# TLUMIP 2nd Generation Model Design

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# Backgound

- Using staged approach for developing and implementing TLUMIP
- 1st generation
  - TRANUS statewide
  - Urbansim for specific metropolitan area
  - to learn for benefit of 2nd generation
  - 1st generation TRANUS pressed into practical service, showing added benefit of staged approach
- now working on 2nd generation, continue until mid-2001
- plans for a 3rd generation

# Backgound

- 2nd generation
  - single framework
    - resource constraints
    - facilitate greatest possible interface & integration
  - specified (by ODOT) attributes
    - transport, land use, and economic components fully integrated
    - fully dynamic
    - hybrid of equilibrium (transport and economic markets) and disequilibrium (land markets and activity interactions)
    - activity-based treatment of household travel
    - required data affordable, both in terms of time and money

# Motivation and Objectives of this Presentation

- Present design of 2nd generation framework
- Show how drawing on
  - 1st generation work
  - developments in work elsewhere
  - anticipated developments in computing capabilities
- Encourage
  - reaction
  - feedback
  - constructive input

# Authorship

- Large and distributed team contributing, including:
  - P Costinett, Parsons Brinckerhoff
  - J Freedman, Parsons Brinckerhoff
  - J Hicks, Parsons Brinckerhoff
  - J Abraham, University of Calgary
  - C Batten, EcoNorthwest
  - A Dunn, ECONorthwest
  - Susan Hendricks, KJS
  - T Heier

# Authorship

- Formed into several groups of model developers working on different components
- Presenters have roles in technical lead and development coordination - but very much a team effort
- Resulting software available as open-source code

# Outline

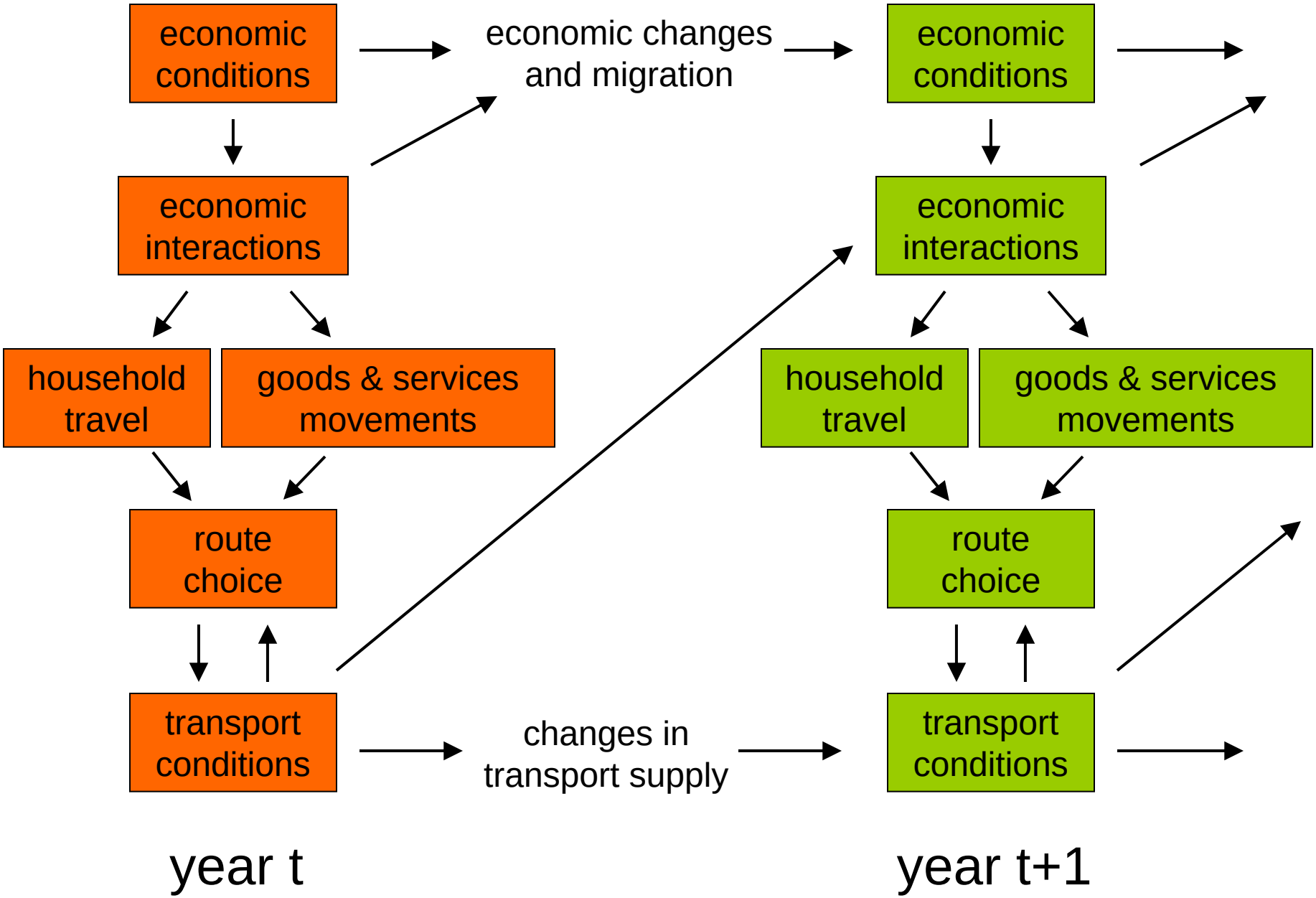
- Simulation Framework
- User Interface
- Calibrator
- Data
- Development Approach
- Conclusions

# Simulation Framework

# Treatment of Time:

- System evolves in series of one-year steps
- Representation for year t+1 influenced in part by conditions determined for year t, providing:
  - lagged effects
  - inertia
- Equilibrium solution used for some aspects of representation, but not others

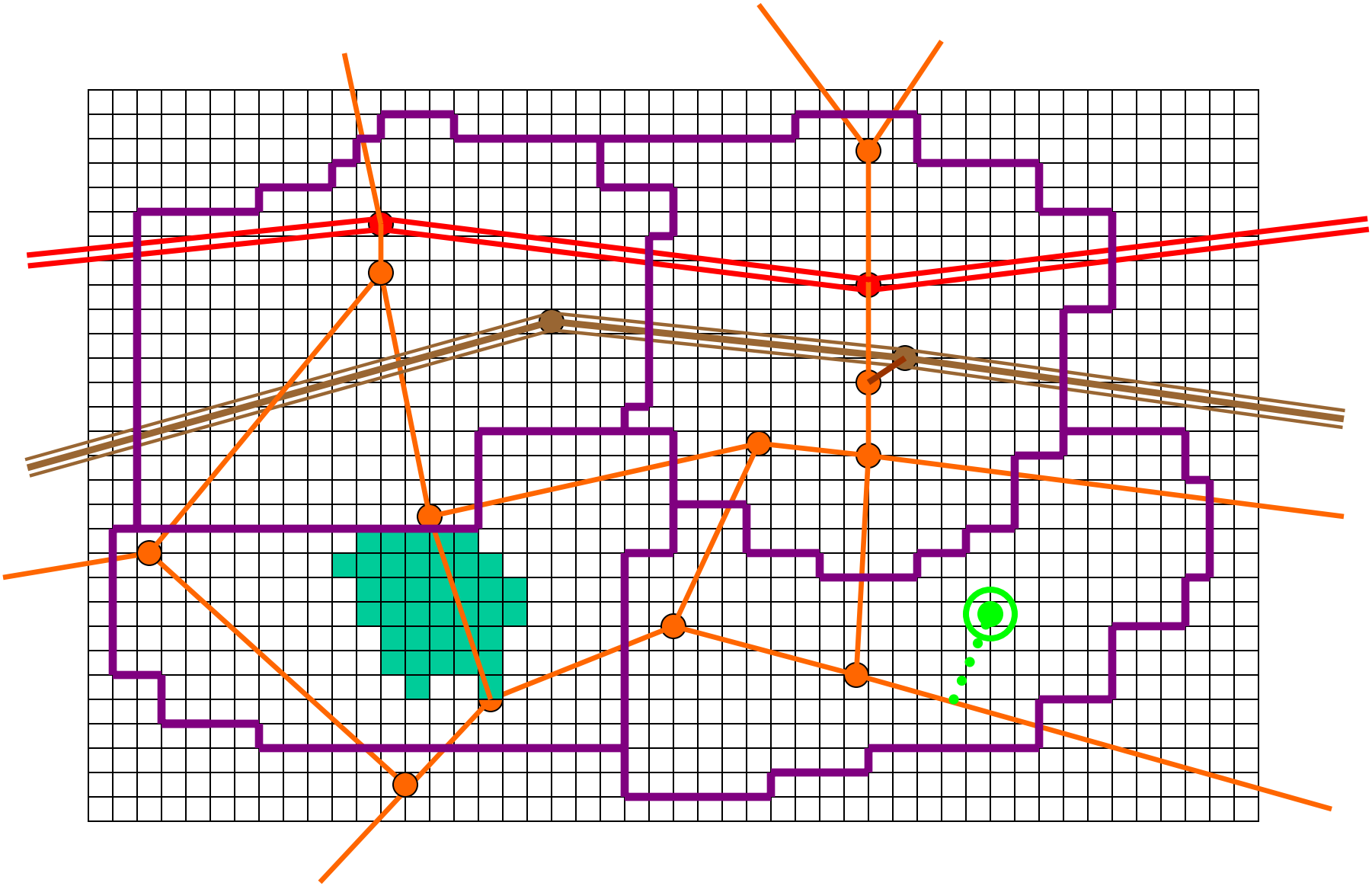
# Treatment of Time:



# Treatment of Space:

- Different representations of space and network conditions used for different parts of the model, reflecting different perceptions and processes
- Internal model area includes Oregon and ‘halo’ about 50 miles out from boundaries to north, east and south

# Treatment of Space:



# Treatment of Behavior: Utility Types

- Rutility values
  - for: aggregate quantity allocations
  - attribute values: zonal or typical
  - coefficients: typical
- Zutility values
  - for: household and person location selections
  - attribute values: zonal
  - coefficients: specific

# Treatment of Behavior: Utility Types

- Lutility values
  - for: network path selections for trips
  - attribute values: link
  - coefficients: specific
- Cutility values
  - for: land development decisions
  - attribute values: cell values
  - coefficients: typical

# Treatment of Behavior: Economic Categories: Production Activities

- Actions and undertakings that produce commodities and consume commodities as part of that production
- ~ 25 categories
- Combinations of industrial classifications and occupations of workers related to type of space required
  - 2-digit SIC categories
  - blue collar and white collar labor related to space

# Treatment of Behavior: Economic Categories: Commodities

- Goods and services produced, exchanged and consumed by production activities
- exchange generally required transport
- ~ 50 categories
- Combinations of standard commodity descriptions, related production activities and transport considerations
  - 2-digit STCC categories
  - designations in make-use tables
  - shipping and mode usage

# Treatment of Behavior: Economic Categories: Labor

- Produced by households and consumed by production activities (employers)
- exchanged where consumed
- ~ 15 categories
- Standard occupation descriptions, NOT industry classifications
  - 2-digit SOC categories

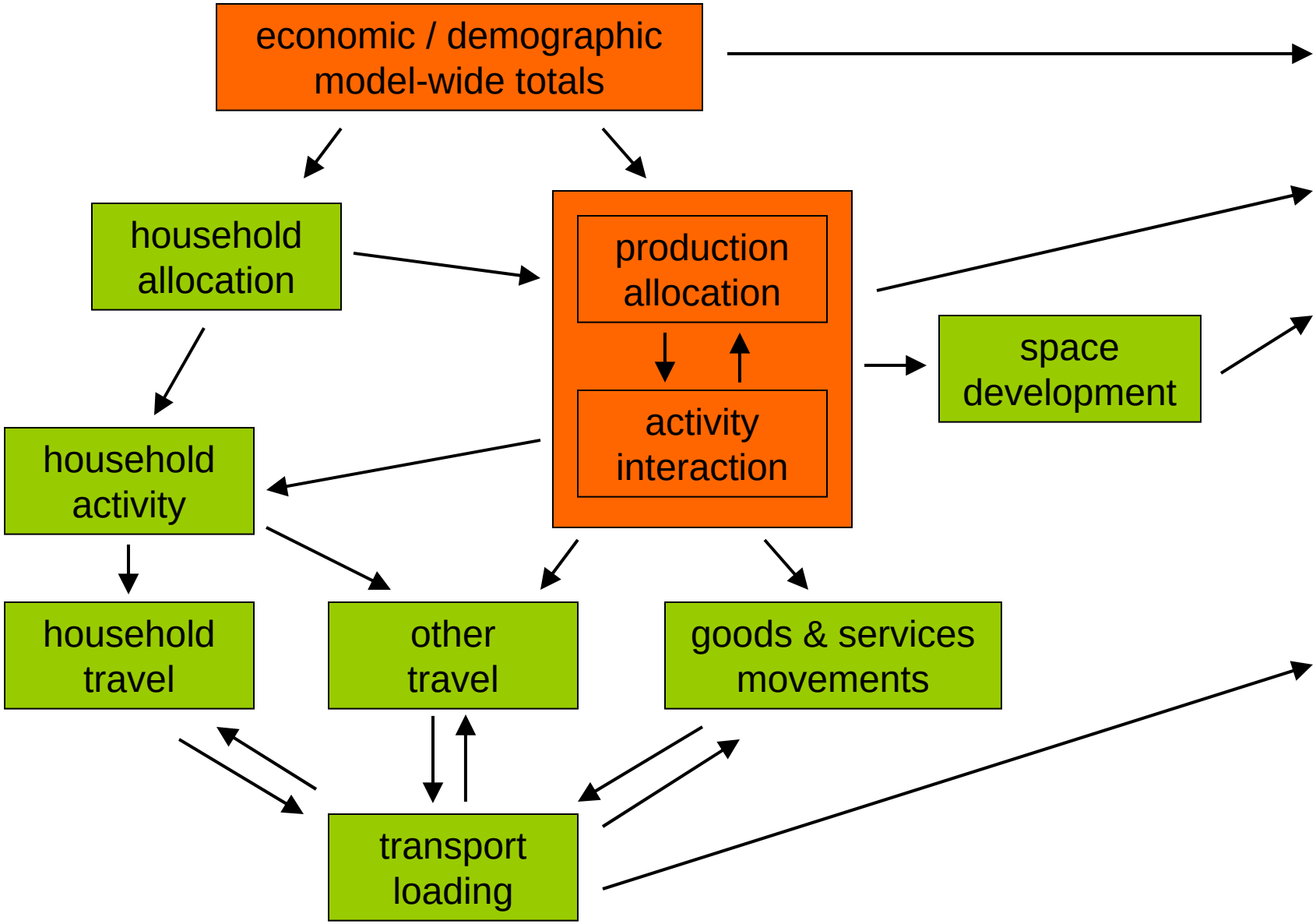
# Treatment of Behavior: Economic Categories: Space

- Available through development process and consumed by production activities (employers)
- non-transportable
- ~ 10 categories
- Based on production activity requirements and zoning regulations

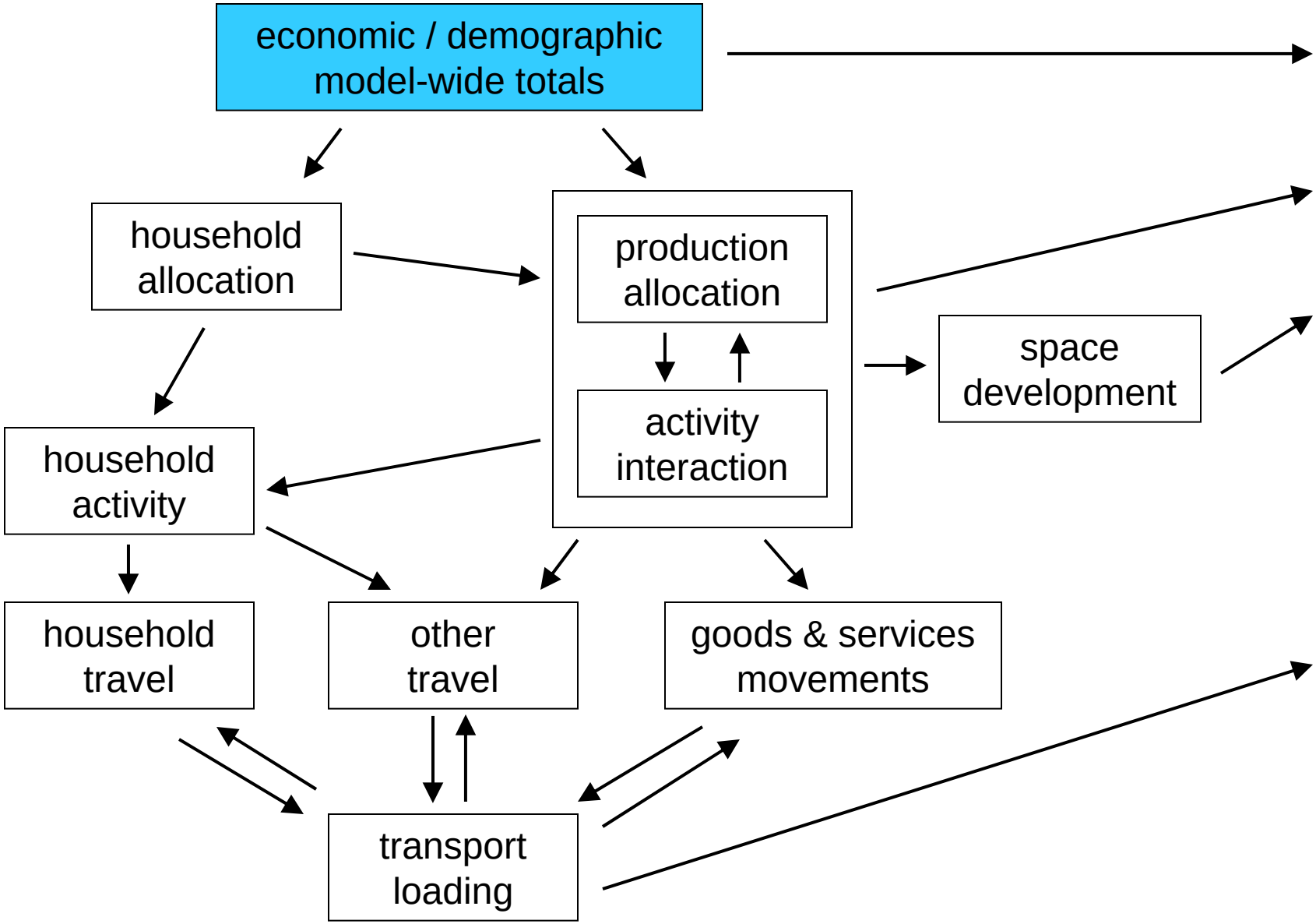
# Treatment of Behavior: Framework Modules

- Model a collection of 9 separate by highly connected modules
- Covering different components of system
- Allows sort-of ‘plug+play’ upgrading and flexibility
- Allows different approaches for different components:
  - fully dynamic vs quasi-dynamic
  - equilibrium vs dis-equilibrium
  - aggregate (behavior of flows) vs disaggregate (behavior of individual units)
  - statistical (pattern) vs simulation (process)

# Treatment of Behavior: Framework Modules



# Economic / Demographic Totals



# Economic / Demographic Totals: Purpose / Coverage

- Model-area totals for
  - production activity by economic sector
  - final demand
    - exports
    - consumption
      - motor vehicles
      - other durable goods
      - non-durable goods
      - services
    - investment
      - residential construction
      - non-residential construction

# Economic / Demographic Totals: Purpose / Coverage

    - government
        - infrastructure
        - education
        - other government operation
    - in-migrating employment and households
- Import and export trade flows to 3 regions bordering model area and rest-of-world

# Economic / Demographic Totals: Approach

- Uses aggregate, ‘quasi-dynamic treatment’
  - sequence of sets of simultaneous equations with lag terms
- Combined I/O and macro-economic model
- Determine production activity, imports and exports for 3 bordering regions and model area using
  - national forecasts
  - current and lagged values for 3 regions

# Economic / Demographic Totals: Approach

- lagged values for model area, with other modules providing
  - production location utilities for model area (these are composite Rutilities for all zones in model area)
  - changes in auto ownership
  - residential and non-residential construction
  - education
- Allocate trade flows between model area and 3 bordering regions and rest-of-world using
  - forecasts for model area and for 3 bordering regions
  - import and export totals from production allocation module for previous period

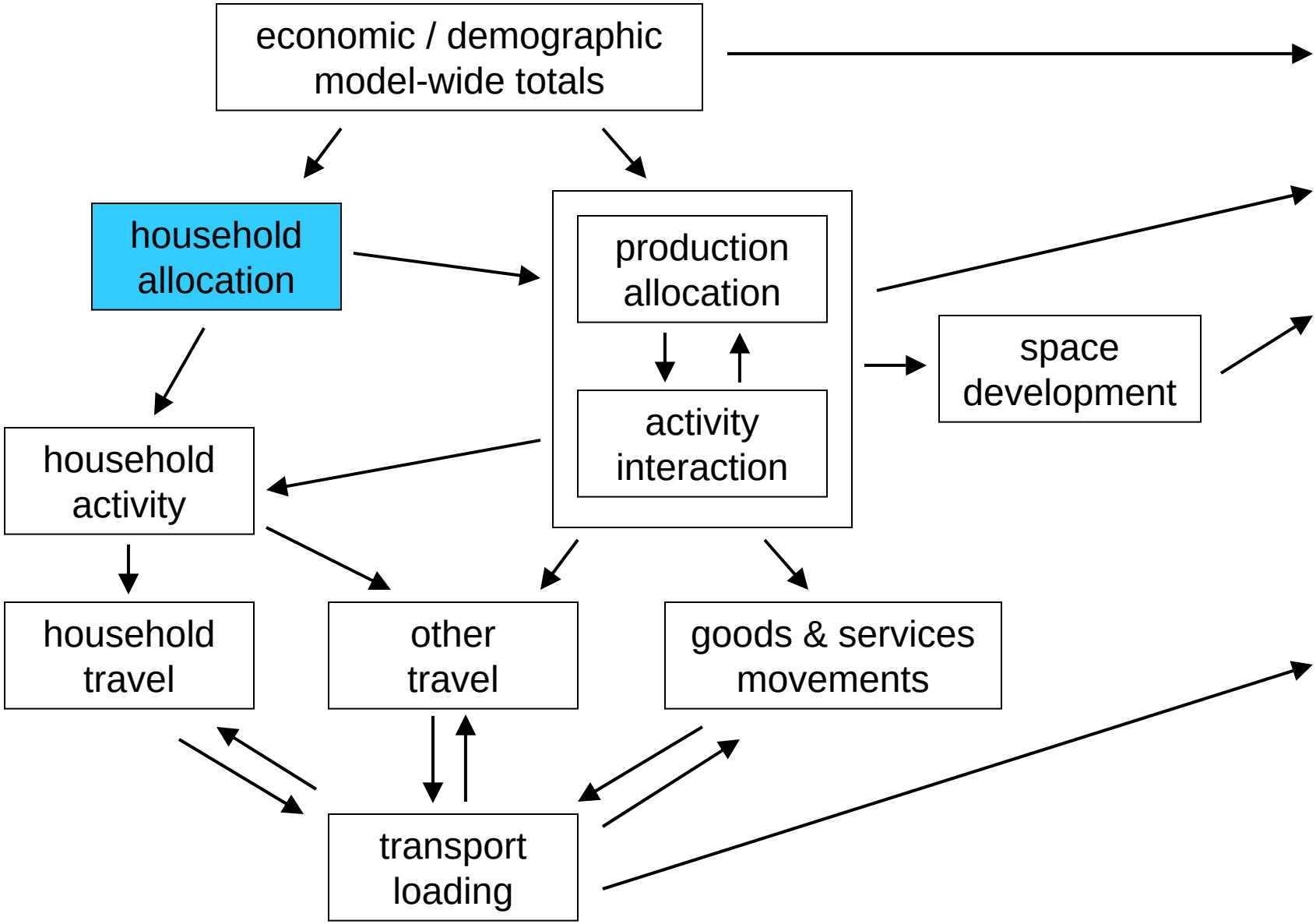
# Economic / Demographic Totals: Approach

- Determine in-migration of employment using
  - changes in labor markets and household location utilities determined in production allocation module for pervious period
- Determine in-migration of households using
  - in-migration of employment
  - household location utilities determined in production allocation module for pervious period
  - trends
- Note that corresponding out-migrations are determined in household allocation module

# Economic / Demographic Totals: Approach

- Initial version up and running

# Household Allocation



# Household Allocation: Purpose / Coverage

- Changes in household composition
  - number of members
  - lifecycle of household
  - age and gender of each member
  - SOC potentials for each member
  - job status and school status for each member
  - utility function coefficients for each member
- Changes in household characteristics
  - income
  - car ownership
  - utility function coefficients for household

# Household Allocation:
# Purpose / Coverage

- Household actions regarding home location
  - both primary residence and secondary residences
- Out-migration of households and employment
- Quantity of residential space used in each zone
- Unit price for residential space in each zone

# Household Allocation: Approach

- Microsimulation
  - each household and each member of each household
  - Monte Carlo assignment of characteristics or states
    - sometimes ‘statistical’, from specified sampling distributions
    - sometimes ‘behavioral’, from choice probabilities
- Take through demographic transitions
- Assign specific utility function coefficients, facilitating use of Zutilities
- Determine movers and reallocate movers
- Consider primary and secondary residence decisions

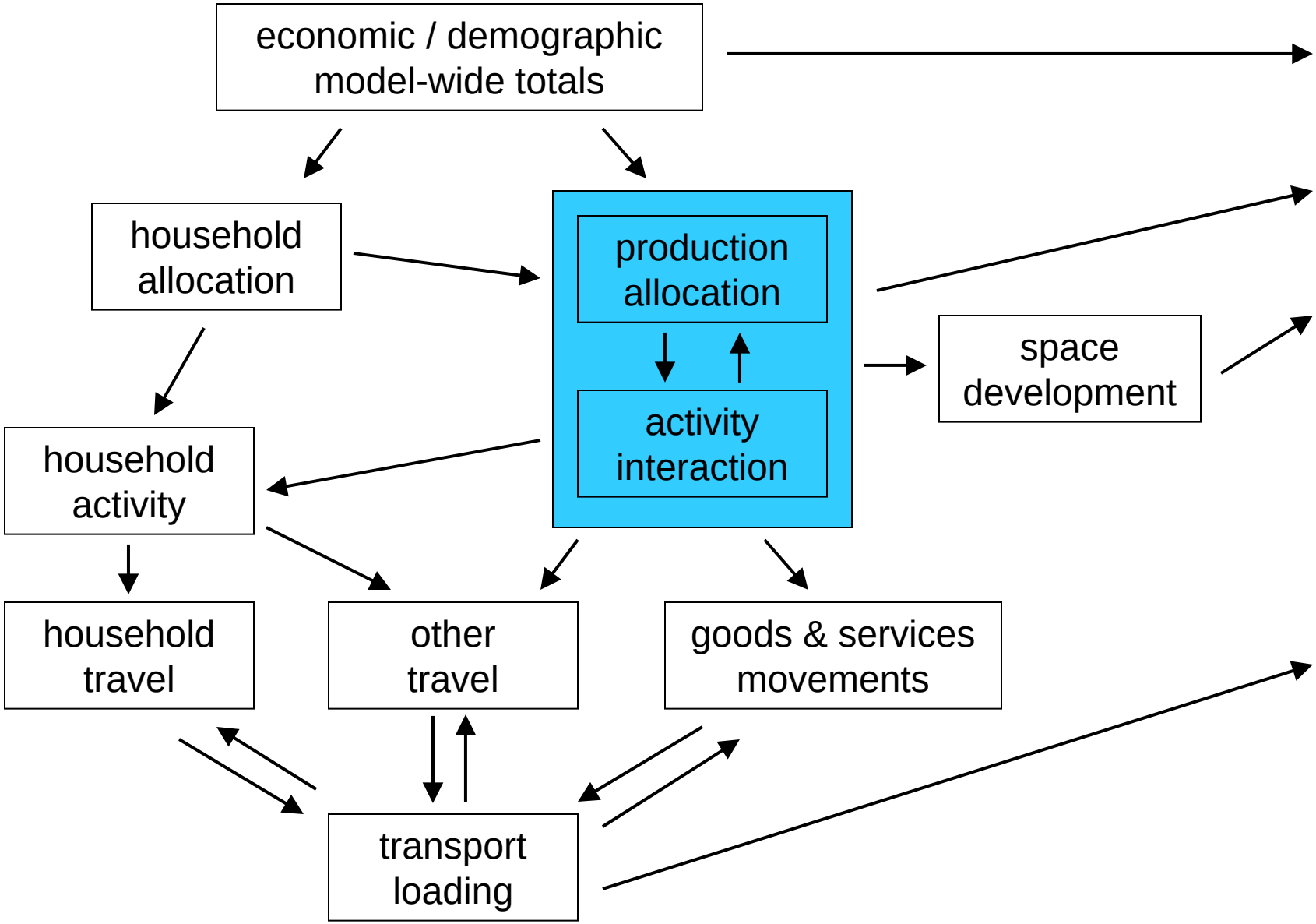
# Household Allocation: Approach

- Some movers re-locate outside model area, determining out-migration
- Unit price for residential space in each zone adjusts and evolve in response to supply and demand, without requiring full market clearing

# Household Allocation: Approach

- Generate initial synthetic population of households
  - use Beckmann process
  - assign all required characteristics based on marginal distributions
- Respect totals and marginal distributions from economic/demographic module for
  - in-migrating employment and households
  - out-migrating employment and households

# Production Allocation / Activity Interaction:



# Production Allocation / Activity Interaction: Purpose / Coverage

- Distribution of production activity by sector among zones
- Consumption of space by production activities in zones
- Flows of commodities and labor from production location (zone) to consumption location (zone)
- Exchange prices for
  - commodities
  - labor
  - space

# Production Allocation / Activity Interaction: Approach

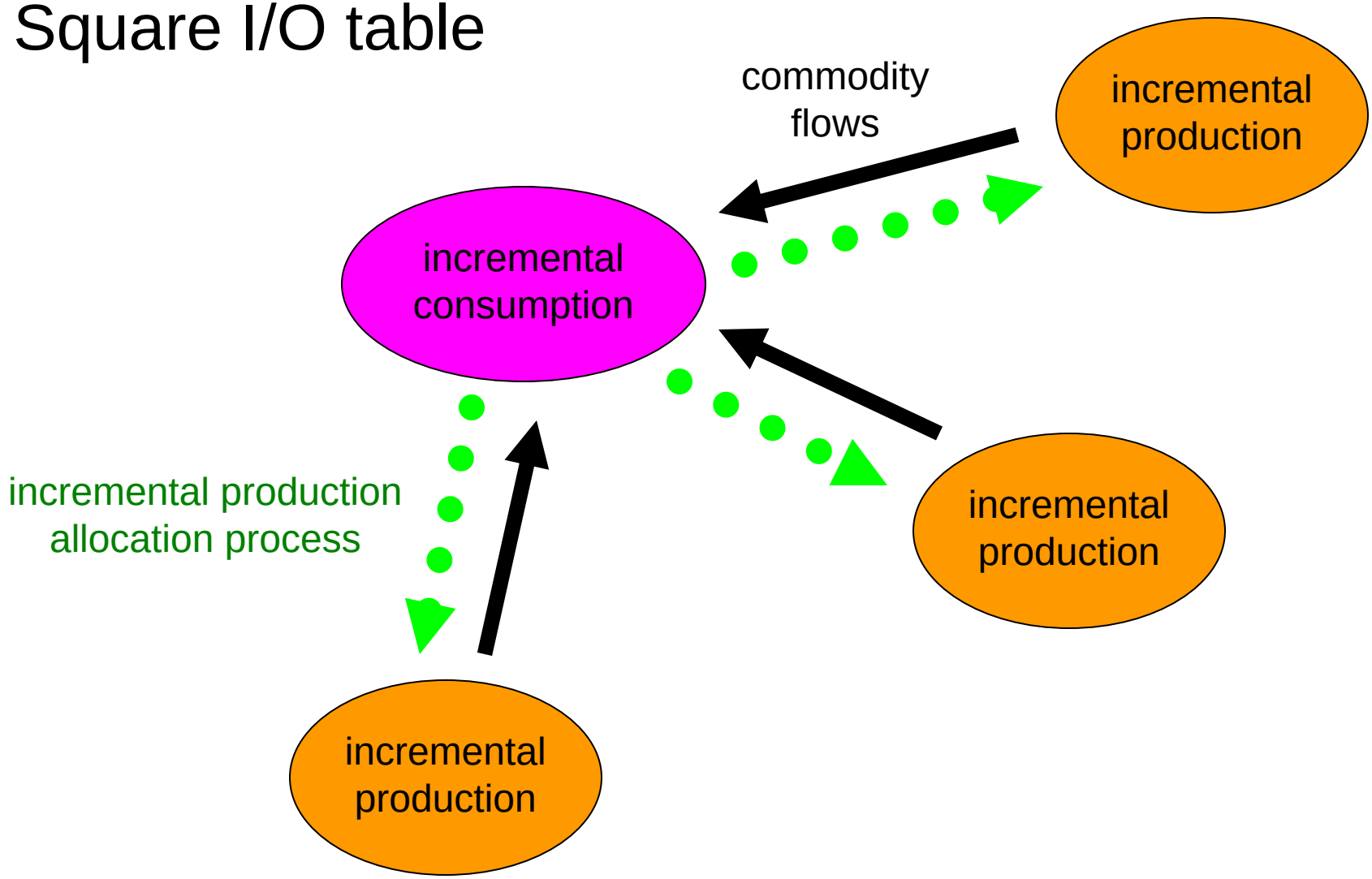
- Use extended form of spatially-disaggreated input-output for aggregate allocation
  - commodities represented explicitly, with make and use tables
  - exchange locations and exchange prices, with resulting direct transport cost allocation
  - total production allocated ‘centrally’ with consistent utility treatment
  - households fixed as determined in household allocation module
  - labor supply in exchange zones fairly inelastic around quantities determined in previous year

# Production Allocation / Activity Interaction: Approach

- Uses ‘quasi-dynamic treatment’
  - equilibrium solution identified with lag terms
- Rutilities used for allocation functions

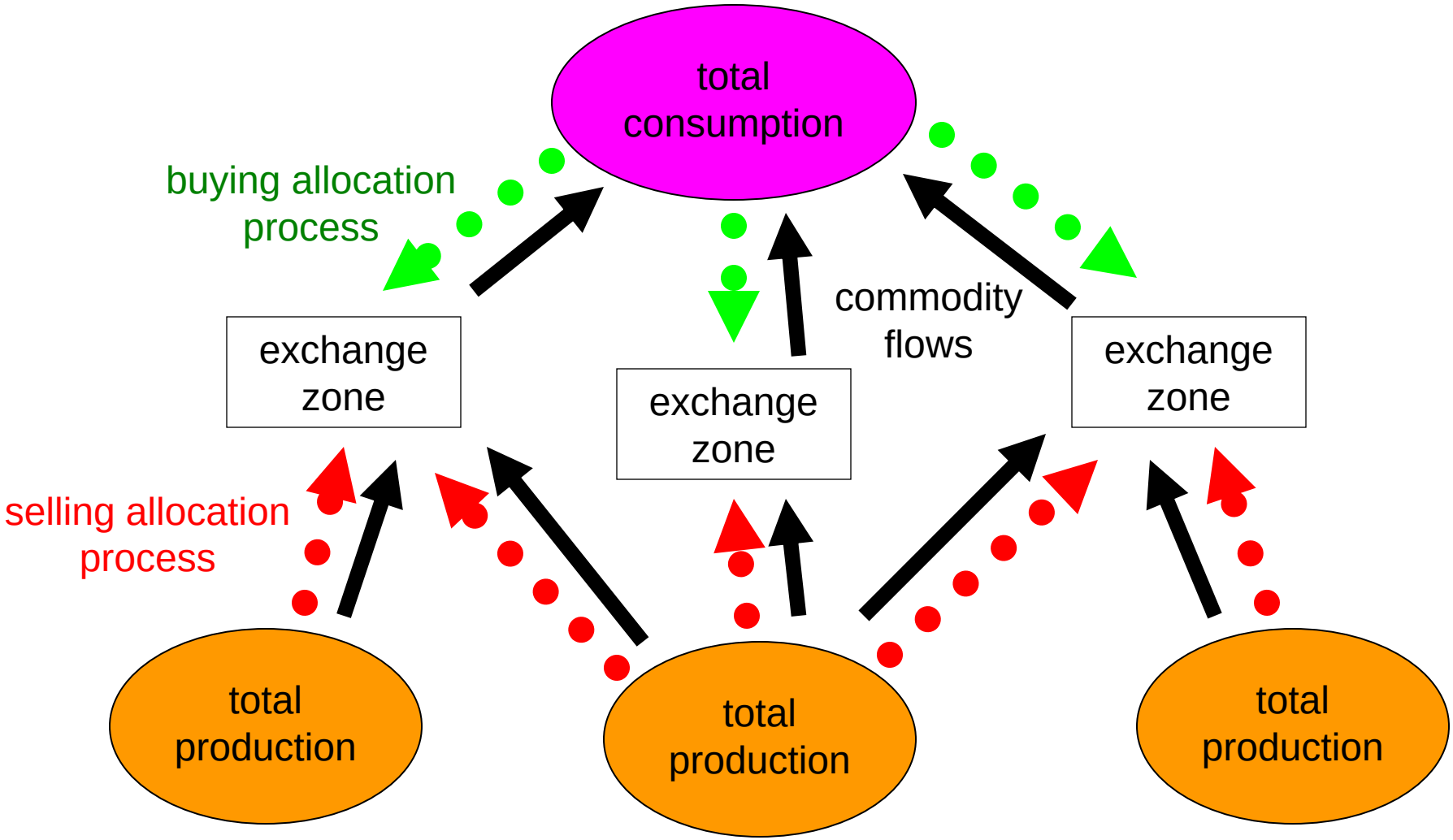
# MEPLAN & TRANUS Approach

- Square I/O table



# Production Allocation / Activity Interaction Approach

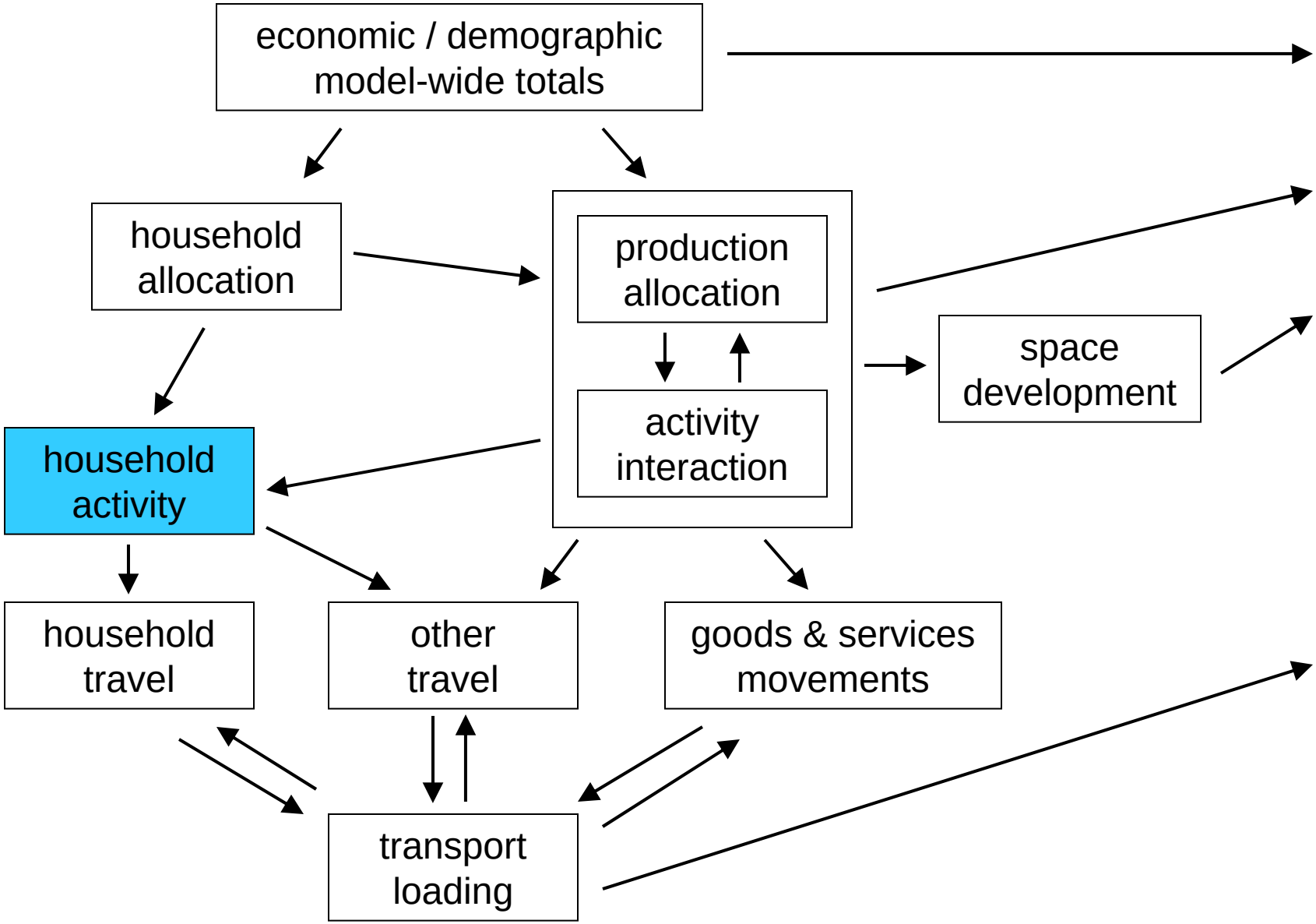
- Make and Use I/O tables



# Production Allocation / Activity Interaction: Approach

- Generalization of MEPLAN & TRANUS approach
  - commodities not demands
  - producer perspective explicit in allocation, which is essential with the treatment of households as labor providers in this framework
  - transport cost allocation explicit
  - uniform, consistent representation of behavior using random utility theory - allowing consistent evaluation of consumer and producer surplus changes
- Reduces to MEPLAN approach with certain simplifications
- Version up and running

# Household Activity



# Household Activity: Purpose / Coverage

- Vector of inputs for each household
- Changes in status for each household member
  - employment/SOC status and wage rates
  - workplace locations
  - school status
  - school location
- Weekly activity pattern for each household member
  - activity type
    - working
    - attending school

# Household Activity: Purpose / Coverage

- shopping
- medical, financial, etc (personal business)
- social, recreational
- other

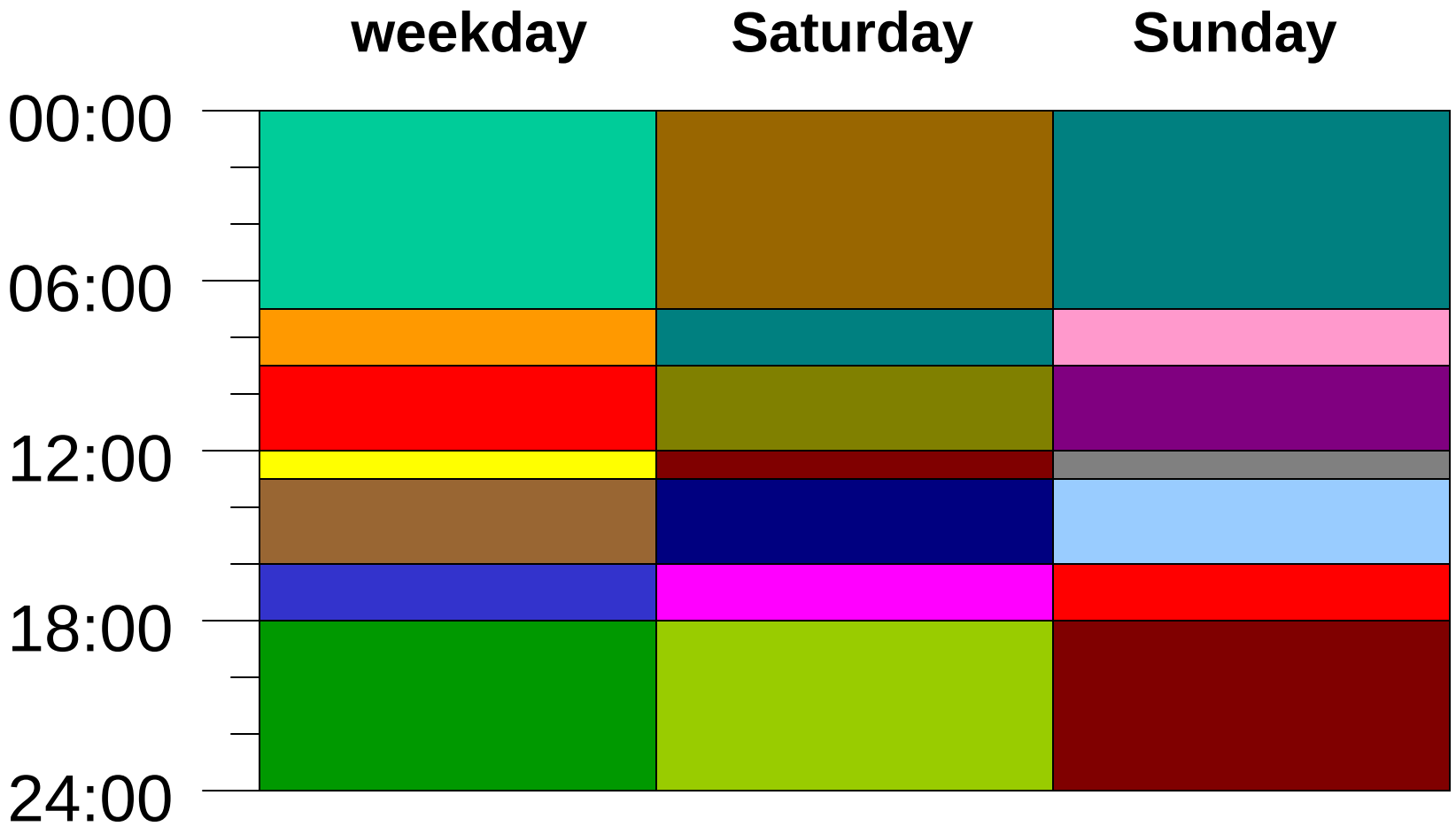
– nominal location

- home
- workplace
- school
- other

– in each time slot

- weekday, Saturday, Sunday
- segmented into times in day
- total of 21 slots

# Household Activity: Purpose / Coverage



# Household Activity: Approach

- Microsimulation
  - each household and each member of each household
  - Monte Carlo assignment of characteristics or states
    - sometimes ‘statistical’, from specified sampling distributions
    - sometimes ‘behavioral’, from choice probabilities
- Determine
  - vector of monthly input commodities for household
  - employment/SOC for each household member, respecting SOC potentials for member
  - workplace location for each job (0,1 or 2) for each household member

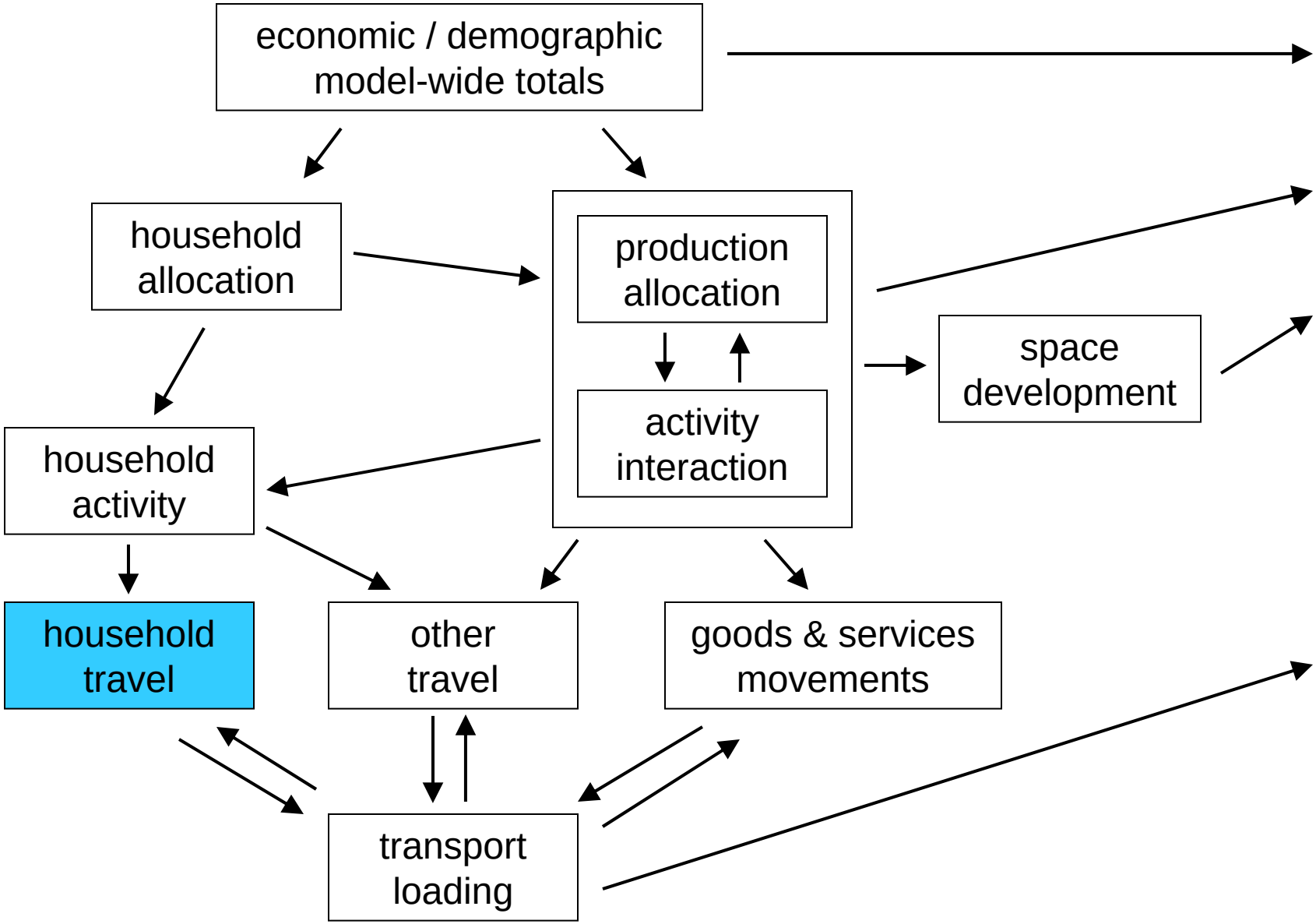
# Household Activity: Approach

  - school status for each member
  - school location for each household member
  - weekly activity pattern for each household member
  - particular job and associated workplace for each ‘workplace’ nominal location when member has 2 jobs
- Zutilites used for behavioral assignments

# Household Activity: Approach

- Uses ‘lagged quasi-dynamic treatment’ regarding labor markets
  - labor adjusts to new wage rates established in aggregate allocation, with households still fixed as determined in household allocation and labor flows to exchange zones adjusting as required
  - then new household location utilities determined
  - and then household location decisions and SOC potentials updated in response in the next year

# Household Travel



# Household Travel: Purpose / Coverage

- Set of tours by each household member for a given day, including for each tour
  - tour category
    - home-based work
    - home-based school
    - home-based other
    - work-based non-work obligatory
    - work-based non-work discretionary
  - number of stops, with patterns
    - primary destination
    - intermediate then primary destination
    - primary destination then intermediate
    - intermediate then primary destination then intermediate

# Household Travel: Purpose / Coverage

- locations (links) of stops
- time slot for each trip to each stop
- primary mode for tour, which conditions modes available for specific trips on tour
  - ‘driver’ - drives for all trips
  - ‘cyclist’ - cycles for all trips
  - ‘passenger-AA’ - auto passenger for all trips
  - ‘passenger-AT’ - auto passenger before primary destination and transit passenger after
  - ‘passenger-TA’ - transit passenger before primary destination and auto passenger after
  - ‘passenger-TT’ - transit passenger for all trips

# Household Travel:
# Purpose / Coverage

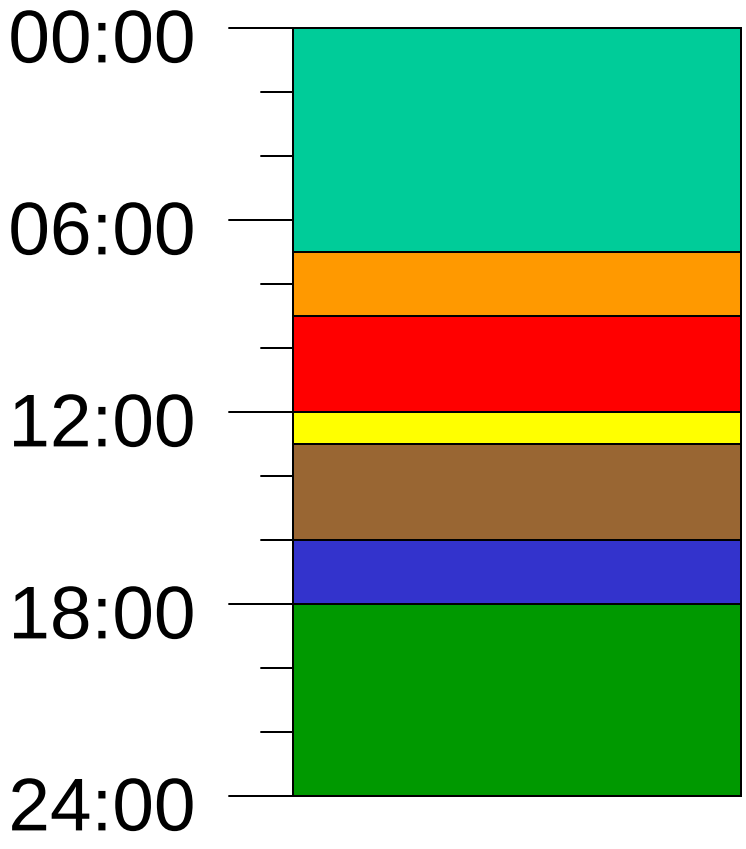
- ‘passenger-PP’ - transit passenger with auto access to and from base of tour
- ‘walker’ - walks for all trips

# Household Travel: Approach

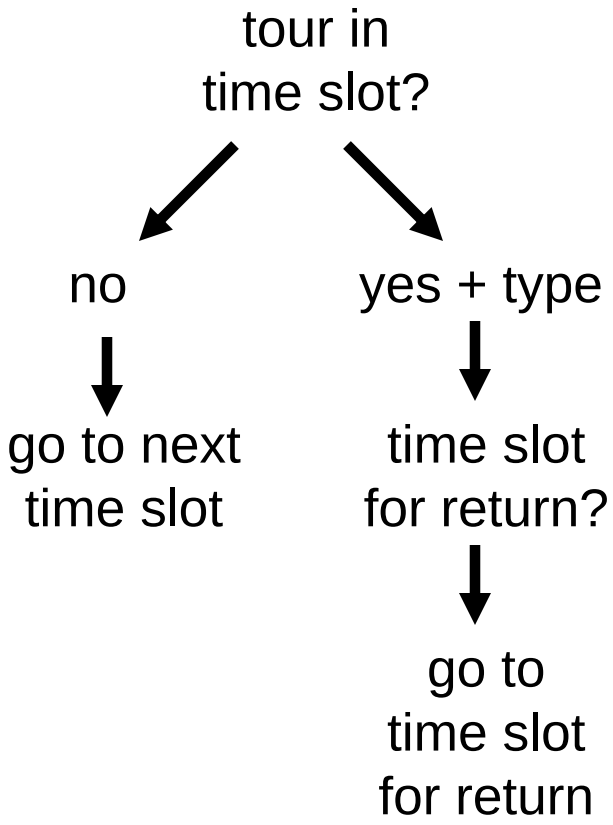
- Microsimulation
  - each tour for each member of each household
  - Monte Carlo assignment of characteristics or states
    - ‘behavioral’, from choice probabilities
- Zutilites used for all allocations other than stop locations and for allocation of stops to zones
  - zonal-level attributes
  - specific utility function coefficients for person
- Zonal-level stops allocated among links in zone using distributions of attributes among cells in zone

# Household Travel: Purpose / Coverage

**travel day**



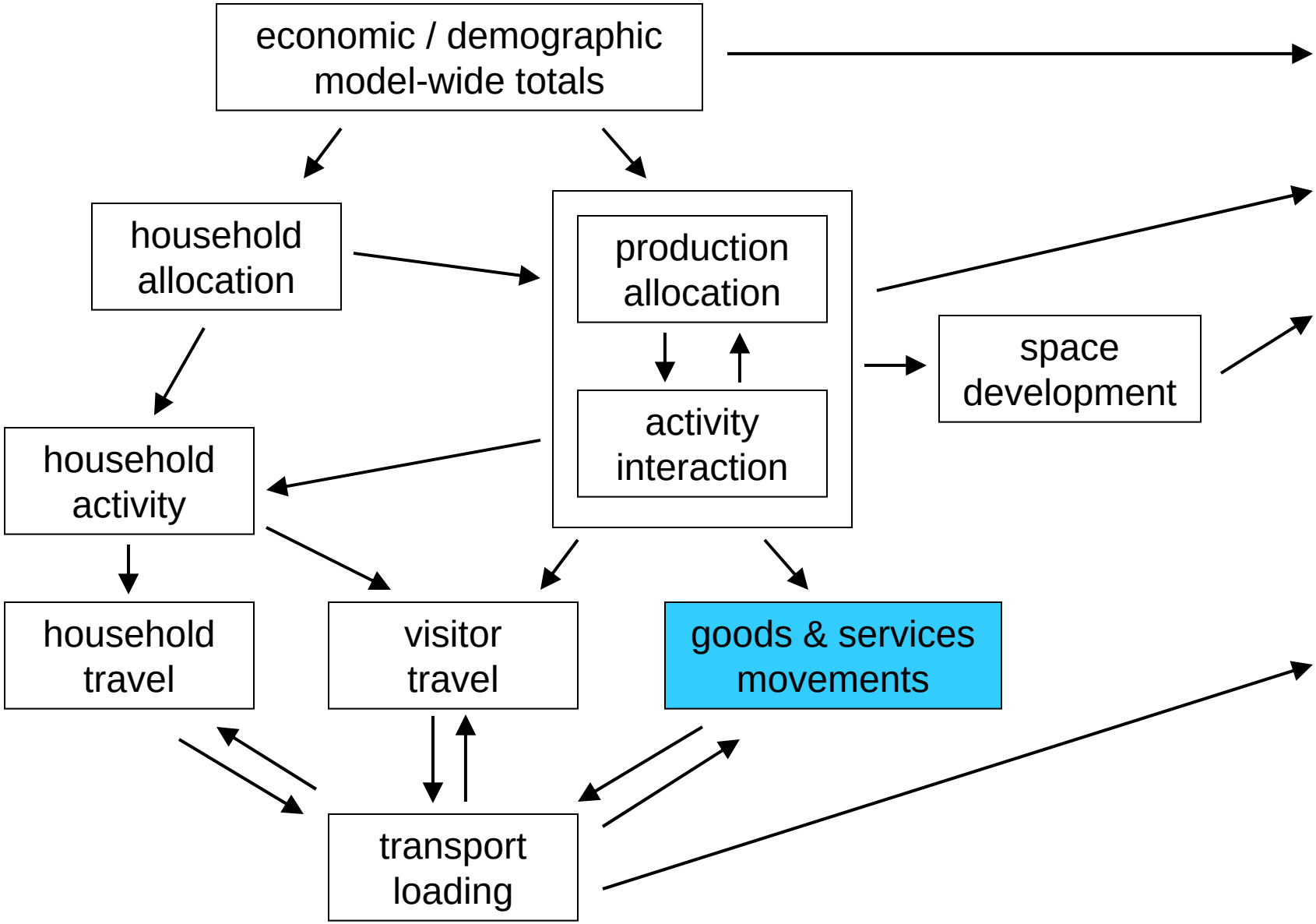

**choice sequence in each slot**



# Household Travel: Approach

- Primary destination zone and intermediate stop zones assigned using information from
  - household activity module
  - production allocation / activity interaction module
- Primary mode assigned using zonal level attributes for both outbound and return components

# Goods & Services Movements



# Goods & Services Movements: Purpose / Coverage

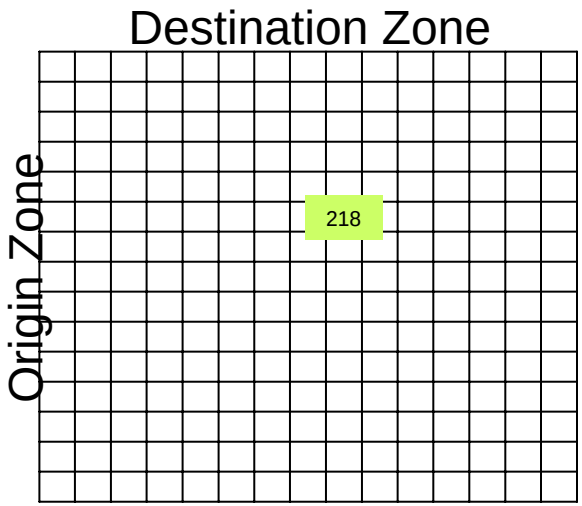
- Vehicle and person movements link-to-link for transporting goods and services consistent with activity interactions for a given day
  - vehicle type
    - light single-unit
    - heavy single-unit
    - articulated
  - time slot
  - for-hire vs own account

# Goods & Services Movements: Approach

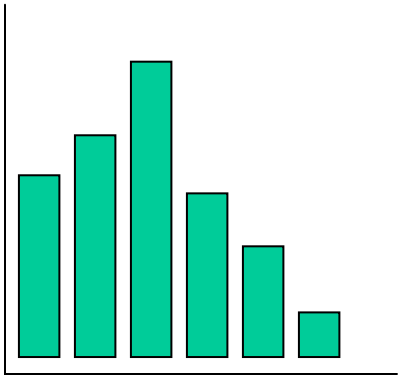
- Create synthetic micro-level data from aggregate zone-to-zone commodity flows determined in production allocation / activity interaction module
  - for each commodity category separately
  - from zone-to-zone flow to individual link-to-link shipments for each time slot
- For each shipment in resulting micro-level data
  - determine trans-shipment
  - assign carrier and vehicle type
  - consolidate with compatible vehicle loads and determine tours and return leg generation according to optimization from perspective of carrier

# Goods & Services Movements: Approach

Daily flow for commodity




Payload weight distribution (for commodity)



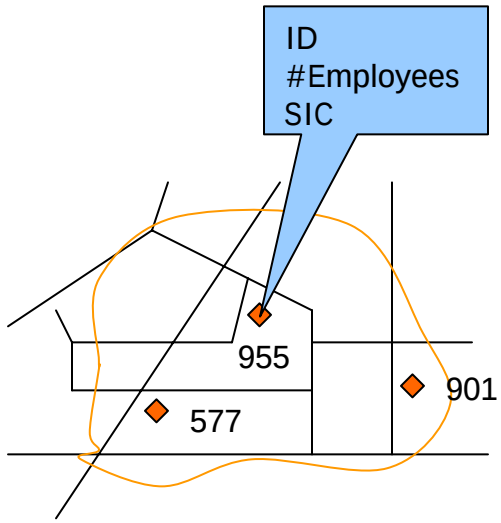
Shipment list

| C | O | D | Wgt |
|---|---|---|---|
| 37 | 5 | 6 | 14.2 |
| 37 | 5 | 6 | 20.1 |
| 37 | 5 | 6 | 97.0 |
| 37 | 5 | 6 | 66.7 |
| 37 | 6 | 7 | 1.5 |
| 37 | 6 | 21 | 112 |
| 37 | 6 | 22 | 7.9 |

# Goods & Services Movements: Approach

Shipment list

| C | O | D | Wgt | **OID** |
|---|---|---|---|---|
| 37 | 5 | 6 | 14.2 | **577** |
| 37 | 5 | 6 | 20.1 | **577** |
| 37 | 5 | 6 | 97.0 | **901** |
| 37 | 5 | 6 | 66.7 | **955** |
| 37 | 6 | 7 | 1.5 | **811** |
| 37 | 6 | 21 | 112 | **99** |
| 37 | 6 | 22 | 7.9 | **99** |




At both origin and destination

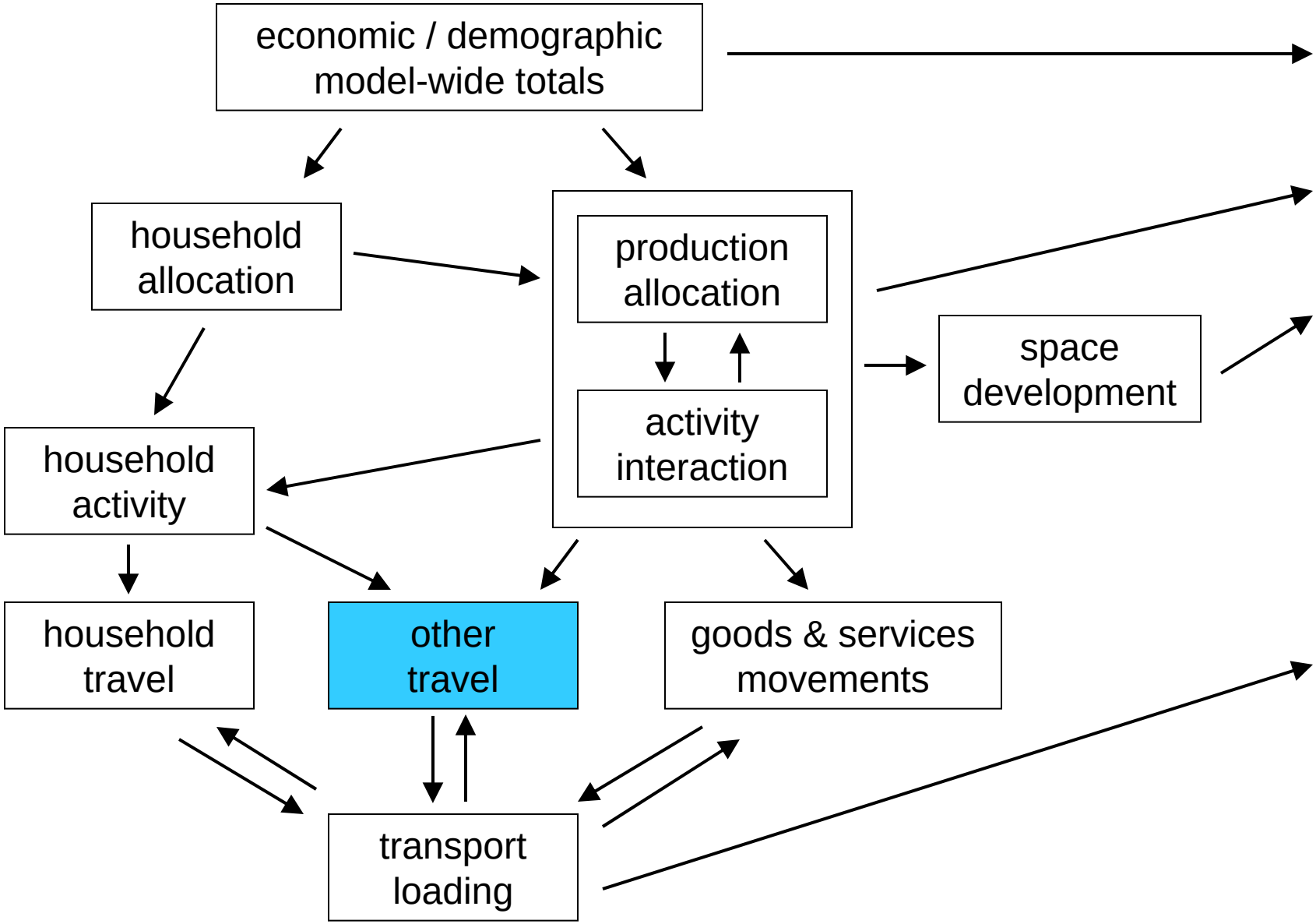
# Goods & Services Movements: Approach

Shipment list

| C | O | D | Wgt | OID | DID | TSP |
|---|---|---|---|---|---|---|
| 37 | 5 | 6 | 14.2 | 577 | 301 | |
| 37 | 5 | 6 | 20.1 | 577 | 460 | |
| 37 | 5 | 6 | 97.0 | 901 | 695 | |
| 37 | 5 | 6 | 66.7 | 955 | 14 | |
| 37 | 6 | 7 | 1.5 | 811 | 333 | 12 |
| 37 | 6 | 21 | 112 | 99 | 714 | |
| 37 | 6 | 22 | 7.9 | 99 | 999 | |

| carrier | vehicle |
|---|---|
| for-hire | HSU |
| own act | HSU |
| own act | HSU |
| own act | LSU |
| for-hire | LSU |
| own act | LSU |
| for-hire | HSU |

# Other Travel



# Other Travel:
# Purpose / Coverage

- Trips by visitors staying in households
- Trips by visitors staying in hotels & motels
- Trips by people related to business activity apart from commodity delivery
- External to external vehicle movements

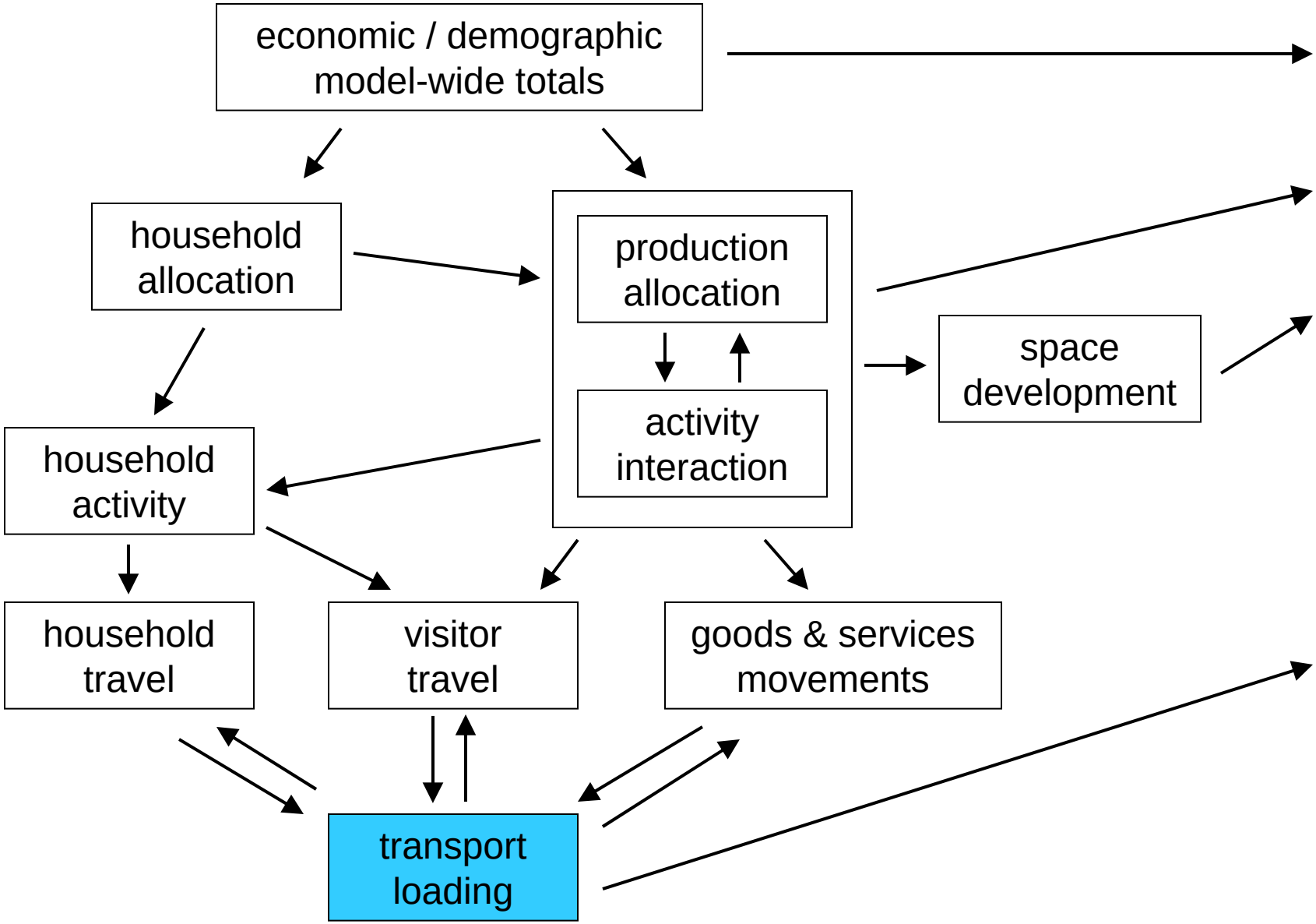
# Other Travel: Approach

- Microsimulation for each category of person trips
  - each tour for each visitor and worker
  - Monte Carlo assignment of characteristics or states
    - ‘behavioral’, from choice probabilities
  - same general process as used with household trips, but with fewer tour types
  - components of tours related to business activity conditioned by activity interactions between economic sectors
  - visitors allocated
    - to hotels according to production activity quantities
    - to households as part of household allocations

# Other Travel: Approach

- External-to-external vehicle flows related to trade flows between 3 bordering regions and rest-of-world, as determined in economic / demographic module
  - direct factoring from trade flows to vehicle flows by mode
- Note that vehicle flows with one end external can be related to import and export demand components in exchange zones, as determined in production allocation module, then proportioned according to trade flows as appropriate

# Transport Loadings



# Transport Loadings: Purpose / Coverage

- Load travel demand to transport supply
  - vehicles to roadway links
  - persons to modes
- Determine congested travel conditions
  - times
  - costs
  - feedback to travel demand modules in this time period and to economic modules for next time period

# Transport Loadings: Approach

- Information available for each trip from trip modules
  - starting link in origin zone
  - ending link in destination zone
  - primary mode, resolved into vehicle occupancies
  - specific utility function coefficients indicating specific sensitivities of traveler for this trip, including components of travel time, money cost and mode-level ASCs

# Transport Loadings: Approach

- Steady-state for a given time slot
- All trips in the time slot
- Two-stage approach
  - first a Frank-Wolfe equilibrium assignment, to get initial loaded times
  - then a Micro-level assignment considering each trip, to get variation in behavior consistent with information from other modules
    - mode use for each trip
    - distribution of paths for detailed networks
    - auto allocations

# Transport Loadings: Approach

- For Frank-Wolfe stochastic user equilibrium
  - convert trip lists (from trip modules) to traditional origin-destination matrices
  - trips loaded through zone centroids
  - trips routed on minimum cost, multimodal path through the network
  - uses Rutilities
    - zonal attributes
    - typical utility function coefficients
  - allowable links based on primary mode choice
  - provides ‘loaded’ link travel times

# Transport Loadings: Approach

- For Micro-level assignment
  - one pass through all trips (or more?)
  - consider each trip in turn
  - use Lutilities
    - link attributes
    - trip specific utility function coefficients
  - identify maximum utility (minimum disutility) path from starting link to ending link for those Lutlities
  - increment flow on each path link by 1
  - re-calculate link travel costs (Lattributes)
  - remove portion of O/D flows allocated to each path in the Frank-Wolfe solution

# Transport Loadings: Approach

- Some special considerations for transit modes
  - EMME/2's optimal strategies used in Frank-Wolfe equilibrium assignment
    - provides distribution among alternative transit paths
  - Micro-level assignment then uses resulting distributions among transit links in further Monte Carlo selection of path for each transit trip

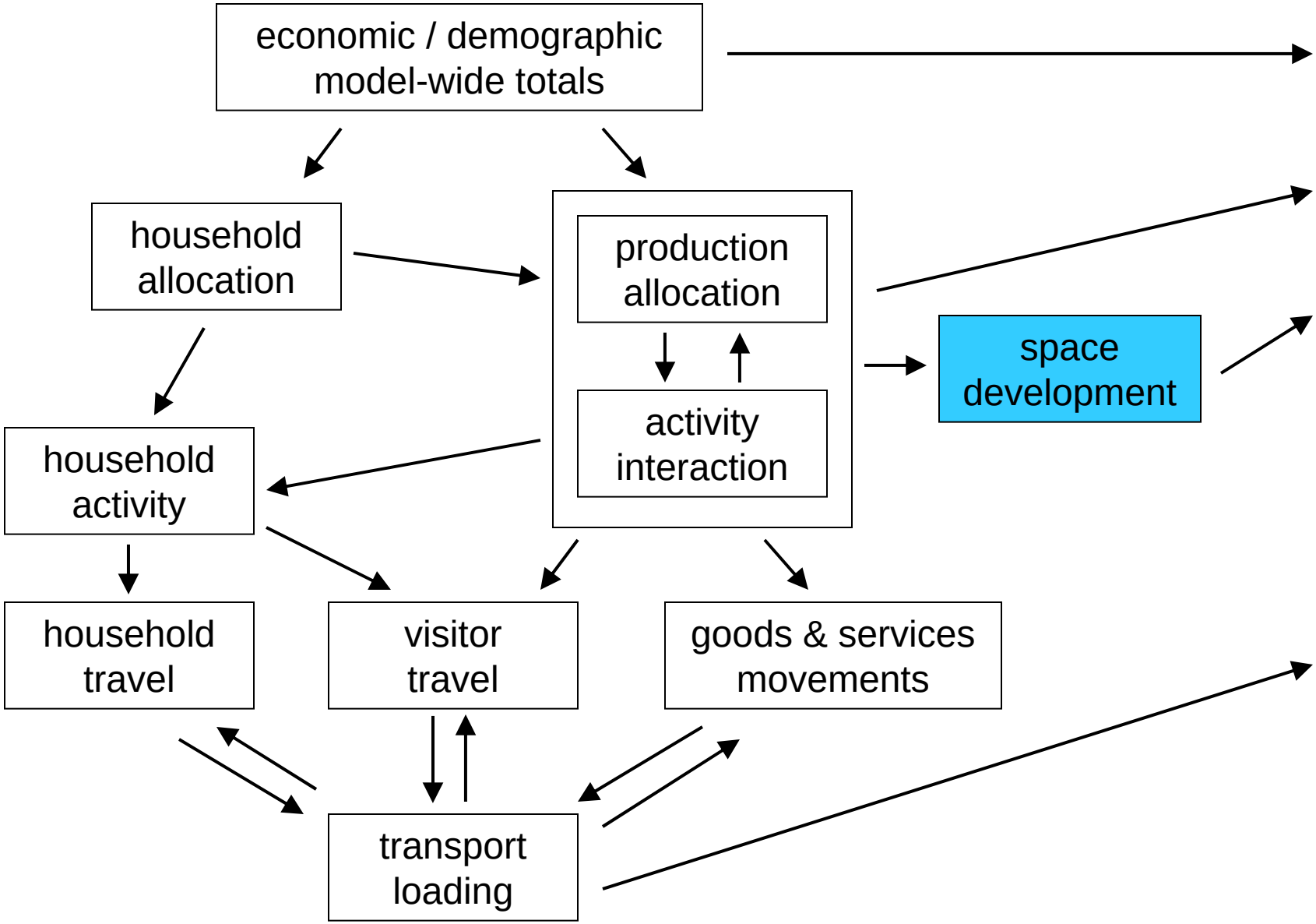
# Transport Loadings: Approach

- Computationally, most-demanding module
- Initial version up and running
- Some practical considerations
  - large memory demands
    - Frank-Wolfe paths must be stored in memory
    - microassignment carried out in separate Java VM
  - long processing times
    - two-stage approach provides orders of magnitude decrease in run times
    - 15 Frank-Wolfe iterations runs in same time as single microassignment iteration
    - expect about 3 hours to process 12 million trip records
    - multi-threading tricky but potentially helpful

# Transport Loadings: Approach

- Final step is to build primary mode skims using typical utility function coefficients, for use in other modules

# Space Development



# Space Development:
# Purpose / Coverage

- Quantity of developed space in each category of space in each zone in each year
  - gross decreases and increases
  - both new development and re-development

# Space Development: Approach

- Microsimulation for each cell of land in each zone
  - each cell considered explicitly
  - Monte Carlo assignment of characteristics or states
    - ‘behavioral’, from choice probabilities
- For each cell in turn:
  - Age existing development
  - Determine if type or quantity of space are to change
  - Select type and/or quantity according to allowable
    - current type is possible if allowable
    - ‘vacant’ is also possible
- One space type in a cell; ‘pseudo-cells’ for mixed use zoning

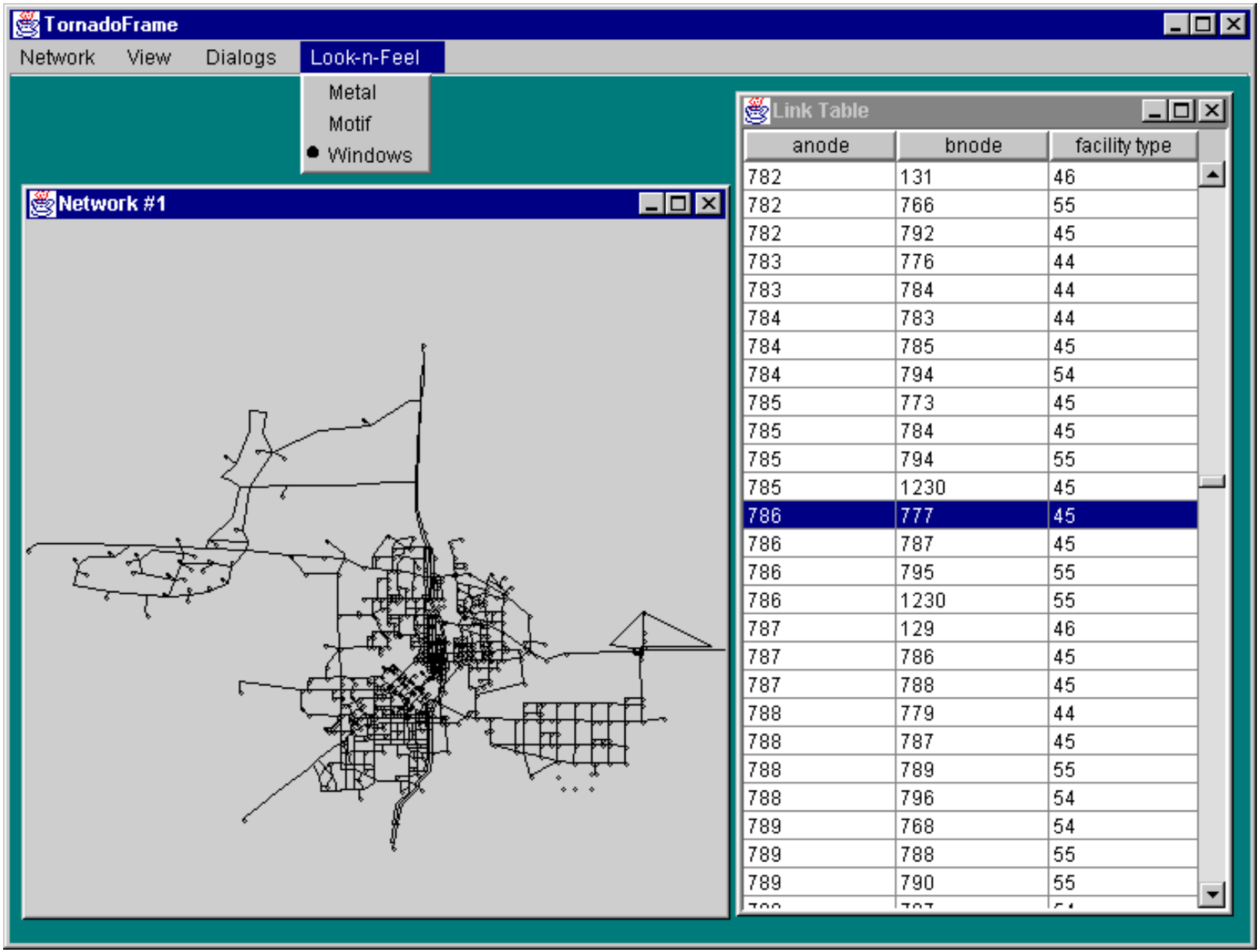
# Space Development: Approach

- Cutilities used
- Consider zonal-level prices for developed space determined in other modules and relevant area and model-wide vacancy rates
- Quantities by type in cells
  - used in distribution of zonal values to links
  - summed to provide zonal values for other modules

# User Interface

# User Interface:
# Principal Components of Software System

- Model modules
- Database
- Process controller
- Calibrator
- User Interface
  - Process visualizer
  - GUI for input and output
  - Scenario/Run archiver


TornadoFrame
Network
View
Dialogs
Look-n-Feel
Metal
Motif
Windows
Network #1
Link Table
anode
bnode
facility type
782 131 46
782 766 55
782 792 45
783 776 44
783 784 44
784 783 44
784 785 45
784 794 54
785 773 45
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785 794 55
785 1230 45
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787 129 46
787 786 45
787 788 45
788 779 44
788 787 45
788 789 55
788 796 54
789 768 54
789 788 55
789 790 55

# Calibrator

# Calibrator:
# Purpose / Coverage

- Guidance in selection of parameter values for model components
  - to large extent, the parameters are for the sampling distributions for the various utility function coefficients being used

# Calibrator:
# Purpose / Coverage

- Supports a Bayesian sequential process
  - first the components are calibrated separately
  - then the components are combined and certain parameters are re-estimated according to an overall goodness-of-fit
    - for parameters that
      - have substantial impacts on component interactions
      - have largest impacts on policy outputs
      - could not be estimated with suitable confidence in separate treatment of components

# Calibrator:
# Approach (extensively discussed previously)

- Target values specified for various model determined values
- Calibrator then uses
  - a ‘merit’ function to measure overall goodness-of-fit that includes
    - weighted least-squares for outputs
    - information on estimation results in separate treatment of components
  - along with a form of steepest ascent algorithm to suggest changes in parameters – facilitating a ‘semi-automated process’

# Data

# Data:
# Space and Land Use

- Land data most problematic data in Gen1
  - Gen2 much more ambitious
    - more sectors
    - more spatial detail
  - will have to mine/integrate/reconcile multiple sources and accept
    - spatial variation in quality and category definition, and/or
    - considerable data synthesis

# Data:
# Space and Land Use

- Promising sources
  - PNW-ERC grid data (based on 30-meter Landsat data)
  - Oregon NLCD (also based on 30-meter Landsat data) (+)
  - USGS digital orthophoto quads (+)
  - Oregon statewide DLCD zoning coverage
  - Oregon Potential Development Impact Area data
- Land price data most problematic
  - add commodity prices in Gen2
  - but full set not required
    - analogy with travel times
    - Still most problematic data
  - will require some synthesis

# Data:
# Network and Zones

- Network inside Oregon
  - MPO networks
  - Gen1 SW/SS network augmented with additional detail from
    - ODOT GIS functionally Classed Road System
    - BLM composite digital coverage of Oregon transportation features (based on 1 to 24000 quad sheets)
    - ODOT rail network coverage

# Data:
# Network and Zones

- Network in ‘halo’ around Oregon
  - use US national network (full detail)
- Network in ROUS
  - use abstraction of US national network

# Data:
# Network and Zones

- Zones inside Oregon
  - MPO TAZs
  - Gen1 SW TAZs
  - Census Places
- Zones in ‘halo’ around Oregon
  - Census Places
  - Counties

# Data:
# Behavior

- Economic activity and I/O Tables
  - as with Gen1, but with further disaggregation
- Household activity and travel
  - large household activity survey statewide
  - further descriptions of behavior in Portland Metro
- Developer data
  - draw on Gen1 work in Eugene-Springfield

# Development Approach

# Development Approach: Personnel

- Distributed team fitting with modular approach
- Spread effort
  - faster progress
  - draw on differing backgrounds and strengths
- For each module
  - modeler as lead
  - computer programmer for support

# Development Approach: Personnel

| Component | Developer(s) | Programmer(s) |
|---|---|---|
| ED | Batten | Dunn |
| HA | Hunt | Abraham |
| LD | Abraham/Hunt | Abraham |
| PA/AI | Hunt | Dunn |
| PT | Hunt/Freedman | Freedman/Abraham |
| CT | Donnelly | Donnelly |
| TS | Hicks/Hunt | Hicks |
| Support | Heier/Donnelly | Heier/Dunn |

# Development Approach: Software and Implementation

- JAVA code
  - object-oriented
  - suitable for modular approach
- Develop initial versions of modules
  - for experimentation
  - test concepts
  - learn for further guidance of development details
- Get modules running and working together as soon as possible

# Development Approach: Software and Implementation

- Also developing various generic ‘support’ task objects, like
  - ‘logit solver’
  - ‘Monte Carlo sampler’
- Calibrate to extent possible by July 2001
  - expect further calibration afterwards

# Conclusions

# Conclusions

- Definitely ‘pushing the envelope’
  - very ambitious
  - very exciting
- Object-oriented perspective has allowed fresh view in design considerations
- Lots of ideas ‘available’ concerning processes involved that aggregate models cannot use
  - microsimulation crucial
  - micro-assignment design very encouraging
    - new capabilities
    - added flexibility
    - resource requirements not prohibitive

# Conclusions

- Calibrator essential to keep development effort reasonable
- Developing initial test versions very useful
  - testing concepts
  - guiding re-design
  - providing ‘level of comfort’
- Distributed team working along ‘module-lines’ seems to be working, but early to tell
- Still a ‘work-in-progress’ and design is evolving
  - data considerations most critical in this regard

# Conclusions

- No need to consider where to go next - entire topic already