Status report on development of the Ver. 2.3 travel model

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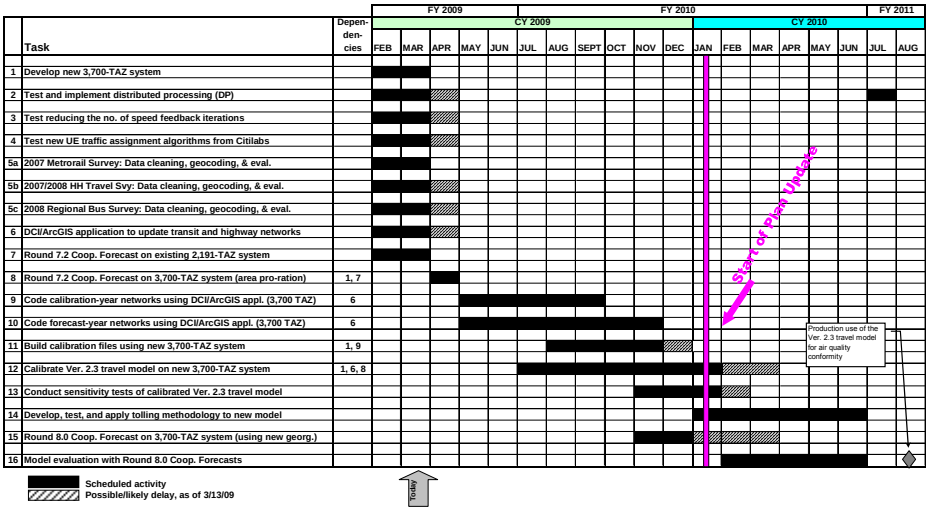
Version 2.3 Model Development

Activities in motion since last meeting:

- Rnd. 7.2 Coop. Forecasts (2,191 TAZ system)
- Cleaning of 2007/8 survey files
- Updated (~3,700) TAZ system development
- GIS-Transportation network project
- Approaches for reducing Version 2.3 model execution times (the focus of this presentation)

Development of Ver. 2.3 model on the new zone system



Global comments on Version 2.3

- Switching from TP+ to Voyager
  - Necessary to take advantage of
    - Distributed processing
    - Newer assignment algorithms
    - Possible future use of the Public Transportation (PT) module
- Development focus is on Voyager, not TP+
- Good news: switch means minimal changes to existing scripts, batch files, and application protocols

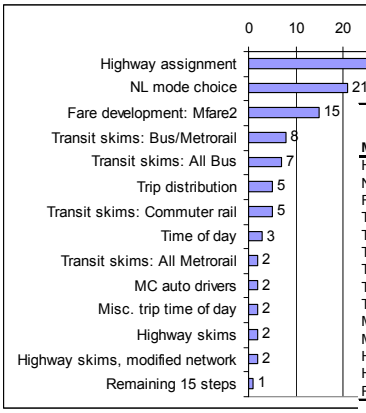
Speeding up model execution times for Ver. 2.3

- Why is model run time an issue?
  - Increased number of TAZs will almost double trip table dimensions
    - 3,700/1,972 = 1.88; $(1.88)^2 = 3.5$
    - 18 hours x 3.5 = 63 hours or 2.6 days
  - TPB staff desires an overnight turn around (12-18 hours)
- What avenues are under examination?
  - Decreasing the no. of speed feedback iterations
  - Implementation of distributed processing (DP)
  - New traffic assignment methods in Cube Voyager

Status report: Using distributed processing in Cube Cluster

Summary from the 1/23/09 meeting

- Highway assignment accounts for 50% of the model run time (iteration 6, 2.7 hrs out of 18.5 hrs)



Modeling step	Elapsed Time (minutes)	Percent of total time	Cumula. Percent
Highway assignment	83	51%	51%
NL mode choice	21	13%	64%
Fare development: Mfare2	15	9%	73%
Transit skims: Bus/Metrorail	8	5%	78%
Transit skims: All Bus	7	4%	83%
Trip distribution	5	3%	86%
Transit skims: Commuter rail	5	3%	89%
Time of day	3	2%	91%
Transit skims: All Metrorail	2	1%	92%
MC auto drivers	2	1%	93%
Misc. trip time of day	2	1%	94%
Highway skims	2	1%	96%
Highway skims, modified network	2	1%	97%
Remaining 15 steps	1	1%	98%
Total	162	100%	

Summary from the 1/23/09 meeting

- There are two types of distributed processing (DP) in Cube Cluster
  - Intra-step distributed processing (IDP)
    - Works for two Cube Voyager modules: HIGHWAY, MATRIX
  - Multi-step distributed processing (MDP)
    - Can be used with any program, Voyager or user-written
    - Can be more versatile than IDP, but also more complex to implement
- We used IDP and 4 processors in highway assignment to reduce model run times
  - 50% time savings for traffic assignment (83 min. => 42 min.)
  - 25% time savings for the entire model run (18.5 hours => 13.6 hours)
- Next steps: Investigate MDP

Today's presentation on distributed processing

- MDP has not yet been tested by TPB staff
- But we have prepared a plan for how to proceed:
  - Comparison of IDP & MDP
  - Recommendation for when to use IDP vs. MDP in the travel model
  - Caveats and phasing of work
  - Possible next steps for DP

Comparison of IDP & MDP for traffic assignment: A graphical example using traffic assignment (AM, PM, OP)

Without DP

Time Step	Proc #1	Proc #2	Proc #3	Proc #4
1	AM			
2	AM			
3	AM			
4	AM			
5	AM			
6	AM			
7	AM			
8	AM			
9	AM			
10	AM			
11	PM			
12	PM			
13	PM			
14	PM			
15	PM			
16	PM			
17	PM			
18	PM			
19	PM			
20	PM			
21	OP			
22	OP			
23	OP			
24	OP			
25	OP			
26	OP			
27	OP			
28	OP			
29	OP			
30	OP			

83 min. total time =>

78 min. traffic assignment =>

26 min./per.

Intra-step distributed processing (IDP)

Time Step	Proc #1	Proc #2	Proc #3	Proc #4
1	Main			
2	Main	AM	AM	AM
3	Main	AM	AM	AM
4	Main	AM	AM	AM
5	Main	AM		
6	Main	PM	PM	PM
7	Main	PM	PM	PM
8	Main	PM	PM	PM
9	Main	PM		
10	Main	OP	OP	OP
11	Main	OP	OP	OP
12	Main	OP	OP	OP
13	Main	OP		
14	Main			
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Multi-step distributed processing (MDP)

Time Step	Proc #1	Proc #2	Proc #3	Proc #4
1	Main			
2	Main	AM	PM	OP
3	Main	AM	PM	OP
4	Main	AM	PM	OP
5	Main	AM	PM	OP
6	Main	AM	PM	OP
7	Main	AM	PM	OP
8	Main	AM	PM	OP
9	Main	AM	PM	OP
10	Main	AM	PM	OP
11	Main	AM	PM	OP
12	Main			
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10

Comparison of IDP & MDP for traffic assignment: Key points, 1 of 2

- Highway assignment is conducted using three time-of-day periods (AM, PM, OP), which can be run independently of each other
- Highway assignment is conducted using
  - HWYLOAD module in TP+ or
  - HIGHWAY module in Cube Voyager
    - (DP is not available in TP+, you must use Voyager)
- For the HIGHWAY module in Cube Voyager, one may use either IDP or MDP (or both)
  - IDP works on only two modules: HIGHWAY & MATRIX
  - MDP can be used for any Cube Voyager program and for user-written programs

Comparison of IDP & MDP for traffic assignment: Key points, 2 of 2

- Highway assignment script (Highway_Assignment.s) uses a loop for each time period (AM, PM, OP)
- It is our understanding that MDP cannot be applied to loops
  - Consequently, to use MDP on the highway assignment process:
    - One script becomes three
      - Highway_Assignment_AM.s
      - Highway_Assignment_PM.s
      - Highway_Assignment_OP.s
    - Drawback: If one wants to update a script, one has to update all three scripts, or the scripts loose their consistency
- Thus, unless MDP is much more efficient than IDP, it would be best to simply use IDP for traffic assignment.
  - This assumption is based on a computer with 4 processors
- However, there is another step where MDP might make sense…

Recommendation for first use of MDP in the regional travel model

- Application of the nested-logit mode choice model using the Fortran program AEMS.EXE
  - This is the 2nd most time-consuming procedure, after traffic assignment (accounting for 13% of model run time)
  - Since MC is applied with a Fortran program, IDP is not an option
  - AEMS is run four trip purposes (HBW, HBS, HBO, NHB) and each run is independent
  - Run times
    - Without DP: 21 min. (≈ 5 min. per trip purpose)
    - With DP: 6 min. (assumes all four trip purposes run in parallel, plus some extra time for overhead)
  - Time savings with DP
    - Per speed feedback iteration: 15 min. (= 21 min. - 6 min.)
    - Per model run: 90 min. (= 15 min. x 6 speed feedback iterations)

Caveats and phasing of work

- We recommended using IDP, not MDP, for traffic assignment, but this recommendation could change based on input from Citilabs and/or testing by TPB staff
- Citilabs recommends:
  - "Implementing Cube Cluster should generally be performed after model development and calibration/validation" (Citilabs, 2008, online help for Ver. 5)
- So there would be two phases to DP testing and implementation (both are shown on the timeline)
  - 1) Testing phase: We are in this phase now
  - 2) Implementation phase: Once the Ver. 2.3 travel model is calibrated/validated => Add Cube Cluster enhancements

Possible next steps for distributed processing

- Consult with Citilabs staff to see if they concur with our recommended strategy for implementation of IDP and MDP
- If time permits, attempt:
  - MDP on mode choice
  - MDP on traffic assignment??
  - IDP & MDP together on traffic assignment??

New traffic assignment methods in Cube Voyager

- Citilabs is planning to release new assignment options in the next Cube release (Spring 2009)
- The assignment options attain faster and tighter convergence
- TPB staff has received the new release in advance (*Cube 5.1.0 alpha*) and has begun examining the new assignment options
- Caveat: The alpha version does not replicate the existing modeling results exactly, but the results are quite close

Traffic assignment approach

- User Equilibrium (UE) approach has been used in TPB models for over 10 years
- The UE algorithm is considered to be state-of-the-practice for traffic assignment
- UE principle: 'Equilibrium' means no traveler can improve his/her travel cost by unilaterally changing routes
  - All used paths have equal and minimum travel times
  - All unused paths have equal or higher travel times
- Caveat of principle: assumption of perfect knowledge of all possible routes

UE algorithms

Types:

- Link-Based (e.g., Frank-Wolfe)
- Path-based
- Origin-based link flow (e.g., Origin-Based Algorithm or OBA)

Latest algorithms offered by Citilabs:

- Two link-based variations on the FW algorithm
  - Frank-Wolfe Conjugate
  - Frank-Wolfe Bi-Conjugate

Convergence

- Any EU algorithms are essentially a series of (AON) assignments, where a global link flow and/or path flow optimizing function is adjusted
- Optimizing objective seeks to adjust O-D flows so to minimize system-wide delay with each successive iteration
- Optimizing function 'converges' on a solution with each iteration
- The standard statistic used to measure convergence: Relative Gap (RG)

What is a desired/acceptable RG value?

- Should be as small as possible
- Depends on context
- Highly converged solutions are vital when comparing two assignment alternatives.
- Trade-off: Higher RG requires longer running times

Decimal	Exponential
1	10^{0}
0.1	10^{-1}
0.01	10^{-2}
0.001	10^{-3}
0.0001	10^{-4}
0.00001	10^{-5}

TPB tests

- Version 2.3 Traffic Assignment / Year 2002
  - Three assignments executed (AM,PM,OP)
  - 60 UE iterations (current TPB travel model)
  - 200 UE iterations (tested)
- Algorithms tested
  - Frank-Wolfe (existing algorithm used in Ver. 2.2 & 2.3)
  - Conjugate (new algorithm)
- Metrics analyzed
  - Running time
  - Relative gap
- Traffic assignment tests were examined in isolation (from other modeling steps)

Running times: 60 iterations

Period	**minutes** Frank Wolfe TP+	Conjugate Voyager	
AM	50.22	50.25	
PM	48.07	48.87	
OP	50.40	52.35	
Total	148.68	151.47	~ 2.5 hours

Note: Distributed Processing not used

Level of convergence reached at 60 iterations

		Rel Gap	Minutes	Rel Gap Reduction
AM	Frank-Wolfe	0.01209	50	
	Conjugate	0.00428	50	-64.6%
PM	Frank-Wolfe	0.01541	48	
	Conjugate	0.00820	49	-46.8%
OP	Frank-Wolfe	0.00233	50	
	Conjugate	0.00089	52	-61.8%

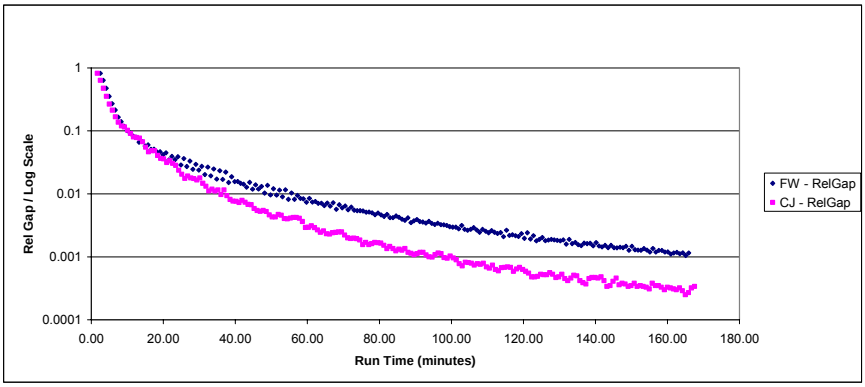
Note: Distributed Processing not used

Level of convergence reached at 200 iterations

		Rel Gap	Minutes	Rel Gap Reduction
AM	Frank-Wolfe	0.00113	166	
	Conjugate	0.00034	168	-80.9%
PM	Frank-Wolfe	0.00178	160	
	Conjugate	0.00051	163	-71.3%
OP	Frank-Wolfe	0.00028	172	
	Conjugate	0.00010	175	-64.3%

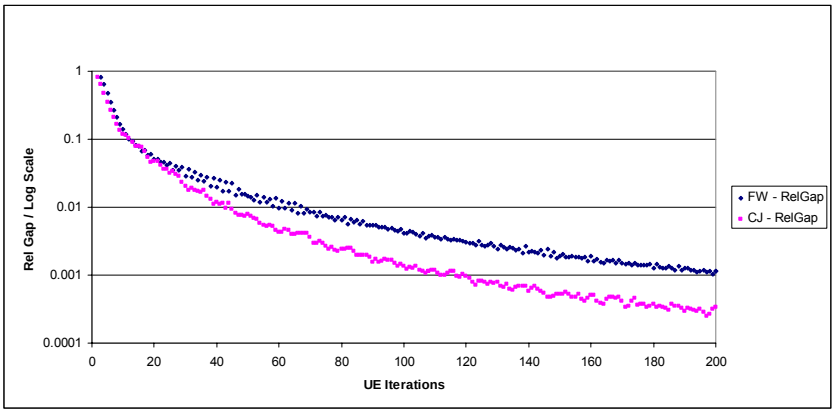
Note: Distributed Processing not used

Frank-Wolfe (FW) vs. Conjugate (CJ)
Relative gap by running time (min.)
AM peak assignment



Note: Distributed Processing not used

Frank-Wolfe (FW) vs. Conjugate (CJ)
Relative gap by UE iteration
AM peak assignment



Conclusions on new assignment algorithms

- The new conjugate assignment option does converge faster than the existing Frank-Wolfe algorithm used by the TPB
- New options to consider with conjugate algorithm:
  - A) Use a smaller number (<60) of iterations for shorter running time and the same level of convergence
  - B) Maintain existing running time for a higher level of convergence
  - C) Accept a longer running time and more iterations (>60) to achieve a higher level of convergence