An Integrated Urban Model of Transportation, Land-Use, Energy, and Environment

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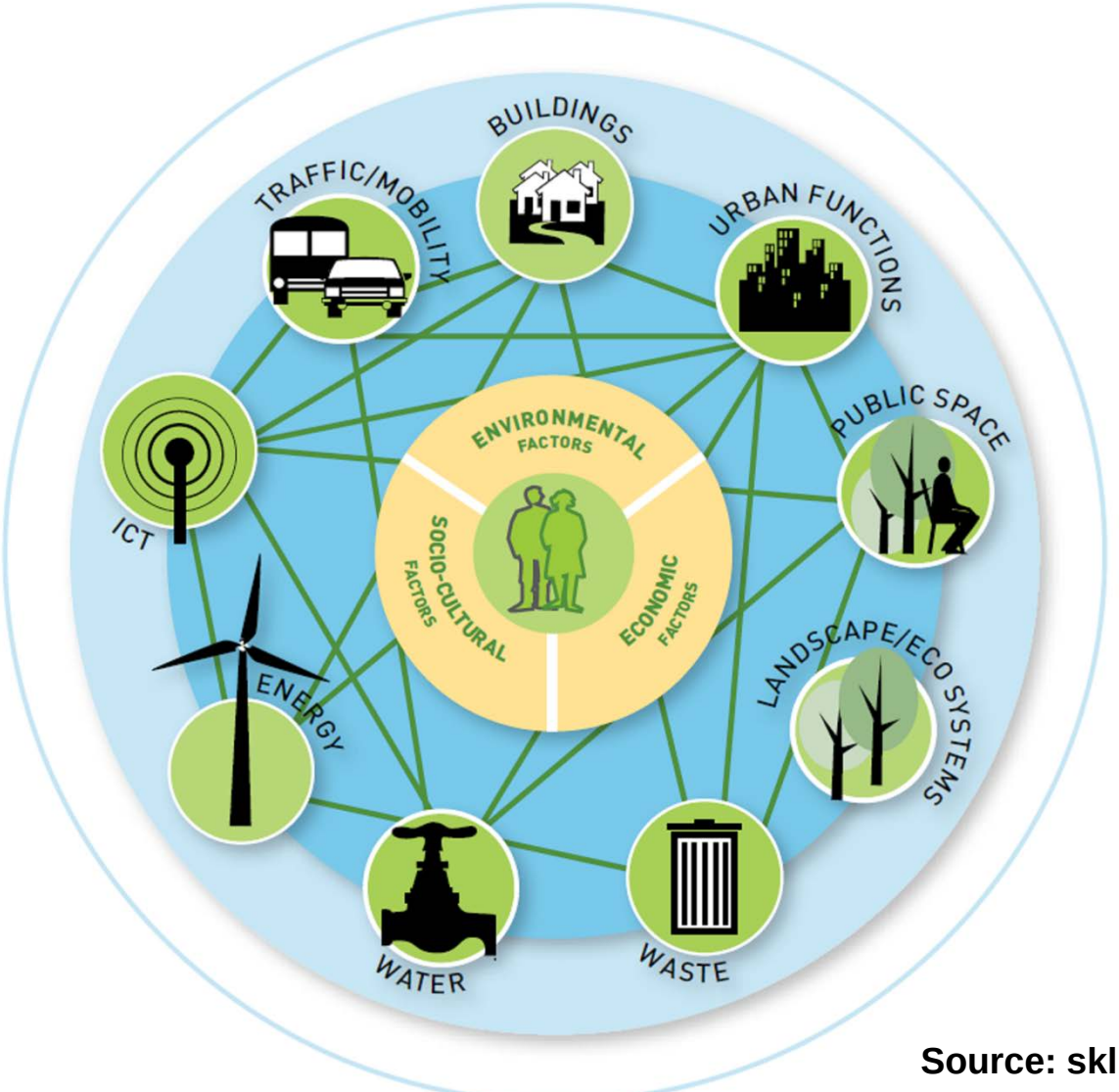
Why an Integrated Urban Model?

- More than 50% of the world's population live in urban areas
- By 2050, 70% of people are likely to be city dwellers
  - compared with less than 30% in 1950
- Cities consume over 2/3 of the world's energy and account for more than 70% of global CO_2 emissions
- This trend brings with it challenges and threats in urban areas
- Need to consider a comprehensive, multi-faceted, approach for an enhanced , efficient, resilience, and sustainable urban built infrastructure
- To date, a comprehensive and holistic approach to study large-scale and inter-dependent urban infrastructures has not been developed thoroughly

An Integrated and Holistic Approach to Urban Infrastructure Development

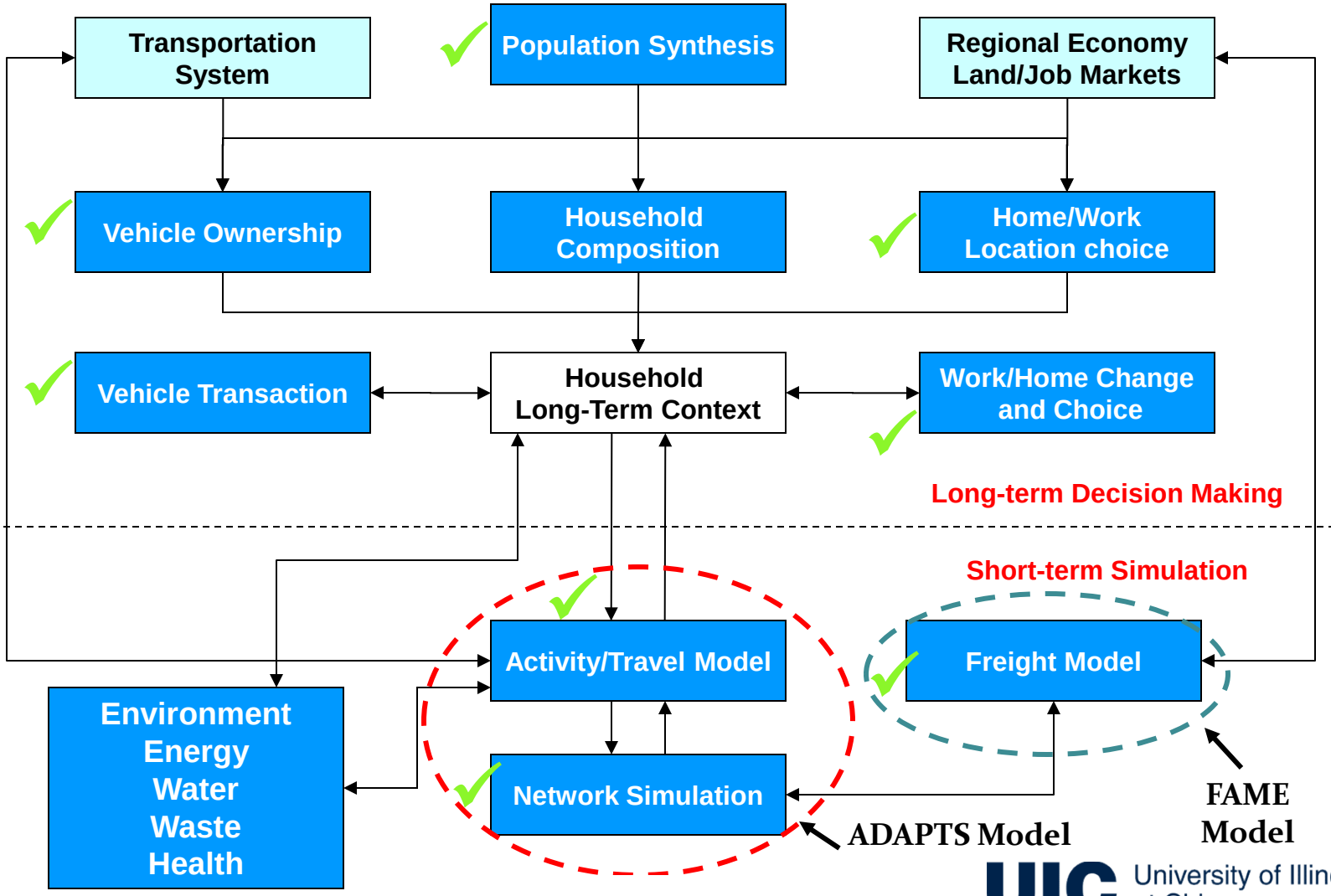


Source: sklinternational.se

Transportation and urban form are fundamentally linked. How we build our city directly determines travel needs, viability of alternative travel modes, etc.

Transportation, in turn, influences land development and location choices of people & firms.

Overall Integrated Urban Model Framework



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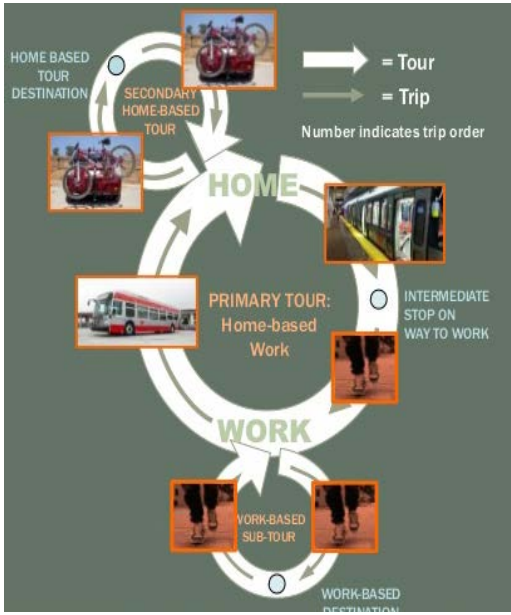
Criticisms of Current Travel Demand Models

- Unrealistic behavioral assumptions
  - Utility maximization
- Artificially restrict activity scheduling to predefined choices
  - Can not represent full range of "scheduling behavior"
  - No consideration of "dynamics" (full day selected at one time)
- Limitations on time-scale of analysis



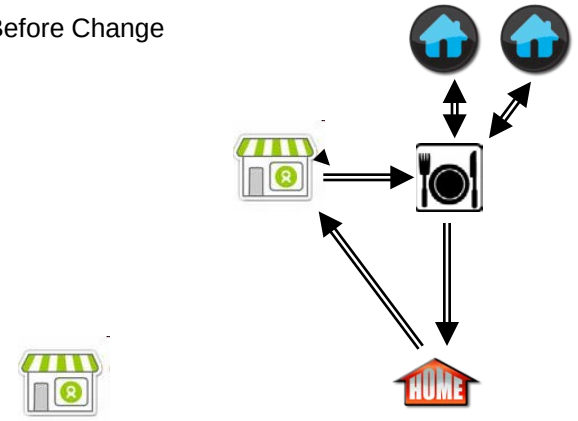
Research Gaps in ABM

- Simplification of scheduling process
  - Priority rules, fixed order of choices
  - Only out of home activities
  - Interactions between in-home and out-of-home activities are ignored
- No representation of planning dynamics
  - Impact of planning time on choices made
- Short-term, diary data used
  - Most rule-based models implemented using 1-2 day diary data
- Limited integration with traffic simulation
  - Static assignment for fixed time-periods
- Limited policy/scenario analysis capability

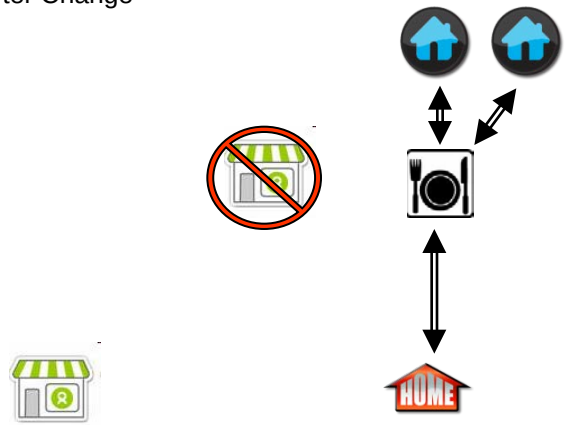
Scheduling Order Example

A) Impulsive Shop - Preplan Eat Out

Before Change

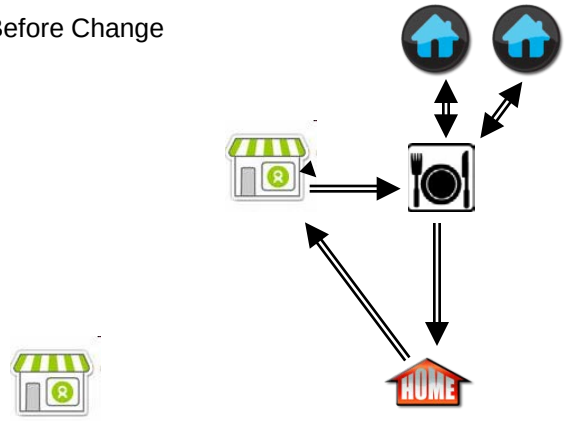


After Change

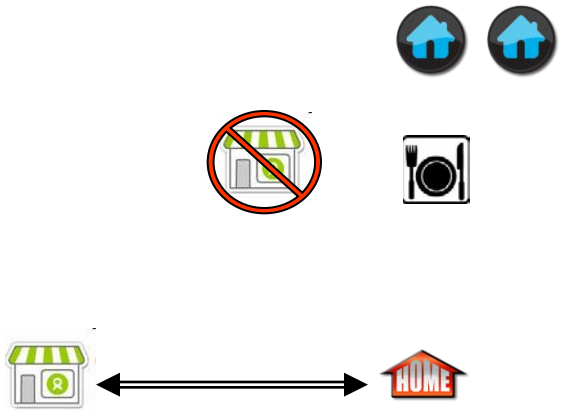


B) Preplan Shop - Impulsive Eat out

Before Change



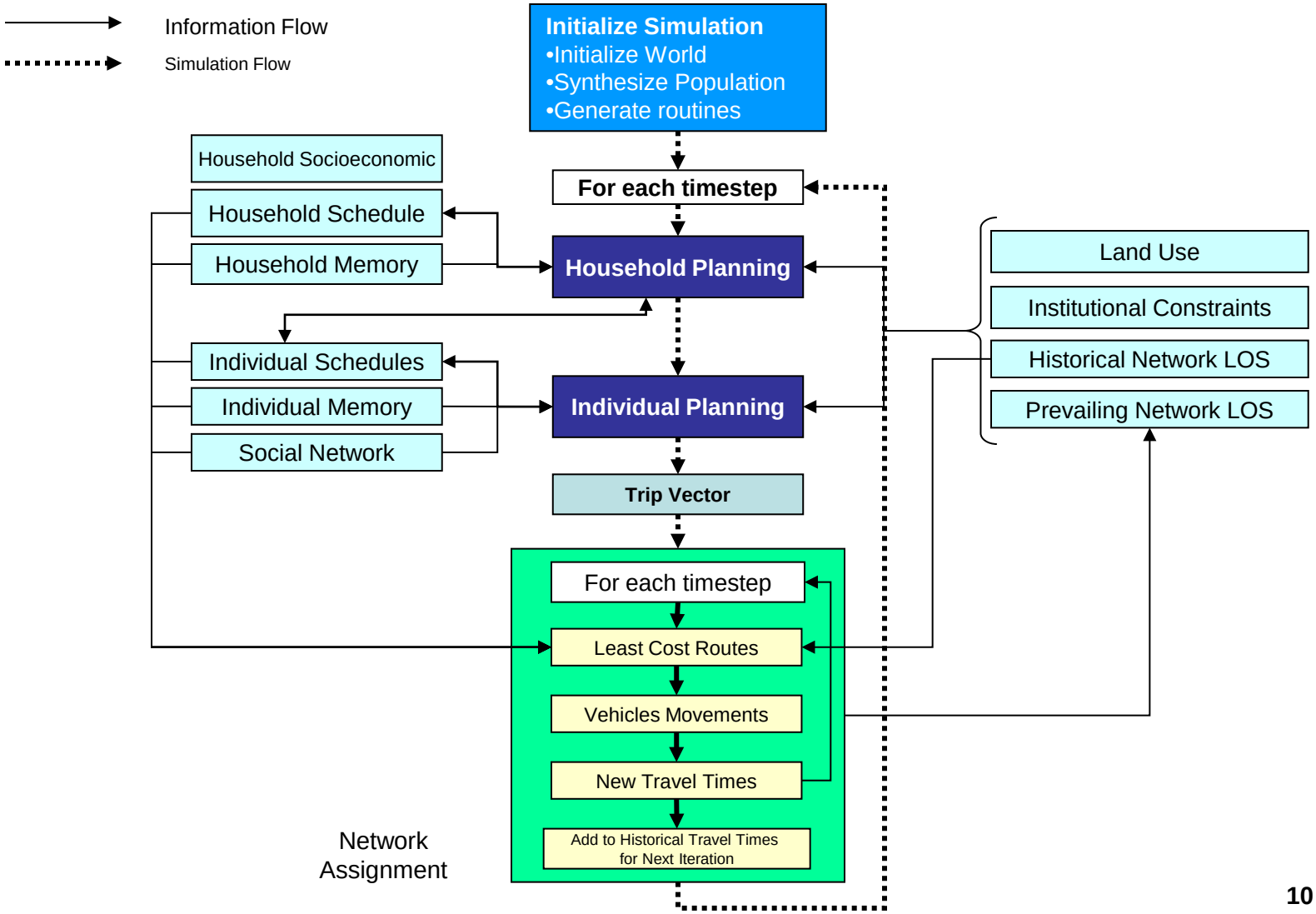
After Change



Motivation

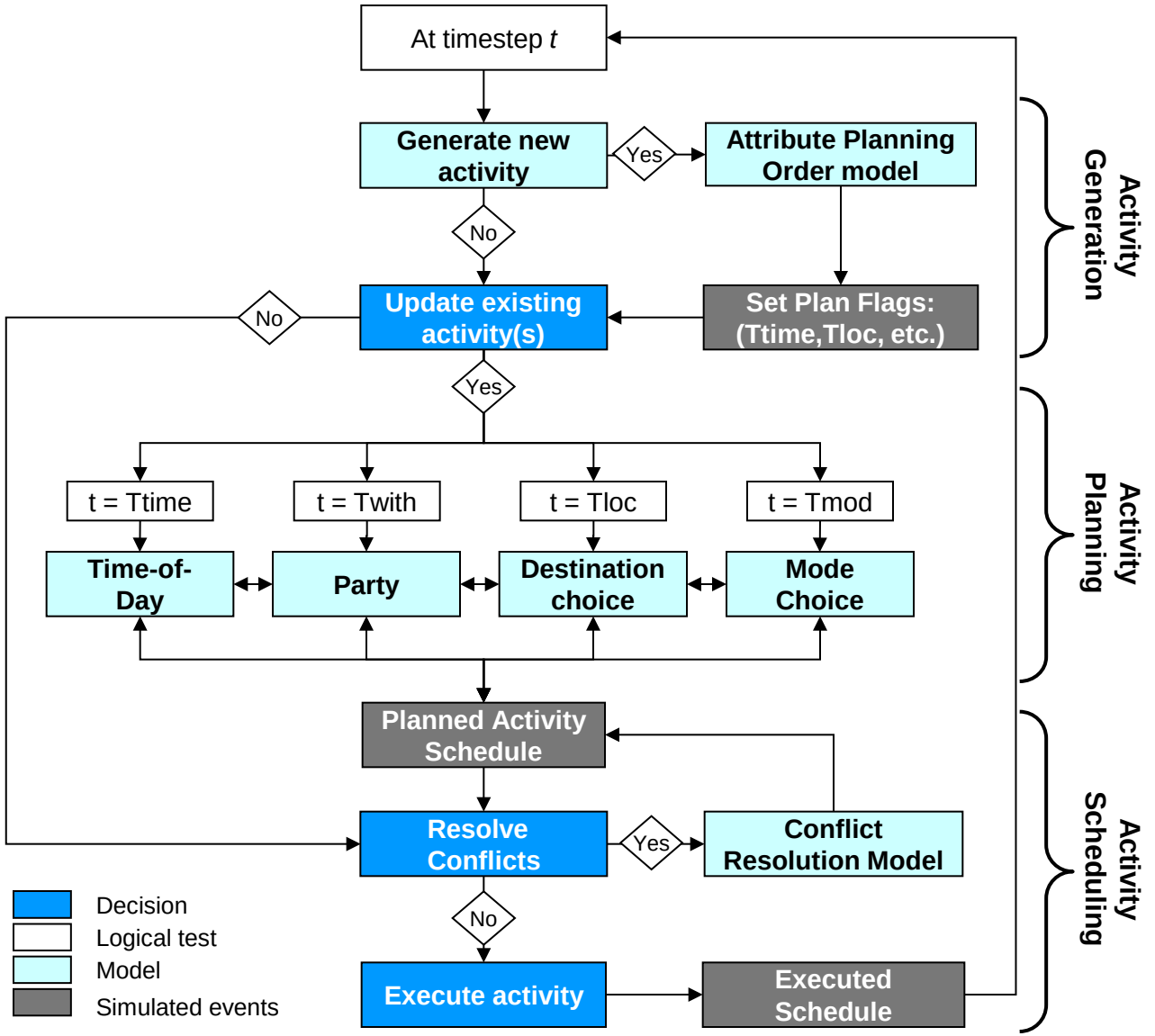
- Hypothesis: When and how activity planning decisions are made can impact final daily activity pattern
- ADAPTS:
  - Next generation ABM paradigm accounting for “behavioral processes”
  - Retains link b/w activities and travel at the individual level
  - Adds element of activity planning, to activity generation and activity scheduling, rather than relying on sequential series of models
- Account for planning dynamics
  - when is each decision made in relation to other decisions, activities, schedule, etc.
  - Planning and scheduling occurring in time-dependent manner, also impacted by time-dependent traffic network
  - Within day and en-route re-planning
- Represent macro-level changes from impacts of policies on planning dynamics at individual level

ADAPTS Simulation Framework



ADAPTS Planner/Scheduler

- ADAPTS planning and scheduling framework
- Handles at each timestep:
  - Generation
  - Planning
  - Scheduling
- Generation, planning and scheduling can occur at different times for same activity
- Core of the framework is the *Attribute Plan Order Model*
- Operationalized using multiple scheduling process surveys



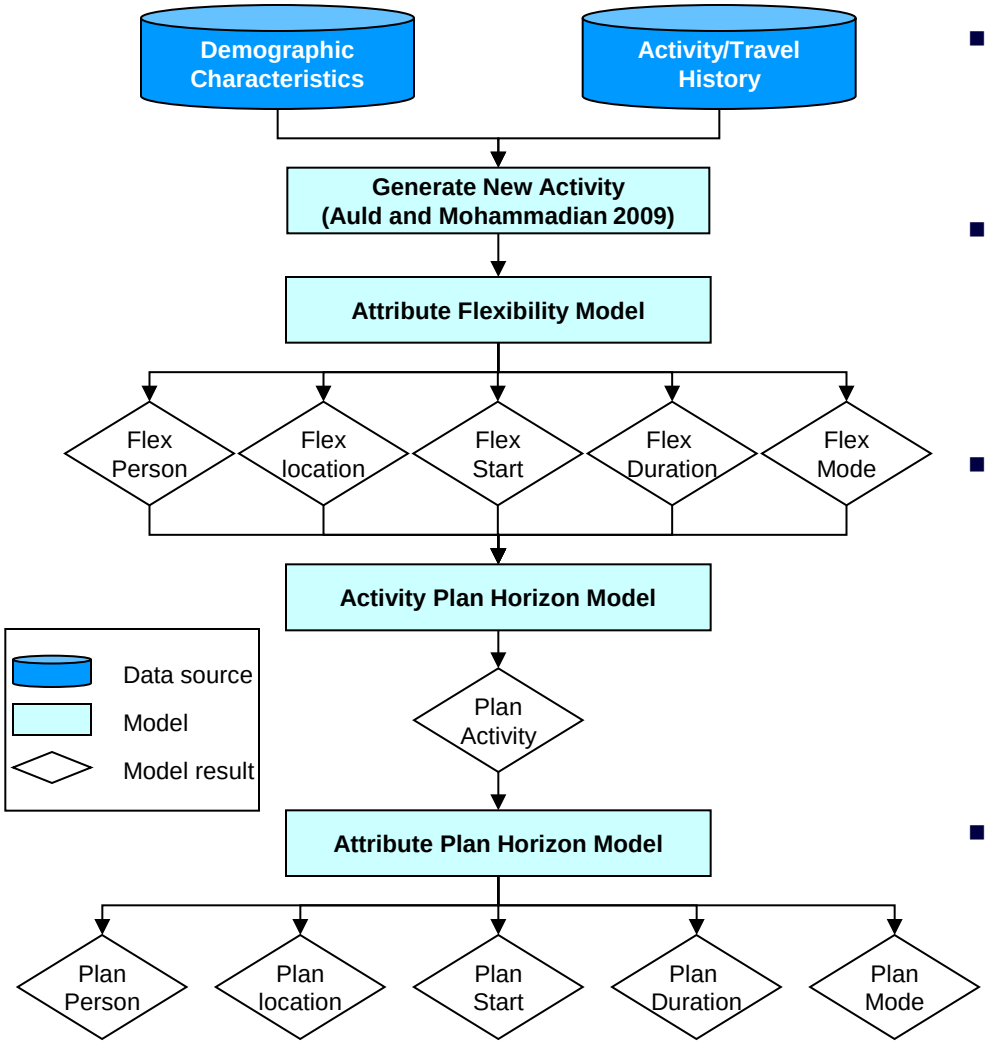
ADAPTS Components

Activity Generation

- Activity generation with joint hazard-duration equations
  - Significant socio-economic variables
  - Impact of hazard rate from other activities
- Failure probability (generation) calculated each timestep
  - Based on time-since-last activity
  - Calculated using observed UTRACS data (14-day survey)
  - Fit to Chicago 1-day survey through updating

$$\begin{cases} h_i^{wev}(t_i, x_i, h_j^{nev}, h_k^{nev}, \ldots) = h_0^i \; e^{-(\beta_i x_i + \beta_{ji} h_j^{nev} + \beta_{ki} h_k^{nev} + \ldots)} \\ h_j^{wev}(t_j, x_j, h_i^{nev}, h_k^{nev}, \ldots) = h_0^k \; e^{-(\beta_k x_k + \beta_{ij} h_i^{nev} + \beta_{kj} h_k^{nev} + \ldots)} \\ h_k^{wev}(t_k, x_k, h_i^{nev}, h_j^{nev}, \ldots) = h_0^k \; e^{-(\beta_k x_k + \beta_{ik} h_i^{nev} + \beta_{jk} h_j^{nev} + \ldots)} \\ \vdots \end{cases}$$

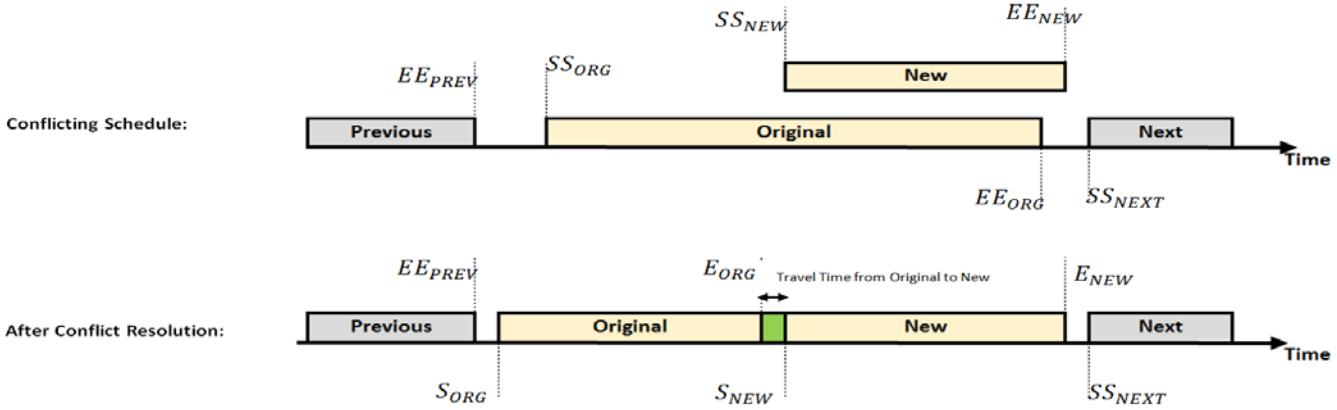
Activity Planning Order Framework



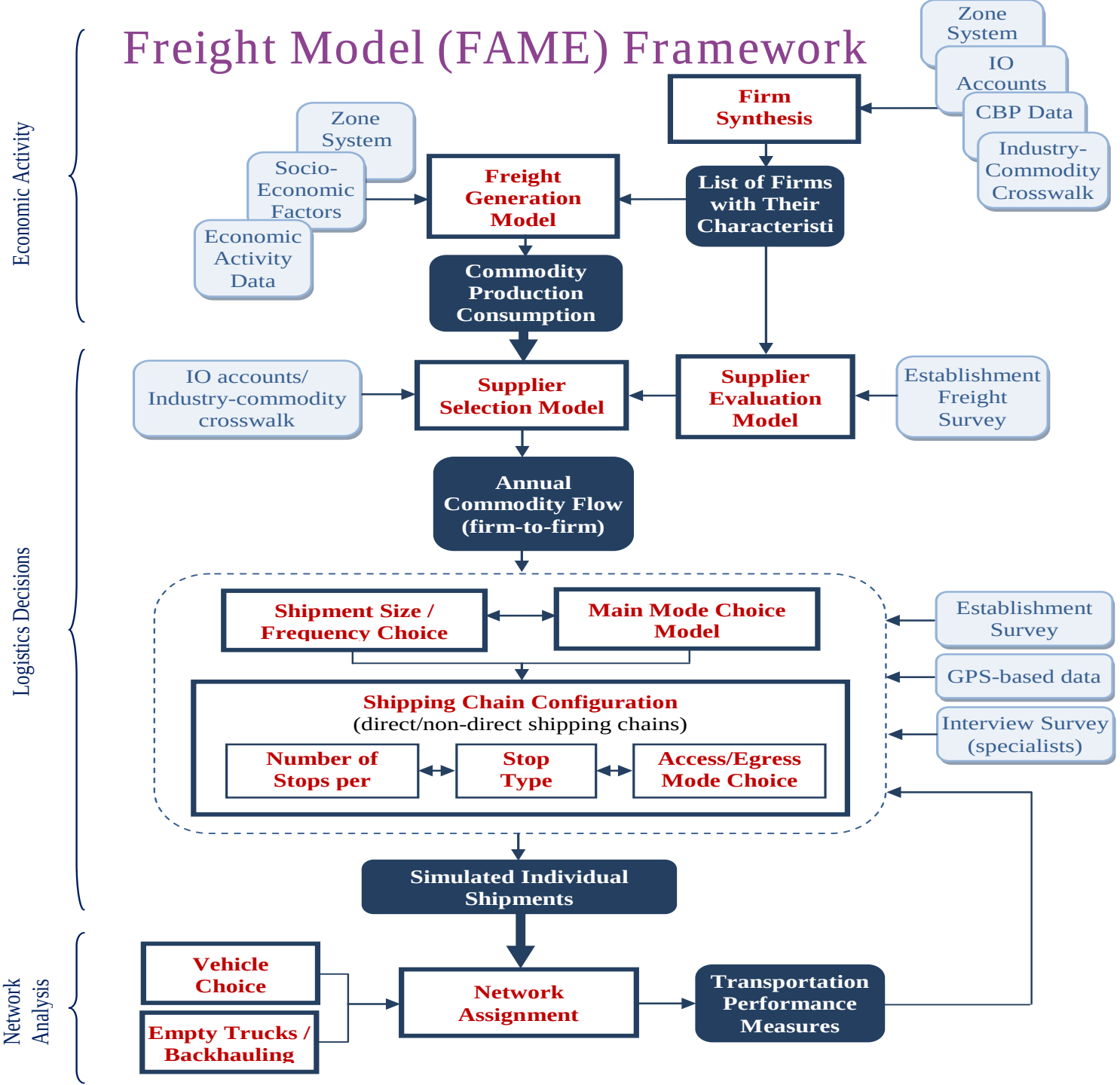
- Assign plan horizon to each attribute
  - After activity generated
- Plan order model process
  - Assigns attribute flexibility
  - Get activity plan horizon
  - Attribute plan horizons
- Plan horizons for each attribute based on:
  - Attribute flexibilities
  - Activity plan horizon
  - General activity attributes
  - Socio-demographics, etc.
- Defines the *meta-attributes* of the activity attributes

Scheduling Heuristics

- Set of rules for scheduling activities
  - Attempts to resolve conflicts by modifying each activity
- Includes results of conflict resolution model:
  - TASHA – conflict resolution based on heuristic rules
  - New rules – heuristic rules determine how conflict resolution strategy is implemented
- New rules allow for the consideration of more complicated conflict types and deletion operations
- A new optimization model is developed

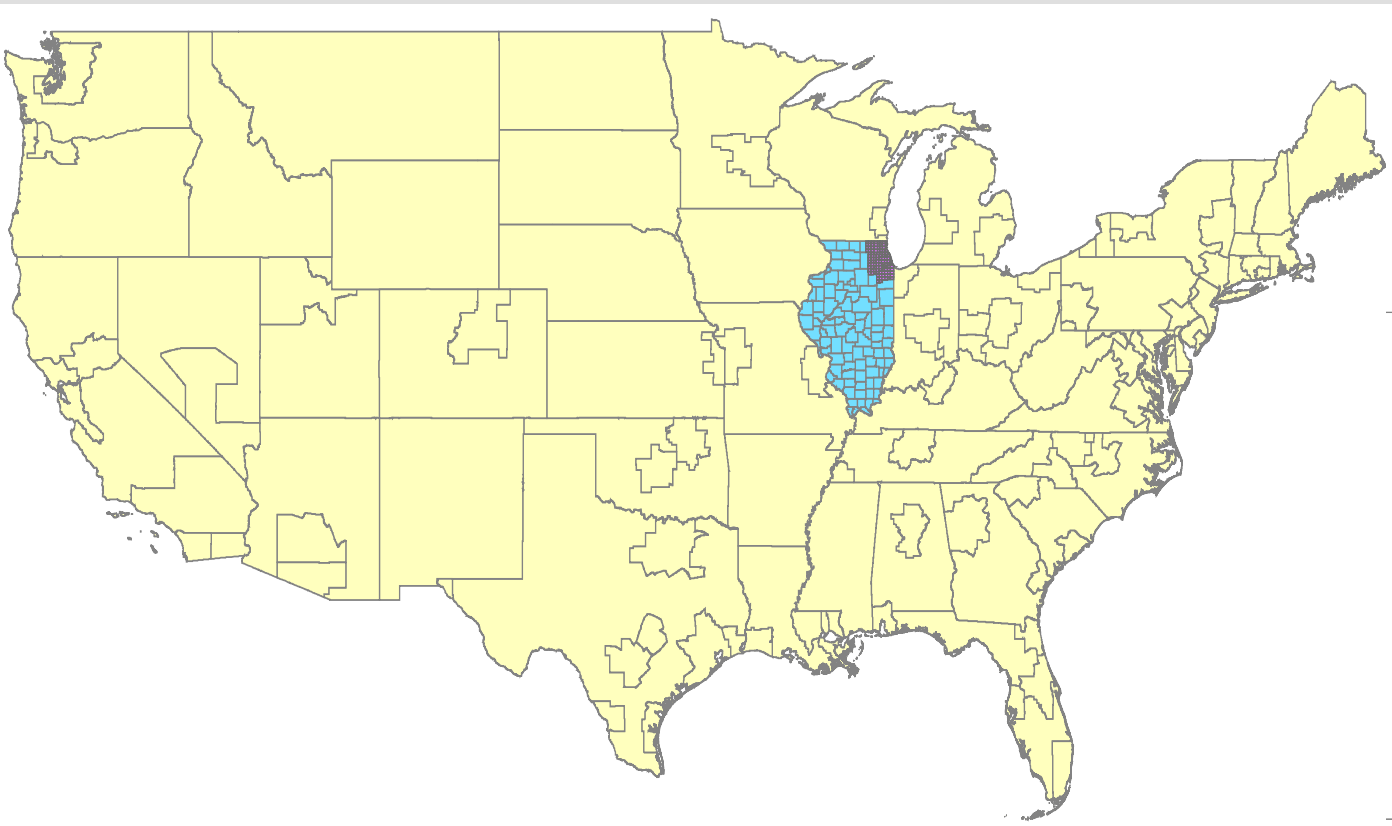


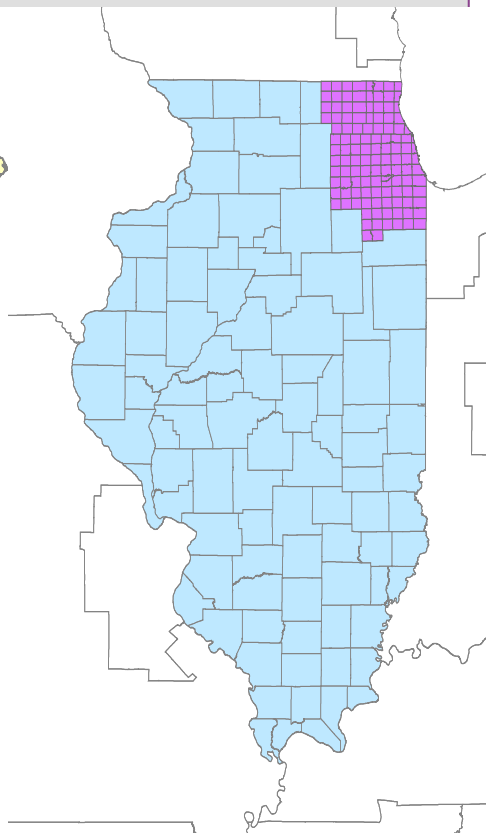
Traffic Assignment and Simulation


Freight Model (FAME) Framework
Economic Activity
Logistics Decisions
Network Analysis
Zone System
IO Accounts
CBP Data
Industry-Commodity Crosswalk
Firm Synthesis
Zone System
Socio-Economic Factors
Economic Activity Data
Freight Generation Model
List of Firms with Their Characteristi
Commodity Production Consumption
IO accounts/ Industry-commodity crosswalk
Supplier Selection Model
Supplier Evaluation Model
Establishment Freight Survey
Annual Commodity Flow (firm-to-firm)
Shipment Size / Frequency Choice
Main Mode Choice Model
Establishment Survey
GPS-based data
Interview Survey (specialists)
Shipping Chain Configuration
(direct/non-direct shipping chains)
Number of Stops per
Stop Type
Access/Egress Mode Choice
Simulated Individual Shipments
Vehicle Choice
Empty Trucks / Backhauling
Network Assignment
Transportation Performance Measures

FAME's zoning system

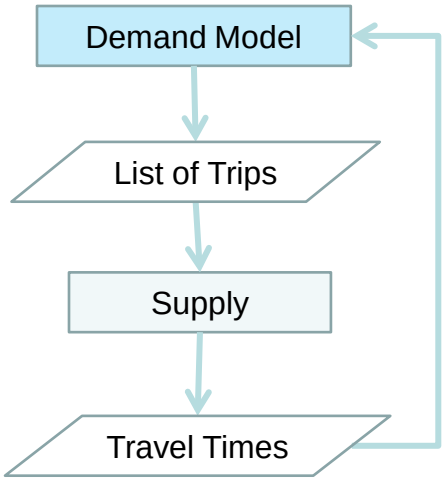
- *Zone System*
  - Township level zones in the Chicago area (118 zone)
  - County level zones in rest of Illinois (95 zone)
  - FAF zones in the rest of US (120 zone)





Integration with Network Simulation

- Advanced Demand models (Activity Based Models)
- Advanced Supply Models (Dynamic Traffic Assignment)
  - MATSim, DynusT, TRANSIMS, AIMSUN, ...
- Interfacing, Interacting, Integrating!?!
  - Feedbacks
  - Tight Integration
- Issues:
  - Behavioral Realism
  - Dynamic Activity Based Models
  - Dynamic pricing scenarios
  - Congestion related unreliability



Integration with TRANSIMS

- TRANSIMS Version 5.0
- Router
  - Label constrained time dependent shortest path
- Microsimulator: executes the trip plans
  - explicitly simulate:
    - Multiple travelers per vehicle
    - Multiple trips per traveler
    - Vehicles with different operating characteristics
    - Intermodal travel plans
  - does not simulate:
    - Walking legs
    - Interaction between cars and pedestrians
    - Rail road crossings
- Issues:
  - Behavioral Realism
  - Dynamic Activity Based Models

- Network: Chicago
  - Zones: 1,961
  - Signals: 9,822
  - Nodes: 19,038
  - Act Location: 98,204
  - Link: 31,339
- Population:
  - Households: 2,910,510
  - Person: 7,755,490

Integration Issues

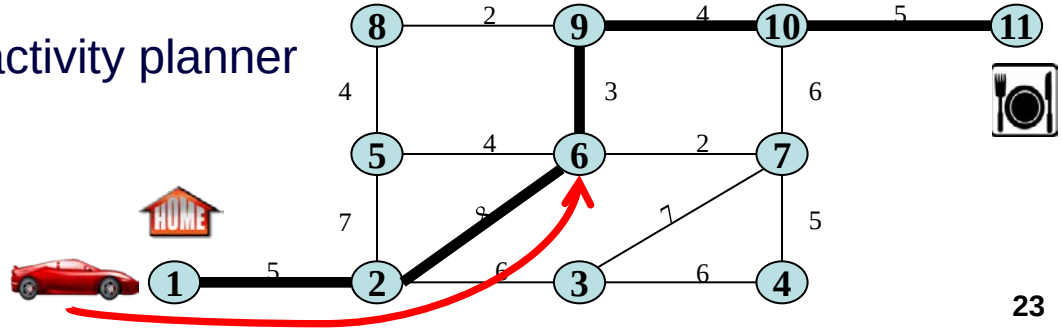
- Variable Demand
- Vehicle Rerouting
- Performance
  - Running two different software, reduces the performance
- Issues with Traffic Assignment Software Packages
  - Documentation
  - Programming Language Differences
  - Zoning Differences
  - Availability of high-fidelity network
  - Open Source, Cost

Integration with Traffic Simulation

- Characteristics
  - Disaggregate & Mesocopic level
  - Agents could respond to dynamics in terms of activity planning, scheduling, and trip characteristics (mode, route)
  - Updating network characteristic second by second
  - Considering users' response to **network real time attributes** in their route choice process
  - Able to **track each user** during the simulation and access to its **real time characteristics**

Embedded Traffic Simulator

- Integrated model has been implemented directly in ADAPTS simulation
- Consists of individual person-agents who:
  - Perform activity planning and scheduling (ADAPTS model)
  - Select routes based on prevailing traffic & information provision (A* router)
- Travel through the network (Newell's model)
- Can interact with ITS elements to modify or update plans
- Two Modules: Router and Simulator
  - Router Calculates Shortest Path for P1
  - Simulator Moves P1 along shortest path
- Send details back to activity planner



Computational Issues

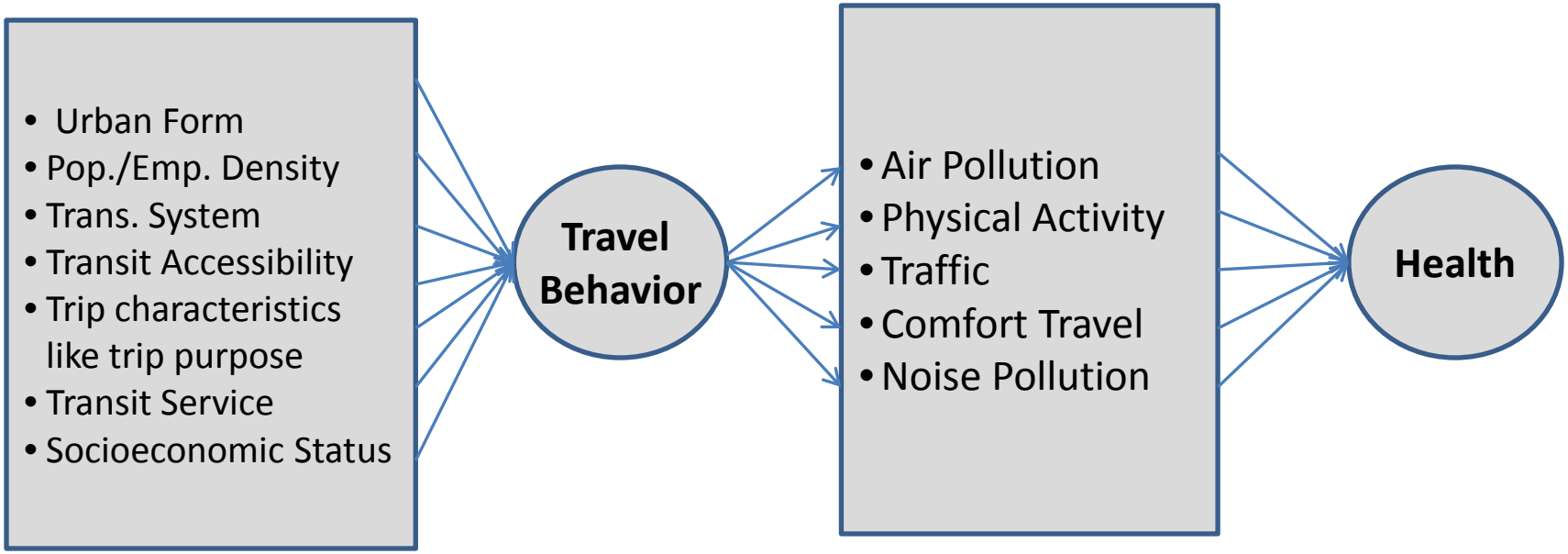
- Slow performance discourages practitioners who need many scenario analysis and calibration
- We may have the resources and patience, but others may not, so it is important to optimize the program and use minimum hardware
- Advance models are very time-consuming and computationally intensive (DTA, ABMs, in-home activities, complex and dynamic policies, high level visualization, etc.)

Simulation

- **Number of Threads: 64**
- **Machine: RAM 256 GB, 32 AMD Opteron(TM) Processors 2.3 GHz**
- **Full Microsimulation with dynamic traffic assignment**
- **Tracking vehicles and individual locations every 30s**
- **Activity generation and scheduling simulation every 15 minutes**
- **28 days of out-of-home activity preplanning and real-time in-home activity generation**
- **Average activity statistics are recorded for the sample.**
- **Simulated results for one week**

Extensions of the ADAPTS Model

Travel Behavior and Health



- Every percent increase in Transit-use:
  - Decreases Heart Attack by 0.07%
  - Decreases Obesity by 0.29%
  - Improves General Health by 0.09%
  - Increases chance of Asthma infection by 0.03%
- Every percent decrease in Auto-use:
  - Reduce chance of High Blood Pressure by 0.26%
  - Reduce chance of High Blood Cholesterol by 0.18%
- Pedestrian friendly neighborhoods motivate people to walk more and be healthier.

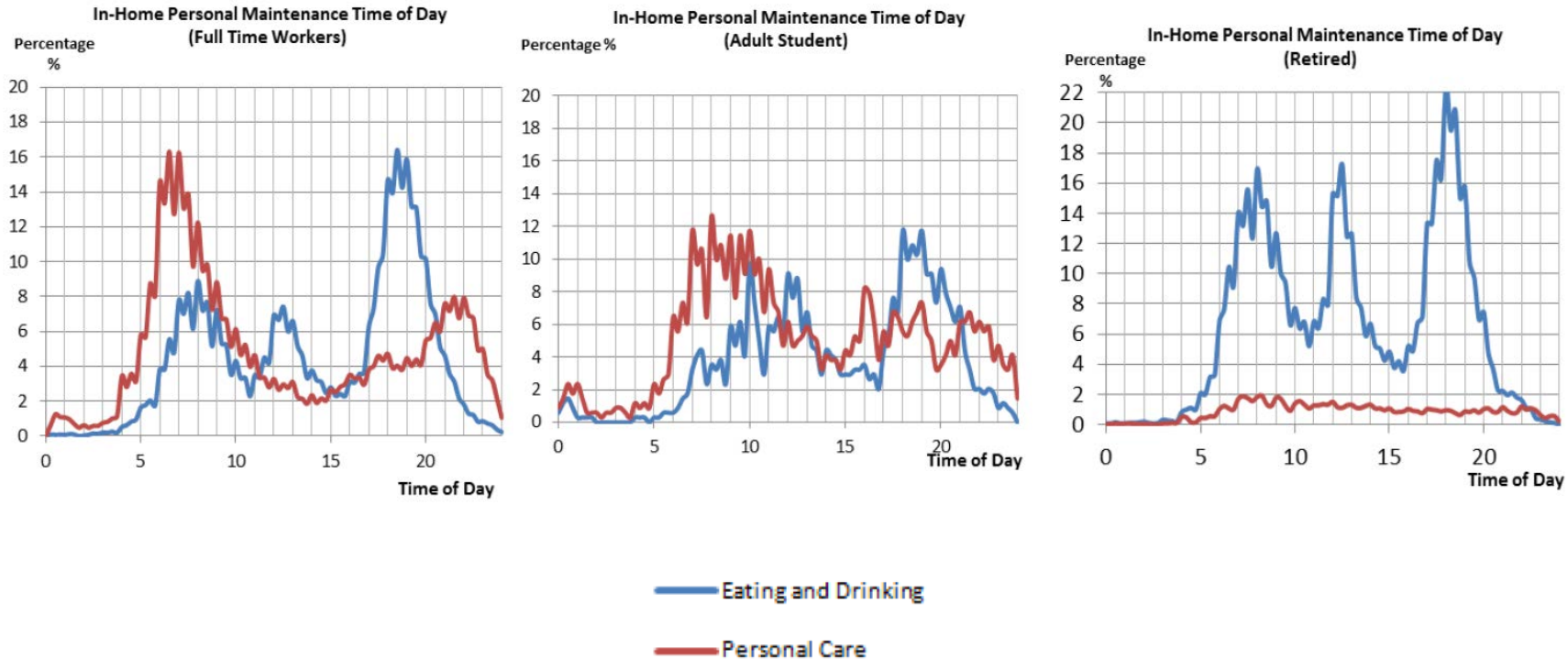
Incorporating In-Home Activities

- What People do at home could affect:
  - Transportation
    - No Trips on the network
  - Electricity
    - US Residential utility per day: 30 KWh
  - Water
    - Every individual per day: 100 Gallons of Water
  - Natural Gas
  - Economy

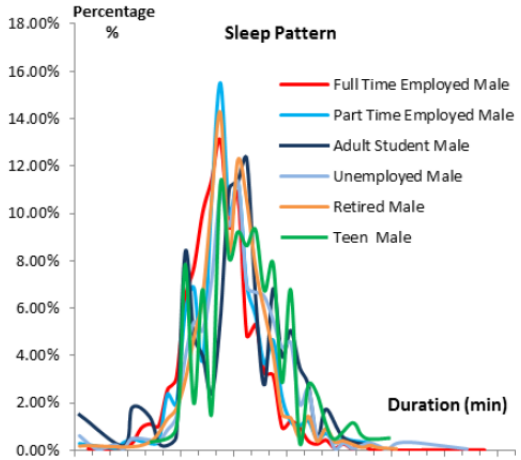
Incorporating In-Home Activities

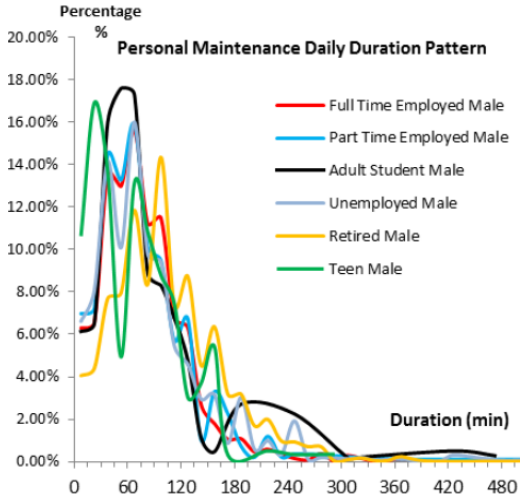
- In-Home Activities that are being considered:
  - **Sleep**
  - **Personal Maintenance**
    - Eating and Drinking
    - Personal Care
  - **Household Maintenance**
    - Household Activities
    - Caring for & Helping Household Members
    - Caring For & Helping Non-HH Members
  - **Leisure/Social**
    - Sports, Exercise, and Recreation (at Home)
    - Socializing, Relaxing, and Leisure
      - Socializing and Communicating
      - Relax and Leisure
        - Watching TV
        - Etc..
  - **Discretionary**
    - Religious and Spiritual Activities
    - Telephone Calls
  - **Mandatory**
    - Work & Work-Related Activities
    - Education Related

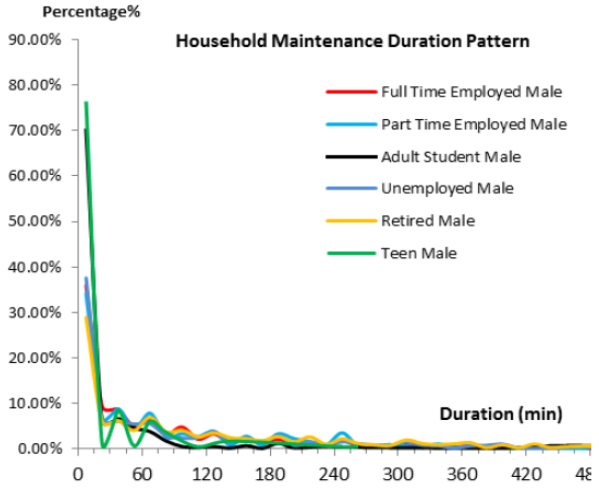
In-Home Personal Maintenance Time of Day Frequencies

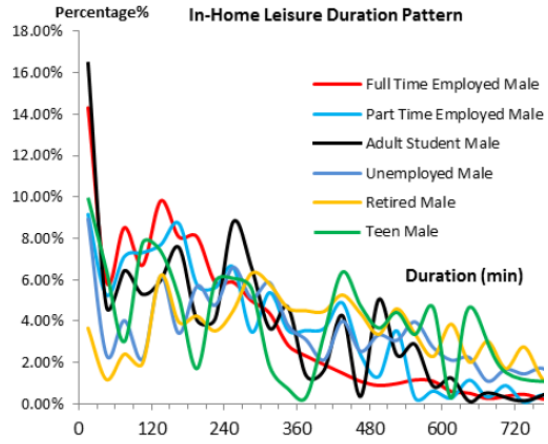


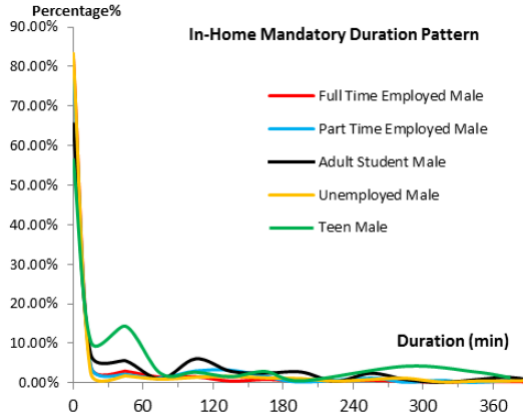
In-Home Activity Duration Frequencies

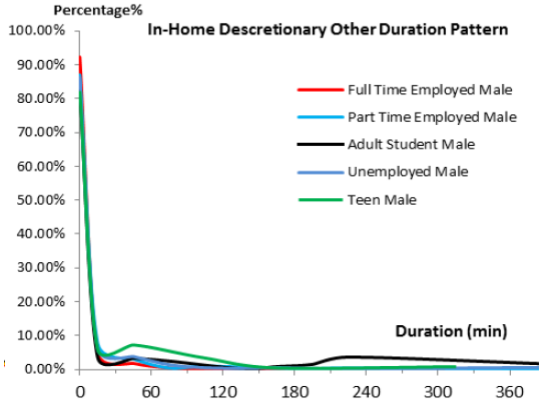












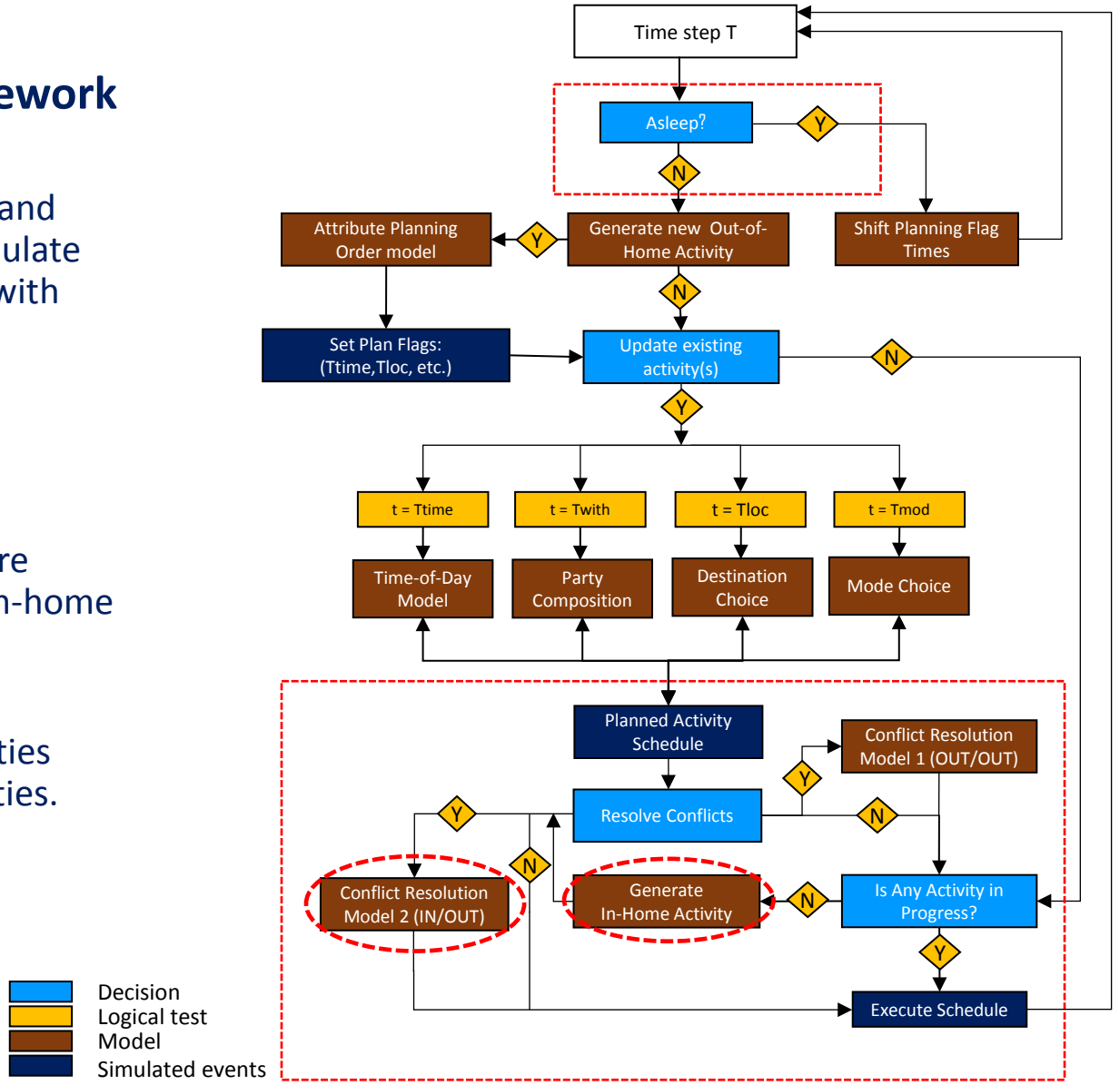
ADPATS ABM Framework

ADAPTS Updated Framework

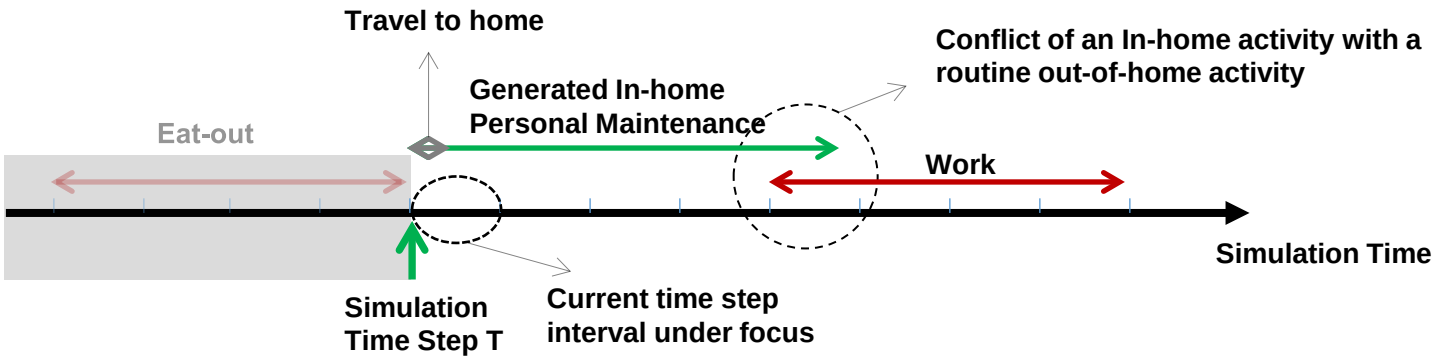
- A combination of rule-based and econometric models that simulate in-home activities alongside with out-of-home ones

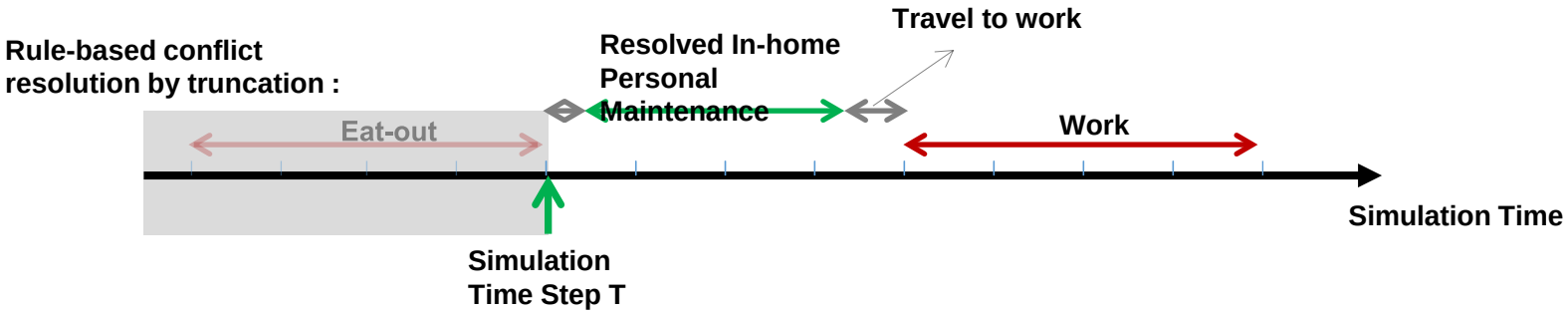
➢ Assumptions:

- Out-of-home activities that are preplanned have priority to in-home activities.
- Impulsive out-of-home activities compete with in-home activities.

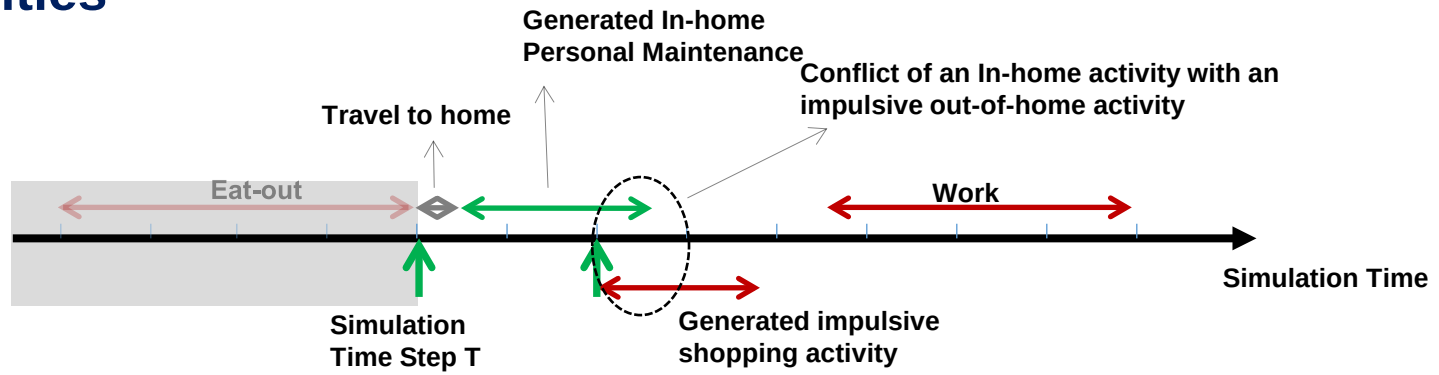


Priority of out-of-home preplanned/routine activities to in-home activities

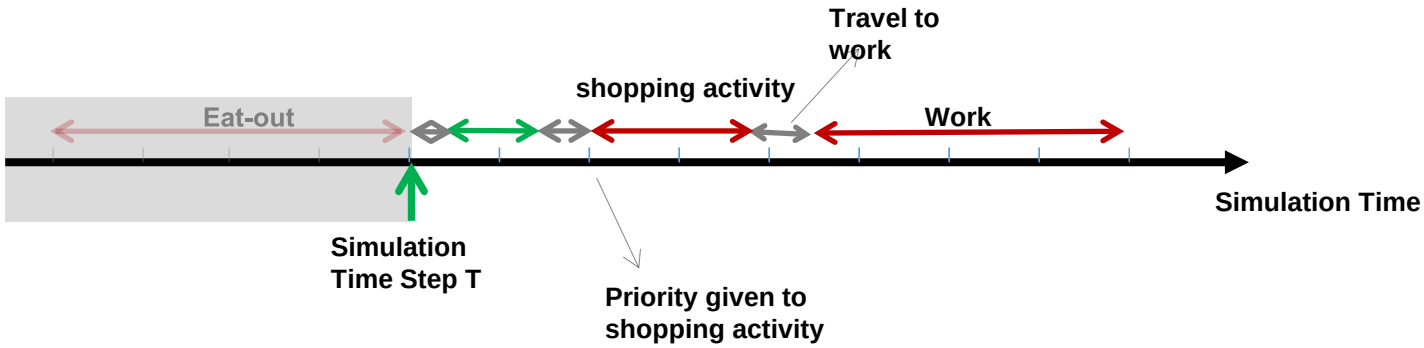




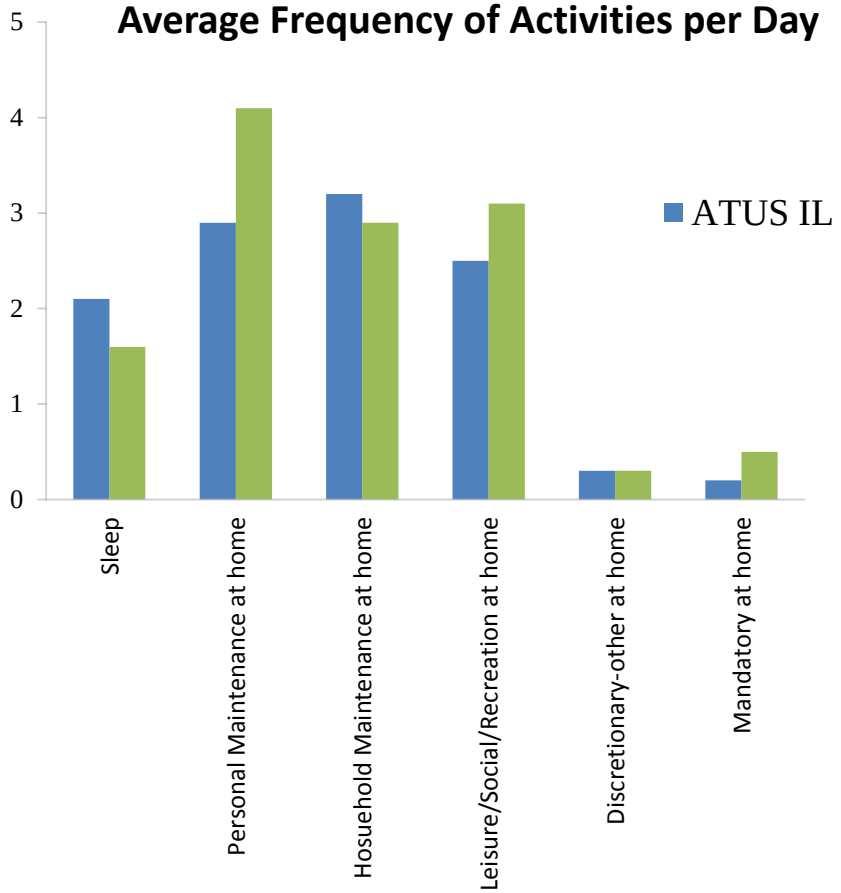
Competition of out-of-home impulsive activities with in-home activities

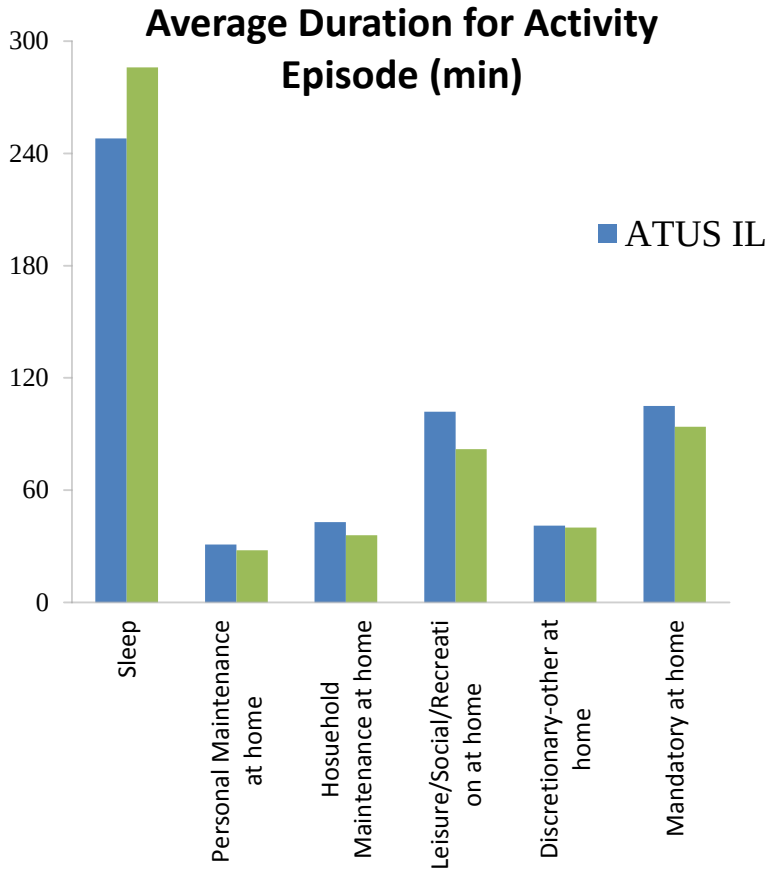


Priority conflict resolution by the reverse pairwise model:



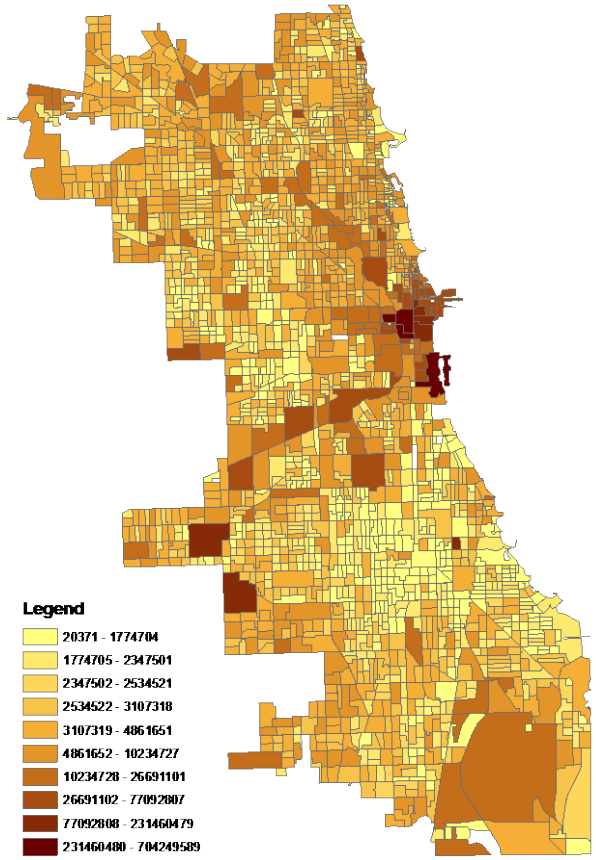
Validation of In-Home Activity Simulation



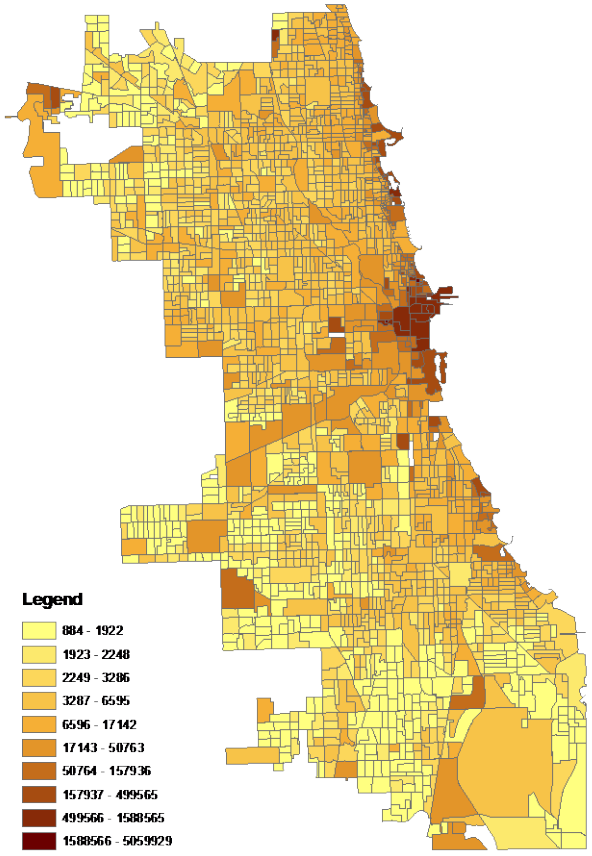


What’s next?

- Electricity
- Water
- Energy
- Waste
- Food
- CAVs
- ….



Total Electricity Consumption by Census Block



Per square foot Electricity Consumption by Census Block

Conclusion

- ADAPS is a framework for model development
- ADAPTS' unique framework incorporates planning dynamics
  - Enroute route-switching and activity re-planning
  - reactions to unexpected events
- Potentially more useful for certain applications
  - Operational simulations (e.g., CAV fleets, …)
  - Agents responding to unexpected events
  - Emergency planning
- Further Challenges
  - Still computationally intensive
  - Incorporating other urban systems
  - Incorporating social networks
  - Incorporating joint decision making processes
  - Incorporating agent history in decision making
  - Accounting for uncertainty
  - Data availability

Questions!