Dynamic Choices in Coordinated Household Activity-Travel Systems

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Motivation

- Trip-based models are not adequate for some of the more complex questions we face
  - Time of day sensitivity
  - Dynamic congestion effects
  - Variable pricing and tolls
  - Reliability of both highways and transit systems
  - Incident response and adaptation
- Most existing activity/tour-based models do not fully consider temporal variation in utility
  - Potential to misrepresent space-time constraints
  - Time-dependent path costs do not inform travel choices

Inspiration

- Metro project team work with TRANSIMS in Portland
- P.I.'s work on disaggregate commercial vehicle model for Ohio DOT (with PB)
  - Gliebe, J. P., O. Cohen, and J. D. Hunt. 2007 "A Dynamic Choice Model of Commercial Vehicle Activity Patterns." In *Transportation Research Record: Journal of the Transportation Research Board, No. 2003.* Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 17-34.

Usual Approach to Travel Time Consistency Through Feedback

- Choose activity events, locations, travel modes, and starting and ending times, forming complete daily patterns
- Create trip lists/tables and assign to a network
- Obtain results and feedback travel times
- Adjust various activity pattern dimensions (starting times, locations, modes, etc.)
- Repeat feedback and adjustment procedures until output trip tables and travel time/cost skims do not change too much
  - Not really a problem for static assignment

Problems with Activity-Based Demand and Dynamic Assignment

- Consistency between input and output travel times and trip tables does not guarantee a credible solution!
- If you look closely, you may find that…
  - Infeasible or unreasonable travel patterns prevail due to inconsistent treatment of time across choice dimensions
  - Space-time constraints are violated
  - Particularly acute with schedule-based transit assignment due to sudden service hour changes
  - Resolution?
    - Not clear which model dimensions to adjust…theory?
    - Might take many iterations to achieve consistency
    - May never achieve consistency if model specifications are not sensitive to time of day

Which better describes how individuals make activity-travel decisions?

- People choose their daily number of tours and trips *a priori*, following a hierarchy, set an activity duration, and calculate space-time constraints or time windows. They fit interaction with other household members into these spaces. If things don't make sense, they reconsider the day and adjust timing, locations and/or travel modes, iteratively, until they do.

….or

- Individuals consider their personal responsibilities, and attempt to engage in activities commensurate with their role. As the day progresses, they consider what they have done so far, how much time is left in the day, whether businesses are open, and what other household members might be doing, then make a choice for what to do next, where to do it, and how to get there.

Some Existing Activity and Tour-Based Models

- Day Pattern Approaches
  - SFCTA, SACSIM
- Household Role Hierarchical
  - NYBPM, MORPC
- Activity Patterns + Dynamic Networks
  - TRANSIMS
- Activity Patterns + Explicit Re-scheduling
  - MATSIM (+ dynamic network)
  - ALBATROSS-AURORA-FEATHERS
- Continuous Time/Prism Constraints
  - PCATS/FAMOS (DEBNets), CEMDAP (VISTA)

Utility is Time Dependent

- A few examples…
  - Duration of time spent in an activity depends on time of day, cumulative time spent in all activities, and competing demands from other activities
  - Some activities become less appealing or less feasible at certain times of day (e.g., shopping at 10 p.m., personal business at 6 a.m.)
  - The appeal of eating out changes throughout the day
  - Transit service is reduced during certain times of day
  - Bicycling and walking are less appealing late at night
  - Locations closer to home (or work or children) become more important at certain times of day

Dynamic Utility Propositions

- Activity participation and travel choices are made by individuals based on expected utility
- Expected utility of a future event depends on…
  - Consideration of one's household role (responsibilities)
  - Reflection upon experiences in similar and other events that have already taken place… same day, tour, activity
  - Time-of-day-specific effects related to that event
  - Consideration of other household members
    - What is their role?
    - What are they doing right now?
    - Where are they?
    - Do they have a car?
- Utility values are updated, not necessarily accumulated
  - Decisions are made "in the moment"

Basic Idea for a “Dynamic Activity Simulator for Households” (*DASH*)

- Step each individual (& household) through a simulated day
  - Initiate each individual with a household-oriented role
  - Individuals make dynamic activity-travel choices…
    - What to do next?
    - Where to do it?
    - How to get there?
    - Whether to go with someone else?
  - Utilities for alternative answers to each of these questions are updated through simulated time
  - A choice is made
  - Travel times between activity locations are realized
  - One activity ends and another begins when a decision is made to switch to another activity

Markov Decision Process

Possible Activity State Transitions with Intensity Rates $\pi(k',k)$

	Destination Activity State k								
Starting Activity State k	Stay at Current Activity	Work	Work-related	Shopping	Social, Recreate	Escort	Eating Out	Return Home	Sum
Home	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$		1.00
Work	$\pi(k',k)$		$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00
Work-related	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00
Shopping	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00
Social, Recreate	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00
Escort	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00
Eating Out	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	$\pi(k',k)$	1.00

Dynamic Choice Model Formulation

$$\pi_{k'k}(t) = \frac{\sum_{t=1}^{T} I\left(Y_t = k \mid Y_t' = k'\right)}{T_{k'}}$$

$$L_n = \prod_{k=1}^{K} \left(P_{nk'k}\right)^{S_{nkk'}}$$

$$S_k = \frac{T_{k'}}{T_{k'} + 1}, k = k'$$

$$P_{njk'} = \frac{\exp(U_{nk'j})}{\sum_k \exp(U_{nk'k})}$$

$$S_k = \frac{Y_k}{T_{k'} + 1}, k \neq k'$$

$$U_{nk'k}\left(t_j\right) = \theta_{k'k} + \beta_k' X_n + \tau_k\left(t_j\right) + \varepsilon_{k'k}$$

Rescaling of Time for Estimation

- Example of 30 minute duration
  - Case 1: assume 1-minute intervals

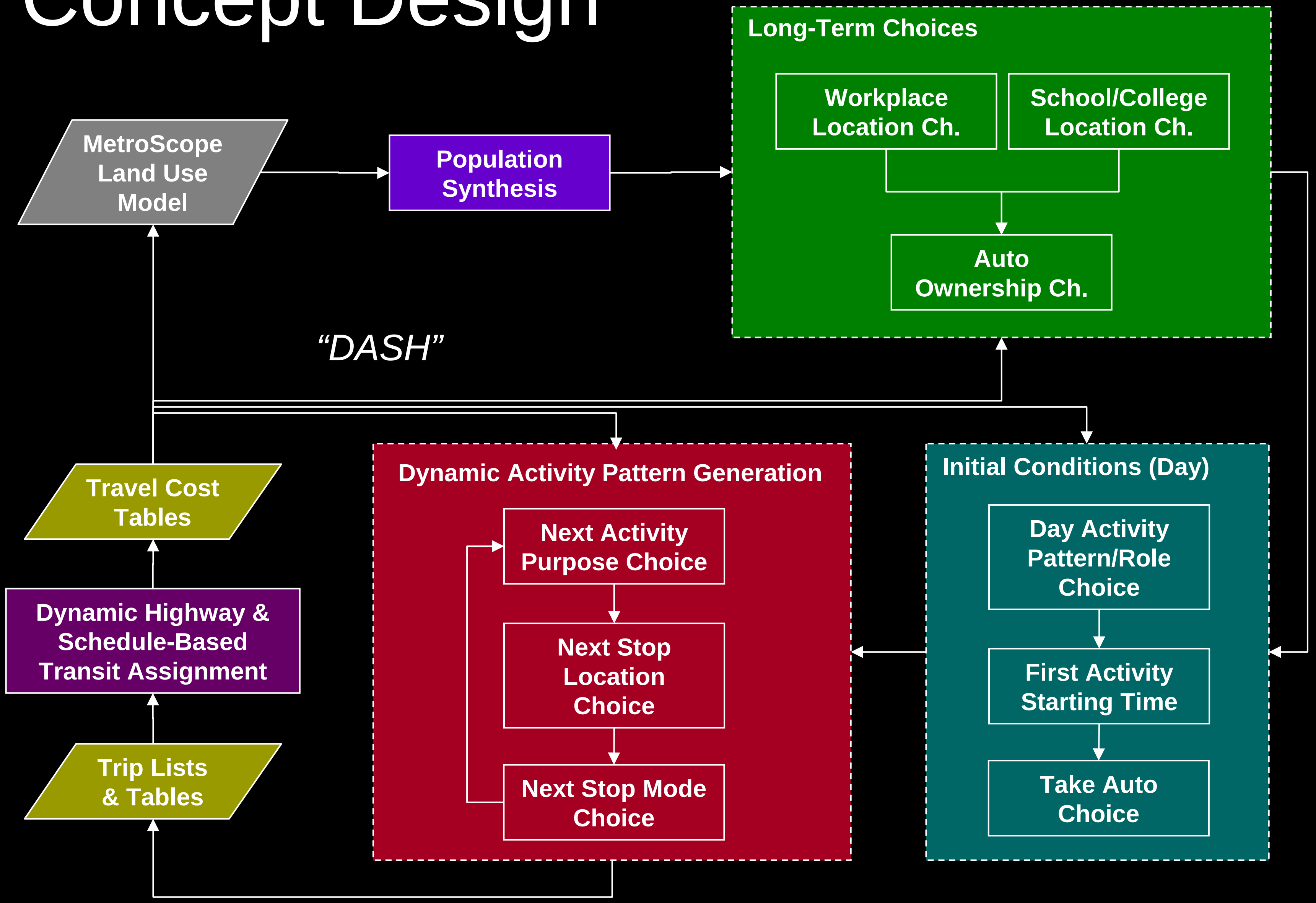
$$S_{k'} = \frac{30}{30+1} = \frac{30}{31} \qquad S_k = \frac{1}{30+1} = \frac{1}{31}$$

  - Case 2: assume 15-minute intervals

$$S_{k'} = \frac{2}{2+1} = \frac{2}{3} \qquad S_k = \frac{1}{2+1} = \frac{1}{3}$$

- 5-minute intervals provided best fit?

Metro Dynamic Activity Model Concept Design



Role Choice

- Adult stay at home
- Child dependent at home
- Child non-driver K-12 student
- Child driver K-12 student, may work
- Adult not working without childcare responsibilities
- Adult not working with childcare responsibilities
- Adult working without childcare responsibilities
- Adult working with childcare responsibilities
- College student
- Adult planned joint activities (non-work/school)

Next Activity Choice

- Stay at current activity
- Return Home
- New activity of same type at different location
- New activity of different type at different location
  - Work
  - Work-related (not primary work location)
  - School/Daycare
  - College
  - Shopping
  - Social/Recreational
  - Escort Household Member
  - Personal Business
  - Eating Out

Next Activity Choice Utility

- Given ThisActivity, Choose NextActivity →
  - activity role
  - status of other adults
  - status of children
  - HasCar, HasBike
  - time of day, accumulated activity time, accumulated tour time, accumulated activity time since start of day's travel (specific to role, e.g., work, school, college time), travel time from home/work
  - Demographics
  - spatial opportunity set (e.g., access to retail within ¼ mile or continuous accessibility with steep impedance coefficient).

Next Location Choice

- Given NextActivity, ThisLocation, Choose NextLocation
  - HasCar=true/false, HasBike=true/false, CarAtPnR=true/false, ChildPresent=true/false
  - Size variables (specific to activity type)
  - impedance from ThisZone to AltZone
  - and impedance from either
    - (a) HomeZone to AltZone or
    - (b) WorkZone to AltZone

      (determine by time of day, cumulative work time, role).

Next Mode Choice

- Given NextActivity, NextLocation, Choose NextMode
  - HasCar=true/false, HasBike=true/false
  - ChildPresent=true/false
  - travel times, fare and parking costs, demographics, travel party size, role, time of day.

Household Member Status Updates

- Status of other household members will be maintained through the Household object. This will enable interpersonal interaction in decision making.
- Status will include:
  - Role
  - Current Activity
  - Proposed Next Activity
  - Location (TAZ)
  - HasCar
  - HasBike

Coordination Between Household Members

- May be Planned or Opportunistic
  - Heavily influenced by household role choice
  - Joint adult non-work activities is one role alternative
- Two-stage Proposal-Accept framework
  - One household agent signals an activity state change, or shared ride mode proposal
  - Other household agents react to accept or reject, and initiator may reconsider

Coordination Between Household Members – Joint Activities

- Proposal-Accept Framework
  - Initiated when a household member signals a state change
  - Stage 1, Time 18:35, State Change Signal
    - Given Adult 2, Child 1 as “at home” at 18:30, Adult 1 chooses “stay” as next activity
    - Given Adult 1 “stay” at 18:35, Child 1 as “at home” at 18:30, Adult 2 chooses “dine out” as next activity
    - Given Adult 1 “stay” at 18:35, Adult 2 as “dine out” at 18:35, Child 1 chooses “stay” as next activity

Coordination Between Household Members – Joint Activities (cont’d.)

- Proposal-Accept Framework
  - Stage 2, Time 18:35, Reconsideration
    - Given Adult 2 “dine out”, Child 1 as “stay” at 18:35, Adult 1 chooses “dine out” as next activity
    - Given Adult 1 as “dine out”, Child 1 as “stay” at 18:35 Adult 2 chooses “dine out” as next activity
    - Given Adult 1, Adult 2 as “dine out” at 18:35, Child 1 chooses “dine out” as next activity
  - Resolution: Adult 1, Adult 2, Child 1 choose “dine out” (with high probability)

Ending Joint Activities

- Proposal-Accept
  - One person signals for a state change
  - Other participant has option to accept (choose consistent alternative) or counter offer (another alternative)
  - Initiator may reconsider
  - (Very high probability of agreement)

Serving Passengers

- Passenger drop off
  - Stage 1 Signal initiated by potential rider's mode choice of "ride in household auto"
  - Stage 2 Resolved by other household member's state change to "drop off passenger" or non-acceptance.
  - If "ride" proposal not accepted at Stage 2, potential rider must choose other mode (remove ride in household auto from choice set)

Serving Passengers

- Passenger pick up
  - Stage 1 Signal initiated by a driver's activity state change to "pick up passenger"
  - Stage 2 Resolved by other household member's state change to "return home," change to some other activity, or non-acceptance.
  - If "ride" proposal not accepted at Stage 2, driver must choose another activity (remove from "pick up passenger" from choice set)

Theoretical Advantages

- Time-dependency in updating utility functions
  - Implicit values of time vary by time of day and context
  - Able to represent multiple responses to changes in time constraints and opportunities
    - Activity episodes added/deleted
    - Shifts in starting times
    - Durations shortened/lengthened
    - Locations moved closer/farther
    - Mode changes
  - Eliminates infeasibility of predicted travel patterns
  - Readily conforms to an individual traveler’s unique spatio-temporal opportunity set

Theoretical Advantages

- Simpler decision paradigm
  - No structural assumptions about activity prioritization, hierarchies, trip/tour frequencies
  - Easier to explain?
- Random utility modeling used throughout
  - Activity start and end times and durations derived by arrival times at subsequent activities and deciding to end a current activity
  - No need for a separate activity duration model with assumed error term distributions, or a separate activity start/end time model

Computational Advantages

- Scalability of utility/time for increased temporal resolution, or improved run-time performance
- Reduced need for feedback between network supply and demand because demand is dynamically informed by path feedback
- Much of the burden of the typically large number of iterations needed to produce consistency between travel time inputs and outputs can be shifted to the calibration task

Development Plan & Timeline

- 2008 Estimation, calibration and testing using Metro's 1994 survey and static skims from trip-based models
  - 1995 VISUM network
  - 2005 VISUM network validation
- 2009 Testing and calibration using dynamic assignment (source TBD)
- 2010 – 2011 Update with new survey results

Ultimate Future Development

- Develop a fully integrated regional microsimulation program
- DASH decisions produce stochastic demand, loaded at network nodes, as agents move from one node to the next at each time interval

Thank you!

- Discussion?