IRA A. FULTON SCHOOL OF ENGINEERING

Leading engineering discovery and innovative education for global impact on quality of life.

Activity-Based Travel Demand Models

Baltimore Metropolitan Council

Realizing a Vision

NATIONAL CENTER FOR SMART GROWTH RESEARCH & EDUCATION

RSG INC. TRANSPORTATION

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Understanding Travel Behavior

- Derived nature of travel demand (Jones, 1979)
  - Travel generally undertaken to fulfill activity needs and desires
  - Activities distributed in time and space necessitating travel
- Desire travel demand models that reflect this fundamental notion

Roots of Activity Based Paradigm

- Microsimulation of individual activity-travel patterns
- Bring together two schools of thought
  - Hägerstrand's Constraints School (1969)
  - Chapin's Activity-pull (Needs and Desires) School (1971 and 1974)

The Perfect Storm

- Why is vision being realized now?
  - Disaggregate modeling of travel behavior
  - Advances in statistical and econometric estimation methods
  - Quantum leaps in computational power
  - Policy questions with complex behavioral implications
  - Availability of databases (land use, travel behavior, GPS, networks)

An Evolutionary Stream of Research

- Chapin (1971 and 1974) studied human activity patterns in urban contexts
- Hägerstrand (1969) examined activity patterns in the time-space domain (continuum) and identified series of constraints
- Activity-based analysis traces its roots to these schools of thought

Hägerstrand's Constraints

- Three primary types of constraints identified
  - *Authoritative*: Time-space constraints
  - *Capability*: Biological needs and resources (sleep, income)
  - *Coupling*: Inter-agent interactions (children)

Activity-Based Paradigm in Transportation

- Jones (1979) explicitly identified relationships among activities, travel, time, and space
  - Travel demand is a derived demand
- Followed with a conference in 1981 on *Travel Demand Analysis: Activity-Based and Other New Approaches*

Activity-Based Paradigm in Transportation

- Impetus grew in late 1980s and into 1990s
  - Key legislative acts such as ISTEA (1991), CAAA (1990), and TEA-21 (1998)
  - Major lawsuit filed by Sierra Club against San Francisco Bay Area MTC
  - Federal Travel Model Improvement Program (TMIP)

Activity-Based Paradigm in Transportation

- Early research efforts under TMIP
  - Development of TRANSIMS at Los Alamos National Laboratory
  - Activity-based model development research (AMOS)
- Four key papers published in *Transportation* (1996) offered frameworks for activity models

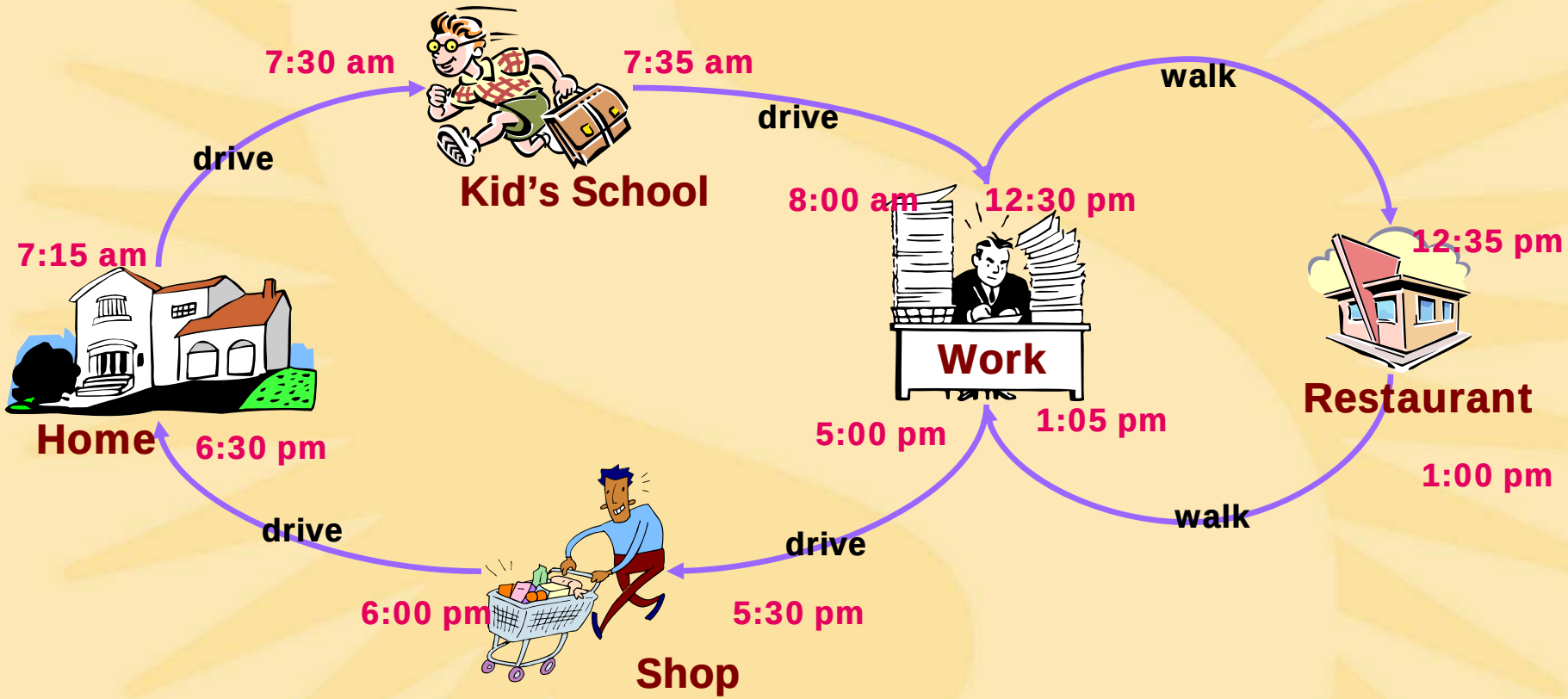
Activity-Based Paradigm in Transportation

- Four papers in *Transportation*
  - Late Kitamura/Pas
  - Ben-Akiva/Bowman
  - Stopher/Hartgen
  - Slavin
- Other key publications
  - Kitamura (1988); Axhausen and Gärling (1992); Jones et al (1990); Bhat and Koppelman (1999)

Activity-Based Paradigm in Transportation

- Other key events
  - 1996 Activity Based Modeling Conference (New Orleans) organized by TMIP – *everybody from Missouri?*
  - 1995 and 2004 Netherlands Conferences in Progress in Activity-Based Analysis
  - TRB Task Force on Moving Activity-Based Approaches to Practice (2003-2008) – *chaired by Prof. Kostas Goulias*

A Daily Activity Itinerary



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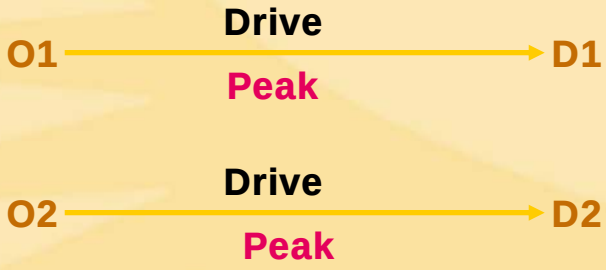
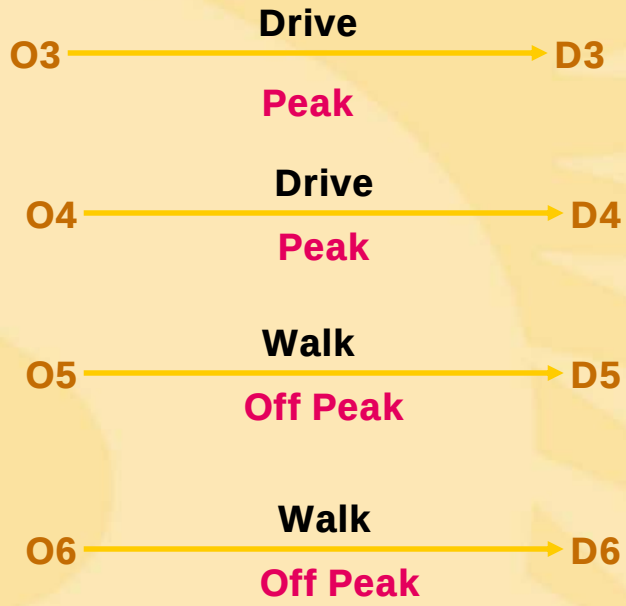
Interactions and Constraints

- How does a four-step trip-based model view this itinerary?

Two **Home-based trips**

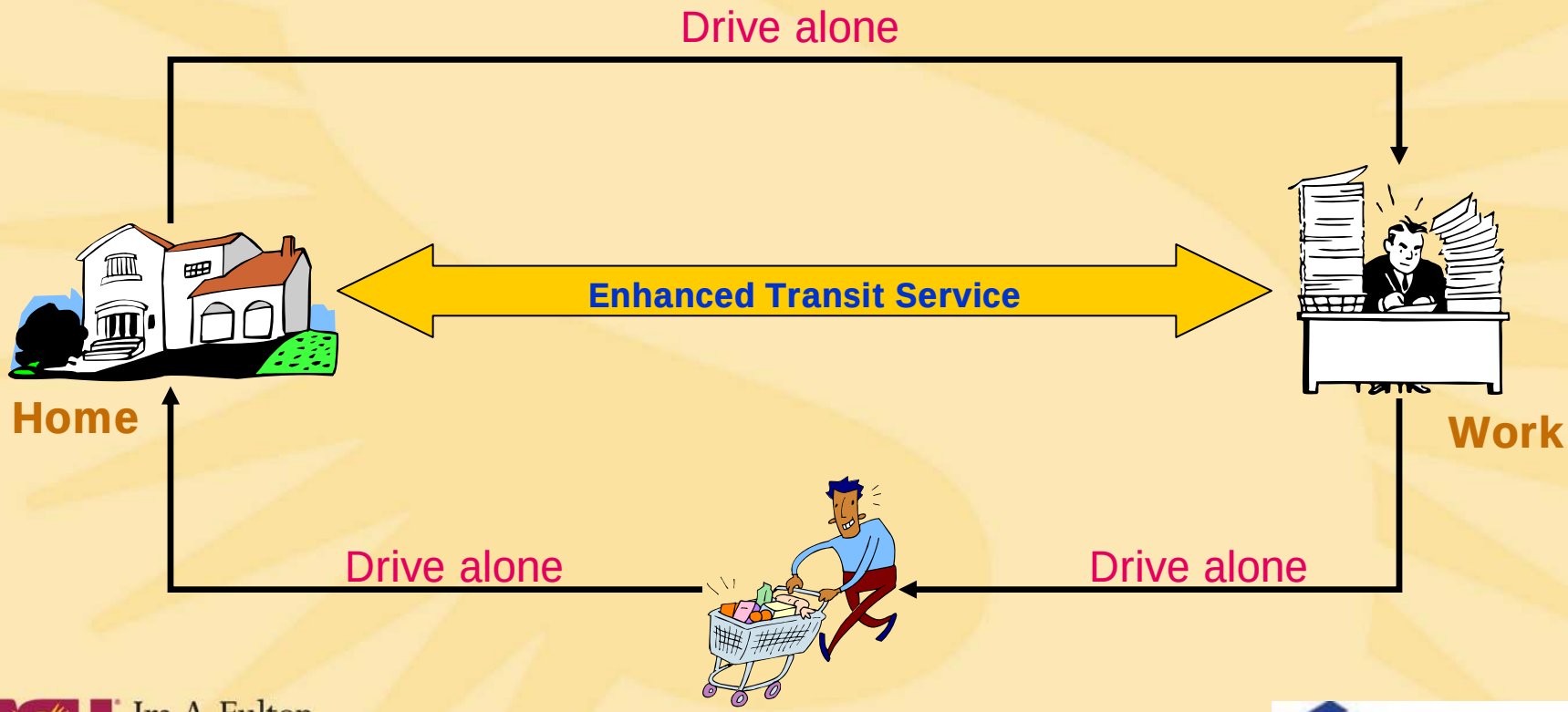


Four **Non home-based trips**



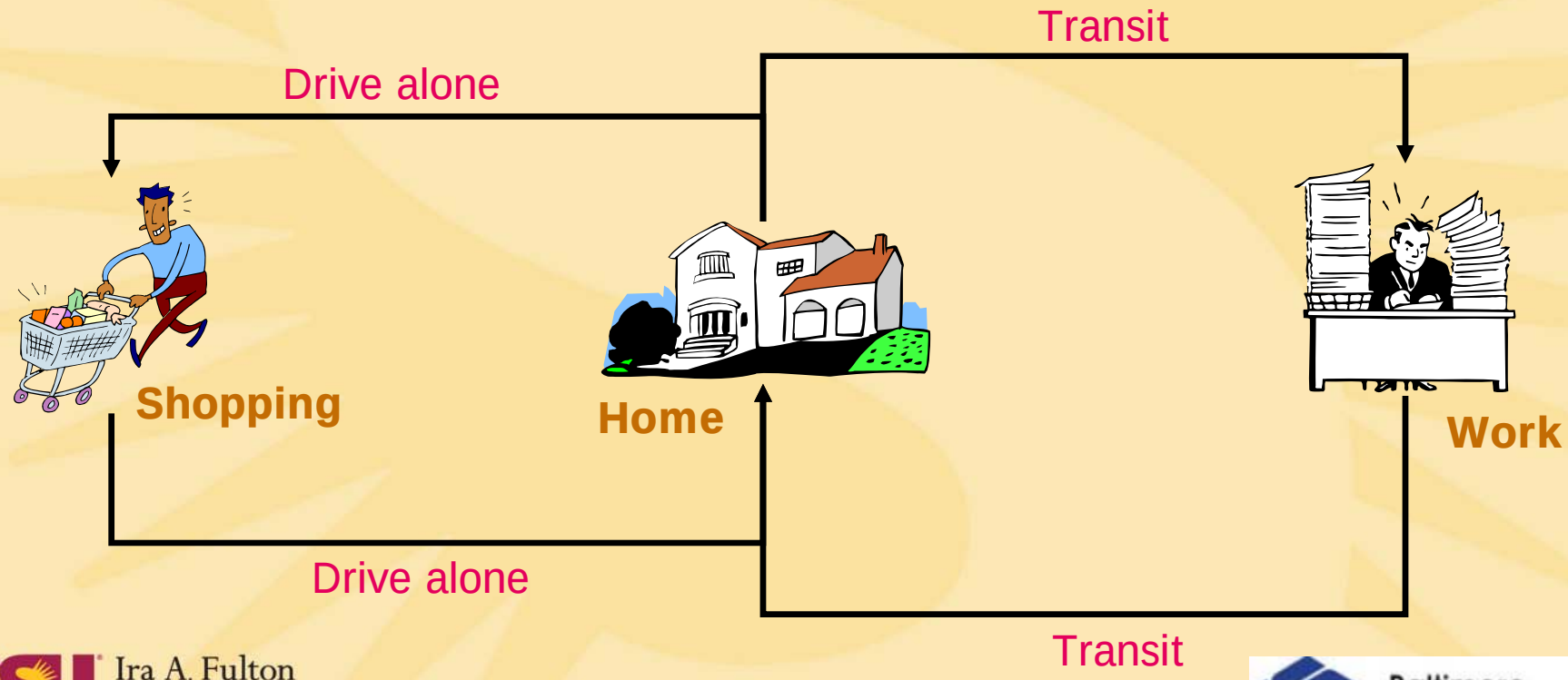
Influence of Trip Chaining

- Consider a transit enhancement



Influence of Trip Chaining

- How can a switch to transit be accommodated?



Activity-Travel Inter-relationships

- Note series of inter-related behavioral responses
  - Shift in mode choice to work
  - Shift in destination choice for shopping
  - Shift in timing of shopping activity
  - Impact on trip generation (4 trips instead of 3 trips)

Limits of Four-Step Trip-Based Models

- Consider a change in system conditions
  - Increase in capacity
  - Increase in congestion (travel time)
  - Change in fuel price

Limits of Four-Step Trip-Based Models

- What do people do?
  - According to USA Today/Gallop Poll in June 2008, >80% consolidate errands → Direct impact on trip generation
  - However, activity participation remained largely unaltered
- Trip generation models in practice
  - Largely insensitive to system conditions

Limits of Four-Step Trip-Based Models

- Insensitivity of trip generation to system conditions
  - Inability to model suppressed demand or induced demand
- Could incorporate accessibility measures in trip generation models, but…
  - Still very limited in ability to reflect interactions and constraints

Social Equity and Quality of Life Issues

- Quality of life tightly connected to human activity patterns and how people spend “time”
- Activity-based paradigm offers ability to construct utility measures that directly address these issues

Planning Issues

- Traditional/novel multimodal capacity additions/subtractions
- Transit/Pedestrian Oriented Development
- Bicycle facility enhancements
- HOV/HOT lanes, Congestion Pricing, Variable Pricing, Parking Pricing
- Telecommuting (Telecommunications), Flexible Work Schedules
- ITS deployments
- Equity, Social Exclusion, Environmental Justice
- Energy (Fuel Prices) and Environment (Air Quality)
- Homeland security and disaster management

Basis for Model Design

- Policy issues and questions of interest
- Realistic behavioral paradigm/representation
- Computationally feasible and tractable
  - Estimation
  - Implementation
- Data availability (present and future)

A Focus on Behavioral Considerations

- Multitude of choices define activity-travel behavior
  - Activity type/purpose
  - Activity timing (time-of-day)
  - Travel mode and destination
  - Activity duration
  - Activity linkage (trip chaining)
  - Accompanying persons
  - Network-level choices

Behavioral Decision Processes

- Multitude of decision hierarchies possible
  - What is the sequence in which choices are made?
  - Virtually all model systems imply a certain decision hierarchy
- To what extent are choices made sequentially versus simultaneously/jointly?

Decision Hierarchies

- Large variety of decision hierarchies possible
  - Heterogeneity in the population
  - Careful market segmentation based on decision processes
- Growing evidence of simultaneity in choice decisions
  - People choose an activity-travel (lifestyle) package
- If choice process is sequential, more constrained choice precedes less constrained choice
  - In household with vehicle ownership constraints, would mode choice precede destination choice?

The Role of Time

- The notion of time and time use is central to the activity-based modeling paradigm
  - Time is not just a “cost” to be minimized
  - Rather, it is a finite resource whose “use” people strive to “optimize”
  - Time is an all-encompassing entity in activity-based models

The Role of Time

- Time appears in activity-travel agendas in numerous ways
  - Daily time allocation to activities and travel
  - The duration of single activity and travel episodes
  - The timing (time-of-day) of activities/trips
  - Multi-day (weekly) activity scheduling

The Role of Time

- Consideration of relationships between in-home and out-of-home activity time use
- Evidence of increased availability of leisure time
- Evidence of increase in travel time expenditures
  - Productivity efficiencies brought about by specialized services and technology deployment

The Role of Time

- Do people treat time as a continuous entity or a discrete entity?
  - Discrete time-of-day choice models (break the day into discrete periods)
  - Continuous duration models where activity timing is modeled along the continuous time axis
- Scheduling may be discrete while time allocation may be continuous

Agent Interactions

- Task allocation and joint activity-travel engagement
  - With whom and for whom?
- Activity dependency (children)
- Household vehicle allocation
- Residential and workplace location choices
- Real-time activity scheduling
  - Influence of mobile technologies
  - Generate activities on-the-fly in model?

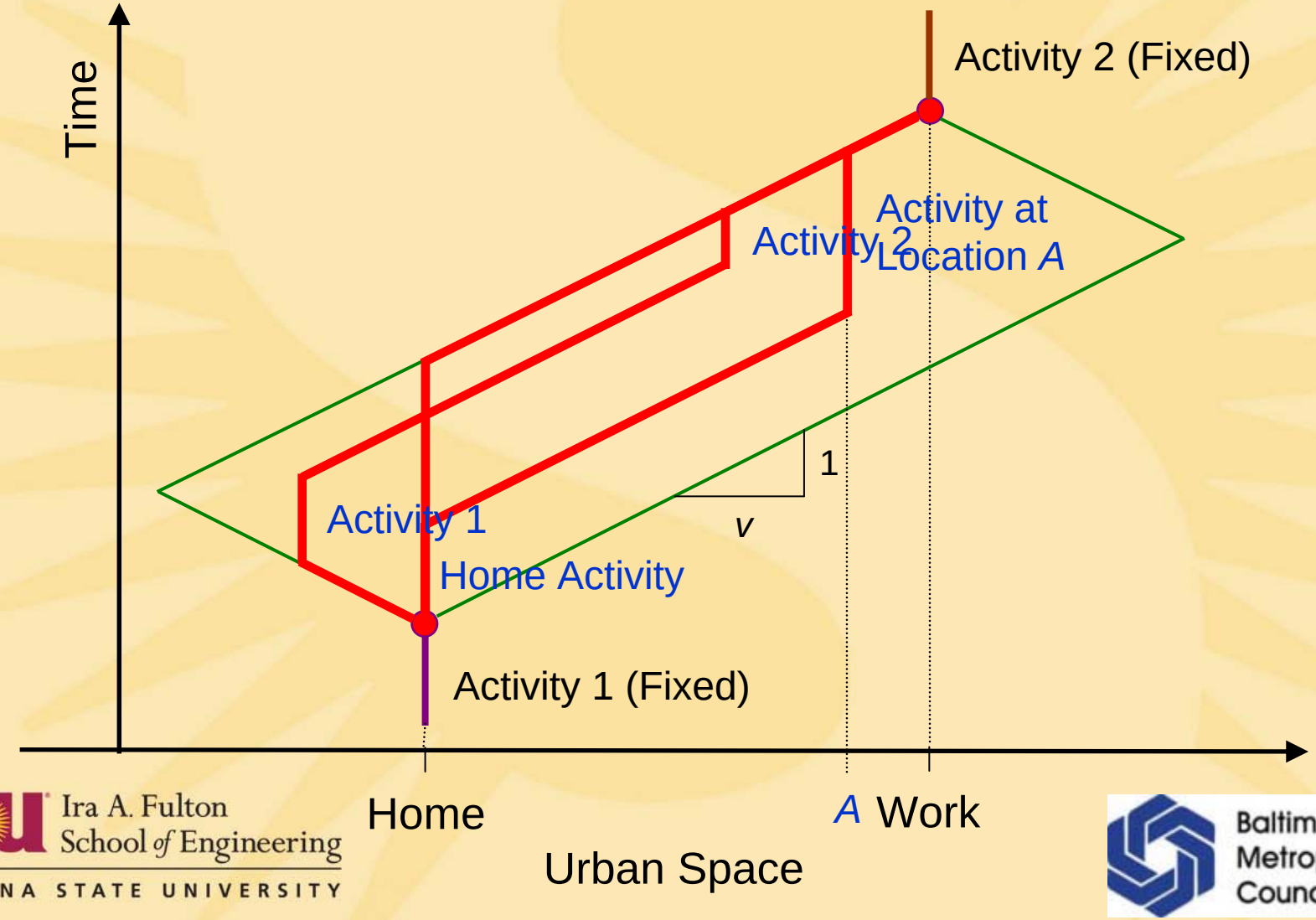
Time-Space Interactions

- Gain realism by incorporating time-space prism constraints
- Constraints on modal transition, public transit availability, and destination choices
- Generate work/school schedules and tours first (define anchor points)
  - Discretionary activities simulated along the time axis recognizing constraints imposed by work and school

Time-Space Interactions

- *P*rism *C*onstrained *A*ctivity-*T*ravel *S*imulator (PCATS) of Kitamura – now embedded in *OpenAMOS*
- Divides a day into open periods and blocked periods
- Defines a Hägerstrand's prism for each open period and simulates activities and travel within it

Time-Space Interactions



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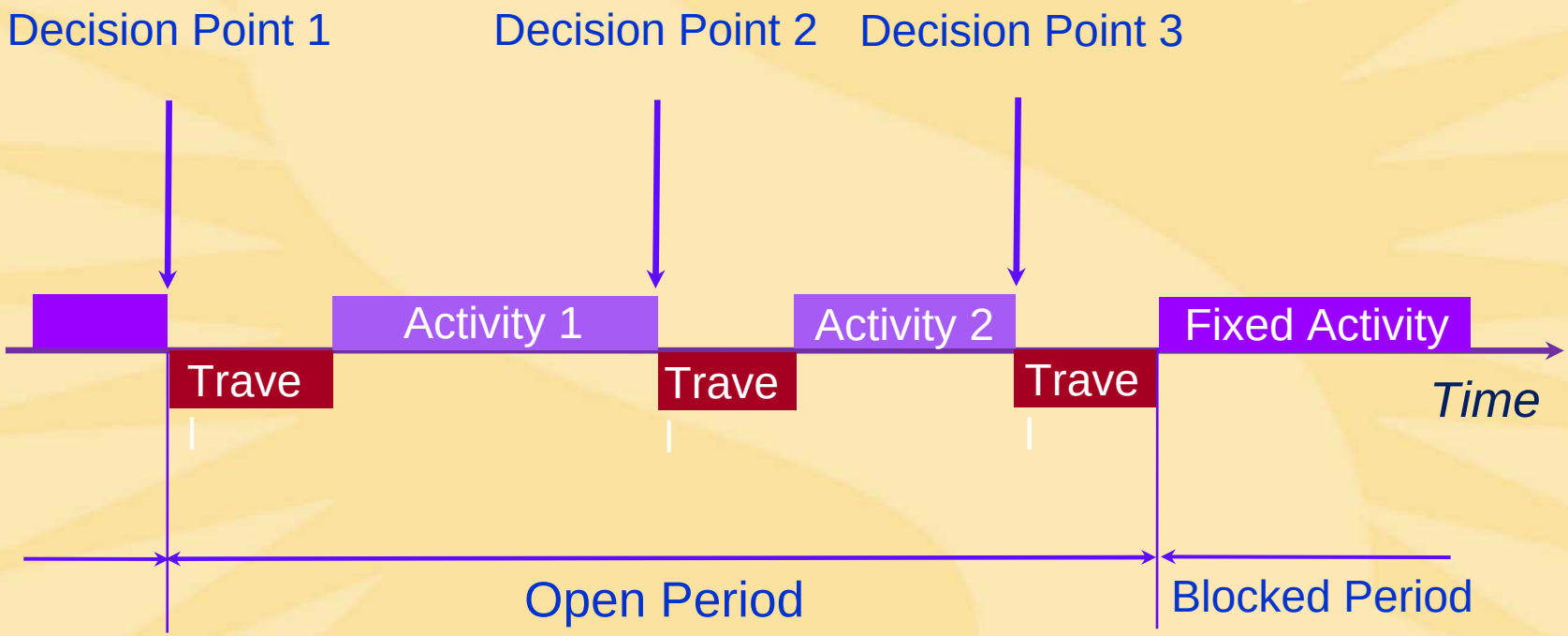
Time-Space Interactions

- Sequential structure
  - The attributes of an activity and trip to it are simulated activity by activity, conditional on past activity engagement
  - Operational hierarchy: activity type → mode-destination → activity duration
- Representation of prism constraints
  - Activity type choice/generation ← remaining time in prism
  - Mode-destination choice ← constrained choice set
  - Duration choice ← remaining time in prism

Decision Time Points for Discretionary Activities



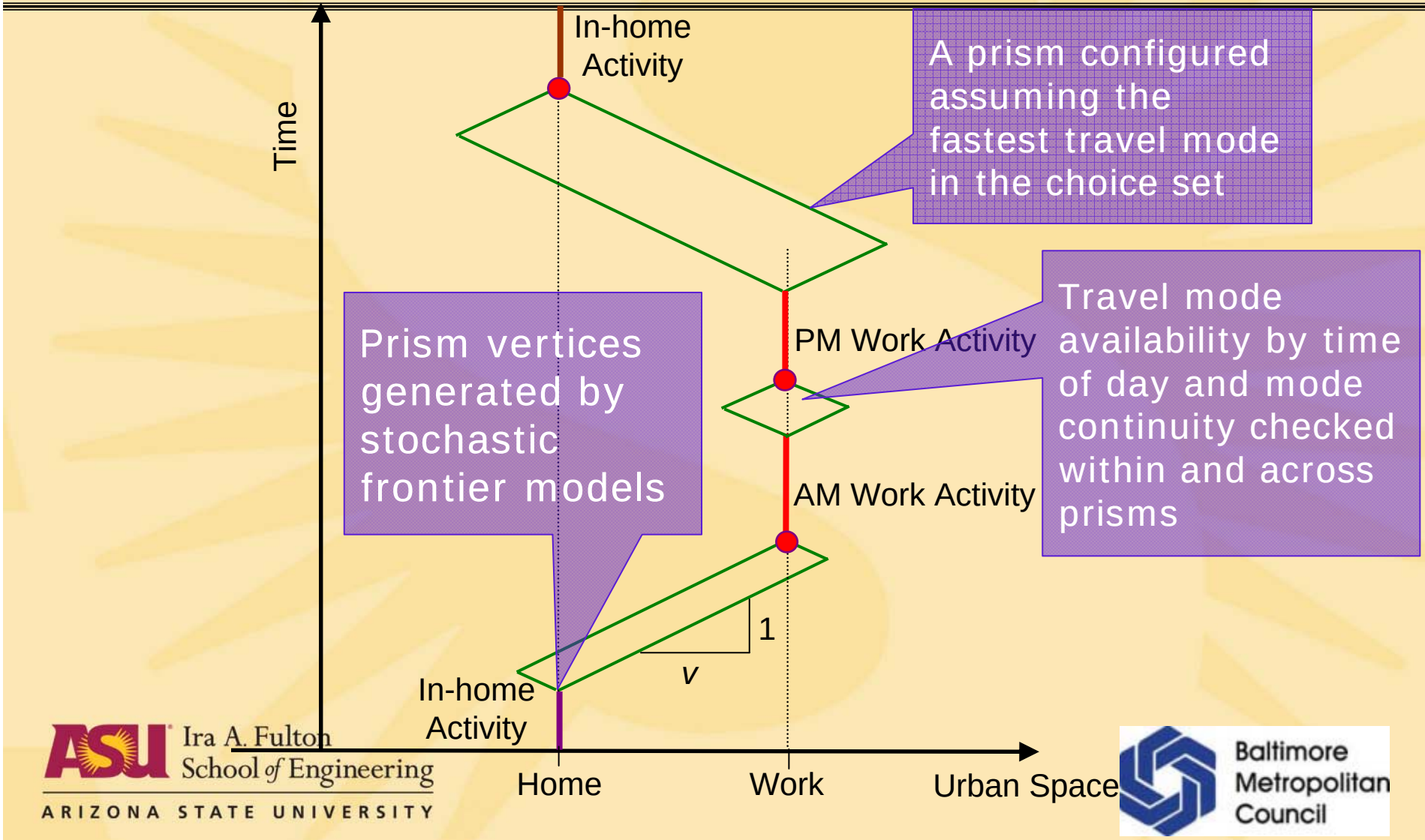
PCATS Model Components

- Prism vertex models
  - Stochastic frontier models to determine unobserved prism vertices
- Activity type choice models
  - Multinomial logit models that determine activity engagement in each open period

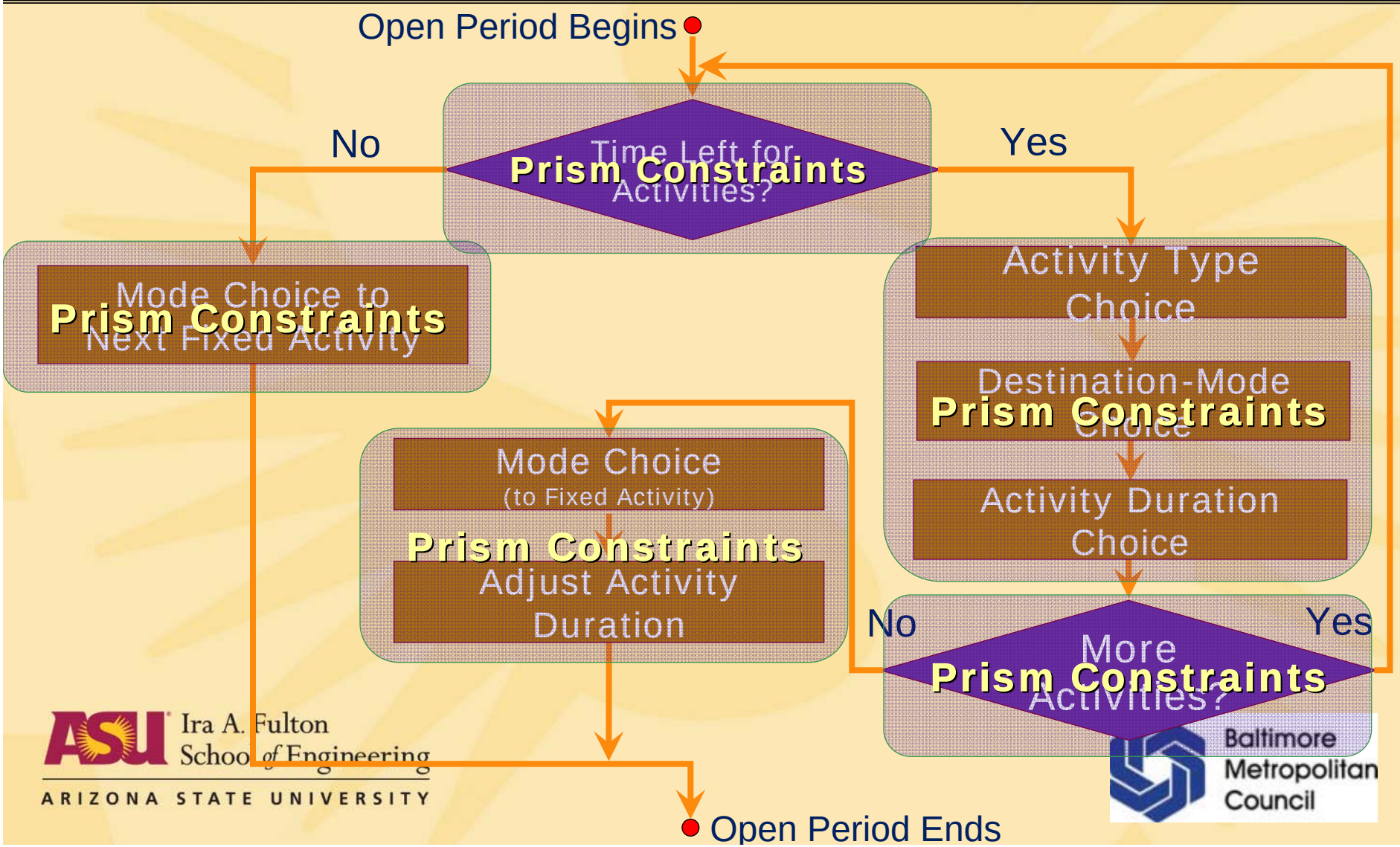
PCATS Model Components

- Destination-Mode choice models
  - Nested logit models that assign a destination-mode pair to each activity within a prism
- Activity duration models
  - Split-population survival models that determine length of each activity while considering the prism size

Representing Prism Constraints



Activity Generation Process



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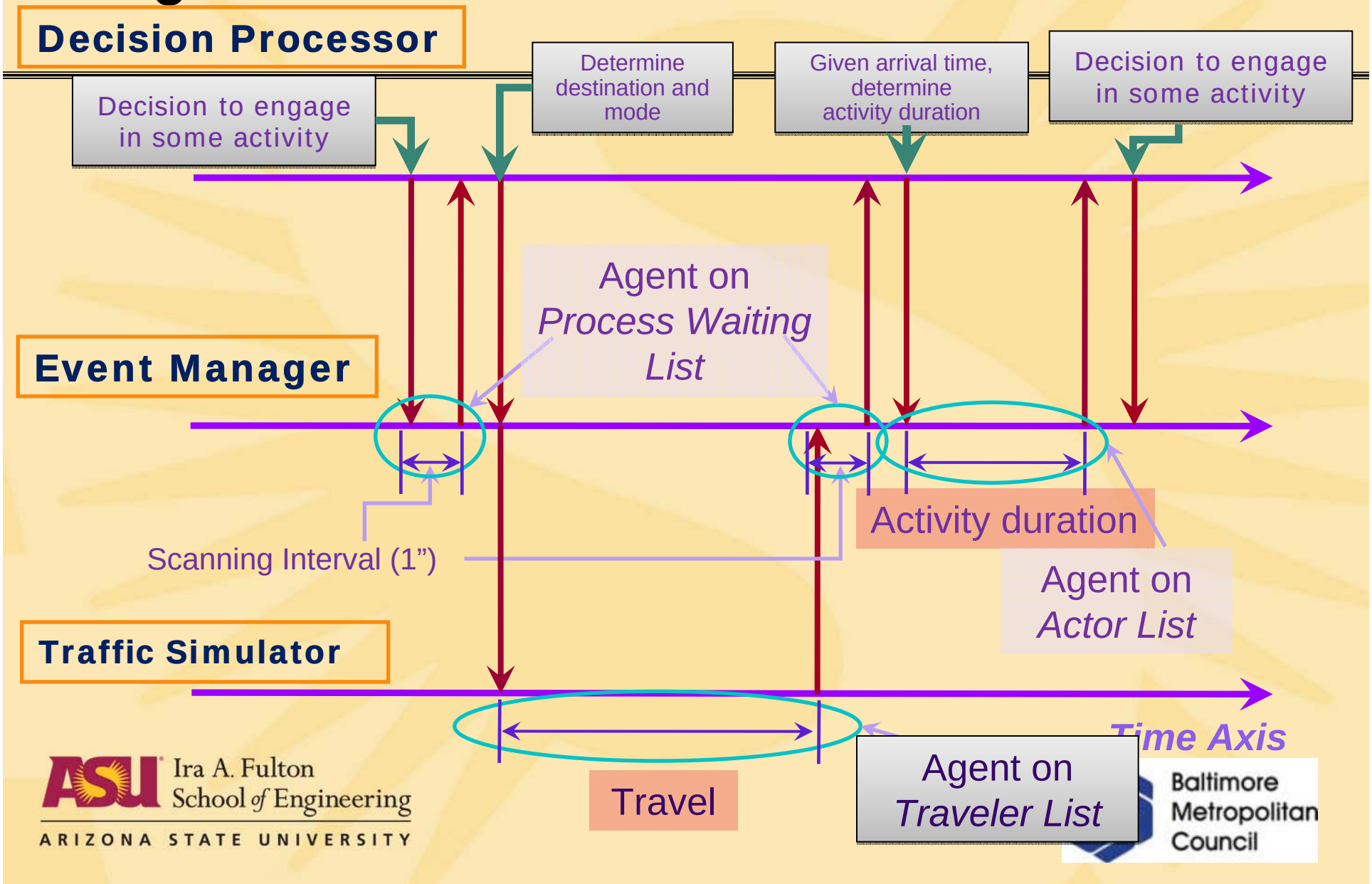
Integrate with Dynamic Traffic Simulator

- Maximize use of information from activity-based model system
  - Activities and trips generated along the continuous time axis
  - Load trips on the network as they are generated (at one-minute resolution)
  - Dynamic interface and concurrent execution, along the time axis, of the activity simulator and a network simulator
  - No post-processing of model outputs

Integration with Traffic Simulator



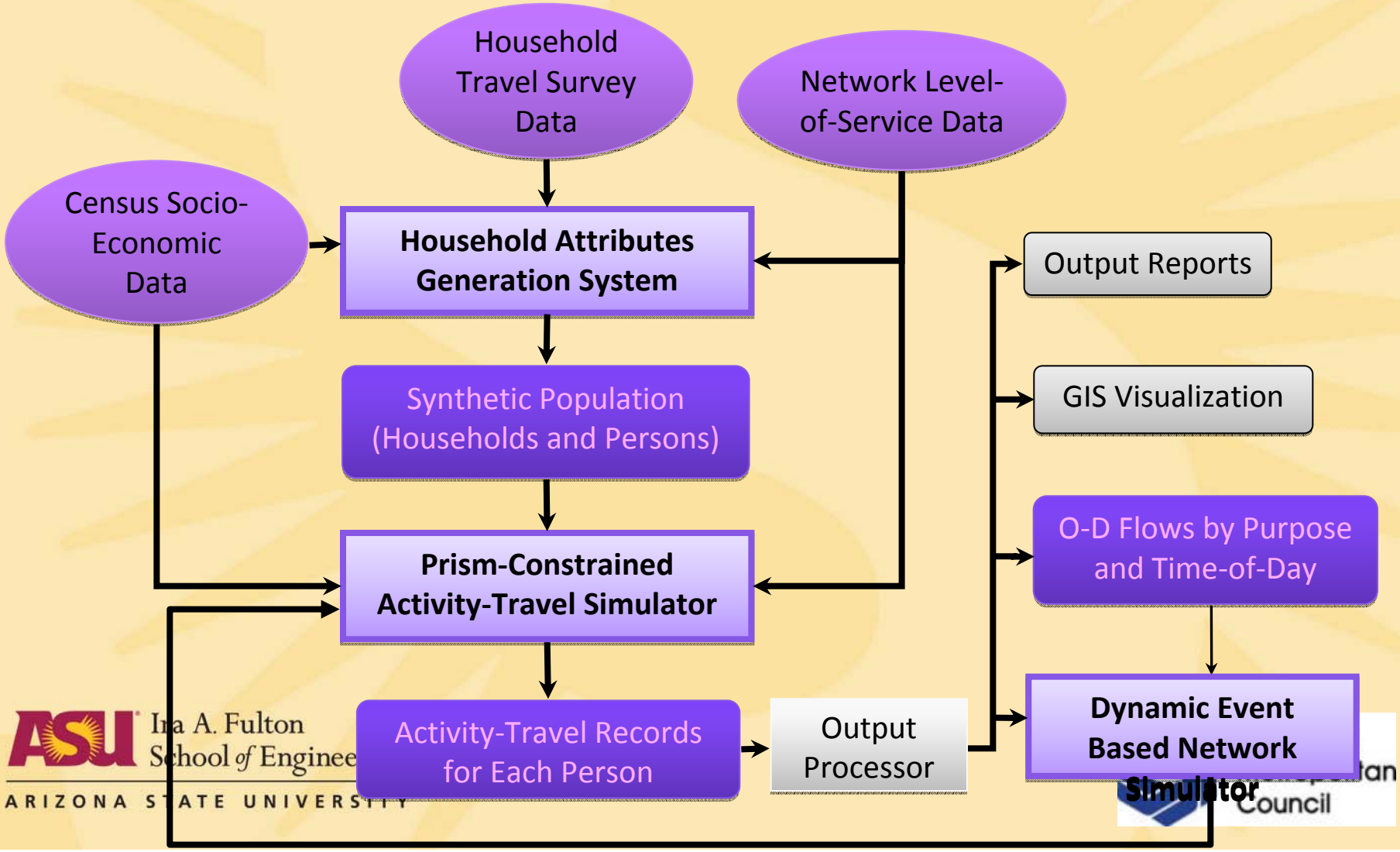
Enhancing Behavioral Realism

- Exact trip durations not known until trips are completed
- Need to consider issues of unmet mobility
  - An agent may be late for work, cannot finish errand, cannot return home, etc.
  - Prism constraints may not always be satisfied
  - Prism constraints increasingly fuzzy? (technology effects)

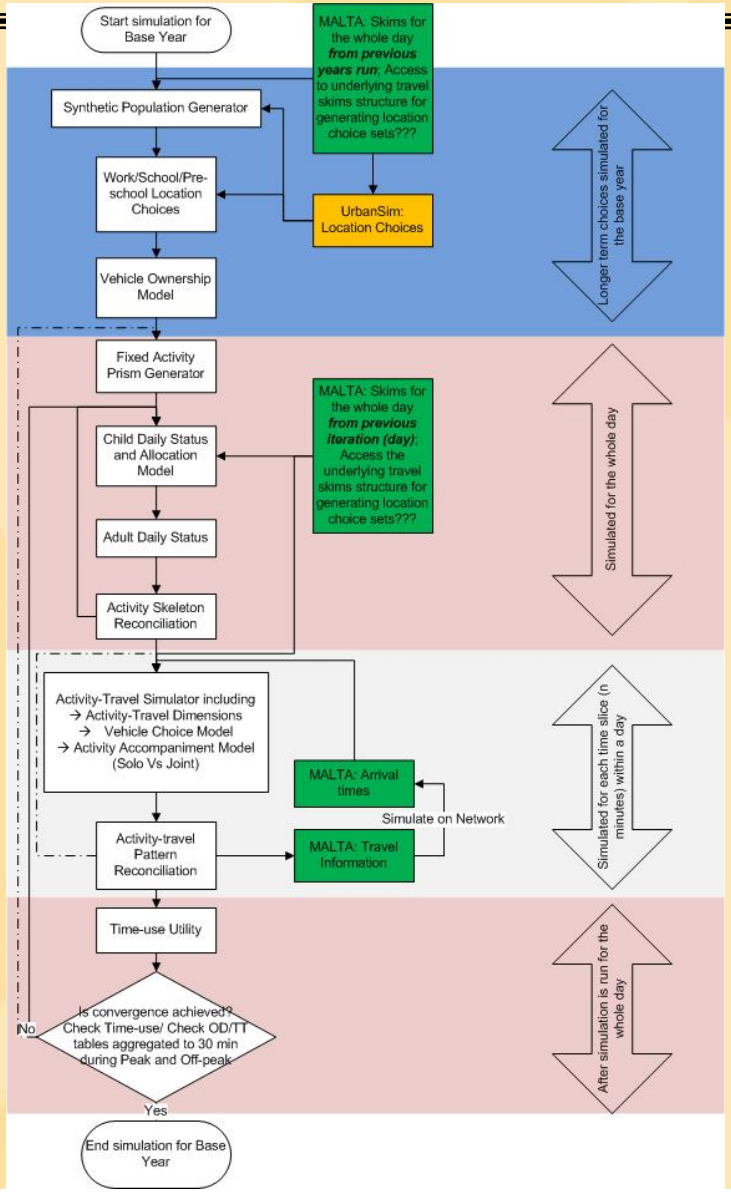
Activity-Based Model Systems

- Numerous activity-based model systems developed in research arena
- Models have matured to varying degrees
  - Attempt to incorporate aspects of behavior highlighted in presentation

Activity-Mobility Simulator (AMOS, FAMOS)



Model Design: SimTRAVEL



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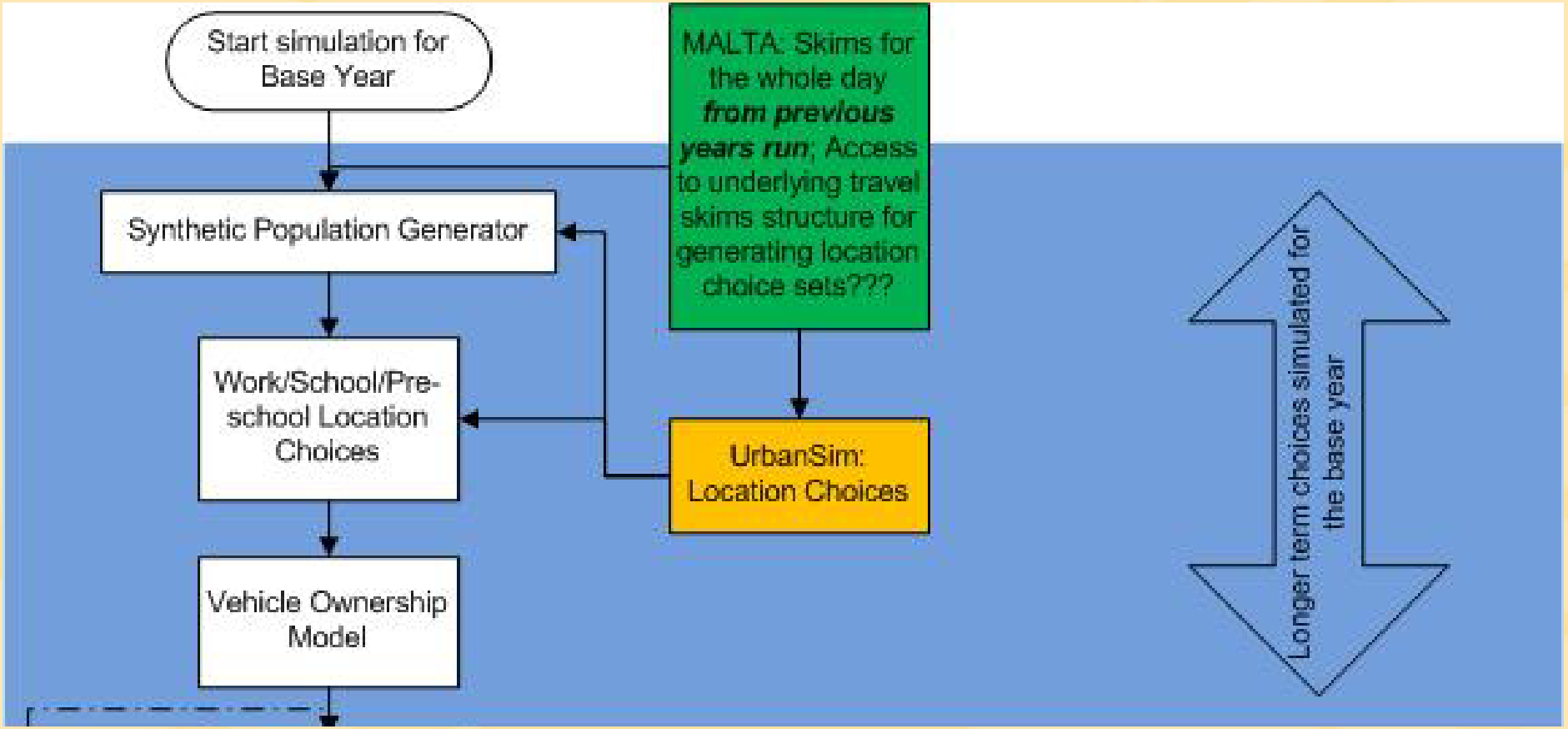
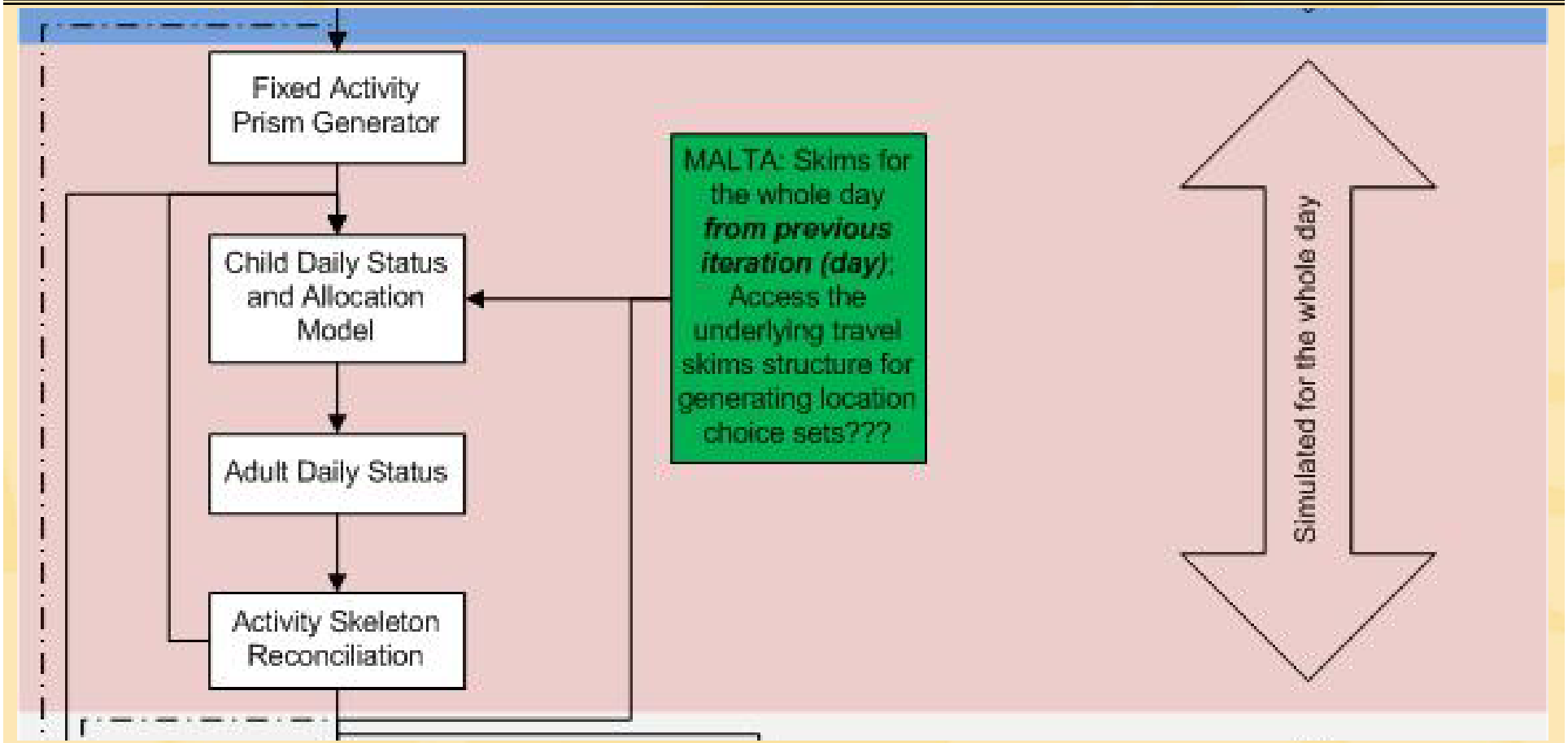
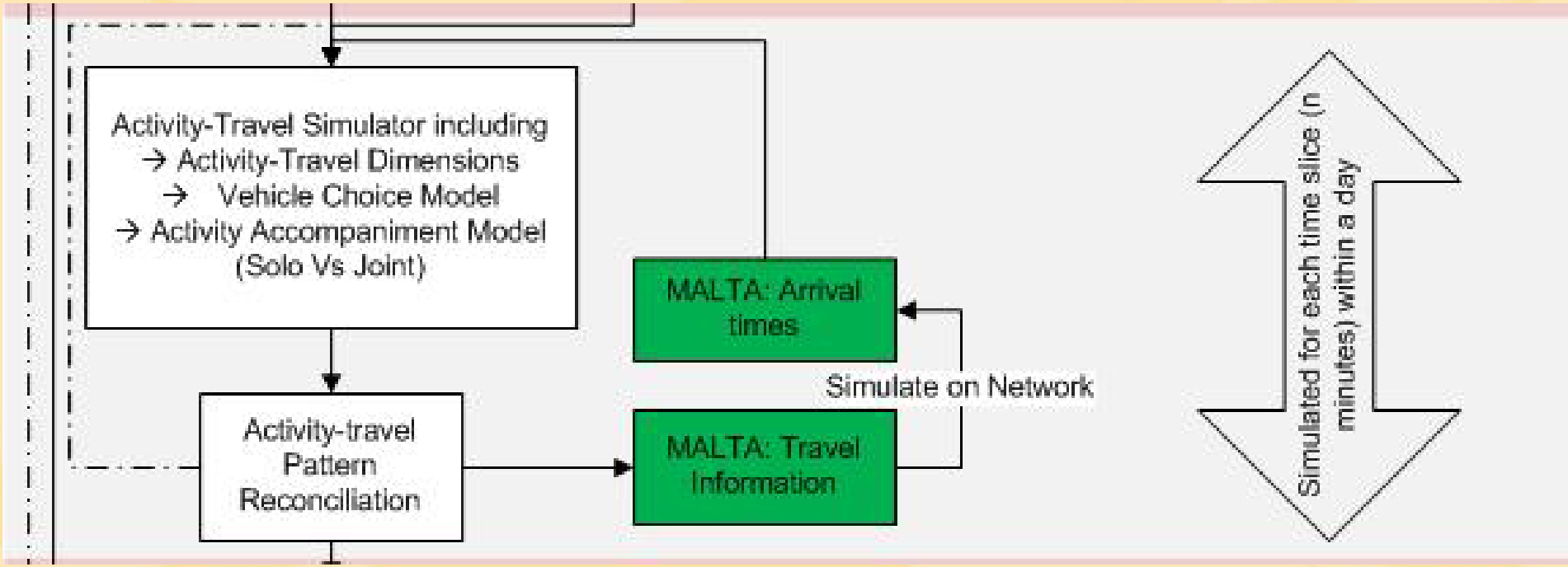
Model Design



Model Design



Model Design



SimTRAVEL: Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land

Funded by FHWA through Exploratory Advanced Research Program

See: http://simtravel.wikispaces.asu.edu

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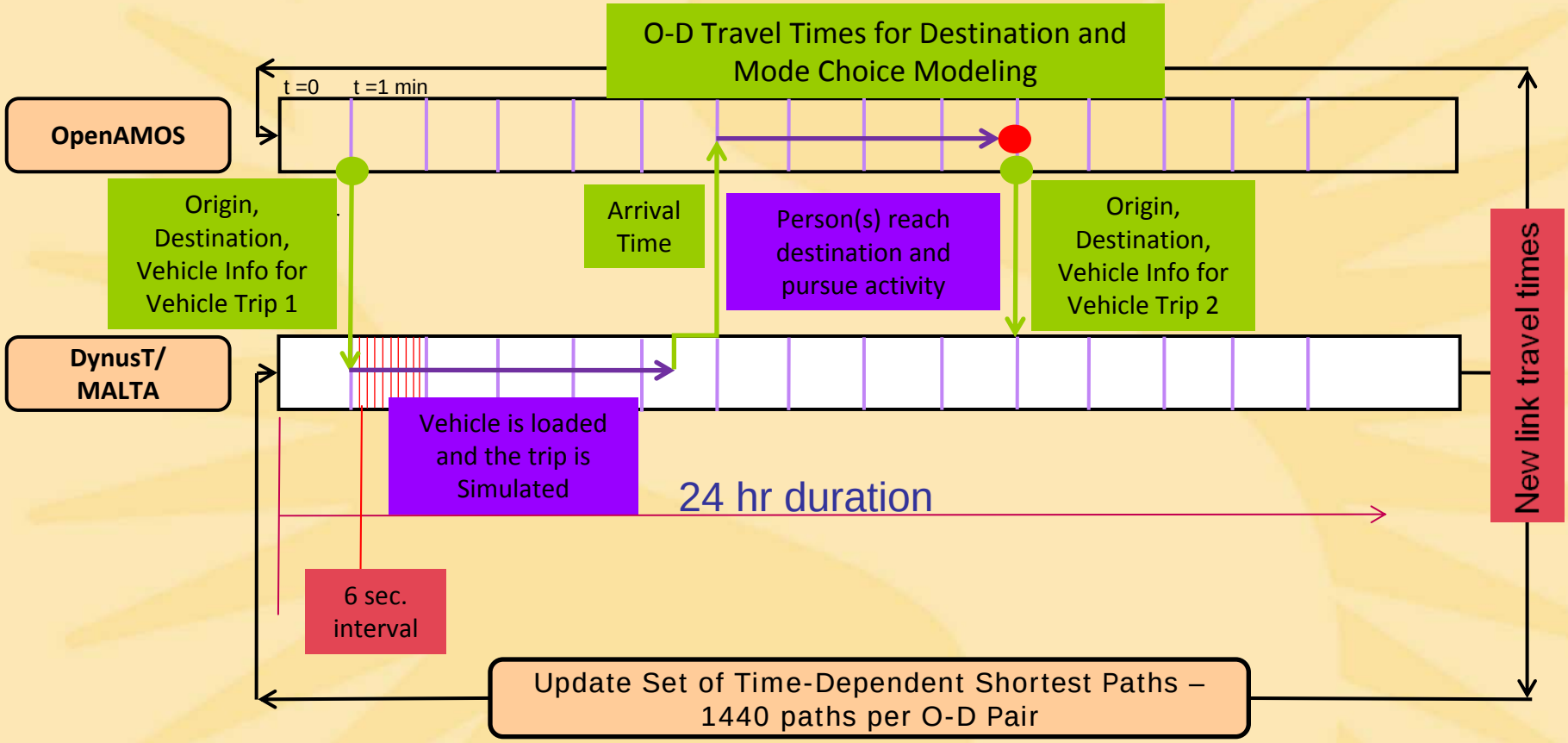
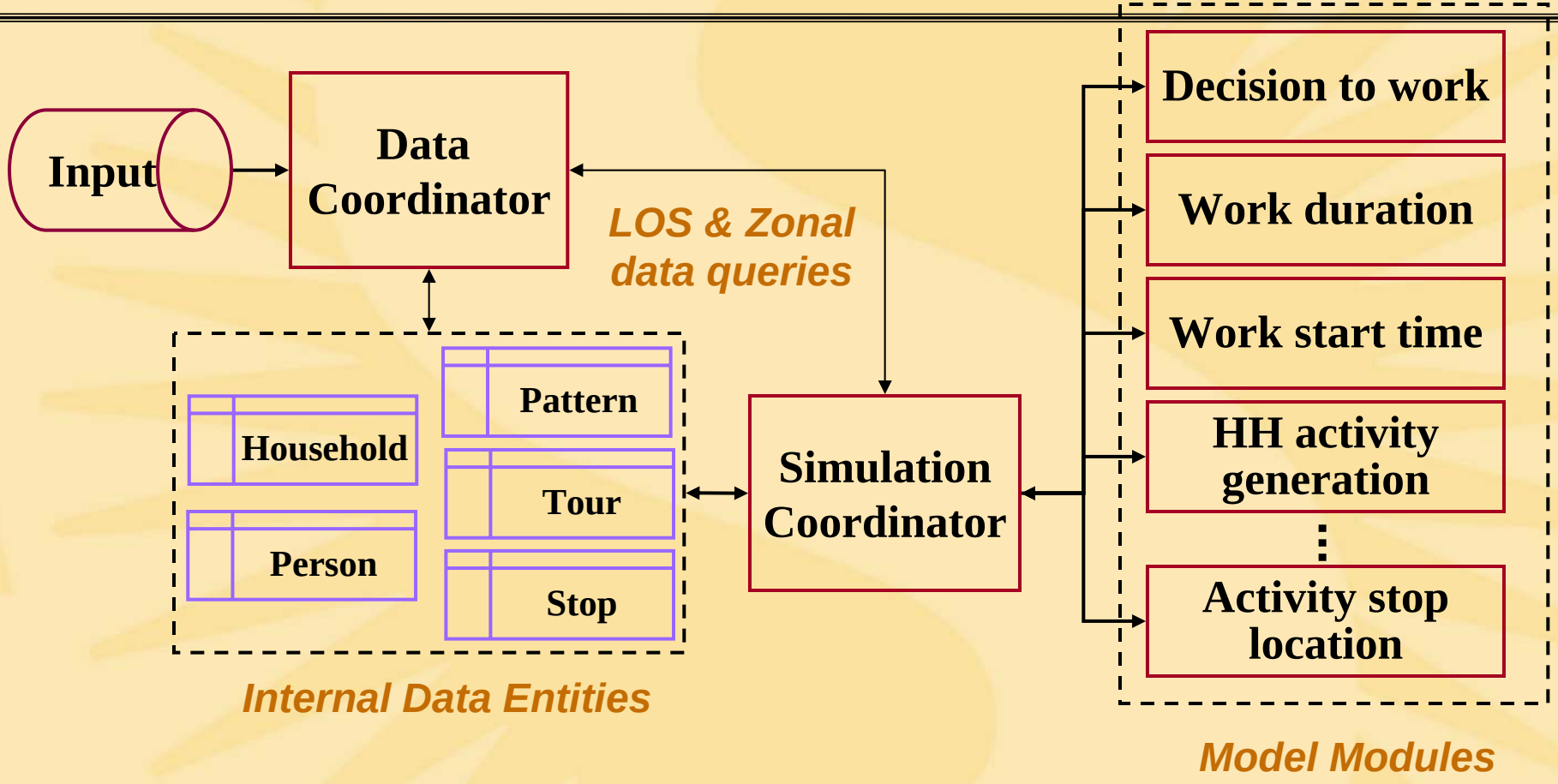
Integrated Model: Supply and Demand



CEMDAP (Bhat)



Comprehensive Econometric Microsimulator of Daily Activity-travel Patterns

CEMDAP: Model Components

Application of the Generation-Allocation Model System

Work and school activity participation and timing decisions

↓

Children's travel needs and allocation of escort responsibilities to parents

↓

Independent activity participation decisions

↓

Application of the Scheduling Model System

Work-to-home and home-to-work commute characteristics

↓

Drop-off tour of the nonworker escorting children to school

↓

Pick-up tour of the nonworker escorting children from school

↓

School-to-home and home-to-school commutes

↓

Joint tour of the adult pursuing discretionary activity with children

↓

Independent home-based and work-based tours for each worker

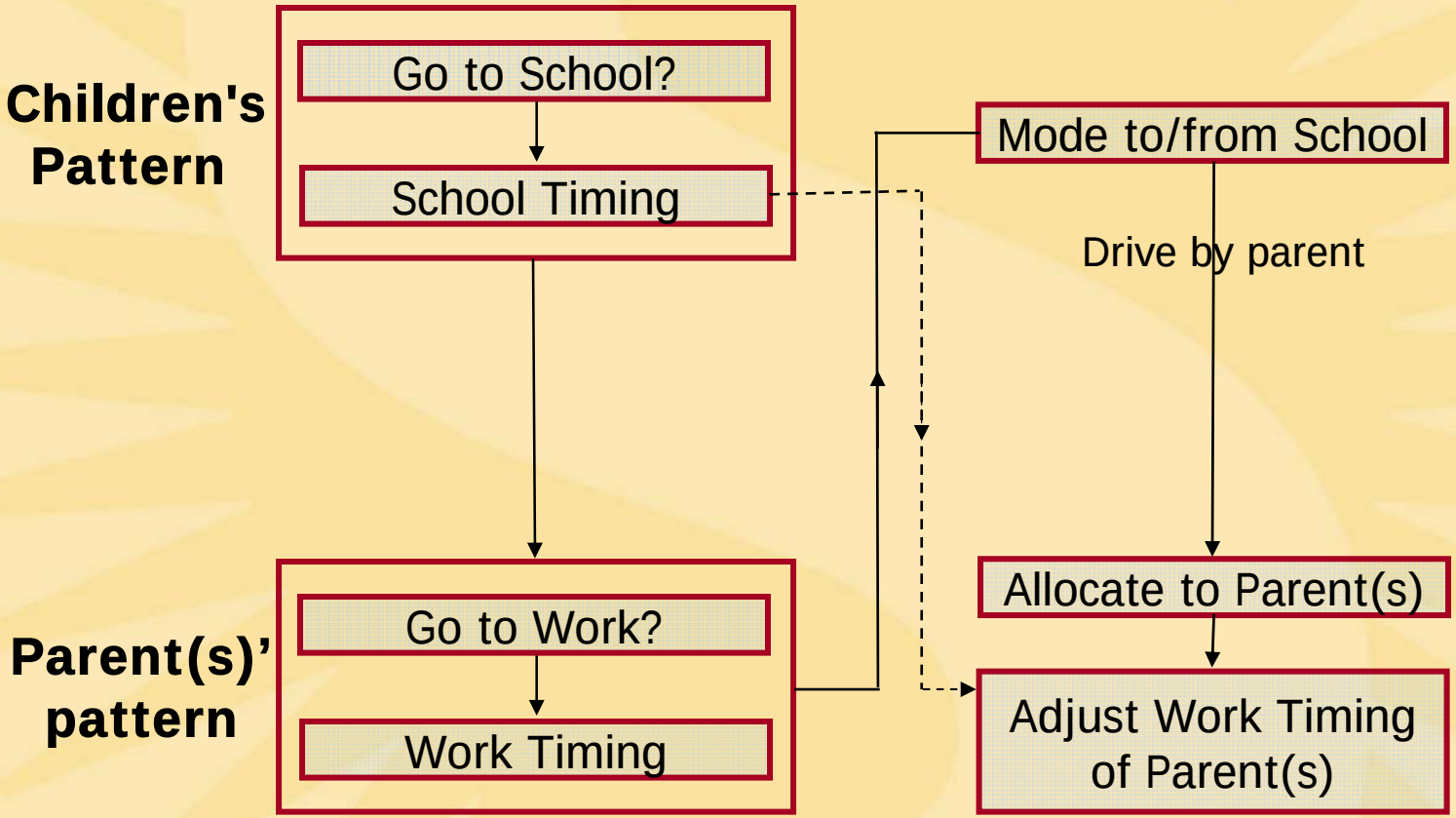
↓

Independent home-based tours for each non-worker

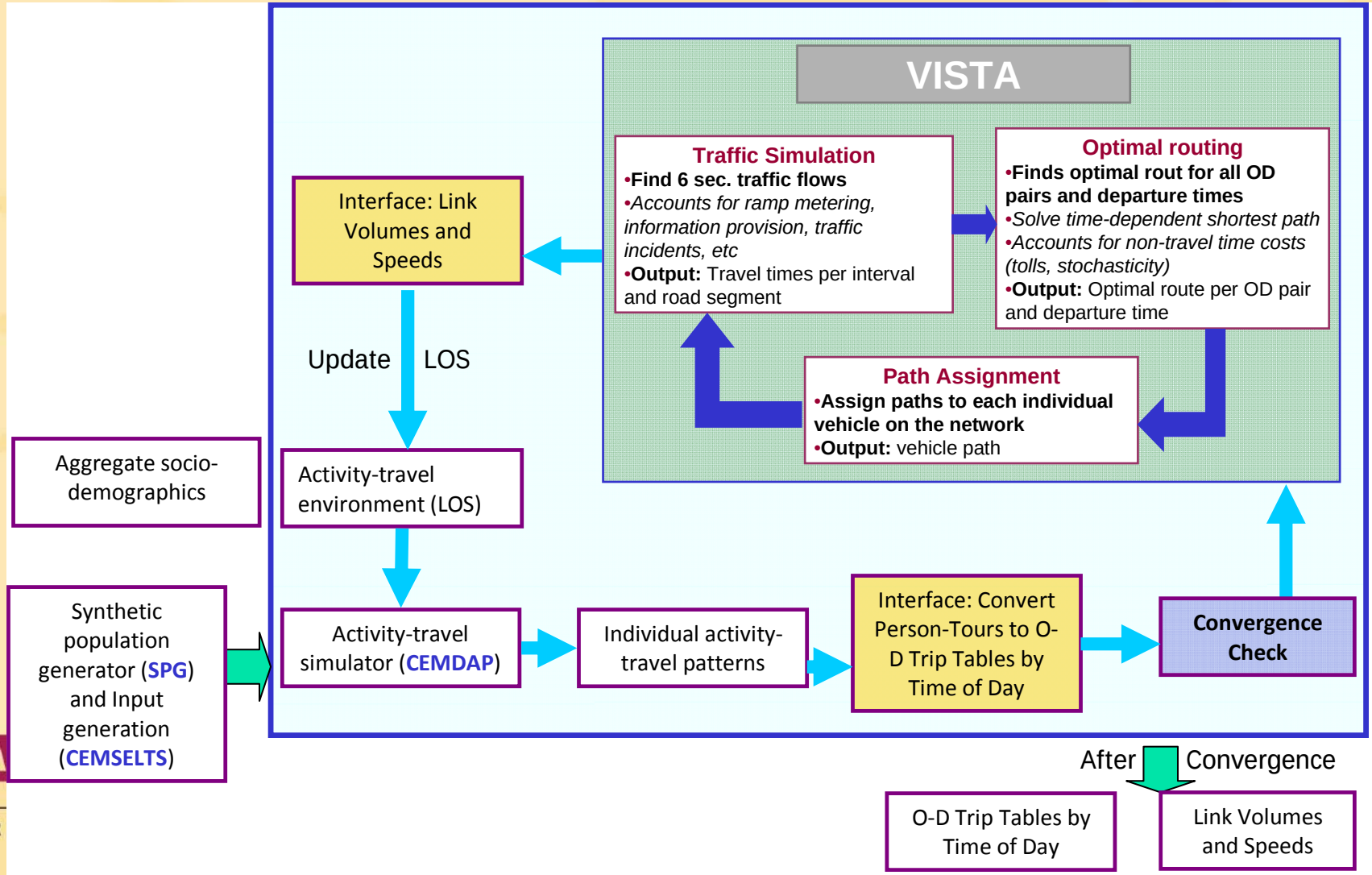
↓

Independent discretionary activity tour for each child

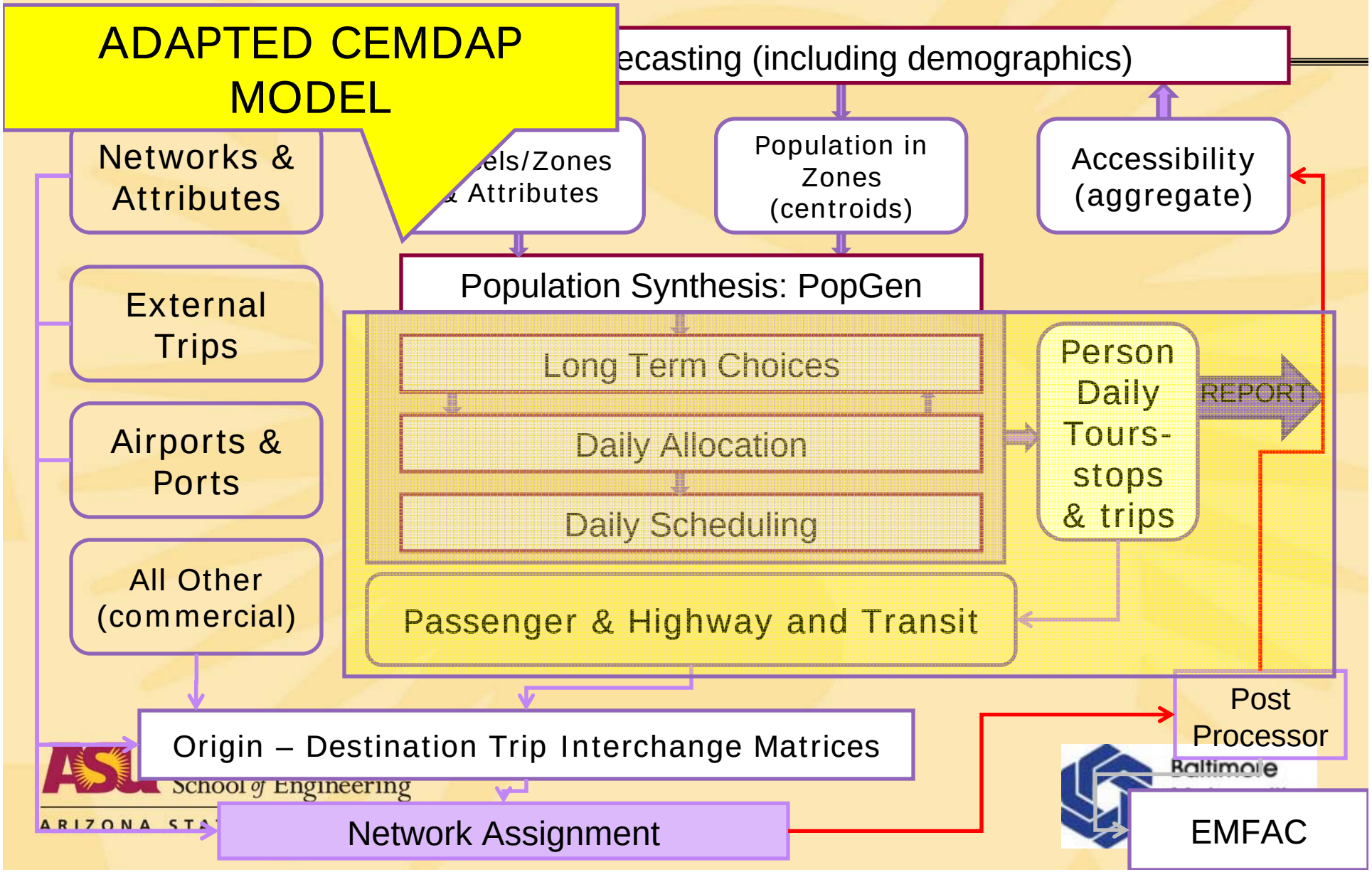
CEMDAP: Parent-Child Interaction



Integrated Activity-Travel Demand and Dynamic Traffic Assignment Model System (CEMDAP-VISTA: Bhat/Waller)



SimAGENT for SCAG



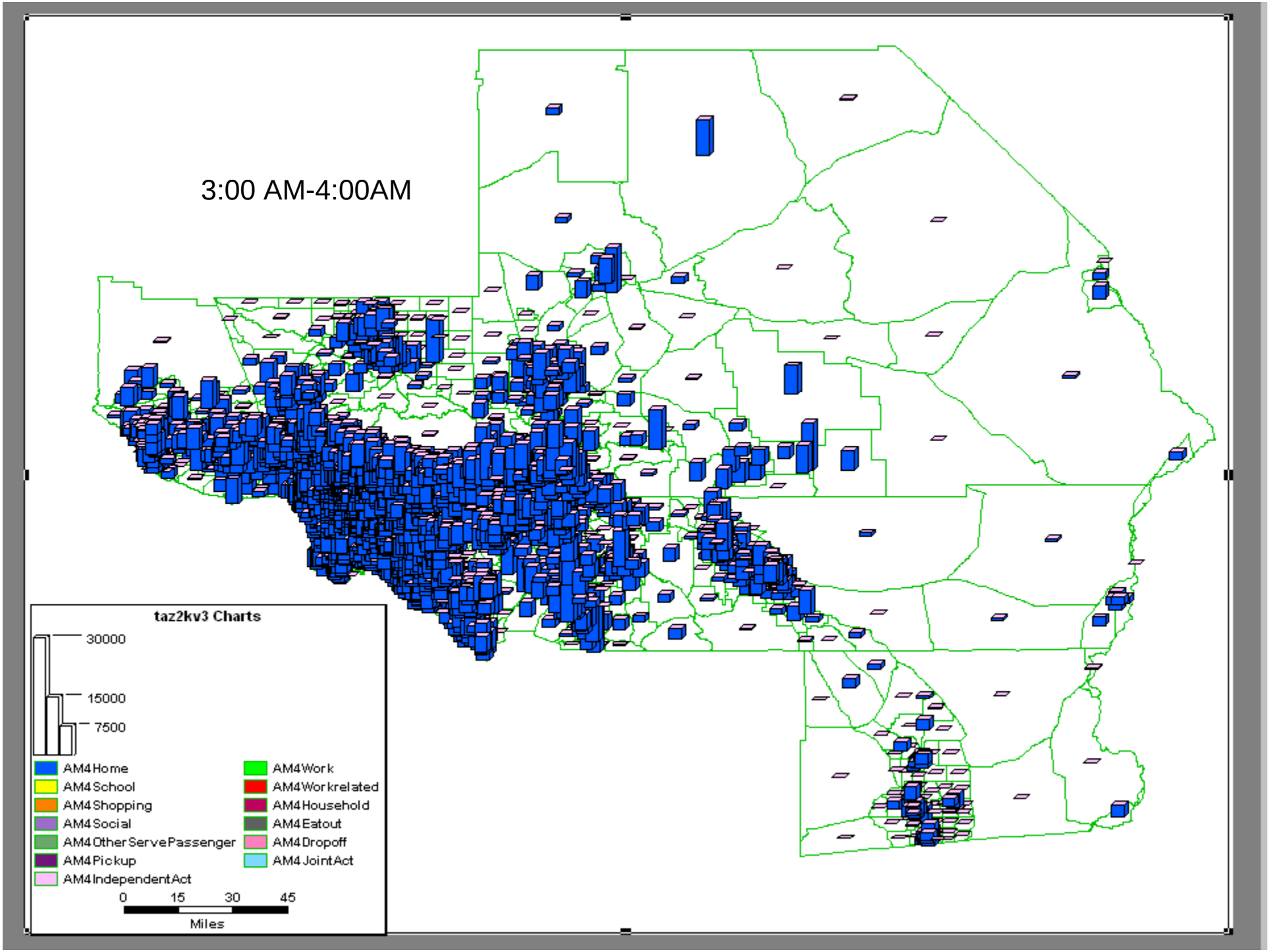
SimAGENT

*Sim*ulator of *A*ctivities, *G*reenhouse *E*missions, *N*etworks, and *T*ravel

- Address provisions/mandates of SB375
  - Requires metropolitan planning organizations (MPOs) to include sustainable communities strategies (SCS) for the purpose of reducing greenhouse gas emissions
- Address wide range of policies, e.g.:
  - Economic analysis: location-based welfare, wages, and exports
  - Equity analysis: change in welfare by household income class
  - Evaluate the energy use and GHGs produced by households and workers in building space
  - Comprehensively evaluate economic development impacts
  - Evaluate time-of-day roadway tolls

SimAGENT Phased Implementation Plan for SCAG

Phase	Title	Description
1	Model Development Plan and Strategy	Work closely with SCAG staff to finalize model development plan, model structure, model implementation path, and software and data requirements and specifications
2	Development and Implementation of SimAGENT Version 1	Adapt CEMDAP to SCAG region Add Synthetic Population Generator Compare to 2003 Trip-Based Model Extensive Validation and Sensitivity Testing Conduct Hands-on Staff Training Sessions Estimate GHG using EMFAC
3	Development and Implementation of SimAGENT Version 2	Enhanced CEMDAP Model Specifications More Detailed Spatial/Network Resolution Full Incorporation of Time-Space Concepts Extensive Validation and Sensitivity Testing
4	Training and Reports	Submission of Final Deliverables Conduct Hands-on Staff Training Sessions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AM4School
AM4Shopping
AM4Social
AM4OtherServePassenger
AM4Pickup
AM4IndependentAct
AM4Work
AM4Workrelated
AM4Household
AM4Eatout
AM4Dropoff
AM4JointAct
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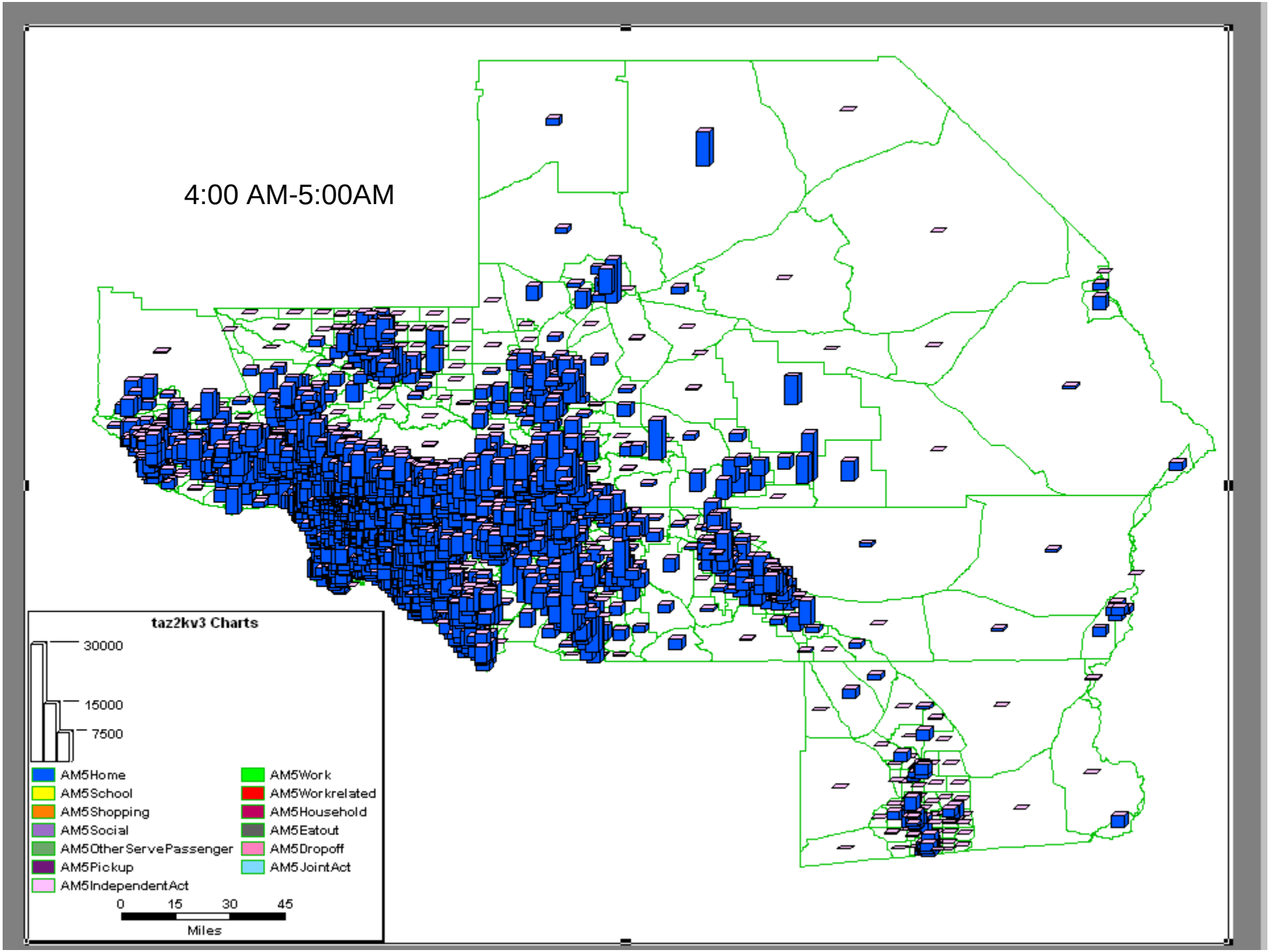
Miles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AM5School
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AM5Pickup
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AM5Work
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AM5Household
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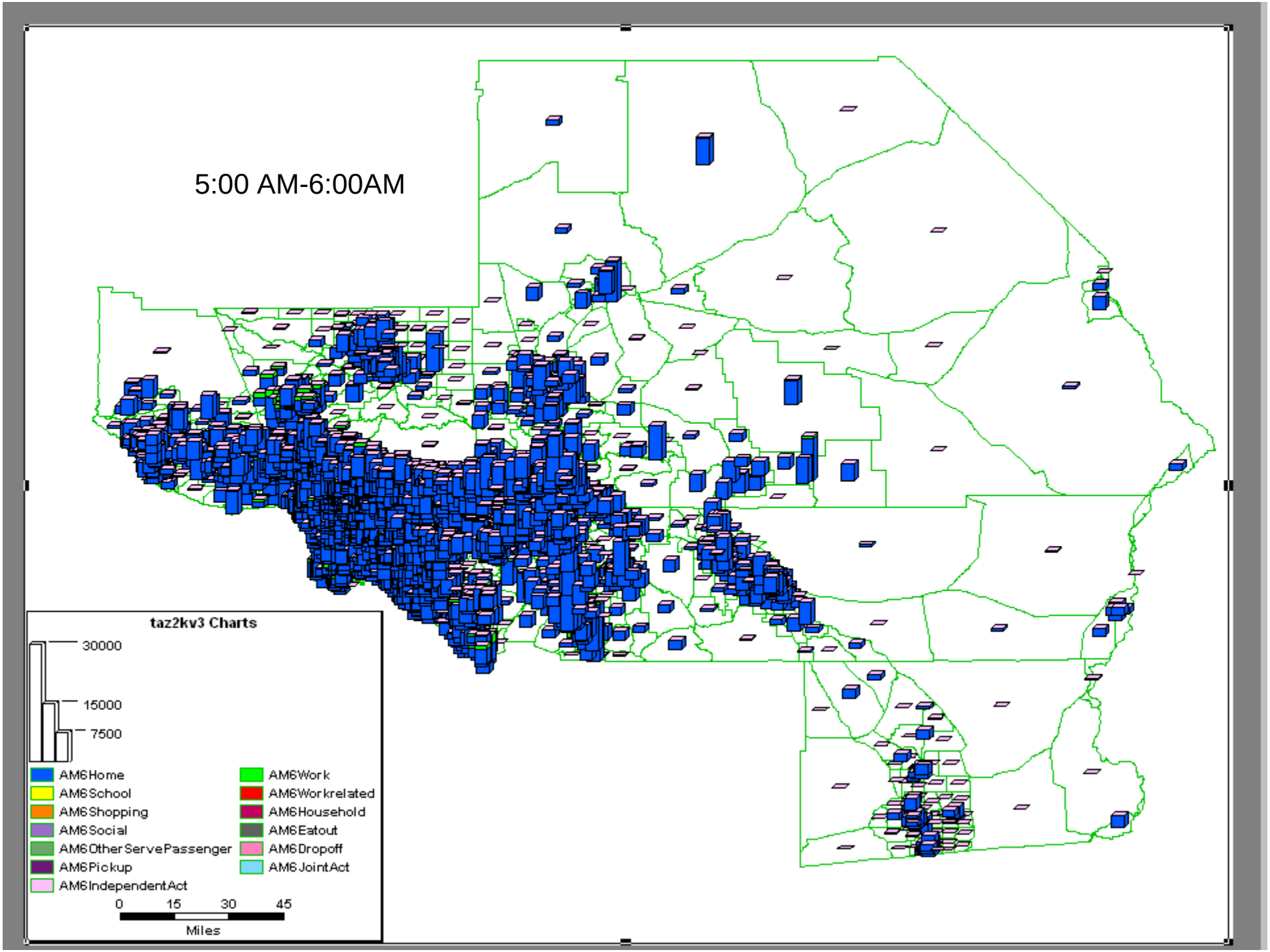
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AM6Pickup
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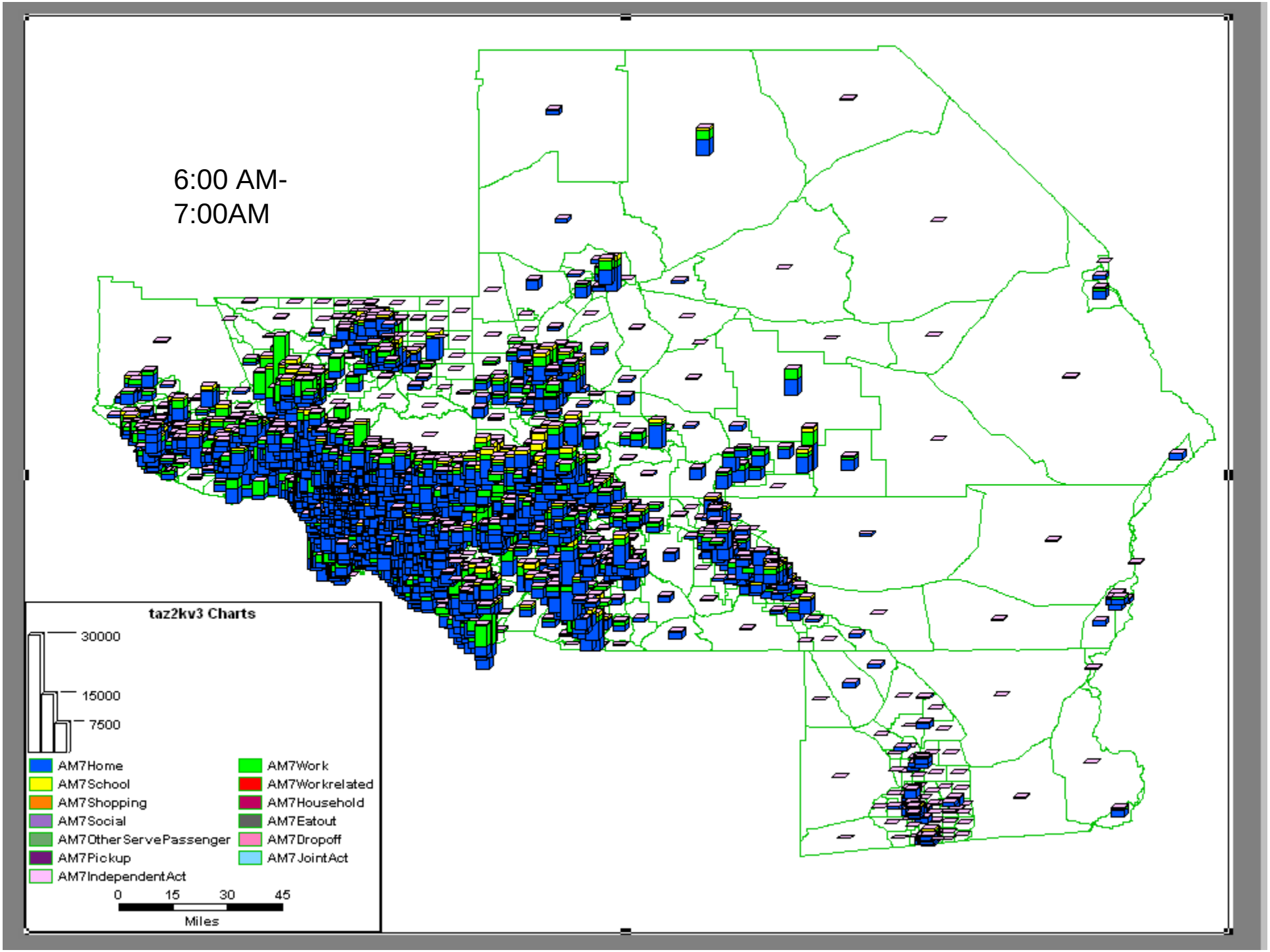
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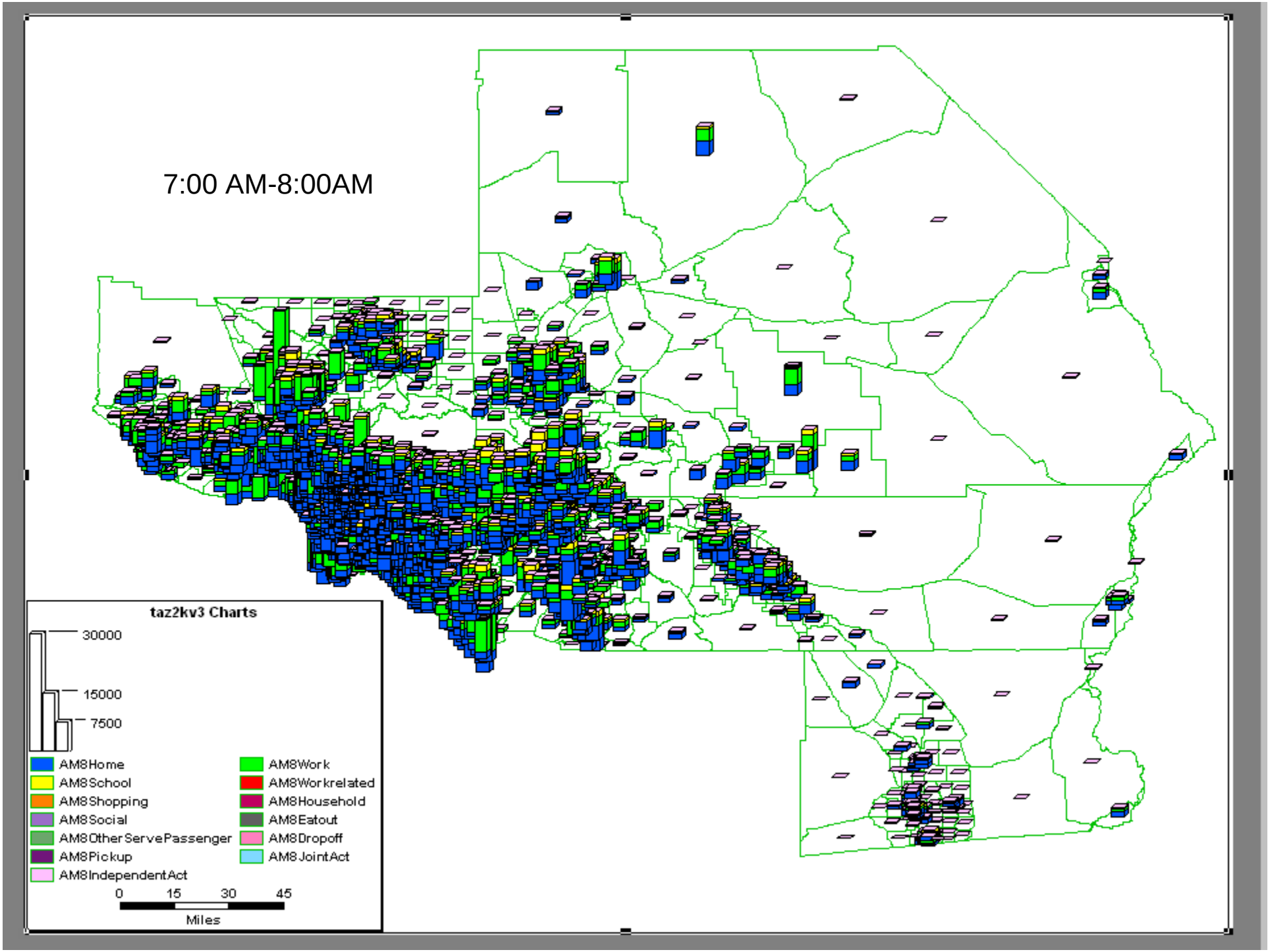
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AM8Pickup
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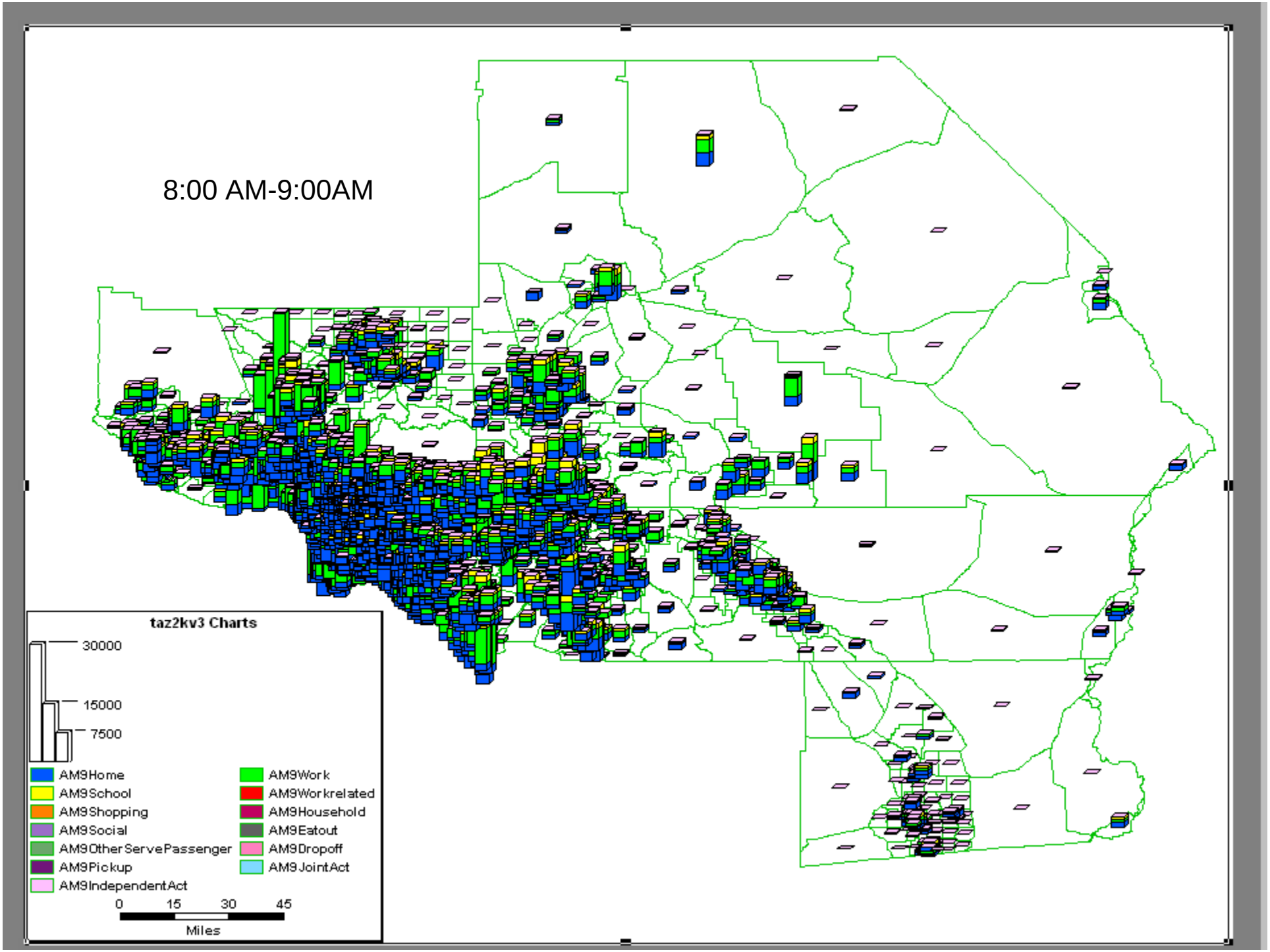
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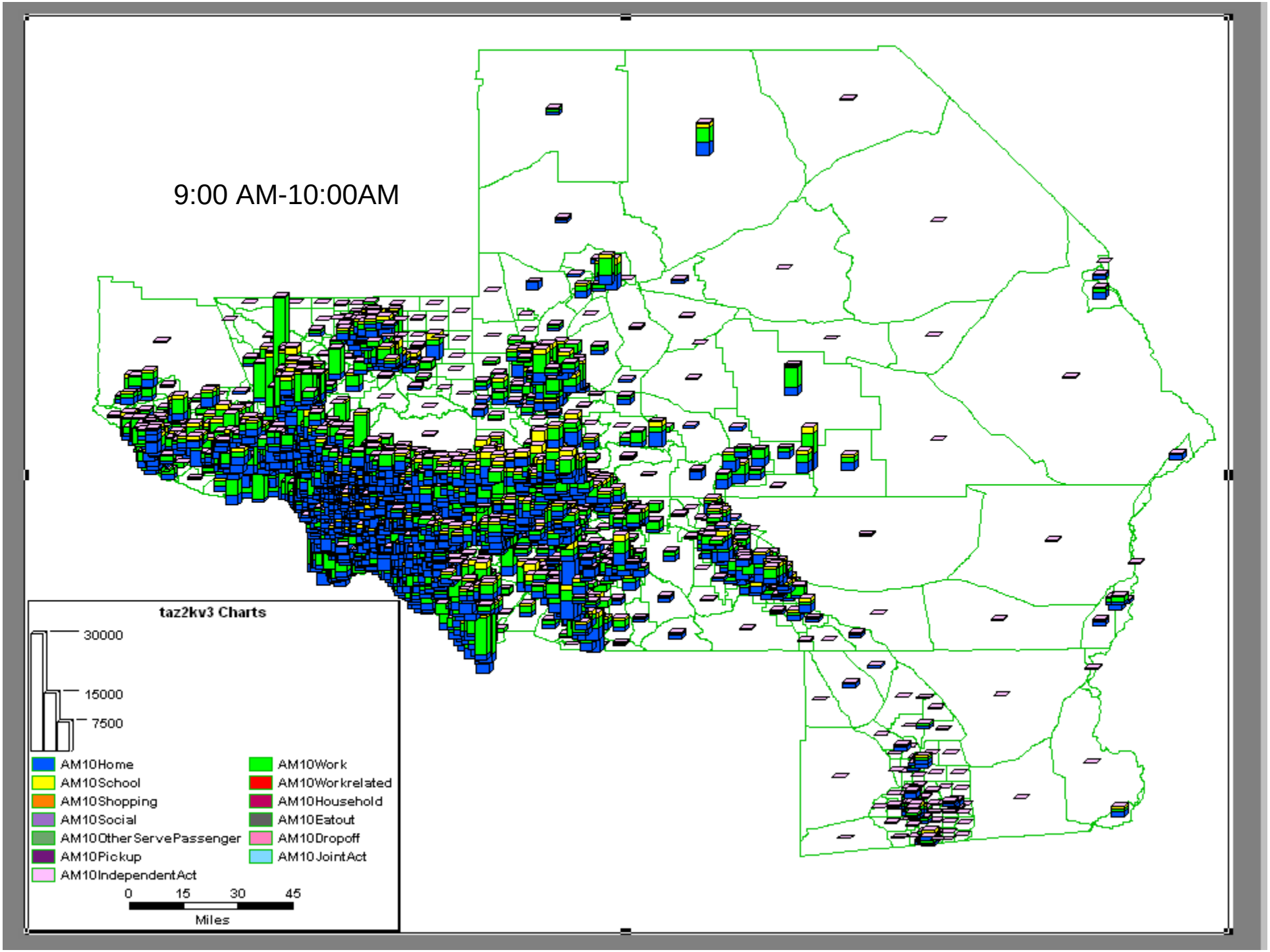
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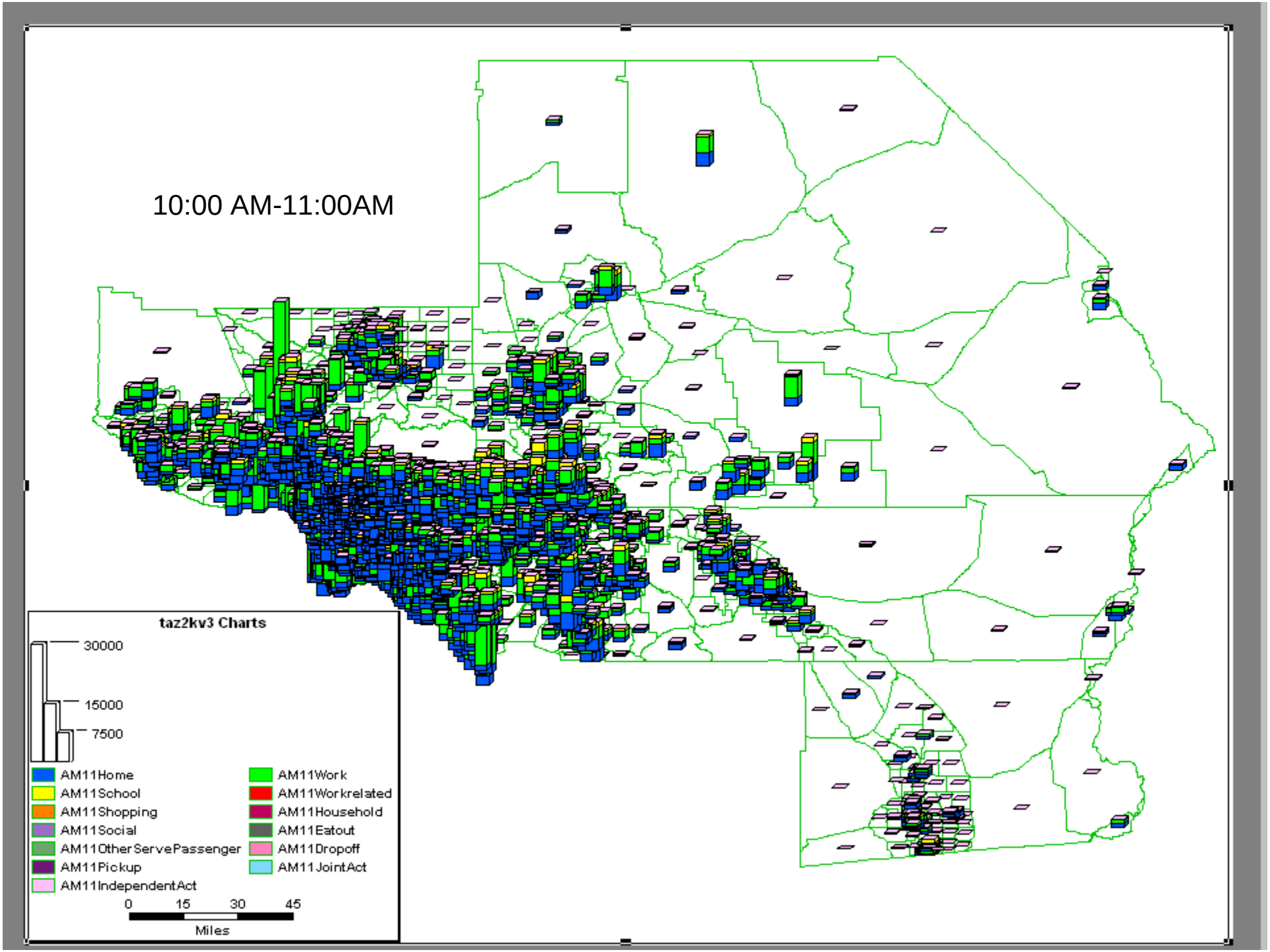
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AM11Work
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AM11Eatout
AM11Dropoff
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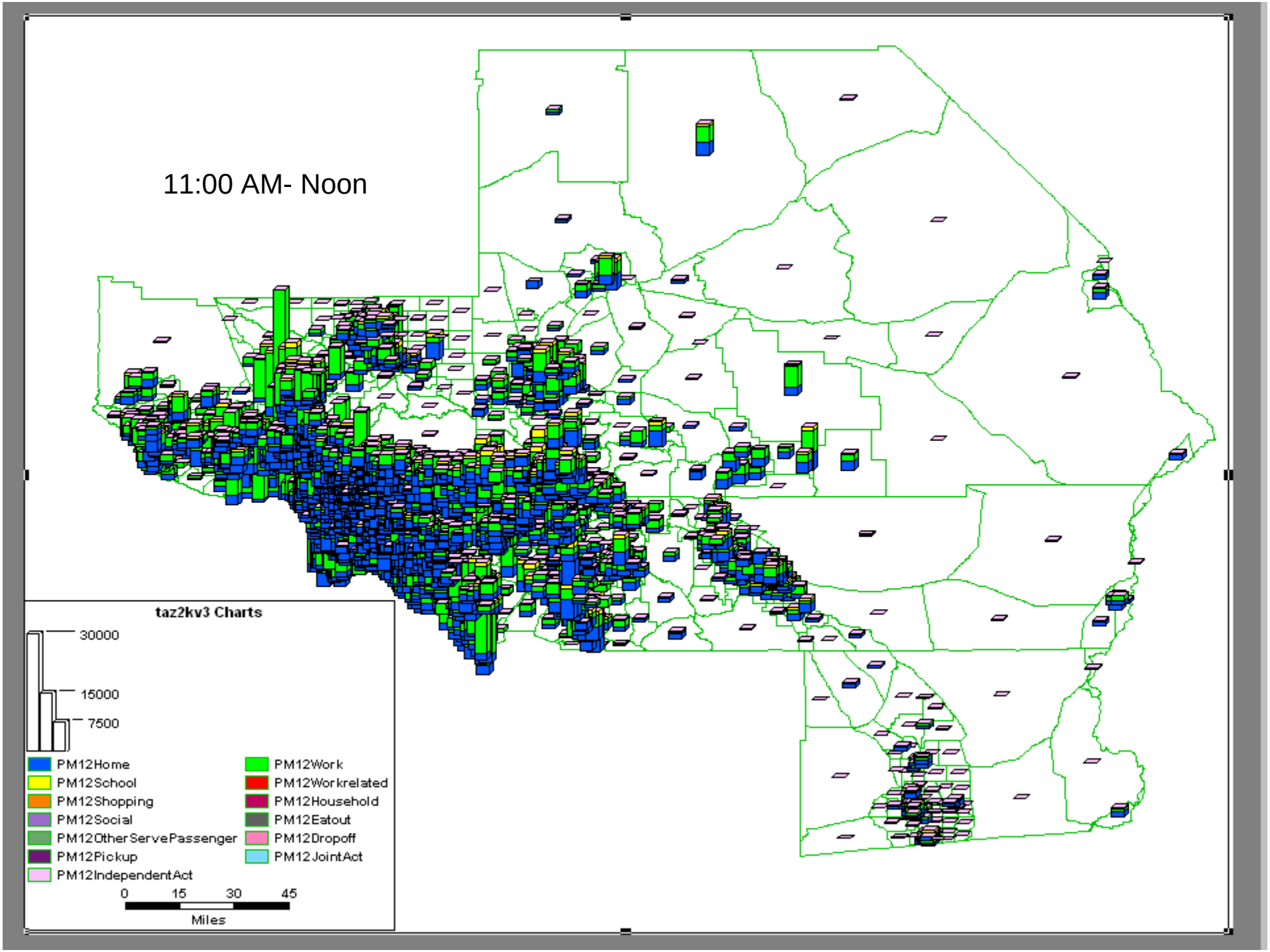
Miles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30000
15000
7500
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PM12School
PM12Shopping
PM12Social
PM12OtherServePassenger
PM12Pickup
PM12IndependentAct
PM12Work
PM12Workrelated
PM12Household
PM12Eatout
PM12Dropoff
PM12JointAct
0
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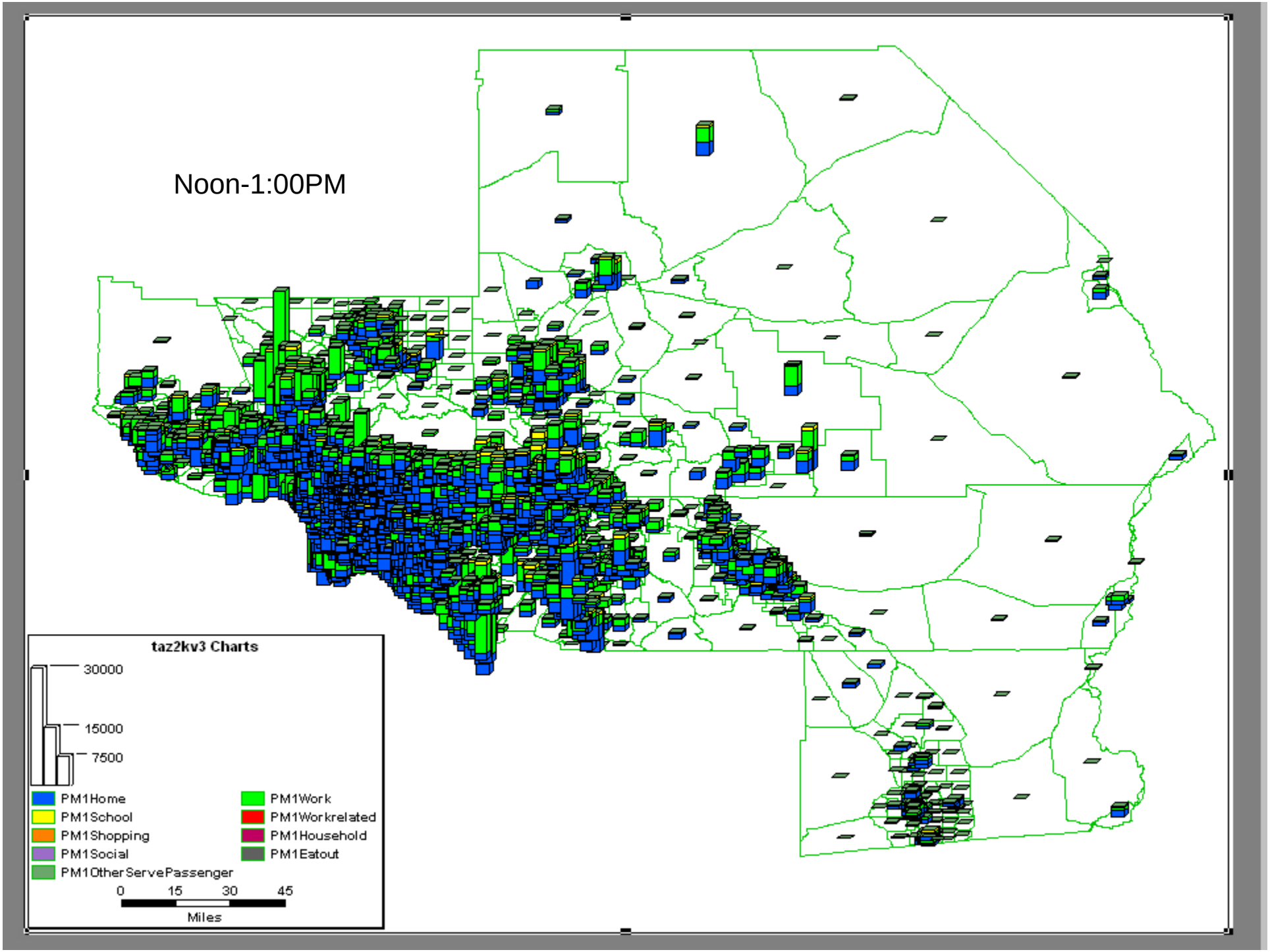
Miles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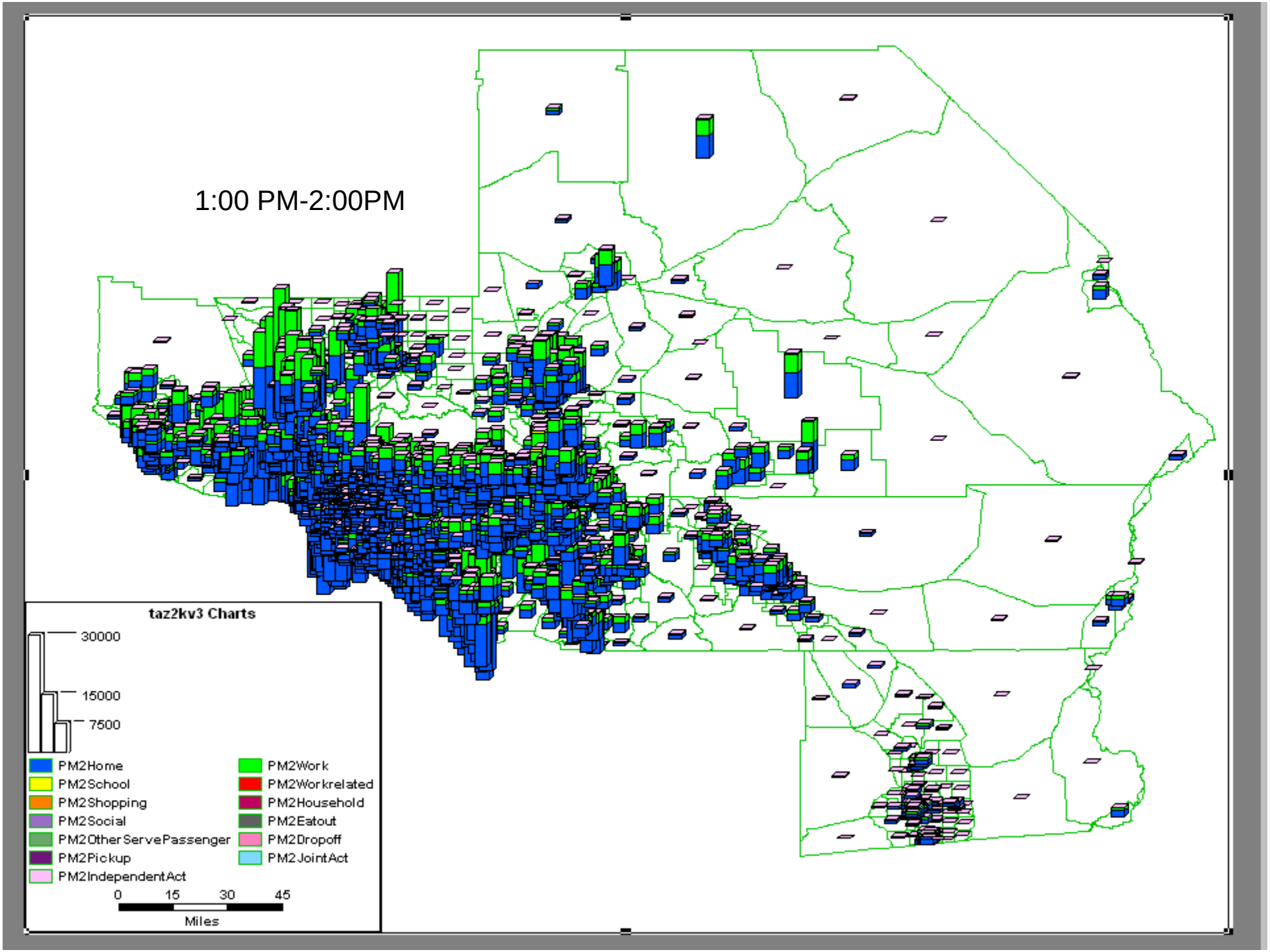
Miles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PM2Pickup
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PM2Household
PM2Eatout
PM2Dropoff
PM2JointAct
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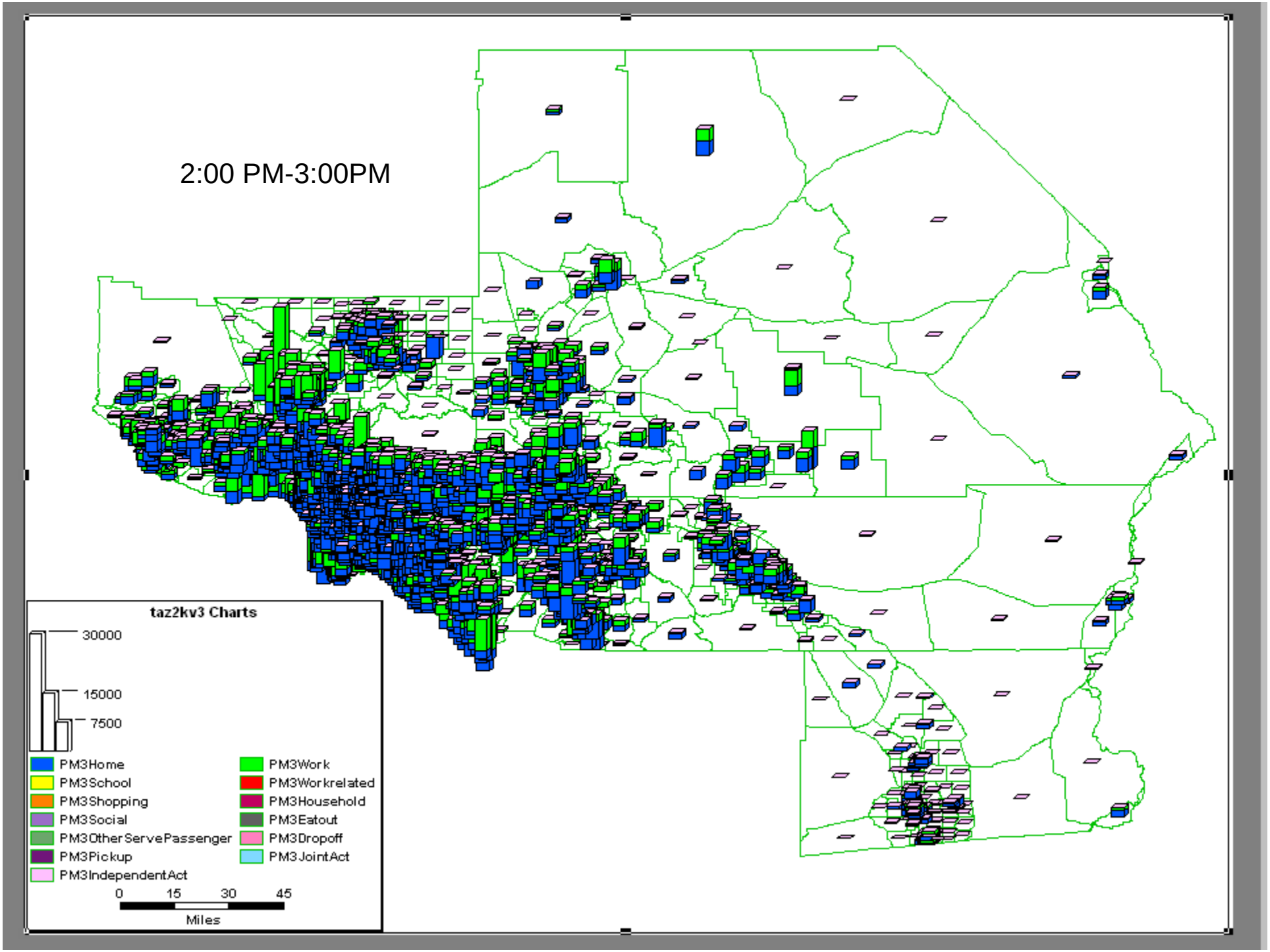
Miles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PM3Pickup
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PM3Work
PM3Workrelated
PM3Household
PM3Eatout
PM3Dropoff
PM3JointAct
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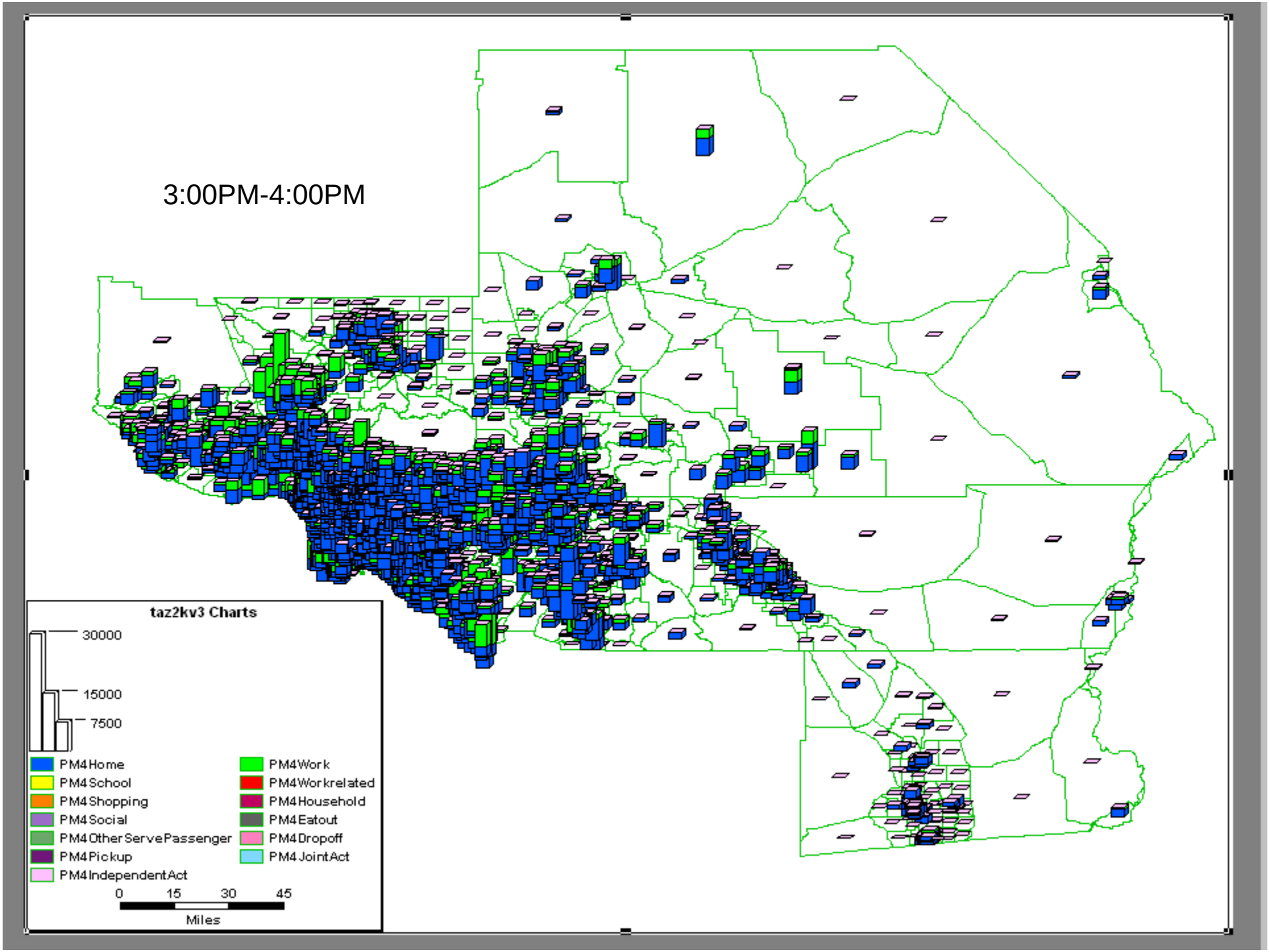
Miles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PM4Pickup
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PM4Dropoff
PM4JointAct
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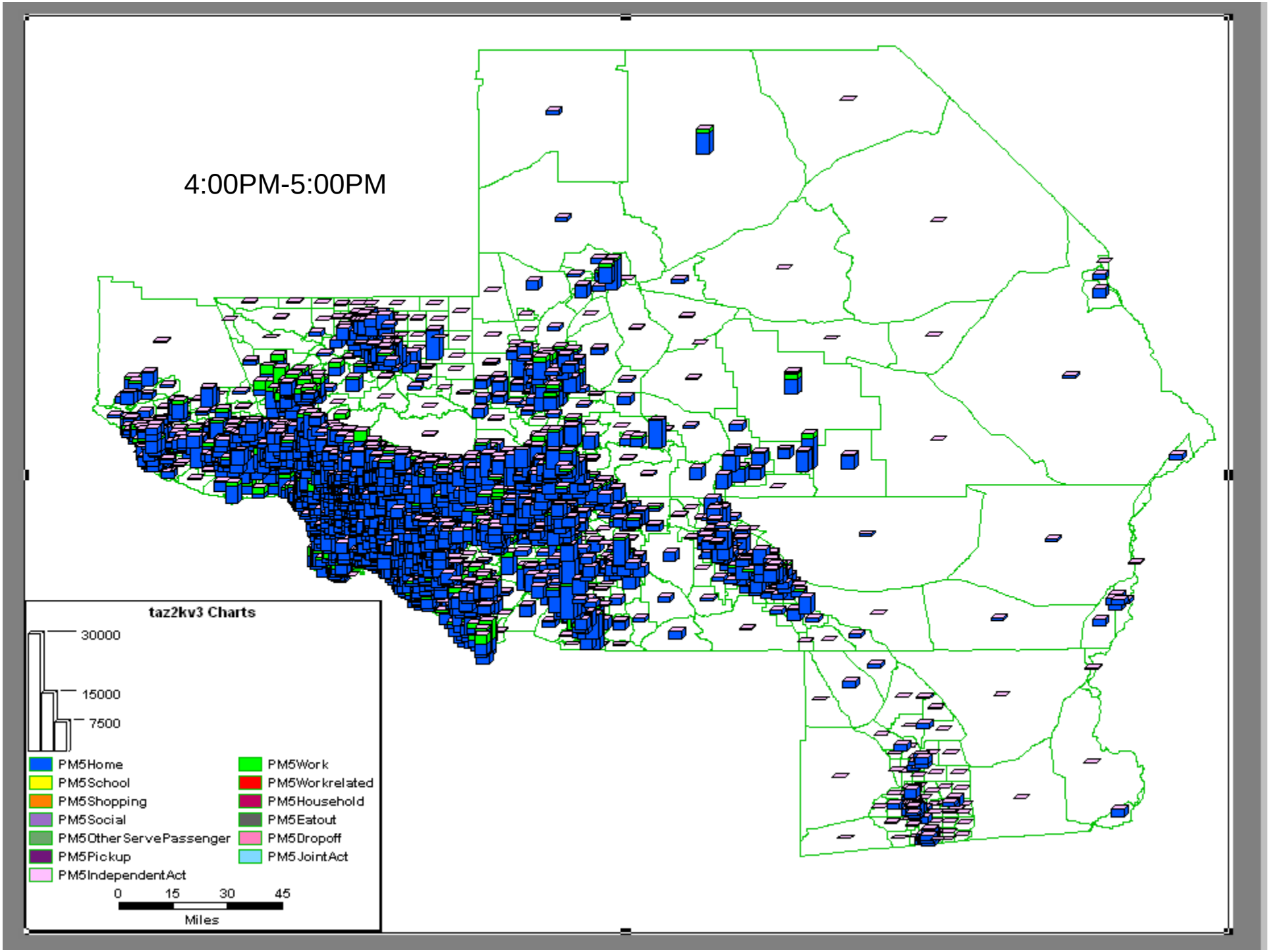
Miles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PM5Social
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PM5Pickup
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PM5Dropoff
PM5JointAct
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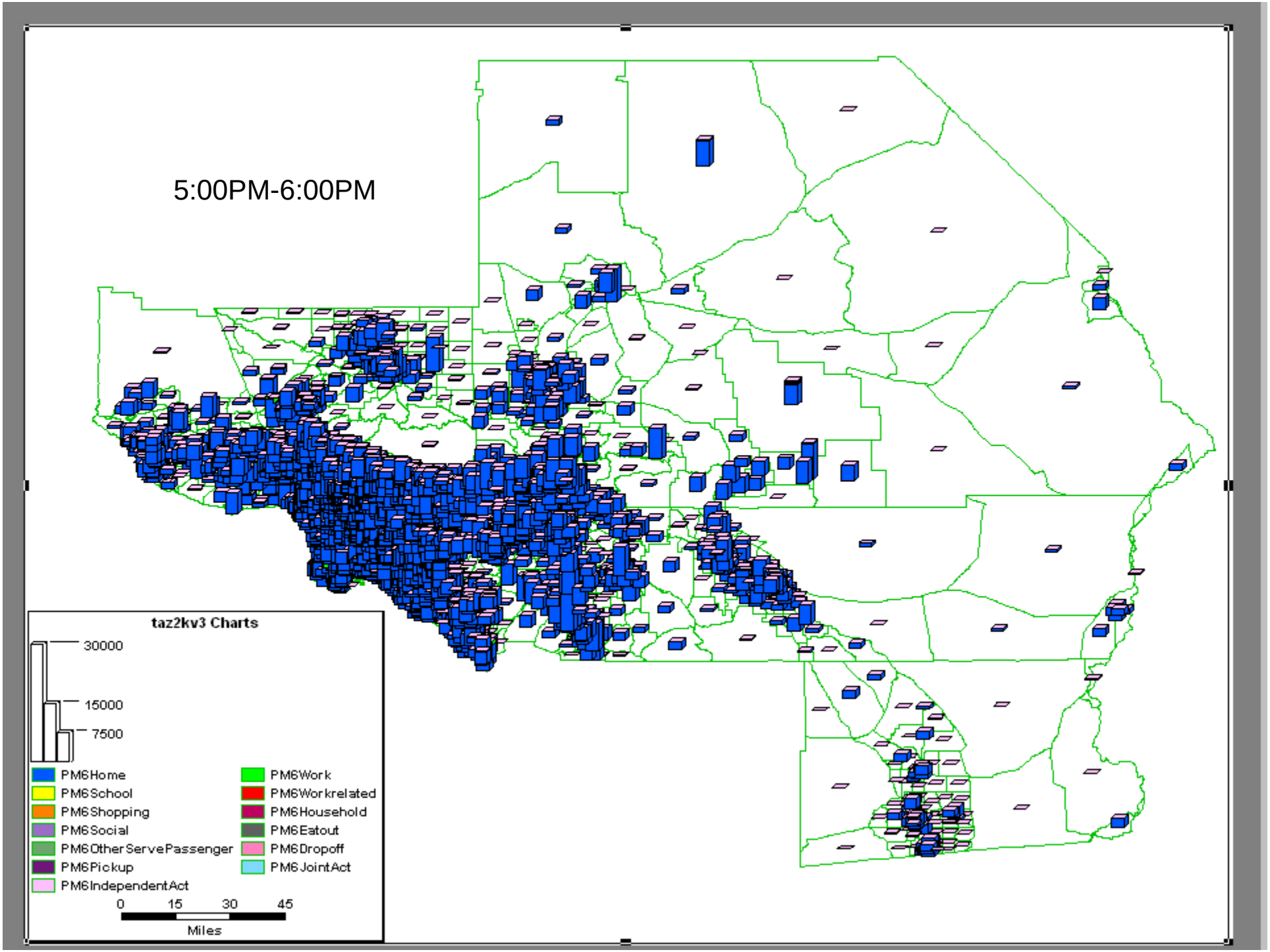
Miles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PM6Eatout
PM6Dropoff
PM6JointAct
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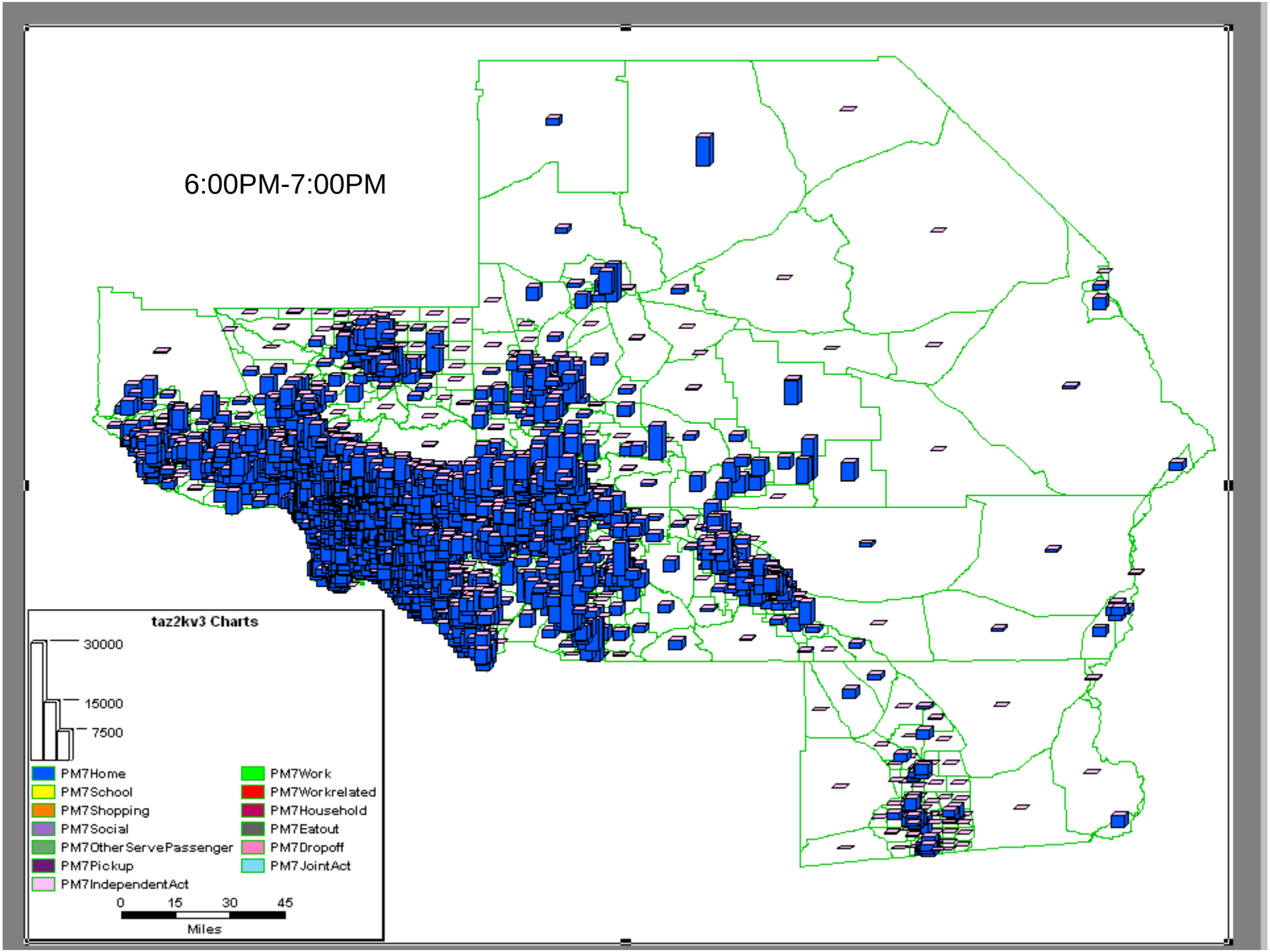
Miles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15000
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PM7School
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PM7Eatout
PM7Dropoff
PM7JointAct
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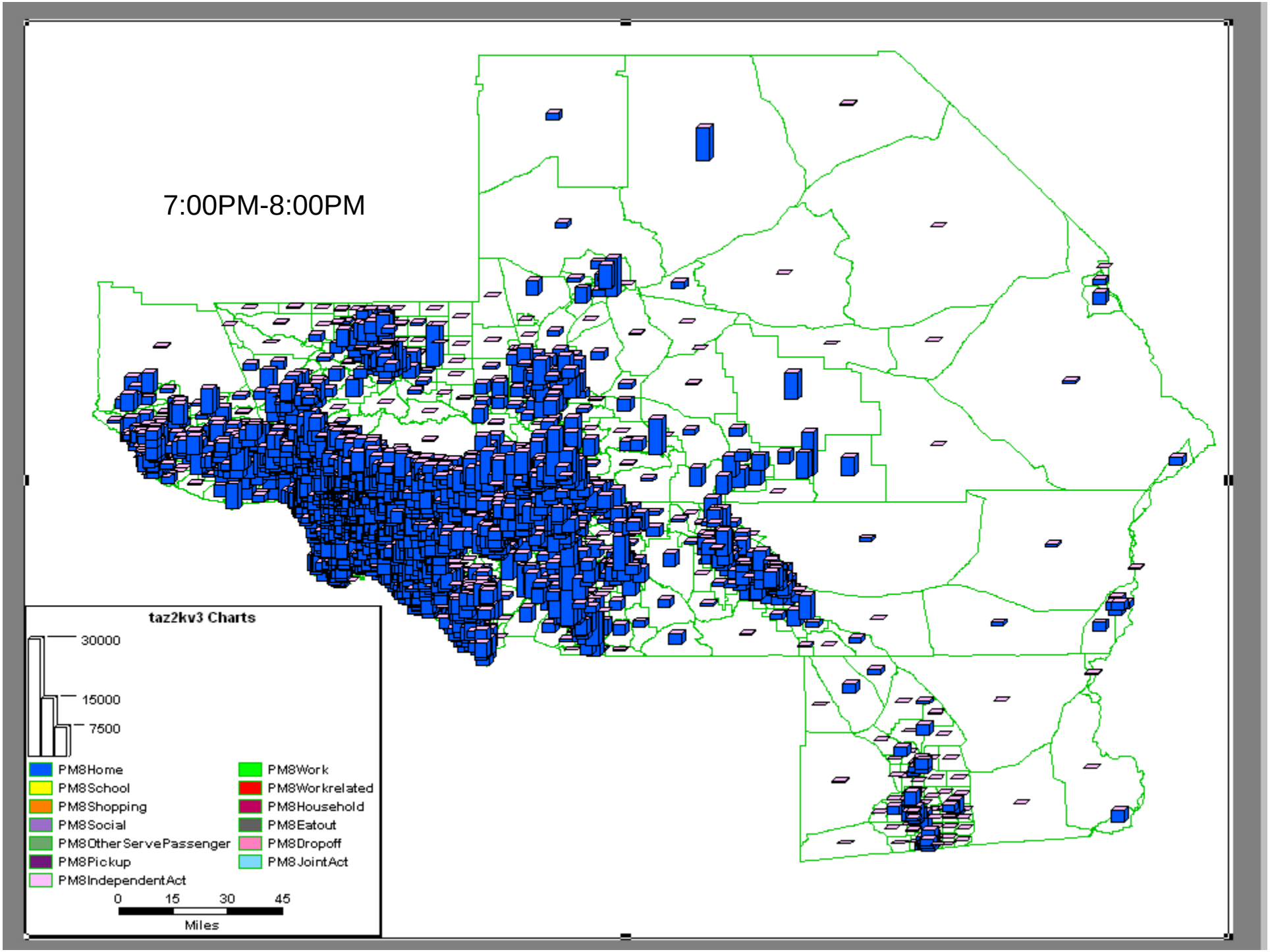
Miles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PM8School
PM8Shopping
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PM8Pickup
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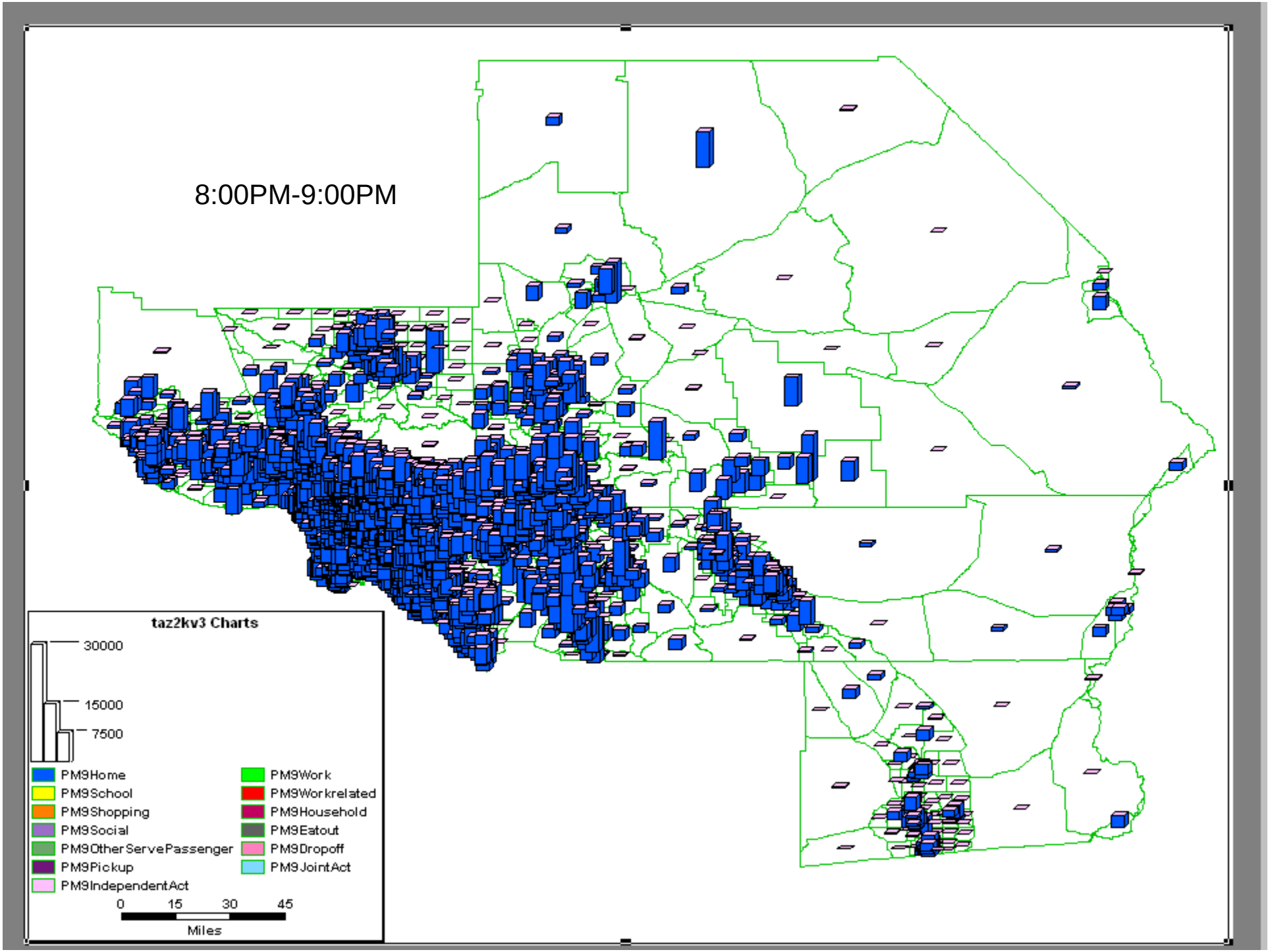
Miles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PM9Pickup
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PM9Dropoff
PM9JointAct
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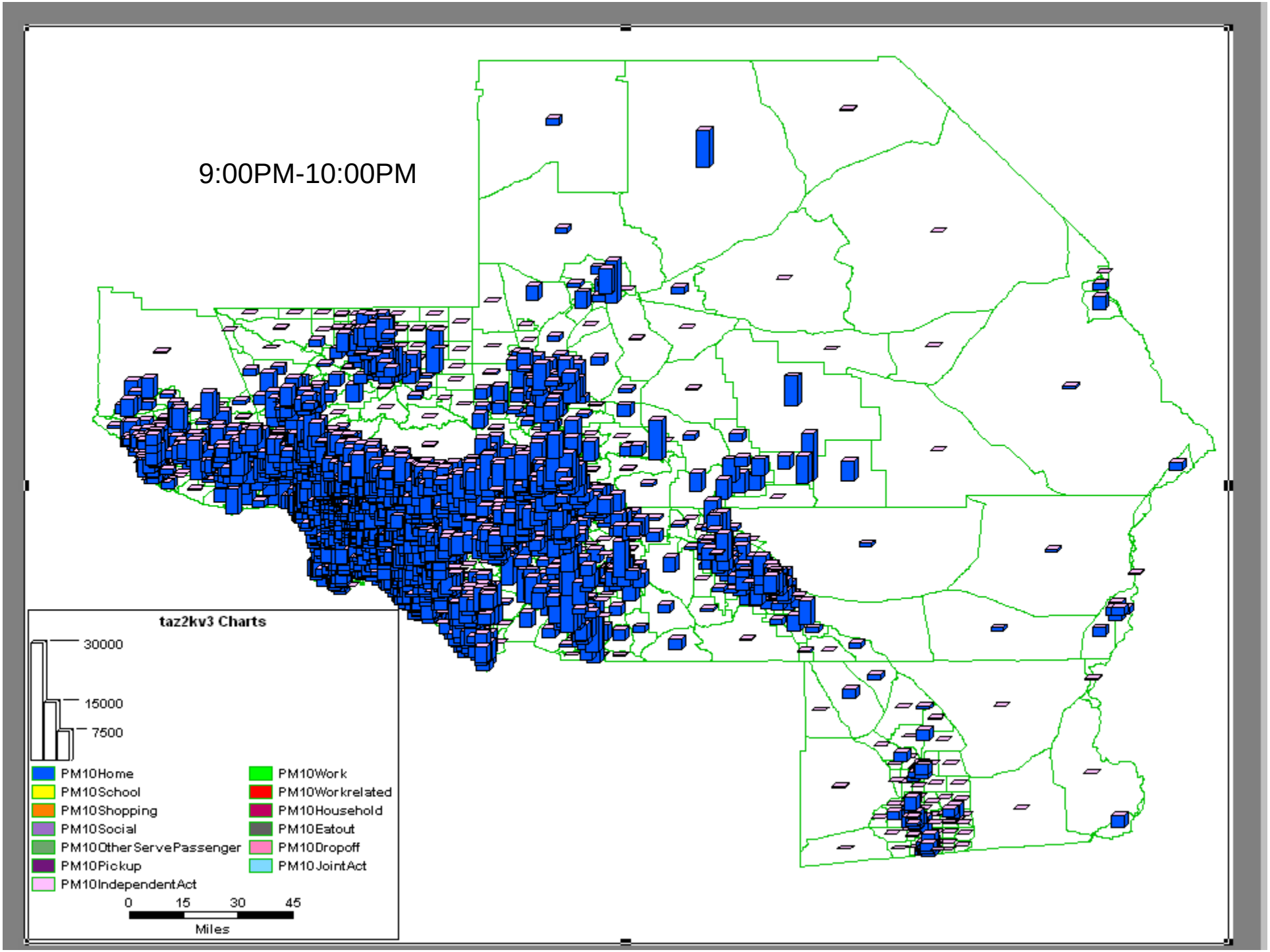
Miles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PM10Dropoff
PM10JointAct
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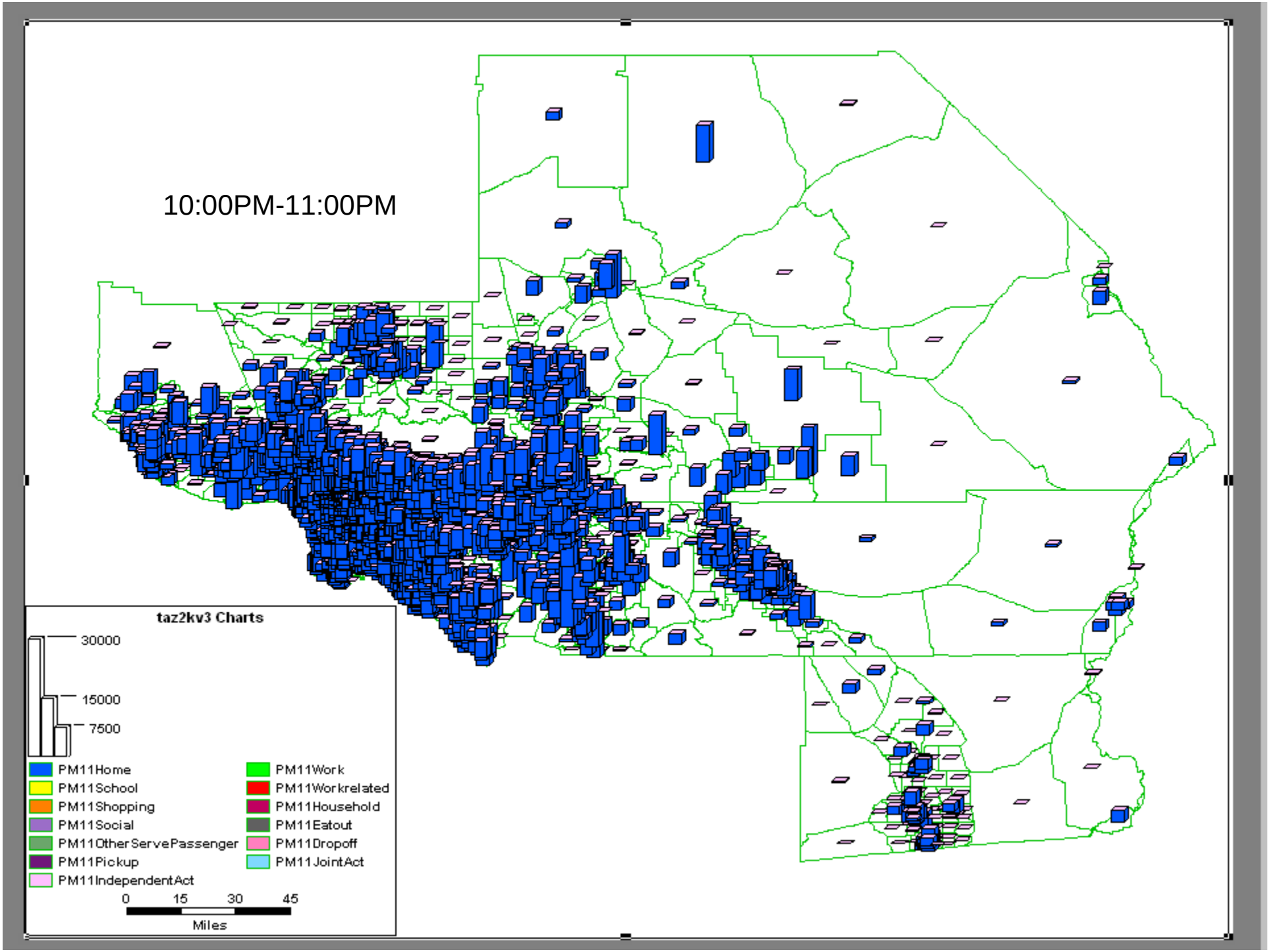
Miles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PM11Pickup
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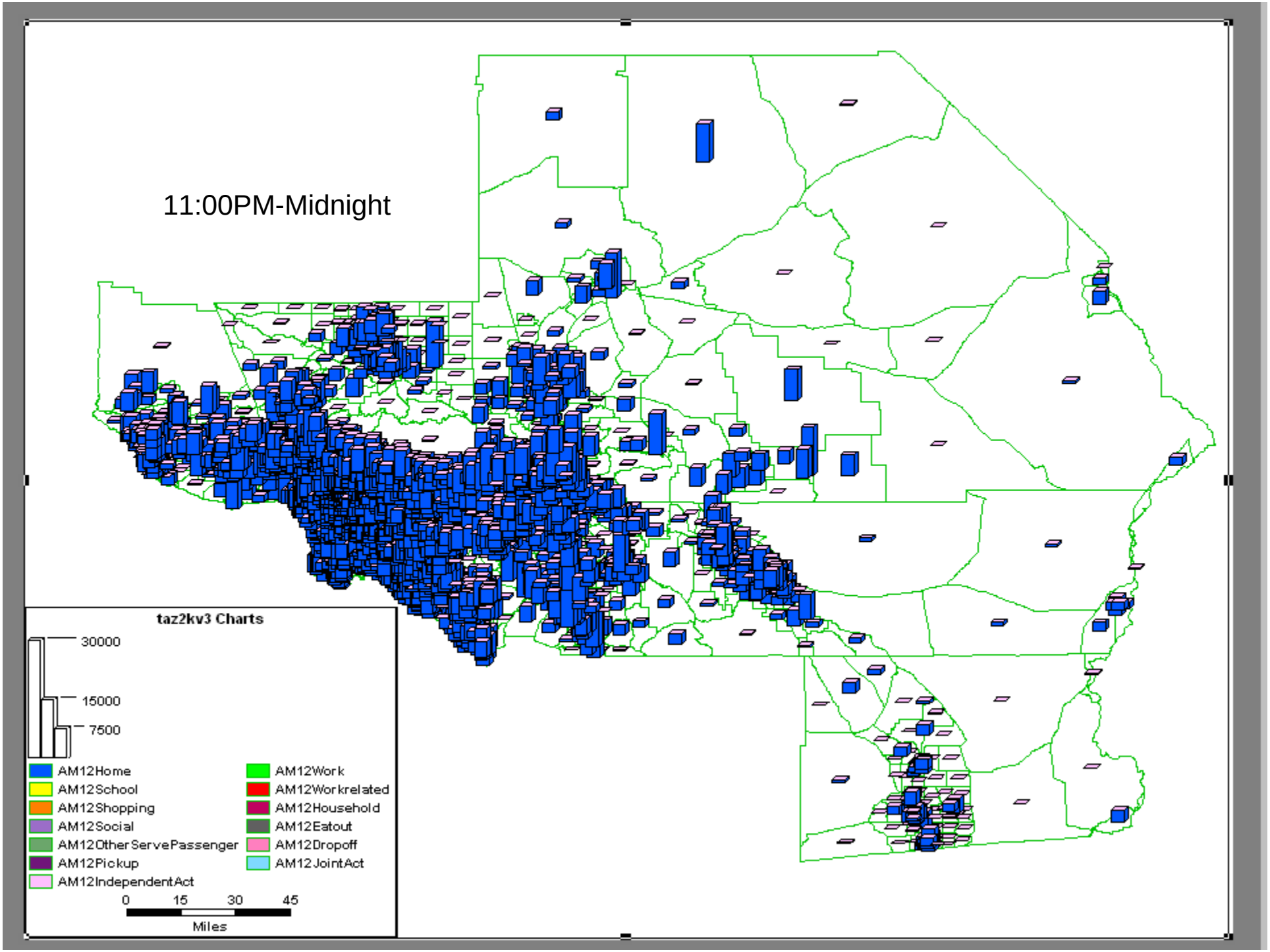
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AM12Shopping
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AM12OtherServePassenger
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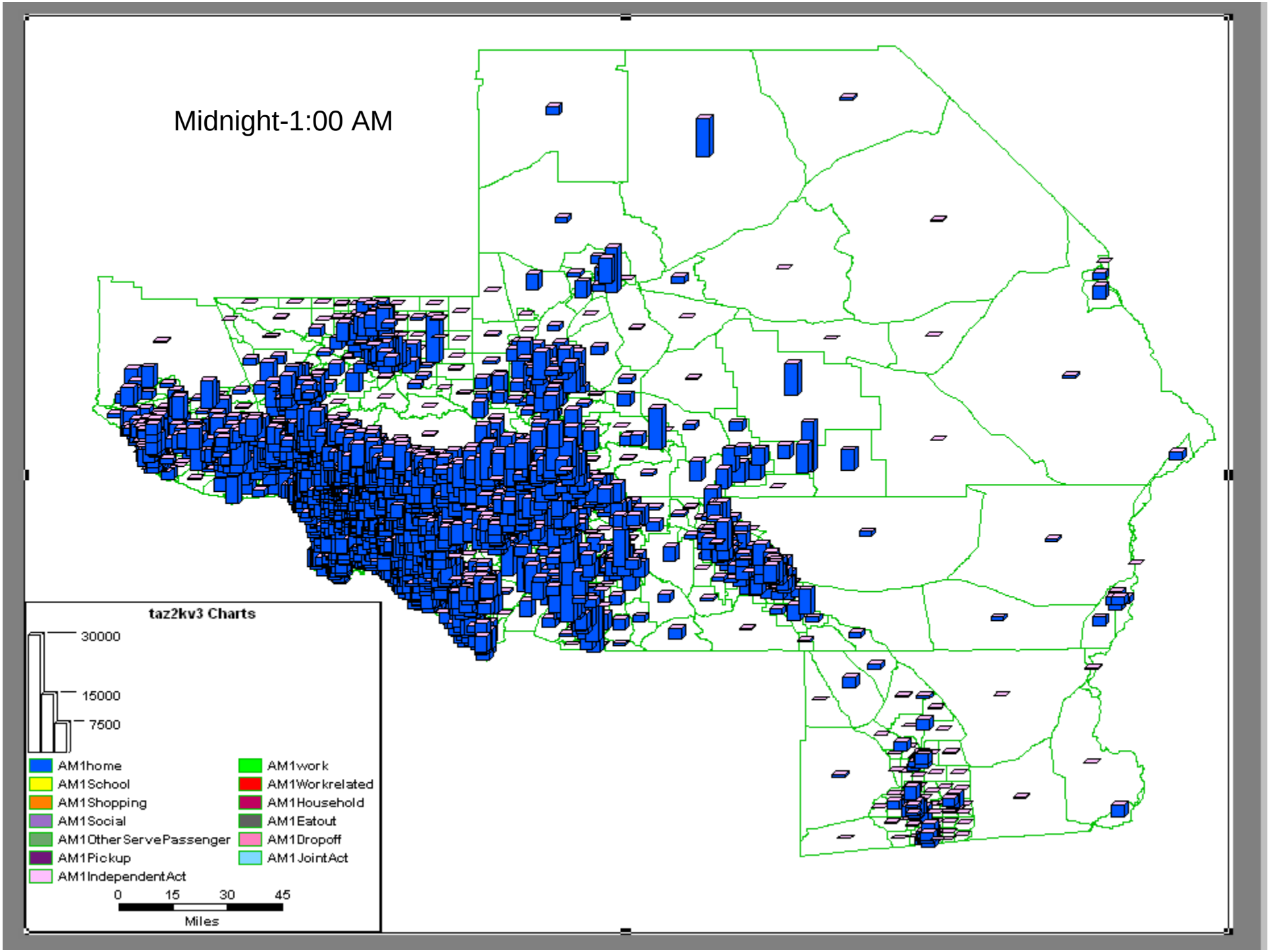
Midnight-1:00 AM
taz2kv3 Charts
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7500
AM1home
AM1work
AM1School
AM1Workrelated
AM1Shopping
AM1Household
AM1Social
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AM1Dropoff
AM1Pickup
AM1JointAct
AM1IndependentAct
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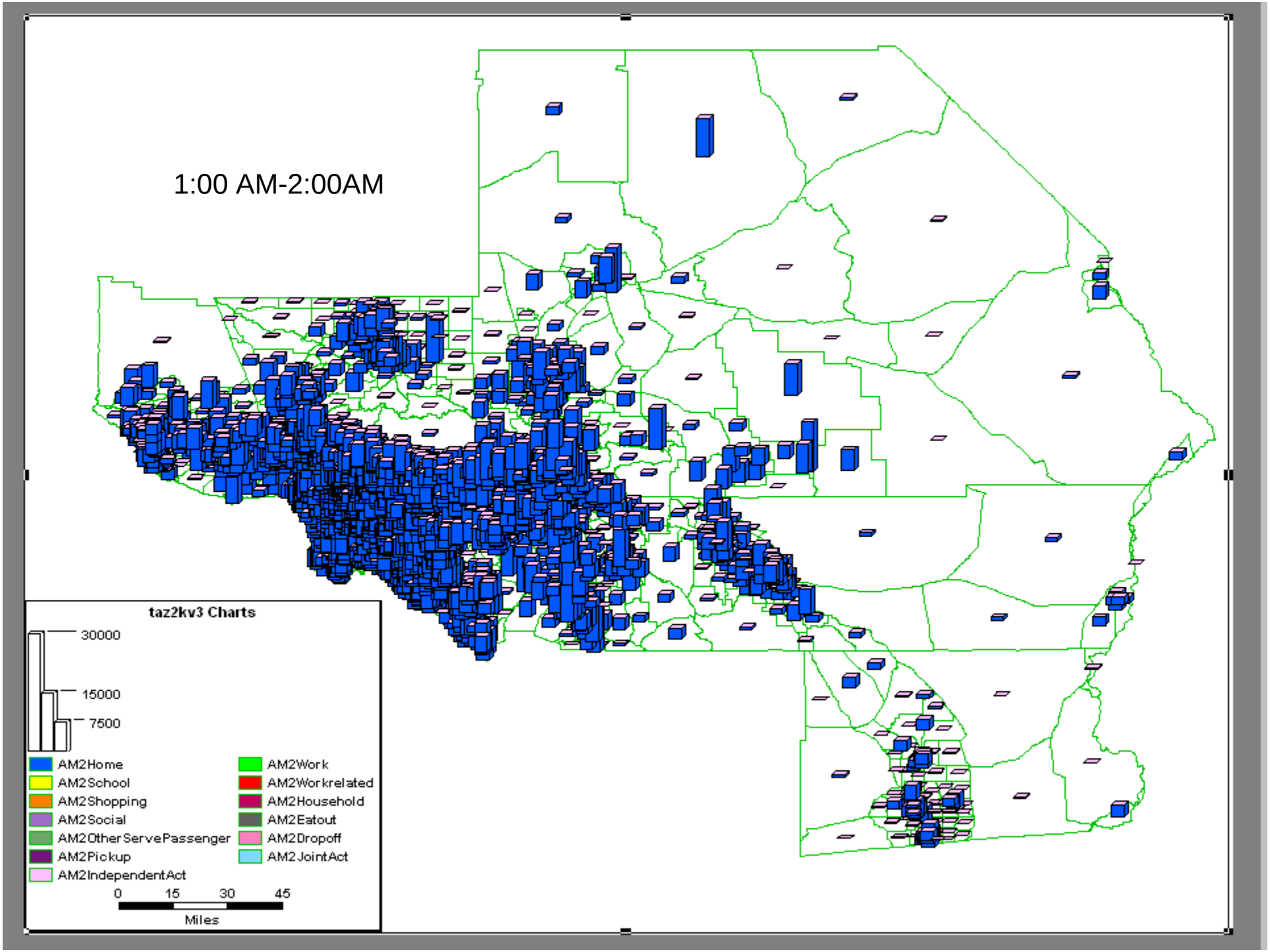
1:00 AM-2:00AM
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AM2Home
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AM2OtherServePassenger
AM2Pickup
AM2IndependentAct
AM2Work
AM2Workrelated
AM2Household
AM2Eatout
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Miles

PSRC Model Design
(Bowman, Bradley, Castiglione)

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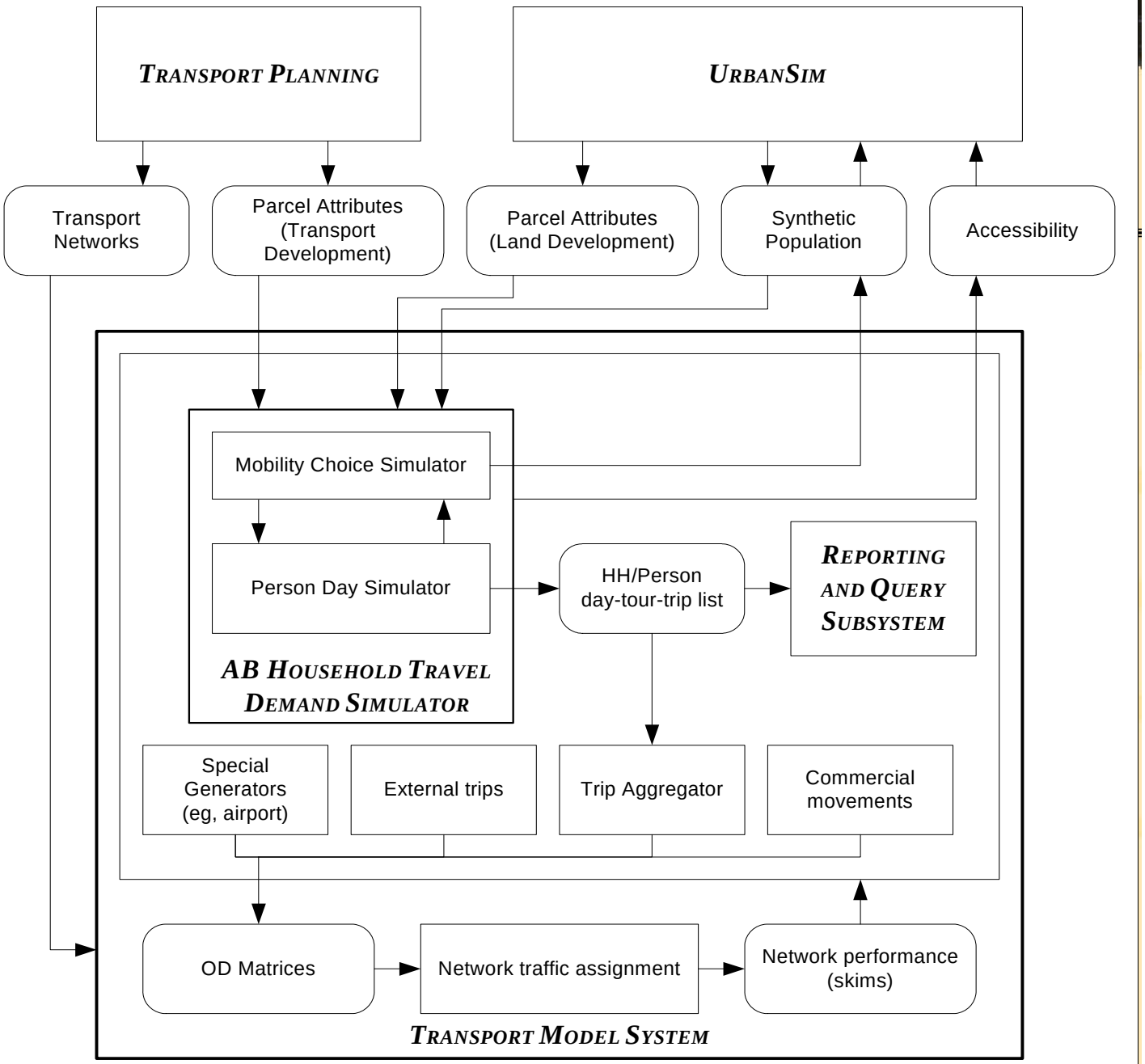
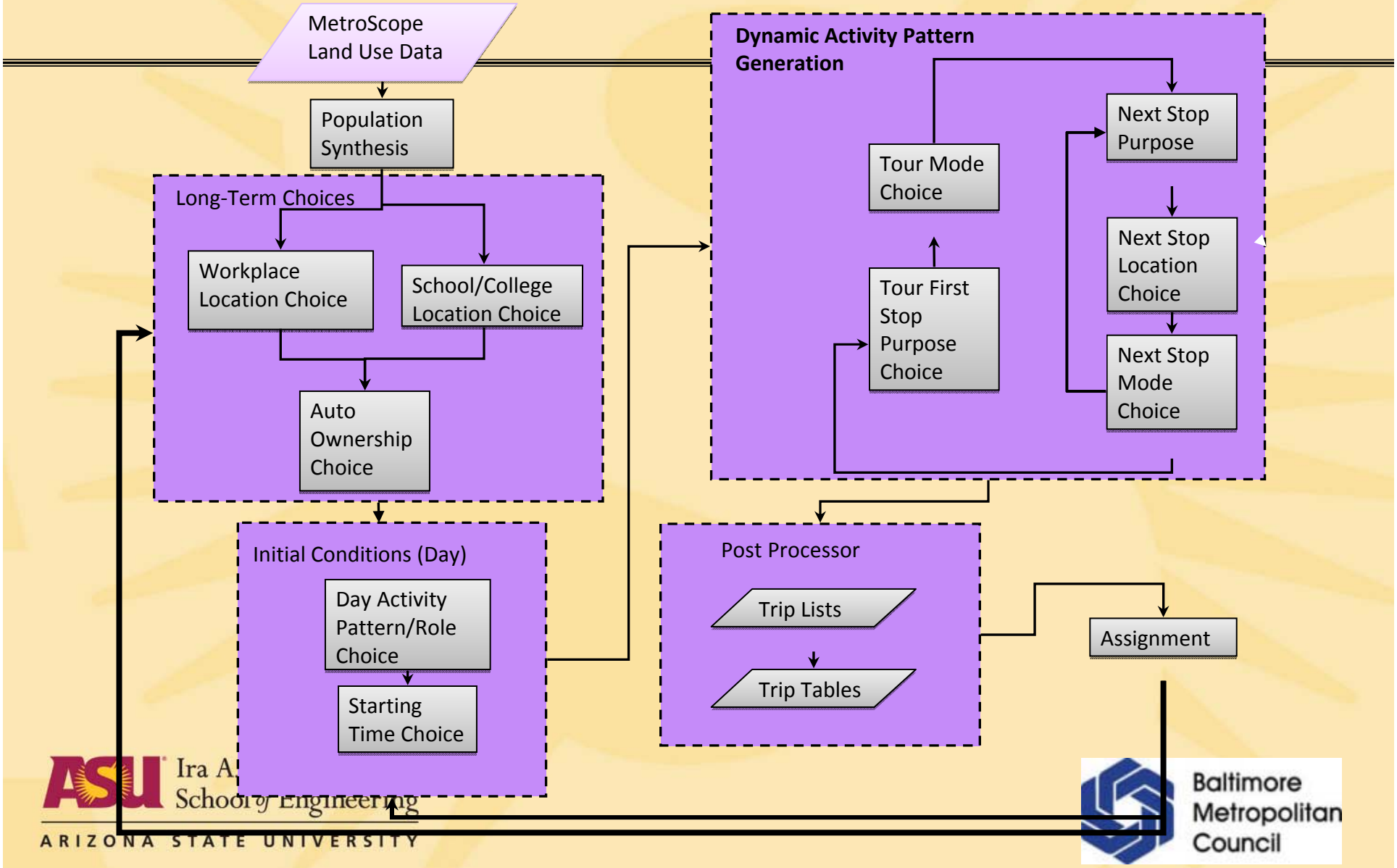


OPUS FRAMEWORK

Activity-Based Model System - DASH(Gliebe)



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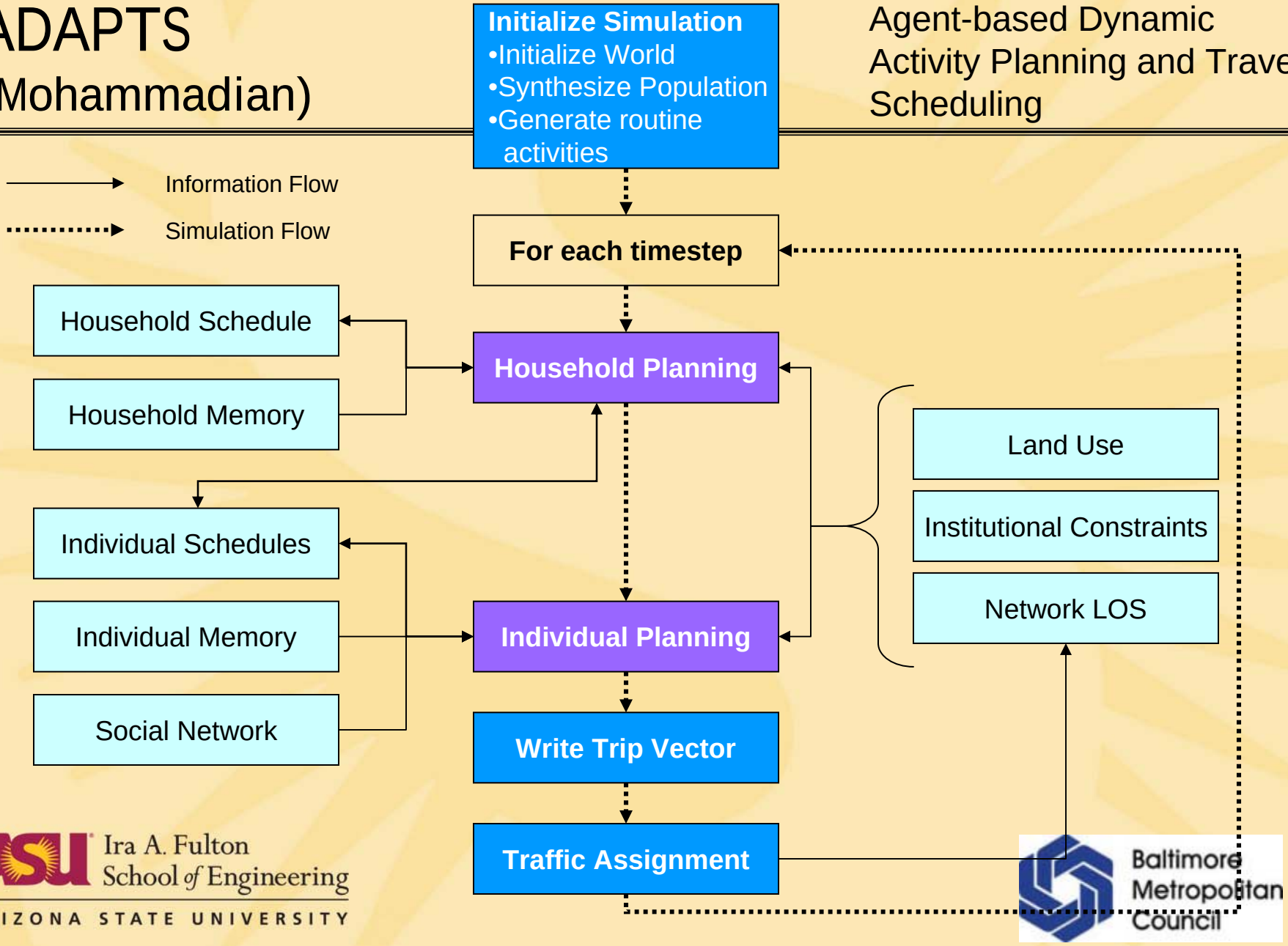
ADAPTS (Mohammadian)

Agent-based Dynamic Activity Planning and Travel Scheduling



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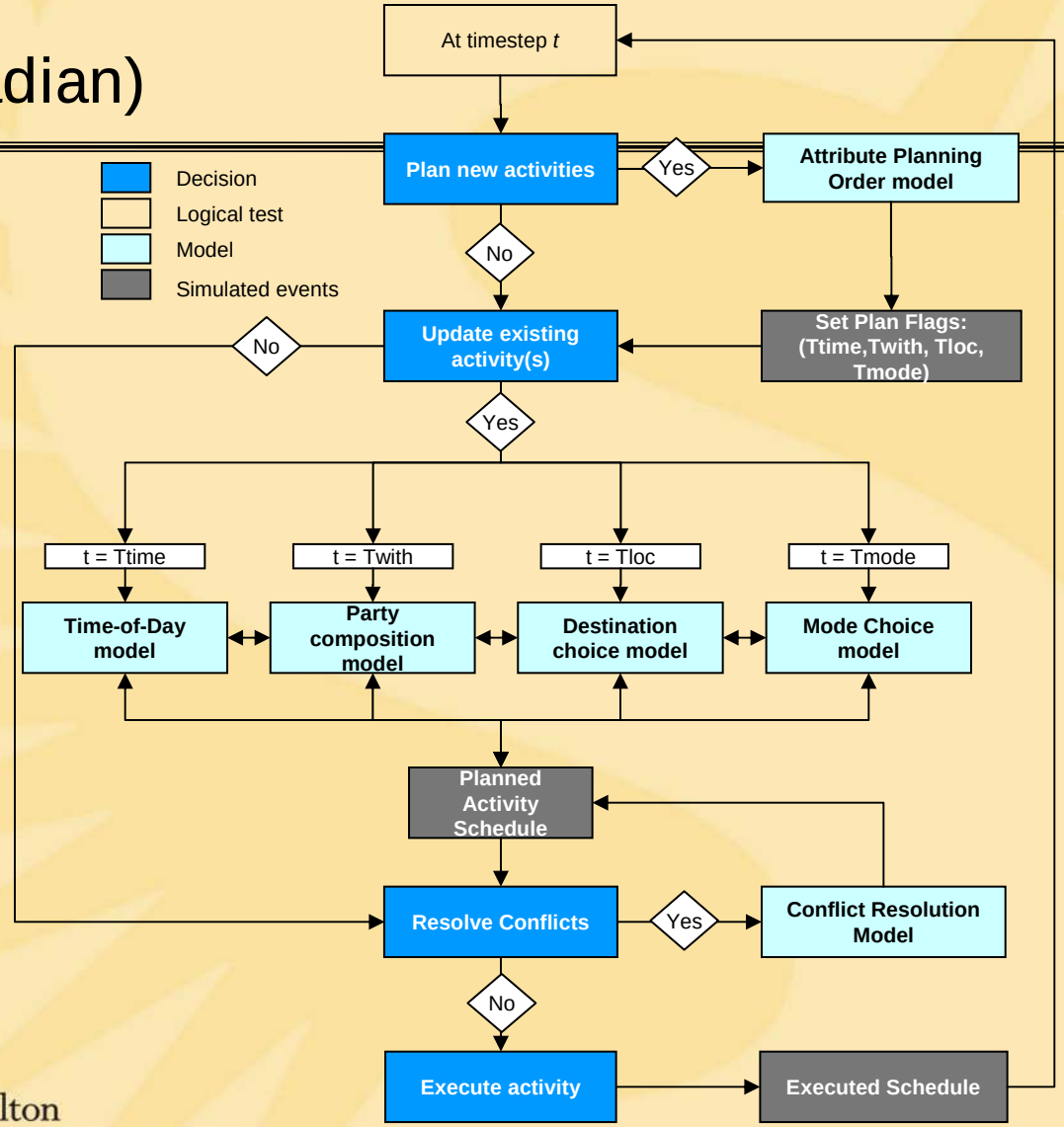
Baltimore Metropolitan Council

ADAPTS
(Mohammadian)



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ALBATROSS (Timmermans/Arentze)

- A learning-based activity-based travel model system
- Employs theories of choice heuristics to represent behavioral processes
- Decision tree approaches used to formalize heuristics and predict choice behavior
- Explicit consideration of multitude of constraints

ALBATROSS (Timmermans/Arentze)

- *Albatross* assumes that choice behavior is based on rules that are formed and continuously adapted through learning
- Individual interacts with the environment (reinforcement learning) or communicates with others (social learning)
- *Albatross* is based on a learning theory which implies that rules governing choice behavior are:
  - heuristic
  - context-dependent
  - adaptive in nature

ALBATROSS (Timmermans/Arentze)

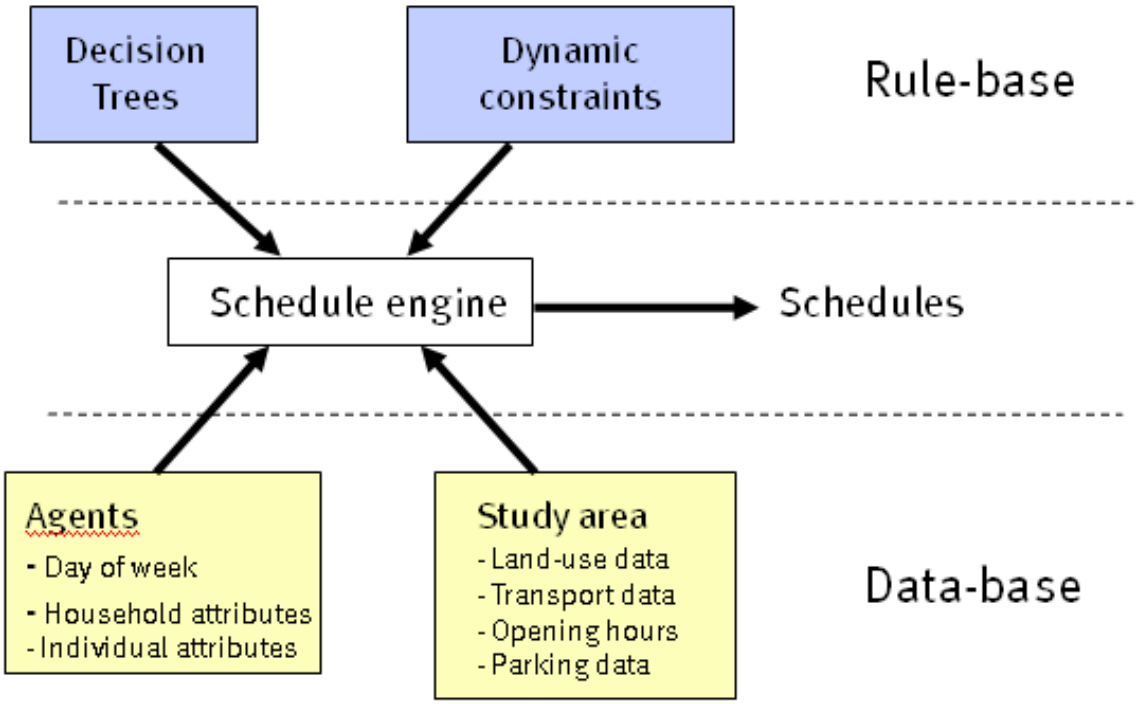
a-priori defined

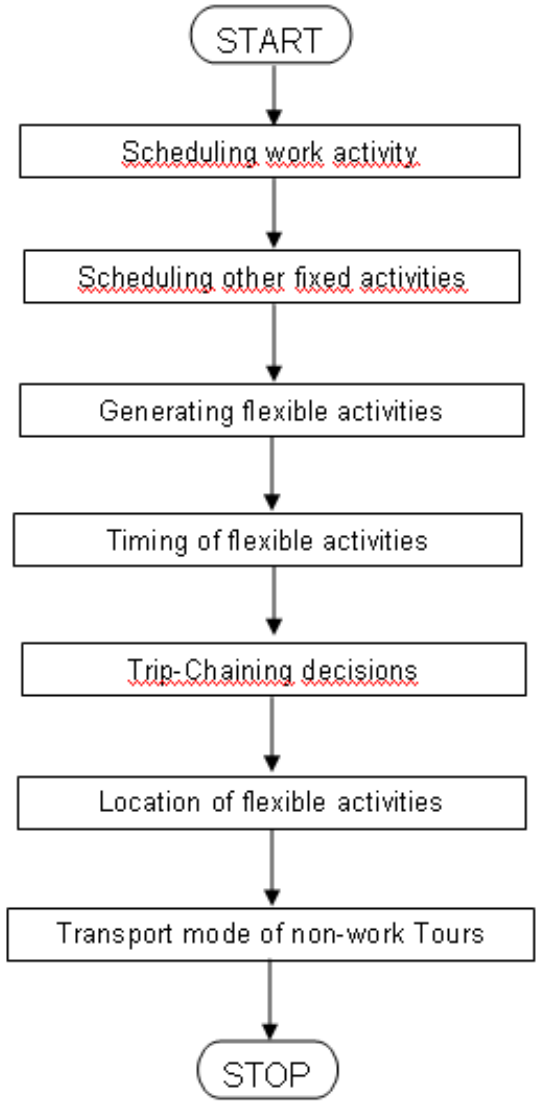
- Components:
  - a model of the sequential decision making process
  - models to compute dynamic constraints on choice options

derived from observed choice behavior

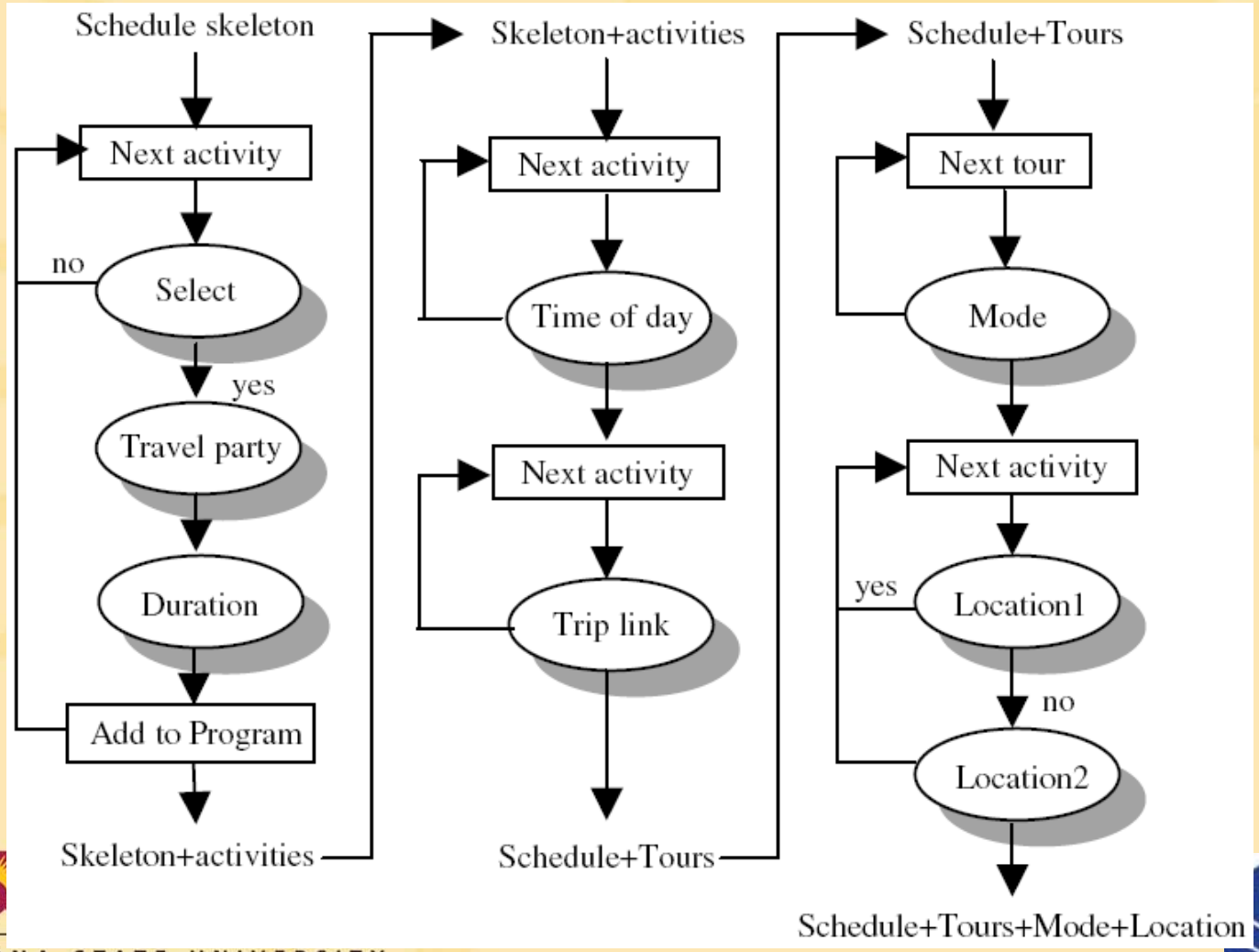
- A set of decision trees representing choice behavior of individuals related to each step in the process model

ALBATROSS (Timmermans/Arentze)





ALBATROSS (Timmermans/Arentze)



ALBATROSS (Timmermans/Arentze)

Rule-Based Heuristics

Let L be the choice set for the given activity defined by Eqs. (1)–(4), $L^+ \subseteq L$ be the subset of non-inferior locations, t_l^t be the travel time to location l, $r_1 < r_2 < r_3 < \cdots < r_m$ be pre-defined critical travel times of increasing lengths, $R_r \subseteq L$ be the subset of locations reachable within travel time r. Then, the heuristics can be written as

h_1 : choose location l if $l \in L^+ \wedge t_l^t = \min_{l' \in L}(t_{l'}^t)$

h_2 : choose location l if $l \in L^+ \wedge o_l = \max_{l' \in L}(o_{l'})$

$h_{3.1}$: choose location l if $l \in L^+ \wedge l \in R_1 \wedge o_l = \max_{l' \in R_1}(o_{l'})$

$h_{3.2}$: choose location l if $l \in L^+ \wedge l \in R_2 \wedge o_l = \max_{l' \in R_2}(o_{l'})$

...

$h_{3.m}$: choose location l if $l \in L^+ \wedge l \in R_m \wedge o_l = \max_{l' \in R_m}(o_{l'})$

h_4 use some other heuristic

ALBATROSS (Timmermans/Arentze)

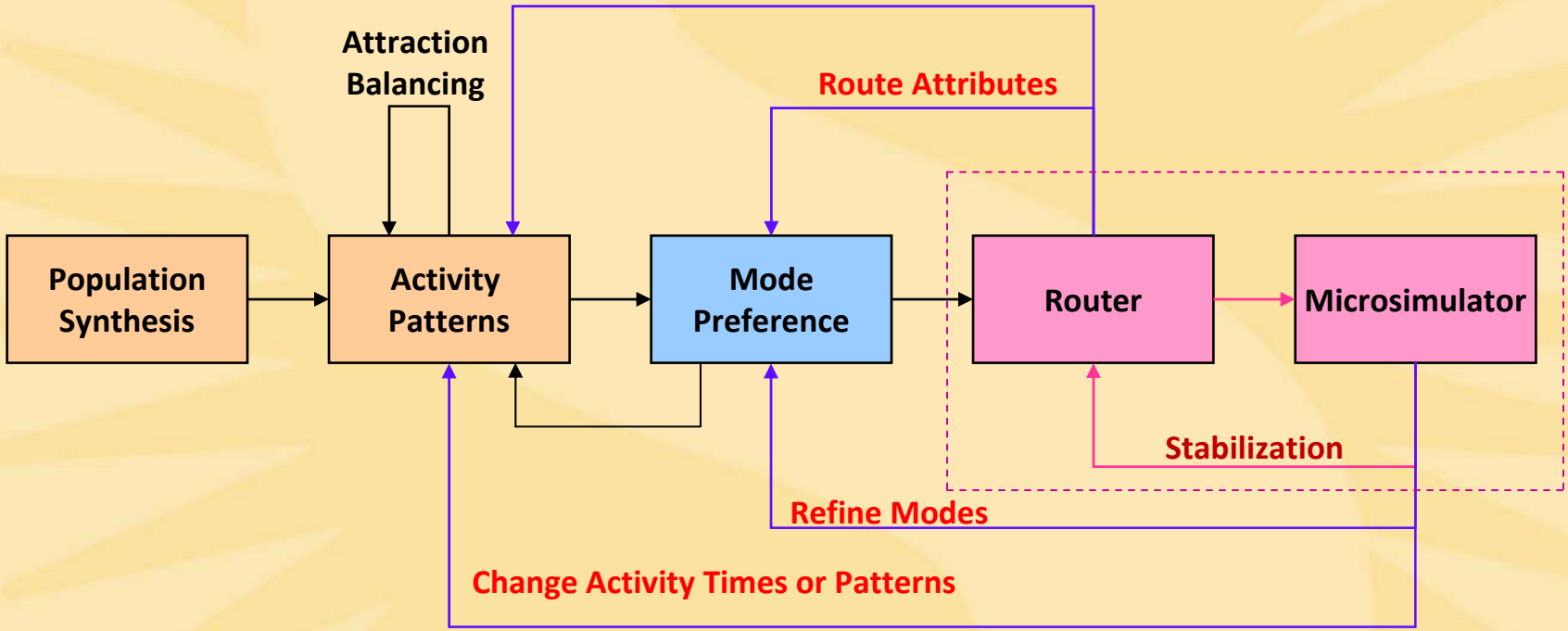
Classification of Activities

Fixed activities	Flexible activities
Work/school	Daily shopping
Bring or get persons or goods	Service related activities (post office, bank etc.)
Medical visits	Non-daily shopping
Personal business (a rest category)	Social activities (visiting friends, relatives etc.)
Sleep and eat	Leisure activities (sports, concert, library, restaurant etc.)
	Home-based activities (other than sleep and eat)

TRANSIMS (FHWA/LANL)

- Transportation Analysis and Simulation System
- Generates and simulates activity/travel patterns for individuals in a region over a 24 hour period
- Supports highly detailed road and transit networks
- Time dependent link delays are considered for routing trips through the network

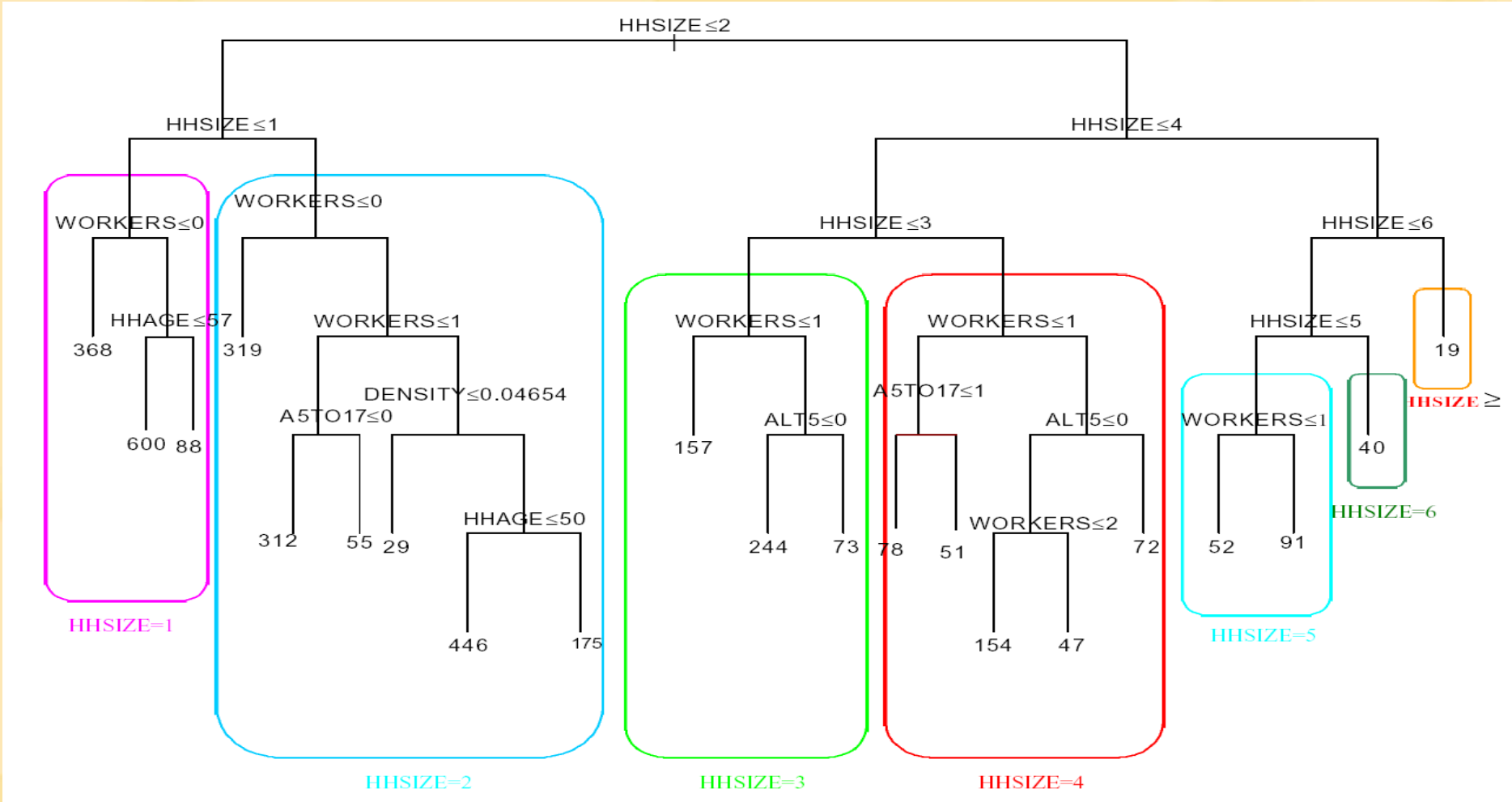
TRANSIMS: Framework



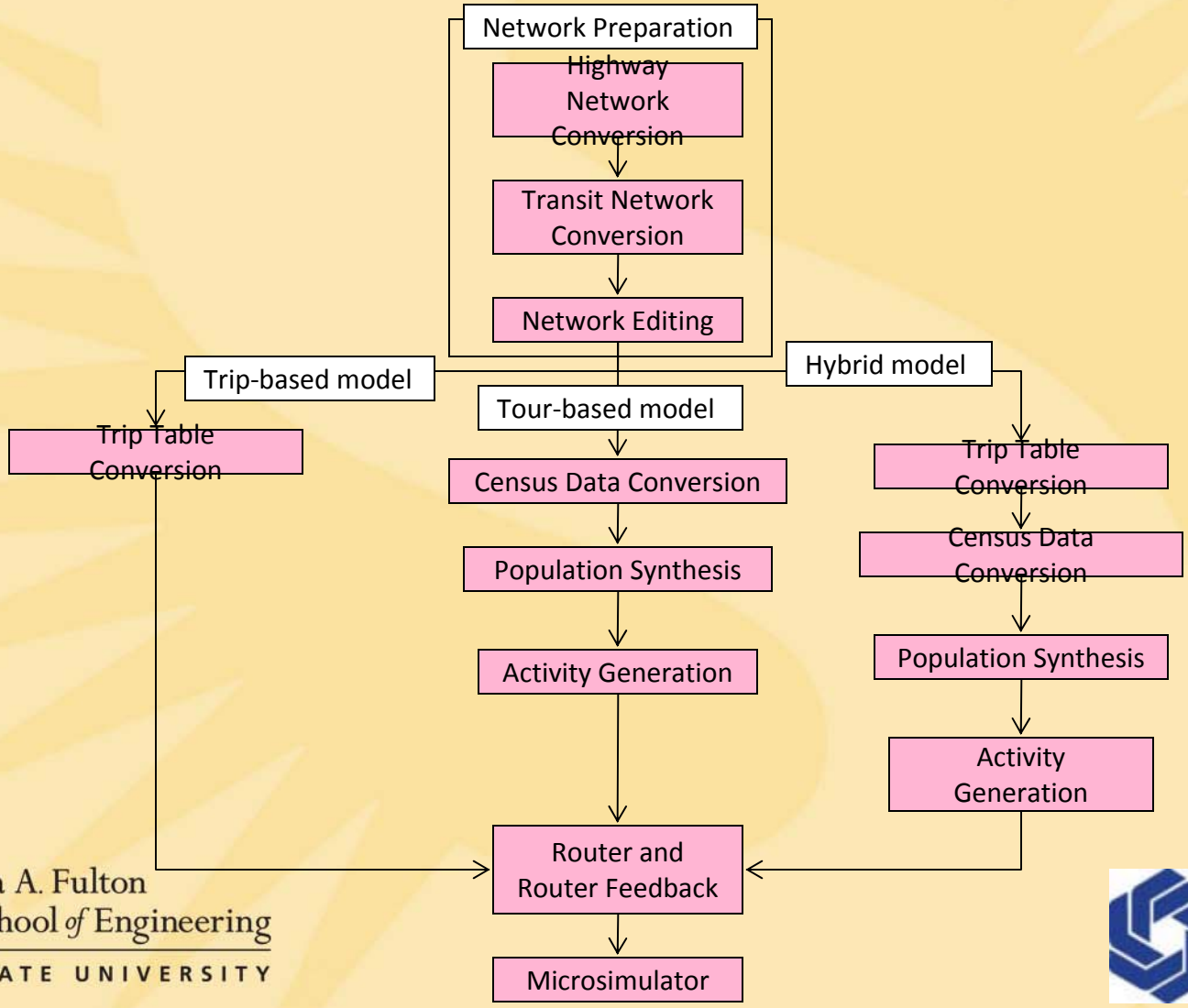
TRANSIMS: Activity Generator

- Generates activity engagement patterns for each member of a household over a 24-hour period
- Out-of-home activity locations determined using a destination choice model
- Activity engagement patterns generated by sampling from activity patterns of individuals in a travel survey
  - In the current implementation, Classification and Regression Trees are used

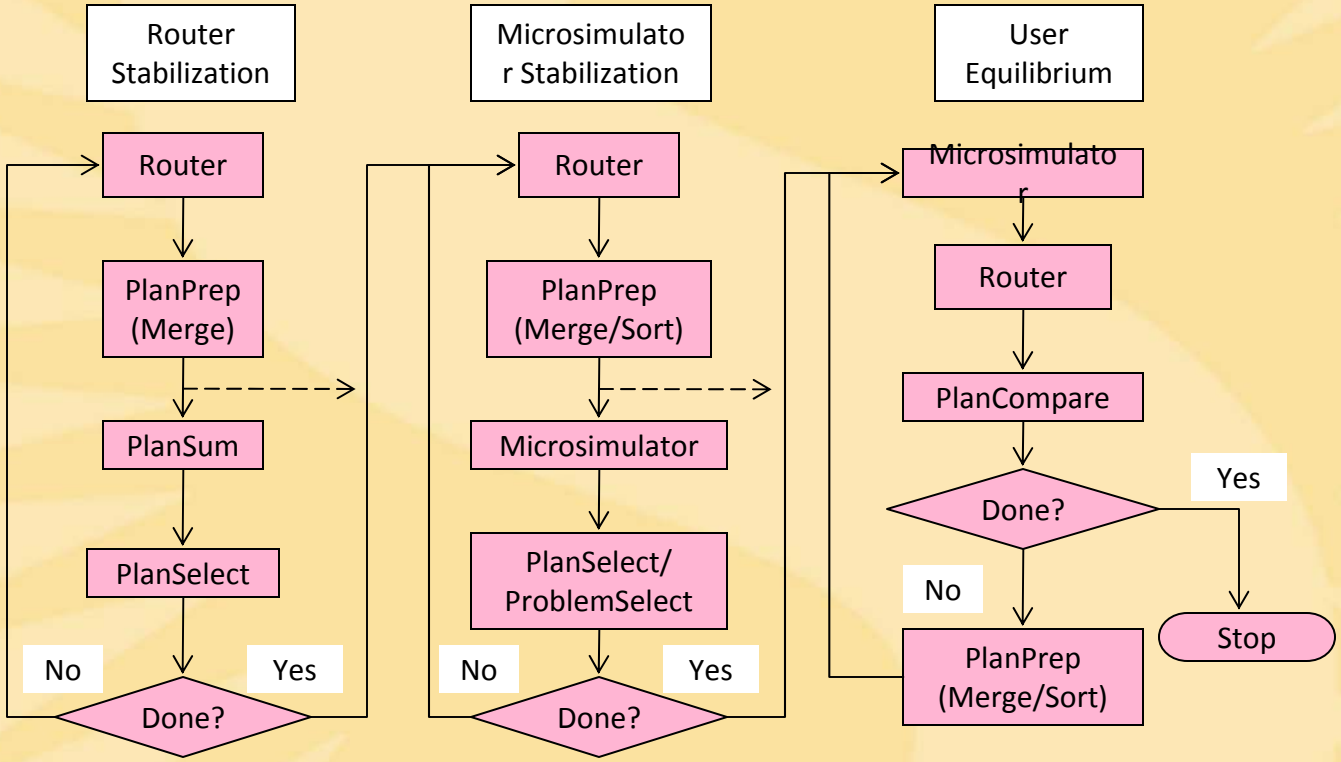
TRANSIMS: Activity Generator (continued)



TRANSIMS: Application



TRANSIMS: Feedback Processes



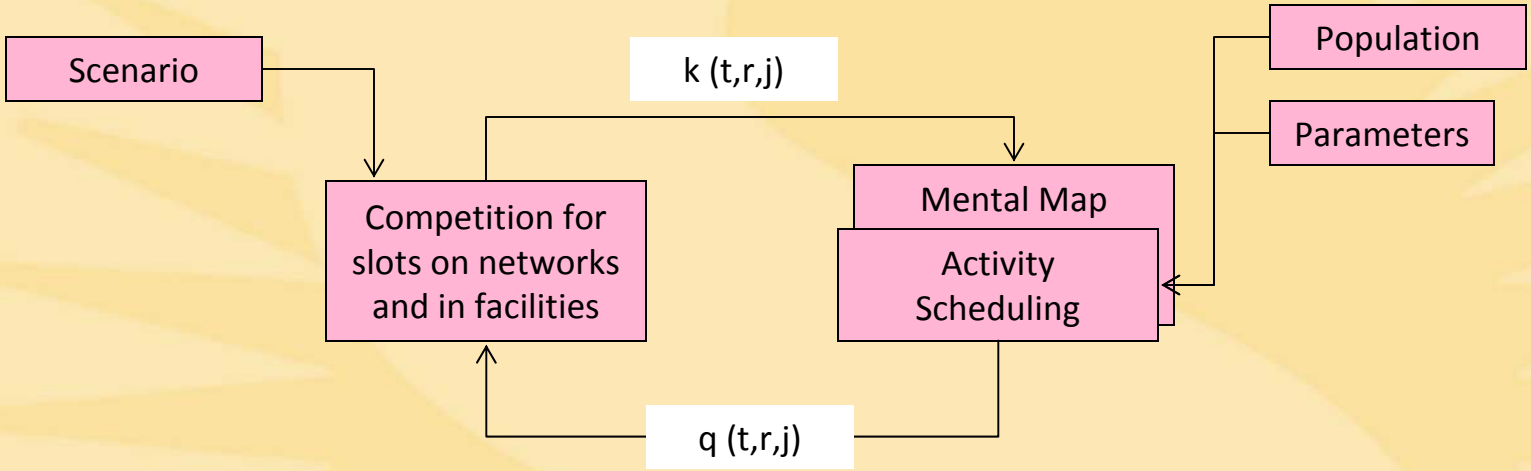
MATSIM-T (Axhausen/Nagel)

- Multi-Agent Transport Simulation Toolkit
- Iterative agent-based traffic simulation framework
- Only autos are simulated
- Involves two main components
  - Agent generation (grouped as households)
  - Activity Scheduling

MATSim-T: Scheduling Tasks

Task	Frequency per run	Model type
Number, sequence and type of activities	Once	Conditional probability
Start and duration of activities	Per iteration	Best response model (GA-based optimizer)
Composition of the group undertaking the activity	---	---
Expenditure and its allocation among the participants	---	---
Secondary location choice	Once	Imputed (Proportional to size and distance)
Mode/vehicle choice	Per iteration	Imputed (Chain based MNL)

MATSim-T: Framework

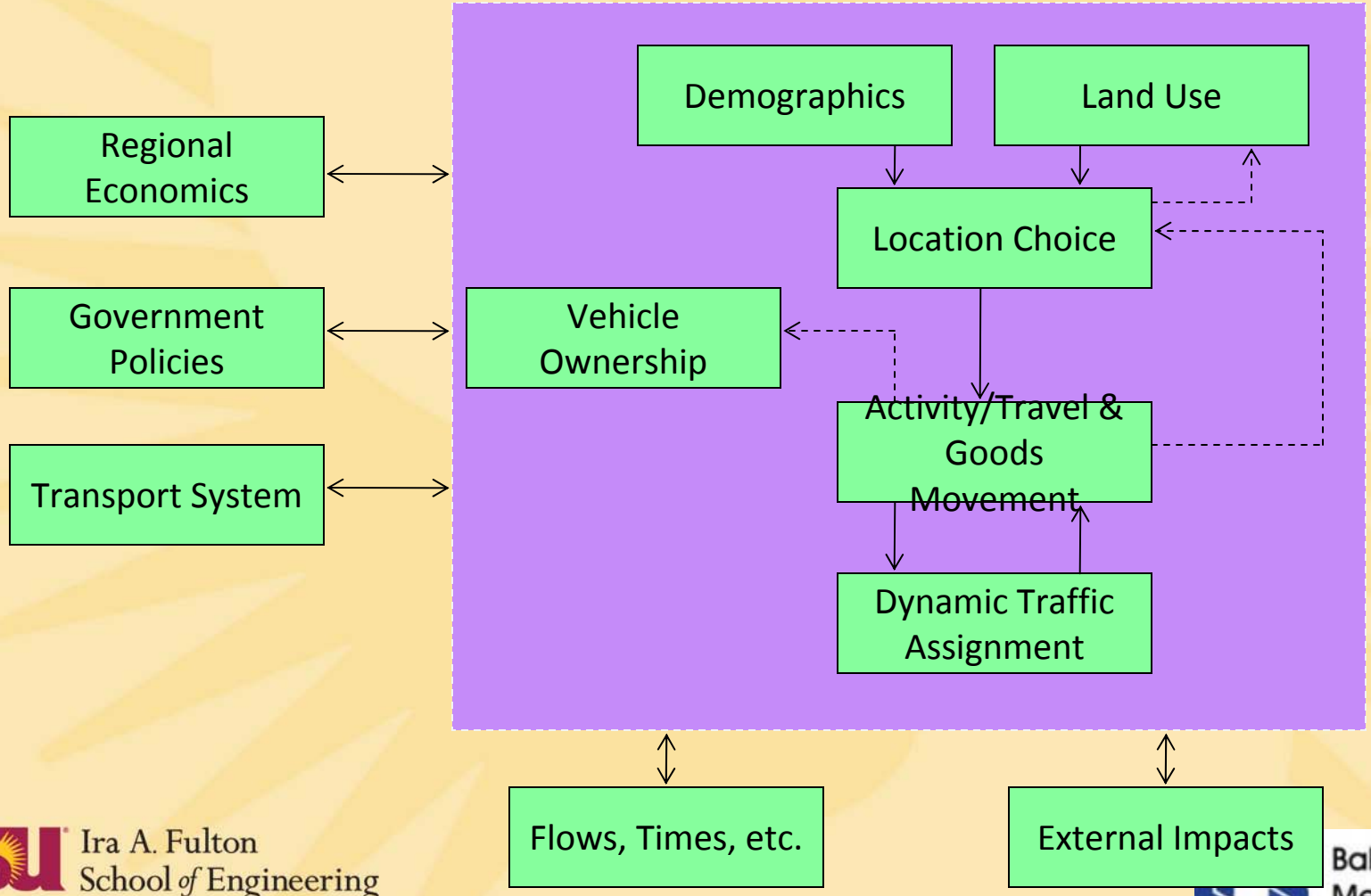


- Travel demand q is generated and microsimulated
- Resulting generalized costs k are used to adjust schedules, capacities and prices of facilities
- Route (r) adaptation process also extends towards time choice (t), mode choice, location choice (j), etc

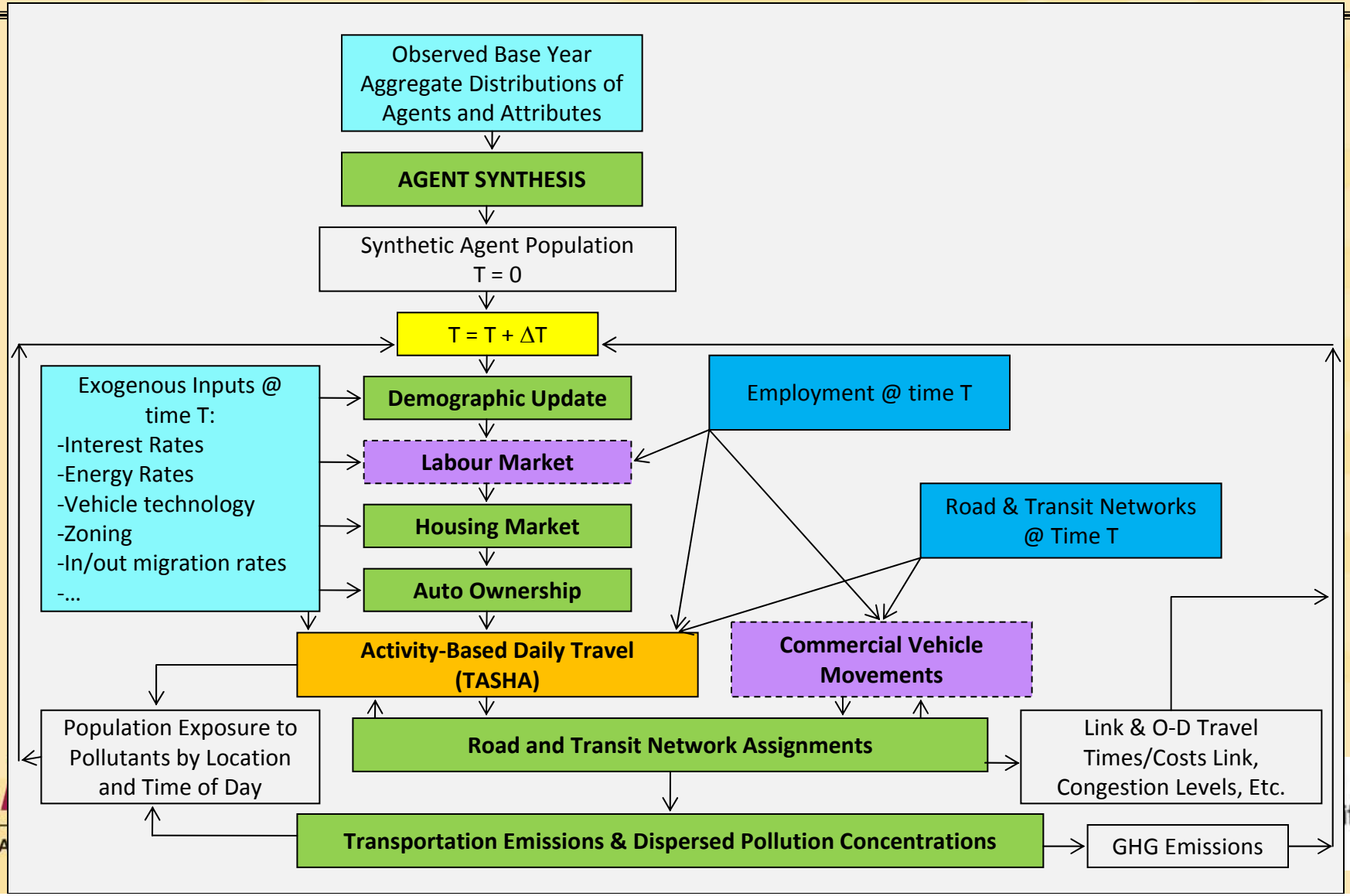
ILUTE (Miller)

- Integrated Land Use, Transportation, Environment (ILUTE) model system
- ILUTE mainly tries to model the "spatial markets and the persons' daily decision-making within a household-based context"
- Simulates the evolution of agents and objects over time
  - Agents and objects include individuals, transportation networks, the built environment, the economy, and the job market

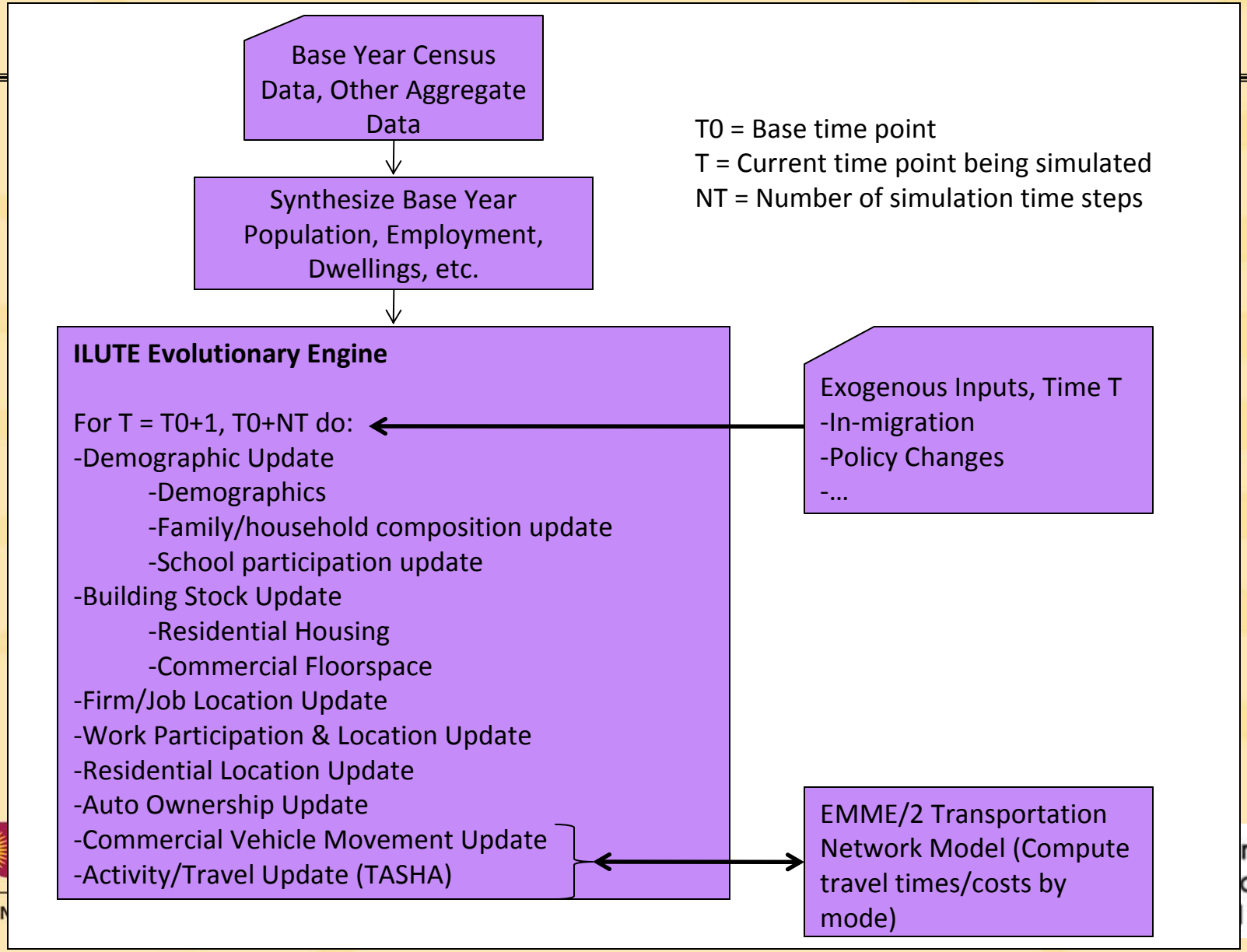
ILUTE: Framework



ILUTE: Structure and Current Implementation



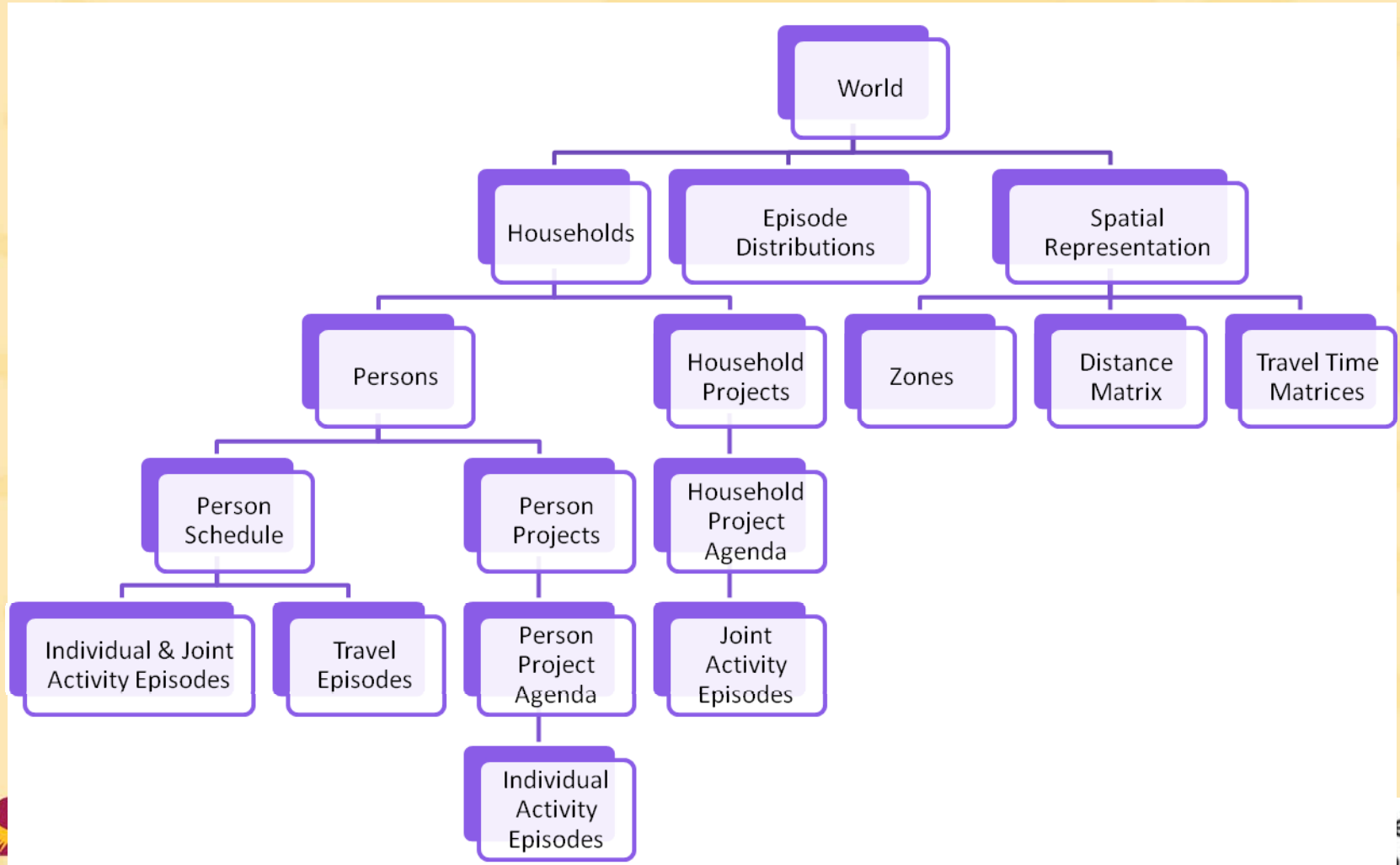
ILUTE: Evolutionary Engine



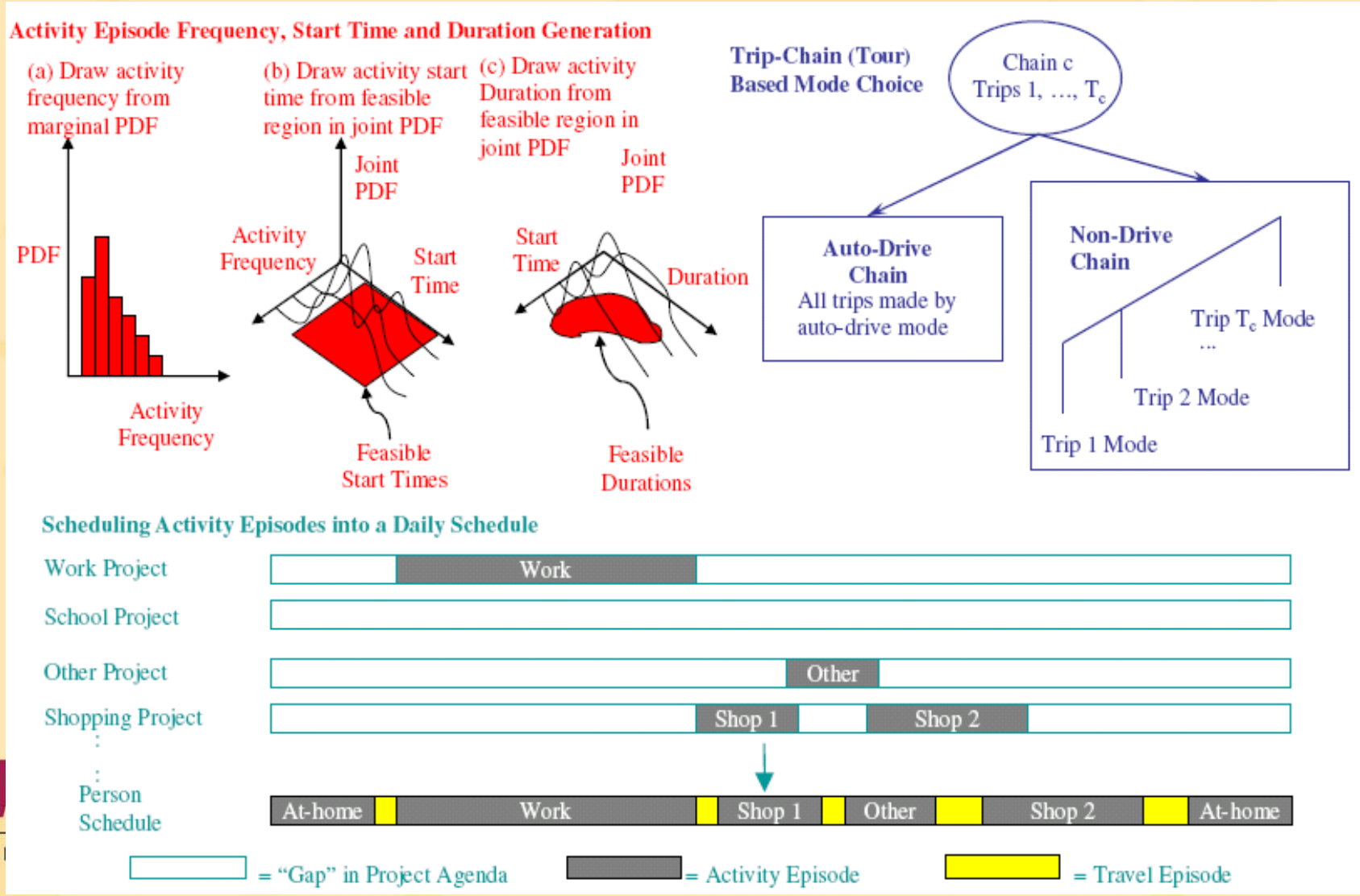
TASHA (Miller/Roorda)

- Travel/Activity Scheduler for Household Agents
- Simulates out-of-home activity and travel patterns for individuals recognizing household-level interactions and constraints
- TASHA uses the concept of *project* introduced by Axhausen (1998)
- TASHA comprises of:
  - An activity episode generator
  - An activity scheduler
  - A random utility tour-based mode choice model

TASHA: Class Structure and Project Definitions



TASHA: Activity Generation, Scheduling and Mode Choice



Time Use Utility Measures

- Time use allocation is central to the activity-based modeling paradigm
- Offers strong framework for analyzing measures of welfare that people derive from their activity-travel patterns
- Address social equity and quality of life issues

Formulation of Time Use Utility Measure

- Utility formulation

$$U_q = [x_q \beta + \gamma \ln(S_q + 1) + \varepsilon_q] \ln(T_q + 1)$$

U_q is utility derived from activity of type q

T_q is cumulative daily time expenditure on activity of type q

S_q is cumulative daily time expenditure on travel for activity of type q

x_q is a vector of covariates affecting utility U_q

γ is a scalar coefficient associated with $\ln(S_q+1)$

β is a vector of coefficients associated with x_q

ε_q is an i.i.d. random error term in U_q.

Formulation of Time Use Utility Measure

- Utility formulation

$$U_s = \ln(T_s + 1)$$

Maximize $$U = \sum_q U_q + U_s$$

Subject to $$\sum_q T_q + \sum_q S_q + T_s = T_f$$

U_s is the utility derived from sleep
U is the total utility derived from the time use pattern
T_s is cumulative daily time expenditure on sleep
T_f is the total time available in a day.

Baseline Activity Pattern

Activity Type	Daily Duration (min)
Sleep	472
In-home maintenance	202
Out-of-home maintenance	53
Travel for out-of-home maintenance	37
In-home discretionary	166
Out-of-home discretionary	76
Travel for out-of-home discretionary	16
Commute time (round trip)	*60*

Modified Activity Pattern: After Telecommuting

Activity Type	Daily Duration (min)
Sleep	492 (+20)
In-home maintenance	202
Out-of-home maintenance	53
Travel for out-of-home maintenance	37
In-home discretionary	186 (+20)
Out-of-home discretionary	90 (+14)
Travel for out-of-home discretionary	22 (+6)
Commute time (round trip)	*0*

Example

- Time use utility measure formulated as a function of:
  - Socio-economic and demographic characteristics
  - Travel durations to and from activities
  - Activity durations for different activity types/episodes
- Time Use Utility before capacity enhancement = 25.570
- Time Use Utility after capacity enhancement = 27.531
- Could translate into monetary benefits
- Also examine equity across market segments

Example

Activity Type	Utility Value Before Telecommuting	Utility Value After Telecommuting
Sleep	6.159	6.201
In-home maintenance	2.939	2.939
Out-of-home maintenance	0.777	0.777
In-home discretionary	2.882	2.946
Out-of-home discretionary	12.813	14.669
Total	25.570	27.531

Key Considerations

- Representation of fuzzy time-space prism constraints, inter-agent interactions, and time use behavior
- Greater level of simultaneity in choice processes to reflect choice of lifestyle package
- Recognition of heterogeneity in population – behavioral structure, decision hierarchy, parameters/coefficients
  - Careful market segmentation, trip purpose definition, representation of time, space, and networks

Key Considerations

- Central role of time and space
  - Disaggregate representation of time-space domain
  - Continuous representation of time
  - Disaggregate spatial representation
- Maximize use of information from activity-based travel model

Things to Think About

- Feedback processes
  - Feedback within activity-travel simulator from destination/mode choice to time-of-day choice to activity type/generation
  - Feedback from network assignment to activity type/generation (tour stops), and mode and destination choice
  - Criteria for convergence and equilibrium conditions

Things to Think About

- Stochastic simulation
  - One run represents one realization of stochastic process
  - How many runs are required to achieve stable results?
  - Impacts on computation time and hardware/software requirements
- Data requirements
  - Travel survey data
  - Multimodal network data by time of day
  - Detailed land use data
  - Greater level of disaggregation for activity microsimulation

Things to Think About

- In-house resources
  - Staff training and expertise
  - Computational resources
  - Phased development plan
    - Comprehensive model design upfront with staged development and implementation schedule