INVESTIGATION OF CUBE VOYAGER PUBLIC TRANSPORT (PT) TRANSIT MODELING SOFTWARE WITH THE TPB VERSION 2.3 TRAVEL MODEL

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Travel Forecasting Subcommittee
July 17, 2020

Introduction

- Cube offers two transit modeling programs: TRNBUILD and Public Transport (PT).
- Although they are different in many ways, a key difference between TRNBUILD and PT is path-building:
  - **TRNBUILD**: Single-path path builder that considers combined headways
  - **PT**: Primarily designed as a multi-path path builder ("Multi-Routing" mode), although it also provides a single-path path building option ("BESTPATHONLY" mode)
- In the past decade, COG/TPB staff has had experiences working with both programs

Background

- In 2011, COG/TPB adopted TRNBUILD in Ver. 2.3 Model
  - When the travel model was upgraded from Ver. 2.2 to Ver. 2.3, travel forecasting software was also switched from Cube TP+ to Cube Voyager. However, TRNBUILD, which was bundled with TP+, was retained
  - TRNBUILD has since been used in Ver. 2.3 Model
- In 2017, COG/TPB implemented PT in the developmental Version 2.5 Model with consultant assistance
  - "BESTPATHONLY," as opposed to "Multi-routing," was used in PT to be comparable to the TRNBUILD program in Ver. 2.3 Model
  - Model was tested on and off during 2018 and 2019 but was never brought into production use for various reasons
  - As a result, the PT implementation has not been rigorously examined

Background

- In 2018, COG/TPB staff set out to develop a next-generation travel demand model, to be known as the Generation-3 (Gen3) Model
- In 2020, RSG, the consultant on the Gen3 Model development project, made the following software recommendations for Gen3:
  - Continue to use Cube since "it satisfies existing and near-term network modeling needs while avoiding the significant startup costs associated with switching network modeling platforms"
  - Move to PT in Gen3 mainly because "TRNBUILD is no longer being maintained or enhanced by Bentley (the developers of Cube software)"
- Spurred by an initial consideration of switching to PT in Gen3, TPB staff conducted a PT investigation with Ver. 2.3 Model during February through May 2020

Objectives

- Objectives of this PT investigation included:
  - Implementing PT in Ver. 2.3 Model in a relatively fast manner, by leveraging the PT functionality already developed in Ver. 2.5 Model;
  - Gaining a deeper understanding of PT network development and modeling processes;
  - Evaluating the strengths and limitations of PT relative to TRNBUILD by comparing the two programs implemented in the same Ver. 2.3 Model;
  - Creating a future test bed for exploring PT functionality that RSG recommended for the Gen3 Model (such as multi-routing and transit crowding); and
  - Informing future decisions related to COG/TPB's network databases

Outline

- This PT investigation with Ver. 2.3 Model is the focus of this presentation
- The remainder of this presentation will discuss:
  - ❑ PT implementation in Ver. 2.3 Model
  - ❑ Comparison of PT and TRNBUILD
    - ▪ Model runtime
    - ▪ Path tracing for select OD pairs
    - ▪ Standard model summaries
    - ▪ Transit ridership validation
  - ❑ Findings
    - ▪ Strengths of PT
    - ▪ Limitations of PT
  - ❑ Next steps

PT Implementation

- PT was implemented in one of the latest Ver. 2.3 developmental models by stitching the PT processes from Ver. 2.5 Model with the Ver. 2.3.85 Model
- Ver. 2.5 PT processes were kept, to the maximum extent possible, with only three changes:
    - Ver. 2.5 PT processes were modified to work with an additional layer of transit market segmentation in Ver. 2.3 Model, as Ver. 2.5 Model features a "flattened" multinomial-logit mode choice model while Ver. 2.3 features a more complex nested-logit mode choice (NLMC) model
    - Additional skim functions were put into Ver. 2.3 PT skimming process, as Ver. 2.3 NLMC Model requires a slightly different set of transit skims
    - Ver. 2.3 parallelization setup with concurrent command windows was adopted to reduce PT runtime. Original Ver. 2.5 PT processes did not use distributed processing or parallelization

Comparison of PT and TRNBUILD

- There are now two developmental Ver. 2.3.85 Models at TPB staff's disposal: One with TRNBUILD and the other with PT ("BESTPATHONLY")
- The two models are largely comparable:
  - Both work with shortest paths in transit modeling
  - All the non-transit model components are identical
- Two year-2014 runs were executed using the two models for comparison

Model Run	1	2
Model Year	2014	2014
Model	Ver. 2.3.85 (TRNBUILD)	Ver. 2.3.85 (PT)
Land Use Inputs	Round 9.1	Round 9.0
Network Inputs	Visualize 2045 (2018 LRTP) with minor updates to network coding	2016 CLRP
Executed at	tms8	tms8
Model runtime (hh:mm:ss)	10:16:18	23:27:43

Comparison Results: Model Runtime

- Substantial increase in runtime between Run 1 and Run 2 was alarming as TPB staff has been keen to keep model runtime in a reasonable range
- With assistance from Bentley Citilabs, staff investigated a variety of possible causes of excessive PT runtime, such as model setups, path-building parameters, hardware speeds and parallelization setups
- This follow-up investigation found the following:
  - Dual calculation of fares inherited from the Ver. 2.5 Model contributed to about 45% of the runtime increase when switching from TRNBUILD to PT
  - Some model enhancements, such as consolidating Non-Transit (NT) leg generation and additional parallelization in skimming, can improve PT runtime marginally (each by 1% - 2%)
  - Even if the dual calculation of fares were removed and all the above model enhancements were implemented, Ver. 2.3 Model runtime would still increase by around 50%, moving from TRNBUILD to PT

Dual Calculation of Fares

- Ver. 2.3 Model uses MFare1.s and MFare2.s processes to calculate zone-to-zone average transit fares
  - Ver. 2.3 fare inputs are periodically reviewed and updated by TPB staff
- Ver. 2.5 Model, instead, adopted a dual calculation of fares:
  - One set of fares are calculated using simplistic PT fare functions (flat rate or distance based) for path building while a different set of fares are calculated using the MFare processes for mode choice
  - Dual calculation was adopted as the PT functions were too simplistic and PT fares were not validated to ground-truth fare data
  - TRNBUILD built-in functions used in original Mfare processes are not provided in PT, and the workaround substantially increased runtime
- PT provides various distance- and zone-based fare functions that could be used to model different fare systems in this region

Comparison Results: Path Tracing

- TPB staff selected four zones in this region, developed and compared the TRNBUILD and PT paths between the select zones
- As many as 288 paths could be developed, but the comparison was limited to 60 paths, focusing on AM Peak and walk- and PNR- access modes
- The 60 selected paths could be classified into five (5) categories based on path comparison results

Category	# Cases
(1) TRNBUILD and PT developed identical or largely identical paths	28
(2) TRNBUILD and PT developed similar (partly different) paths	7
(3) TRNBUILD and PT developed significantly different paths	4
(4) Only TRNBUILD developed a path	8
(5) Only PT developed a path	13

Comparison Results: Path Tracing

- It was not surprising to see TRNBUILD and PT (“BESTPATHONLY”) develop identical paths in 28 cases, as both programs develop shortest paths
- In 8 cases, TRNBUILD developed a path but PT did not. Those TRNBUILD paths involved an extremely long walk (>45 min) to access transit, which was prohibited in PT
- In 13 cases, PT developed a path but TRNBUILD did not. 4 of those paths had a total perceived time over 6 hours, which was prohibited in TRNBUILD; 9 of those paths were not developed in TRNBUILD because of access-related restrictions on drive-access link development (NCT codes)
- The 4 cases where TRNBUILD and PT paths were vastly different could all be attributed to the access-related restrictions on maximum drive access distance in the Ver. 2.3 Model (NCT codes)
- In 7 cases, TRNBUILD and PT developed partly different paths from/to Union Station. In areas with many transit options, TRNBUILD and PT may have chosen different routes due to a small difference in fare or time

Comparison Results: Path Tracing

- Other observations on path comparison results:
  - Transit fare is considered in PT path-building but not in TRNBUILD
  - Even when TRNBUILD and PT paths were identical, skims on those paths could be different due to different treatments of transfer penalties and different headway combining weights
  - A glitch was noted in both TRNBUILD and PT with their single-path path builders: While they are intended to develop the shortest path for a specific mode, they may develop a path that uses a different mode
    - This glitch had unintended, adverse effects on mode choice
    - While some workaround could be instituted in a single-path path builder, a better solution would be switching to a multi-path path builder

Comparison Results: Standard Summaries

- Switching to PT had a moderate effect on auto travel, as indicated by the differences in total VMT (<1%) & total VHD (<6%) between Runs 1 and 2
- This switch, however, substantially increased estimated transit person trips from mode choice by about 36%, largely because Ver. 2.3 NLMC Model was originally calibrated using TRNBUILD skims
- TPB staff re-calibrated the NLMC Model using 2007 PT skims (generated by an additional 2007 run with PT) & conducted a third 2014 run ("Run 3")
- Region-level statistics of Run 3 are very comparable to those of Run 1

Run	1	2	3	2 minus 1		3 minus 1	
	2014	2014	2014				
Model	Ver. 2.3.85 (TRNBUILD)	Ver. 2.3.85 (PT)	Ver. 2.3.85 (PT|Calibr.)	Diff.	% Diff.	Diff.	% Diff.
MC Transit Trips	1,137,089	1,543,227	1,151,198	406,138	35.72%	14,109	1.24%
Total VMT	159,697,185	158,468,076	160,163,401	-1,229,109	-0.77%	466,216	0.29%
Total VHD	1,046,832	993,022	1,054,451	-53,810	-5.14%	7,619	0.73%

Comparison Results: Transit Validation

- Estimated to Observed Ratio ("E/O Ratio") indicates how well estimated transit ridership by mode validates to observed data in three 2014 runs
- Focusing on Run 1 vs. Run 3, switching to PT and recalibrating the NLMC model using PT skims led to:
  - Improved validation statistics for MARC and for commuter rail overall
  - Comparable validation statistics for Metrorail and VRE
  - Increased over-estimation of bus ridership (1.09 to 1.25), indicating a potential need to re-calibrate bus transfer rate

	Observed ("O")	Estimated ("E") (E/O Ratio)		
	Run	1	2	3
	Model	Ver. 2.3.85 (TRNBUILD)	Ver. 2.3.85 (PT)	Ver. 2.3.85 (PT | Calibr.)
Metrorail	737,679	744,383 (1.01)	678,081 (0.92)	735,149 (1.00)
Commuter Rail	36,482	27,768 (0.76)	39,656 (1.09)	30,183 (0.83)
MARC	20,171	17,271 (0.86)	33,171 (1.64)	20,056 (0.99)
VRE	16,311	10,497 (0.64)	6,485 (0.40)	10,127 (0.62)
All Bus	648,083	704,951 (1.09)	1,424,990 (2.20)	808,868 (1.25)
Total:	1,422,244	1,477,101 (1.04)	2,142,727 (1.51)	1,574,199 (1.11)

Findings: Strengths of PT

- PT considers fares in transit path building and offers a lot more flexibility to model the various fare systems specific to mode, operator or line
- PT provides both single-path and multi-routing modeling. As discussed earlier, multi-routing could overcome some of the shortcomings associated with single-path modeling
- PT multi-routing modeling enables the modeling of transit crowding in consideration of transit capacity constraints
- PT can generate useful transit loading summaries through loading analysis functionalities such as stop-to-stop transit volumes, system transfers, select-link analysis and fare revenue
- Future improvements and new developments of transit modeling functionality in Cube will be focused on PT, as “TRNBUILD is no longer being maintained or enhanced by Bentley”

Findings: Limitations of PT

- PT, at least in the current setting, significantly increased model runtime relative to TRNBUILD
- PT is more complicated and has a steeper learning curve for network developers, modelers and model users
- Under the "BESTPATHONLY" mode, PT does not provide built-in functions that can skim the first and last stations by mode, which are required in the current Ver. 2.3 Model fare development process

Next Steps

- This PT investigation could be extended in many directions. Staff may:
  - Continue to explore means to improve PT modeling run time;
  - Explore ways to improve transit validation;
  - Explore various PT functionalities using Ver. 2.3 Model as a test bed
- Staff recommends the following PT-related refinements for Gen3 Model:
  - Gen3 Model should rely only on PT fare functions to calculate fares. PT fare functions should be carefully specified, and PT fares should be compared to ground-truth fare data for reasonableness checks
  - Gen3 Model should incorporate access-related rules (NCT codes) in the development of PNR/KNR non-transit legs
- Network databases and COGTools should be enhanced to support network development activities both for Gen3 Model, which will use PT, and for Gen2/Ver. 2.4 Model, which will likely continue to use TRNBUILD, but with a possibility to switch to PT in the future

Acknowledgements

- This is a collective effort by Travel Forecasting and Emissions Analysis (TFEA) Team in COG/TPB
- I would like to express my sincere thanks to:
  - Jim and Meseret, who developed the 2007 transit network in PT format in support of this investigation
  - Ray and Sanghyeon, who conducted some tests related to PT runtime and path tracing
  - Mark, Dusan, Jane, Ron, Joel Freedman (RSG), Eric Ho (Gallop) and others, who provided valuable feedback, and
  - Vipul Modi (Bentley Citilabs), who offered insights, suggestions and technical assistance with the testing related to PT runtime

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