Modeling the Urban Continuum in an Integrated Framework: Location Choice, Activity-Travel Behavior, and Dynamic Traffic Patterns

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

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Outline of Meeting

- Integrated Model Design
  - Conceptual framework and model paradigm
  - Operational details and structure
- Proposed Work Plan
  - Major milestones for model system components
  - Prototype development plan and workflow
- Model Validation and Acceptance Criteria
  - Model validation procedures and measures
  - Model acceptance criteria
  - Sensitivity analyses
- Software Architecture and Data Structures
Project Description

- **Project objective**
  - Design and develop a set of methods, computational procedures, data models and structures, and software tools for the integration of land use, activity-travel behavior, and dynamic traffic assignment model systems in a microsimulation environment

- **Proposed Work Plan**
  - Year 1: Design the model system – concepts, strategies, and constructs
  - Year 2-3: Develop the prototype model system – procedures, data, and software tools
  - Year 3: Validate and test the integrated model system; documentation and dissemination
Design Constructs/Considerations

- **Representation of time as a continuous entity**
  - Model location choices, activities, and travel along continuous time axis

- **Representation of constraints**
  - Host of constraints that affect choices
    - Time-space prism constraints, modal constraints, coupling constraints, institutional constraints, household constraints

- **Representation of interactions**
  - Interactions among household members and non-household members
  - Interactions among activities and trips
  - Interactions among choice dimensions (e.g., residential self-selection)
Design Constructs/Considerations

- Representation of feedback processes
  - Mimic learning processes (experiences) over time
  - Bring model system to stable state - equilibrium

- Computational burden/efficiency
  - Efficient computational procedures and data structures with fine-grained treatment of time and space

- Explicit treatment of transit
  - Incorporate transit into model design – multimodal model system

- Behaviorally sound integration of model components
  - Go beyond simple interfacing or stitching of models
Strategies for Integration

- Strategies for Integrating Demand and Supply models
  - **Sequential process**
    - Demand and Supply models are run separately without any cross-talking
    - Models are run sequentially until convergence is achieved
  - **Dynamic event-based process**
    - Demand and Supply models are run simultaneously with constant interaction
    - Models are run concurrently with information flow between model systems along the continuous time axis

- Dynamic event-based strategy is proposed as the preferred approach for integrating the demand and supply models
Integrated Model: AMOS

Open period

Departure time choice; if departure time < start time

Joint Activity-type/Duration choice

Destination and Mode choice

Establish a link with Supply Model here

Arrival time

Adjust Activity Duration choice

Activity end time

Is there time available?

Yes

Engage in new activity

No

Adjust last activity

Go to next fixed activity

No

Go to next fixed activity
Integrated Model: Supply and Demand

**AMOS**
- Origin, Destination, Vehicle Info for Vehicle Trip 1

**DynusT/ MALTA**
- Vehicle is loaded and the trip is Simulated

**24 hr duration**

**Update Set of Time-Dependent Shortest Paths**
- 1440 paths per O-D Pair

**O-D Travel Times for Destination and Mode Choice Modeling**

**Person(s) reach destination and pursue activity**

**Update Set of Time-Dependent Shortest Paths**
- 1440 paths per O-D Pair

**Vehicle is loaded and the trip is Simulated**

**6 sec. interval**

**Update Set of Time-Dependent Shortest Paths**
- 1440 paths per O-D Pair

**Person(s) reach destination and pursue activity**
Integrated Model Design

- Model activities and travel at one-minute resolution
- In each minute, activity model provides list of persons and vehicles with origin-destination travel information to dynamic traffic assignment model
- Dynamic traffic assignment model routes the trip along time-dependent shortest path to destination
- Dynamic traffic assignment model simulates movement of vehicle at 6-second time resolution
- Arrival time simulated by dynamic traffic assignment model determines set of trips/persons passed back to demand model at any one-minute time step
- Activity duration is adjusted based on actual arrival time
**Integrated Model: AMOS**

**Open period**

- Departure time choice; if departure time < start time

**Activity-type choice**

- Destination and mode choice

  - Arrival time

- Activity duration choice

**First Pass** – Use travel times estimated from a Bootstrapping procedure

**Subsequent Passes** – Use travel times from previous iteration

**Based on the network conditions** – Obtained dynamically from dynamic traffic assignment model

**Activity end time**

- Is there time available?
  - Yes
  - Engage in new activity
  - Yes
  - Go to next fixed activity
  - No
  - Extend last activity
  - No
  - Go to next fixed activity
Bootstrapping

- **Goal**: Obtain travel times that are more consistent with a temporally disaggregate integrated model system
- Sequentially run the Demand model followed by the Supply model until convergence is achieved
- Run models at a coarser time resolution than integrated model, but substantially finer resolution than four-step travel model
- Implement averaging schemes to prevent oscillations and bring process to rapid convergence
- **Convergence**
  - Trip Tables vs Travel Times
Bootstrapping Procedure

1. Initial travel times from a four step model
2. AMOS
3. Trip Tables at a 30 minute temporal resolution
4. MALTA
5. Travel Times at a 30 minute temporal resolution
6. Is convergence achieved?
7. No
8. Travel Times
9. Yes
10. Proceed to the Dynamic Integrated Model System with Set of Estimated Travel Times
Integrated Model: Supply and Demand

AMOS

Origin, Destination, Vehicle Info for Vehicle Trip 1

DynusT/ MALTA

Vehicle is loaded and the trip is Simulated

24 hr duration

Update Set of Time-Dependent Shortest Paths – 1440 paths per O-D Pair

O-D Travel Times for Destination and Mode Choice Modeling

Person(s) reach destination and pursue activity

Origin, Destination, Vehicle Info for Vehicle Trip 2

t = 0

t = 1 min

6 sec. interval

Update Set of Time-Dependent Shortest Paths – 1440 paths per O-D Pair
Integrated Model: Data Transfer

- After every minute, demand model provides a list of vehicle trip records to the supply model
  - Vehicle trip record → vehicle id, vehicle trip id, person ids for the occupants, origin, destination, and departure time
- After every minute, supply model communicates back arrival times of vehicles that have reached their destinations; subsequently demand model makes activity engagement decisions
- Supply model routes and simulates the vehicle trips; vehicle locations are updated every 6 seconds in the simulation
- The above steps are repeated to generate activity engagement patterns for all individuals for an entire day
Feedback Loops

- Feedback origin-destination travel times at 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
- How does one define “convergence” in the integrated modeling context?
Feedback Loops

- Convergence on the supply side well-established and incorporated into modeling paradigms
  - Compare origin-destination travel times from one iteration to the next
  - When travel times show no further change, process comes to a close
  - Set of time-dependent shortest paths will not change further

- Notion of convergence on the demand side not as well-established in a microsimulation context
  - Activity-travel patterns emerge in a 24-hour simulation with each iteration representing a “fresh stochastic realization” of the activity-travel choice processes
  - Each iteration will offer a different “activity-travel pattern” even with the same origin-destination travel times because the model represents a random process
Convergence in Integrated Model

How does one check “convergence” on the demand side?

Comment: Objective is to find travel patterns that are in equilibrium with network. Test should be whether travel patterns are stable; not whether travel times are stable.

This is a new concept in microsimulation of activity-travel demand

Philosophical question about the stability of activity-travel patterns

Well-documented evidence of day-to-day variability of activity-travel demand

Should we be concerned about “stability of activity-travel patterns” as a basis for convergence of the model system?

On the demand side, no output of previous iteration (other than supply measures) serves as input to subsequent iteration
Convergence in Integrated Model

- One possibility is to use approach adopted in bootstrap procedure.
- Produce aggregate 30-min trip tables at end of each iteration and compare between iterations to monitor stability; use averaging schemes to bring process to closure.
- At more disaggregate level, examine time-space prism vertices for each individual in synthetic population.
  - Time-space prisms are based on origin-destination travel times (travel speeds) and therefore well connected to the supply side.
  - If time-space prisms show “stability” from one iteration to the next, process may be approaching convergence.
  - Represents a more disaggregate convergence check, but need measures of difference and comparison – and threshold criteria for convergence.
Discussion
Population Synthesizer

- Development of population synthesizer complete
- Version 1.0 released July 15, 2009 and Version 1.1 scheduled for official release on November 15, 2009
- Software package (PopGen) and source code freely available and beginning to see interest among MPOs and consultants
- Webinar in late June 2009 and hands-on training workshop on November 3, 2009
- Do not plan another major release of PopGen in the near future (other than minor patches and bug fixes)
- Will be working to enhance integration of PopGen with UrbanSim and forthcoming population evolution model stream
PopGen 1.1 Features

- Several new features incorporated in Version 1.1
- Automated import and processing of ACS sample and marginals data
- Scenario manager to setup multiple scenarios within same project
- Ability to modify marginal distributions on the fly using slider bars
- Ability to generate synthetic population using classic procedure of controlling only for household-level variables
- Includes method (option) to refine distributions of key household variables so that known person totals are matched
- Greatly expanded visualization features through interface with QGIS
- Data export allows one to save synthetic population database in alternative formats
## Validation Criteria

<table>
<thead>
<tr>
<th>Model Aspect</th>
<th>Validation Criteria/Method</th>
<th>Acceptance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled Household Variables</td>
<td>Marginal distributions (frequencies)</td>
<td>± 5%</td>
</tr>
<tr>
<td>Controlled Person Variables</td>
<td>Marginal distributions (frequencies)</td>
<td>± 10%</td>
</tr>
<tr>
<td>Uncontrolled Household Variables</td>
<td>Marginal distributions (frequencies)</td>
<td>± 10%</td>
</tr>
<tr>
<td>Uncontrolled Person Variables</td>
<td>Marginal distributions (frequencies)</td>
<td>± 20%</td>
</tr>
<tr>
<td>Individual Geography Person Table</td>
<td>Cell frequencies or values (representing multi-dimensional joint distributions)</td>
<td>Use $\chi^2$ statistic to compare tables; less than 20% of geographies should have a p-value less than 0.05</td>
</tr>
<tr>
<td>Cell Frequencies</td>
<td></td>
<td>No anomaly detected through visual inspection</td>
</tr>
<tr>
<td>Spatial distribution of Household-Level Attributes</td>
<td>Thematic maps showing color-coded intensity of household attributes</td>
<td>No anomaly detected through visual inspection</td>
</tr>
<tr>
<td>Spatial distribution of Person-Level Attributes</td>
<td>Thematic maps showing color-coded intensity of person attributes</td>
<td>No anomaly detected through visual inspection</td>
</tr>
</tbody>
</table>
OpenAMOS: Development Plan

- Activity-based model system based on Activity-Mobility Simulator (AMOS) that embeds the Prism-Constrained Activity-Travel Simulator (PCATS)

- AMOS to be re-engineered in this project to:
  - Enhance behavioral representation of activity-travel decision processes at household and person level
  - Program AMOS to be modular in architecture using Python to the extent possible with C++ routines where computational expediency warrants it
  - Completely flexible model system with ability to define custom model specifications, variable sets, coefficient parameter values, activity purpose categories, and demographic market segments

- Completely open-source and freely available to community
# OpenAMOS: Development Plan

<table>
<thead>
<tr>
<th>Model Component</th>
<th>Milestones</th>
<th>Deliverables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-Space Prism Generator</td>
<td>February 1, 2010</td>
<td></td>
</tr>
<tr>
<td><strong>Child Dependency Allocation Model</strong></td>
<td>March 1, 2010</td>
<td>Memo + Code</td>
</tr>
<tr>
<td><strong>Vehicle Allocation Model</strong></td>
<td>April 1, 2010</td>
<td></td>
</tr>
<tr>
<td>Joint Activity Type – Duration Model</td>
<td>May 1, 2010</td>
<td>Memo + Code</td>
</tr>
<tr>
<td>Joint Destination – Mode Choice Model</td>
<td>June 1, 2010</td>
<td></td>
</tr>
<tr>
<td><strong>Activity Accompaniment Model</strong></td>
<td>July 1, 2010</td>
<td>Memo + Code</td>
</tr>
<tr>
<td>Vehicle Choice Model</td>
<td>August 1, 2010</td>
<td></td>
</tr>
<tr>
<td>Activity Duration Adjustment Model</td>
<td>September 1, 2010</td>
<td>Memo + Code</td>
</tr>
<tr>
<td>Consistency and Feasibility Checks</td>
<td>October 1, 2010</td>
<td></td>
</tr>
<tr>
<td>Time Use Utility Measure of Welfare</td>
<td>November 1, 2010</td>
<td>Year 2 Report +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code</td>
</tr>
</tbody>
</table>
OpenAMOS: Model Validation Approach

- 80 percent of survey sample data set used for actual model estimation
- 20 percent of survey sample data set set aside for disaggregate model validation checks
- Apply estimated models to simulate activity-travel characteristics of the 20 percent sample
- Compare actual observed behavior against predicted behavior
- Potential futility in performing comparisons at individual person- and household-level, but will be done
- Comparisons of aggregate distributions of all activity-travel characteristics
## OpenAMOS: Model Validation Criteria

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<tr>
<th>Model Component</th>
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<th>Acceptance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-Space Prism Generator*</td>
<td>Actual distributions of departure/arrival times versus model predicted distributions of time-space prism vertices</td>
<td>Departure/arrival times do not violate time-space prism vertices for 90 percent of cases</td>
</tr>
<tr>
<td>Child Dependency Allocation Model</td>
<td>Frequency or proportion of occurrences where children accompany adult on mandatory activities including school and after-school activities (by age group)</td>
<td>No statistically significant difference in the proportion (by age group)</td>
</tr>
<tr>
<td>Vehicle Allocation Model</td>
<td>Compare predicted allocation of vehicles against actual driving trends (a primary driver of a vehicle is defined as one who drives the said vehicle more than any other household member)</td>
<td>80 percent of vehicles correctly allocated to primary driver</td>
</tr>
<tr>
<td>Joint Activity Type – Duration Model and Activity Duration Adjustment Model*</td>
<td>Distribution of activity purposes; distribution of activity durations by purpose for different market segments (male, female, high and low income)</td>
<td>No statistically significant difference in the activity type and duration distributions by market segment</td>
</tr>
</tbody>
</table>
## OpenAMOS: Model Validation Criteria

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<tr>
<td>Joint Destination – Mode Choice Model*</td>
<td>Trip length distributions by purpose by market segment; modal splits by purpose by market segment</td>
<td>No statistically significant difference between observed and predicted distributions</td>
</tr>
<tr>
<td>Activity Accompaniment Model</td>
<td>Distribution of activity accompaniment type (household members only, non-household members only, combination of household and non-household members) and vehicle occupancy distribution by activity type and time of day</td>
<td>No statistically significant difference between observed and predicted distributions</td>
</tr>
<tr>
<td>Vehicle Choice Model</td>
<td>Joint distribution of vehicle type by trip length category by activity type</td>
<td>No statistically significant difference between observed and predicted distributions</td>
</tr>
<tr>
<td>Temporal Distributions of Activity-Travel Choices</td>
<td>Time of day distributions of travel by activity category (purpose) and market segment</td>
<td>No statistically significant difference between observed and predicted distributions</td>
</tr>
</tbody>
</table>
### OpenAMOS: Model Validation Criteria

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<th>Model Component</th>
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</thead>
<tbody>
<tr>
<td>Consistency and Feasibility Checks*</td>
<td>Examine all individual activity-travel patterns simulated by the activity-travel model; identify inconsistencies in the patterns (will also help refine heuristic rules and consistency checks)</td>
<td>90 percent of simulated activity travel patterns show within-household and within-person consistency</td>
</tr>
<tr>
<td>Trip Chaining*</td>
<td>Distribution of different trip chaining patterns in the holdout sample (e.g., H-W-X-H)</td>
<td>No statistically significant difference between observed and predicted distributions of trip chain types</td>
</tr>
<tr>
<td>Time Use Utility Measure of Welfare*</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
OpenAMOS: Model Validation Approach

- In addition to disaggregate model validation using 20 percent holdout sample, model validation must be done against true ground conditions or other known “regional” travel demand characteristics/measures.

- However, model validation is not limited to merely attempting to replicate known conditions.

- A model is “valid” only when it responds to changes in input conditions in a manner that is consistent with expectations and behaviorally intuitive.

- Need to also check model “validity” or “usefulness” based on extensive sensitivity analysis.
## OpenAMOS: Model Validation Criteria

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<tr>
<th>Model Aspect</th>
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</thead>
<tbody>
<tr>
<td>Destination Choice</td>
<td>Trip length distributions by trip purpose and time of day</td>
<td>No statistically significant difference</td>
</tr>
<tr>
<td>Mode Choice</td>
<td>Modal splits by trip purpose and time of day</td>
<td>No statistically significant difference</td>
</tr>
<tr>
<td>Activity/Trip Frequency</td>
<td>Total number of trips by type by time of day</td>
<td>± 10% of actual values</td>
</tr>
<tr>
<td>Amount of travel</td>
<td>Vehicle miles of travel and vehicle hours of travel by activity category and time of day</td>
<td>± 10% of actual values</td>
</tr>
<tr>
<td>Spatial distribution of travel</td>
<td>Origin-destination matrix flows from validated four-step travel model by activity category and time of day</td>
<td>Within ± 20% for 85% of O-D flows</td>
</tr>
<tr>
<td>Temporal distribution of travel</td>
<td>Time of day distribution of travel by activity category</td>
<td>No statistically significant difference</td>
</tr>
</tbody>
</table>
## OpenAMOS: Model Sensitivity Tests

<table>
<thead>
<tr>
<th>Scenario Type</th>
<th>Conditions</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-economic</td>
<td>Regional increase/decrease in population (10%, 25%)</td>
<td>Model shows increases or decreases in travel demand measures consistent with known trends or elasticities</td>
</tr>
<tr>
<td>scenarios</td>
<td>Regional increase/decrease in employment (10%, 25%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Localized increase/decrease in population (10%, 25%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Localized increase/decrease in employment (10%, 25%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changes in population/employment density (10%, 25%)</td>
<td></td>
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<tr>
<td></td>
<td>New residential or business developments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changes in distributions of population attributes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Car ownership, income, household size, number of workers, number of children, dwelling unit type, occupational distribution, age, gender</td>
<td></td>
</tr>
<tr>
<td>Highway scenarios</td>
<td>Change in highway travel time – regional and link-specific</td>
<td>Model shows increases or decreases in travel consistent with expected trends; empirical data available in the MAG region for recently opened or expanded stretches of roadways</td>
</tr>
<tr>
<td></td>
<td>Change in link-specific capacity or speed</td>
<td></td>
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<tr>
<td></td>
<td>• Consider both increase and decrease in capacity</td>
<td></td>
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<tr>
<td></td>
<td>Change in fuel price</td>
<td></td>
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<tr>
<td></td>
<td>Change in parking capacity/availability</td>
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</tr>
</tbody>
</table>
OpenAMOS: Model Sensitivity Tests

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<tr>
<th>Scenario Type</th>
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<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit scenarios</td>
<td>Change in transit fares</td>
<td>Model shows increases or decreases in transit usage consistent with known trends and elasticities (TCRP Report 95 Series)</td>
</tr>
<tr>
<td></td>
<td>Change in transit service frequency – regionwide and route-specific changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change in transit routes – new routes, elimination of routes, new stops, elimination of stops</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduction of new transit mode – BRT or Light Rail</td>
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<tr>
<td></td>
<td>Introduction of new circulator bus system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Impact of new transit-oriented development (enhanced pedestrian and bicycle access, enhanced mix of land uses)</td>
<td></td>
</tr>
<tr>
<td>Travel demand management scenarios</td>
<td>Introduction of HOV lane</td>
<td>Modest reductions in peak period travel demand, consistent with numbers found in the literature and the Puget Sound travel choices study; also check empirical evidence on new HOV lane impact (MAG region)</td>
</tr>
<tr>
<td></td>
<td>Introduction of HOT lane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduction of pricing strategy (mileage-based fee, parking pricing)</td>
<td></td>
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<tr>
<td></td>
<td>Alternative work schedules</td>
<td></td>
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<td></td>
<td>Telecommuting</td>
<td></td>
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<tr>
<td></td>
<td>Traveler information systems</td>
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</tr>
</tbody>
</table>
Discussion
SimTRAVEL Prototype Development

- Close coordination during Year 2 to facilitate data sharing and model development, integration, and testing
- Will use appropriate code repository and version control mechanisms for managing both data and code updates and share resources across team members
- Refine schedules and milestones to be in sync with one another and facilitate testing of integration approaches and inter-model communication protocols
SimTRAVEL Prototype Development

- Two proposed sites for model development and prototype testing
- Puget Sound region (Puget Sound Regional Council)
  - Considerable infrastructure and data in place due to UrbanSim implementation and initial activity-based model development effort
  - Recent household travel survey (2006), availability of panel data (Puget Sound Transportation Panel), and travel choices study data (behavioral response to pricing signals)
- Greater Phoenix Metro Area (Maricopa Assoc of Governments)
  - Have implemented PopGen and in the process of implementing UrbanSim
  - Have initiated activity-based model development effort
  - Have 2008 NHTS add-on travel survey data set fully geo-coded and extensive traffic data for model validation
  - Exploring use of Dynamic Traffic Assignment tools (Nov 20 Seminar/Webinar)
SimTRAVEL Prototype Development

- Proposed sites are large areas, thus permitting full-scale testing of proposed software and model architectures
  - However, for testing purposes, one needs rapid turn-around on model runs
- Use sampling procedures (5% sample) or subarea modeling approaches to perform test runs and work out wrinkles
- Backup options
  - Eugene-Springfield, Oregon – small area could serve as useful test bed for rapid turn-around on test runs)
  - San Francisco County – interfaced tour-based model with UrbanSim successfully – considerable infrastructure in place
  - Tucson Metro area (Pima Assoc of Governments) – small area could serve as useful test bed
SimTRAVEL Prototype Development

- Validate and test individual model components that comprise SimTRAVEL
- How does one validate and test the integrated model system as a whole?
- Do the same component-level validation and acceptance criteria apply to the model as a whole?
- Will errors associated with each model component get compounded in an integrated model system?
  - Should model validation and acceptance criteria be relaxed for an integrated model system?
- Initiate testing early to answer questions and establish criteria
## A Project Timeline

<table>
<thead>
<tr>
<th>Model/Task</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity-Based Model System (AMOS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Traffic Assignment Model (MALTA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Transit Assignment Model (TrAM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration of AMOS Modules in UrbanSim/OPUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integration of AMOS and MALTA</td>
<td></td>
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<tr>
<td>Development of PopSim: Population Evolution Models</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SimTRAVEL Software System and Testing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Timeline Details: **
- **Activity-Based Model System (AMOS)**: Begins in Jan 2010 and ends in Aug 2010.
- **Dynamic Transit Assignment Model (TrAM)**: Begins in Jan 2010 and ends in Sep 2010.
- **Integration of AMOS Modules in UrbanSim/OPUS**: Begins in Mar 2010 and ends in Jul 2010.
- **Integration of AMOS and MALTA**: Begins in Apr 2010 and ends in Jun 2010.
- **SimTRAVEL Software System and Testing**: Begins in May 2010 and ends in Jul 2010.