Discussion-piece #8
CTPP-based Aggregate Model
Federal Transit Administration
June 6, 2006

1. Motivation. Unlike conditions 25 years ago in the early days of the New Starts program, today there are many recently built rail lines and other transit guideways – many in locations outside the very largest metropolitan areas where rail transit has been in continuous operation for nearly a century. As part of efforts to support quality control testing of forecasts for new proposals, FTA has sponsored research on the ability of completed projects to supply insights on ridership potential through simple, easily applied ways. This research has produced the Aggregate Rail Ridership Forecasting Model (yes, the AARF model) that uses data from the Census Transportation Planning Package (CTPP2000) to predict unlinked rail transit trips for light rail and commuter rail systems. This model is intended by FTA as a way for project sponsors to develop order-of-magnitude estimates of ridership for new rail lines in metropolitan areas where no existing fixed guideway transit facilities are present – often called "new" New Starts. Forecasts from the model are not intended to replace carefully prepared forecasts from local travel models; rather, they provide another source of insights into the reasonableness of those local forecasts. Careful thought on differences between predictions from the AARF model and from local models can help inform the discussion of the reliability of the local estimates.

2. Overview. The AARF model has been calibrated against ridership on existing systems throughout the country that are generally similar to proposed "new" New Starts. Because these proposals are generally in growing cities without an extensive history of fixed guideway transit, the calibration excluded light rail systems in the very largest metropolitan areas and those that have been in operation for many decades. Similarly, the calibration has excluded commuter rail systems where they are part of a large network that has been in operation for many decades. The model applies a series of expected rail shares to the total work-travel flows (by any mode) found in CTPP2000 in the rail corridor. In calibration with rail systems that existed in 2000, the flow data represented development patterns and travel that may have been encouraged by the rail line itself. For proposed systems, the resulting model provides a ridership estimate based on "current" (year 2000) development and travel flows. Estimates of future-year ridership should either be adjusted to represent expected growth in the corridor or used as part of the calibration process to adjust conventional travel forecasting models.

3. CTPP data. The basic inputs to the model are the CTPP2000 work-flow data, disggregated by auto-ownership class and employment density at the work end. To identify the travel markets served by a rail line, the model uses a series of concentric buffers around each rail station. Workers traveling between residence and workplace locations that are both within station buffers establish the overall markets from which rail riders are drawn. In essence, these data provide an estimate of the total market for a candidate rail line and the remainder of the model provides information on the typical number of rail trips generated by these flows.

4. <u>Level-of-service data.</u> For the LRT version of the model, the only necessary supplemental information is the directional route miles for the service. The model uses this variable to generate an alternate estimate of ridership based solely on route miles. For the commuter rail version, the model uses a broader set of characteristics:

   - Annual revenue vehicle-miles;
   - Annual revenue vehicle-hours (used with miles to generate average speed);
   - Average consist length;
   - Weighted operating days per year;
   - Directional route miles (used with preceding items to compute train miles per route mile);
   - Flag indicating whether the system connects or does not connect to a rail distributor (i.e., LRT or rapid transit line connecting the commuter rail station to downtown destinations)

5. <u>Ridership data used for model calibration.</u> Wherever possible, model calibration used Year 2000 ridership and rail stations (to define the rail corridors) to preserve consistency with Year 2000 CTPP data. In several cases, however, more detailed information (i.e., trips by purpose or mode of access) was known for survey years other than 2000. In those cases, calibration relied upon the ridership and station locations for the survey year rather than the Year 2000. In cities where the system was extended during 2000 (or the system was not yet opened), ridership for another year was used so that the data unambiguously represents the stabilized volume associated with the system being modeled. Table 1 summarizes the selected data used to calibrate the LRT model. Table 2 summarizes the commuter rail data.

Table 1. Ridership Data Used for Weekday LRT Model Calibration

Statistic	Baltimore LRT Only	Buffalo LRT	Cleveland LRT Only	Dallas LRT Only	Denver* LRT	Portland LRT	Sacramento LRT	Salt Lake City LRT	San Diego LRT Only	San Jose** LRT Only	St. Louis LRT
Survey Year	1996	2003	1994	1998	unknown	2002	1999	2002	2003	2000	2002
Survey Reported Ridership											37,381
Selected Year	2000	2000	2000	2000	2001	2000	2000	2002	2000	2001	2002
Select NTD or APTA?	NTD	NTD	NTD	NTD	NTD	NTD	NTD	NTD	NTD	NTD	Survey
NTD Mileage for Year	57.6	12.4	30.8	40.8	28.0	64.9	40.7	34.2	96.6	58.4	68.8
NTD Ridership for Year	27,415	23,155	14,062	37,682	31,423	73,562	29,102	33,615	83,474	30,295	43,541
APTA Ridership for Year	25,600	23,800	12,900	38,100	32,800	71,100	28,800	31,400	82,600	25,200	38,400
Selected Ridership	27,415	23,155	14,062	37,682	31,423	73,562	29,102	33,615	83,474	30,295	37,381
Mileages (from GIS Data)											
LRT Miles	54.1	12.6	29.1	38.4	27.2	62.2	39.7	32.7	90.3	55.7	64.1
Streetcar Miles	-	-	-	-	-	4.5	-	-	-	-	-
RRT Miles	-	-	-	-	-	-	-	-	-	-	-
CR Miles	-	-	-	-	-	-	-	-	-	-	-

*SW Corridor Opened 7/17/00
*'00 NTD data for year ended 12/31/00, use 2001

**Tasman Opened 12/17/99
**'00 NTD data for year ended 6/30/00, use 2001

6. <u>Calibration Approach.</u> Data on a variety of station buffer distances, purpose segmentation, and access mode segmentations were tested and the models that generated the highest regression coefficients with generally explainable coefficients signs and magnitudes were selected as the final model. In the case of commuter rail, the wide range of service levels offered by the different systems had a significant impact on ridership. Two level of service variables (average speed and average weekday train miles per weekday directional route mile) were defined and demand was adjusted up or down by comparing the system-specific values to the nationwide average and an assumed elasticity of +0.3. Thus, systems with 10 percent faster average speeds would generate 3 percent more ridership. Systems with 100 percent more train miles per route mile (i.e., twice as much service) would generate 30 percent more ridership. Finally, based on one case (Seattle) where no connecting rail service was available to the CBD, a rail connection variable was tested. Similar level-of-service

adjustments were not found to be necessary for the LRT model. A possible reason is that existing LRT systems are more alike in fundamental service levels than the different commuter rail systems.

Table 2. Commuter Rail Data Used for Weekday Model Calibration

Data Source	Statistic	Baltimore MARC	Dallas TRE	Los Angeles MetroLink	Miami Tri-Rail	San Diego Coaster	San Francisco Penn. JTP	San Jose ACE	Seattle Sounder	Virginia VRE
GIS Charactersitics	CR Miles	354.2	50.5	683.9	138.1	71.5	151.1	147.8	75.8	152.5
Year 2000 NTD	Directional Miles	373.4	51.6	770.0	142.2	82.2	153.6	172.0	78.6	177.5
	Avg Weekday Unlinked Trips	20,851	4,229	26,300	7,381	4,327	30,616	8,197	1,120	8,057
	Annual Passenger Miles	160,111,921	6,610,264	256,386,730	67,099,046	33,852,130	189,566,786	22,481,408	3,010,800	67,617,944
	Annual Vehicle Rev Mile	4,537,502	324,525	6,484,857	1,819,317	1,058,768	4,269,766	440,320	73,476	1,545,177
	Annual Vehicle Rev Hours	113,029	17,206	157,007	51,887	24,482	133,064	11,776	1,872	45,741
	Peak:Base Ratio	1	4	2	2	2	1	-	-	-
APTA 2000	Avg Weekday Unlinked Trips	22,200	4,300	30,000	8,700	4,300	31,400	3,500	1,200	9,600
Calibration TargetRidership	Avg Weekday Unlinked Trips	20,851	4,229	26,300	7,381	4,327	30,616	3,500	1,120	8,057

Note: 1999 NTD for ACE (San Jose) reported 1480 weekday unlinked trips and 2001 NTD reported 3631 weekday unlinked trips.
Year 2000 NTD was not deemed represented and was replaced with 2000 APTA data.

7. Final LRT Model. The final LRT Model is documented below. Table 3 and Figure 1 present the performance of the model.

Weekday Unlinked
Drive Access to Work
Rail Trips = 0.030 * CTPP PNR 6 -to-1 Mile JTW Flows (<50K Den) +
0.202 * CTPP PNR 6 -to-1 Mile JTW Flows (>50K Den)

Weekday Unlinked Other
(Non-Drive Access to Work)
Rail Trips = 0.395 * CTPP 2 -to-1 Mile JTW Flows (<50K Den) +
0.445 * CTPP 2 -to-1 Mile JTW Flows (>50K Den)

Total Weekday Unlinked Rail Trips
Rail Trips = Weekday Unlinked Drive Access to Work Rail Trips +
Trips Weekday Unlinked Other Rail

Where:

- CTPP PNR 6-to-1 Mile JTW Flows (<50K Den) is the total JTW flow for cases where home is within 6 miles of a rail station with Park-Ride facilities, work is within 1 mile of any rail station, and the worker density (from the CTPP) at the work end of the journey is less than 50,000 workers per square mile.

- CTPP PNR 6-to-1 Mile JTW Flows (>50K Den) is the total JTW flow for cases where home is within 6 miles of a rail station with Park-Ride facilities, work is within 1 mile of any rail station, and the worker density (from the CTPP) at the work end of the journey is greater than 50,000 workers per square mile.

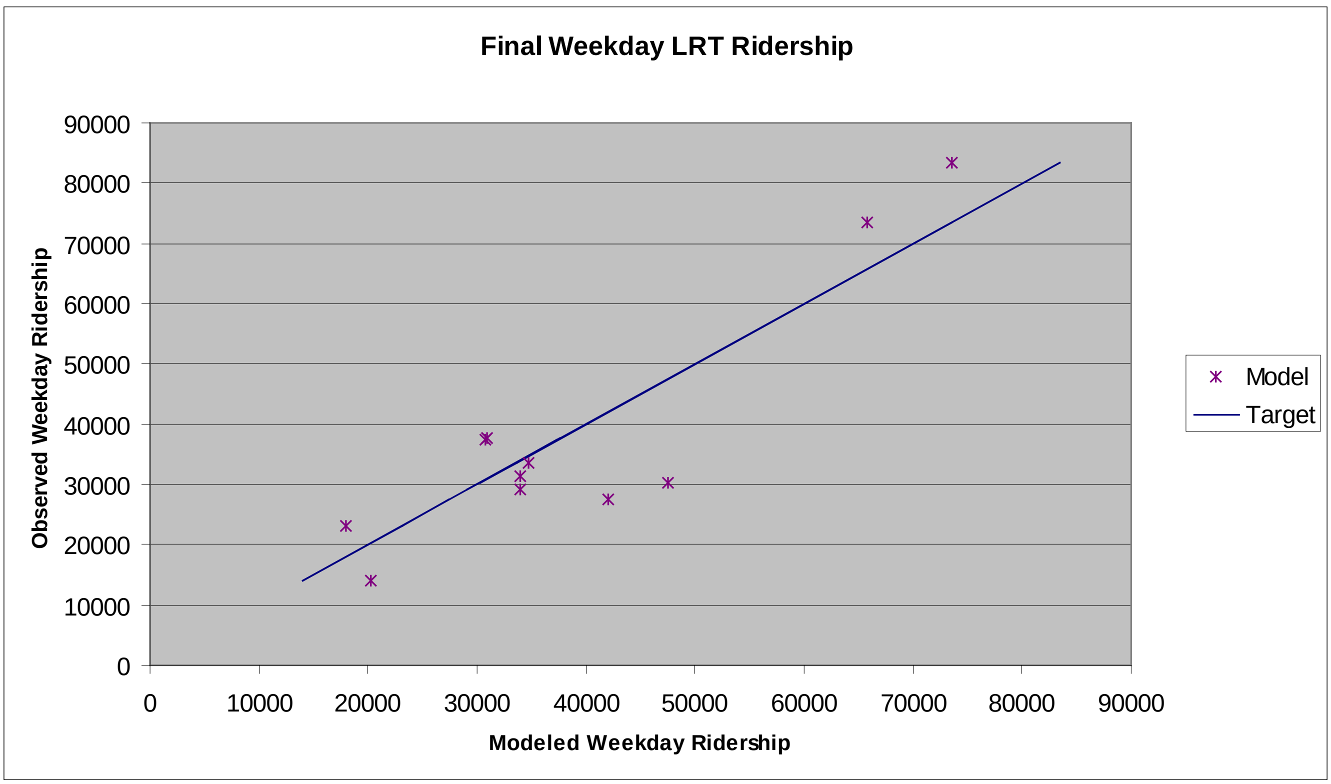
- CTPP 2-to-1 Mile JTW Flows (<50K) is the total JTW flow for cases where home is within 2 miles of any rail station, work is within 1 mile of any rail, and the worker density (from the CTPP) at the work end of the journey is less than 50,000 workers per square mile.

- CTPP 2-to-1 Mile JTW Flows (>50K) is the total JTW flow for cases where home is within 2 miles of any rail station, work is within 1 mile of any rail, and the worker density (from the CTPP) at the work end of the journey is greater than 50,000 workers per square mile.

Table 3. Comparison of Observed and Modeled LRT Ridership

City	Observed Weekday Unlinked Trips	Drive Access Work Rail Trips	Other Rail Trips	Total Rail Trips	Percentage Error
Baltimore	27,415	13,336	28,704	42,040	53.3%
Buffalo	23,155	4,168	13,753	17,921	-22.6%
Cleveland	14,062	7,088	13,098	20,187	43.6%
Dallas	37,682	9,866	21,050	30,916	-18.0%
Denver	31,423	12,474	21,454	33,928	8.0%
Portland	73,562	13,320	52,431	65,751	-10.6%
Sacramento	29,102	8,539	25,389	33,928	16.6%
Salt Lake City	33,615	8,272	26,525	34,797	3.5%
San Diego	83,474	13,019	60,468	73,487	-12.0%
San Jose	30,295	9,338	38,168	47,506	56.8%
St. Louis	37,381	10,182	20,547	30,729	-17.8%

Figure 1. Comparison of Observed and Modeled LRT Ridership



8. Final Commuter Rail Model. The final Commuter Rail Model is documented below. Table 4 and Figure 2 present its performance.

Commuter Rail Weekday Unlinked Trips =	Nominal Ridership x Demand Adjustment Factor

Where:

Nominal Ridership =	0.069*High Income CTPP Flows within 6 miles of a PNR station at the home end and 1 mile of any station at the work end of the trip + 0.041*Medium Income CTPP Flows within 6 miles of a PNR station at the home end and 1 mile of any station at the work end of the trip + 0.151*Low Income CTPP Flows within 2 miles of any station at the home end and 1 mile of any station at the work end of the trip
Demand Adjustment Factor =	(1+0.3*Percent Deviation in Average System Speed) x (1+0.3*Percent Deviation in Train Miles per Mile) x Rail Connection Index

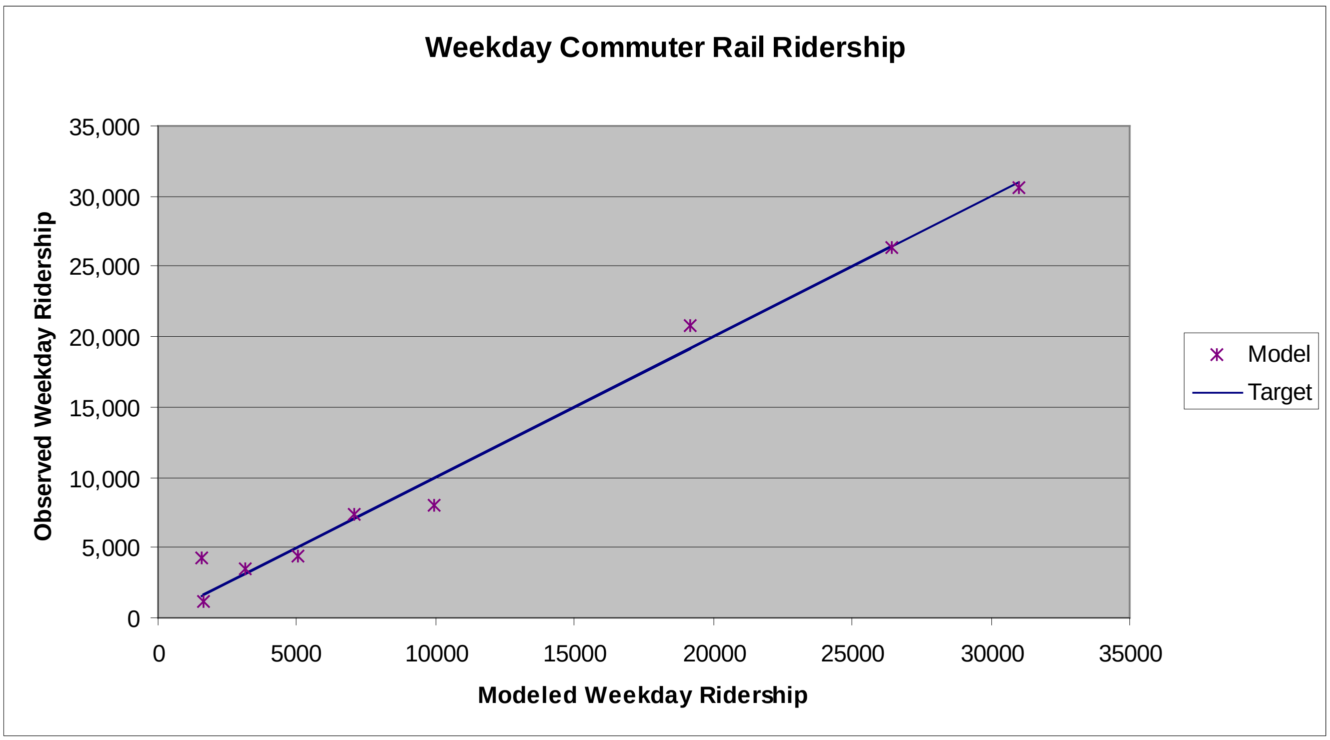
Where:

Percent Deviation in Average System Speed =	$\frac{\text{System Average Speed-35.7 mph}}{\text{(System Average Speed+35.7)/2}}$
System Average Speed =	Annual Revenue Vehicle Miles/Annual Revenue Vehicle Hours
Percent Deviation in Train Miles per Mile =	$\frac{\text{Weekday Train Miles per Directional Route Mile-10.3}}{\text{(Weekday Train Miles per Directional Route Mile+10.3)/2}}$
Weekday Train Miles per Directional Route Mile =	Annual Revenue Vehicle Miles/250/Average Train Length
Rail Connection Index =	1.0 if commuter rail line connects to an urban rail line providing distribution to the CBD, otherwise 0.5
High Income =	Annual Household Income greater than or equal to $60,000
Medium Income =	Annual Household Income greater than or equal to $25,000 and less than $60,000
Low Income =	Annual Household Income less than $25,000

Table 4. Comparison of Observed and Modeled Commuter Rail Ridership

City	Observed Ridership	Modeled Ridership	Percent Difference
Baltimore	20,851	19,145	-8.2%
Dallas	4,229	1,586	-62.5%
Los Angeles	26,300	26,450	0.6%
Miami	7,381	7,061	-4.3%
San Diego	4,327	5,017	15.9%
San Francisco	30,616	31,032	1.4%
San Jose	3,500	3,127	-10.7%
Seattle	1,120	1,642	46.6%
Virginia	8,057	9,972	23.8%

Figure 2. Comparison of Observed and Modeled Commuter Rail Ridership



9. Implementation. FTA will conduct tests and prepare example applications of the AARF model during the remainder of 2006. Beginning in January 2007, FTA will ask sponsors of potential "new" New Starts projects seeking to enter preliminary engineering to generate AARF-model-based aggregate forecasts and compare those estimates with local forecasts. Discussions of differences between the aggregate forecasts and locally prepared forecasts will help to inform consideration of the forecasts. The purpose of the aggregate model is simply to add information to setting that often have little current information – or ridership patterns – to inform conventional models sufficiently to support reliable forecasts of fixed-guideway ridership.