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URBAN LAND USE AND TRANSPORTATION CENTER
of the Institute of Transportation Studies

The CALSIM Framework: Integrated Land Use and Transportation Model for the State of California

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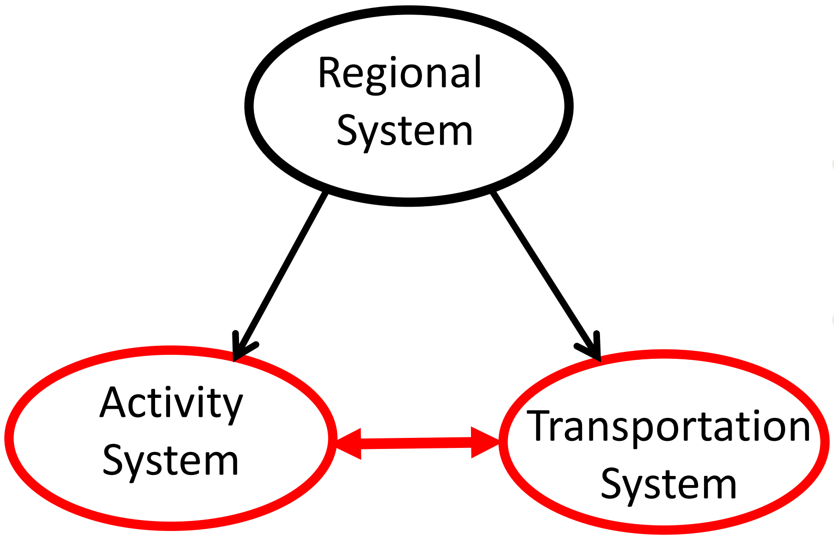
Land Use/Transportation Models

Integrated Land Use/Transportation Models provide an answer to the need for simulating the modifications in the land use and travel demand simultaneously, while accounting for the mutual interactions that occur among the two systems.

Integrated Land Use and Transportation Models

- Long tradition in this field of studies (first studies date back to several decades ago).
- The models fill a gap in the forecast of the future growth of cities and regions.
- Extremely important to support long term decisions in *strategic planning.*

Cities and Regions: Complex Systems to Model



- The transportation system is an important element of the more complex regional system.
- It strongly interacts with the system of the activities.
- A comprehensive approach to modeling should consider the relationships with the system of the activities (in particular, with the relocation of ***residences*** and ***economic activities***).

Cities and Regions: Complex Systems to Model

Different use of transportation, depending on the built environment:

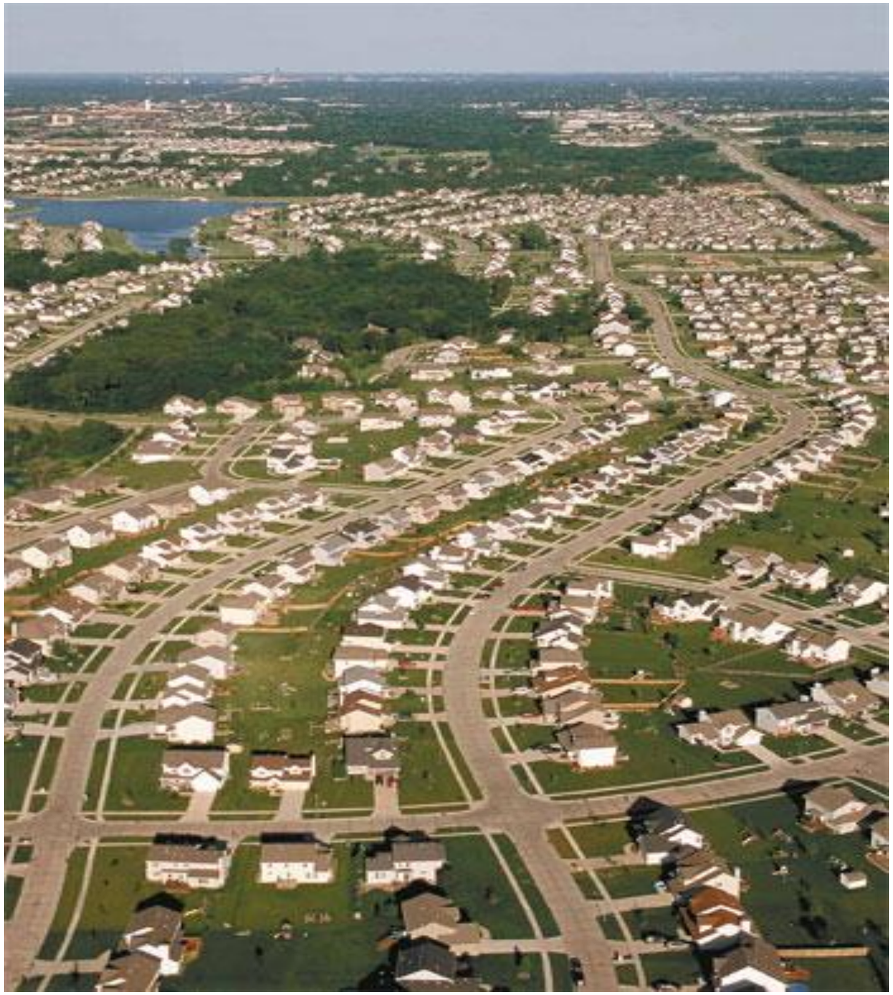
Mixed land use in San José, CA

Cities and Regions: Complex Systems to Model

Different use of transportation, depending on the built environment:

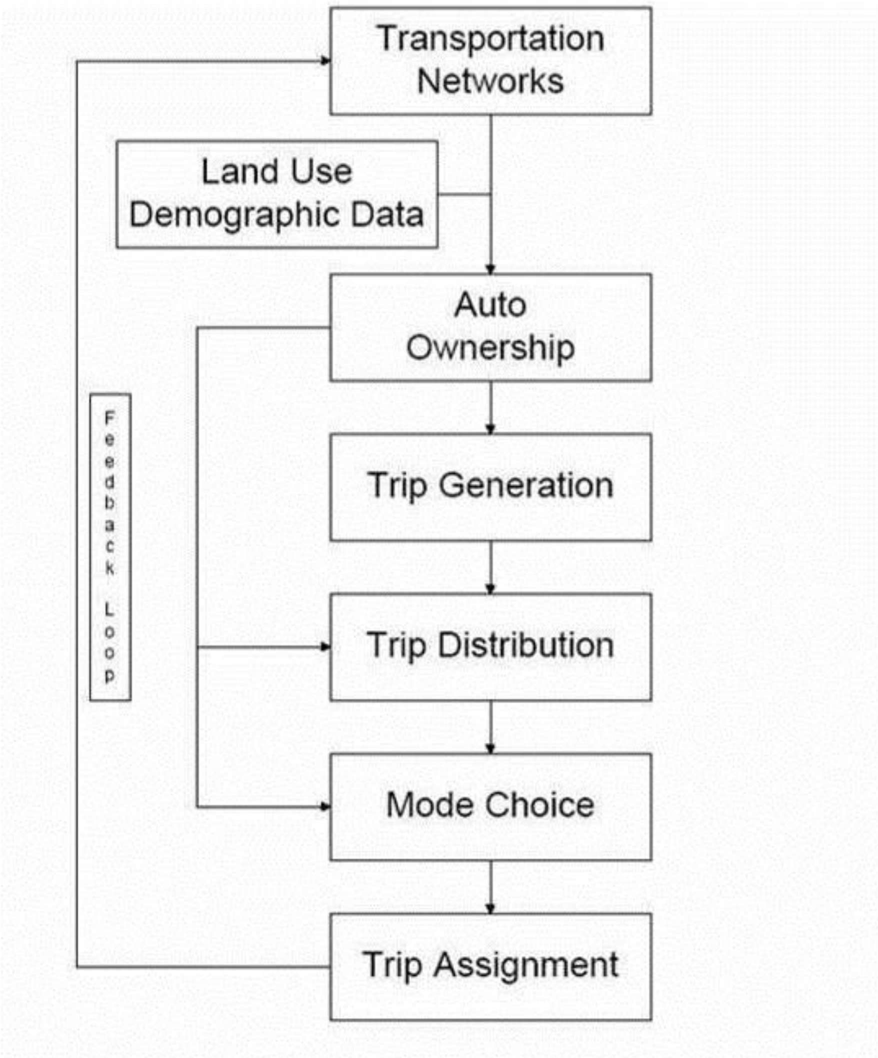
Urban Sprawl in Davis, CA

Cities and Regions: Complex Systems to Model



Enormous impact associated with the spread of specific urban form.

The Interaction with Land Use



Travel Demand Models usually take the *land use* and *transportation network* as “given” (*input* of the model).

Demographic data and land use features are loaded as *input* in the model, and not modified *endogenously* as a result of the model run.

The Need for Land Use / Transportation Models

Modeling approach that allows evaluating the future development of the region, and the results of the adoption of policies in the long term.

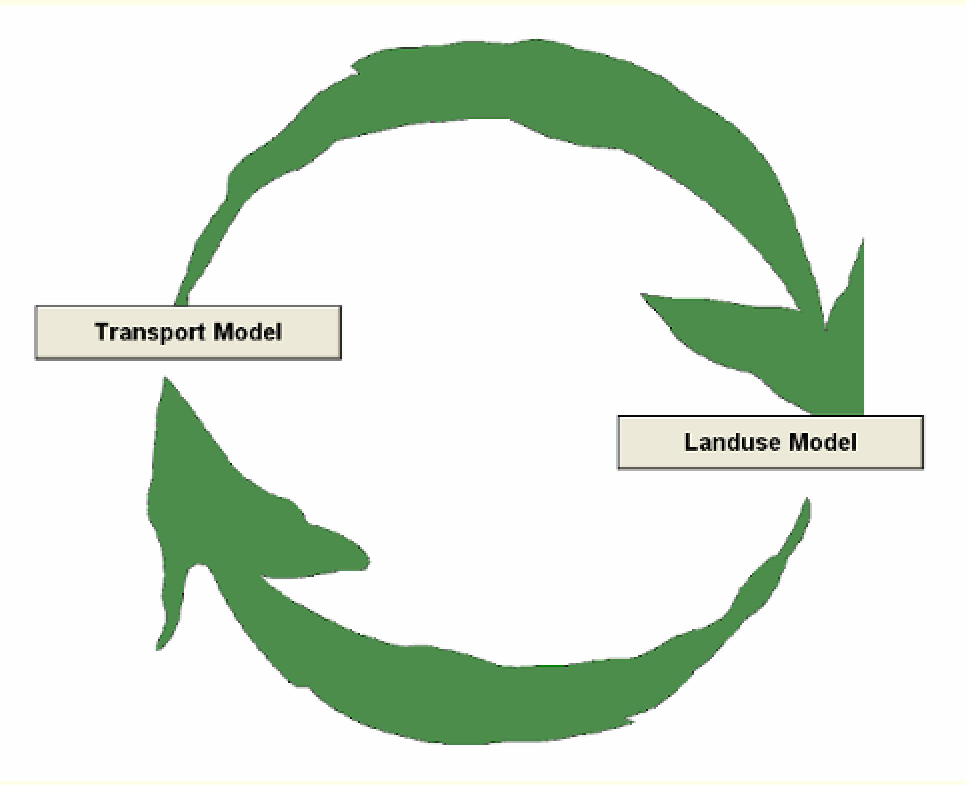
SHORT TERM PLANNING

No changes in socio-demographics and land use

LONG TERM STRATEGIC PLANNING

Simulation of integrated future development

The Land Use Transportation Interaction

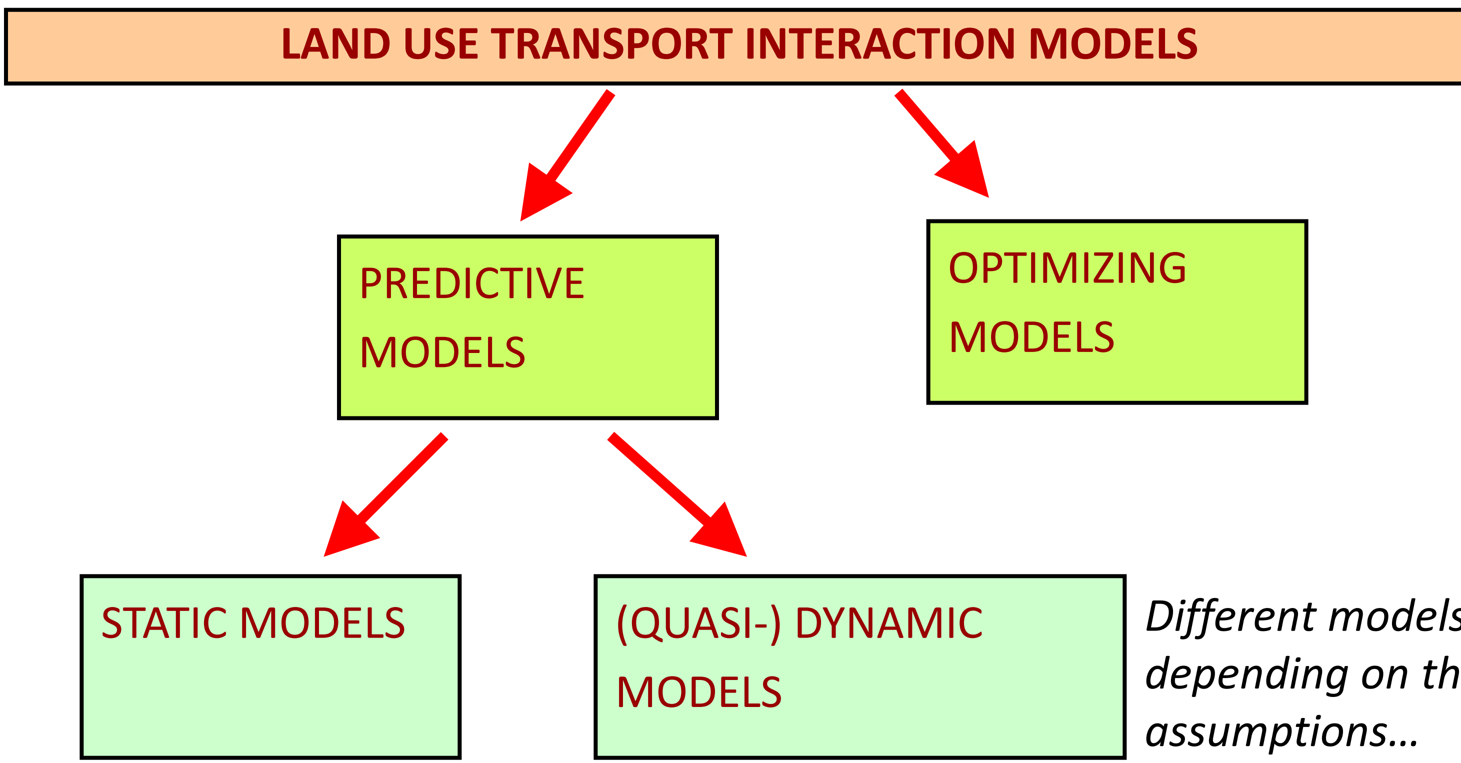


Land Use and Transportation Models allow considering the interactions between land use development and transportation demand/supply.

Most models run in a *iterative way*, in which the output of the land use model is used as input for the transportation model (and *vice versa*).

[Source: Pfaffenbichler, 2003]

Classification of LUTI models

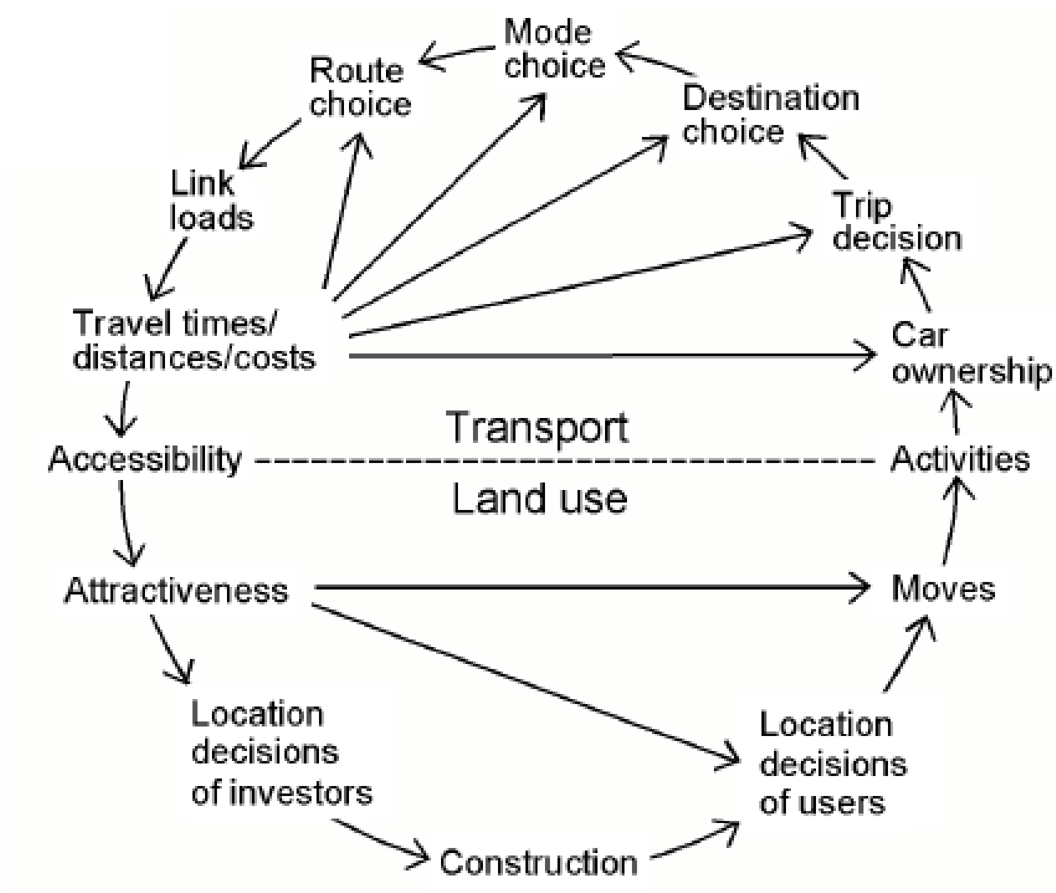


Different models depending on the specific assumptions…

(ENTROPY-BASED, SPATIAL-ECONOMICS, ACTIVITY-BASED)

[source: modified from *David Simmonds Consultancy and Marcial Echenique and Partners Ltd, 1999*]

The Interaction between Land Use and Transportation



The Land Use and Transportation Feedback Cycle [Source: Wegener, 2004]

Integrated Land Use / Transportation Models

- Most packages are composed by a comprehensive model of interaction that activates several sub-modules.
- Feedbacks from one module to the other are allowed in an iterative way, representing the interactions among the organization of the transportation system and the land use and the other sub-modules.
- Different assumptions on the interactions among sub-modules lead to different structures of the models, which can be spatial-economic oriented or activity based, depending on the specific hypotheses (David Simmonds Consultancy and Marcial Echenique and Partners Ltd., 1999).
- LUTI models have various degrees of aggregation in the analyses they carry out, depending on the level of accuracy required by the objectives of the specific analyses.

Urban Change Processes

- *Very Slow Changes*: Networks, Land Use
- *Slow Changes*: Workplaces, Housing
- *Fast Changes*: Employment, Population
- *Immediate Changes*: Goods Transport, Travel

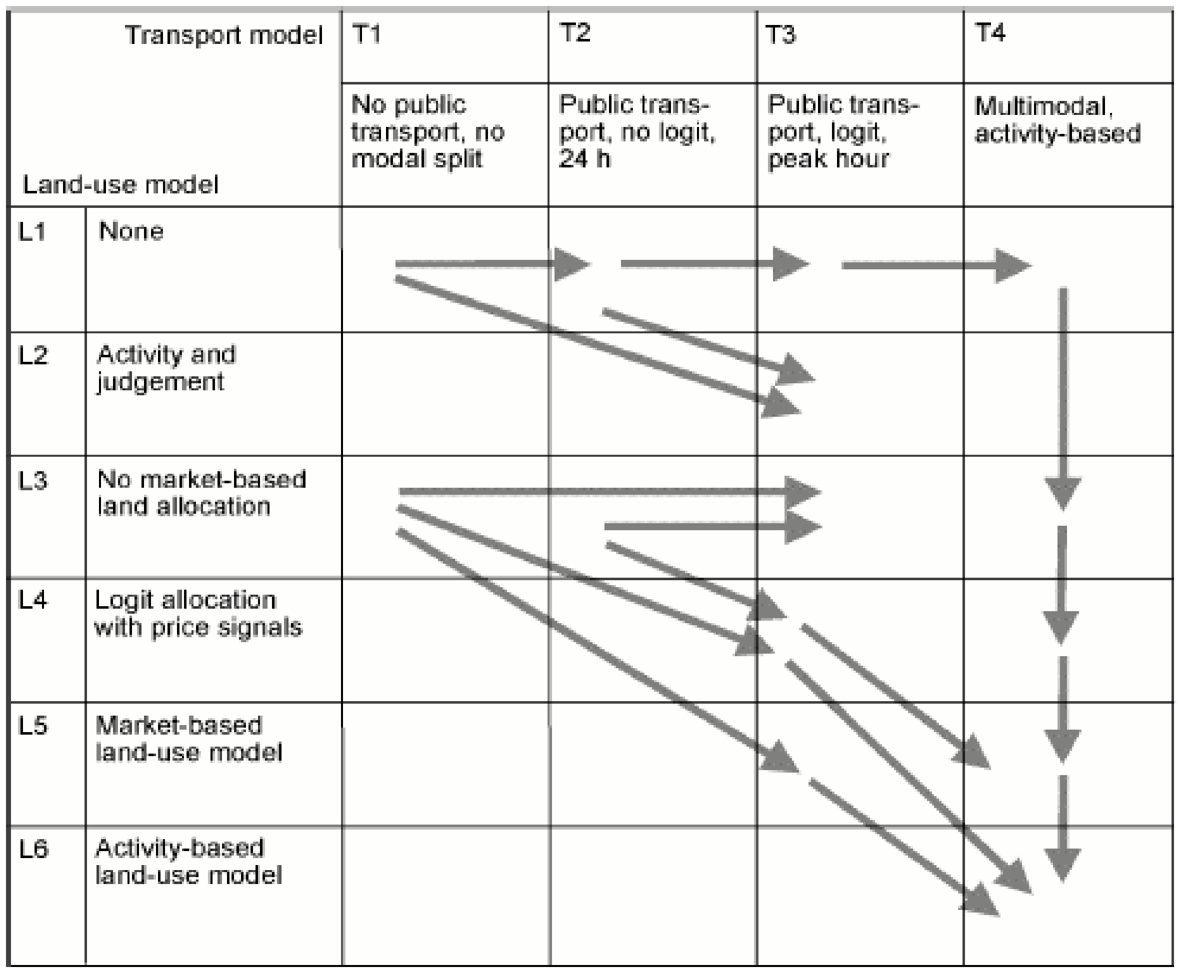
Land Use/Transportation Models

Models	Speed of change							
	Very slow		Slow		Fast		Immediate	
	Networks	Land use	Work-places	Housing	Employ-ment	Popula-tion	Goods transport	Travel
BOYCE	+				+	+		+
CUFM	(+)	+	+	+	+	+		(+)
DELTA	(+)	+	+	+	+	+		(+)
ILUTE	+	+	+	+	+	+	+	+
IMREL	+	+	+	+	+	+		+
IRPUD	+	+	+	+	+	+		+
ITLUP	+	+			+	+		+
KIM	+				+	+	+	+
LILT	+	+	+	+	+	+		+
MEPLAN	+	+	+	+	+	+	+	+
METROSIM	+	+	+	+	+	+		+
MUSSA	(+)			+	+	+		(+)
PECAS	+	+	+	+	+	+	+	+
POLIS	(+)	+			+	+		(+)
RURBAN	(+)	+			+	+		(+)
STASA	+	+	+	+	+	+	+	+
TLUMIP	+	+	+	+	+	+	+	+
TRANUS	+	+	+	+	+	+	+	+
TRESIS	+	+	+	+	+	+		+
URBANSIM	(+)	+	+	+	+	+		(+)

(+) provided by linked transport model

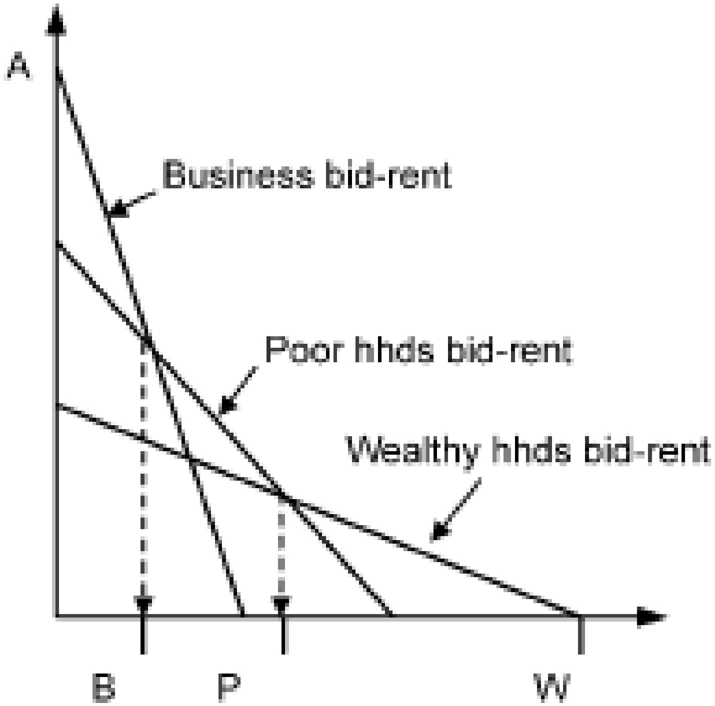
[Source: Wegener, 2004]

Land Use/Transportation Models



[Source: Wegener, 2004]

Urban Economic Theory

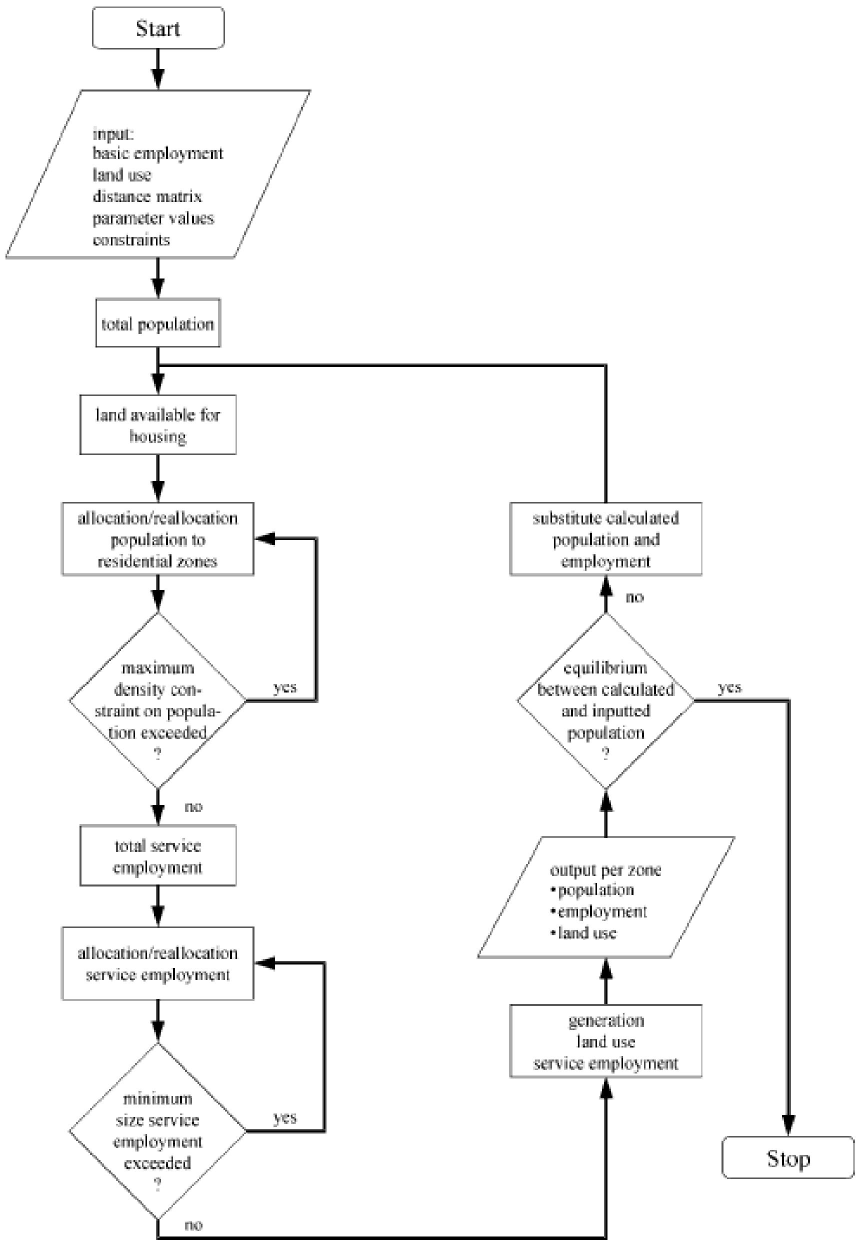


Long experience in the modeling of land use patterns in dependence of rent and transportation costs and rent

The Lowry Model

- The Lowry model is one of the first operational and widespread land use models.
- Developed by Lowry (1964) to simulate the residential location of employees in the city of Pittsburgh.
- The original Lowry model is a spatial activity distribution model, which distributes residential, employment and service activities to the zones of the studied region.
- Employment is divided into the two categories: *basic* and *non basic* (i.e. services).
- The first group is allocated to the zones exogenously, in dependence of the influence of external markets. The location of non basic workplaces is determined in the model.

The Lowry Model



Structure of the original Lowry Model (1964)

The Lowry Model

The model combines two theoretical hypotheses: the ***urban economic theory***, which allows estimating the local population and the number of employed people, and the ***spatial interaction framework*** that regulates the location of residences and service employees.

The Lowry Model

The original Lowry model consists of a set of nine simultaneous equations, and three constraints.

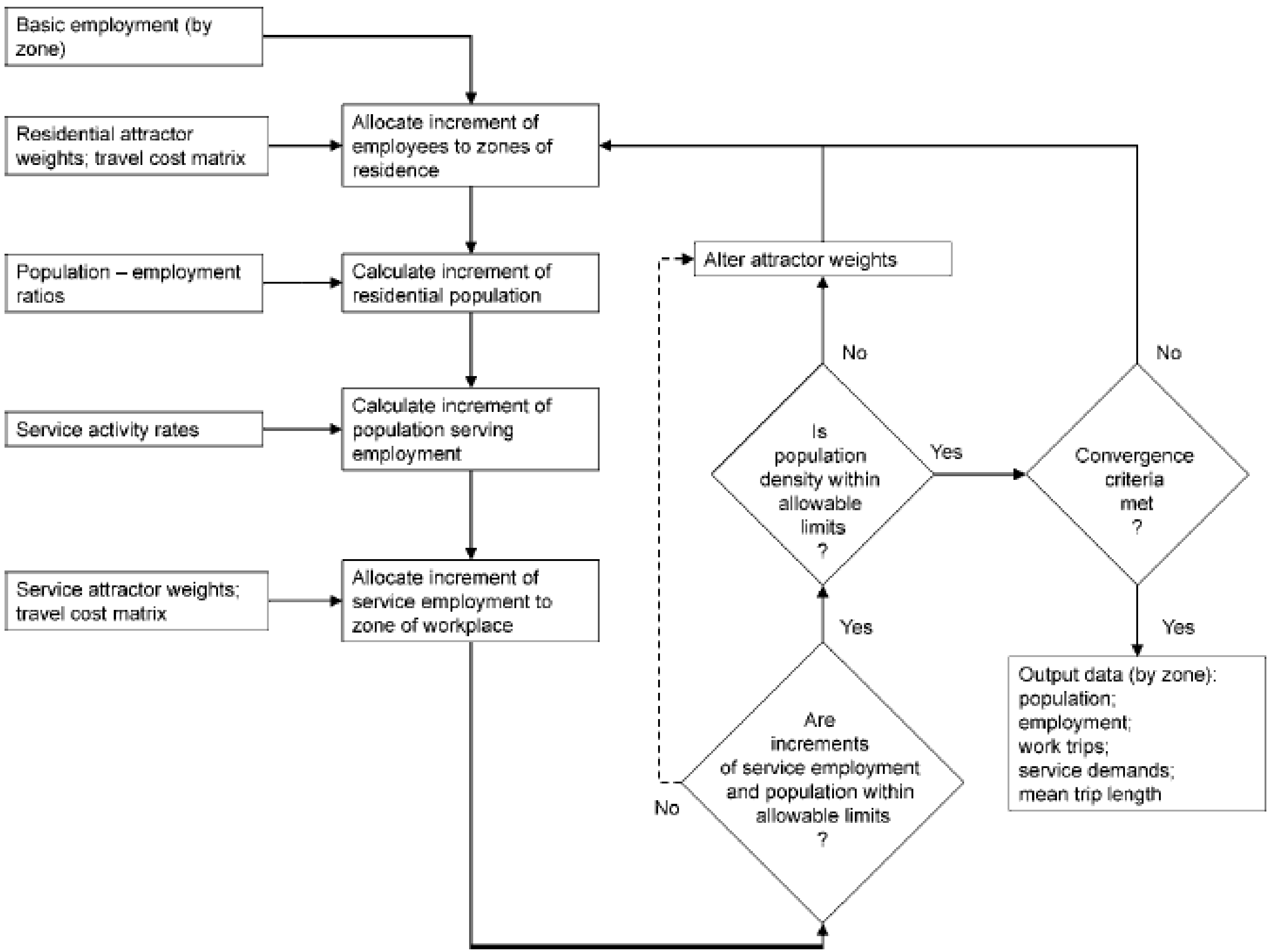
The total population is calculated by multiplying the total basic employment with a work participation rate.

In dependence of the allocated population, the amount of service employment necessary to serve this population is calculated and allocated.

The system checks that the calculated and inputted population is equal. If the condition is not fulfilled, calculated population and employment is substituted, and the next iteration is started.

If the condition is fulfilled, the model provides the output in terms of population, employment and land use per each zone.

The Garin-Lowry model



The Garin-Lowry Model

This model uses explicit sub-models, which, in every iteration, distribute the location of activities in dependence of gravity formulae.

The Garin-Lowry model works with a matrix notation (Garin, 1966).

Input data include zonal basic employment, inter-zonal travel costs and zonal attractiveness for different activities.

In analogy with the original Lowry model, workers of the basic sector are first allocated. The incremental residential population and the resulting incremental service sector employment are calculated and distributed.

A corresponding increment of population is calculated and allocated to spatial zones.

The iterative process continues until a convergence criterion is fulfilled.

The Garin-Lowry model has been used successfully in the analysis of the effects of regional changes, due to the simplicity of its use.

MEPLAN

MEPLAN is a software package developed by the Marcial Echenique and Partners Limited.

It has been developed on the basis of a robust static model for urban spatial development (Echenique *et al.*, 1969).

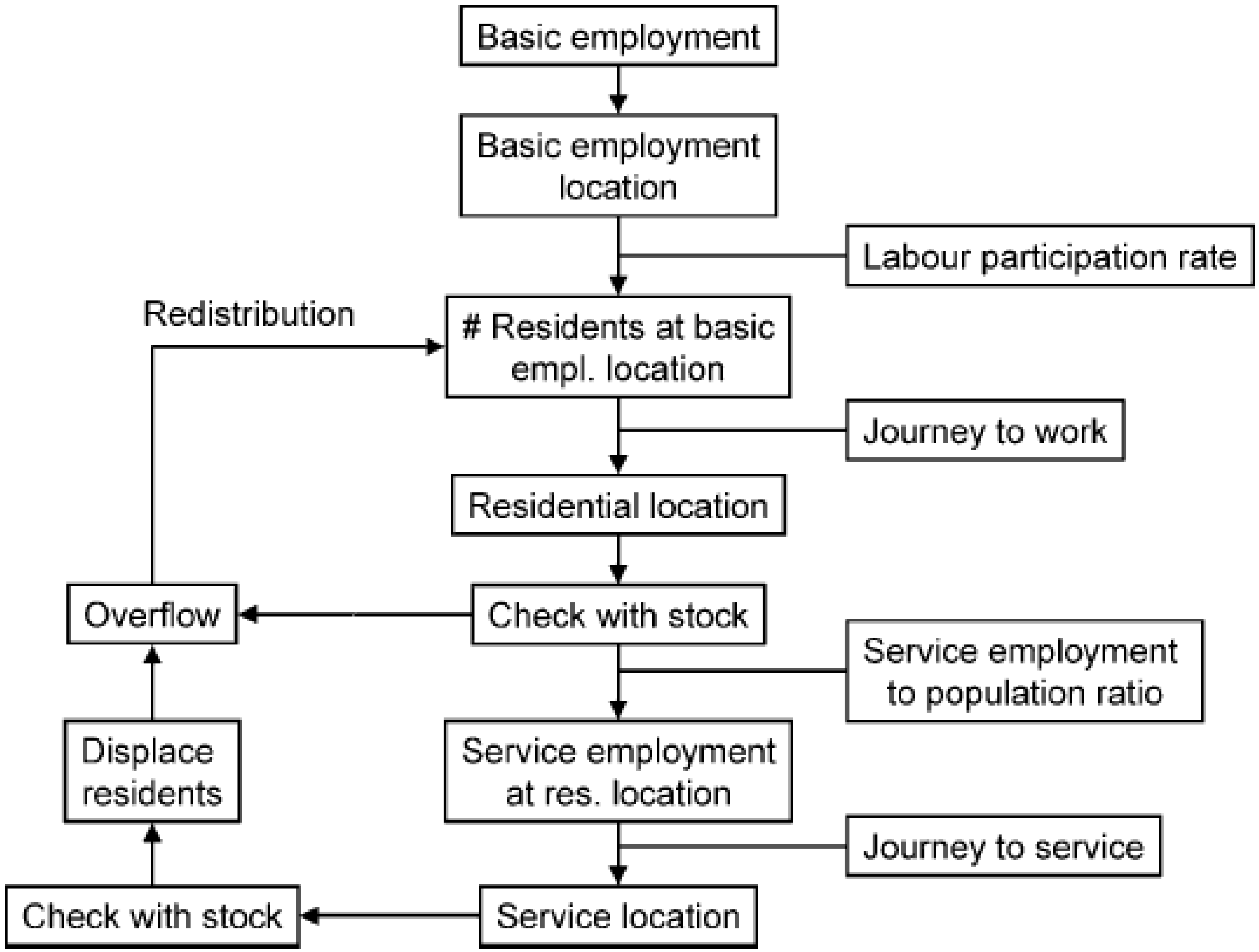
One of the first to become operational in the United Kingdom.

MEPLAN

The model consists of two sub-models: a stock model and an activity model.

Fundamental parts of this model are Lowry type.

MEPLAN



Basic structure of the static model of urban spatial development [Source: Echenique *et al.*, 1969]

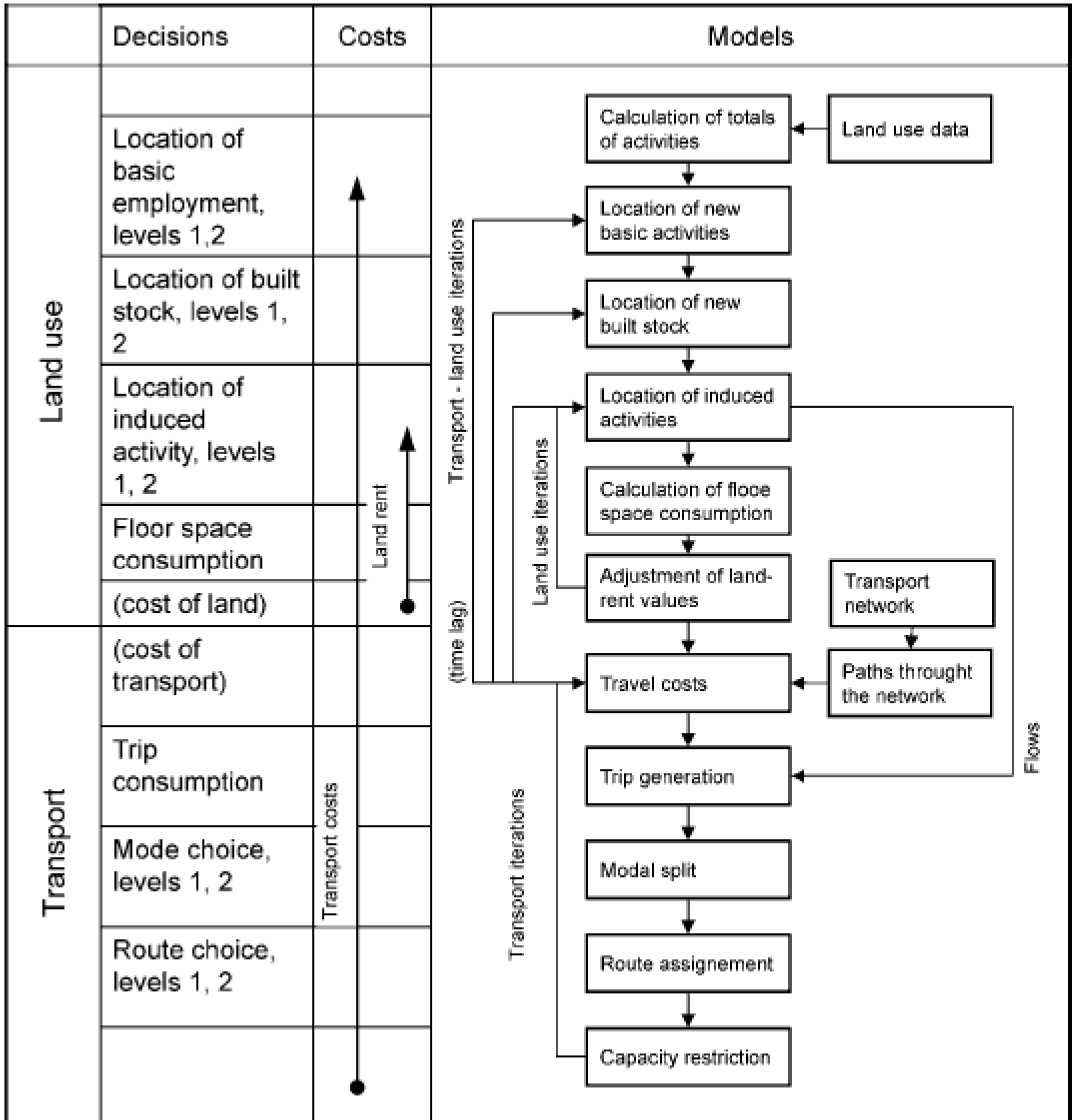
TRANUS

TRANUS is an integrated land use and transport modeling system, which was developed in the 1980s for integrated modeling of transportation and land use (De La Barra *et al*., 1984).

TRANUS is organized with a hierarchical structure.

It includes a flexible activities and land use model, applicable to a wide range of scales and contexts, a transportation model to represent both passengers and freight transportation, and a probabilistic Logit combined modal split and assignment procedure.

TRANUS



Decision Tree and Sequence of Calculation in TRANUS

TRANUS

TRANUS shares an overall similar structure with MEPLAN (Hunt and Simmonds, 1993).

Since 2005, TRANUS is available completely free of charge on the website www.modelistica.com, for applications in research and planning.

In liberating the license and making the source code available, the developers aim to expand the user base of the system considerably, and to transform the TRANUS system in a collaborative research effort with many groups participating.

DELTA

The land use model DELTA was developed by David Simmonds Consultancy.

The DELTA land use model runs in association with the START transport model.

DELTA simulates the urban processes of development, demographic and economic change, location choice, changes in urban area quality and employment market matching.

The sub-models represent urban processes that are important in urban development. Time is explicitly incorporated.

DELTA and START run dynamically at intervals of two years (*iteration process*). This allows to represent time lags, e.g. for construction of floor space.

DELTA

The development model for housing and commercial floor space models private sector developments for greenfield and brownfield sites.

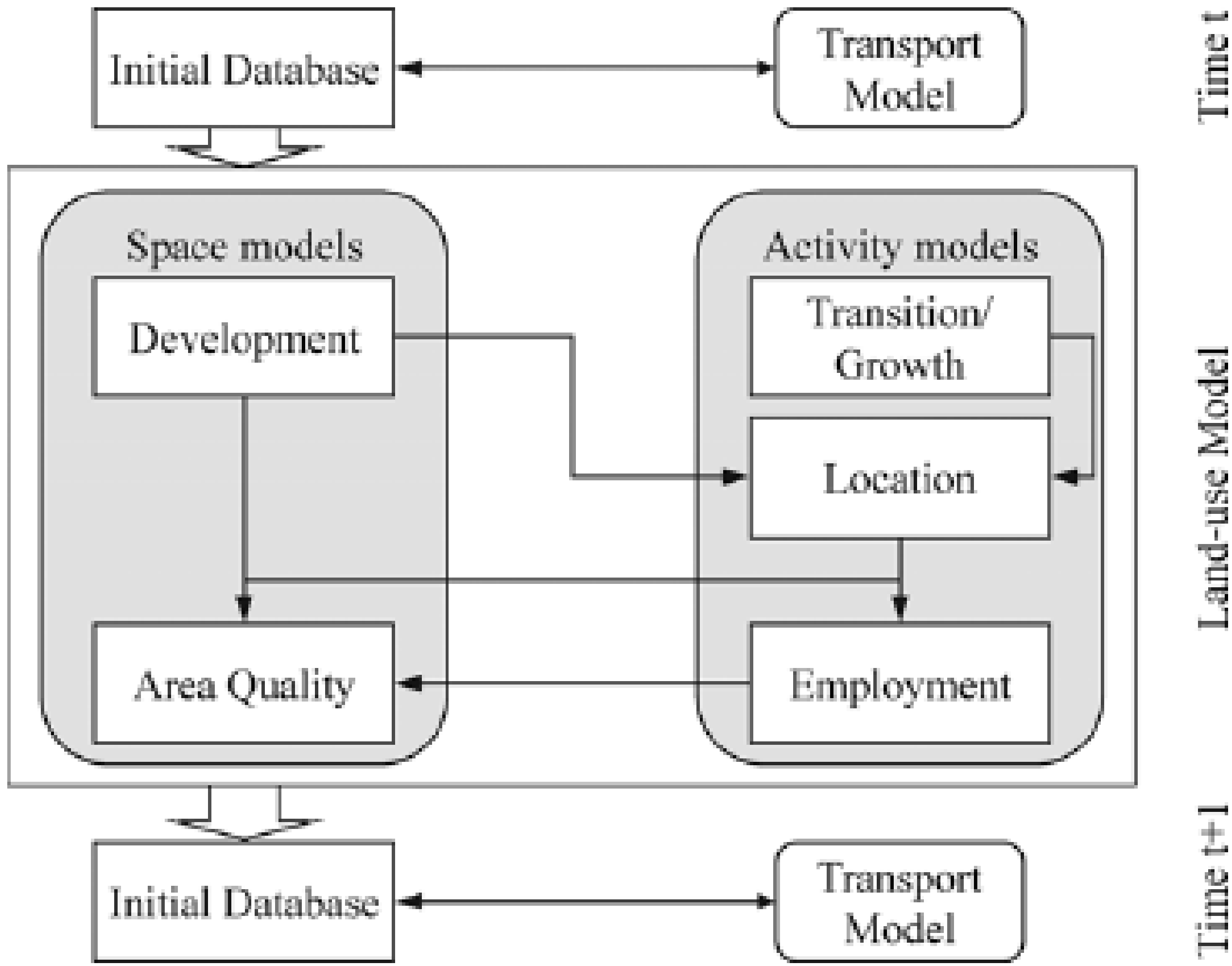
The model calculates the initial demand for floor space. Development is then allocated to zones on the basis of the expected zonal profitability using a weighted LOGIT formula.

The location choice model for employment and households takes into account several factors, namely utility of consumption, accessibility, area quality and transport related environmental quality.

Activity specific measures of accessibility are used by DELTA. The change in utility is used as an incremental LOGIT model location function.

The location model is iterated adjusting rents until all households are located.

DELTA



DELTA land use model structure

URBANSIM

The *UrbanSim* software package is an open-source software application for integrated land use and transportation modeling.

The source code of UrbanSim is distributed at no cost to all users who are interested in applying and implementing the model system. It is downloadable at www.urbansim.org.

The design of UrbanSim significantly differs from other existing modeling approaches. UrbanSim uses 150 by 150 meter grid cells.

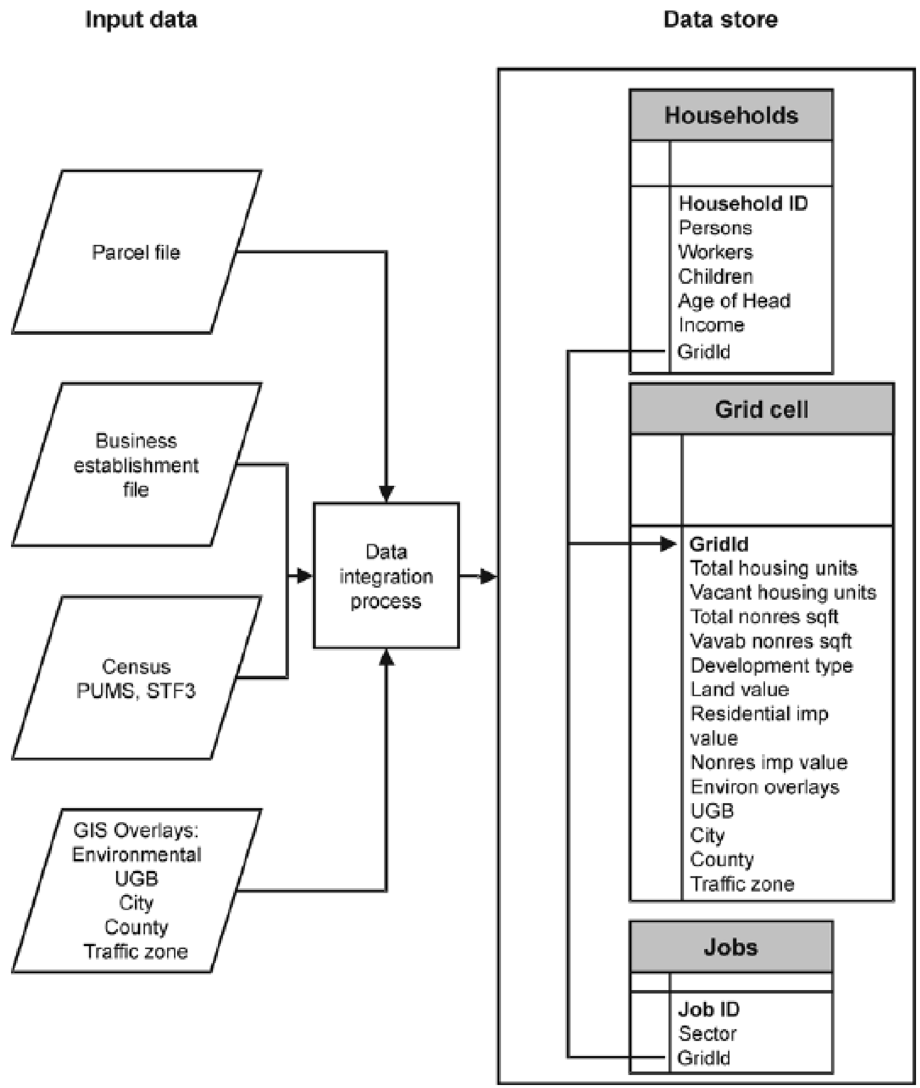
Data from sources like census have to be transformed to grid cell data. Synthesized households are probabilistically assigned to parcel data. Parcel data are collapsed into the cells.

URBANSIM

The individual model components predict:

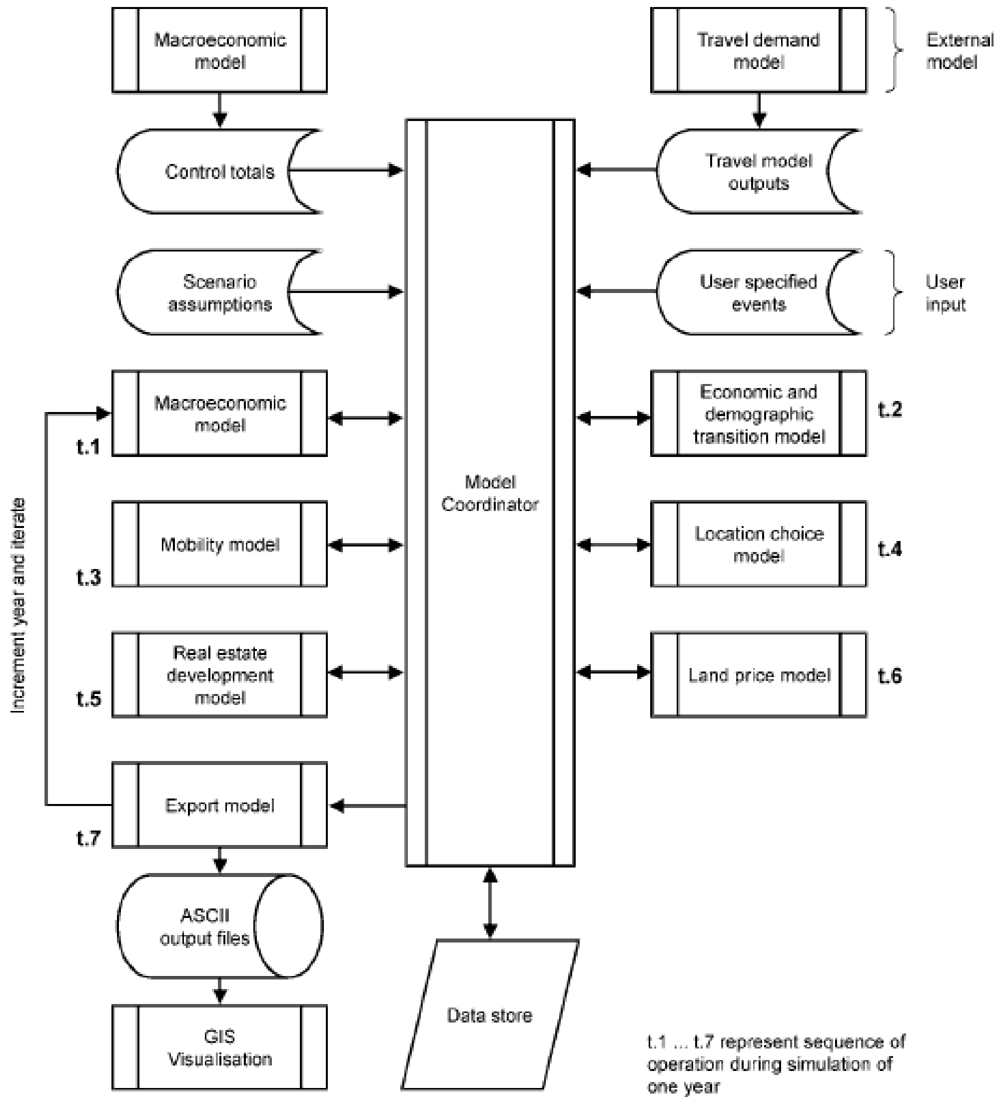
- the pattern of accessibility by car ownership level (access model);
- the creation or loss of households and jobs by type (demographic and economic transition);
- the movement of households or jobs within the region (household and employment mobility model);
- the location choices of households and jobs from the available vacant real estate (household and employment location model);
- the location, type and quantity of new construction and redevelopment by developers (development model);
- the price of land at each location (land price model).

URBANSIM



UrbanSim data integration process [Source: Waddell, 2002]

URBANSIM



UrbanSim model structure [Source: Waddell, 2002]

PECAS

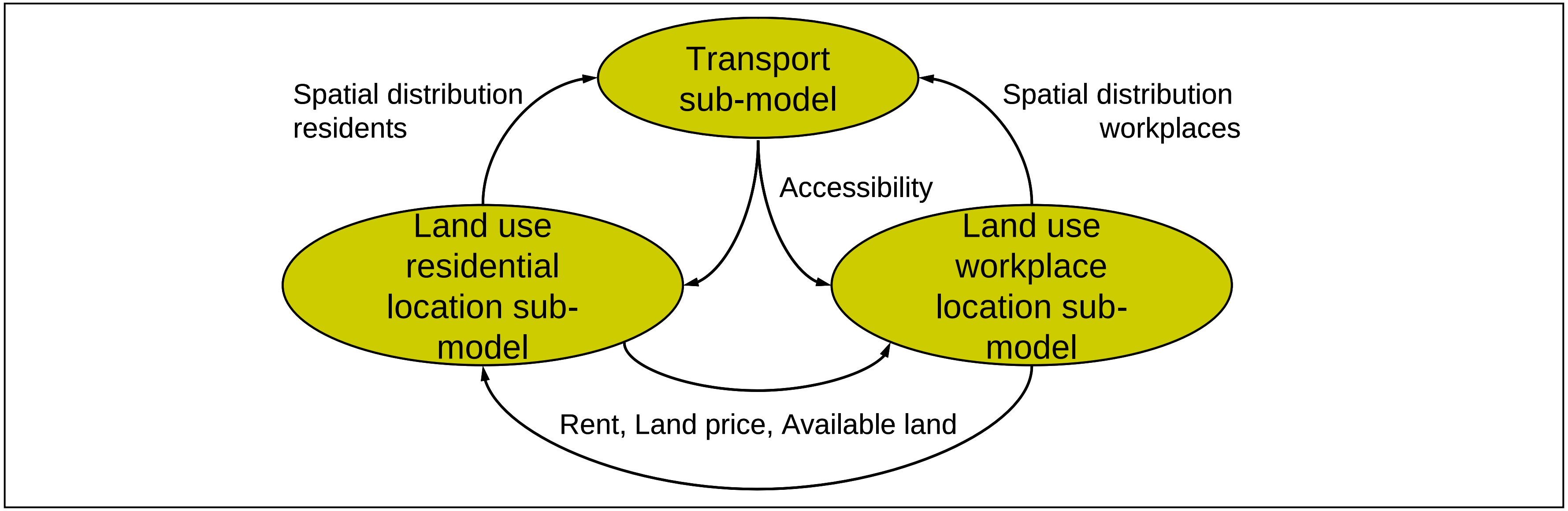
We will talk later about the Production Exchange Consumption Allocation System (PECAS) Model…

MARS

The *Metropolitan Activity Relocation Simulator* (MARS) is a fast land use and transport interaction model, designed to identify optimal land use and transportation strategy packages in land use transport interaction planning (Pfaffenbichler et al., 2006).

MARS works at a rather high level of aggregation, according to the objectives of strategic planning for which it has been designed.

MARS

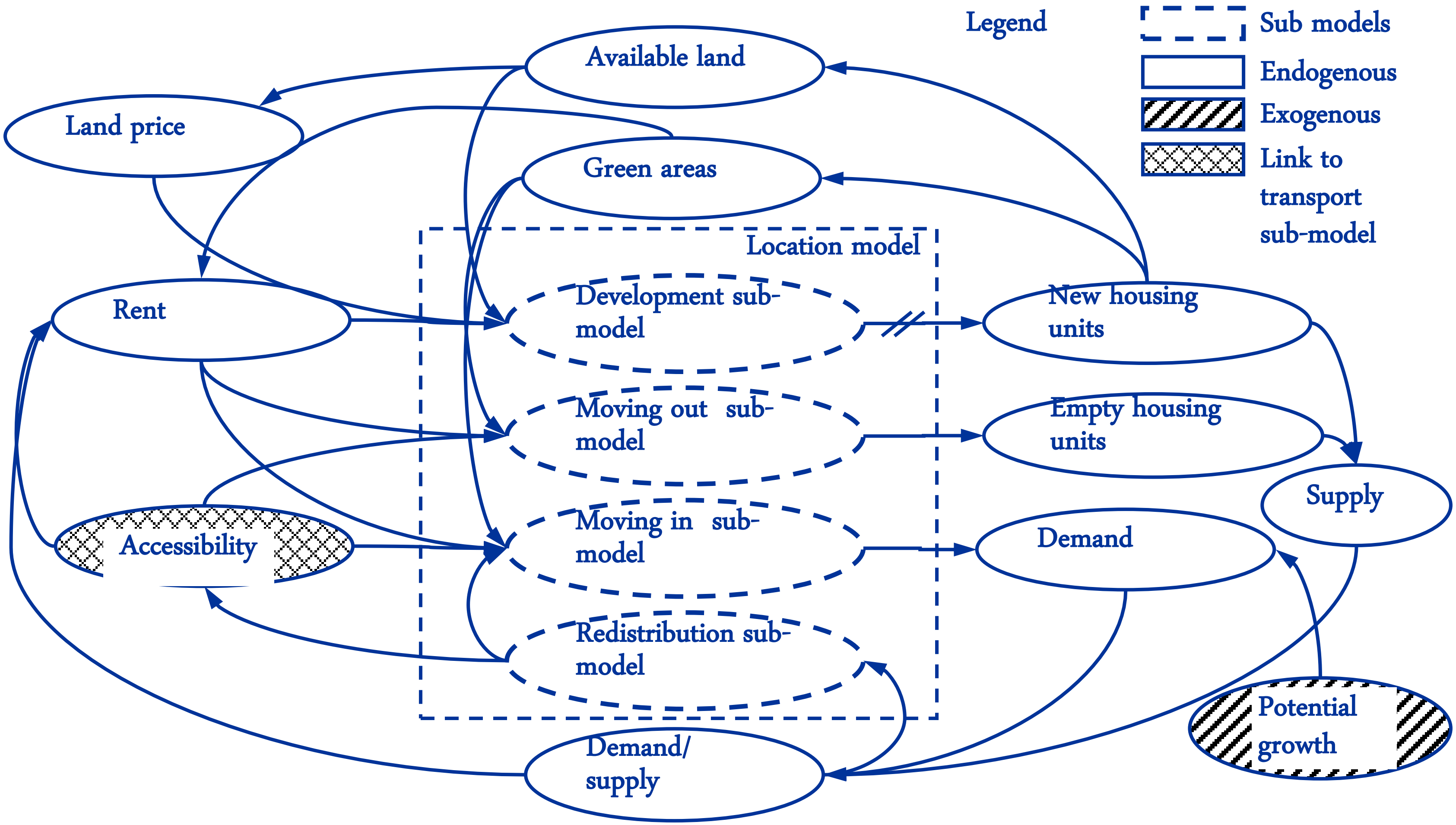


MARS (Metropolitan Activity Relocation Simulator) is a fast integrated strategic and dynamic land-use and transport (LUTI) model system.
The basic underlying hypothesis of MARS is that settlements and activities within them are *self-organizing systems*.

MARS

Transport model	Land use model	Eval Indicators	Process indicators
Transport model	Land consumption per unit	Summary Eval Indicators	Summary process indicators
Friction factor private	Land development	Accessibility	HH Income
Friction factor PT rail	Housing Units	Accidents and noise	Modal split
Friction factor PT bus	Residents	Emissions car	Output control
Friction factor slow	Workplaces	Emissions PT	
Trip time mode		Emissions total	
Speed flow		Fuel and energy consumption	
Policy Setup			
Policy Input			
Energy Consumption			
Vehicle kilometers			

MARS

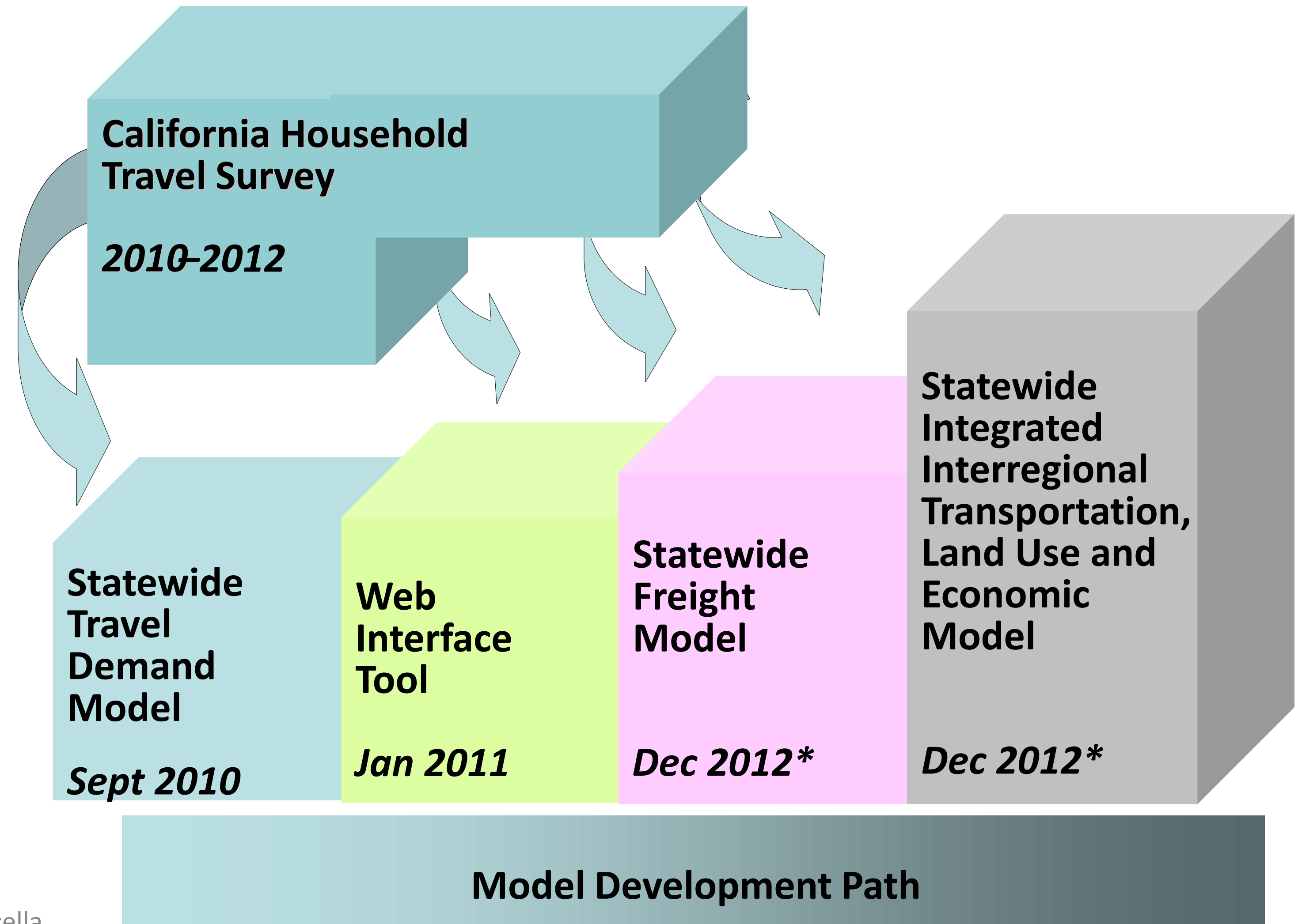


[Source: Pfaffenbichler, 2003]

The California Statewide Integrated Modeling (CALSIM) Framework

- Comprehensive modeling effort to assist strategic planning in California
- Funded by the California Dept. of Transportation (CALTRANS)
- Provides guidance on future development of land use and transportation in the State
- It is based on a Land Use modeling component (PECAS) and a Transportation modeling component (CSTDM)

The California Statewide Integrated Modeling (CALSIM) Framework

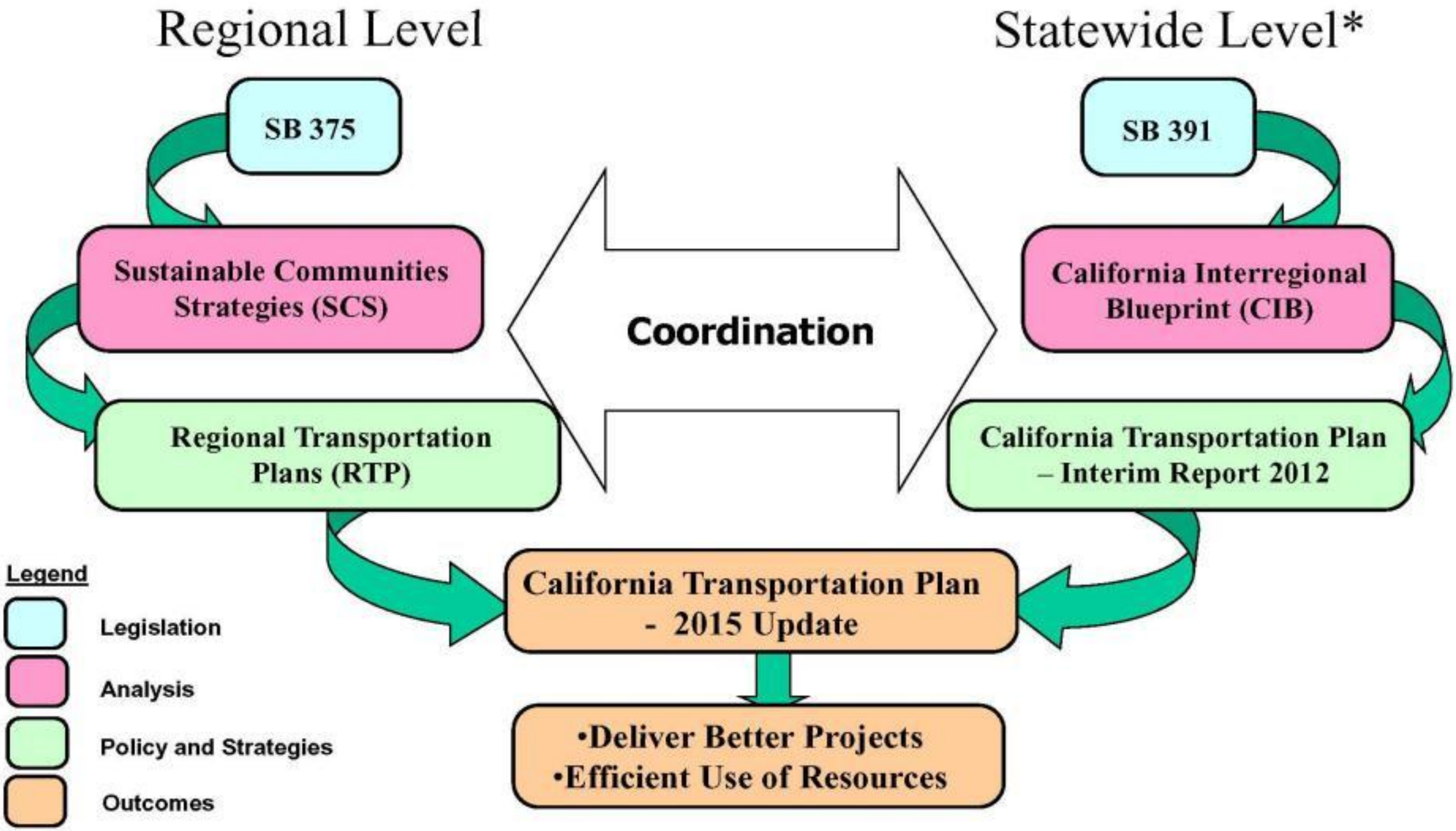


*dates to be confirmed

The California Statewide Integrated Modeling (CALSIM) Framework

- Statewide modeling tool that ensures consistency of regional model forecasts
- Evaluation of the impact of major projects and infrastructures (e.g. *California High Speed Rail System*)
- Evaluation of environmental impacts and greenhouse gas (GHG) emissions
- Supports the current legislative efforts for sustainable strategies in the State of California

Reducing Greenhouse Gases: Shared Responsibilities
SB 375 (Steinberg) and SB 391 (Liu)



*Statewide Integrated Multimodal Transportation System

[Source: CALTRANS, 2011]

The California Statewide Integrated Modeling (CALSIM) Framework

- Land Use component → ***PECAS***
- Travel demand component → ***CSTDM***

CALSIM (PECAS): Land Use

The Land Use Component of the CALSIM framework is based on the Production Exchange Consumption Allocation System (PECAS) Model.

The *Production Exchange Consumption Allocation System* (PECAS) is a model system with an aggregate equilibrium structure with separate flows of exchanges (including goods, services, labor and space) going from production to consumption.

Flows of exchanges from production to exchange zones and from exchange zones to consumption are allocated using nested Logit models according to exchange prices and transport disutilities.

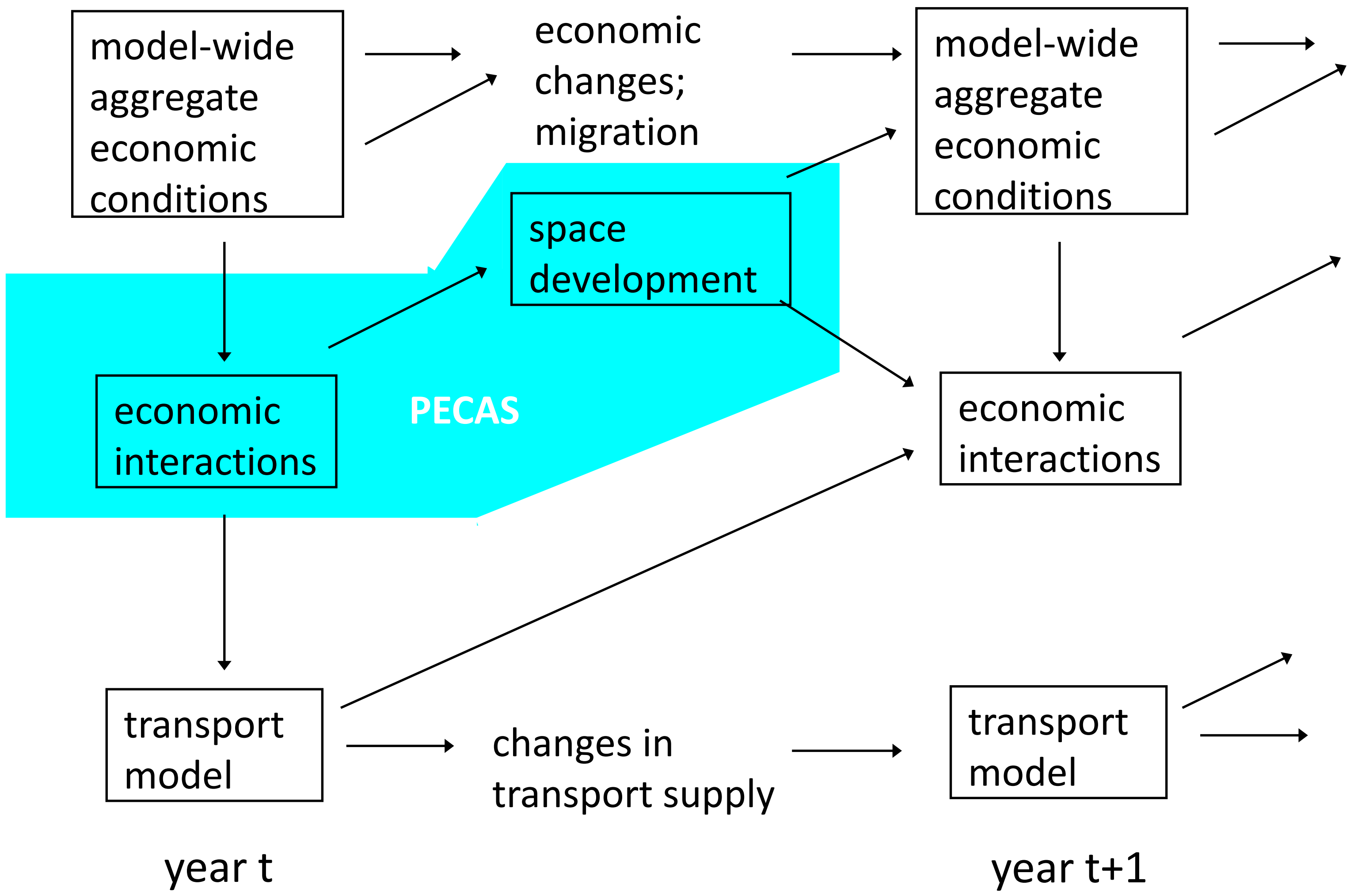
These flows are converted to transportation demand that is loaded to networks in order to determine congested travel disutilities.

CALSIM (PECAS)

PECAS has two component modules:

- The ***space development*** module represents the actions of developers in the provision of space (land and floor space) where activities can locate. It includes new development, demolition and re-development.
- The ***activity allocation*** module represents how activities locate within the space provided by developers, and how these activities interact with each other at a given point in time.

CALSIM (PECAS)



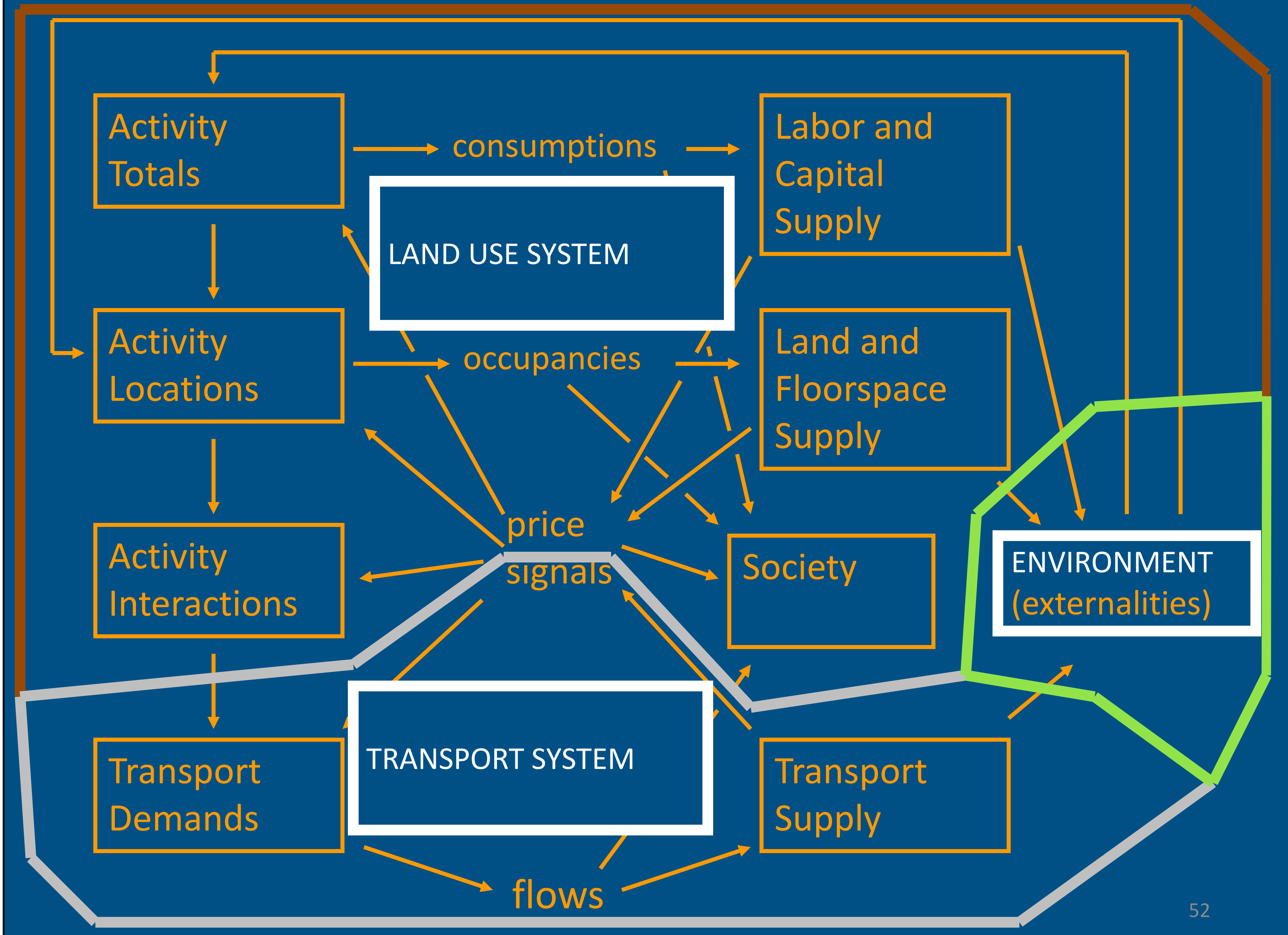
Interactions among modules simulating temporal dynamics in PECAS [Source: modified from Hunt and Abraham, 2003]

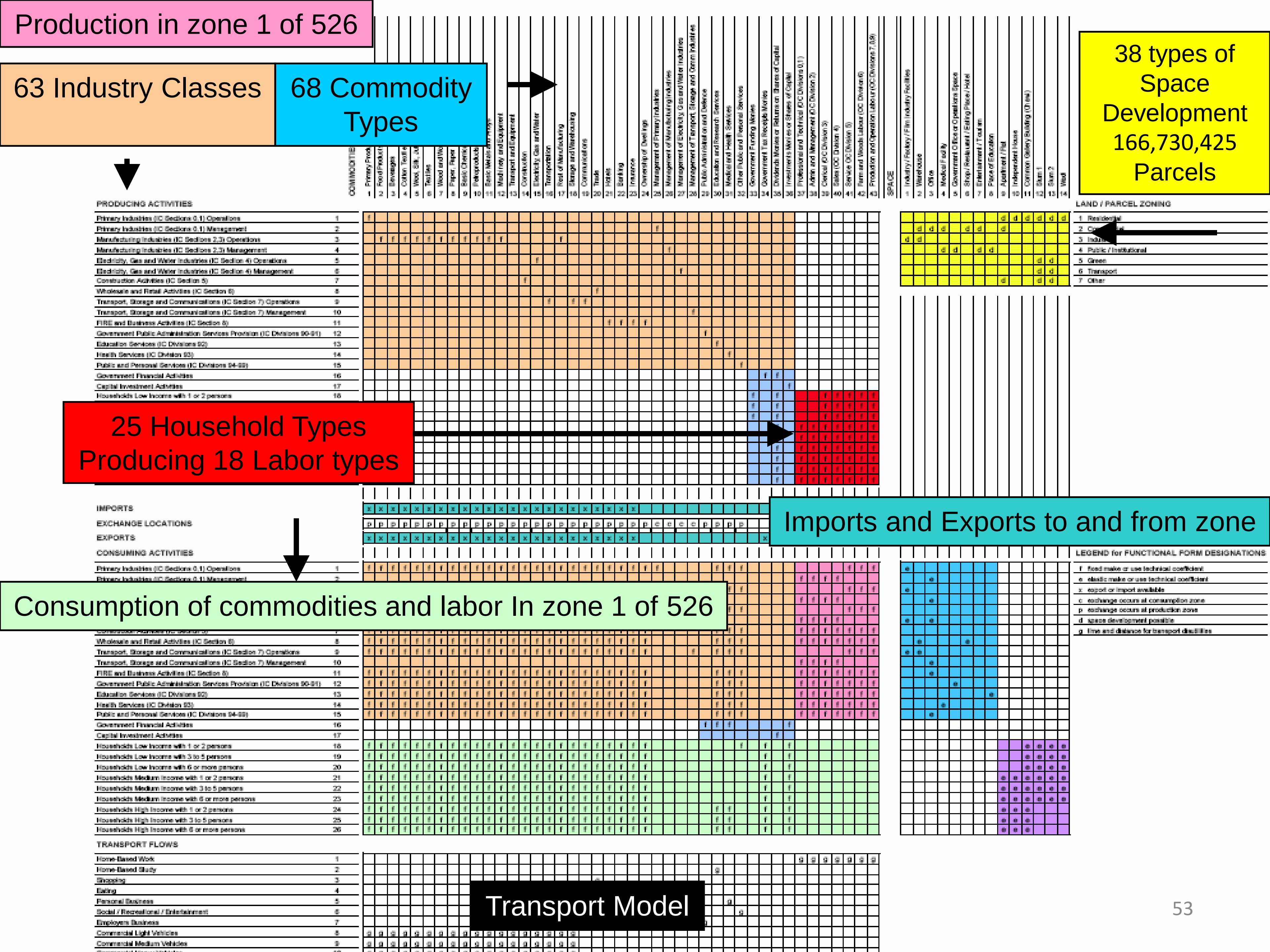
Spatial Units in CALSIM (PECAS)

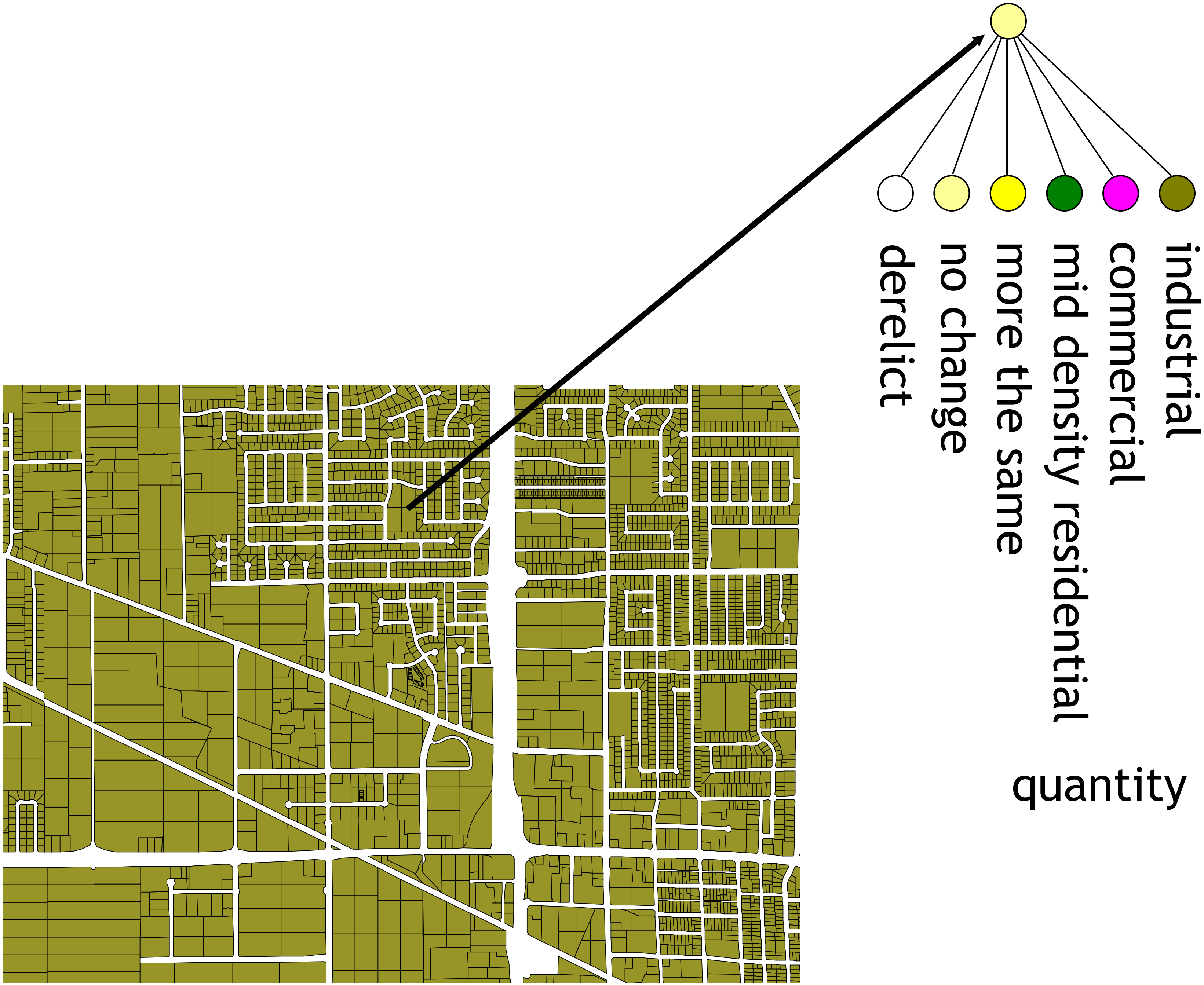
- Land Use Zone (LUZ)
  - User defined
  - 526 in CalSIM
- Traffic Analysis Zone (TAZ)
  - User defined
  - 5191 in CSTDM
- Parcel
  - Parcel
  - Grid (50m x 50m)
- Internal zone
  - LUZ within CA
- External zone
  - LUZ out of CA
  - North Nevada, South Nevada, Arizona, USA Northwest, USA Southwest, USA East, Tijuana, Rest of Mexico, Canada, China, Rest of world

Time in PECAS

- Time step in the AA module
  - 1 year
- Time step in the SD module
  - 1 year
- Iterations with the travel model
  - 5 years


Activity Totals
consumptions
Labor and Capital Supply
LAND USE SYSTEM
Activity Locations
occupancies
Land and Floorspace Supply
price signals
Activity Interactions
Society
ENVIRONMENT (externalities)
TRANSPORT SYSTEM
Transport Demands
Transport Supply
flows


Production in zone 1 of 526
63 Industry Classes
68 Commodity Types
38 types of Space Development 166,730,425 Parcels
PRODUCING ACTIVITIES
LAND / PARCEL ZONING
25 Household Types Producing 18 Labor types
IMPORTS
EXCHANGE LOCATIONS
EXPORTS
CONSUMING ACTIVITIES
Imports and Exports to and from zone
LEGEND for FUNCTIONAL FORM DESIGNATIONS
Consumption of commodities and labor In zone 1 of 526
TRANSPORT FLOWS
Transport Model


derelict
no change
more the same
mid density residential
commercial
industrial
quantity

California Statewide Travel Demand Model (CSTDM)

- Models travel on a typical weekday in the spring / fall (when schools are in session)
- Models personal travel within California made by every California resident, for all modes and purposes
- Models all commercial vehicle movements within California
- Models vehicle trips entering / leaving California

CSTDM System

Inputs → **Models** → **Outputs**

Inputs

- Zone System
- Road Network
- Transit Network
- Population
- Employment
- Other Zonal Properties

Models

- Short Distance Personal Travel Model (SDPTM)
- Long Distance Personal Travel Model (LDPTM)
- Short Distance Commercial Vehicle Model (SDCVM)
- Long Dist. Commercial Vehicle Model (LDCVM)
- External Travel Model (ETM)

Outputs

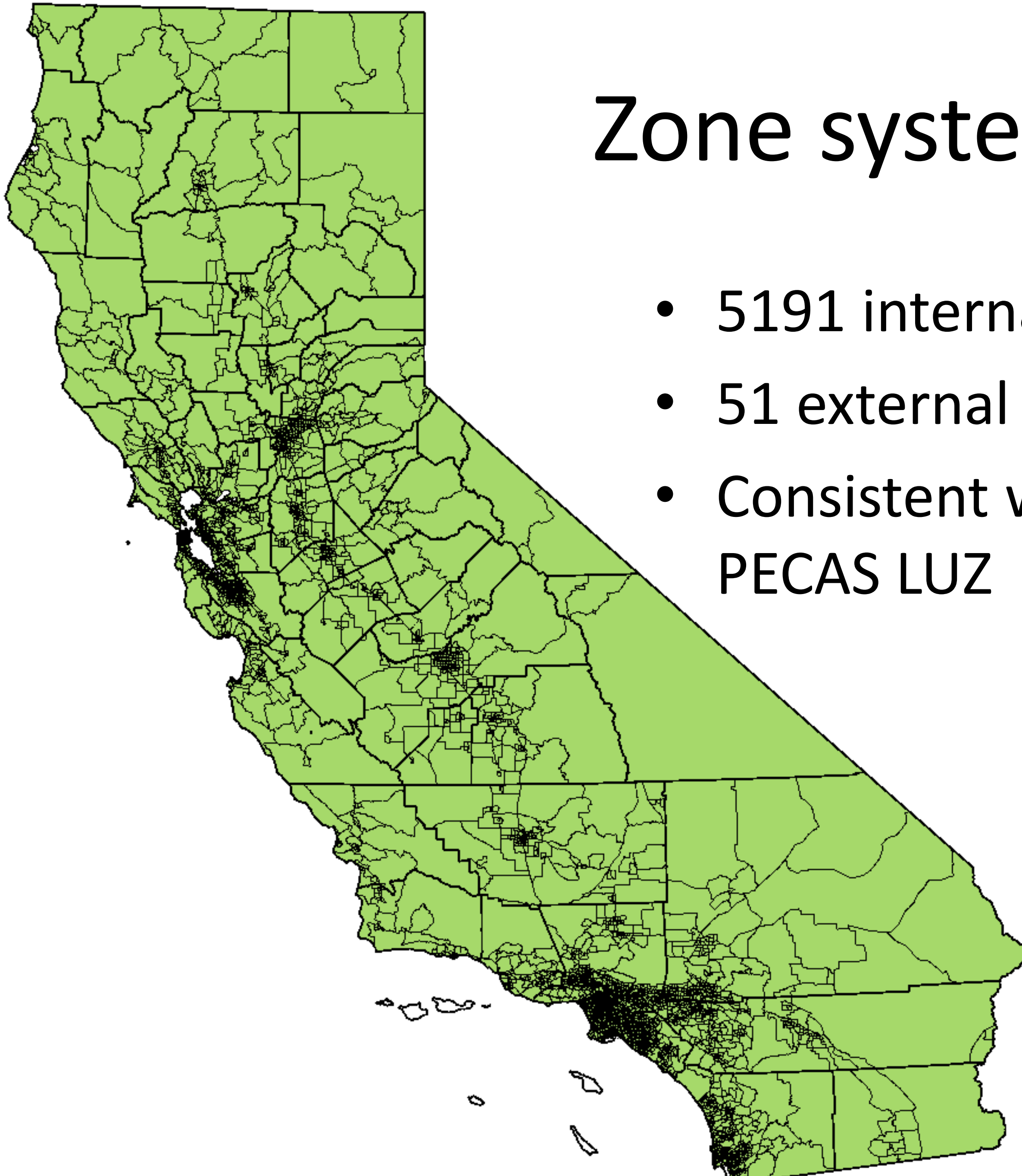
- Trip Lists
- Trip Tables
- Loaded Network
- Travel Times and Costs
- Summary Travel Statistics
- Maps
- Graphs

Modes in Model

Mode	Short Distance Personal	Long Distance Personal	Short Distance Commercial	Long Distance Commercial	External Travel
Auto SOV					
Auto HOV 2 person					
Auto HOV 3+ person					
Transit (bus and rail)					
Bicycle					
Walk					
Air					
Rail					
Light commercial vehicle					
Medium (Single unit) truck					
Heavy (Multiple unit) truck					

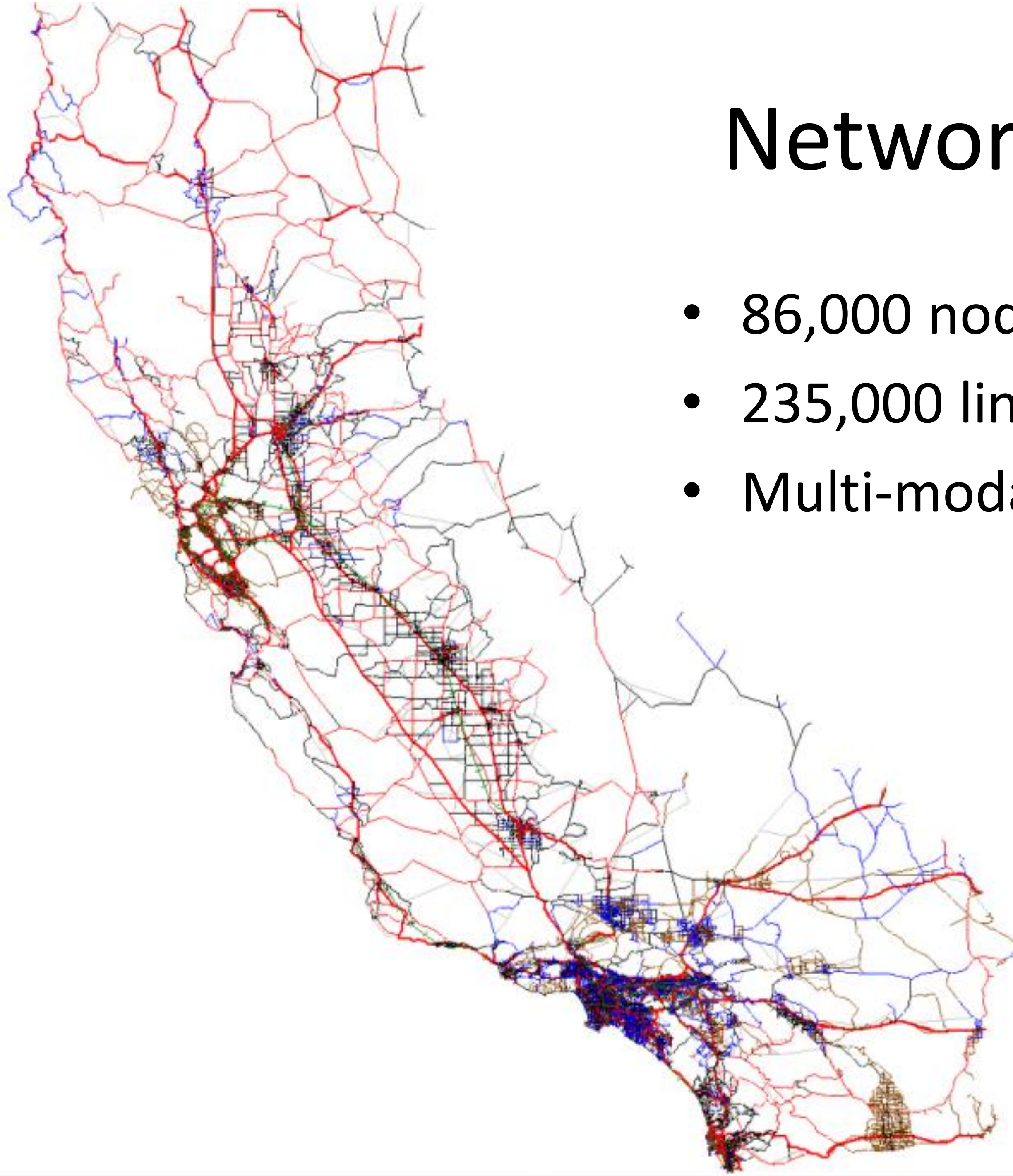
Time Periods

Time period	Definition	Assignment
Offpeak Early	3 AM to 6 AM	Offpeak
AM Peak	6 AM to 10AM	AM Peak
Midday	10 AM to 3 PM	Midday
PM Peak	3 PM to 7 PM	PM Peak
Offpeak Late	7 PM to 3 AM	Offpeak



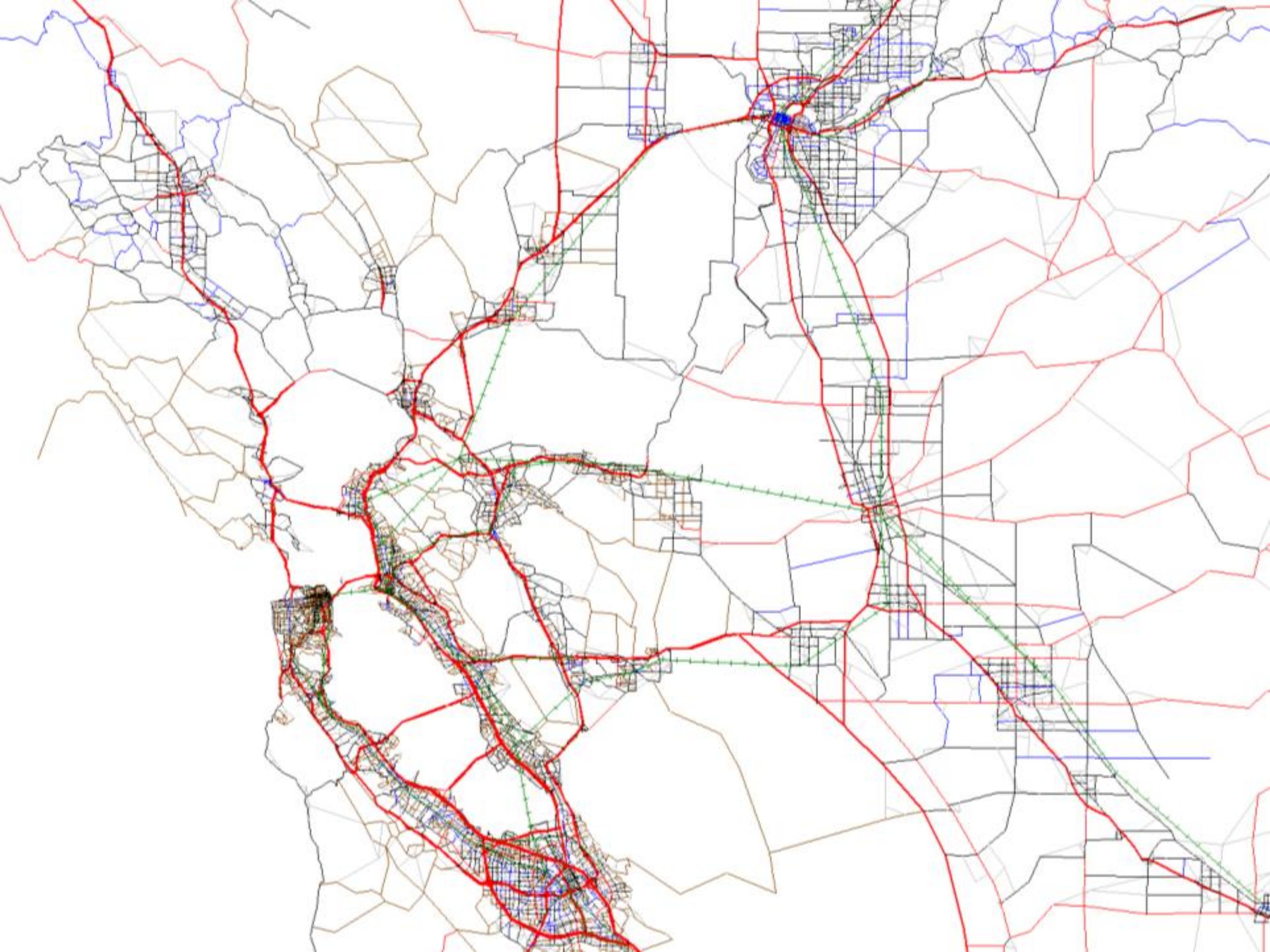
Zone system

- 5191 internal zones
- 51 external zones
- Consistent with 526 PECAS LUZ



Network

- 86,000 nodes
- 235,000 links
- Multi-modal



CSTDM Models

Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Common features:
  - Disaggregate simulation aspect
  - Produces a consistent trip list output
  - Uses the same set of inputs where common data is needed (e.g. # of retail employees; travel skims)

Short Distance Personal Travel Model

Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Travel by individuals < 100 miles
- Includes Walk, Bicycle, Transit
- Disaggregate tour-based approach
- Works off synthetic population
- Developed with ca. 2000 combined (4 survey) California travel data

Long Distance Personal Travel Model

Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Travel by individuals > 100 mi
- Auto, Rail and Air
- Derived from Cambridge Systematics (CSI) model for CHSRA work
- Modified to work off common model inputs (e.g. transit skims) and produce common standard outputs

Short Distance Commercial Vehicle Model

Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Commercial vehicles <50 miles
- Includes goods and service
- Light, medium and heavy CV
- Tour-based disaggregate simulation

Long Distance Commercial Vehicle Model

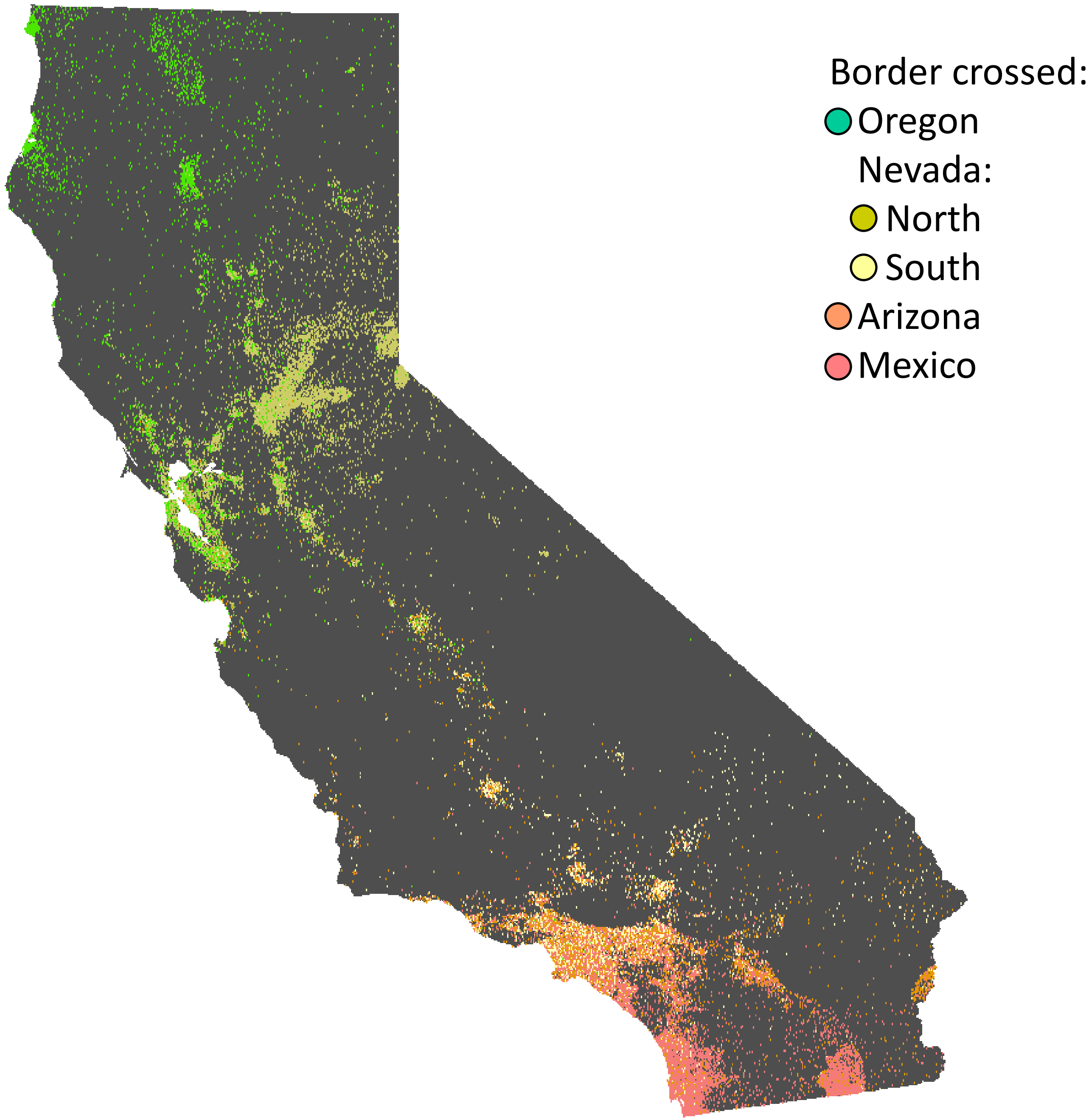
Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Travel by commercial vehicles > 50 miles
- Heavy trucks carrying goods
- Uses CalSIM (PECAS) commodity flows between TAZs
- Flows factored to represent vehicle trips by time period
- Poisson sampling to establish individual vehicle movements

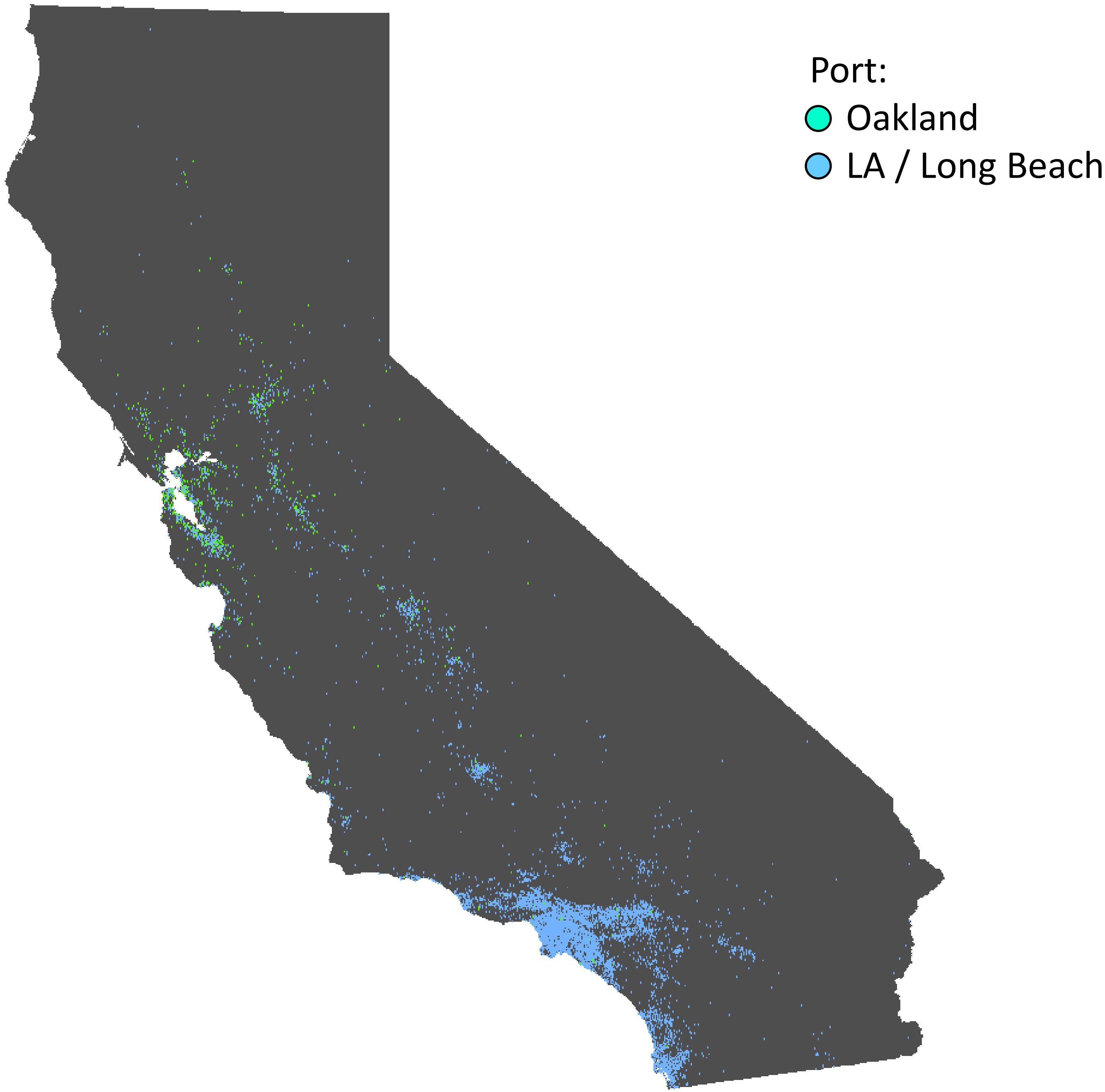
External Travel Model

Models
Short Distance Personal Travel Model (SDPTM)
Long Distance Personal Travel Model (LDPTM)
Short Distance Commercial Vehicle Model (SDCVM)
Long Dist. Commercial Vehicle Model (LDCVM)
External Travel Model (ETM)

- Travel entering, exiting or through California
- Includes port traffic
- Cars, medium & heavy trucks
- Disaggregate simulation of exogenous crossing counts
- Based on models estimated elsewhere; calibrated using FAF / NHTS data



1 dot = 5 trips

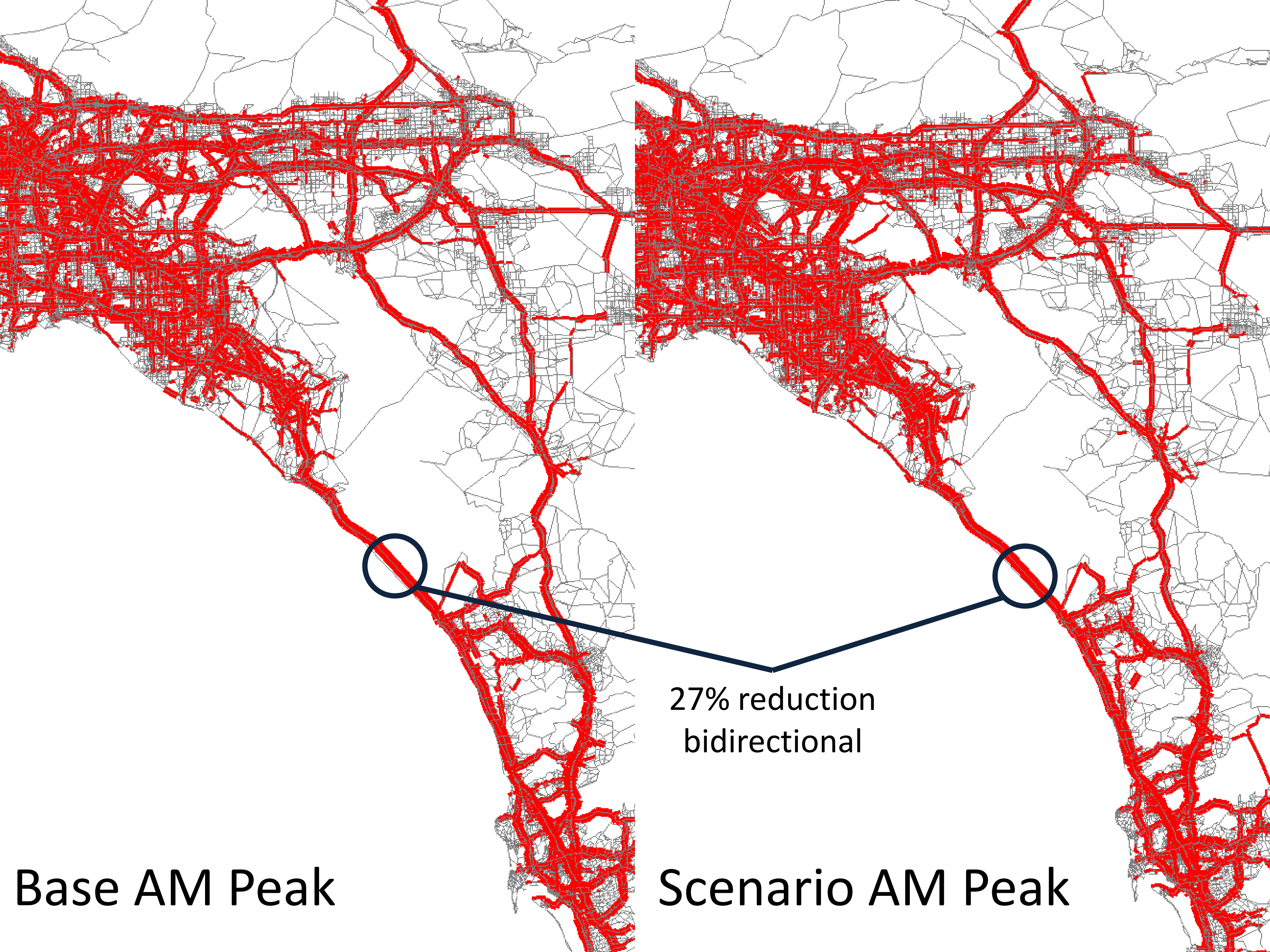


1 dot = 5 trips

CSTDM Outputs

Outputs
Trip Lists
Trip Tables
Loaded Network
Travel Times and Costs
Summary Travel Statistics
Maps
Graphs

- Trip lists output from all 5 models in standardized form
- Loaded networks for each time period in Cube
- Standard output processes developed (e.g. interregional trip matrix)
- Highly flexible


27% reduction
bidirectional
Base AM Peak
Scenario AM Peak

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For more information, please visit:

http://ultrans.its.ucdavis.edu/

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