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A Framework for Network Sensitive Dynamic Activity-Travel Simulation

SimTRAVEL: *Sim*ulator of *T*ransport, *R*outes, *A*ctivities, *V*ehicles, *E*missions, and *L*and

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Research Effort

- Goal
  - Develop a set of methods, computational procedures, data models and structures, and tools for the integration of land use, activity-travel behavior, and dynamic traffic assignment model systems in a microsimulation environment.
    - Universally applicable framework, methods, tools, and data structures
    - Open-source enterprise
- Among first set of projects funded by the FHWA Exploratory Advanced Research Program (EARP)

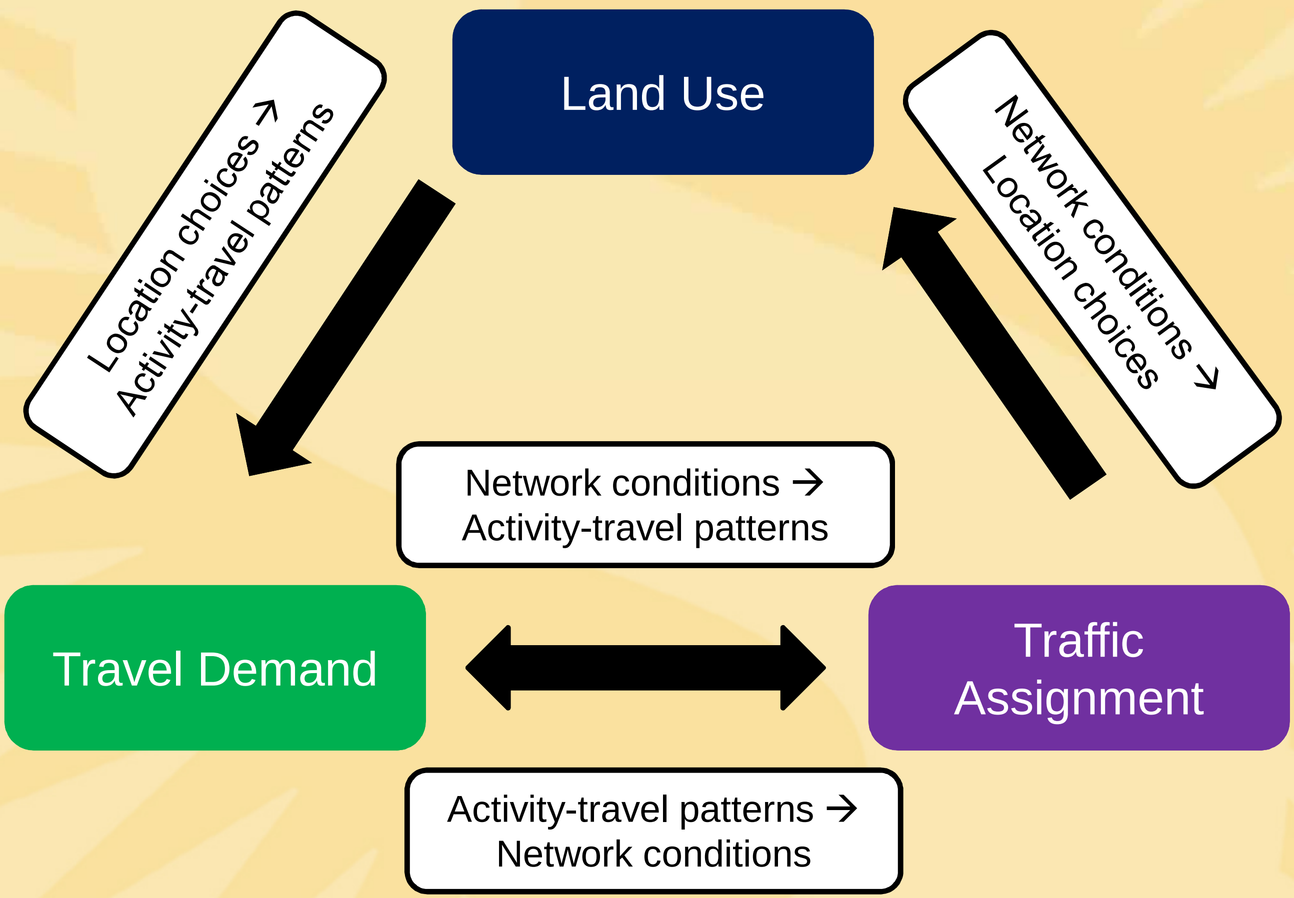
Design Considerations

- Behavioral
  - Consistency in behavioral representation, and temporal and spatial fidelity
  - Explicit recognition of inter-relationships across choice processes
  - Example: Response to increase in congestion from home to work
    - Short term - Alter route and/or departure time
    - Medium term - Adjust work schedule/arrangements
    - Long term - Change home and/or work locations
- Computational
  - Individual models can take several hours to run a single simulation
  - Run times for integrated model systems could be prohibitive
  - Leverage advances in computational power

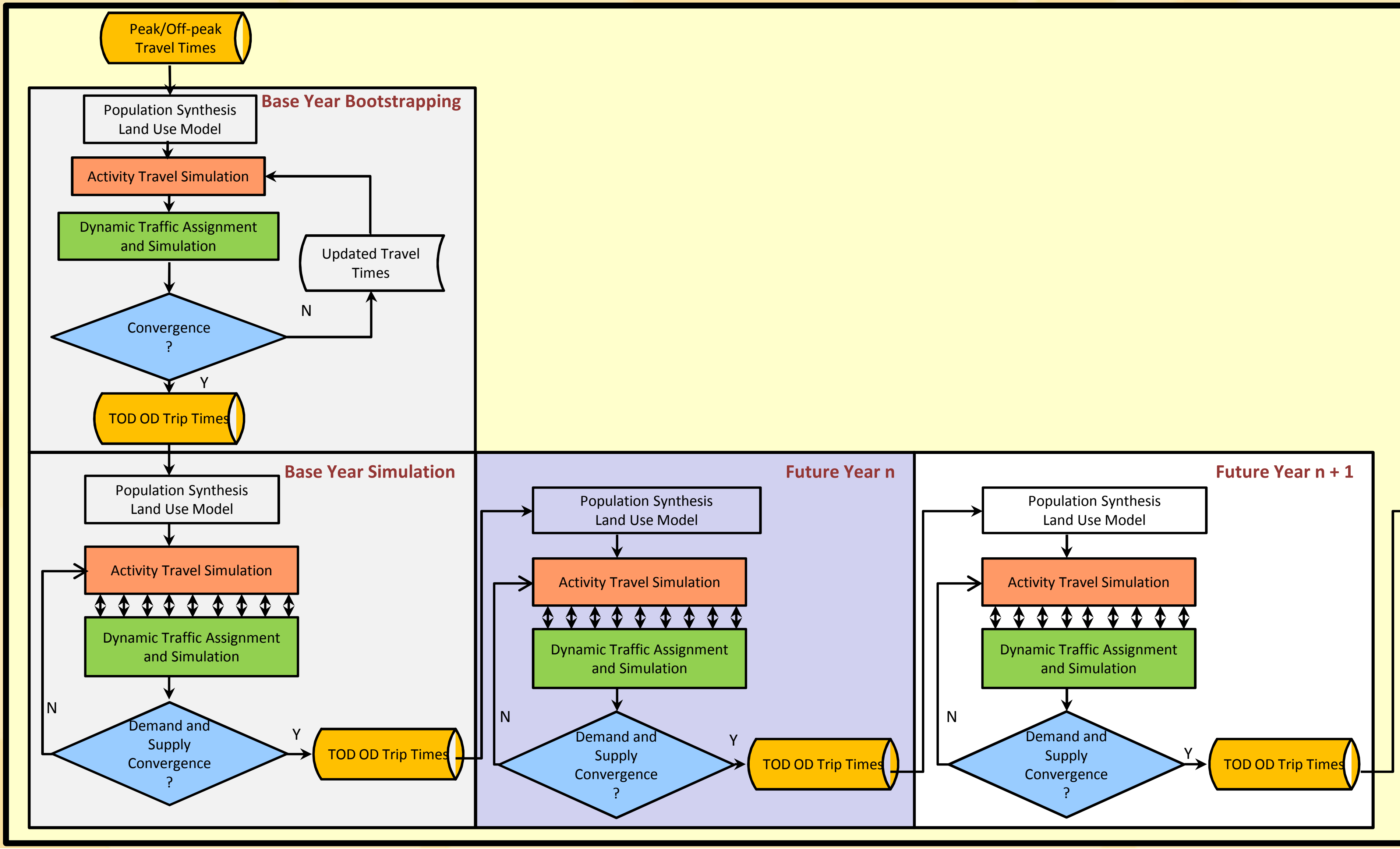
Design Considerations

- Data
  - Land use data available at the parcel level
  - Employment and residential data available at the unit-level (e.g., individual employer)
  - Higher-resolution network data with detailed attributes and vehicle classification counts by time-of-day
  - Detailed activity-travel data including in-home activity information
- Policy
  - HOV/HOT lanes, congestion pricing, parking pricing, fuel price shifts
  - Alternative work arrangements (flex-hours, telecommuting)
- Beyond Interface
  - Make connections across choice processes within a unified entity (as opposed to loose coupling)

Integrated Model System: Linkages



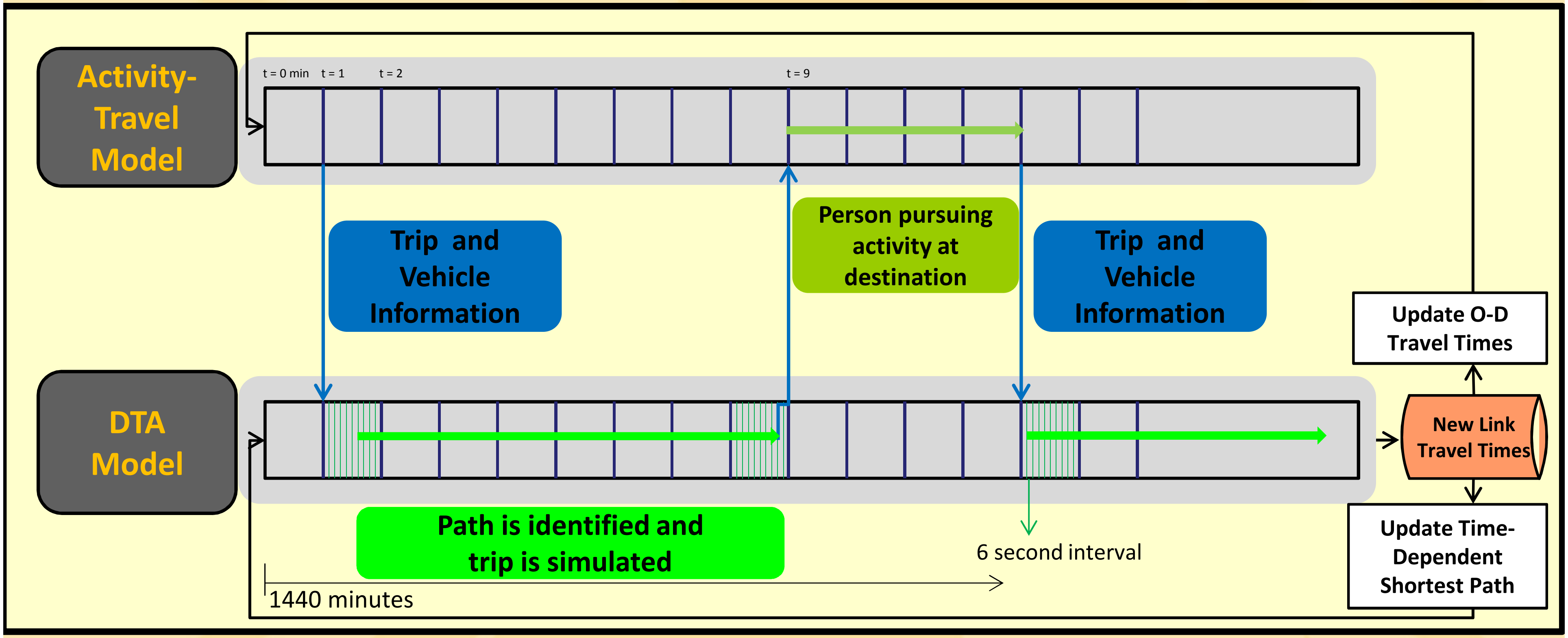
Integrated Model System: Overview



Integrated Model Design

- ❖ Base Year Simulation: Bootstrapping
  - To obtain time-varying travel skims
  - Start with peak/off-peak skims from 4-step model
  - Apply model systems sequentially
  - Iteratively run until demand and supply models converge
- ❖ Model Year Simulation: Integrated Model
  - Location choices are simulated once for a model year
  - Activity-travel patterns are generated and vehicles are routed until both demand and supply side convergence is achieved
  - The converged time-of-day skims feed into the model simulation for subsequent year
  - This process is repeated on an annual time step

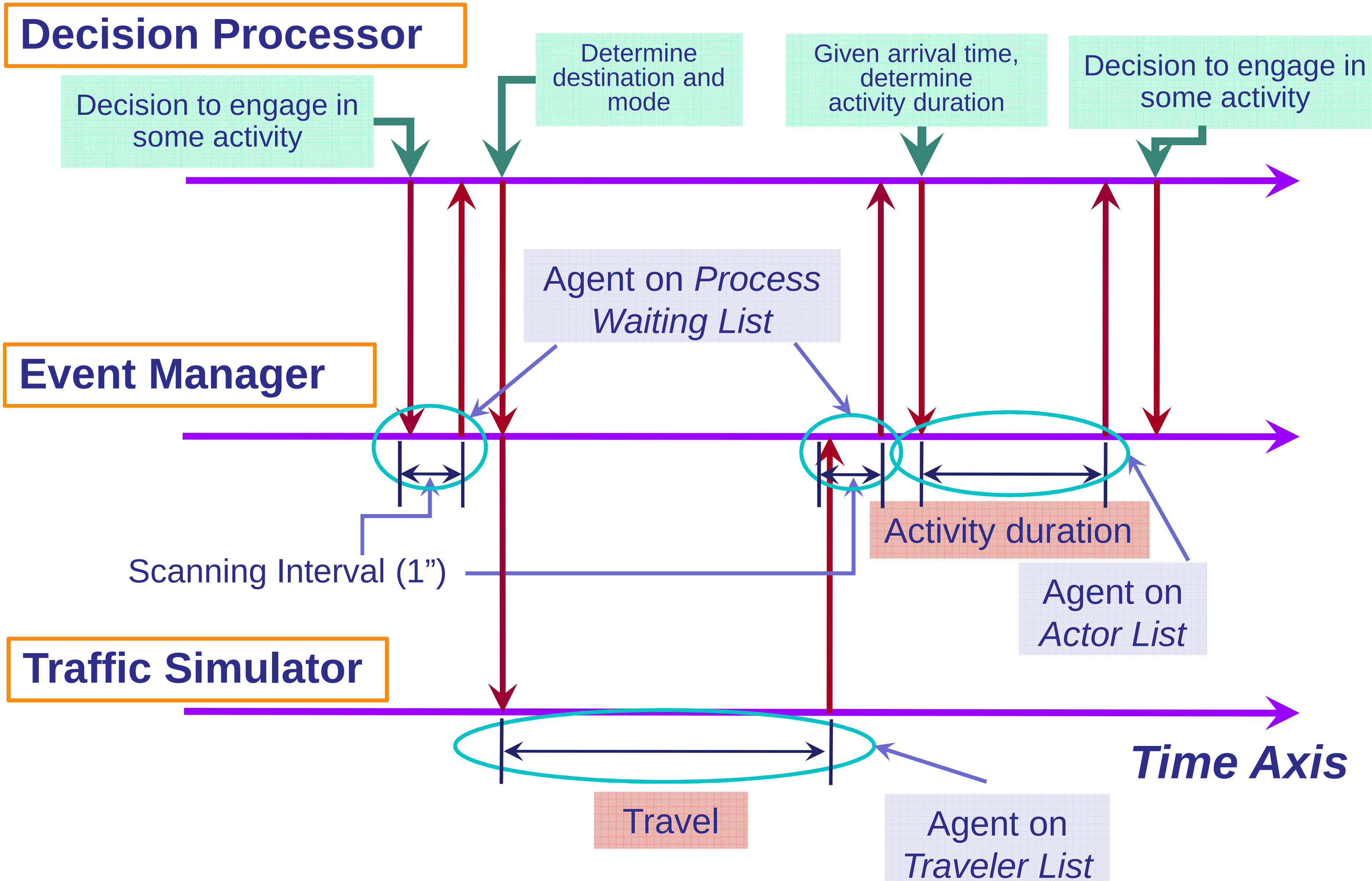
Integrated Model: Supply and Demand



Iterative Process: Feedback Loops

- Feedback origin-destination travel times after each iteration
- Mimics learning process of individual from one day to the next
- Each iteration represents an adaptation of activity-travel schedule based on past experience
- Process is continued until "convergence" is achieved both on the demand and supply side
- Convergence offers consistency between
  - Input travel times used for travel choices in demand model
  - Output travel times from network assignment and microsimulation model
- How does one define "convergence" in the integrated modeling context?

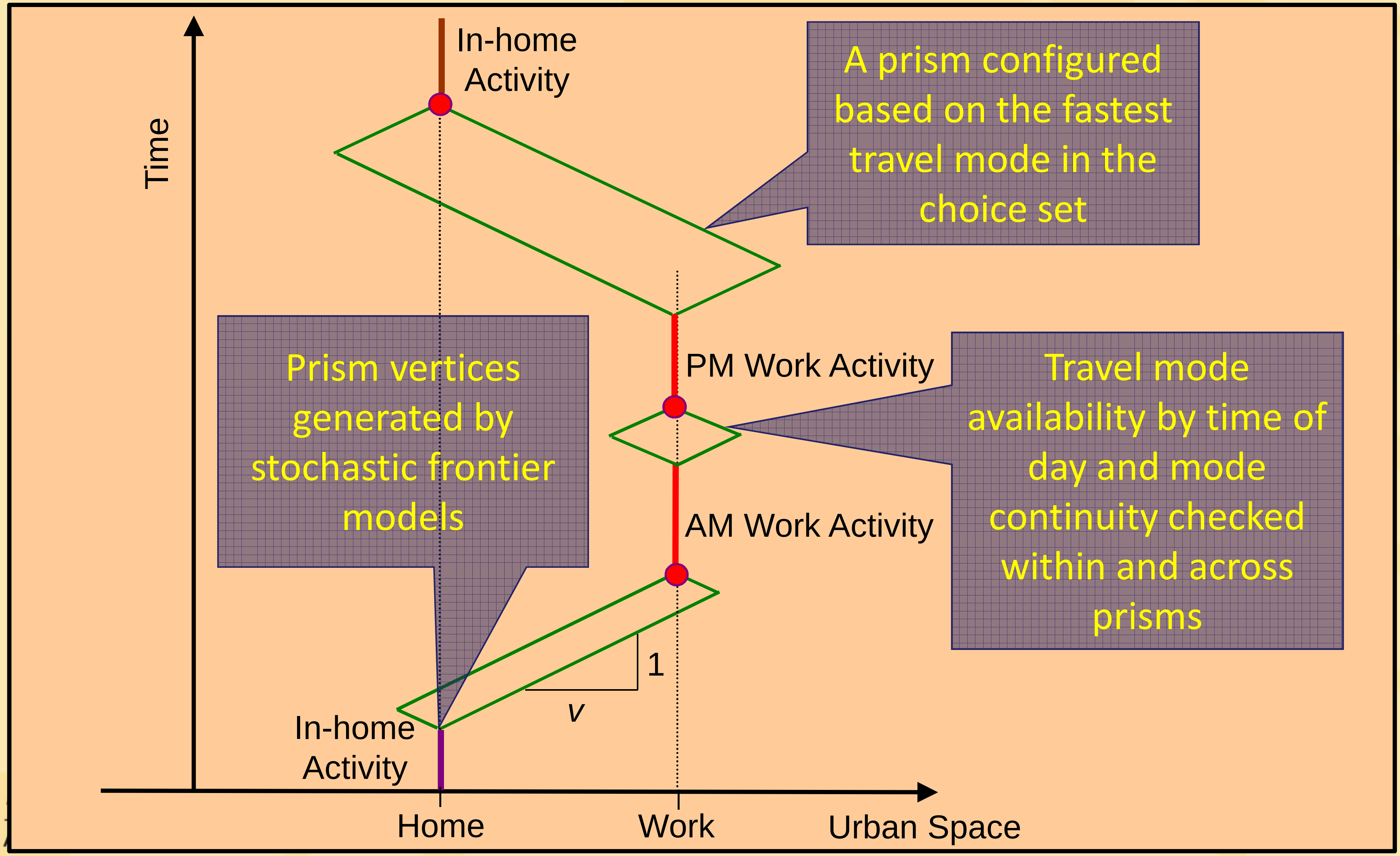
Three Prime Processors of the System PCATS-DEBNetS (Kitamura et al, 2008)



Iterative Process: Convergence

- Supply Side Convergence
  - Well-established and incorporated into modeling paradigms
  - Compare OD travel times from one iteration to the next
  - Use of relative gap function
- Demand Side Convergence
  - No well-established criterion for convergence; simulation results are accepted as stochastic realizations of underlying process
  - Compare daily trip tables from one iteration to next to monitor convergence
  - Use successive averaging schemes as appropriate

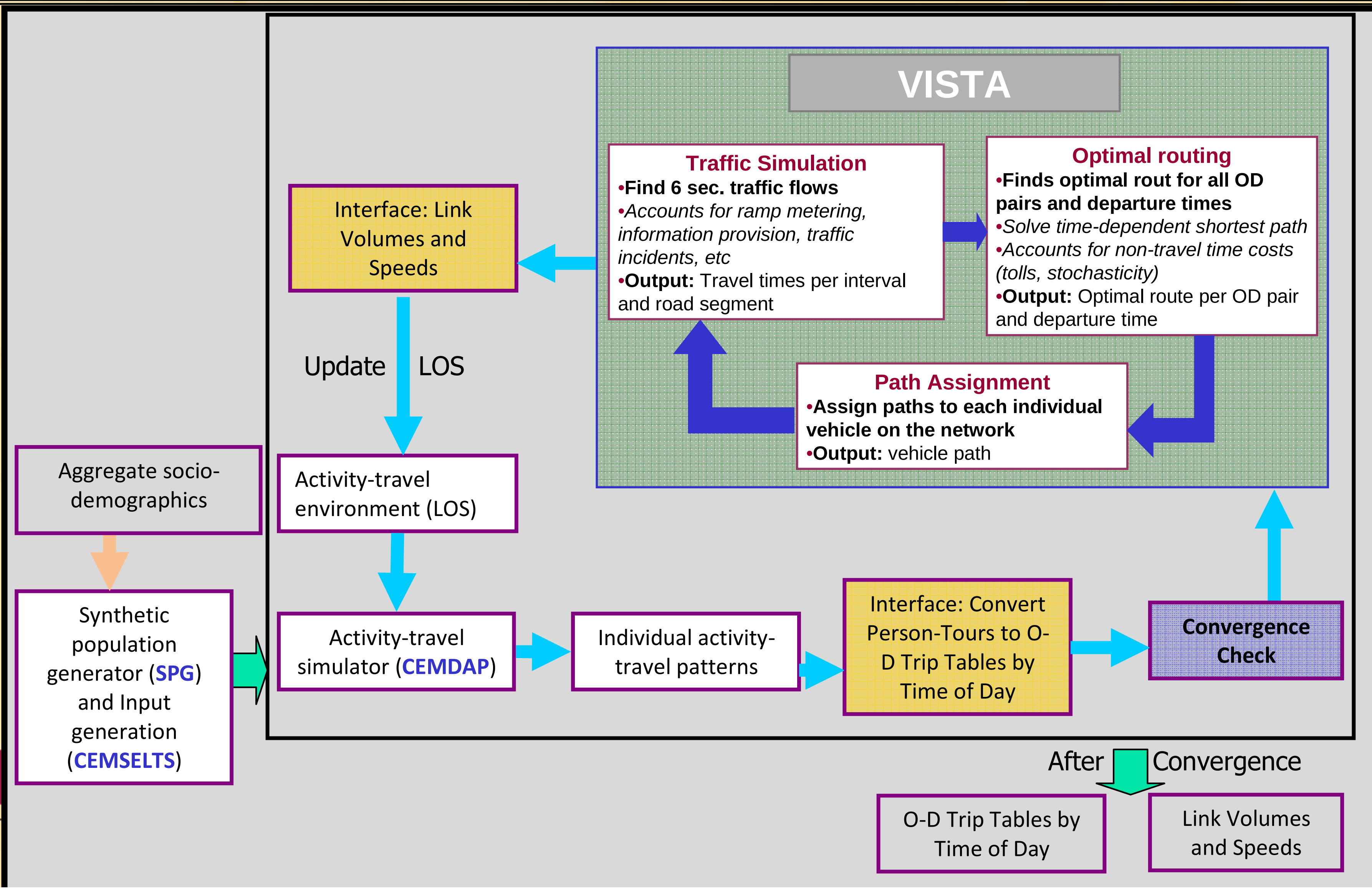
Time-Space Prism Constraints



Alternative Integration Paradigms

- Alternative paradigms to integrated modeling of the urban system
  - Sequential approach
  - Dynamic continuous-time supply-demand interaction approach
- Implications for:
  - Consistency in activity-travel patterns
  - Ability to simulate real-time disruptions/events, interactions, and activity-travel plans

A CEMDAP-VISTA Integration (Lin et al, 2008)



Why Dynamic Approach to Integration

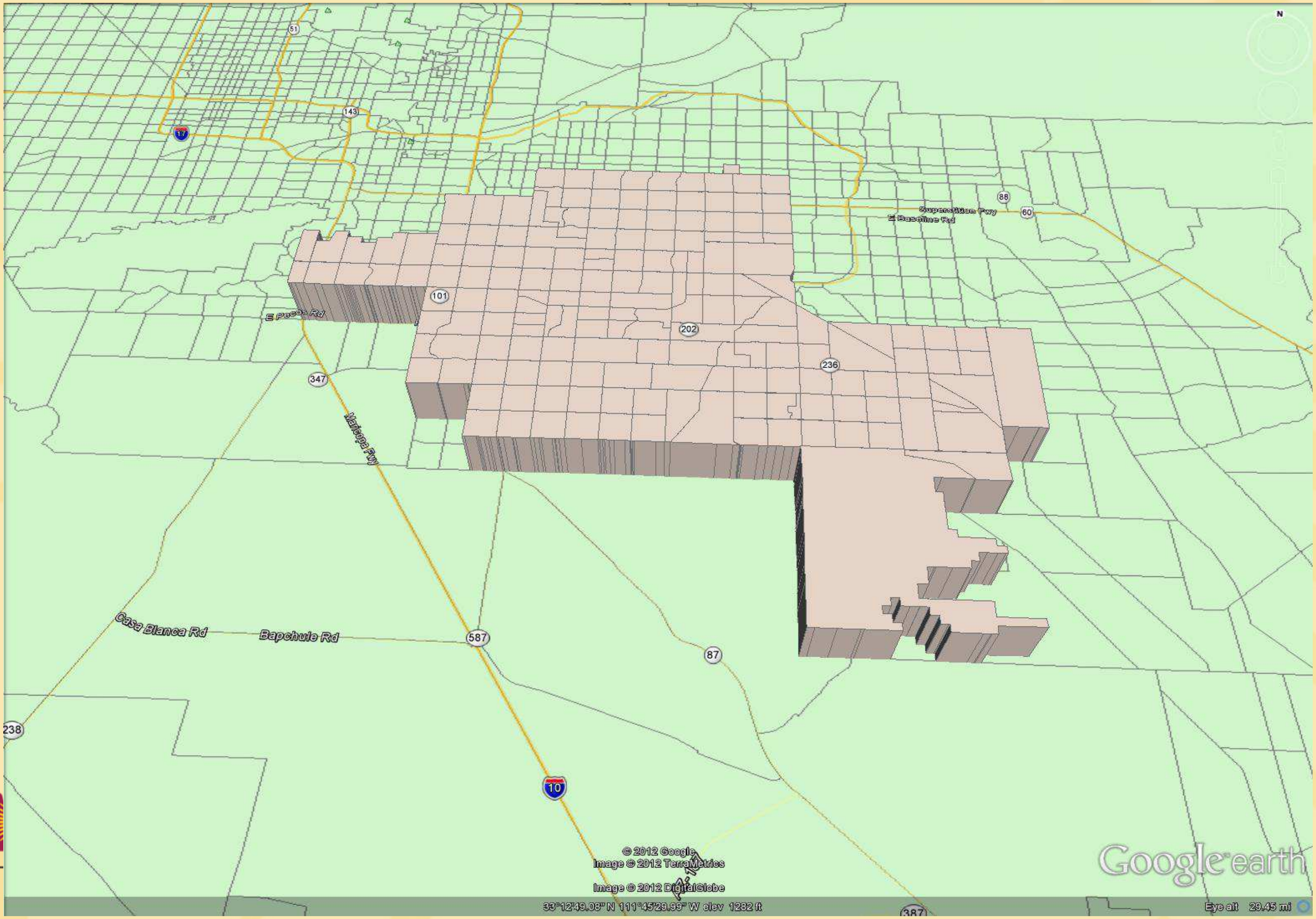
- Because Sean Doherty's 2005 Fred Burggraf Award Winning Paper said the following:

  (Survey) Responses indicate that a large portion of activities were planned impulsively, including almost 30% of all activities, or 20% of activity time. An even higher proportion of modifications and deletions were planned impulsively (45.3%), with about half of these impulsively changed during the activity.

Case Study Area: Maricopa County

- SimTRAVEL prototype run in both sequential and dynamic interactive modes
- Maricopa County, AZ
  - City of Chandler, Town of Gilbert and Town of Queen Creek
  - 505,350 persons, 167738 households
- Spatial resolution of analysis is TAZ

Case Study Area: Maricopa County



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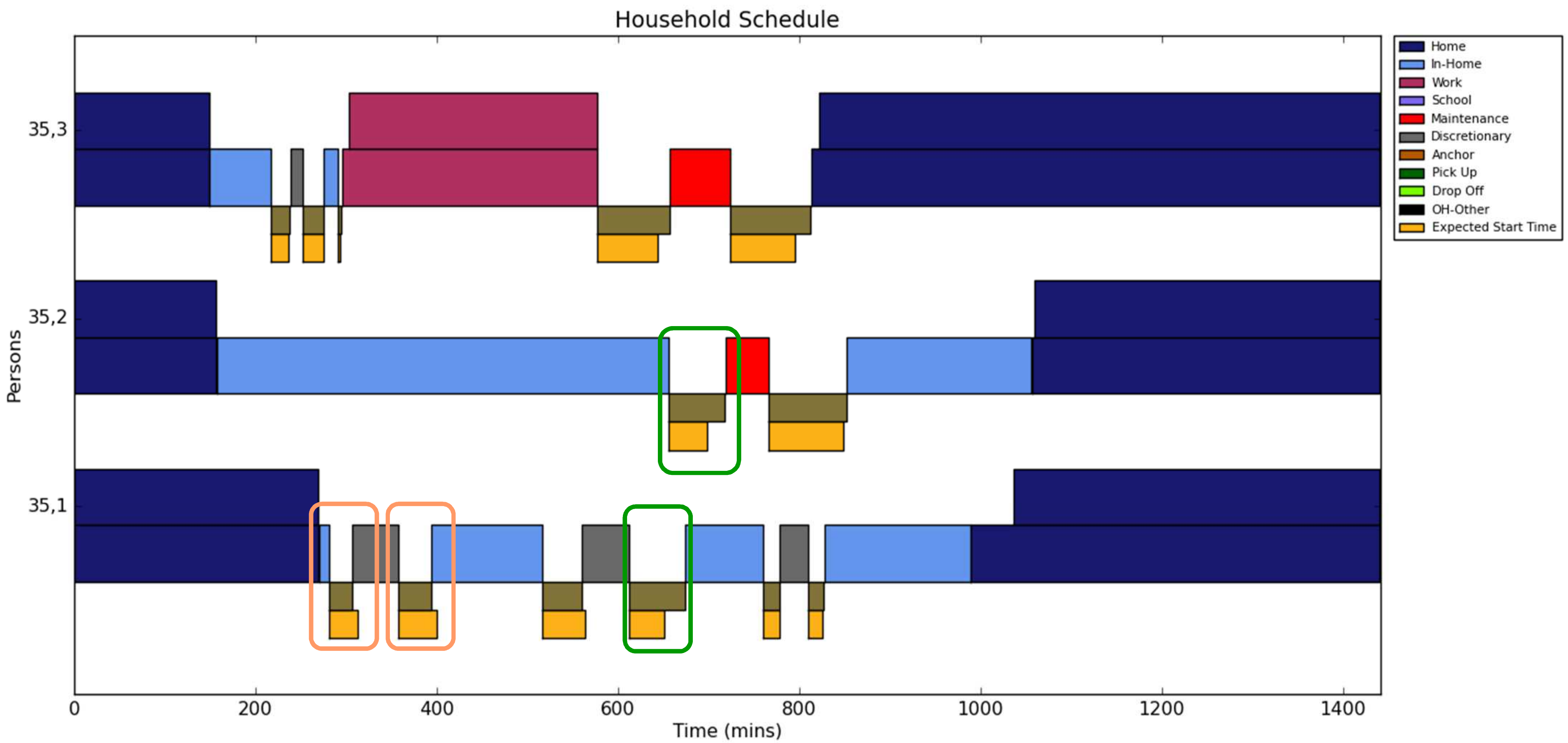
Sequential vs Dynamic Approach

- Behavioral Consistency: Gaps and Overlaps



Sequential vs Dynamic Application

- Implications for behavioral consistency
  - Gap → fewer trips than dynamic approach
  - Overlap → more trips than dynamic approach
- Sequential approach generated 3002 more trips than dynamic approach for subarea population
  - Would have been more (far more?) dramatic if work locations were not confined to three-city subarea
- If the differences between skims and experienced network conditions is high
  - The difference in trips generated will be significant

Why Dynamic Approach to Integration

- Also, accounting deviation (gaps and overlaps) are higher for workers than non-workers
  - In addition to affecting prisms, the arrival information of trips affects workers by having to readjust their fixed activities
  - Nonworkers with less fixed activities that need to be adjusted in response to arrival time and hence the smaller deviation from 1440

Why Dynamic Approach to Integration

- Modeling network perturbations and understanding its impact on activity-travel engagement behavior
  - Incident delays
  - Traveler information systems
- Sequential approach cannot be used
- Dynamic approach with its event-based supply-demand interaction paradigm is best suited for such an analysis

Scenario Analysis

- Model testing involves evaluation of of policies for the full population

Scenario type	Conditions
Socio-economic scenarios	Change in population across the region
	Change in population in some parts of the region
	Change in employment density
Highway scenarios	Change in fuel price or value pricing scheme
	Change in link capacity (Example: link removal)
Transit scenarios	Change in transit fares
	Change in transit service frequency
Travel demand management scenarios	Alternative work schedules
	Telecommuting
	Introducing HOV lanes
	Introducing HOT lanes

Application Challenges

- Variety of Application challenges in use of integrated activity-travel demand and dynamic network supply models
  - Computational burden
  - Data structures and handling
  - Calibration and validation of models (model components) to ground truth conditions
  - Appropriate levels of sensitivity to changes in input conditions
  - Dealing with stochasticity across model runs (say, for policy analysis)
- All of these issues well known and discussed; not necessarily specific to integrated demand and supply models
  - What are some application challenges in the context of "integrated" models?

Network Disruptions

- Class of events that alter the regular flow of traffic
  - Drop in capacity → Delays → Queues → Spillback → Activity-travel patterns
- Planned Disruptions
  - Roadway closures for maintenance or construction
- Unplanned Disruptions
  - Roadway incidents
- Important to understand impact of disruptions on activity-travel engagement
  - Unplanned disruptions → Emergency response services
  - Planned disruptions → Traveler information services

Network Disruptions

- No disruption
  - Establishes the baseline
- Disruption with no information provision
  - Individuals are unaware of the incident
  - Unrealistic but provides a bound for the expected impact
- Disruption with full information provision
  - All individuals are made aware of the incident after its onset
  - Routing and activity-travel engagement decisions are based on prevailing conditions
  - *However, all decisions made pre-trip based on the information provision are "locked"*

Network Disruptions

- Limitations of the current framework
  - No real-time “route-switching” or “activity re-planning” or “activity re-allocation” is accommodated
  - People already on the network at the onset of the disruption must proceed to the destination of the trip and use the specified route
  - No ability to cancel/skip activity, reallocate activity, move activity to later in day, or get off the disrupted route

Tracking Vehicles and Persons

- Much interest in capturing intra-household interactions
  - And extending to inter-household interactions when such data is available
- Joint and solo trip-making behavior
- Interactions between adults and children
- Task allocation among adults
- Vehicle allocation among adults
- Longer term location choices – joint decision-making

Tracking Persons and Vehicles

- Much interest in modeling vehicle fleet composition, vehicle type choice, and vehicle utilization
  - Key implications for greenhouse gas emissions and energy consumption
  - Allocation of vehicles among adults
  - Choice of vehicle for trip – solo and joint
- Accommodate day-level interactions between adults and children – rather straightforward

Tracking Persons and Vehicles

- More challenging is representing interactions that happen during the day – particularly the impulsive variety
- At each decision point, scan for available persons in household to join an individual (adult) on activity/trip
  - May have common origin, or common destination, or both
  - Spur-of-the-moment joint activities – come from different origins and meet at same destination
  - Need to consider available time-space prism of all participating individuals
- Distinguish between joint trip, joint activity, or both (e.g., parent takes child to soccer game)

Sensitivity to Accessibility

- ❖ Many aspects of activity-travel behavior affected by accessibility measures
- ❖ Accessibility measures typically include dimensions of travel time and travel cost
- ❖ Accessibility measures impact:
  - Longer term location choices
  - Medium term vehicle ownership/type choices
  - Daily activity travel choices including *activity generation, destination, mode, time-of-day, party size (accompaniment), and route choice*

Sensitivity to Accessibility

- ❖ Incorporation of land use intensity variables (square feet, number of employees) in accessibility measures
- ❖ Accessibility measures may vary by time of day due to temporal changes in land use intensity
  - Store opening and closing hours
- ❖ Thus accessibility measures should not only be network-sensitive, but should also be land-use sensitive
- ❖ Considerable progress with SCAG SimAGENT effort

Sensitivity to Price Change

- Need to capture effects of cost changes on activity-travel demand
- Ability to reflect effects of cost through logsums that affect higher level choices in nested logit tour-based models
- More challenging in dynamic continuous-time models
  - Convert pricing policies (fuel price change, vehicle mileage based fee) to equivalent time through value of time (VOT) measure
  - Activity-travel decisions made based on generalized cost (time) – impacts activity generation and destination choice
  - Can vary price by time of day
- Need to extend to corridor- or cordon- pricing policies
  - Very possible with dynamic supply-demand interaction approach

Sensitivity to Price Change

- SimTRAVEL uses time-of-day varying skims for simulating activity-travel choices
- Modify time-of-day varying skim at each time step based on OD specific price
  - New generalized travel time forms basis of activity generation and destination choices
  - DTA model routes trip and reports arrival time based on actual network conditions (travel times) experienced by traveler
  - Early arrival (actual experienced travel time is likely to be less than generalized travel time) leads to changes in activity duration
- Operational implementation and computational burden
  - Implement user equilibrium within DTA model to accurately reflect route choice (priced versus non-priced)

Conclusions

- Much progress in integrated transport-demand supply model development
- Greater levels of interaction or coupling between demand and supply model to reflect dynamics of behavior
  - Accurately reflect progression of time as experienced by traveler on network
  - Consistency in patterns of activity-travel behavior simulated
- Application challenges remain in multiple domains
  - Software architecture, data handling (Big Data), and computational burden
  - Enroute activity rescheduling, destination modification, task reallocation, and route switching (e.g., unexpected network disruption)
  - Tracking people and vehicles throughout the course of a day – accommodate spur-of-the-moment or impulsive activity engagement (ICT impact)
  - Reflecting sensitivity to accessibility measures and pricing policies incorporating time of day based changes in land use intensity and OD/time specific changes in price signals