A Simulation Based Dynamic Traffic Assignment Model for Corridor/Regional Operational Planning Analysis

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DynusT (Dynamic Urban Systems in Transportation)

- **Simple, lean** and easy to **integrate** with macro and micro models
- Developed since 2002, tested (in test) for 20 regions since 2005
  - ELP, PAG, MAG, DRCOG, PSRC, SFCTA, HGAC, Las Vegas, NC Triangle, Guam, Florida, SEMCOG, Toronto, SACOG, Mississippi, North Virginia, I-95, US36, New York, Bay Area
- 50+ agency/firm/univ users
- **Memory efficient**
  - The only DTA capable of large-Scale 24-hr simulation assignment
- **Fast simulation/computation**
  - Multi-threaded
- **Realistic microlike mesoscopic traffic simulation**
  - Anisotropic Mesoscopic Simulation (AMS)
- **Managed Open Source in 2010/2011**
DynusT Ongoing Efforts to Support Users and Agencies

- Military deployment transportation improvement in Guam (PB, FHWA)
- Interstate highway corridor improvement (TTI, TxDOT, ELPMP0, Kittleson, ADOT, UA, CDOT)
- Value pricing (ORNL, FHWA; SRF, Mn/DOT, TTI, TxDOT, UA, CDOT/DRCOG)
- Evacuation operational planning (TTI, TxDOT, UA, ADOT; LSU, LDOT; Noblis, FHWA; Univ. of Toronto, Cornell Univ. Jackson State Univ., MDOT, Univ. of Missouri, MDOT)
- Integrated Corridor Management modeling (CS, FHWA, MAG, NCSU, NCDOT, MAG)
- Pilot studies (Portland Metro)
- Activity-based model integration (UA, SHRP2 C10, FHWA EARP)
- Work zone impact management (SHRP2 R11)
Community-Based Open Source (2011 or 2012)

- **Existing Developers**
  - Univ. of Utah(*)
    - Travel demand model importer
  - Texas Transportation Institute
    - VISUM - DynusT interface (PTV)
    - DynusT - VISSIM interface
  - Parsons Brinckerhoff(*)
    - Synchro - DynusT importer
    - Google Earth displayer
    - DynusT - DYNAMEQ (PB)
    - DynusT - VISTA (PB)
  - Pima Associations of Governments(*)
    - Synchro - DynusT importer
  - AECOM
    - TRANSIMS - DynusT converter
Puget Sound Regional DynusT Model
Puget Sound Regional DynusT Model
PAG Regional DynusT Model
PAG Regional DynusT Model
Las Vegas Regional DynusT Model
Portland Regional DynusT Model
Triangle, NC Regional DynusT Model
Toronto, CAN Regional DynusT Model
Minneapolis Regional DynusT Model
Compatibility with Existing Modeling Framework

- Trip-based framework

Strategic Modeling

Mission-Driven Modeling

Diagram:
- Trip Generation Model
- Trip Distribution Model
- Mode Choice Model
- Time of Day Model
- Skims Network Performance Measure
- Mesoscopic Dynamic Traffic Assignment
- Jurisdiction Sub-Area Model 1
- Jurisdiction Sub-Area Model 2
- Jurisdiction Sub-Area Model 3
Compatibility with Existing Modeling Framework

- **Activity-Based Model**
Modeling Demand/Supply Interactions in DynusT

- **Four fundamental elements for a transportation System**
  - Infrastructure
    - Geometries
  - Traffic flows
    - Speed, density, flow, shockwaves, queue
  - Control systems
    - Signals, ramp meters
  - Information
    - Traveler information, message sings
Rich Travel Behavior Representation

- **Driving behavior**
  - Car following
  - Lane changing

- **Travel choice behavior**
  - When to leave
  - Which route to take
  - Diversion or not
  - Reaction to
    - Work zone
    - Congestion
    - Information
    - Pricing
    - Evacuation scenarios
DynusT Simulation-Based Dynamic Traffic Assignment

- **Typical algorithmic structure**

  - Arrays storing time-varying travel time, intersection delay, etc.
  - Route Finding (Time-Dependent Shortest Path)
  - Route Adjustment (MSA or Gradient Projection Based Algorithms)
  - Route Evaluation (Mesoscopic Traffic Simulation)
  - Simulation Interval
  - Assignment Interval
  - Analysis Period
  - Convergence Check
  - Stop
DynusT Simulation Assignment Framework

Iteration $n$ Traffic Simulation

- Time-dependent OD, network
- Initial/Intermediate Vehicle Paths

- Generated Vehicles with Assigned Attributes

- Information Strategy
- Initial Path

- Anisotropic Mesoscopic Simulation (AMS)

- Model MoEs
  - Evacuation Time, Exposure Level, Casualty, etc.

Method of Isochronal Vehicle Assignment

Epoch $k$ Traffic Assignment

- Time-Dependent Shortest-Path Algorithm

- Gap Function Vehicle Based Traffic Assignment Algorithm

$k = k + 1$

All Epochs Assigned?

Assignment Converged?

$n = n + 1$

Yes

Stop

No

No

Yes
Anisotropic Mesoscopic Simulation (AMS)

- Stimulus-response model
- **Net influence** for speed adjustment primarily comes from traffic in the front
- Can define different “average traffic conditions” to model uninterrupted and interrupted flow conditions

\[
k_{i}^{t-1} = \min \left[ k_{\text{target}}, \frac{N_{i}^{t-1}}{mx + n(l - x)} \right]
\]

Appeared in Transportation Research Part B (2010)
Vehicle Trajectories

- Permanently lane drop
- Temporarily blocked area

Graph showing vehicle positions over time with milestones and trajectories.
Gap-Function Vehicle Based Assignment

- Driven by Gap Function

Convergence (Relative Gap)

- Iteration 72

Relative Gap

Iteration
Import Synchro Timing to DynusT

- Another set of slides to follow
Data Preparation Tasks For an Area Similar to the San Francisco County Network (PB)

1 week
- Import the regional network
- Import demand

7 weeks
- Check network
- Add major/minor arterials
- Add Pocket lanes

8 weeks
- Manually import the signals (one time period only)

2 weeks
- Import the signs

~3 weeks
- Process 15-min movement counts for hundreds of intersections
- Process travel time reports
Using One Anchor Point
Model Calibration and Validation

- **Calibration of simulation**
- Multiple traffic flow models for categories of grade along corridor


5/10/2010
Model Calibration and Validation

- **Calibration of simulation**
  - Multiple traffic flow models for categories of grade along corridor

Two-Stage Dynamic Calibration Framework

Total Link Counts

Speed Profile

Discretize time horizon

Calibration time interval

Stage 1 OD Trips Calibration

Stage 2 Departure Profile calibration

5/10/2010
Model Calibration and Validation

- **OD calibration**
  - Automatically match total traffic counts within time period at different locations along corridor with minimal change to original seed matrices
Automatic Departure Curve Calibration to Match Speed Profile

Before calibration: $q$, $k$, $v$ & $N$ curves profile

- Density - time
- Speed - time
- Flow - time
- Cumulative number of vehicles $N$ - time
Automatic Departure Curve Calibration to Match Speed Profile

After calibration: $q$, $k$, $v$ & $N$ curves profile

- **Flow - time**
  - $q_1$ (red)
  - $q_2$ (blue)

- **Density - time**
  - $k_1$ (red)
  - $k_2$ (blue)

- **Speed - time**
  - $v_1$ (red)
  - $v_2$ (blue)

- **Cumulative number of vehicles $N$ - time**
  - $N_1$ (red)
  - $N_2$ (blue)
Model Representative of Actual Traffic Condition

- **EB – Eisenhower Tunnel**
Macro-Meso-Micro Integration

- **Macro**: Proposed toll lanes
- **Meso**: Analyze Ingress/Egress points for weaving
- **Micro**: Estimate toll lane usage and revenue

*Proposed toll lanes*

*Analyzing Ingress/Egress points for weaving*

*Estimating toll lane usage and revenue*
DynusT to VISSIM Conversion

- Sub-area operational analysis
- Retain time-dependent routes and flows
- If nice visual is needed, let VISSIM takes care of it
Applicable to:
- Network capacity changes (work zone, improvement, expansions, etc.)
- Pricing (route and departure time change)
- Demand change (feedback to prior steps)
ICM Incident Diversion Rules (Short-Term Reaction)

- **Delay-Responsive Diversion**
  - A traveler may switch to a different route by comparing his remaining trip time with his/her *experience* when no other information is available.
  - Applicable to: all (100% Pre and Post ICM)

- **Pre-trip information**
  - A traveler has an experienced historical path, but checks for the current network condition at departure and selects the best available path if:
    - (1) his/her historical path is impacted by an incident
    - (2) estimated delay exceeds a threshold N(15,2)
  - Applicable to: a sub-set of travelers
ICM Incident Diversion Rules

- **En-Route Information**
  - A traveler is equipped with a in-vehicle device, or is able to receive updated information to access travel time for the remaining trip of the original route and a new route (auto route only)
    - Information updated every 10 min
    - Switch if travel time saving on the new route exceeds a threshold (5 min)
  - Applicable to: a sub-set of travelers (5%)

- **DMS Information**
  - A certain percent of travelers passing through the sign will choose a new path, which is calculated based on either current or historical experienced travel time
ICM Incident/Work Zone/Evacuation Diversion Rules

- **Comparative Information**
  - At each DMS location, if a traveler is willing to consider transit (5%), then
    - Assess total transit generalized time
      - Access time to boarding stop
      - Transit line-haul time
      - Access time to final destination from the alight stop
      - Fare
    - **Switch if transit saving exceeds a threshold (10 min)**
  - **else**
    - **Apply en-route switch rule**
  - Applicable to: en-route information travelers
Transit Modeling Requirements

Need for a versatile simulation and assignment tool that:
- Captures operational dynamics for transit vehicles
- Captures traveler assignment and network loading in a multi-modal context
  - Transit assignment
  - Inter-modal assignment
Transit Operations in DynusT

- Routes are designated by specific paths for transit vehicles
- Transit vehicles leave terminals at designated scheduled times or at specific headways
- Transit vehicles move through the network
  - Mesoscopic flow characteristics while in the traffic stream
  - Specific modeling of stops, with dwell times:
    - Track number of passengers at specific stops
    - Incremental boarding and alighting time model is used
      \[
      \text{Dwell time} = a + \max \{ b_1 B, b_2 A \}
      \]
Transit Assignment vs. Dynamic Traffic Assignment

DynusT

Analysis Period

Simulation Interval

Assignment Interval

Network Loading

Arrays storing time-varying in-vehicle time, waiting time, transfers,
dwell time, declined boarding, etc.

Hyperpath Set Update (including latest Time-Dependent Shortest Hyperpath)

Hyperpath Adjustment

Arrays storing persons and assigned (selected) hyperpaths
Transit Loading and Assignment

- Operational dynamics through mesoscopic traffic simulation with transit-specific characteristics in the network loading
  - Dwell times, on-street vs. pull-out stop locations
- Dynamic transit assignment
  - Passenger stop choice
  - Passenger path choice / boarding decisions
    - Frequency-based and schedule-based assignment models
- Iterative convergence of an equilibrium assignment, if capacity constraints apply (heavily congested routes)
- Assignment models are calibrated using common data: transit networks, transit schedules, boarding and alighting data
Resource Considerations

- **Initial TDM import and conversion**
  - 100+ hrs

- **Data collection and model calibration**
  - 300+ hrs
  - This could vary depending on data availability and model fidelity requirements

- **Scenario analysis and reporting**
  - 400+ hrs
  - More is needed if linking with existing model components
  - More is needed if micro model integration is needed, but not excessive with DVC tool

- **Total man-hours**
  - 800+

- **Budget 1,000 - 1,500 hours; including climbing learning curve**
How to Get Started and Go Long Miles

• **Capacity building**
  – Training workshop
  – Frequent interaction with developers

• **Strategic Modeling to establish baseline and future scenario datasets**
  – Allow 8-12 months with adequate budget
  – A valuable strategic model for many future applications and sub-area analyses

• **Regional model can be used for mission-driven projects**
Conclusions

- DTA as a dynamical view of system
  - Regional/Corridor
  - Linking planning and operations
- Protecting/enhancing existing model investments
  - Interoperability with macro and micro models
- Plan ahead and make it a priority
  - Budget, data, man hours
  - Intellectual capability building
    - Agency staff
    - Consultants
- Work closely with developers
EMFAC-DTA Integration

- Dataset of Traditional Travel Demand Models
  - Conversion of Road Network Topologies
  - Development of Time-dependent OD Tables

- DynusT
  - Vehicle Trajectory Data
  - Time-dependent Link Activity Data

- Activity Data Processor
  - Trip-based VMT-speed Distribution
  - Link-based VMT-speed Distribution

- EMFAC Emission Factors
  - Trip-based Emissions Inventory
  - Link-based Emissions Inventory

Traffic Activity Modeling
Activity Data Processing
Emission Inventory Modeling
Q&A

- Does DynusT have OD estimator?
  - Yes

- DynusT MRM tools
  - VISUM-DynusT-VISSIM (PTV/TTI)
  - DynusT-Synchro (PB)

- DynusT Visual
  - Combine Excel, VISSIM 3D

- DynusT post-processing
  - More than 10 utilities freely available

- Example on large-scale model
  - Demo today (DRCOG, MAG, Portland Metro, Toronto, SEMCOG, etc.)

- Example on calibration
  - All prior projects applied OD and speed profile calibrations

- DynusT dynamic transit assignment
  - Available early 2011

- How DynusT compare with other DTA models
  - PB performed comparative analysis
More Readings:
“Google DynusT”