TPB Models Development Status Report

Presentation to the
Travel Forecasting Subcommittee

Ron Milone and Mark Moran

National Capital Region Transportation Planning Board (TPB)

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Today's discussion topics

- Development schedule for the Ver. 2.3 model
- Recent updates to Ver. 2.2 model
- Sensitivity testing of the Ver. 2.3 model:
  - Fare elasticities
  - Incorporating transit subsidies explicitly into the model

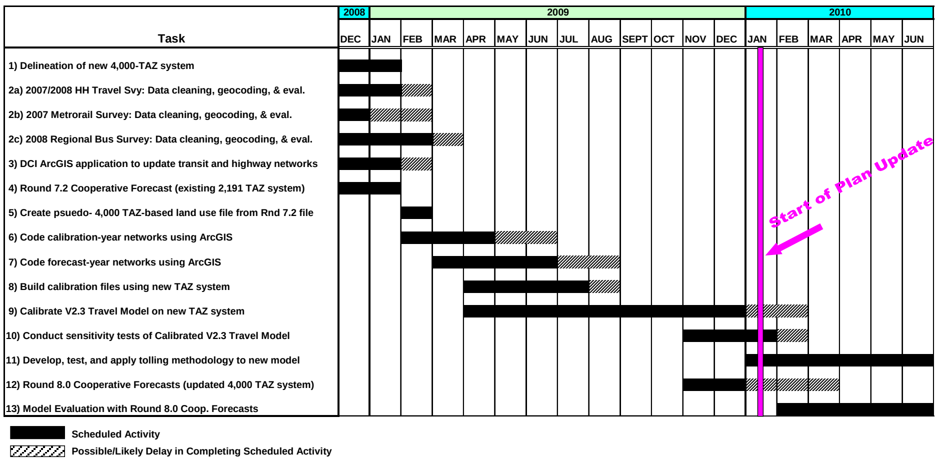
Version 2.3 model schedule

- Primary Objective: To be ready for the approaching Long-Range Plan update in 2010
- What does 'ready' mean?
  - Ideally: Version 2.3 calibrated/validated to newly collected survey data, on the new 4,000 TAZ system, using Round 8.0 land use
  - However, to meet this schedule, several inter-related activities need to be coordinated

Activities that need to be coordinated to meet the schedule

- Cooperative Forecasting
- Models Development
- GIS Technical Support
- Network Development
- Travel Surveys
- Regional Transportation Data Clearinghouse

Version 2.3 model phasing for Plan update



Version 2.2 model updates

- Traffic assignment process updated during recent conformity work (2008 CLRP/2009-2014 TIP)
- Rationale: To improve the assignment of HOV/HOT traffic on the Capital Beltway in Virginia and I-395/Shirley Highway

Previous Ver. 2.2 assignment steps

3 assignments executed by period, 5 markets assigned

	# UE Iterations	Period	Trip Markets Assigned
Assignment 1	60	AM	1 SOV 2 HOV 2-Occ. 3 HOV 3+-Occ. 4 Trucks 5 Airport Pax
Assignment 2	60	PM	1 SOV 2 HOV 2-Occ. 3 HOV 3+-Occ. 4 Trucks 5 Airport Pax
Assignment 3	60	Off-Peak	1 SOV 2 HOV 2-Occ. 3 HOV 3+-Occ. 4 Trucks 5 Airport Pax

Total iterations: 180

Updated Ver. 2.2 Assignment Steps

5 assignments by period & non-HOV/HOV market groups

	# UE Iterations	Period	Trip Markets Assigned
Assignment 1	60	AM	1 SOV 2 HOV 2-Occ. 3 Trucks 4 Airport Pax
Assignment 2	60	AM	1 HOV 3+-Occ.
Assignment 3	60	PM	1 SOV 2 HOV 2-Occ. 3 Trucks 4 Airport Pax
Assignment 4	60	PM	1 HOV 3+-Occ.
Assignment 5	60	Off-Peak	1 SOV 2 HOV 2-Occ. 3 HOV 3+-Occ. 4 Trucks 5 Airport Pax

Total iterations: 300

Details of the Ver. 2.2 model update

- Non-HOV and HOV trips assigned separately for peak periods only
- During non-HOV assignment, general use links are loaded and priority HOV facilities are accessible by *paying* LOVs only (tolls are set to ensure ample capacity exists for HOVs)
- After non-HOV assignment, link speeds on general use links are reduced by congestion.
- HOVs are then assigned using congested speed (not free-flow speed) as starting point on the speed-flow curve.
- Result:
  - HOVs now have a greater incentive to choose HOV facilities
  - Improved HOV loadings on priority and general use facilities
- These updates have not yet been built into the Ver. 2.3 model

The cost of the update

- Increased running times for the traffic assignment step
  - 12 minutes of running time added per assignment step, from 75 to 87 minutes
- Increased running time for the travel model
  - 1 hour and 20 minutes added to model running time from 12.00 to 13.33 hours
- Observation: The number of UE iterations went up 67% (from 180 to 300), but the run times are increasing by only about 15% (see next slide)

The cost of the update

- Previous process has 3 assignments in 3 time-of-day periods
  - 180 iterations =
    - AM: 60(5 tabs) +
    - PM: 60(5 tabs) +
    - OP: 60(5 tabs)
- Updated process has 5 assignments in 3 time-of-day periods
  - 300 iterations =
    - AM: 60(4 tabs) + 60(1 tab) +
    - PM: 60(4 tabs) + 60(1 tab) +
    - OP: 60(5 tabs)
- Both processes use 15 trip tables, but the added time due to adding two explicit assignments is marginal
- Result: 60(4 tabs) + 60(1 tab) takes only about 15% more time than 60(5 tabs), not 67%.

Sensitivity testing of the Version 2.3 travel model:

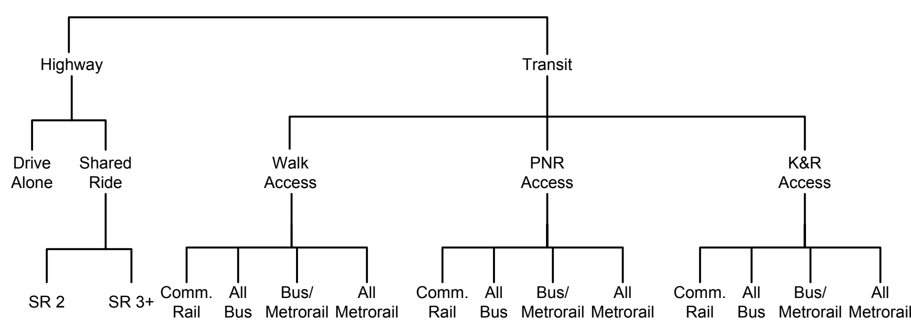
Fare elasticities

Fare sensitivity tests

- We conducted over 20 model runs spanning three modeled years (2002, 2005, and 2030)
- This section of the presentation is focused on the fare sensitivity tests done for the year 2002
  - Increased fare by 20% (both via inputs and via control file)
  - Decreased fare by 20% (via the control file)
    - Zeroed out income constants
    - Zeroed out nesting constants
    - Zeroed out both income and nesting constants

Structure of the nested-logit mode choice model

- 15 choices
  - Three auto modes: Drive alone, shared ride 2, and shared ride 3+
  - Four transit modes: Commuter rail, all bus, all Metrorail, and combined bus/Metrorail
  - Three modes of access to transit: Park and ride (PNR), kiss and ride (KNR), and walk



Changing fare assumptions: The mechanics

- Method 1: Via the inputs
  – Metrorail tariff policy (TARIFF.TXT)
  – "Bus," i.e., non-Metrorail, fare matrices (BUSFARAM.ASC, and BUSFAROP.ASC)
- Method 2: Via the nested-logit mode choice model control files
  – Change some statements so that fares are multiplied by a factor (e.g., 1.20 or 0.80)
  – Change the model batch files so that the appropriate control files are used
- Both methods resulted in roughly the same change
  – However, using the control files is generally easier to implement and more versatile

Elasticity of demand

- In general, the "price elasticity of demand" is the percentage change in the quantity of a commodity demanded, in response to a 1 percent change in the price of the commodity (i.e., a good or service)
- We have calculated fare elasticities using the most common form for transportation analyses:
  – Arc elasticity

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1} = \frac{\log Q_2 - \log Q_1}{\log(P_2 / P_1)}$$

Fare elasticity: Simpson & Curtin

- Aggregate fare elasticity average for U.S. cities, excluding those with heavy-rail transit, is about -0.4 (TRB, 2004)
- This value of -0.4 is very close to what would be predicted from the famous Simpson & Curtin formula (Curtin, 1968, as cited in TRB, 2004)
  - On a percentage basis: a 20% increase in transit fares => 6.8% drop in ridership.
  - In terms of arc elasticity: ≈ -0.39
  - S&C formula was derived from a regression analysis of before-and-after results of 77 surface transit (bus and streetcar) fare changes.
  - Inclusion of systems with heavy rail transit (HRT) tends to lower fare elasticity averages (TRB, 2004, p. 12-10)
  - Consequently, S&C tends to overstate the fare elasticity in cities with HRT, like Washington, D.C.

Fare elasticity: Total transit

- Based on a 20% drop in fares, the nested-logit mode choice (NL MC) model in the Ver. 2.3 travel model shows a fare elasticity of -0.11.
- According to Webster and Bly (1980, as cited in TRB, 2004), the most commonly observed range of aggregate fare elasticity values in United States and Europe is from -0.1 to -0.6.
- Thus, our finding of -0.11 is within the normal range of observed values, though at the lower end of the range.

Fare elasticity: Total transit

- According to a 1980 study which included a sample of U.S. cities with and without heavy rail systems, the mean fare elasticity was found to be -0.28 ± 0.16 (Mayworm, Lago, and McEnroe, 1980, as cited in TRB, 2004).
  – A standard deviation of ± 0.16 implies that about two-thirds of the elasticity observations lie within -0.12 and -0.44.
  – The lower bound of this range matches approximately what we are finding in the Version 2.3 travel model.

Fare elasticity: Total transit: Observations

- The fare sensitivity shown by a model is a function of the cost coefficients in MC
- As a check on the value of the cost coefficients, we computed the value of time (VOT) using the following formula:
  – VOT = 0.60 * (IVTT/Cost)
  – where 0.60 converts cents/min to dollars/hour
- Rules of thumb for VOT
  – Work VOT should be between 25% and 50% of prevailing wage rate
  – Non-work VOT should be between 25% and 50% of the work VOT => 6.25% and 25% of prevailing wage rate

Fare elasticity: Total transit: Observations

- Rules of thumb for VOT
  - Work VOT should be between $4.44 and $8.88 (1994 $)
  - Non-work VOT should be between $1.11 and $4.44 (1994 $)
- Based on the Cost and IVTT coeffs in the model, our calculated VOTs are quite high

	HBW	HBS	HBO	NHB
Income group 1	$6.90	~~$6.44~~	~~$6.90~~	$1.73
Income group 2	$13.80	~~$12.88~~	~~$13.79~~	$1.73
Income group 3	$20.70	~~$19.32~~	~~$20.69~~	$1.73
Income group 4	$27.61	~~$25.76~~	~~$27.59~~	$1.73

(shaded) Falls outside the general rule of thumb for work

~~$x.xx~~ Falls outside the general rule of thumb for non-work

Coefficients used to calculate VOTs

		Trip Purpose (4)			
Variable		**HBW**	**HBS**	**HBO**	**NHB**
In-vehicle time	ivt	-0.02128	-0.02168	-0.02322	-0.02860
Auto access time	aat	-0.03192	-0.03252	-0.03483	-0.04290
Walk access time	ovtwa	-0.04256	-0.04336	-0.04644	-0.05720
Other out-of-vehicle time*	ovtot	-0.05320	-0.05420	-0.05805	-0.07150
Cost - Income group 1	costinc1	-0.00185	-0.00202	-0.00202	-0.00994
Cost - Income group 2	costinc2	-0.00093	-0.00101	-0.00101	-0.00994
Cost - Income group 3	costinc3	-0.00062	-0.00067	-0.00067	-0.00994
Cost - Income group 4	costinc4	-0.00046	-0.00051	-0.00051	-0.00994

Fare elasticity: Expectations

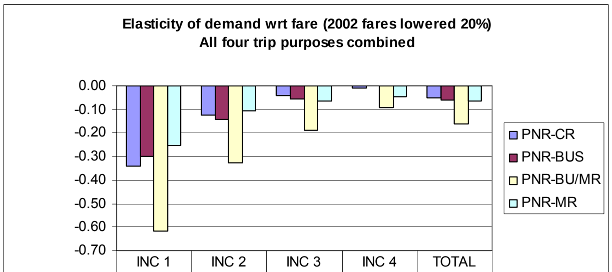
- We have the ability to stratify fare elasticity by income and transit sub-mode
- Expectations
  - Income effect:
    - Households with lower incomes should have higher fare sensitivities
  - Transit sub-mode effect: We would expect
    - HRT (CR & MR) to have the **lowest** elasticities
    - Bus to have the **highest** elasticities

Table 12-3 Bus and HRT/Metro Fare Elasticities

City	Period	Bus	Rail	Source
Chicago[a]	1981–1986	–0.43	–0.18	LTI Consultants, Inc., and E. A. France and Associates (1988)
London	1971–1990	–0.35	–0.17	London Transport (1993)
New York	1948–1977	–0.32	–0.16	Mayworm, Lago and McEnroe (1980)
New York	1970–1995	–0.20 to –0.30	–0.10 to –0.15	Jordan (1998)
New York	1995	–0.36	–0.15	Charles River Associates (1997)
Paris	1971	–0.20	–0.12	Webster and Bly (1980)
San Francisco	1984–1986	—	–0.31	Reinke (1988)

Source: TRB, 2004

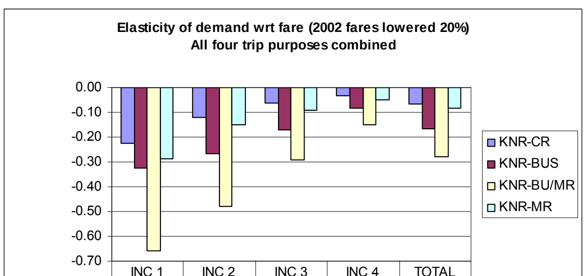
Fare elasticity: PNR access to transit



	INC 1	INC 2	INC 3	INC 4	TOTAL
PNR-CR	-0.34	-0.12	-0.04	-0.01	-0.05
PNR-BUS	-0.30	-0.14	-0.06	0.00	-0.06
PNR-BU/MR	-0.62	-0.33	-0.19	-0.09	-0.16
PNR-MR	-0.25	-0.11	-0.06	-0.05	-0.07

- Income effect: Households with lower incomes do show higher fare sensitivities
- Transit sub-mode effect: Somewhat at odds with expectations
  - Bus does not have the highest elasticity
  - Bus/Metrorail has the highest elasticity
  - HRT elasticities are not as low, relative to the others, as one would expect

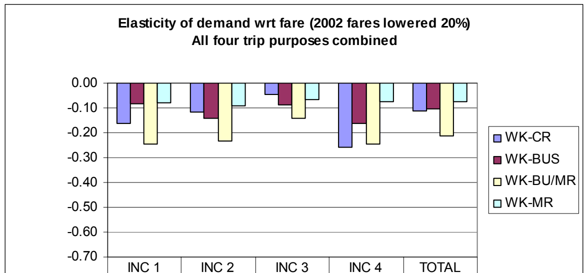
Fare elasticity: KNR access to transit



	INC 1	INC 2	INC 3	INC 4	TOTAL
KNR-CR	-0.22	-0.12	-0.06	-0.03	-0.07
KNR-BUS	-0.33	-0.27	-0.17	-0.08	-0.16
KNR-BU/MR	-0.66	-0.48	-0.29	-0.15	-0.28
KNR-MR	-0.29	-0.15	-0.09	-0.05	-0.08

- Income effect: Present, same as with PNR.
- Transit sub-mode effect: Same as with PNR: Somewhat at odds with expectations
  - We will discuss these counter-intuitive results later in the presentation

Fare elasticity: Walk-acc. to transit



	INC 1	INC 2	INC 3	INC 4	TOTAL
WK-CR	-0.16	-0.12	-0.05	-0.26	-0.11
WK-BUS	-0.08	-0.14	-0.09	-0.16	-0.10
WK-BU/MR	-0.25	-0.23	-0.14	-0.25	-0.21
WK-MR	-0.08	-0.09	-0.07	-0.07	-0.08

- Income effect: Now missing
- Transit sub-mode effect: Same as with PNR & KNR: Somewhat at odds with expectations

Fare elasticity: Walk-acc. to transit

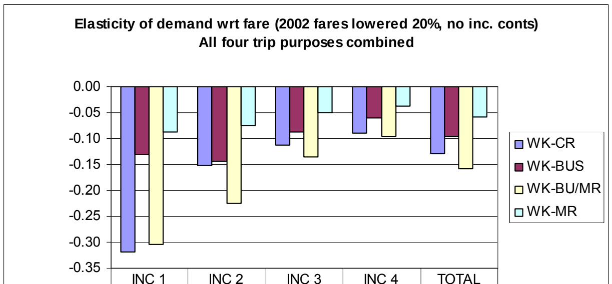
- The TPB NL MC model uses a set of income constants, which were developed by AECOM for the post-processed AECOM/WMATA NL MC model and retained for use in the TPB model.
  - AECOM introduced the income constants to help reduce the high number of modeled boardings in Northwest DC (AECOM, 2005).

	Income stratification		
Mode	**Low**	**Middle**	**High**
All auto modes	0.0	0.0	0.0
Walk to commuter rail	2.0	0.0	-2.0
Walk to all bus	2.0	0.0	-2.0
Walk to bus/Metrorail	2.0	0.0	-2.0
Walk to all Metrorail	2.0	0.0	-2.0
PNR and KNR to transit	0.0	0.0	0.0

- Hypothesis: The income constants added to the NL MC model for walk-access transit trips are adversely effecting the fare elasticity by income group.

Fare elasticity: Walk-acc. to transit

- To test the hypothesis, we zeroed out the income constants
- Result: The income effect was restored for walk-access transit trips



	INC 1	INC 2	INC 3	INC 4	TOTAL
WK-CR	-0.32	-0.15	-0.11	-0.09	-0.13
WK-BUS	-0.13	-0.14	-0.09	-0.06	-0.10
WK-BU/MR	-0.30	-0.23	-0.14	-0.10	-0.16
WK-MR	-0.09	-0.07	-0.05	-0.04	-0.06

Fare elasticity: Walk-acc. to transit

- Although zeroing out the income constants resulted in a restoration of the income effect, this manual adjustment means that the model is no longer calibrated.
- The model would need to be re-calibrated before it is ready for use.

Fare elasticity: Counterintuitive results for the transit sub-mode effect

- Hypothesis: Disparity between the bus and bus/Metrorail fare elasticities could be related to the values of the alternative-specific constants (ASCs).
- Nesting constants serve the role of both ASCs and geographic market segmentation
- Test: Zero out the nesting constants
- Result:
  - Ratio of the bus vs. bus/Metrorail fare elasticities went up (from 0.4 to 0.66), but was still not > 1, like one would expect

Fare elasticity: Counterintuitive results: Possible explanations

1. By definition, the "bus/Metrorail" transit sub-mode includes at least one (forced) transfer.
   - By contrast, the other three transit sub-modes include, on average, fewer transfers, since they include trips with <u>zero</u>, one, or more transfers.
   - This would seem to indicate that transit users who have a forced transfer are more sensitive to changes in fare.
2. Combined bus/Metrorail trips are probably longer distance than bus alone or Metrorail alone, so they might be more sensitive to cost.

Fare elasticity: Conclusions

- Fare elasticity for total transit coming out of the Ver. 2.3 travel model (= -0.11) is on the low end of the scale, but within the range of values found by researchers for cities with heavy rail transit systems
- Incorporating the transit subsidy into model inputs may affect our elasticity value (see next section)
- Fare elasticities generally showed an "income effect"
  - Exception: Walk-to-transit trips.
  - We were able to restore this "income effect" by setting the income constants to zero.
  - Resultant model is uncalibrated

Fare elasticity: Conclusions

- There appeared to be a disparity between the fare elasticity for bus and bus/Metrorail
  - We showed that the value of these elasticities are affected by the values of the nesting constants.
  - Perhaps the relative magnitudes are, in fact, correct
    - Bus/Metrorail sub-mode includes at least one (forced) transfer. The other three transit sub-modes do not.
    - Bus/Metrorail trips are probably longer distance than bus and/or Metrorail, so they might be more sensitive to cost.
  - Incorporating the transit subsidy into model inputs may affect the elasticity values (see next section)
- We were able to change the ratio of these two elasticities by setting the nesting constants to zero
  - Fine tuning of nesting constant values is difficult, since there are so many of them (20 geographic market segments & 15 modes => 20 x (15-1) = 280 nesting constants)
  - A model with fewer nesting constants would be easier to adjust

Fare elasticity: References

- AECOM Consult, Inc. (2005). "Revised Calibration Results with Additional Revisions to Transit Components of Washington Regional Demand Forecasting Model." A presentation on March 2, 2005.
- Transportation Research Board. (2004). *TCRP Report 95: Traveler Response to Transportation System Changes: Chapter 12 – Transit Pricing and Fares*. Transit Cooperative Research Program. Washington, D.C.

Sensitivity testing of the Version 2.3 travel model:

Incorporating transit subsidies explicitly into the model

Incorporating transit subsidy in the Ver. 2.3 model

Today's Discussion:

- Background on the federally legislated transit subsidies
- Proposed method for modifying the Metrorail fare development in Version 2.3
- Results of testing the proposed method for the year 2002

Incorporating transit subsidy in the Ver. 2.3 model

- Benefits
  - More realistic depiction of real world costs!
- Drawbacks/limitations
  - More complicated to develop inputs
  - Currently, only MR subsidy info. is available (no bus)
    - Will likely cause a shift in the model from bus and commuter rail to Metrorail (transit path builder does not include fare, but MC model does)
  - In reality, in a given interchange, there are two populations: unsubsidized and subsidized (e.g., fares of $3.25 and $0.98)
    - Current representation in the model: All people pay full fare (e.g., $3.25)
    - Proposed representation: All people pay a reduced average fare (e.g., $1.93)

SmartBenefits and Metrochek transit subsidy programs

- TEA 21 (June 1998) included a provision to amend the IRS tax code to allow for employer-provided transit subsidies
- Most common forms of transit subsidies in the Washington, D.C. area: Metrochek and SmartBenefits
- Subsidy programs are offered to employees direct tax-free subsidy, as a pre-tax salary deduction, or as a combination
- Program, in turn, offers financial incentives to employers

Maximum allowable monthly benefit over time:

Year	Maximum Monthly Benefit
2000	$ 65.00
2002	$ 100.00
2004	$ 105.00
2007	$ 110.00
2008	$ 115.00
2009 (planned)	$ 120.00

Proportion of Metrorail commuters subsidized by attraction station

(Source: 2007 WMATA Metrorail Survey)

Metrorail Station	Pct. of Subsidized HBW Attractions	Metrorail Station	Pct. of Subsidized HBW Attractions	Metrorail Station	Pct. of Subsidized HBW Attractions
Addison Road	16%	Foggy Bottom-GWU	57%	Rhode Island Ave	15%
Anacostia	43%	Forest Glen	36%	Rockville	37%
Archives	74%	Fort Totten	14%	Rosslyn	57%
Arlington Cemetery	39%	Franconia-Springfield	35%	Shady Grove	32%
Ballston	56%	Friendship Heights	47%	Shaw-Howard Univ	15%
Benning Road	36%	Gallery Place	63%	Silver Spring	51%
Bethesda	54%	Georgia Ave	16%	Smithsonian	84%
Braddock Road	46%	Glenmont	10%	Southern Avenue	7%
Branch Avenue	36%	Greenbelt	28%	Stadium Armory	38%
Brookland-CUA	37%	Grosvenor	40%	Suitland	74%
Capitol Heights	77%	Huntington	23%	Summerfield	0%
Capitol South	74%	Judiciary Square	70%	Takoma	36%
Cheverly	9%	King Street	69%	Tenleytown	41%
Clarendon	62%	Landover	15%	Twinbrook	63%
Cleveland Park	25%	Largo Town Center	9%	Union Station	66%
College Park	58%	L'Enfant Plaza	75%	U-Street-Cardozo	23%
Columbia Heights	14%	McPherson Square	65%	Van Dorn Street	19%
Congress Heights	12%	Medical Center	79%	Van Ness-UDC	37%
Court House	59%	Metro Center	58%	Vienna	37%
Crystal City	74%	Minnesota Avenue	9%	Virginia Square	69%
Deanwood	8%	Mt Vernon Square	41%	Waterfront	48%
Dunn Loring	21%	National Airport	36%	West Falls Church	24%
Dupont Circle	48%	Navy Yard	64%	West Hyattsville	0%
East Falls Church	31%	Naylor Road	6%	Wheaton	15%
Eastern Market	37%	New Carrollton	54%	White Flint	72%
Eisenhower Avenue	67%	New York Ave NE	20%	Woodley Park-Zoo	17%
Farragut North	56%	Pentagon	71%		
Farragut West	57%	Pentagon City	56%		
Federal Center SW	79%	Potomac Avenue	8%		
Federal Triangle	79%	Prince George's Plaza	50%		

Existing method for developing transit fares in the Version 2.3 model

1. Metrorail station-to-station fares computed (MFARE1)
2. *Total* zone-to-zone transit fares computed (MFARE2)
   - Metrorail station-level fares combined with bus/commuter rail fares, developed at the super-district level

These two steps are applied 22 times (i.e., by two time periods and 11 sub-modes)

Method for incorporating transit subsidies into the model

- Four-step approach:
  1. Compute standard Metrorail fare (i to j station)
  2. Express the monthly subsidy as a per trip discount
  3. Compute reduced/discounted fare
  4. Compute weighted average fare based on observed probability of paying

  Final fare = X% * (standard fare) + (1-X)% * (reduced fare)

Guidelines of proposed application

- Model year for which the transit subsidy was tested would be 2002
- Subsidy-related participation would be based on 2007 Metrorail Survey (attraction station)
- Transit subsidy would be assessed for the Metrorail trip only (we do not have bus info. yet)
- Would affect only AM-period Metrorail fare
- It was assumed that each traveler would utilize his/her transit subsidy rationally

Example of Methodology

Shady Grove to Metro Center

Step 1) The standard AM peak Metrorail station-to-station fare for 2002 (WMATA tariff #19 in effect) is: **325 cents**.

Step 2) The maximum allowable monthly monetary subsidy for 2002 is **$100.0** per month, or **227 cents** per work trip:

$100 per month /22 days per month / 2 trips per day * 100 cents per $= **227 cents**

Step 3) The discounted fare equals the normal fare (**325 cents**) less the per-trip subsidy (**227 cents**): **98 cents.**

Step 4) The final station-to-station fare is computed as a weighted average based on the attraction station subsidy probability:

Probability of subsidy at Metro Center = **58%**

Probability of no subsidy at Metro Center= 100% - 58% = **42%**

'Final' Fare = *(0.58 * 98.0 cents) + (0.42 * 325.0 cents) =* ***193*** *cents*

Results of 2002 Test

(Test = incorporating transit subsidy)

- Incorporating the subsidy results in a 25% decline in the ave. transit fare, i.e., from $1.97 to $1.48 (1994 $)
- Subsidy results in about 6,500 more HBW Metrorail-related transit trips (a 1% increase)
- Note: In this particular test, cost and demand changes are for Metrorail-related trips only

Transit subsidy: Conclusions and questions

- TPB should consider including the proposed process in the Version 2.3 model
- Investigate the prevalence of transit subsidies on non-Metrorail-related trips
- If method is adopted, NL model should be re-calibrated using the modified AM transit fare inputs, which are arguably more realistic than fares currently used in the model
- Are other MPOs adopting this type of approach?
- Incorporating transit subsides explicitly in the inputs adds a new input requirement:
  - Forecasting the monthly subsidy (e.g., What will the federal maximum subsidy level be in 2030?)

Next steps

- Speeding up model runs, especially in light of the proposed 4,000-TAZ system
  - Migrating from TP+ to Voyager
  - Testing Cube Cluster (distributed processing)
  - Tests on reducing the number of speed feedback iterations
  - Testing improved traffic assignment algorithms from Citilabs
- Finishing sensitivity tests
  - Add or remove a local bus route
  - Possibly other tests
- Incorporating the fare subsidy in the inputs
  - When the bus survey data becomes available, add this info. to the process