

# Towards an Integrated Model of Location Choices, Activity-Travel Behavior, and Dynamic Traffic Patterns

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

## *Investigators:*

Ram M. Pendyala, Arizona State University, Tempe

Yi-Chang Chiu, University of Arizona, Tucson

Paul Waddell, University of California, Berkeley

Mark Hickman, University of Arizona, Tucson

## *Project Manager:*

Brian Gardner, Federal Highway Administration, USDOT

# Introduction

- ❖ Limitations of current transportation and land use model systems
  - Articulated in TRB Special Report 288
- ❖ Three major streams of research
  - Land use modeling
  - Activity-travel behavior modeling
  - Dynamic traffic assignment and simulation
- ❖ Common thread across innovations in model systems
  - Microsimulation approaches involving disaggregate representation of behavioral unit, time, and space

# Introduction

- ❖ Modeling urban systems calls for integration of these three streams of research
- ❖ Progress in integrated modeling slow and devoid of sound behavioral basis (Timmermans, 2003)
  - Ad-hoc statistical coupling and data stitching of disparate model systems

# Project Description

## ❖ Project objective

- 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

## ❖ Workplan

- 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

# Project Description

## ❖ Project Tasks

- Tasks 1-3: Identification of issues/challenges and development of a comprehensive study design
- Tasks 4-6: Development of computational/analytical solutions along with integrated data structures and management protocols
- Tasks 7-9: Data collection and individual component calibration for test sites; Development of prototype integrated model system
- Tasks 10-14: Calibration, validation and policy/scenario sensitivity analysis using integrated model system

# Design Considerations

## ❖ Behavioral

- Consistency in behavioral representation, and temporal and spatial fidelity
- Explicit recognition of inter-relationships across choice processes
- Example: Response to Congestion increase from home to work
  - Short term - Alter route and/or departure time
  - Adjust work schedule/arrangements
  - Change home and/or work locations

## ❖ Computational

- Separate model systems can take several hours to run a single simulation
- Run times for integrated model systems could be prohibitive
- Advances in computational power and parallel processing offer hope

# 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

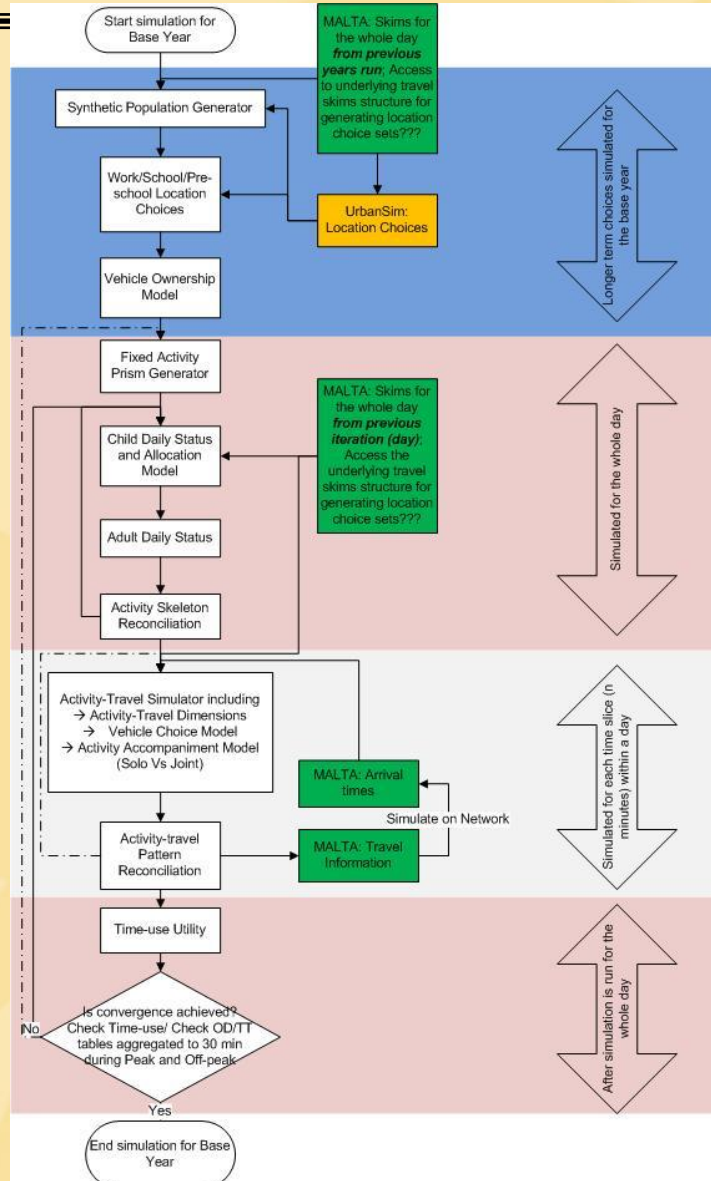
- Make connections across choice processes within a unified entity (as opposed to loose coupling)

# Model Systems

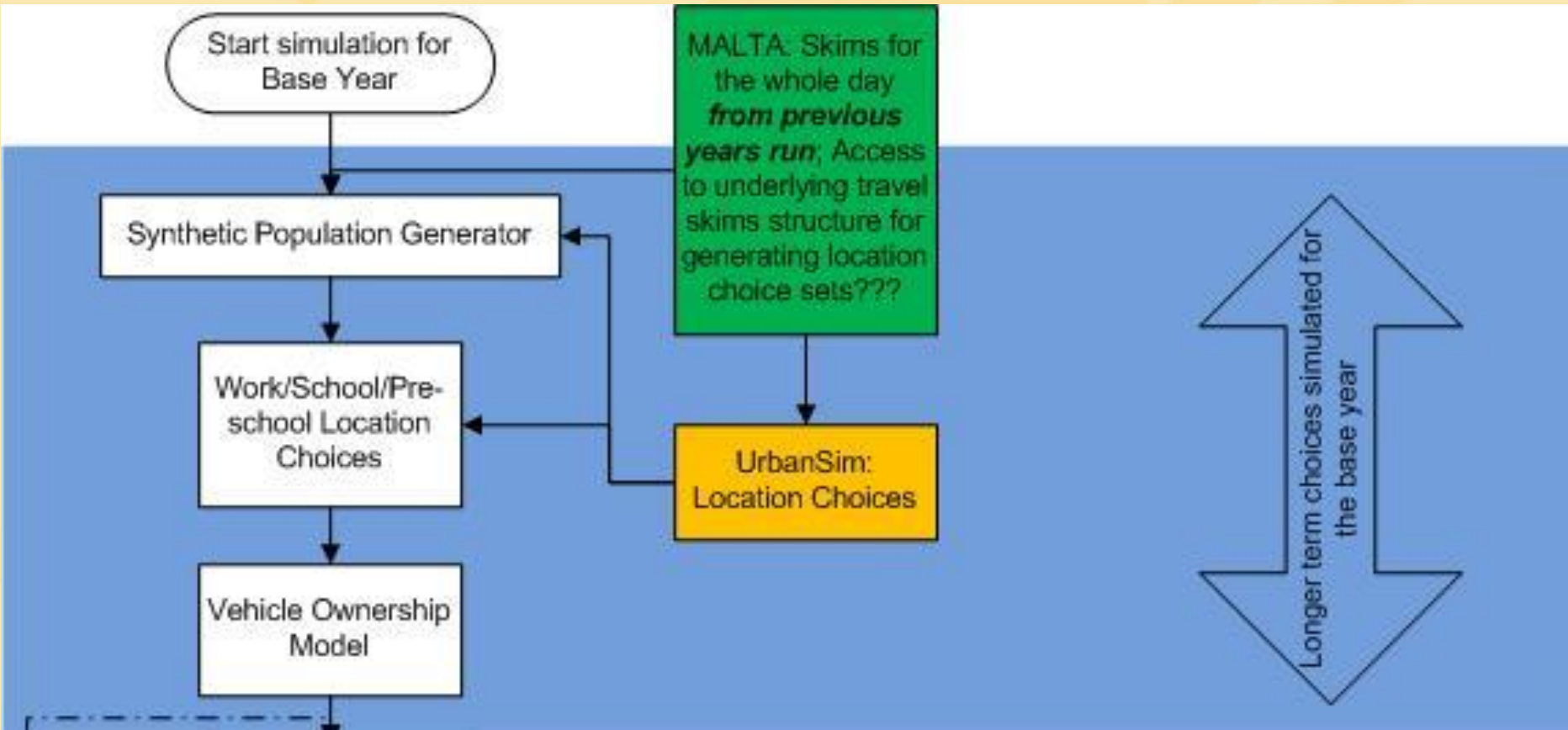
- ❖ UrbanSim/OPUS: Land use microsimulation model system
- ❖ PopGen: Synthetic population generation model
- ❖ OpenAMOS: Activity-based travel microsimulation model system
- ❖ MALTA: Simulation-based dynamic traffic assignment model
- ❖ TrAM: Dynamic transit assignment model (interfaced with MALTA)



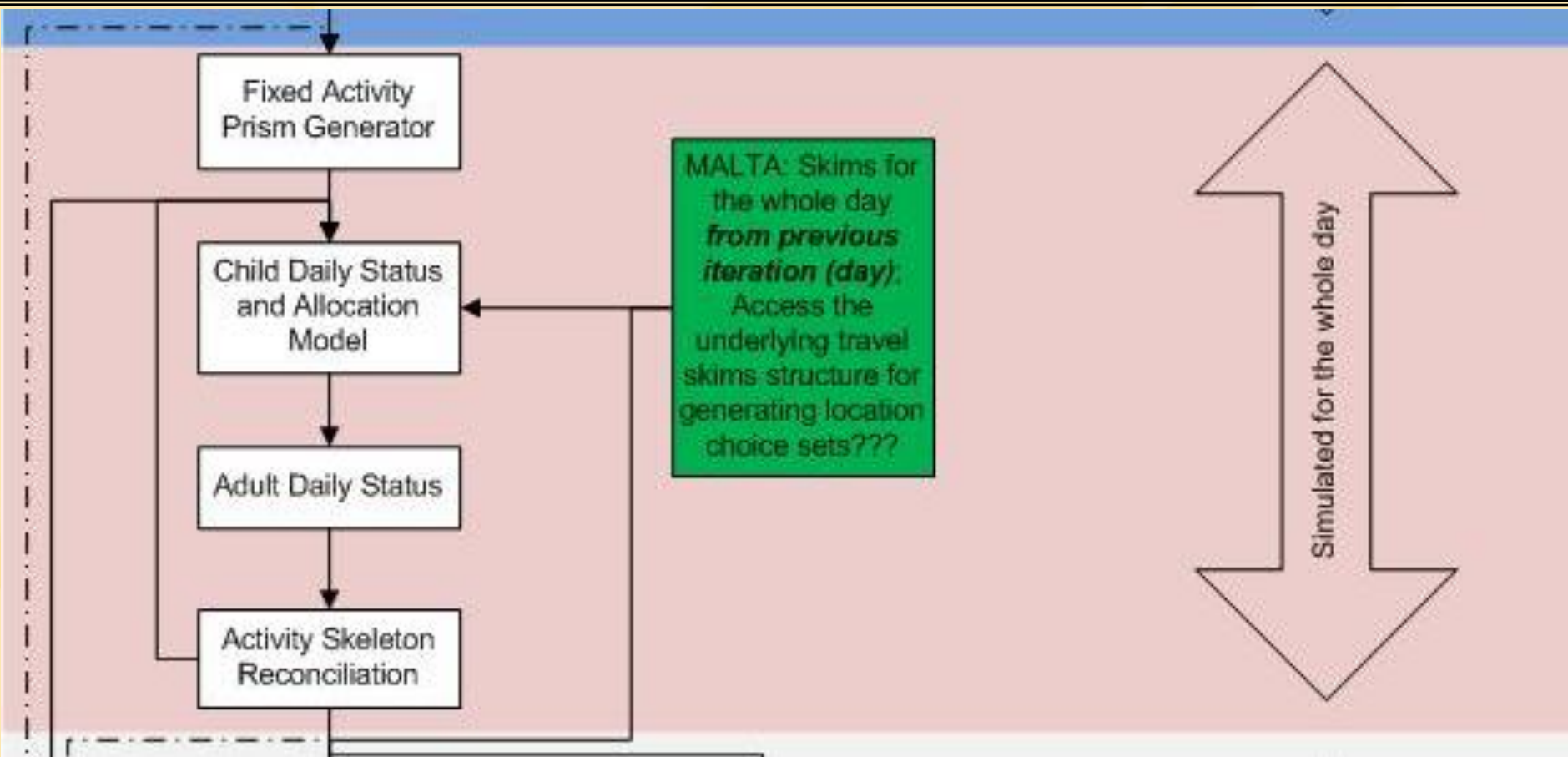
# Model Design: SimTRAVEL



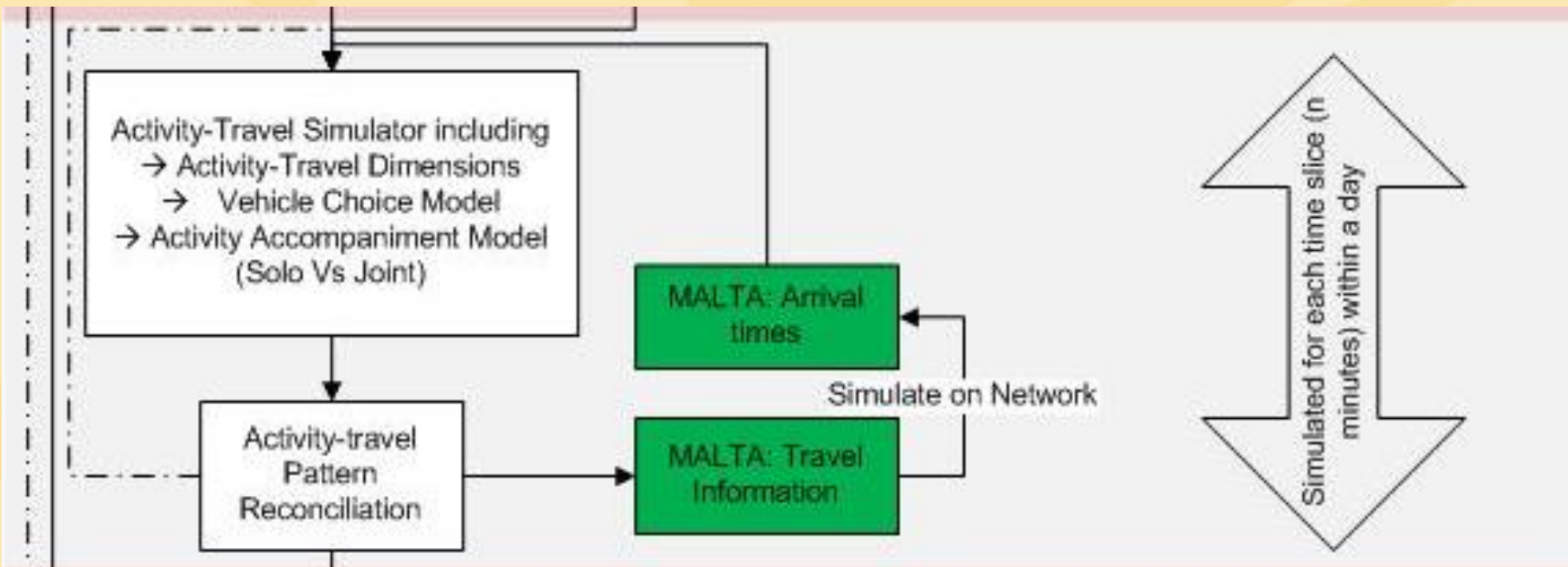
# Model Design



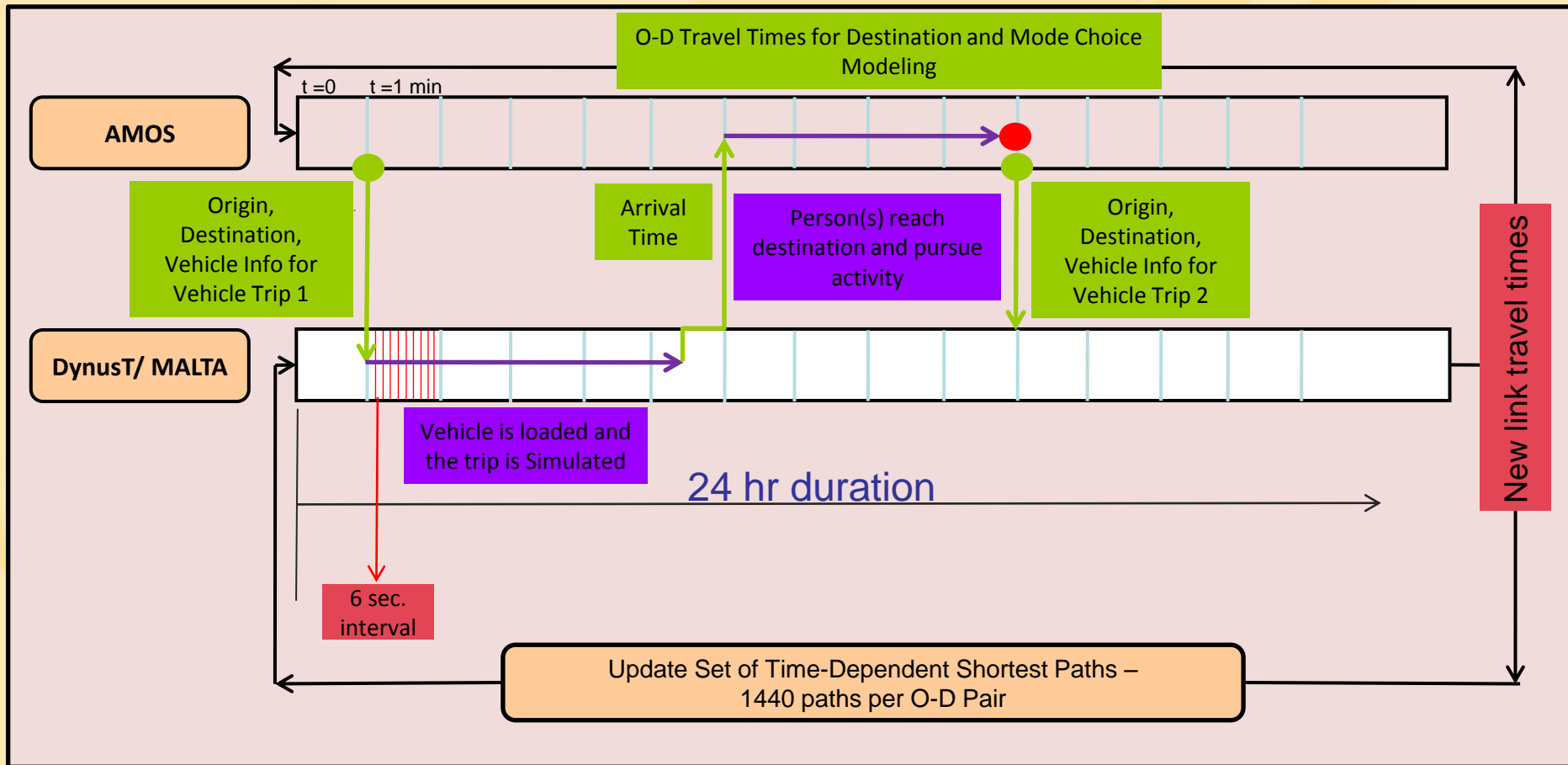
# Model Design



# Model Design



# Integrated Model: Supply and Demand



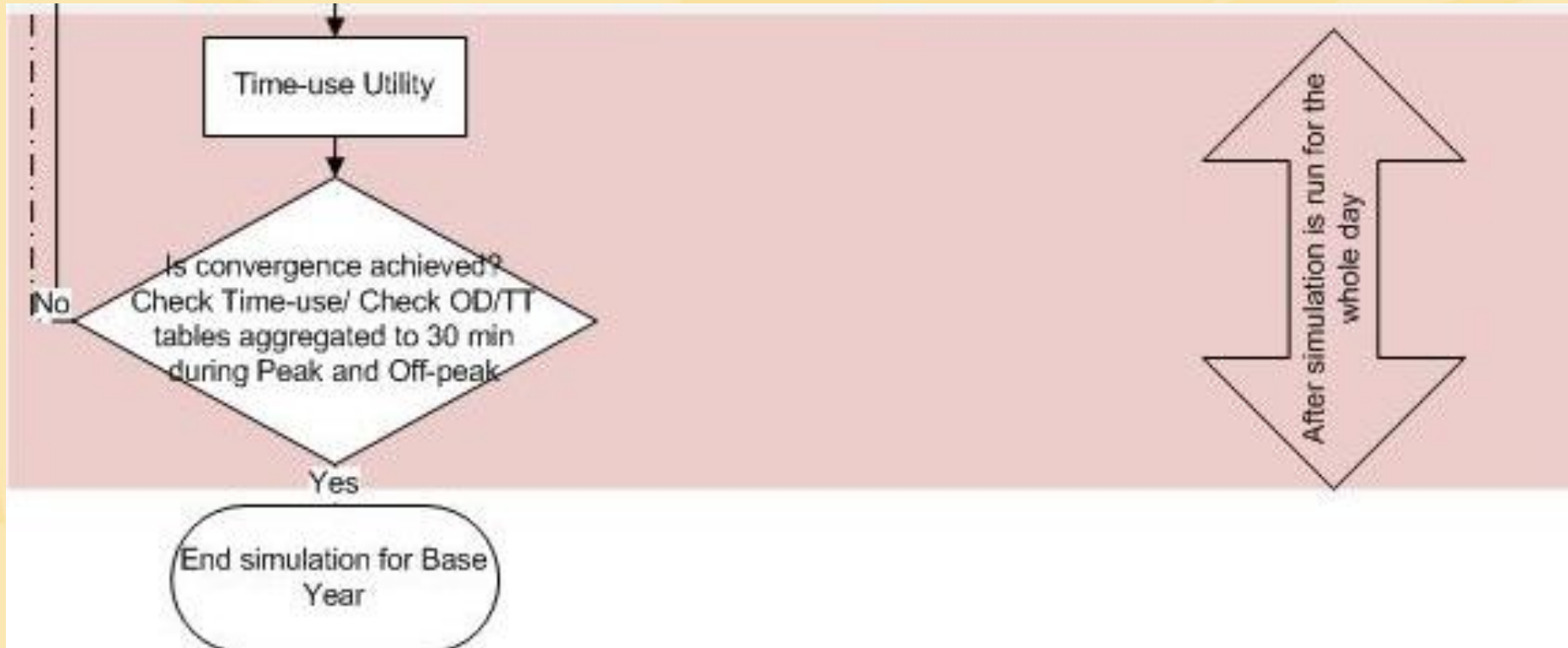
# Model Design

- ❖ 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

# 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

# Model Design





# 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?

# Convergence in Integrated Model

- ❖ 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
- ❖ 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.

# Convergence in Integrated Model

- ❖ One possibility is to use approach adopted in bootstrapping 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

# Software Development

- ❖ Completely open-source and freely available to community
- ❖ Programming Languages
  - Python used for UrbanSim and OpenAMOS
  - C/C++ used for MALTA/TrAM
- ❖ Database Management
  - PostgreSQL is commonly supported in all model systems
  - Other database protocols are supported in the individual model systems including SQLITE, MySQL
- ❖ Graphic User Interfaces
  - Individuals Model Systems - PyQt4 used for GUI's in OpenAMOS and UrbanSIM
  - Integrated Model - PyQt4 will be used to develop a GUI which will control the three model systems

# Testing Environments

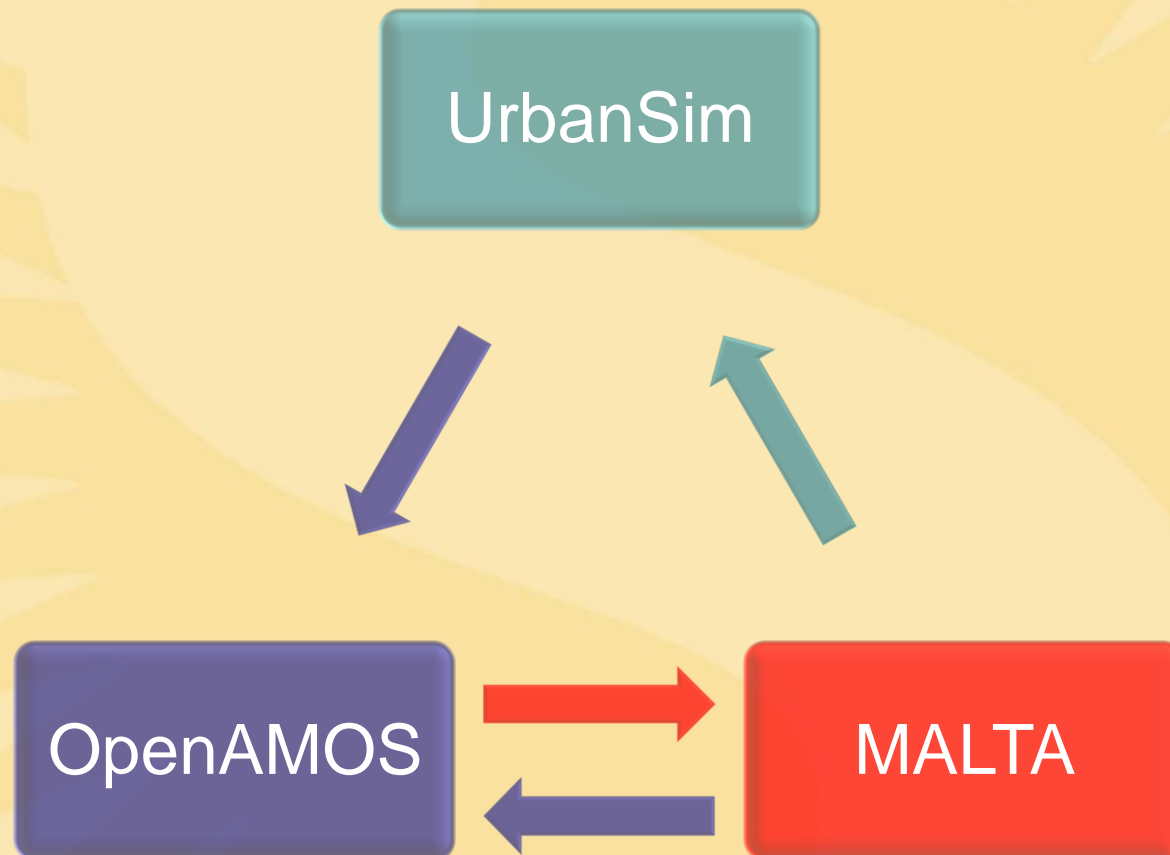
## ❖ Option 1: Single workstation environment

- The three model systems will be run on a single high end workstation
  - Will enable faster and smoother integration
- Allow application to small and medium metropolitan regions

## ❖ Option 2: Distributed computing environment

- Various solutions are being explored
  - Running the model systems in a cluster computing environment using MPI/OpenMP protocols
  - Geographically distributed computing wherein individual model systems will be running on remote computers and will interface through network/socket programming protocols
- These solutions will allow for application of the Integrated Model for large metropolitan regions

# Data Flow between Model Systems



# Interface: UrbanSim and MALTA

## ❖ Data flow between the model systems

- One way: UrbanSim ← MALTA

## ❖ Data exchanges

- Accessibility measures (←)
- Travel times and costs (←)

## ❖ Implementation

- SWIG will be used to wrap the MALTA/TrAM functionalities
  - SWIG is a framework which enables access to code in C/C++ from Python
- UrbanSim will use the APIs created using SWIG to communicate with MALTA
  - Send query using the API and obtain results

# Interface: UrbanSim and OpenAMOS

## ❖ Data flow between the model systems

- One way: UrbanSim → OpenAMOS

## ❖ Data exchanges

- Household location choices (→)
- Fixed activity location choices (→)
- Activity locations by type (→)

- within a time-space prism

## ❖ Implementation

- Location choices
  - Access the shared databases

- Activity locations by type

- Send data requests using the query language in UrbanSim



# Interface: OpenAMOS and MALTA

## ❖ Data flow between the model systems

- Two way: OpenAMOS ↔ MALTA

## ❖ Data exchanges

- Activity locations (←)
- within a time-space prism
- Travel times and costs (←)
- Information about trips within a simulation interval (→)
- Arrival information about trips at the end of a simulation interval (←)

## ❖ Implementation

- SWIG will be used to wrap the MALTA/TrAM functionalities
- OpenAMOS will use the APIs created using SWIG
  - send queries and obtain results

# MALTA/TrAM API's

- ❖ MALTA/TrAM developed using C/C++
- ❖ Therefore, SWIG will be used to develop Application Programming Interfaces (APIs) to access the functionalities within MALTA/TrAM
- ❖ The APIs will enable communication between the model systems developed in Python (UrbanSim and OpenAMOS) with MALTA/TrAM
- ❖ Two APIs being developed to facilitate the integration
  - Skims Generator
  - Dynamic Activity-Travel Simulator

# Skims Generator

- ❖ The API will support only one-way data flow
  - from MALTA to UrbanSim or OpenAMOS
- ❖ Implementation
  - MALTA processes queries from the individual model systems and returns results
  - Incorporates a hybrid-approach for building and scanning a network using link travel times
    - provides memory efficiency over the traditional approach of querying O-D travel time matrices
- ❖ Implementation
  1. `skims_generator.process_query('what is the travel time between location A and location B')`
  2. `skims_generator.process_query('what are the locations accessible within a time-space prism')`

# Dynamic Activity-Travel Simulator

- ❖ The API will support two-way data flow
  - from OpenAMOS to MALTA and vice-versa
- ❖ Implementation
  - Key component for the dynamic handshaking between OpenAMOS and MALTA
  - Involves simulation clock synchronization
    - Individual model systems may need to pause at the end of a simulation interval for the other model to finish simulation for that time interval
    - MALTA waits for trips to be loaded onto the network before continuing
    - OpenAMOS waits for information about travelers that have reached their destination before proceeding
- ❖ Implementation
  1. `travel_simulator.run_trips('trip information')`
  2. `travel_simulator.get_arrival_information()`

# Open Source Products

## ❖ Enhanced model systems for modeling:

- Land use: UrbanSim
- Population Synthesis: PopGen
- Activity-travel demand: OpenAMOS
- Dynamic traffic patterns: MALTA

## ❖ Code residing in repositories

- UrbanSim: <https://svn.urbansim.org/src/tags/>
- PopGen: <http://code.google.com/p/populationsynthesis/>
- OpenAMOS: <http://code.google.com/p/simtravel/>
- MALTA: <https://dev.urbansim.org> (MALTA directory)

# Open Source Products

- ❖ Consistent data structures that facilitate model integration
- ❖ Data structures that seamlessly link across model systems

## Household and Person Related Tables

Vehicle File	Household File	Person File	Person Activity File	Person Trips File	Vehicle Trip File
<ul style="list-style-type: none"> <li>● Vehicle ID</li> <li>● Body Type</li> <li>● Age</li> <li>● Household ID</li> </ul>	<ul style="list-style-type: none"> <li>● Household ID</li> </ul>	<ul style="list-style-type: none"> <li>● Person ID</li> <li>● Household ID</li> </ul>	<ul style="list-style-type: none"> <li>● Person Activity ID</li> <li>● Activity Type ID</li> <li>● Start Time</li> <li>● End Time</li> <li>● Parcel ID</li> <li>● Person ID</li> </ul>	<ul style="list-style-type: none"> <li>● Person Trip ID</li> <li>● Person Activity ID</li> <li>● Trip ID</li> </ul>	<ul style="list-style-type: none"> <li>● Trip ID</li> <li>● Mode</li> <li>● Vehicle ID</li> <li>● Start Time</li> <li>● Start Link ID</li> <li>● End Link ID</li> <li>● Simulated Arrival Time</li> </ul>

## Network Related Tables

Nodes File	Links File	Parcels File	Travel Data File	Parking Costs File
<ul style="list-style-type: none"> <li>● Node ID</li> </ul>	<ul style="list-style-type: none"> <li>● Link ID</li> <li>● From Node</li> <li>● To Node</li> </ul>	<ul style="list-style-type: none"> <li>● Parcel ID</li> <li>● Link ID</li> </ul>	<ul style="list-style-type: none"> <li>● From Link ID</li> <li>● To Link ID</li> <li>● From Time</li> <li>● To Time</li> <li>● Mode</li> <li>● Travel Time In-Vehicle</li> <li>● Travel Time Out-of-Vehicle</li> <li>● Travel Cost</li> <li>● Tolls</li> </ul>	<ul style="list-style-type: none"> <li>● Parking Cost ID</li> <li>● Link ID</li> <li>● Parking Cost – Peak</li> <li>● Parking Cost – Off-peak</li> <li>● Parking Spaces</li> </ul>

# Code Repository

<http://code.google.com/p/simtravel/>

simtravel - Project Hosting on Google Code - Mozilla Firefox


File Edit View History Bookmarks Tools Help

http://code.google.com/p/simtravel/source/browse/#svn/src/trunk/openamos/core/agents

Most Visited Getting Started Latest Headlines

simtravel - Project Hosting on Googl... My favorites | Sign in

**Project Hosting will be READ-ONLY [Wednesday at 7:30am PDT](#) due to brief network maintenance.**

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

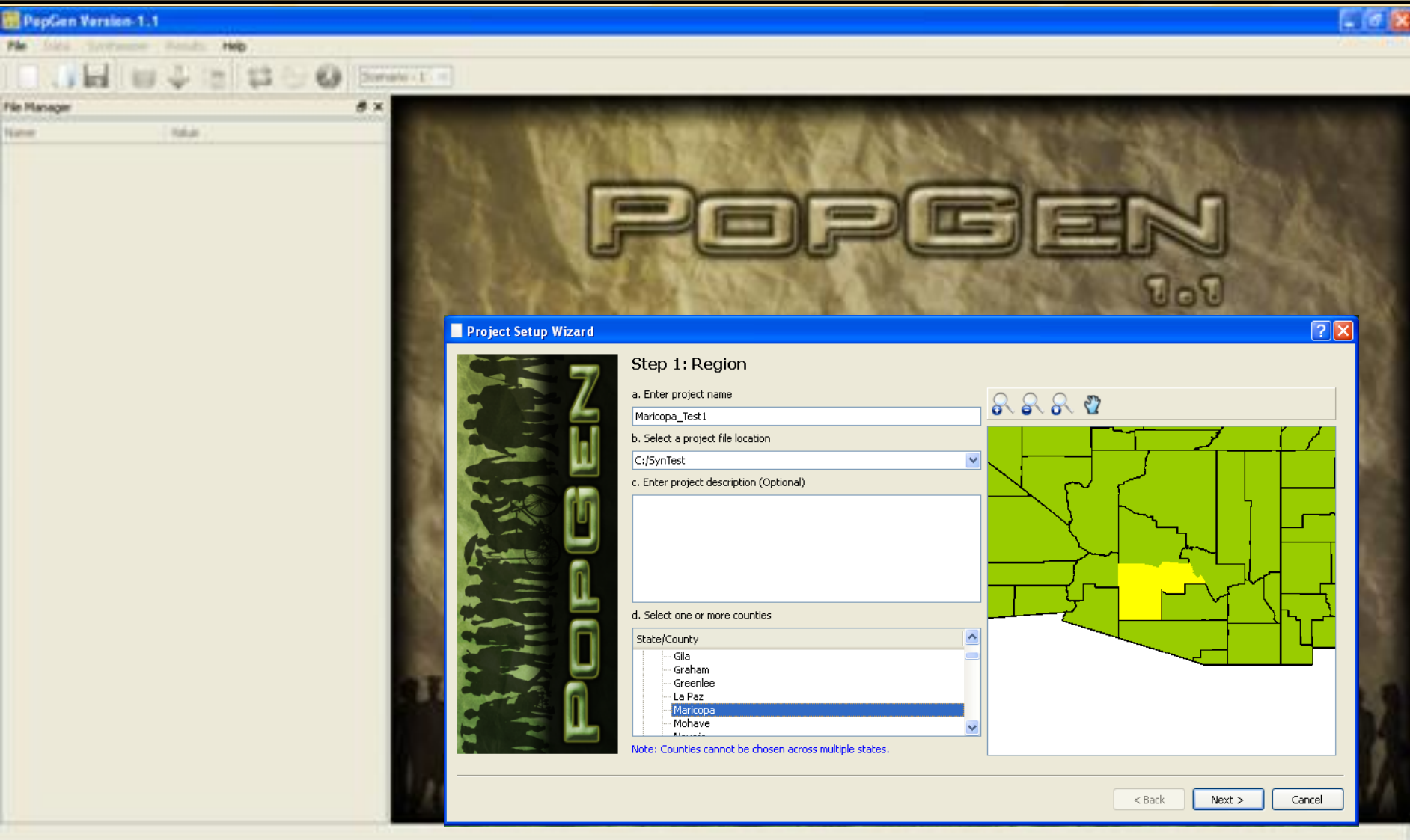
Project Home Downloads Wiki Issues **Source**

Checkout | Browse | Changes | Search Trunk

Source path: svn/ [< r101](#) [r102](#)

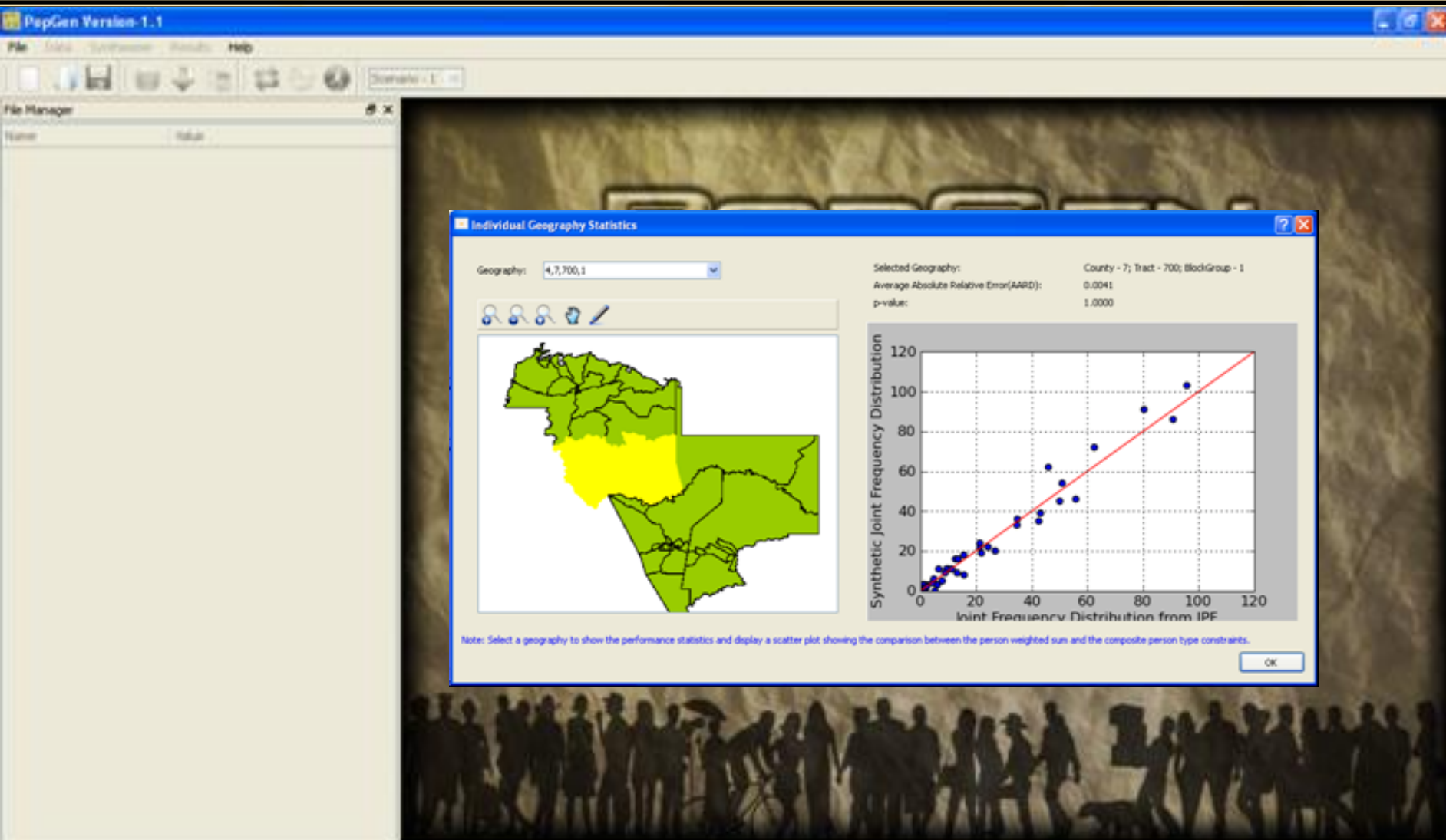
Directories	Filename	Size	Rev	Date	Author
▼ svn	<a href="#">__init__.py</a>	177 bytes	r2	Mar 05, 2010	bhargavakishore.sana
▼ src	<a href="#">activity.py</a>	2 bytes	r20	Mar 24, 2010	bhargavakishore.sana
branches	<a href="#">geography.py</a>	0 bytes	r20	Mar 24, 2010	bhargavakishore.sana
tags	<a href="#">household.py</a>	0 bytes	r20	Mar 24, 2010	bhargavakishore.sana
▼ trunk	<a href="#">person.py</a>	0 bytes	r20	Mar 24, 2010	bhargavakishore.sana
▼ openamos	<a href="#">trip.py</a>	0 bytes	r20	Mar 24, 2010	bhargavakishore.sana
▼ core	<a href="#">vehicle.py</a>	0 bytes	r20	Mar 24, 2010	bhargavakishore.sana
agents					
component					
database_management					
models					
▼ gui					
data_manager					
file_menu					
images					
misc					
model_manager					

# Example Product: PopGen





# Example Product: PopGen



# Example Product: PopGen

PopGen Version 1.1

File Edit System Tools Help

Scenario: 1

File Manager

Name: Value:

**Thematic Map of Household Variables**

Variables in Table

- NHdtype
- NHdsize
- NHdinc
- agep
- NHdlan
- childpresence

Categories

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8

Thematic Map

Legend

	Lower Limit	Upper Limit	Color
1	0.0637	0.1711	Lightest Red
2	0.1711	0.2785	Light Red
3	0.2785	0.3859	Medium Red
4	0.3859	0.4934	Dark Red
5	0.4934	0.6008	Red

Note: Select a variable and category to view a thematic map displaying the proportion of the synthetic population belonging to a particular category of the selected variable within each geography

OK Cancel

# Current Status

- ❖ PopGen - tool for population synthesis completed and released July, 2009
- ❖ SimTRAVEL prototype development (Year 2)
  - Using code repository and version control mechanisms for managing both data and code updates and share resources across team members
  - Modularized coding of OpenAMOS components
  - Developing dynamic communication interfaces between OpenAMOS and MALTA
  - Setting up and processing of test databases
  - Currently pursuing a single workstation test environment for the integrated model prototype

# Wiki Site

<http://simtravel.wikispaces.asu.edu>

**SimTRAVEL** - Integrated Urban Systems Modeling - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://simtravel.wikispaces.asu.edu/Integrated+Urban+Systems+Modeling

Most Visited Getting Started Latest Headlines

SimTRAVEL - Integrated Urban Syst...

SimTRAVEL

Integrated Urban Systems Modeling Protected page discussion history notify me

Actions

- Join this Wiki
- Recent Changes
- Manage Wiki

Search

Navigation

- Home
- Integrated Urban Systems Modeling
- TRANSIMS Application and Deployment
- Population Synthesis
- Arizona Travel Characteristics

guest · Join · Help · Sign In

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

- \* Sponsor: Federal Highway Administration, US Department of Transportation
- \* Duration: July 2008 to June 2011
- \* Project Manager: Brian Gardner, brian.gardner@dot.gov

Over the past decade, great strides have been made in the microsimulation of land use, human activity-travel demand, and dynamic transportation networks. The advent of microsimulation modeling tools in these three distinct arenas offers the unique opportunity to develop integrated models of the entire urban system including location choices of households and firms, activity and travel patterns of passengers and freight, and emergent traffic flows on time-dependent networks. This research project constitutes a significant attempt at developing the modeling framework, database systems and structures, and methods and tools for integrated modeling of the urban continuum – from long-term location choices to short-term route choices along the continuous time axis. The project involves the development of a model system that seamlessly integrates models of land use, activity-travel behavior, and dynamic traffic assignment. The project team includes Professor Paul Waddell from the University of Washington and Professors Yi-Chang Chiu and Mark Hickman from the University of Arizona. Agency partners assisting the project team include the Maricopa Association of Governments (MAG), Pima Association of Governments (PAG), Arizona Department of Transportation (ADOT), Maricopa County Department of Transportation (MCDOT), and Puget Sound Regional Council (PSRC).

[OpenAMOS Modeling Framework](#)

[Integrated UrbanSIM - OpenAMOS - MALTA Framework](#)

[SimTRAVEL Project Updates](#)

[Software Development and Implementation](#)

simtravel.asu@gmail.com

# Wiki Site

## Weekly status updates

SimTRAVEL - SimTRAVEL Project Updates - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://simtravel.wikispaces.asu.edu/SimTRAVEL+Project+Updates

Most Visited Getting Started Latest Headlines

SimTRAVEL - SimTRAVEL Project Upd...

bsana My Wikis My Account Help Sign Out

**SimTRAVEL**

SimTRAVEL Project Updates [Edit This Page](#) [page](#) [discussion](#) [history](#) [notify me](#)

**Actions**

- New Page
- Recent Changes
- Manage Wiki

Search

**Navigation**

- Home
- Integrated Urban Systems Modeling
- TRANSIMS Application and Deployment
- Population Synthesis
- Arizona Travel
- Characteristics
- [edit navigation](#)

Update: May 7, 2010



This week, the team continued to work on items previously reported:

- Work on the development of user interfaces for model specifications is being continued. Specifically, some of the dynamic interactions involved have been coded and tested.
- The preparation of data for generating synthetic population for San Francisco is going on. In addition to the socio-economic variables for households and persons, housing unit related variables will be controlled. When preparing/processing data for the synthetic population generation, the project team encountered an issue with sum of the households and groupquarters not matching the total number of occupied units. The project team is currently exploring options for resolving the issue.

---

Update: May 2, 2010

In the last week, the following progress was made:

- We have continued work on the component implementation framework code. Also, an example configuration file with the various model specifications in the Fixed Activity Prism Generator (an OpenAMOS component) was also setup. The example file is shown -  [config.xml](#). In the coming week, this example file will be used to develop and expand the component implementation framework code.
- Work is also continuing on the development of user interfaces for specifying the project attributes and for specifying the model configurations. Following are some of the screenshots of the user interfaces - [Probability Distribution Model.jpg](#), [Logistic Regression Model.jpg](#), [Negative Binomial Model.jpg](#), [Stochastic Frontier Model.jpg](#), [Multinomial Logit Model.jpg](#), [Ordered Probit Model.jpg](#), [Nested Logit Model.jpg](#)
- All the three project teams are working closely in setting up data for the San Francisco Bay area which will be used as the preliminary test bed for developing and testing the integrated modeling software. Work has already begun on the generation of synthetic population. In the last week we identified various land use and socio-economic variables that are important for successfully simulating the land use and activity-travel choices. The document here  [sfcounty\\_lu\\_sample\\_sf\\_cats.xlsx](#) provides a list of the land use variables and the category definitions for the variables. In the coming week, the variables will be collapsed into manageable number of categories and a synthetic population will be generated.

# Wiki Site

SimTRAVEL - UrbanSIM - OpenAMOS - MALTA Framework - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://simtravel.wikispaces.asu.edu/UrbanSIM+-+OpenAMOS+-+MALTA+Framework

Most Visited Getting Started Latest Headlines

SimTRAVEL - UrbanSIM - OpenAMOS ...

**SimTRAVEL** [UrbanSIM - OpenAMOS - MALTA Framework](#) [Edit This Page](#) [page](#) [discussion](#) [history](#) [notify me](#)

**bsana** [My Wikis](#) [My Account](#) [Help](#) [Sign Out](#)

**Model Description**

**Flowchart**

```

graph TD
    Start([Start simulation for Base Year]) --> SPSG[Synthetic Population Generator]
    SPSG --> WSP[Work/School/Pre-school Location Choices]
    WSP --> VOM[Vehicle Ownership Model]
    VOM --> FAPG[Fixed Activity Prism Generator]
    FAPG --> CDAM[Child Daily Status and Allocation Model]
    CDAM --> ADS[Adult Daily Status]
    
    USLC[UrbanSim: Location Choices] --> SPSG
    MALTA1[MALTA: Skims for the whole day from previous years run; Access to underlying travel skims structure for generating location choice sets???] --> SPSG
    
    MALTA2[MALTA: Skims for the whole day from previous iteration (day); Access the underlying travel skims structure for generating location choice sets???] --> CDAM
  
```

**Actions**

- New Page
- Recent Changes
- Manage Wiki

Search

**Navigation**

- Home
- Integrated Urban Systems Modeling
- TRANSIMS Application and Deployment
- Population Synthesis
- Arizona Travel
- Characteristics
- [edit navigation](#)

# Conclusions

- ❖ Several issues and challenges arise in integrated modeling
- ❖ Involve making decisions and/or assumptions regarding behavior and its representation
- ❖ Representation of space, time and networks
- ❖ Simulation-based dynamic traffic assignment approaches to reflect traffic dynamics
- ❖ How to incorporate heterogeneity in traveler route choices within equilibrium analysis framework
- ❖ Critical feedback processes from network conditions to activity-travel scheduling
  - Consistency in travel times between those used in destination and mode choice and those obtained from traffic assignment

# Conclusions

- ❖ Design of efficient data structures to overcome computational issues
- ❖ Model calibration and validation of individual models as well as integrated system
- ❖ Need for consistency and coordination across model systems that comprise the integrated model
- ❖ In parallel with other cutting edge projects around the country
  - C10
  - SimAGENT at Southern California Association of Governments
  - Sacramento Council of Governments