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

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

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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 sytems
  - 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

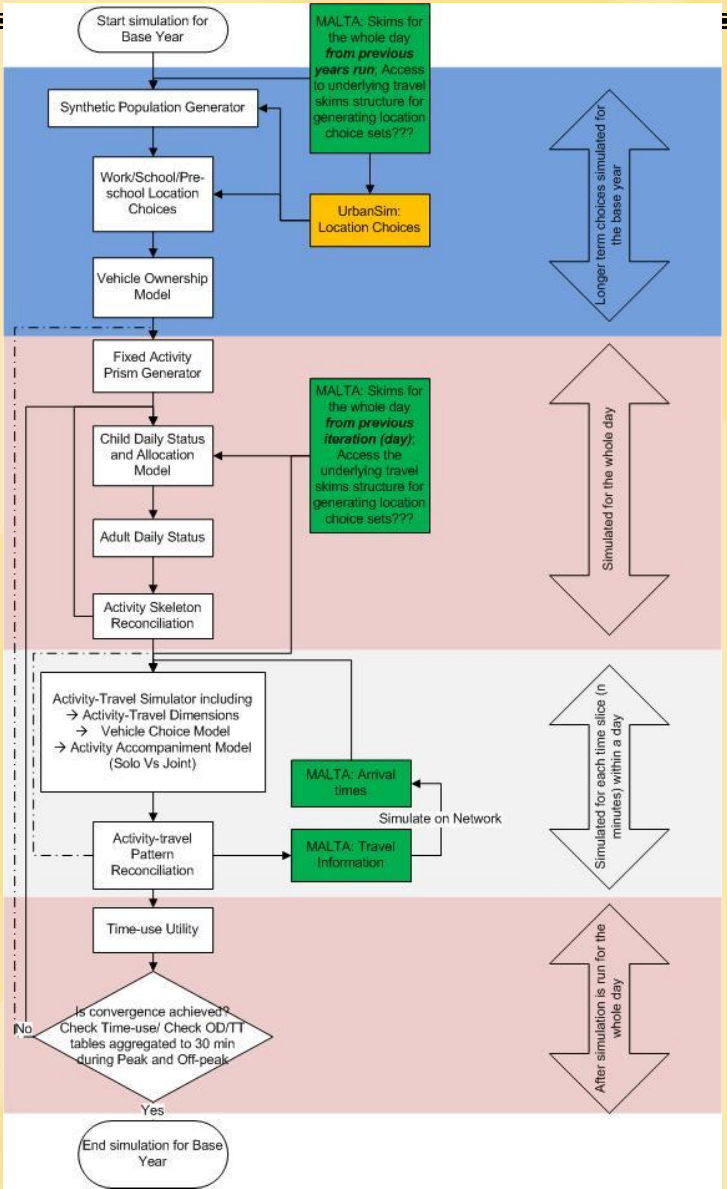
Design Considerations

- 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)

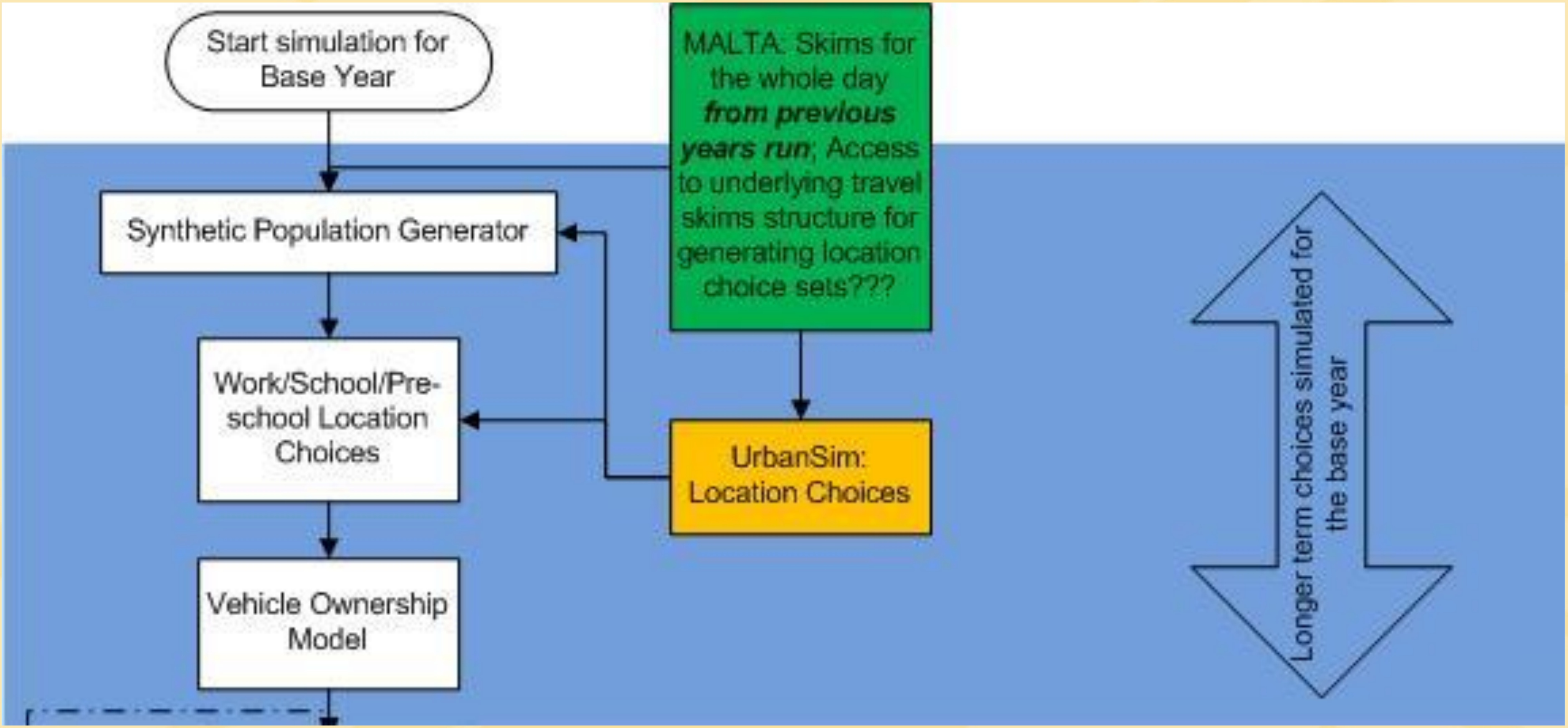
Model Systems

- 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)

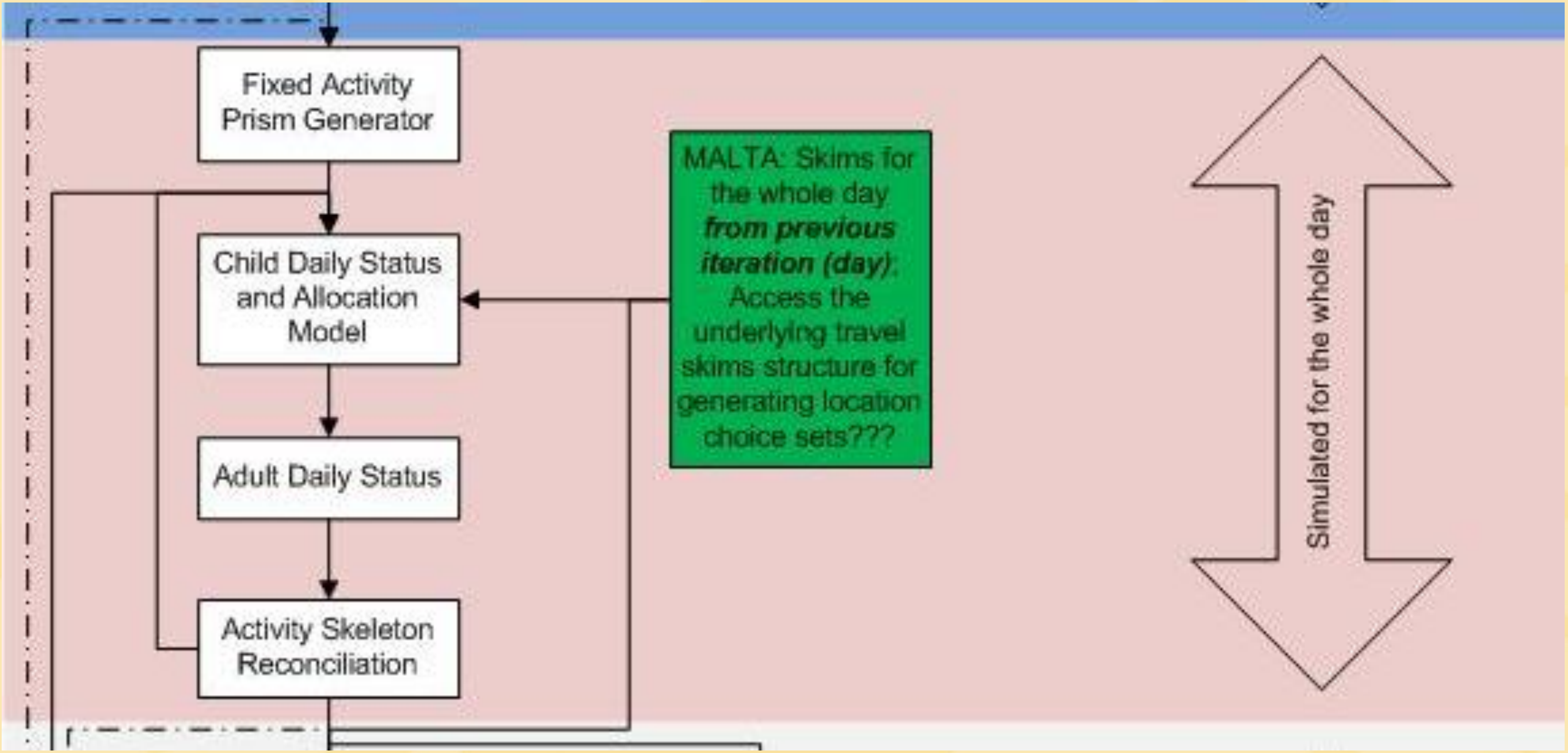
Model Design: SimTRAVEL



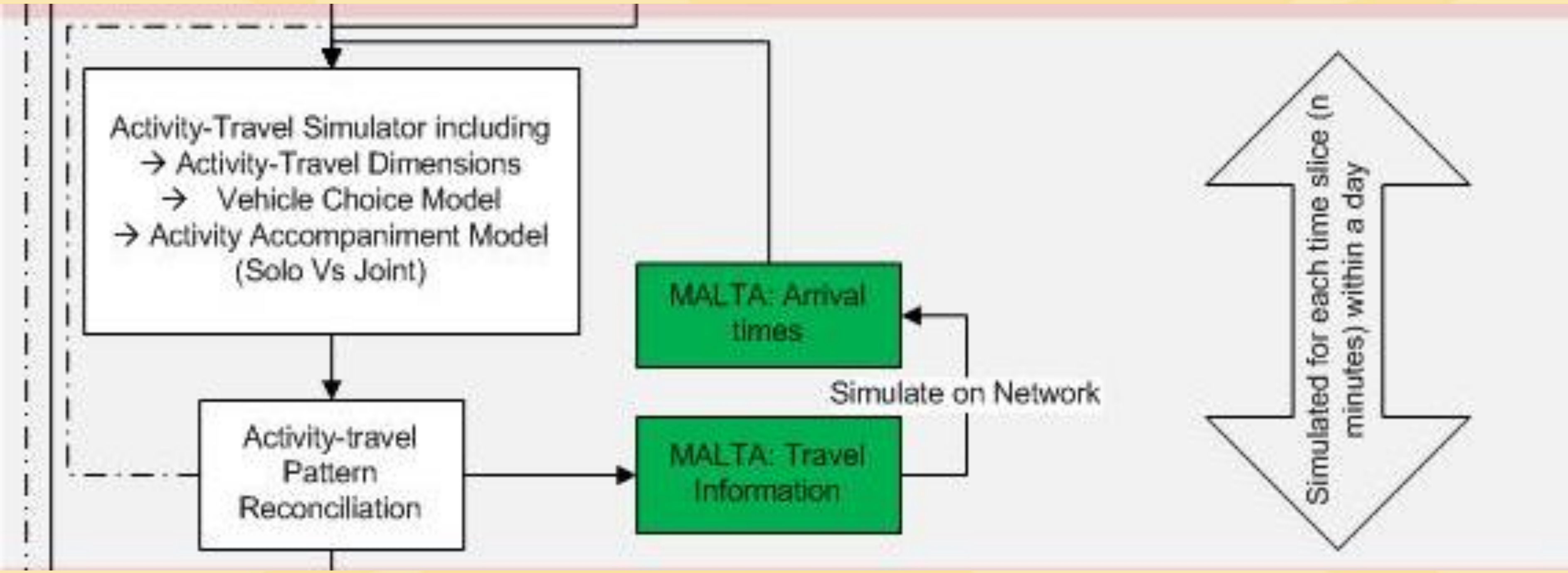
Model Design



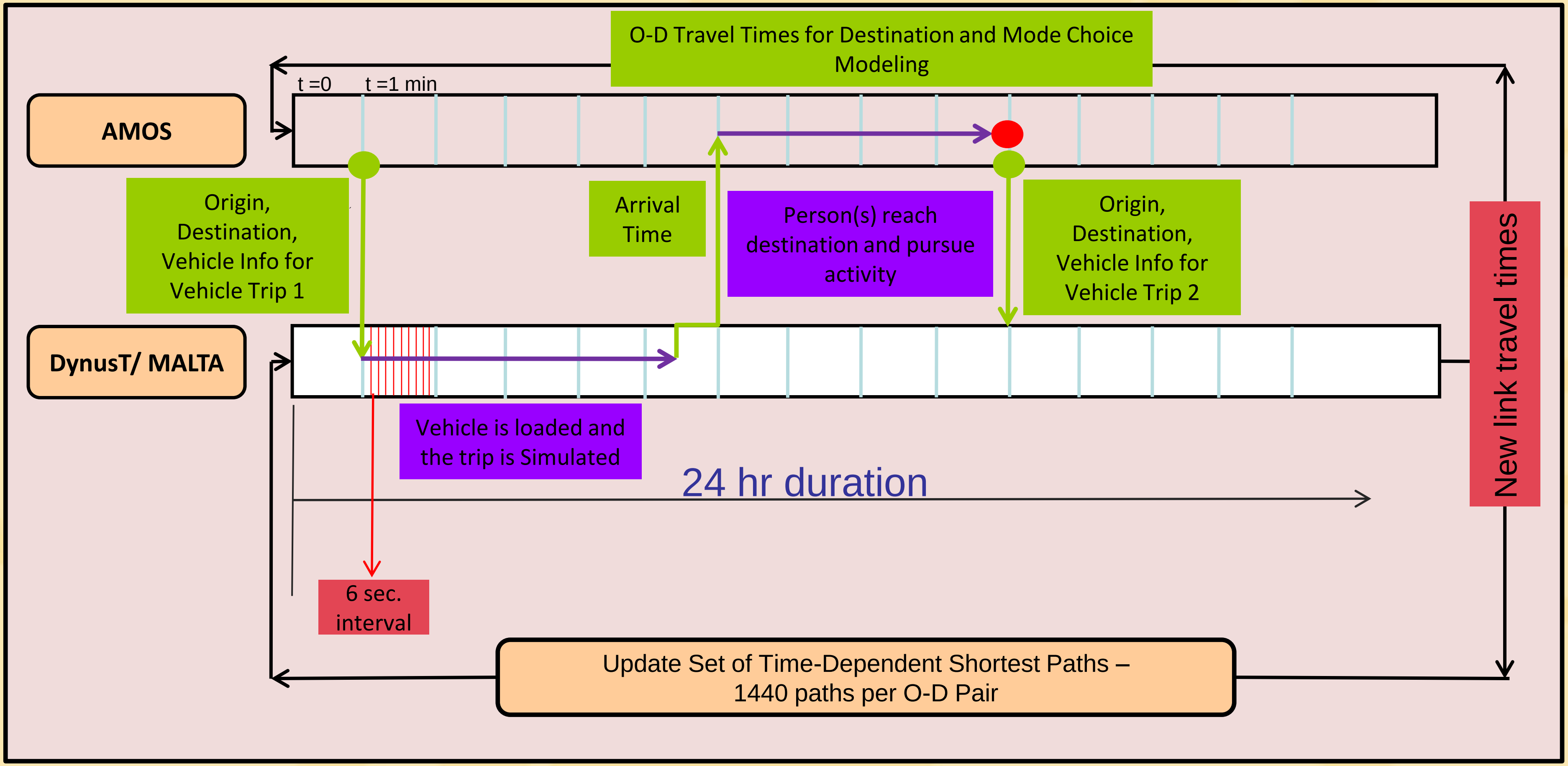
Model Design



Model Design



Integrated Model: Supply and Demand



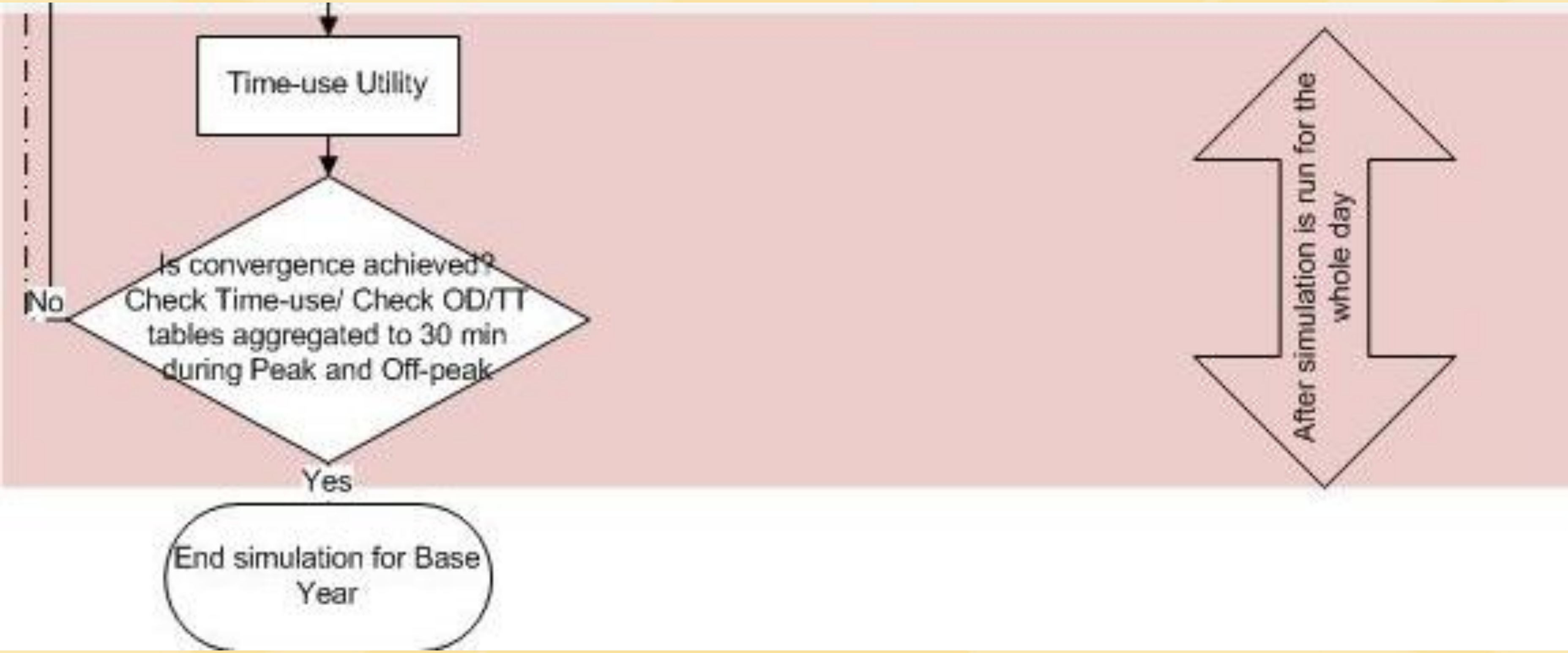
Model Design

- 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

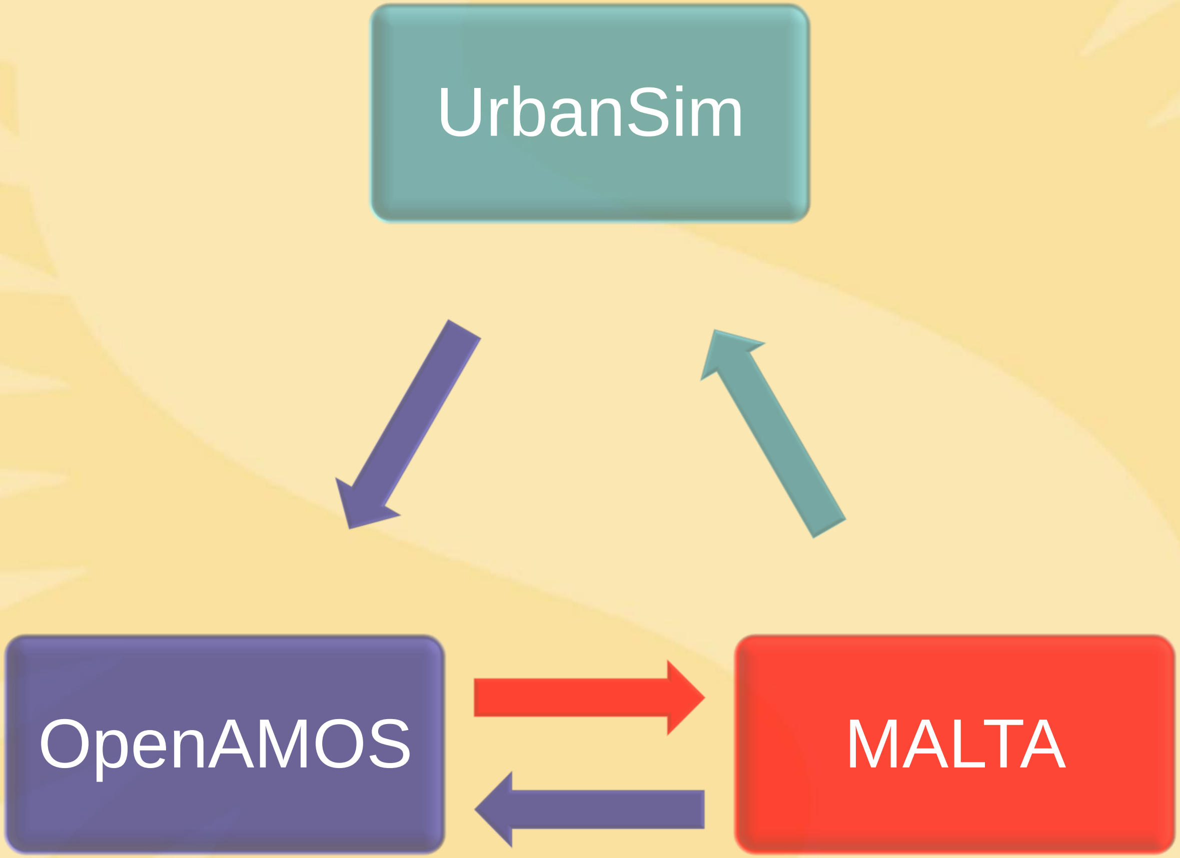
Software Development

- 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

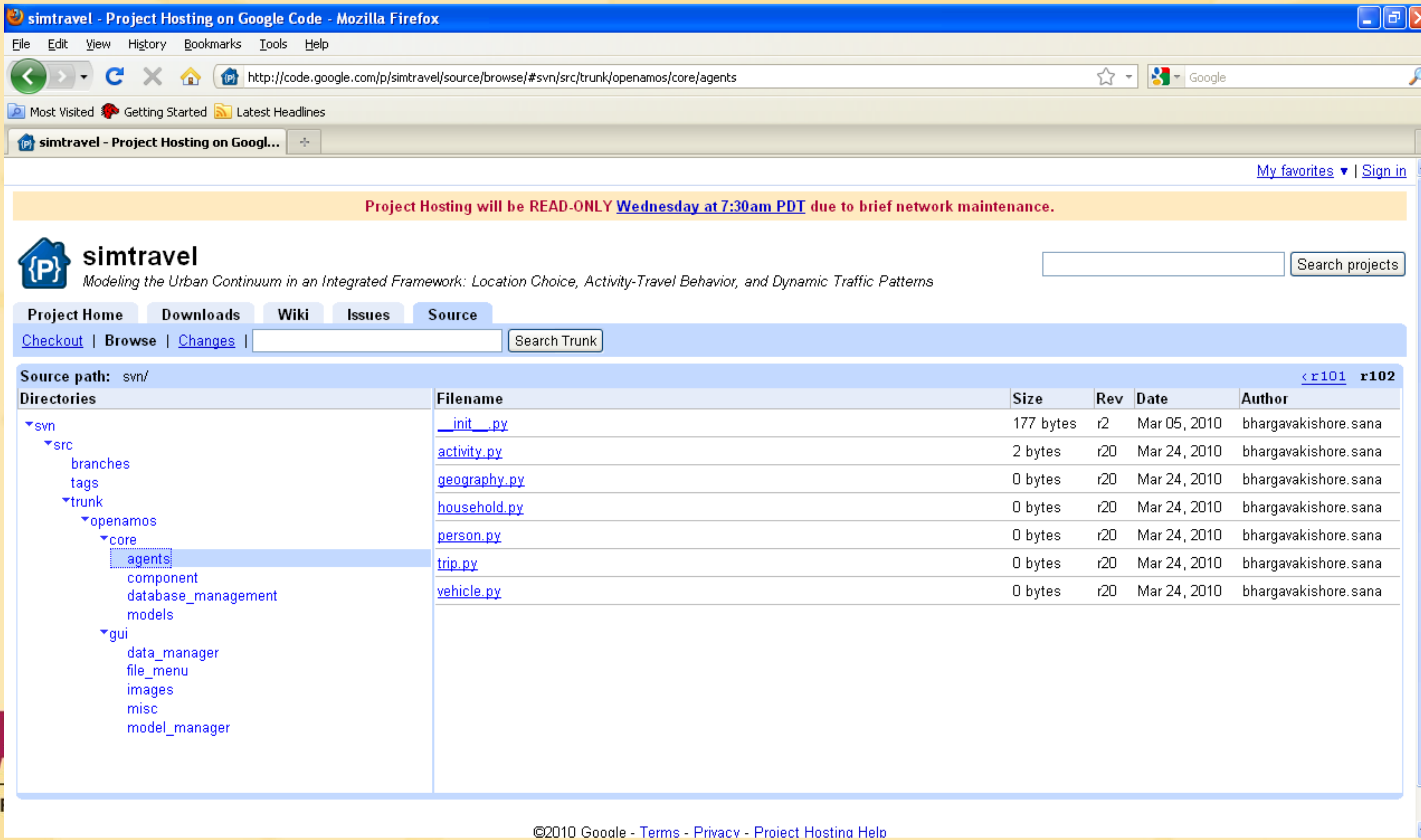
Vehicle File	Household File	Person File	Person Activity File	Person Trips File	Vehicle Trip File
• Vehicle ID • Body Type • Age • Household ID	• Household ID	• Person ID • Household ID	• Person Activity ID • Activity Type ID • Start Time • End Time • Parcel ID • Person ID	• Person Trip ID • Person Activity ID • Trip ID	• Trip ID • Mode • Vehicle ID • Start Time • Start Link ID • End Link ID • Simulated Arrival Time

Network Related Tables

Nodes File	Links File	Parcels File	Travel Data File	Parking Costs File
• Node ID	• Link ID • From Node • To Node	• Parcel ID • Link ID	• From Link ID • To Link ID • From Time • To Time • Mode • Travel Time In-Vehicle • Travel Time Out-of-Vehicle • Travel Cost • Tolls	• Parking Cost ID • Link ID • Parking Cost – Peak • Parking Cost – Off-peak • Parking Spaces

Code Repository

http://code.google.com/p/simtravel/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Modeling the Urban Continuum in an Integrated Framework: Location Choice, Activity-Travel Behavior, and Dynamic Traffic Patterns

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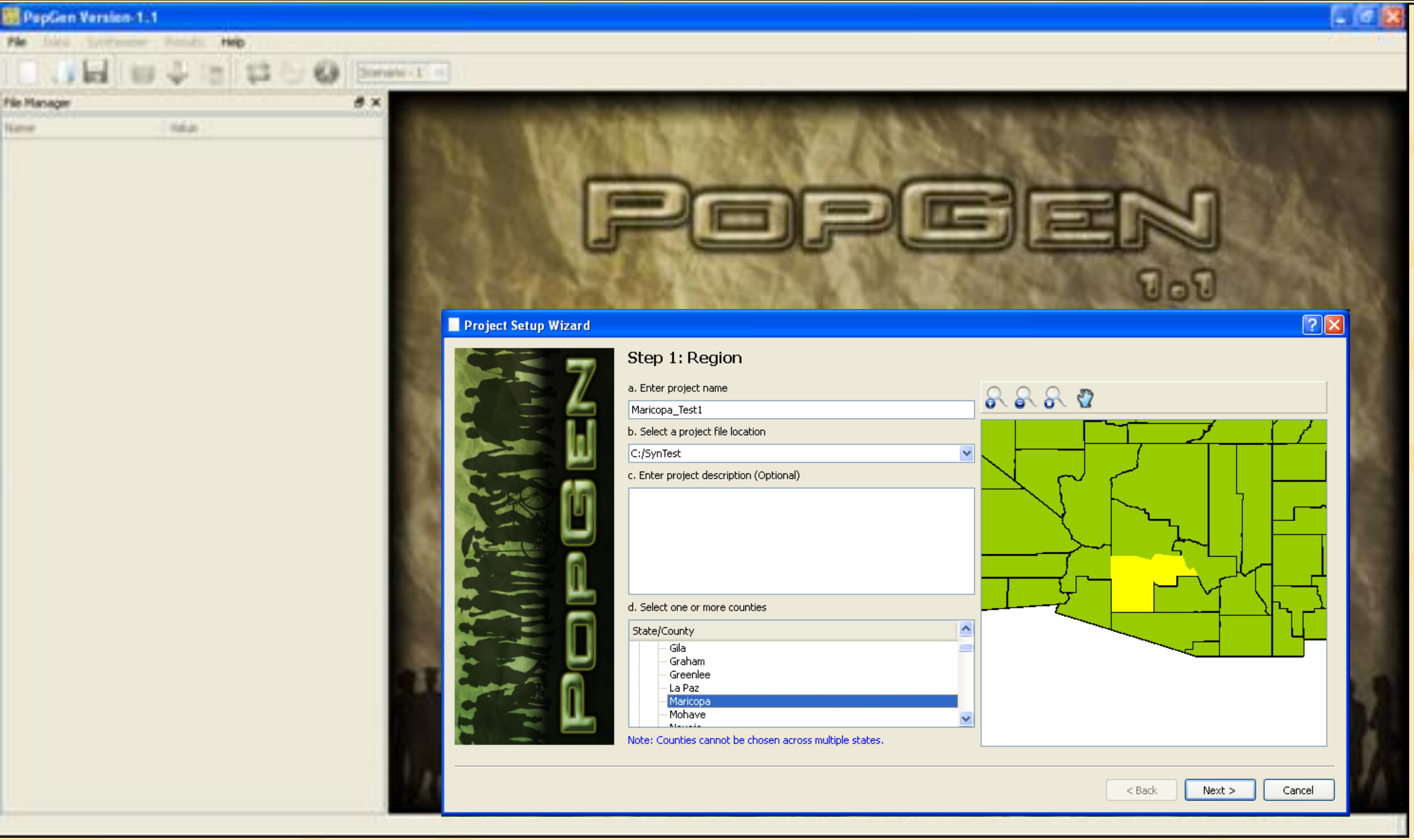
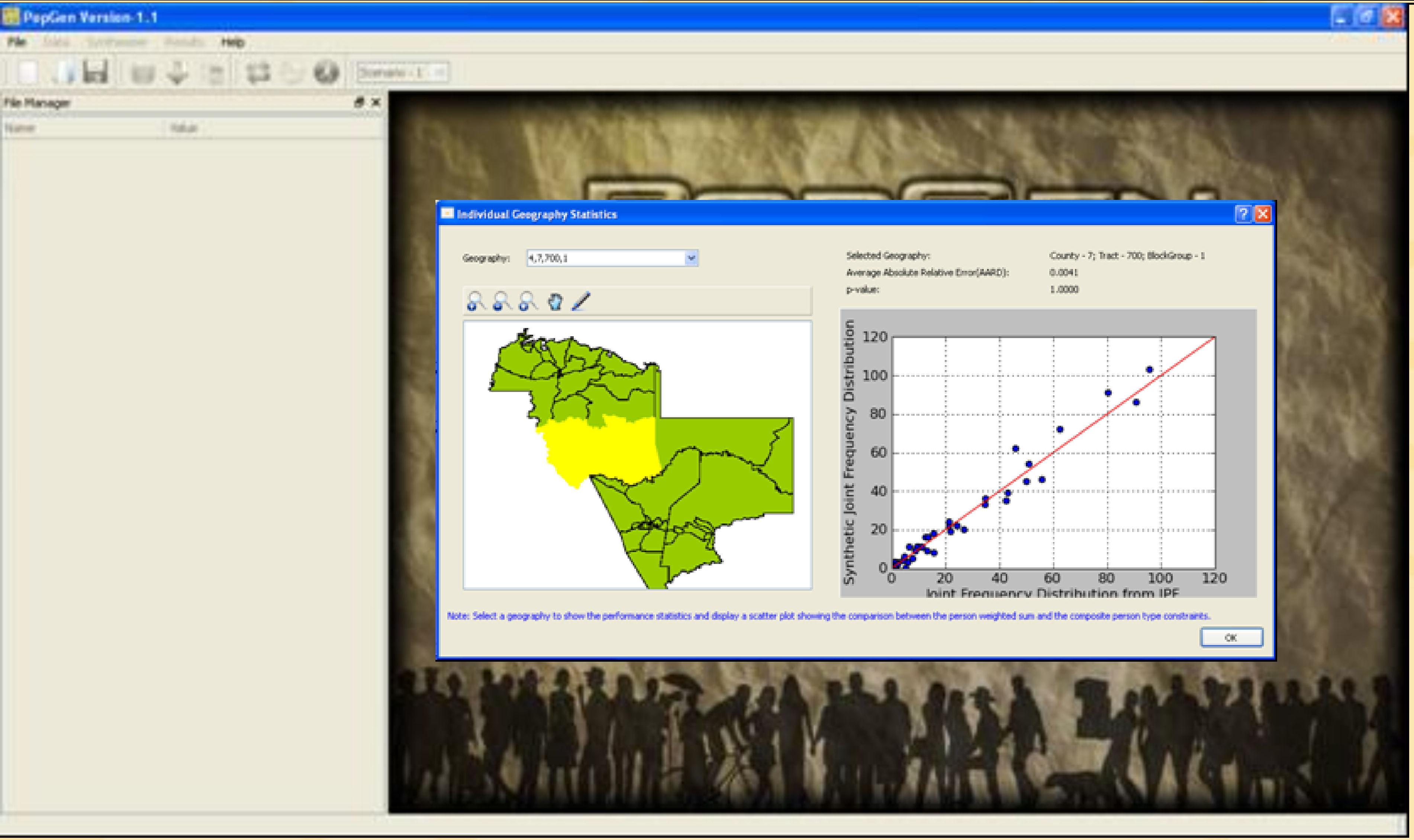
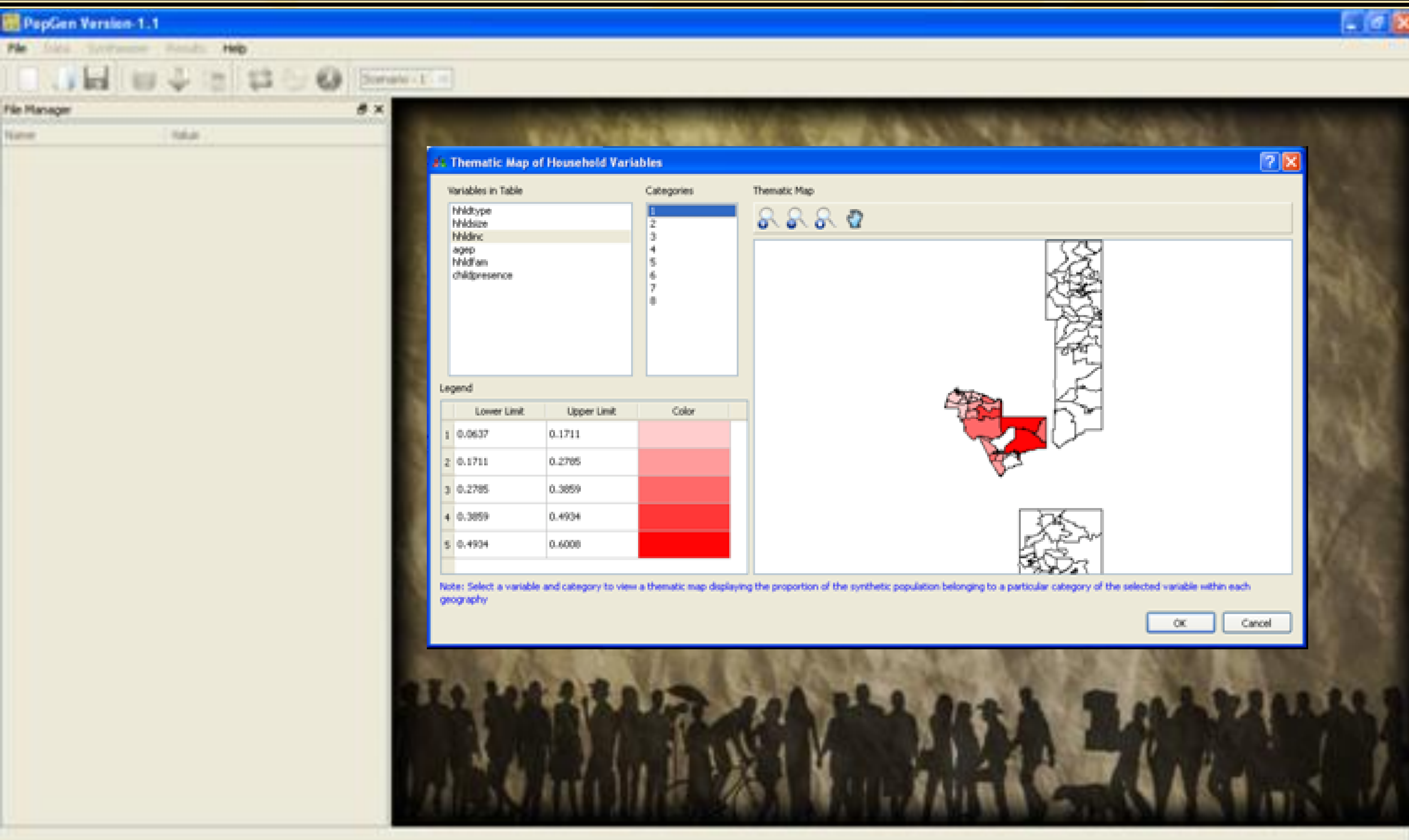
Example Product: PopGen



Example Product: PopGen



Example Product: PopGen

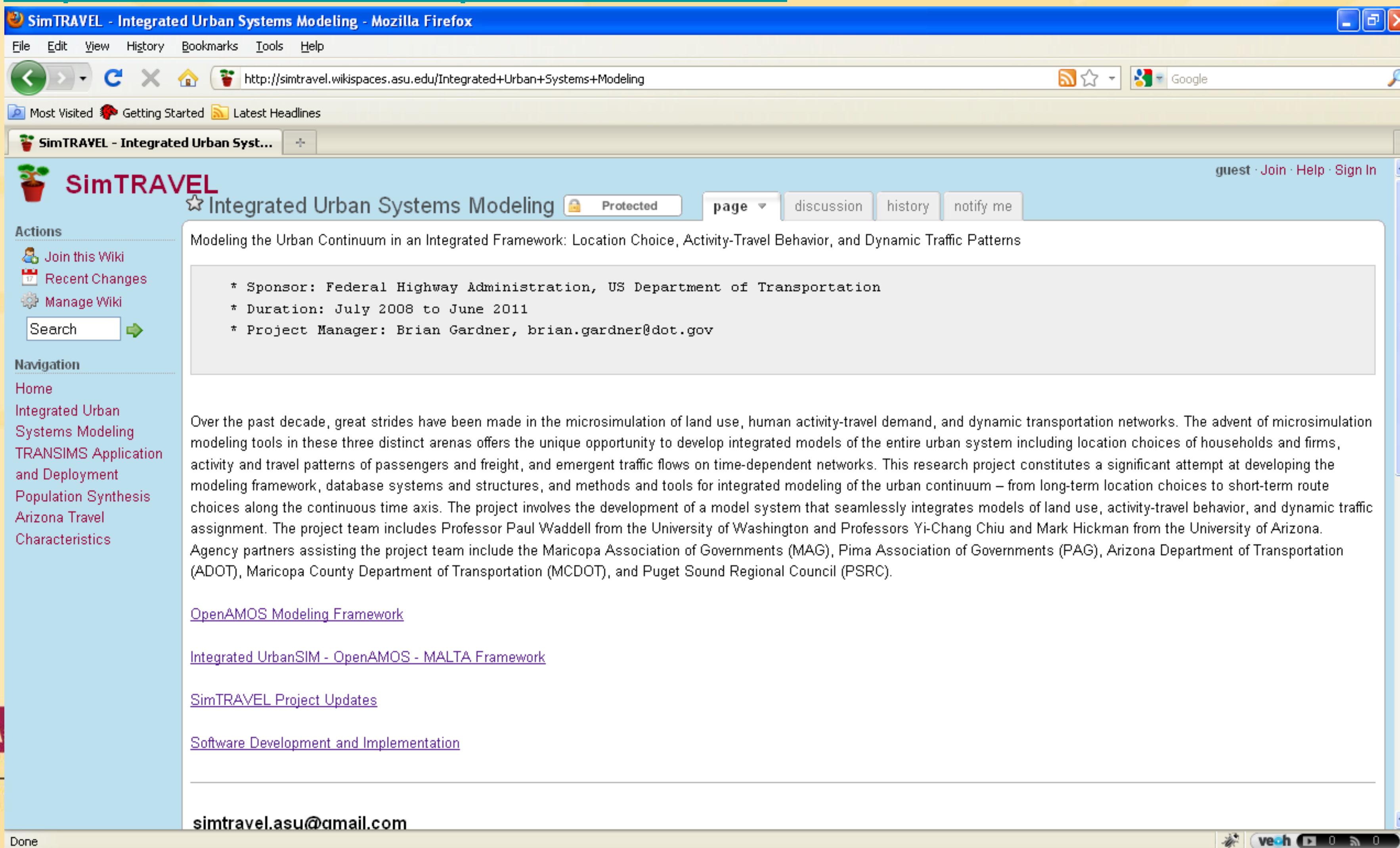


Current Status

- 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

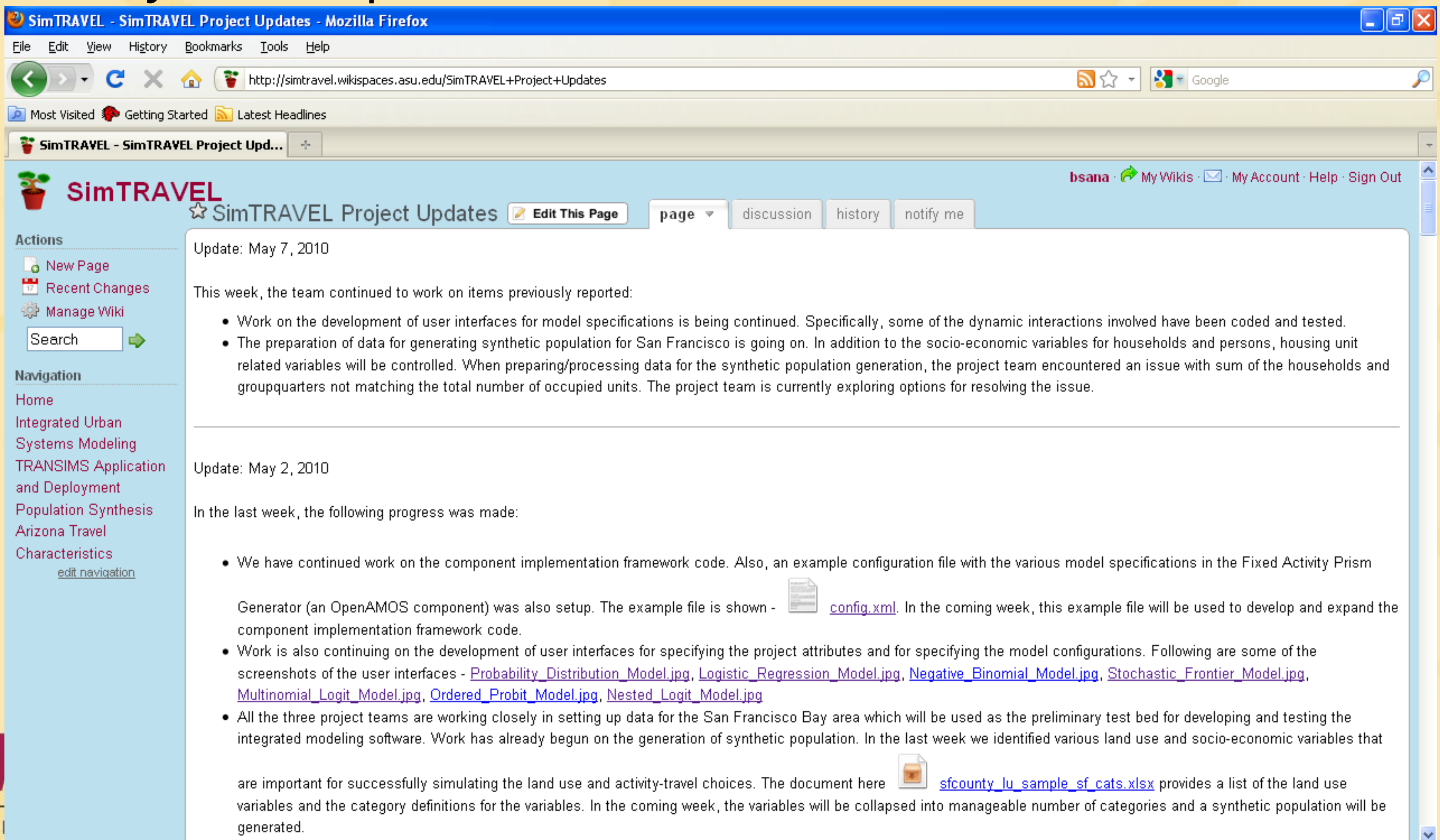
Wiki Site

http://simtravel.wikispaces.asu.edu



Wiki Site

Weekly status updates



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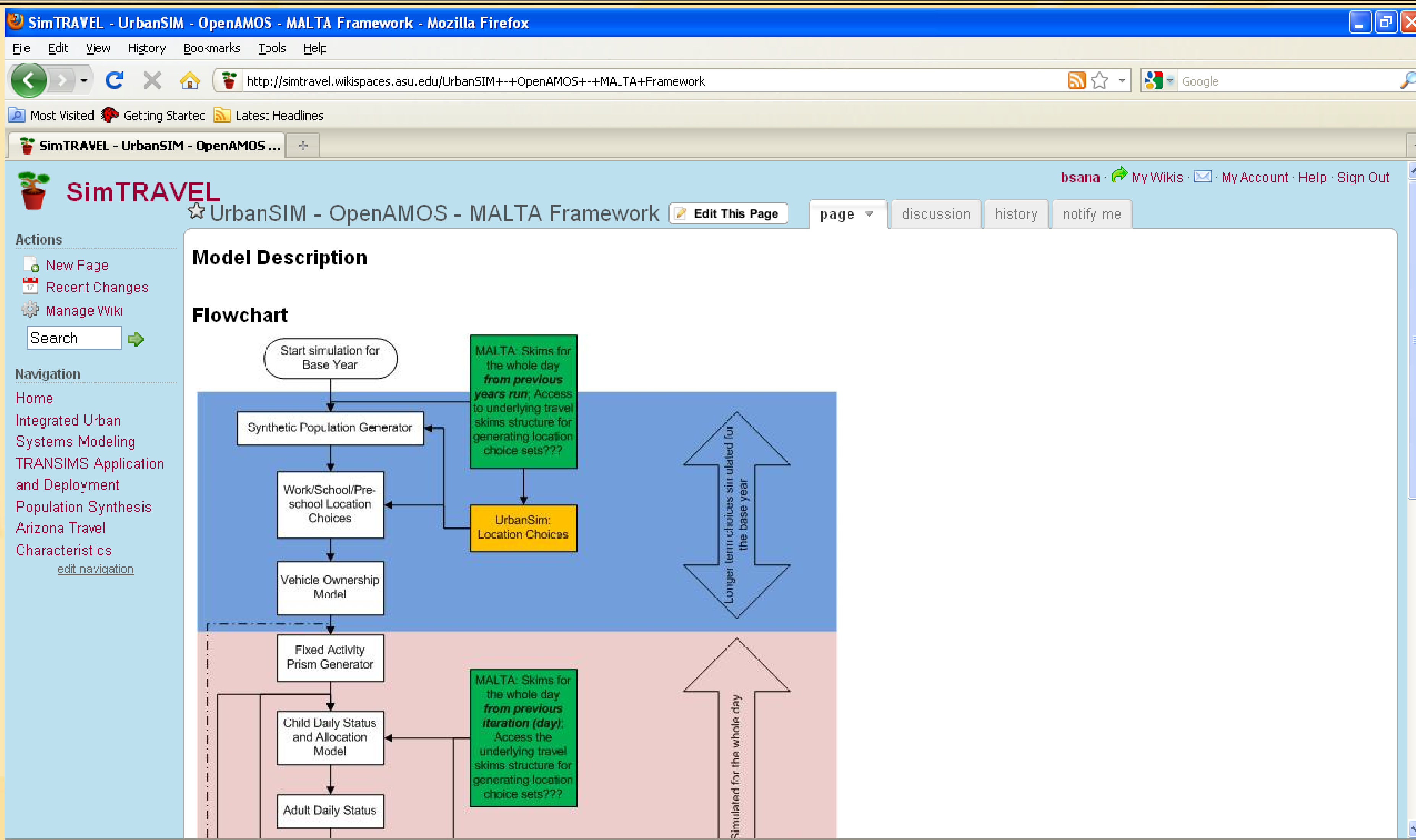
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Population Synthesis
Arizona Travel Characteristics
edit navigation
Model Description
Flowchart
Start simulation for Base Year
MALTA: Skims for the whole day from previous years run; Access to underlying travel skims structure for generating location choice sets???
Synthetic Population Generator
Work/School/Pre-school Location Choices
UrbanSim: Location Choices
Vehicle Ownership Model
Longer term choices simulated for the base year
Fixed Activity Prism Generator
Child Daily Status and Allocation Model
MALTA: Skims for the whole day from previous iteration (day); Access the underlying travel skims structure for generating location choice sets???
Adult Daily Status
Simulated for the whole day

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