brushes (Power Down)	Under Car	27.00				1						11/15/2010
LF 130	MIL130	Transmission oil sample /breather /Change	Under Car	40.50					1				---------	11/15/2010
LF 135	MIL135	Transmission Breather (see above)	Under Car	0.00										11/15/2010
LF 140	MIL140	Track brakes	Under Car	9.00		1								11/15/2010
LF 145	MIL145	Friction brakes	Under Car	4.50	1									11/15/2010
LF 147	MIL147	Friction brakes caliper lubrication	Under Car	81.00						1				11/15/2010
LF 149	MIL149	E.H. Unit Accumulator/M.R.U.	Under Car	27.00				1						11/15/2010
LF 150	MIL150	Sanding system	Under Car	9.00		1							---------	11/15/2010
LF 152	MIL152	Sand Box Heater Test	Car Body and Interior	81.00						1			---------	11/15/2010
LF 155	MIL155	Load Weight Sensor	Under Car	27.00				1						11/15/2010
LF 165	MIL165	ATS	Car Body and Interior	9.00		1								11/15/2010
LF 170	MIL170	Passenger seating	Car Body and Interior	0.00										11/15/2010
LF 172	MIL172	Flooring	Car Body and Interior	0.00										11/15/2010
LF 175	MIL175	Operator seat Lubrication	Car Body and Interior	40.50					1				---------	11/15/2010
LF 180	MIL180	Cab equipment	Car Body and Interior	0.00										11/15/2010
LF 185	MIL185	Windshield wiper / washer	Car Body and Interior	9.00		1							---------	11/15/2010
LF 186	MIL186	Windshield Wiper Linkage	Car Body and Interior	40.50					1				---------	11/15/2010
LF 190	MIL190	Communication system	Car Body and Interior	27.00				1						11/15/2010
LF 191	MIL191	PA Volume Adjustment	Car Body and Interior	81.00						1		---------	---------	11/15/2010
LF 192	MIL192	Test Radio Power	Car Body and Interior	0.00										11/15/2010
LF 197	MIL197	Event recorder	Car Body and Interior	40.50					1		---------		---------	11/15/2010
LF 198	MIL198	Automated Passenger Counting	Car Body and Interior	0.00										11/15/2010
LF 200	MIL200	Emergency equipment	Car Body and Interior	40.50					1					11/15/2010
LF 205	MIL205	Lighting / destination signs	Car Body and Interior	27.00				1						11/15/2010
LF 210	MIL210	Interior electrical compartments	Car Body and Interior	27.00				1					---------	11/15/2010
LF 211	MIL211	CCTV Test	Car Body and Interior	40.50					1			---------	---------	11/15/2010
LF 212	MIL212	Interior electrical compartments (extensive)	Car Body and Interior	81.00						1				11/15/2010
LF 213	MIL213	Side View CCTV	Car Body and Interior	4.50	1								---------	11/15/2010
LF 215	MIL215	Doors Operation/Safety	Car Body and Interior	4.50	1								---------	11/15/2010
LF 216	MIL216	Doors Adjust and Timing	Car Body and Interior	81.00						1			---------	11/15/2010
LF 220	MIL220	Doors lubrication	Car Body and Interior	40.50					1				---------	11/15/2010
LF 221	MIL221	Door / Bridgeplate Summary	Car Body and Interior	40.50					1				---------	11/15/2010
LF 225	MIL225	Bridgeplates Operation/Safety	Car Body and Interior	9.00		1							---------	11/15/2010
LF 226	MIL226	Bridgeplates Adjust and Timing	Car Body and Interior	81.00						1			---------	11/15/2010
LF 230	MIL230	Bridgeplates lubrication	Car Body and Interior	40.50					1				---------	11/15/2010
LF 235	MIL235	Coupler electrical head	Under Car	4.50	1								---------	11/15/2010
LF 240	MIL240	Coupler	Under Car	13.50			1						---------	11/15/2010
LF 245	MIL245	Coupler (extensive)	Under Car	40.50					1				---------	11/15/2010
LF 250	MIL250	Car body (Power Down)	Car Body and Interior	40.50					1					11/15/2010
LF 251	MIL251	Articulation	Car Body and Interior	40.50					1		----------	----------		11/15/2010
LF 255	MIL255	Auxiliary Inverter (Power Down)	Roof Top	13.50			1						---------	11/15/2010
LF 260	MIL260	Exterior electrical compartments (extensive - Pwr Down)	Roof Top	81.00						1				11/15/2010
LF 265	MIL265	Propulsion TCU Download	Car Body and Interior	4.50	1								---------	11/15/2010
LF 270	MIL270	Propulsion container cleaning (Power Down)	Roof Top	13.50			1						---------	11/15/2010
LF 275	MIL275	High Speed Circuit Breaker (Power Down)	Car Body and Interior	81.00						1	---------	---------		11/15/2010
LF 290	MIL290	Knife switch (Power Down)	Roof Top	81.00						1	---------	---------		11/15/2010
LF 300	MIL300	HVAC (Power Down)	Roof Top	9.00		1							---------	11/15/2010
LF 305	MIL305	HVAC (extensive - Power Down)	Roof Top	27.00				1					---------	11/15/2010
LF 310	MIL310	HVAC Coil cleaning	Roof Top	81.00						1			---------	11/15/2010
LF 315	MIL315	Pantograph (Power Down)	Roof Top	4.50	1						---------	---------		11/15/2010
LF 320	MIL320	Pantograph (extensive - Power Down)	Roof Top	40.50					1		---------	---------		11/15/2010
LF 322	MIL322	Transverse shock absorber lubrication (Power Down)	Roof Top	27.00				1			---------	---------		11/15/2010
LF 325	MIL325	Batteries (Power Down)	Roof Top	27.00				1				---------	---------	11/15/2010

Appendix C Type 2 Tasks

ITEM	Comp	DESCRIPTION	Location	Frequency	N10	N11	N12	N13	N14	N15	A-END	B-END	C	UpdateDate
LF 120	MI120	Truck appurtenances	Under Car	9.00	1		1		1					22-Sep-10
LF 122	MI122	Traction motor cleaning (Power Down)	Under Car	81.00						1			---------	22-Sep-10
LF 125	MI125	Ground brushes (Power Down)	Under Car	27.00	1									22-Sep-10
LF 130	MI130	Transmission oil sample /breather /Change	Under Car	40.50									---------	22-Sep-10
LF 135	MI135	Transmission Breather (see above)	Under Car	0.00										22-Sep-10
LF 140	MI140	Track brakes	Under Car	9.00	1		1		1					22-Sep-10
LF 145	MI145	Friction brakes	Under Car	4.50	1	1	1	1	1	1				22-Sep-10
LF 147	MI147	Friction brakes fluid Sample	Under Car	81.00	1									22-Sep-10
LF 149	MI149	E.H. Unit Accumulator/M.R.U.	Under Car	27.00				1						22-Sep-10
LF 150	MI150	Sanding system	Under Car	9.00	1		1		1				---------	22-Sep-10
LF 152	MI152	Sand Box Heater Test	Car Body and Interior	81.00				1					---------	22-Sep-10
LF 155	MI155	Load Weight Sensor	Under Car	27.00		1								22-Sep-10
LF 165	MI165	ATS	Car Body and Interior	9.00		1		1		1				22-Sep-10
LF 170	MI170	Passenger seating	Car Body and Interior	0.00										22-Sep-10
LF 172	MI172	Flooring	Car Body and Interior	0.00										22-Sep-10
LF 175	MI175	Operator seat Lubrication	Car Body and Interior	40.50						1			---------	22-Sep-10
LF 180	MI180	Cab equipment	Car Body and Interior	0.00										22-Sep-10
LF 185	MI185	Windshield wiper / washer	Car Body and Interior	9.00	1		1		1				---------	22-Sep-10
LF 186	MI186	Windshield Wiper Linkage	Car Body and Interior	40.50			1						---------	22-Sep-10
LF 190	MI190	Communication system	Car Body and Interior	27.00	1									22-Sep-10
LF 192	MI192	Test Radio Power	Car Body and Interior	0.00										22-Sep-10
LF 197	MI197	Event recorder	Car Body and Interior	40.50				1			---------		---------	22-Sep-10
LF 200	MI200	Emergency equipment	Car Body and Interior	40.50										22-Sep-10
LF 205	MI205	Lighting / destination signs	Car Body and Interior	27.00				1						22-Sep-10
LF 210	MI210	Interior electrical compartments	Car Body and Interior	20.25			1						---------	22-Sep-10
LF 211	MI211	CCTV Test	Car Body and Interior	40.50				1				---------	---------	22-Sep-10
LF 212	MI212	Interior electrical compartments (extensive)	Car Body and Interior	81.00			1							22-Sep-10
LF 215	MI215	Doors Operation/Safety	Car Body and Interior	4.50	1	1	1	1	1	1			---------	22-Sep-10
LF 216	MI216	Doors Adjust and Timing	Car Body and Interior	81.00									---------	22-Sep-10
LF 220	MI220	Doors lubrication	Car Body and Interior	40.50					1				---------	22-Sep-10
LF 221	MI221	Door / Bridgeplate Summary	Car Body and Interior	40.50						1			---------	22-Sep-10
LF 225	MI225	Bridgeplates Operation/Safety	Car Body and Interior	9.00		1		1		1			---------	22-Sep-10
LF 226	MI226	Bridgeplates Adjust and Timing	Car Body and Interior	81.00									---------	22-Sep-10
LF 230	MI230	Bridgeplates lubrication	Car Body and Interior	40.50						1			---------	22-Sep-10
LF 235	MI235	Coupler electrical head	Under Car	4.50	1	1	1	1	1	1			---------	22-Sep-10
LF 240	MI240	Coupler	Under Car	13.50		1			1				---------	22-Sep-10
LF 245	MI245	Coupler (extensive)	Under Car	40.50		1							---------	22-Sep-10
LF 250	MI250	Car body (Power Down)	Car Body and Interior	40.50	1									22-Sep-10
LF 251	MI251	Articulation	Car Body and Interior	40.50				1			----------	----------		22-Sep-10
LF 255	MI255	Auxiliary Inverter (Power Down)	Roof Top	13.50		1			1				---------	22-Sep-10
LF 260	MI260	Exterior electrical compartments (extensive - Pwr Down)	Roof Top	81.00										22-Sep-10
LF 265	MI265	Propulsion TCU Download	Car Body and Interior	4.50	1	1	1	1	1	1			---------	22-Sep-10
LF 270	MI270	Propulsion container cleaning (Power Down)	Roof Top	13.50			1			1			---------	22-Sep-10
LF 275	MI275	High Speed Circuit Breaker (Power Down)	Car Body and Interior	81.00							---------	---------		22-Sep-10
LF 290	MI290	Knife switch (Power Down)	Roof Top	81.00							---------	---------		22-Sep-10
LF 300	MI300	HVAC (Power Down)	Roof Top	9.00		1		1		1			---------	22-Sep-10
LF 305	MI305	HVAC (extensive - Power Down)	Roof Top	27.00				1					---------	22-Sep-10
LF 315	MI315	Pantograph (Power Down)	Roof Top	4.50	1	1	1	1	1	1	---------	---------		22-Sep-10
LF 320	MI320	Pantograph (extensive - Power Down)	Roof Top	40.50		1					---------	---------		22-Sep-10
LF 322	MI322	Transverse shock absorber lubrication (Power Down)	Roof Top	40.50							---------	---------		22-Sep-10
LF 325	MI325	Batteries (Power Down)	Roof Top	27.00						1		---------	---------	22-Sep-10
LF 191	MI191	PA Volume Adjustment	Car Body and Interior	81.00					1			---------	---------	22-Sep-10
LF 198	MI198	Automated Passenger Counting	Car Body and Interior	0.00										22-Sep-10
LF 213	MI213	Side View CCTV	Car Body and Interior	4.50	1	1	1	1	1	1			---------	22-Sep-10

Appendix C - Type 1 Tasks

ITEM	Comp	DESCRIPTION	Location	Frequency	N00	N01	N02	N03	N04	N05	A-End	B-End	C	UpdateDate
251	MI251	HVAC Coil Cleaning	Roof Top	81.00						1			-------	11/4/2010
135	MI135	Inspect Brake Pads and Disc	Under Car	4.50	1									11/4/2010
265	MI265	Check Door Operation and Safety System	Car Body and Interior	4.50	1								-------	11/4/2010
301	MI301	Couplers Electrical Contacts	Under Car	4.50	1								-------	11/4/2010
370	MI370	Brake and Power Test	Car Body and Interior	4.50	1								-------	11/4/2010
400	MI400	Inspect Traction Motors (Power Down)	Under Car	4.50	1								-------	11/4/2010
445	MI445	Pantograph (Power Down)	Roof Top	4.50	1						-------		-------	11/4/2010
120	MI120	Check Truck Appurtenances	Under Car	9.00		1								11/4/2010
130	MI130	Track Brake Assemblies	Under Car	9.00		1								11/4/2010
335	MI335	Test "Emergency" Mushroom Operation	Car Body and Interior	9.00		1							-------	11/4/2010
401	MI401	Traction Motor Cleaning (Power Down)	Under Car	9.00		1							-------	11/4/2010
425	MI425	Inspect Roof Mounted Equipment (Power Down)	Roof Top	9.00		1							-------	11/4/2010
132	MI132	1/4 Turn Brake Actuators	Under Car	9.00		1								11/4/2010
235	MI235	Check Window Wiper	Car Body and Interior	9.00		1							-------	11/4/2010
245	MI245	HVAC	Roof Top	9.00		1							-------	11/4/2010
340	MI340	ATS System Functional Test	Car Body and Interior	9.00		1								11/4/2010
105	MI105	Drain Labyrinth Seals	Under Car	13.50			1						-------	11/4/2010
300	MI300	Couplers	Under Car	13.50			1						-------	11/4/2010
310	MI310	Inspect Interior Electrical Compartments	Car Body and Interior	13.50			1						-------	11/4/2010
405	MI405	Clean and Inspect Exterior Electrical Compartments (Power Down)	Under Car	13.50			1							11/4/2010
325	MI325	Manual Brake Release Pump	Car Body and Interior	18.00			1							11/4/2010
155	MI155	Test Load Weigh Sensor	Under Car	27.00				1						11/4/2010
250	MI250	HVAC (Extensive)	Roof Top	27.00				1					-------	11/4/2010
225	MI225	Test Communication System	Car Body and Interior	27.00				1						11/4/2010
295	MI295	Lighting/Dest. Signs	Car Body and Interior	27.00				1					-------	11/4/2010
415	MI415	Inspect Batteries	Under Car	27.00				1				-------	-------	11/4/2010
275	MI275	Door Lubrication	Car Body and Interior	40.50					1				-------	11/4/2010
280	MI280	Door Summary	Car Body and Interior	40.50					1				-------	11/4/2010
350	MI350	Event Recorder (Train-Logger)	Car Body and Interior	40.50					1		-------		-------	11/4/2010
385	MI385	Inspect Ground Brushes (Power Down)	Under Car	40.50					1					11/4/2010
450	MI450	Pantograph (Extensive)	Roof Top	40.50					1		-------		-------	11/4/2010
185	MI185	Auxiliary Inverter (Power Down)	Under Car	40.50					1		-------		-------	11/4/2010
403	MI403	Check contactor timing (Power Down)	Under Car	40.50					1				-------	11/4/2010
190	MI190	Inspect Carbody	Car Body and Interior	40.50					1					11/4/2010
205	MI205	Operators Seat	Car Body and Interior	40.50					1				-------	11/4/2010
302	MI302	Coupler (Extensive)	Under Car	40.50					1				-------	11/4/2010
390	MI390	DC-DC Converter (Power Down)	Under Car	40.50					1			-------	-------	11/4/2010
100	MI100	Gearbox Oil Sample/Change	Under Car	40.50					1				-------	11/4/2010
137	MI137	Caliper Pivot Pin Lubrication	Under Car	40.50					1					11/4/2010
220	MI220	Check Emergency Equipment	Car Body and Interior	40.50					1				-------	11/4/2010
312	MI312	CCTV Test	Car Body and Interior	40.50					1			-------	-------	11/4/2010
330	MI330	Test Sandbox Heaters	Car Body and Interior	81.00						1			-------	11/4/2010
410	MI410	Exterior Electrical Compartments (Extensive)	Under Car	81.00						1				11/4/2010
226	MI226	PA Volume Adjustment	Car Body and Interior	81.00						1	-------		-------	11/4/2010
270	MI270	Doors Adjustment	Car Body and Interior	81.00						1			-------	11/4/2010
315	MI315	Interior Electrical Compartments (Extensive)	Car Body and Interior	81.00						1				11/4/2010
371	MI371	Pad Force Measurement	Under Car	81.00						1				11/4/2010
455	MI455	Articulation Roof Linkage	Roof Top	81.00						1	-------	-------		11/4/2010
456	MI456	Articulation Floor Swivel Plate	Car Body and Interior	81.00						1	-------	-------		11/4/2010
461	MI461	Lubricate Slewing Ring	Under Car	81.00						1				11/4/2010

APPENDIX D

Preventive Maintenance Force Account Plan Budgets

BUD1 Personnel Services OPERATIONS - RAIL MAINTENANCE OF WAY

Position Title	09/10 Actual Total	10/11 Actual Total	11/12 Budget Total	11/12 Est Total	12/13 Budget Total
Rail Maintenance:					
Manager, Rail MOW Operations	$ 139,941	$ 92,000	$ 93,510	$ 93,510	$ 93,510
Training/Engineering Supervisor	68,121	66,694	68,121	68,121	68,121
Train/Eng Supervisor-Green Line	68,121	69,039	68,121	68,121	68,121
Maintenance of Way Supervisor	438,750	437,088	438,750	438,750	438,750
MOW Project Engineer	73,125	73,143	73,125	73,125	73,125
Assistant Supervisor - MOW	727,351	723,657	739,057	739,057	805,326
Track Maintainer	524,716	489,743	637,025	637,025	621,858
Track Maintainer PMLR					37,877
Substation Maintainer/Apprentice	365,746	379,384	303,779	303,779	318,409
Substation Maint/Apprentice PMLR			20,049	20,049	63,682
Power Maintainer/Apprentice	749,346	717,173	729,069	729,069	764,182
Power Maint/Apprentice PMLR			60,756	60,756	191,045
Signal Maintainer/Apprentice	623,628	631,679	637,029	637,029	690,762
Signal Maint/Apprentice PMLR			38,801	38,801	125,593
Maintenance of Way Laborer	428,757	338,480	336,371	336,371	352,800
Field Technician/Apprentice	1,260,223	1,265,030	1,275,870	1,275,870	1,337,274
MMIS/Clerk	100,829	104,211	105,071	105,071	110,104
Fringe Benefits	3,220,808	2,529,795	2,899,070	2,899,070	2,812,743
Workers' Compensation	266,978	119,392	19,704	19,704	242,444
Longevity Premium			201,814	201,814	197,255
Night & Shift Differential			57,983	57,983	61,953
Unscheduled Overtime	592,705	333,703	245,480	245,480	255,299
Tool Allowance			25,522	25,522	26,543
Unemployment			10,660	10,660	11,282
Union Insured Premium Repayment					42,335
Capitalized Labor/Fringe	(12,553)	$ (51,719)	(219,458)	(219,458)	(684,549)
Total	$ 9,636,593	$ 8,318,493	$ 8,865,277	$ 8,865,277	$ 9,125,845

BUD2 Materials & Services OPERATIONS - RAIL MAINTENANCE OF WAY

Expense Category	Actual 09/10	Actual 10/11	Budget 11/12	Estimate 11/12	Budget 12/13
Contracted Maintenance - Landscaping	$ 40,866	$ 18,782	$ 12,125	$ 12,000	$ 13,000
Contracted Maintenance - Power Facility			3,000	3,000	4,000
Contracted Maintenance - Signals	7,897	25,895	60,000	60,000	64,000
Contracted Maintenance - Track	205,662	98,021	150,000	140,000	154,500
Contracted Maintenance - OCS	17,500	27,500			
Contracted Maintenance - Bridges	37,041	37,041	86,000	50,000	45,000
Contracted Maintenance - Stations	2,047				
Contracted Maintenance - Communications	438,560	453,102	417,174	450,000	26,556
Contracted Maintenance - Fare Equipment	103,430	39,579	59,678	162,000	162,000
Contracted Maintenance - Substation			50,000	48,000	56,500
Calibration & Tool Repair	538	24,405	4,000	24,000	10,000
Other Services	22,162	5,599	4,000	4,000	5,000
Tickets & Passes	1,256				
Office Supplies	5,783	4,503	3,000	3,000	3,400
Freight	3,460	11,298		8,000	
Maintenance Materials - Outside Plant		40			
Maintenance Materials - Shop		30			
Small Hand Tools	10,113	9,731	4,000	8,000	8,000
Other Materials	9,099	19,647	7,000	18,000	16,000
Safety Supplies	28,394	24,091	10,000	24,000	18,000
Maintenance Materials - Fare Equipment	355,859	256,606	285,973	260,000	290,000
Maintenance Materials - Track	139,807	98,462	130,945	124,000	136,000
Maintenance Materials - Signals	150,840	183,586	127,075	120,000	132,000
Maintenance Materials - Communications	30,799	43,963	24,000	30,000	48,000
Maintenance Materials - OCS	37,995	45,515	34,489	34,000	36,000
Maintenance Materials - Substations	29,696	20,262	21,131	22,000	22,000
Electrical Power (Propulsion)	4,085,751	4,075,996	4,592,808	4,400,000	4,854,626
Telephone	86,581	78,626	67,000	68,000	69,347
PI/PD Expense	28,410	88,302		5,000	
Dues & Subscriptions	194	197		200	200

BUD2 Materials & Services OPERATIONS - RAIL MAINTENANCE OF WAY

Expense Category	Actual 09/10	Actual 10/11	Budget 11/12	Estimate 11/12	Budget 12/13
Local Travel & Meetings		$ 10		$ 120	$ 100
Education & Training	$ 44,360	5,971		10,000	10,000
Education & Training-PMLR			$ 1,206		2,188
Out-of-Town Travel	8,965	2,756		5,000	4,500
Steel Bridge Maintenance Agreement	284,277	278,320	270,000	270,000	330,000
CDL Renewals	1,104	247		450	400
Employee Recognition	2,038	1,297	872	300	800
Rentals	16,763		30,000	20,000	30,000
OCC Equipment & Supplies	5,623		10,000		
Computer Supplies	7,271	2,250			
Contracted Maintenance - Fac. & Equipment	388				
Obsolete Inventory	6,769	13,479			
Hillsboro Maintenance Agreement			10,000	10,000	10,000
	$ 6,257,297	$ 5,995,109	$ 6,475,476	$ 6,393,070	$ 6,562,117

Position Title	09/10 Actual Total	10/11 Actual Total	11/12 Budget Total	11/12 Est Total	12/13 Budget Total
Director, Rail Maintenance	$ 66,430				
Manager, Rail Equip. Maintenance	88,009	$ 87,681	$ 88,009	$ 88,009	$ 88,009
Manager, Rail Equip. Maintenance	92,582	92,219	92,582	92,582	92,582
Manager, Warranty Programs		86,219	82,309	82,309	82,309
Operations Specialist	51,010	50,833	51,010	51,010	69,175
Training/Engineering Supervisor	162,879	165,040	146,442	146,442	146,442
Training/Engineering Supervisor	73,221	73,355	73,221	73,221	73,221
Rail Maintenance Supervisor	512,711	511,786	512,711	512,711	512,711
Engineering Technician III	55,395	55,182	55,395	55,395	55,395
Assistant Supervisor	446,560	450,904	380,750	380,750	398,941
MMIS/Clerk	90,575	93,922	52,535	52,535	55,052
Janitor	273,929	327,697	149,769	149,769	140,840
Vehicle Cleaner/Helper	949,422	974,124	1,388,856	1,388,856	1,456,599
Vehicle Maintainer/Apprentice	5,006,938	5,154,977	5,576,117	5,576,117	5,842,643
Vehicle Maintainer/Apprentice PMLR					481,873
Vehicle Maint/Apprentice Streetcar		508,706	276,045	276,045	
Stores Supervisor	67,902	67,643	67,902	67,902	67,902
Assistant Storekeeper	128,640	129,359	118,782	118,782	126,027
Junior Partsman	93,033	91,548			
Partsman	175,271	177,209	113,004	113,004	120,077
Vehicle Cleaner/Helper					336,138
Vehicle Maintainer/Apprentice					694,175
Vehicle Cleaner/Helper OTO					(56,023)
Vehicle Maintainer/Apprentice OTO					(404,936)
Fringe Benefits	5,767,353	4,608,310	5,021,978	5,021,978	5,085,296
Workers' Compensation	49,478	90,062	244,866	244,866	586,417
Longevity Premium			257,803	257,803	323,905
Unscheduled Overtime	267,547	324,134	326,439	326,439	540,800
Tool Allowance			60,428	60,428	67,515
Night & Shift Differential			93,942	93,942	102,580
Unemployment			8,278	8,278	9,388
Union Insured Premium Repayment					80,919
Capitalized Labor/Fringe		(728)			(788,591)
Total	$ 14,418,884	$ 14,120,183	$ 15,239,171	$ 15,239,171	$ 16,387,381

BUD2 Materials & Services OPERATIONS - RAIL EQUIPMENT MAINTENANCE

Expense Category	Actual 09/10	Actual 10/11	Budget 11/12	Estimate 11/12	Budget 12/13
Professional & Technical	$ 10				
Calibration & Tool Repair	15,129	$ 6,677	$ 5,450	$ 6,000	$ 5,600
Contracted Maintenance	2,351		16,045	10,000	16,000
Laundry	67,894	65,706	89,250	72,000	96,050
Other Services	10,377	14,318	21,011	10,000	20,000
Graphics Supplies		676	1,200	600	1,000
Office Supplies	9,058	7,270	7,000	8,800	7,000
Computer Supplies	4,446	5,298	1,500	500	1,500
Maint. Materials - LRV Overhaul	1,465,381	1,289,127	1,130,494	1,940,000	1,200,000
VT Maintenance Materials - Trolley	393	679	2,500	1,500	2,000
Repair Materials - LRV Accident			17,500	12,000	18,000
Repair Materials - Rev Equipment	25,564	2,909			
Repair Materials - LRV Vandalism	47,695	69,913	44,000	70,000	46,000
Maint. Materials - Service Equip.	10,201	6,325		7,000	
Maint. Materials - LRVs	1,712,631	1,810,810	2,143,147	2,300,000	2,209,124
Freight	55,524	90,496	70,307	64,000	72,000
Furniture & Equipment <$5,000	265	58,201			
Shop Equipment	75,975		70,500	75,000	72,000
Cleaning Supplies	86,323	85,202	95,771	83,000	90,000
Small Hand Tools	59,033	61,434	7,700	51,000	15,000
Other Materials	78,051	66,193	62,500	81,000	64,000
Safety Supplies	36,101	51,564	55,134	41,000	54,700
Obsolete Inventory	5,268	7,968		1,600	
Invoice Price Variance	(3,395)	(28,279)		(500)	
Average Cost Variance	394	(825)		1,200	
Telephone	2,417	2,636	2,400	3,000	2,275
Education & Training	8,643	4,927	963	3,300	2,145
Out-of-Town Travel	2,293				
Inventory Adjustments	130,953	131,457		32,000	
CDL Renewals	593	552	2,350	3,000	2,550
Employee Recognition	1,103	162		900	
	$ 3,910,669	$ 3,811,398	$ 3,846,722	$ 4,877,900	$ 3,996,944

APPENDIX E

Service Related Failures MDBF Oct. Nov. & Dec. 2012

REM - MDBF

for the combined months of

October - November - December 2012

The number of times, during the months listed above, a symptom code is used to log in a repair on the pending worklist.

SYMPTOM CODE	RVSR	MDBF	GOALS for 12/12		RVSR	MDBF	GOALS for 12/12		RVSR	MDBF	GOALS for 12/12		RVSR	MDBF	GOALS for 12/12		TYPES	MDBF	GOALS for 12/12	
	T4	T4 RVSR	FAILS	MDBF	T3	T3 RVSR	FAILS	MDBF	T2	T2 RVSR	FAILS	MDBF	T1	T1 RVSR	FAILS	MDBF	1, 2, 3, 4	All RVSR	FAILS	MDBF
S01 AUXILIARY INVERTER FAILURE	2	172,968	2.0	180,000	4	108,534	3.0	164,359	21	39,264	7	125,415	7	52,647	3.0	106,534	34	58,034	15	112,706
S02 CONVERTER FAILURE	0		0.0		0		0.0		0		0		2	184,264	3.0	106,534	2	986,574	3	563,529
S03 PANTOGRAPH FAILURE	4	86,484	3.0	120,000	2	217,068	1.5	328,718	13	63,427	3	351,162	4	92,132	1.0	319,603	23	85,789	8	211,323
S04 ACCIDENT DAMAGE	3	115,312			2	217,068			2	412,275			1	368,528			8	246,644		
S05 ARTICULATION FAILURE	0		1.0	360,000	0		1.0	493,077	0		1	877,905	0		1.0	319,603	0		4	422,647
S06 ATS/TWC FAILURE	3	115,312	6.0	60,000	2	217,068	6.0	82,180	11	74,959	12	73,159	8	46,066	6.0	53,267	24	82,215	30	56,353
S07 CAB ELECTRIC CONTROLS	11	31,449	6.0	60,000	14	31,010	6.0	82,180	23	35,850	11	79,810	23	16,023	5.0	63,921	71	27,791	28	60,378
S08 CARBODY/CAR/CAB INTER FAILURE	44	7,862			46	9,438			166	4,967			86	4,285			342	5,769		
S09 COUPLER FAILURE	2	172,968	1.0	360,000	7	62,019	7.0	70,440	20	41,228	12	73,159	8	46,066	5.0	63,921	37	53,328	25	67,623
S10 COMMUNICATION FAILURE	31	11,159	33.0	10,909	55	7,893	48.0	10,272	98	8,414	99	8,868	43	8,570	39.0	8,195	227	8,692	219	7,720
S11 DOOR FAILURE	10	34,594	24.0	15,000	39	11,132	27.0	18,262	81	10,180	45	19,509	32	11,517	30.0	10,653	162	12,180	126	13,417
S13 FRICTION BRAKE FAILURE	2	172,968	6.0	60,000	14	31,010	15.0	32,872	13	63,427	30	29,264	16	23,033	12.0	26,634	45	43,848	63	26,835
S14 HVAC FAILURE	4	86,484	9.0	40,000	5	86,827	15.0	32,872	22	37,480	30	29,264	27	13,649	21.0	15,219	58	34,020	75	22,541
S15 LIGHTING FAILURE	13	26,610			35	12,404			57	14,466			22	16,751			127	15,537		
S16 PROPULSION FAILURE	8	43,242	15.0	24,000	34	12,769	15.0	32,872	70	11,779	30	29,264	42	8,774	33.0	9,685	154	12,813	93	18,178
S17 SANDING SYSTEM FAILURE	0		1.0	360,000	2	217,068	2.0	246,539	4	206,138	4	219,476	1	368,528	2.0	159,802	7	281,878	9	187,843
S18 TRUCK EQUIPMENT FAILURE	7	49,419	9.0	40,000	18	24,119	7.0	70,440	34	24,251	13	67,531	1	368,528	4.0	79,901	60	32,886	33	51,230
S19 VANDALISM	16	21,621			5	86,827			13	63,427			8	46,066			42	46,980		
S21 BRIDGEPLT MECHANISM & CONTRL	10	34,594	6.0	60,000	8	54,267	3.0	164,359	29	28,433	12	73,159	0		0.0		47	41,982	21	80,504
S22 ELECTRICAL CONTROLS FAILURE	1	345,935	1.0	360,000	0		1.0	493,077	3	274,850	2	438,953	3	122,843	3.0	106,534	7	281,878	7	241,512
S23 CCTV/APC/EVENT RECORDER FAILS	19	18,207	30.0	12,000	2	217,068	15.0	32,872	14	58,896	30	29,264	2	184,264	6.0	53,267	37	53,328	81	20,871
TOTALS	190		153.0		294		172.5		694		341		336		174.0		1,514	1,303	840	
SERVICE RELATED MDBF	**65**	**5,322**	**103.0**	**5,000**	**117**	**3,711**	**108.5**	**4,544**	**297**	**2,776**	**213**	**4,131**	**151**	**2,441**	**123.0**	**2,598**	**630**	**3,132**	**547**	**3,749**

Total Mileage for:
October - November - December 2012

3 Month Mileage for Type 4 Rev Cars =	345,935
3 Month Mileage for Type 3 Rev Cars =	434,135
3 Month Mileage for Type 2 Rev Cars =	824,550
3 Month Mileage for Type 1 Rev Cars =	368,528
3 Month Mileage for all Rev Cars =	1,973,148 Total Miles

Goal Miles

360,000	493077	877905	319603	2,050,585