A Unified Model of Household Decision-Making

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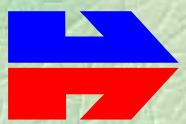
Presented at the
Third Oregon Symposium on Integrated
Land Use and Transport Models
Portland, July 25, 2002



Joint Program in
Transportation
University of Toronto

Presentation Outline

1. A model of household decision-making
2. Household-based activity scheduling
3. Extension to other household decisions
4. Microsimulating markets

Acknowlegements to

1. Matt Roorda (activity scheduling)
2. John Abraham (microsimulating markets)

Unified Model of Household-Based Decision-Making

In ILUTE we are working towards a unified model of household-based decision-making which applies to and integrates **long-run** decisions (housing, jobs, cars, etc.) with **short-run** decisions (activity/travel within a given day or week).

Model of Household-Based Decision-Making, cont'd

The unifying theme within this model is that it must represent decision-making in both the short- and the long-run with respect to the **acquisition**, **allocation** and **usage** of tangible household and personal resources:

- time
- money
- goods & services

Activities & Episodes

- We live our lives through a sequence of **activities** in which we engage
- Activities are manifested in terms of individual **episodes**
- Each episode has:
  - duration
  - start time (end time = start + duration)
  - location
- Trips are **travel episodes**; additional attributes:
  - location involves two points -- origin & destination
  - mode
  - route

Schedule

- Episodes exist within a **schedule** which is a planned, feasible set of activity and travel episodes
- Once executed, the schedule becomes an observed (realized) **activity pattern**
- Decision-making concerning activity and travel is a problem in **scheduling**
- Scheduling is on-going, continuous, over multiple time periods (daily, weekly, yearly, lifetime)
- Note that this scheduling/planning/decision-making process applies to **all** activities, both in the long and the short run

Goods & Services

- Two major types:
  - **consumables**
    - one-time acquisition cost
    - one-time “benefit”
  - **durables**
    - acquisition (“capital”) cost
    - on-going costs (maintenance; debt service)
    - on-going benefits
    - “big-ticket” items/resources/“projects” for households:
      - housing
      - cars
      - ….

Goods & Services, cont'd

Goods & services are of importance within the model for many reasons:

- acquisition/consumption/usage of goods & services major linkage to the urban economic (firm activity) "side" of the modeling system
- "shopping" a major travel generator (etc.)
- acquisition/usage of "big ticket" durables (houses, cars) of major interest within ILUTE

Budgets

- Households and persons are constrained in their actions by time, money and other resource **budgets**
  - In each time period, each person must spend each minute doing “something”
  - In each time period all money available to the household must be spent (includes “spending” on savings)
  - Only one driver at a time can use a car (etc.)
- In long-run, durable acquisition decisions (houses, cars), monetary budget tends to dominate
- In short-run activity/travel decisions, time budget (and car availability constraints) tend to dominate
- Both time & money constraints, however, potentially operative within all time frames

Projects

- Axhausen [1998]defines a **project** as a coordinated set of activities tied together by a common goal or outcome.
- In this conceptual model, the project is **the** fundamental organizing principle
- It is argued that **all** activities (short- and long-run) are embedded within and generated by projects
- This approach can be tied back (at least loosely) to Maslow's **Hiearchy of Needs** as a possible philosophical/theoretical starting point

Projects, cont’d

- Projects may have sub-projects, which can have sub-sub-projects, and so on
- An activity is thus an “elemental” project which contains exactly one type of action

Conceptual Potential of Projects

It is hoped that we can *encapsulate* behavior within the project class in a way that will allow us to model very complex behavior in a manageable manner.

That is, each project needs only to “know about” its own activities -- can therefore decompose the complexity of daily activities into separate, more “bite size pieces” in a theoretically defensible way.

Projects interact with one another through the scheduling process, and through competition for household (and personal) resources.

Project Attributes

- **Type**
- **Objective**
- **Task List:** The set of activities that must/might be executed within the project
- **Agenda:** The list of specific episodes that the project is currently looking to schedule (i.e., actually plan and execute)

Task List

- The elements of the task list persist throughout the life of the project
- Its elements are activities which the person/household **might** engage at some point in the project (but may not necessarily do so during the current planning period)
- Activities are objects
  - possess little in the way of attributes
  - defined in terms of their behavior
- I.e., activities possess the information and procedures/methods needed to generate specific instances of activity episodes (i.e., to generate the agenda)

Agenda

- List of specific activity episodes which are being considered for insertion into the schedule during the current planning period (although these insertions need not successfully occur)
- Episodes are objects
  - defined by their attributes
  - have no behavior *per se* (episodes are acted upon; they do not act)
- Episodes persist within the agenda only until they are scheduled (or, perhaps, deemed infeasible and deleted from the agenda)
- Hence, the elements of the agenda change over time as they are scheduled and deleted and as new episodes are generated out of the task list and added to the agenda

Example Projects & Agendas

Person 1
Project 1:Work
Agenda:
- Primary work event
- Prepare end of quarter report
- Business trip to Montreal
- ….

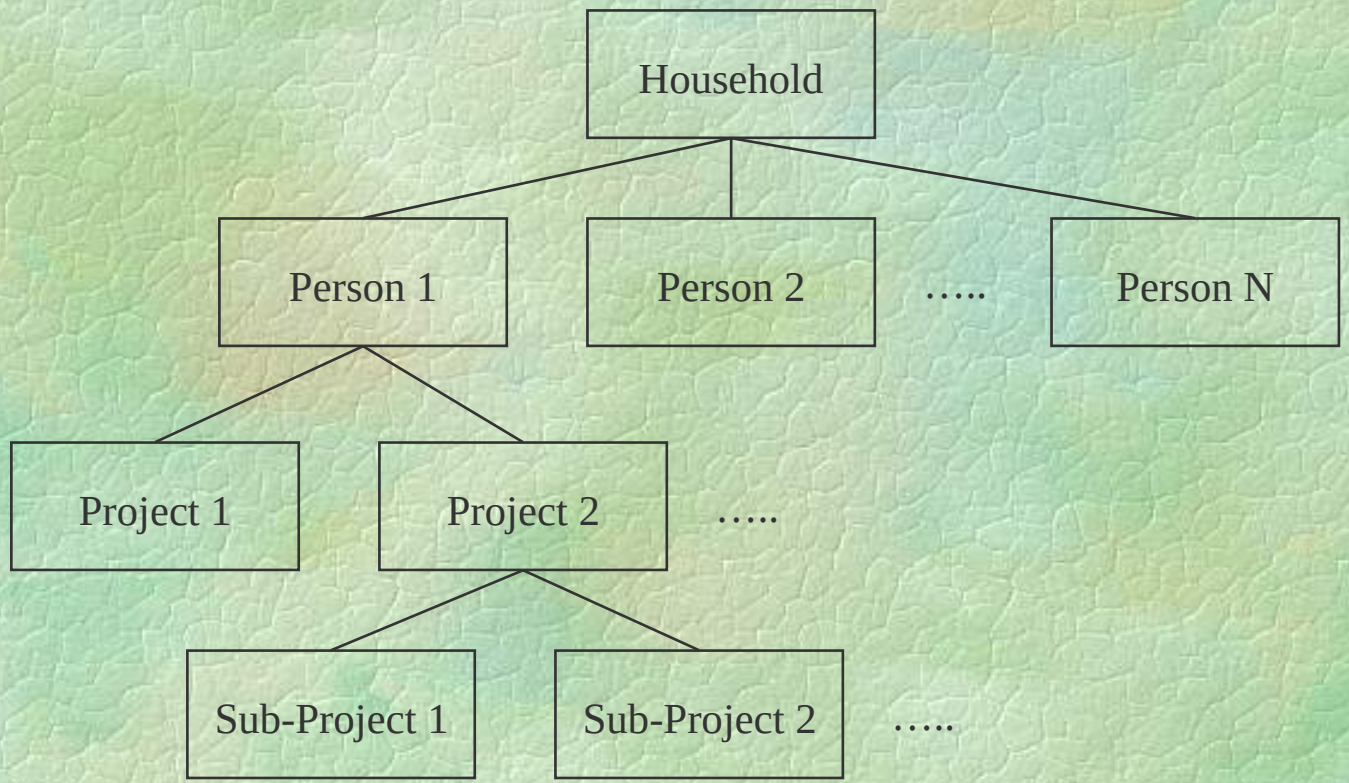
Person 1
Sub-project 1.1: Report
Agenda:
- Get sales report
- Meet with Fred
- Write report
- ….

Person 1
Sub-project 1.2: Trip
Agenda:
- Meeting Montreal 9:30-4:30; April 23
- Book plane tickets
- ….

Projects and Scheduling

- Decisions about what activity episodes are to be participated in, and their (nominal) attributes are **encapsulated** within the project (e.g., the work project determines work-related episodes and does not need to know about home-maintenance activities to do this)
- An **interface**, however must exist between projects so that time, money and other resource **requirements**, **constraints** and **allocations** can be communicated and determined
- It is argued that a **hierarchy** of decision-making exists within the household

Hierarchy of Household Decision-Making



Definition of constraints (i.e, allocation of resources) and allocation of activities

Requests for resources

Primary Projects

- Community service
- Education
- Family
- Health care
- Religious group
- Mobility
- Personal maintenance
- Recreation (personal/household)
- Shelter
- Socializing (with non-household members)
- Sustenance
- Vacation
- Work

Household-Level Decision-Making

- Acquisition of durable goods
  - housing
  - vehicles
- Allocation of household resources to household members
  - money
  - vehicles
- Allocation of household activities/responsibilities to household members
  - serve-dependent
  - household “chores”
  - joint household activities

Conceptual Model Applications

The conceptual model has been applied to date to the development of a prototype activity/travel scheduling model.

Work is proceeding on extending it to auto ownership and residential location choice.

Scheduling Daily/Weekly Activity & Travel

- Assume that we are modeling the scheduling of one week of activities for all persons within a household for an arbitrary week
- Problem naturally divides into:
  - activities which have been **pre-planned** prior to the beginning of the week
  - activities which are planned **within-week** for the week in question
- The pre-planned activities define a **schedule skeleton** around which within-week activities are scheduled
- Is useful to define two activity attributes:
  - type
  - mode

Activity Types

- **Type I: On-going contract with an external agent**
  - Pre-planned; high priority
  - Weekly frequency (or more)
  - Examples: “regular” work, school, group (religious, cultural, sports, community, etc.)
  - Typically relatively inflexible scheduling/rescheduling
  - Type I activities define the schedule skeleton

Activity Types, cont'd

- **Type II: One-time contract with external agent**
  - Less than weekly frequency
  - Examples: medical; personal business; socialize
  - Often initial scheduling flexibility
  - Re-scheduling/modifying may be difficult
  - Even though pre-planned (by definition), treat as within-week for modeling purposes

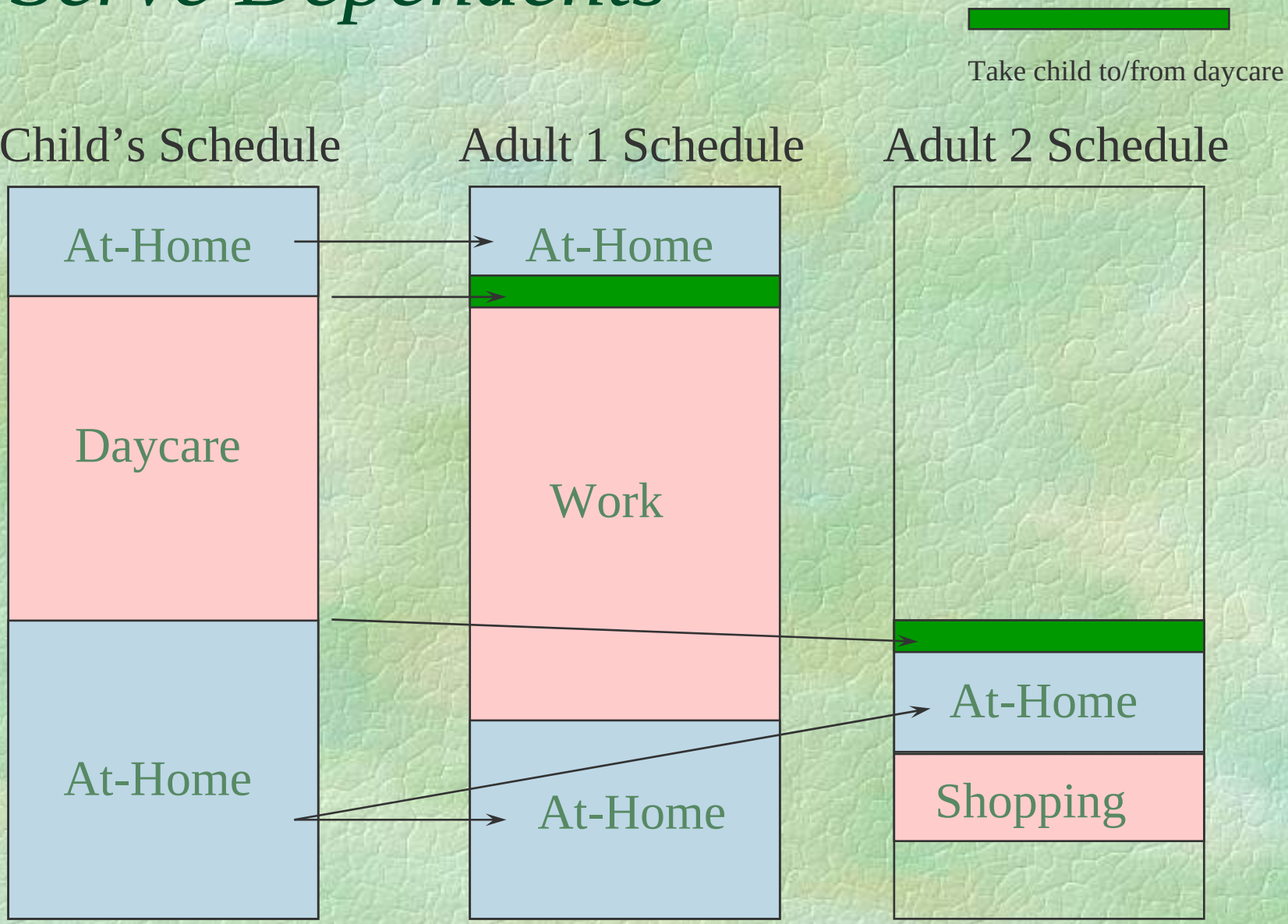
Activity Types, cont'd

- **Type III: Within-household**
  - Decision lies entirely within the household (i.e., no external agents involved)
  - Examples: shopping; joint recreation; personal & household maintenance
  - May be high priority
  - Often flexibly scheduled/rescheduled
  - May be pre-planned, but treat as within-week

Activity Types, cont'd

- **Type IV: Serve Dependent**
  - These activities are generated by the needs of the dependent
  - Different "modes" exist:
    - Supervision
    - Chauffeuring
    - Participation
    - Attending to needs (shopping, cooking, etc.)
  - High priority
  - Flexibility determined by dependent's scheduling flexibility
    - If dependent's activity is Type I, so is the serve dependent activity

Serve Dependents



Activity Mode

- Just as a travel episode is executed within a given travel mode, so to, it is argued, activity episodes occur within an activity **mode**
- E.g., shopping is an activity; possible shopping modes include:
  - in-store
  - catalogue
  - internet
- Argue that activities are relatively universal/invariant
- What changes over time and from one society/culture/economy to another are the modes available for executing these activities

Activity Mode, cont'd

- Activity modes largely defined by economic and technological state
- Activity modes are **supplied** in the same way as travel modes are (i.e., demand-supply-performance interactions exist as in travel)
- This supply may be either endogenously or exogenously determined with respect to the model (typically exogenously determined, as with travel)

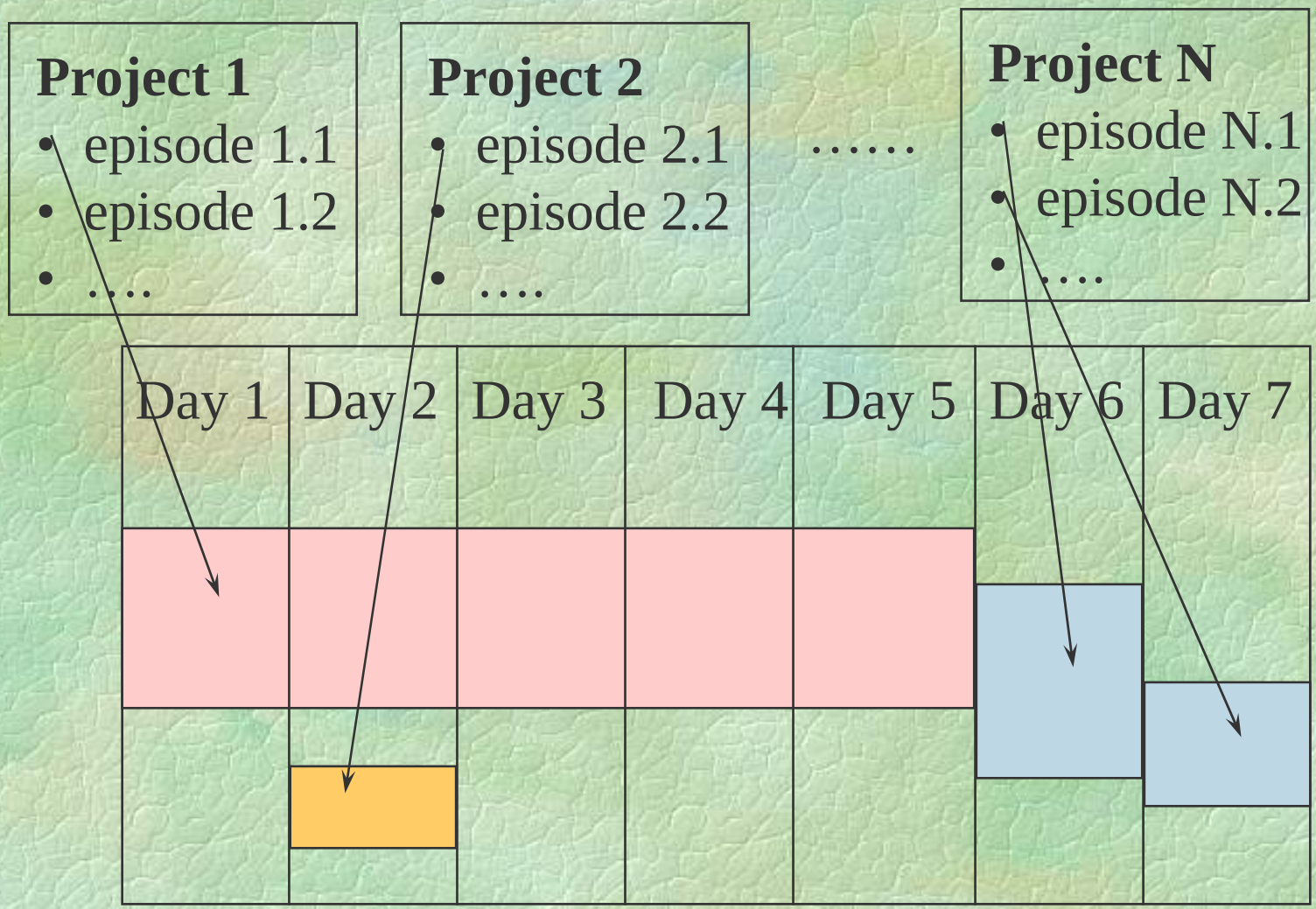
Activity Set

Activity	Possible Categorization	Example Modes
Entertainment/recreation	In-home, personal	Reading; radio; television; stereo; hobby
	In-home, joint	Radio; television; games; story-telling
	Out-of-home, personal	Movies; theatre; concerts
	Out-of-home, joint	Movies; theatre; concerts; "family outing"
Formal group activity	Team sport game/practice	At sport facility
	Attend religious service	At church, synagogue, etc.; radio; television
	Religious/community group meeting	Face-to-face; teleconference; internet; video conference
	Religious/community group activity	At activity location
Household maintenance	Household dwelling unit	
	Household vehicle(s)	
	Food preparation/clean-up	
Information gathering	By project	Newspapers; radio; television; friends; "window shopping"; internet
Personal business	Doctor	House-call; in-office; clinic; hospital emergency room
	Dentist	In-office
	Lawyer	In-office; telephone
	Bank/Financial	In-office; telephone
Personal maintenance	Sleeping	
	Eating (in-home; out-of-home)	Cook one-self; "frozen meals"; sit-down restaurants; take-out; "fast food"
	Personal grooming (in-home; out-of-home)	
	Exercise (in-home; out-of-home)	Jog in the park; go to the gym; personal trainer
Serve-dependent	Supervise dependent	Household member; non-household family member; "nanny"; "daycare"
	Chauffeur dependent	Household member; school bus; taxi
Shopping	Grocery	In-store; internet
	"Other consumables"	In-store; catalogue; internet
	"Durables"	In-store; catalogue; internet
Socialize with friends/relatives	In-home	Party; dinner/brunch/etc.; "family gathering"; "hanging out"
	At their home	Party; dinner/brunch/etc.; "family gathering"; "hanging out"
	Out-of-home	Restaurant; bar; "hanging out"
Work	Desk-based (working independently)	Usual place of work; at home
	Internal meetings (interaction with co-workers)	Face-to-face; telephone; internet
	External meetings, local clients, conferences, etc.	Face-to-face; teleconference; internet
	External meetings, out-of-town clients, etc.	Face-to-face; teleconference; internet; video conference

Scheduling Personal Activities/Travel

- Scheduling is an event-driven, sequential process
- Scheduling is **not** a “global” optimizing procedure
- Travel episodes are generated by and must be scheduled along with activity episodes
- While the overall scheduling process is a rule-based “computational process”, utility-based calculations seem a sensible approach for operationalizing trade-off calculations and benefit-money conversions
- Schedules are dynamically evolved and always provisional until actually executed

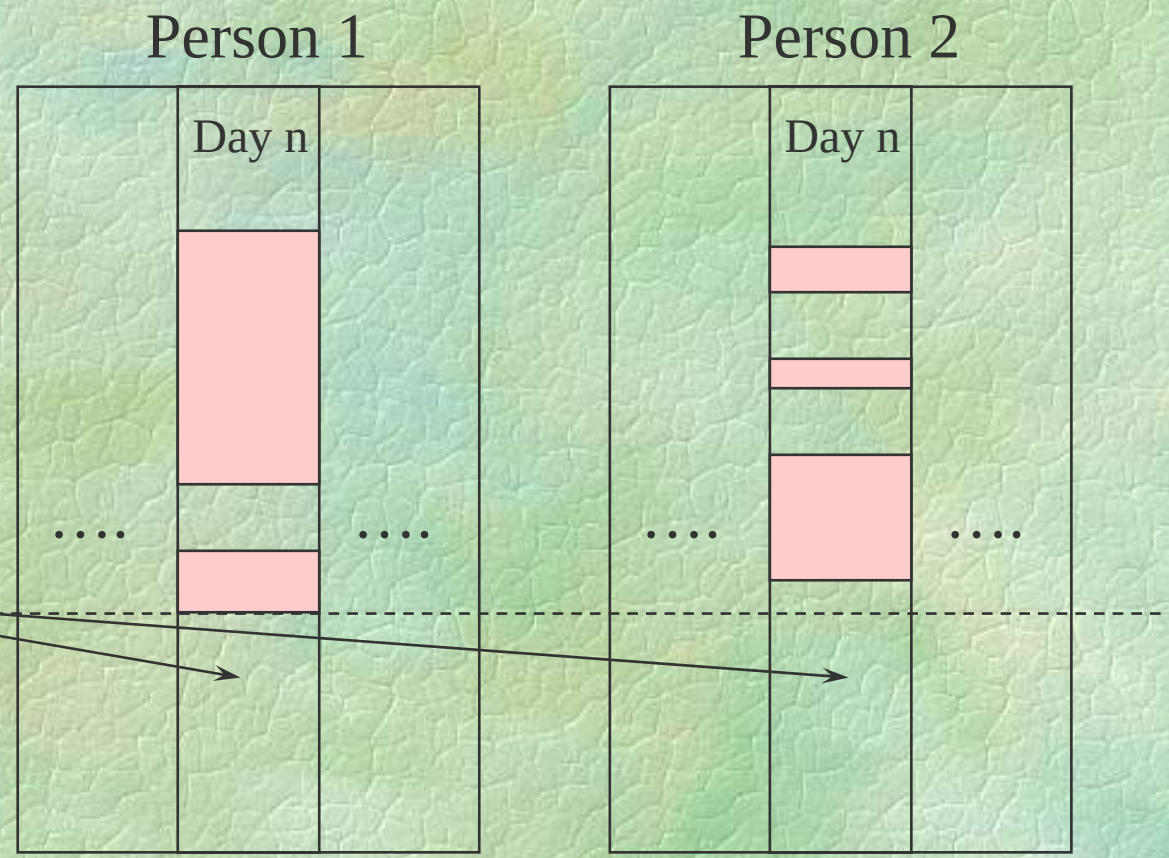
Scheduling Episodes



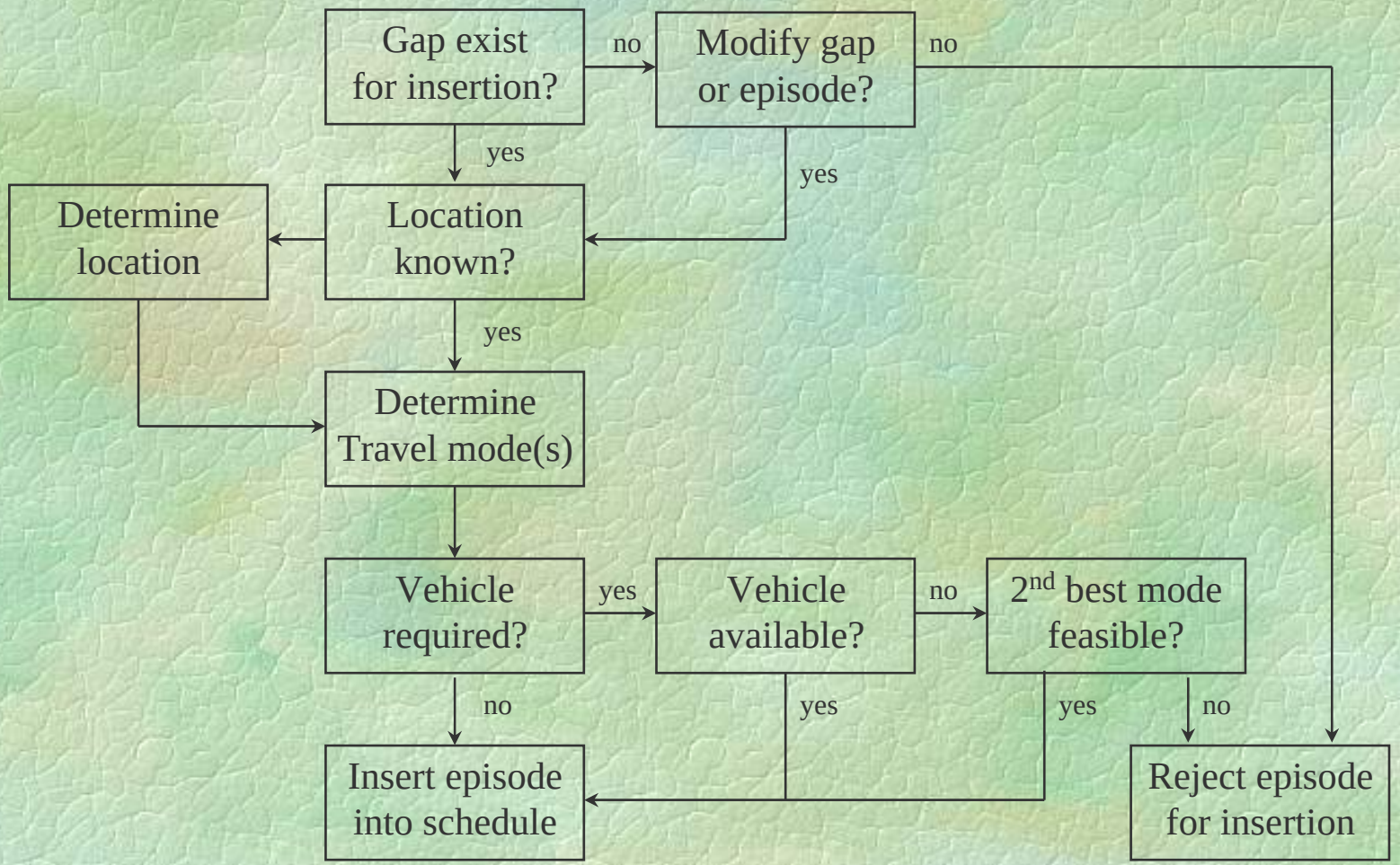
Joint Activities

Joint Shopping
Activity:
Duration: 2 hrs
Location: The Mall

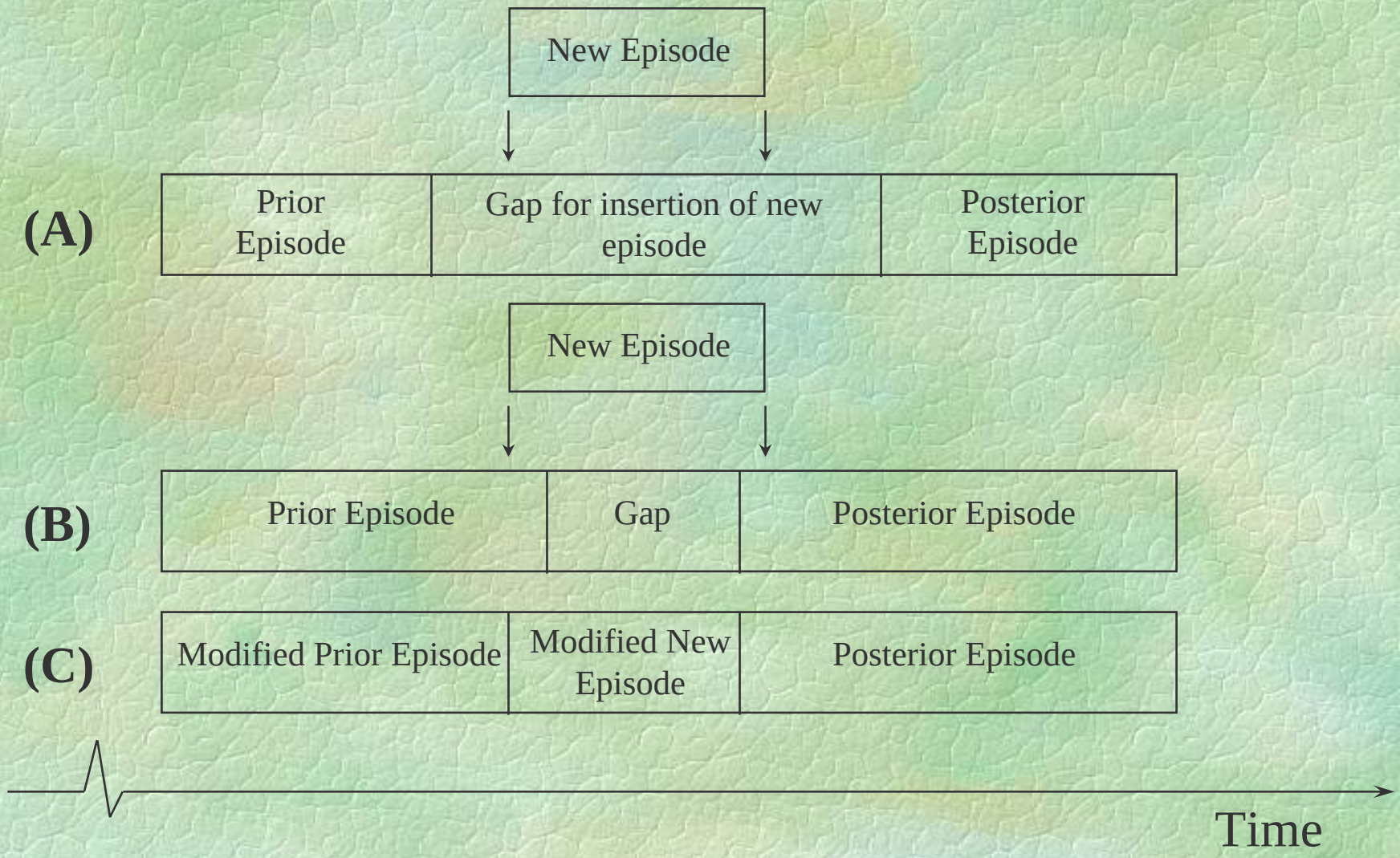
Search for feasible
joint time slot



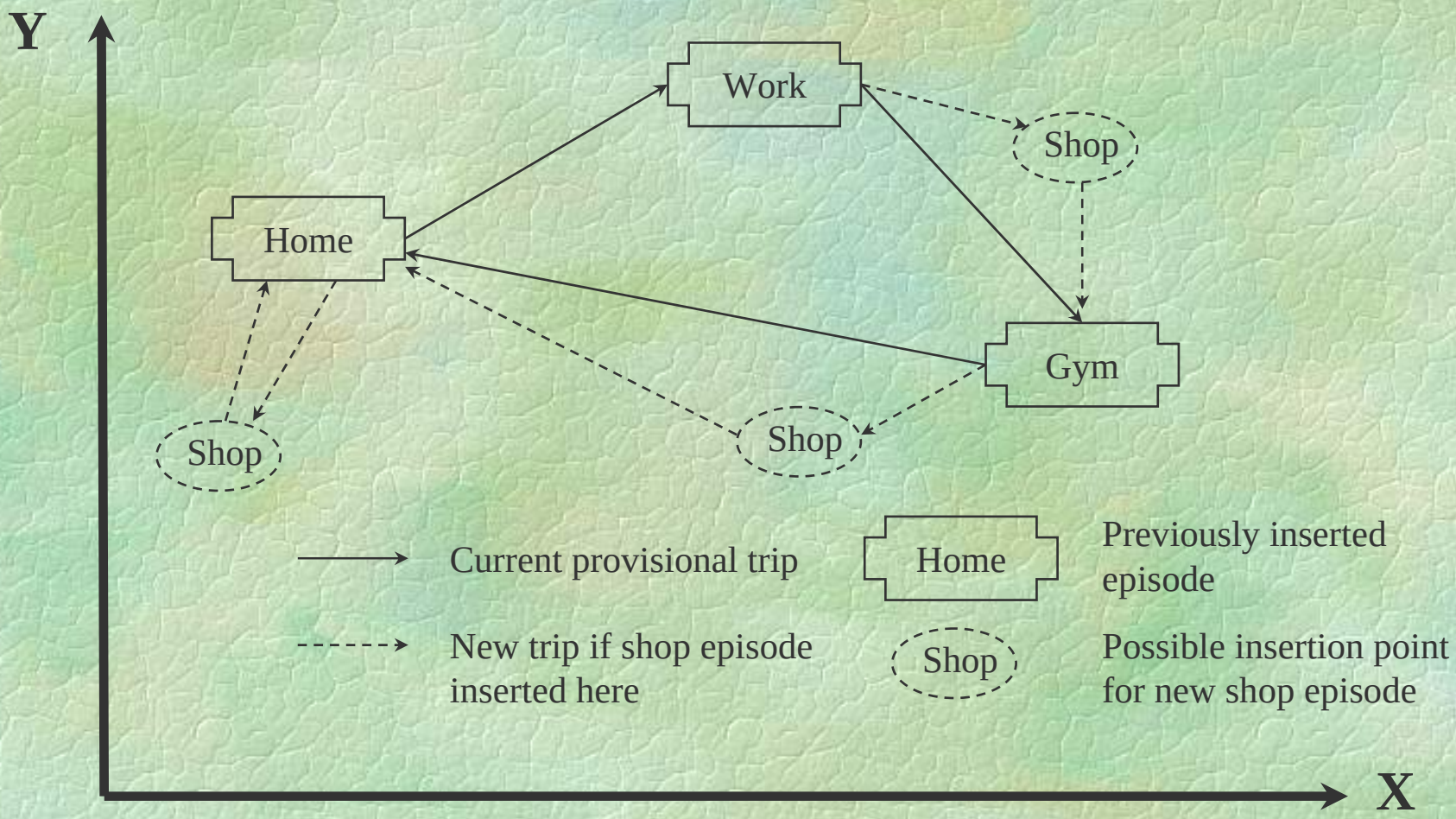
Inserting an Activity Episode into the Schedule



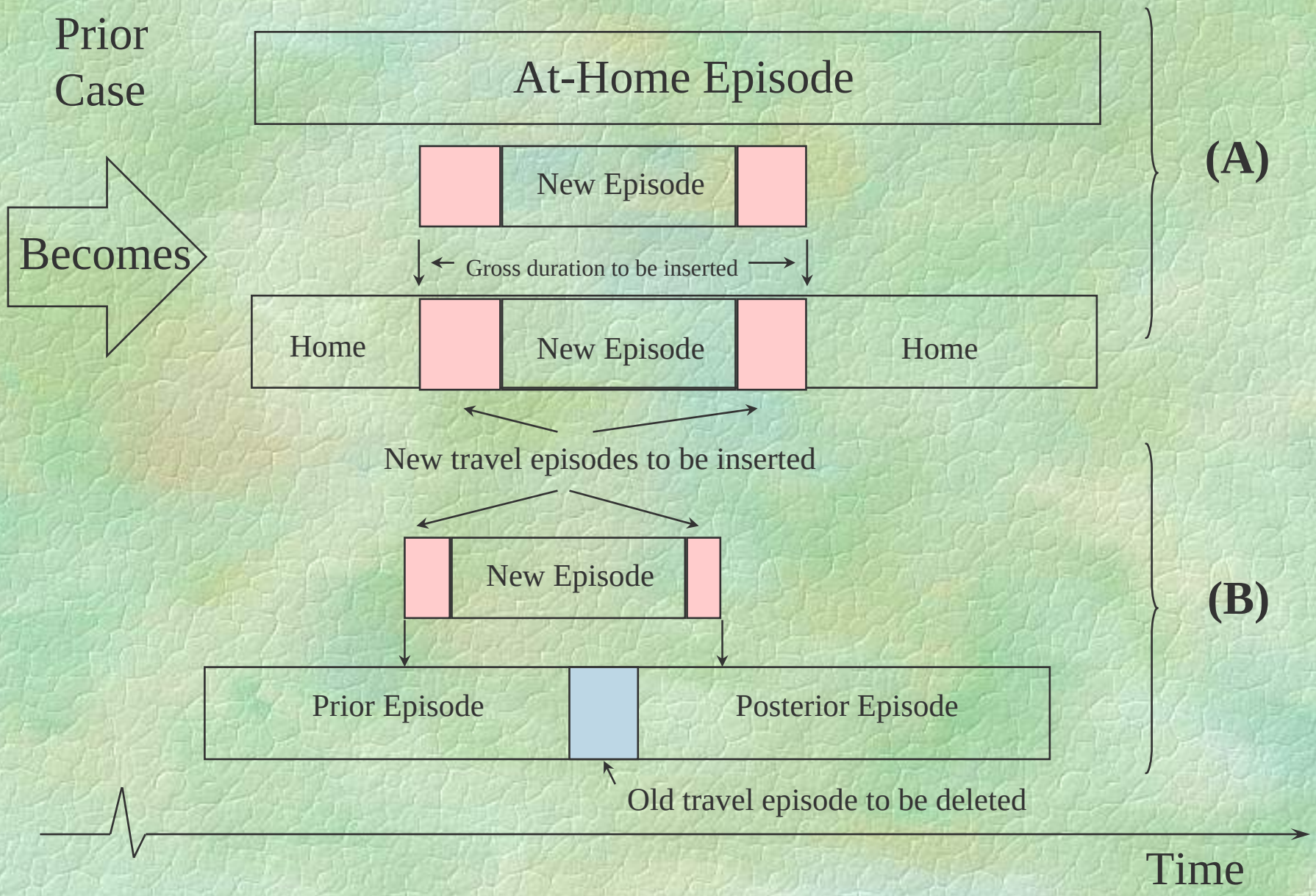
Finding/Creating a Gap for Episode Insertion



Gap Selection and Episode Location Choice

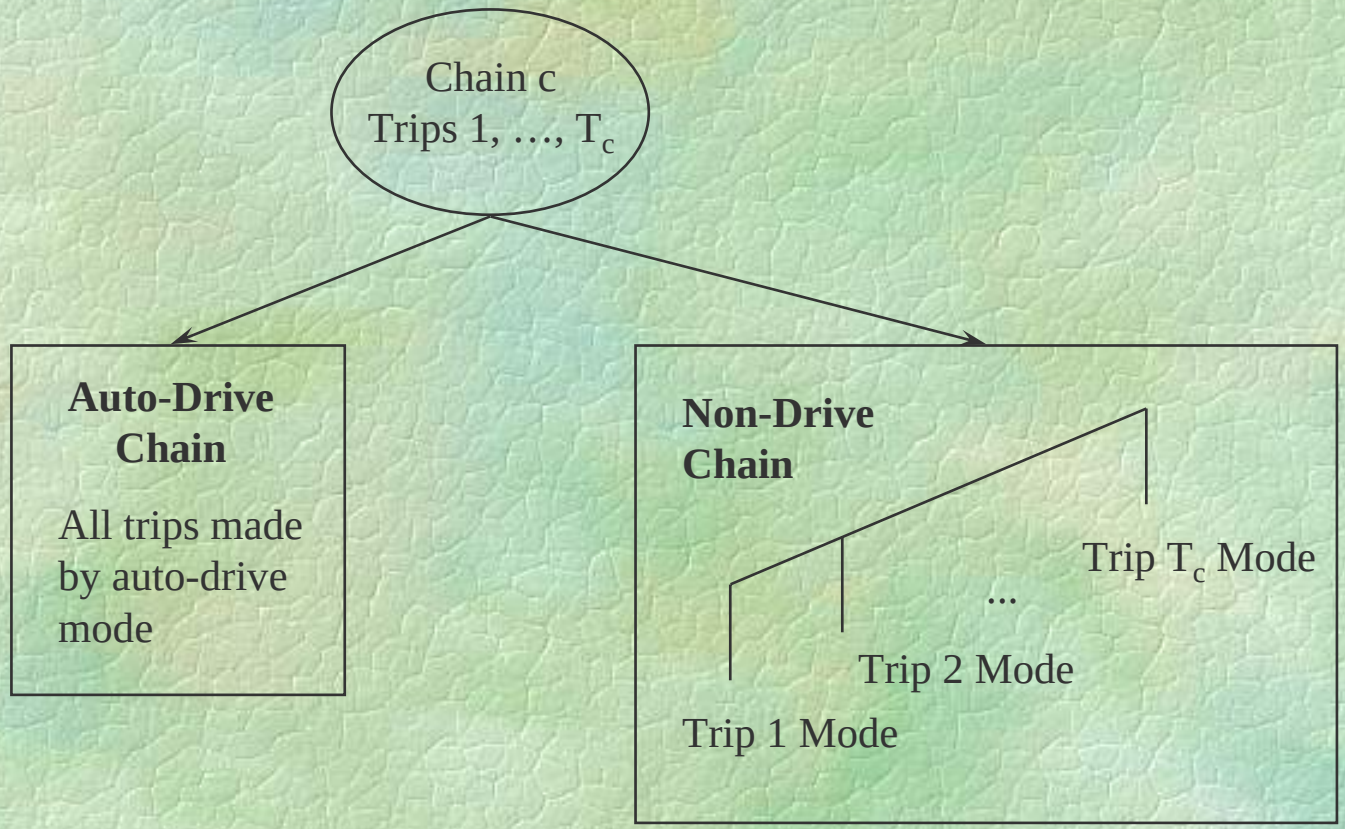


Scheduling Travel Episodes

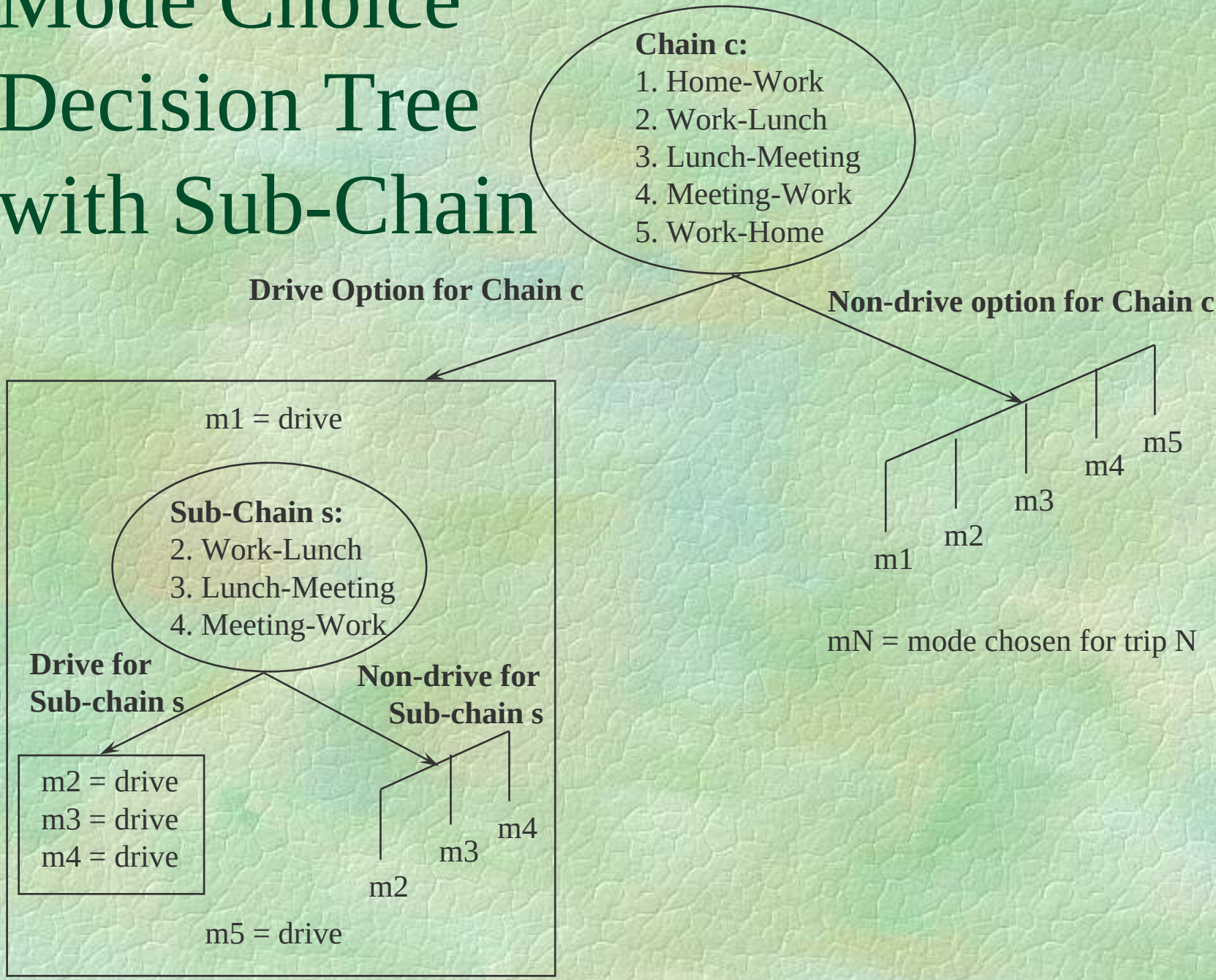


Trip-Chain-Based Mode Choice

Once an activity pattern has been scheduled, it translates into chains of trips that begin & end at home. To properly account for car usage, need to model mode Choice at the chain level, rather than the individual trip.



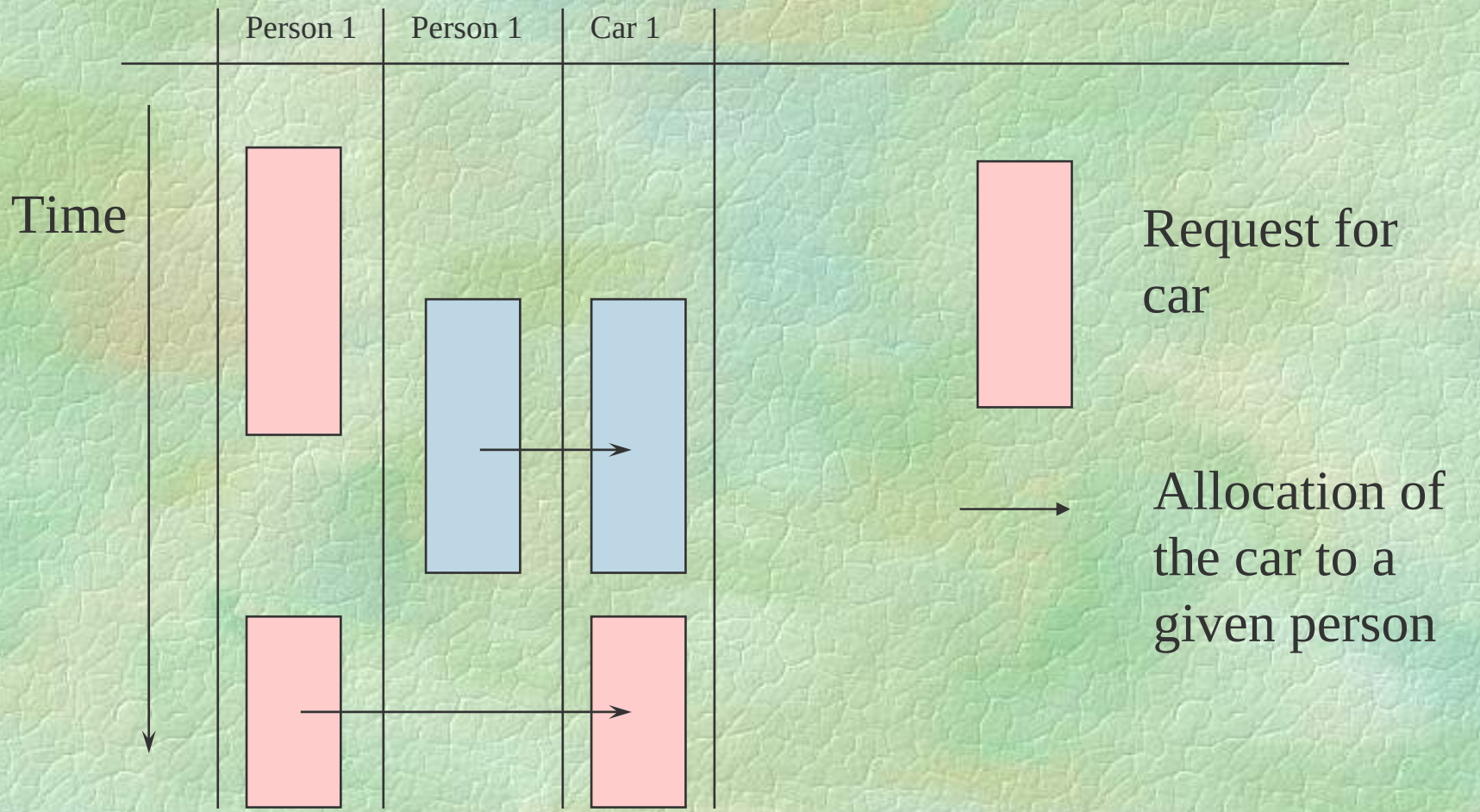
Mode Choice Decision Tree with Sub-Chain



Vehicle Allocation

- If at any time the number of drivers wishing to use the household's vehicles exceeds the number of vehicles available, then the household must determine which drivers are allocated the vehicles and which must use their "second best" travel mode (or otherwise re-schedule their activities/travel)
- Opportunities for (within-household) ride-sharing are also explored at this point

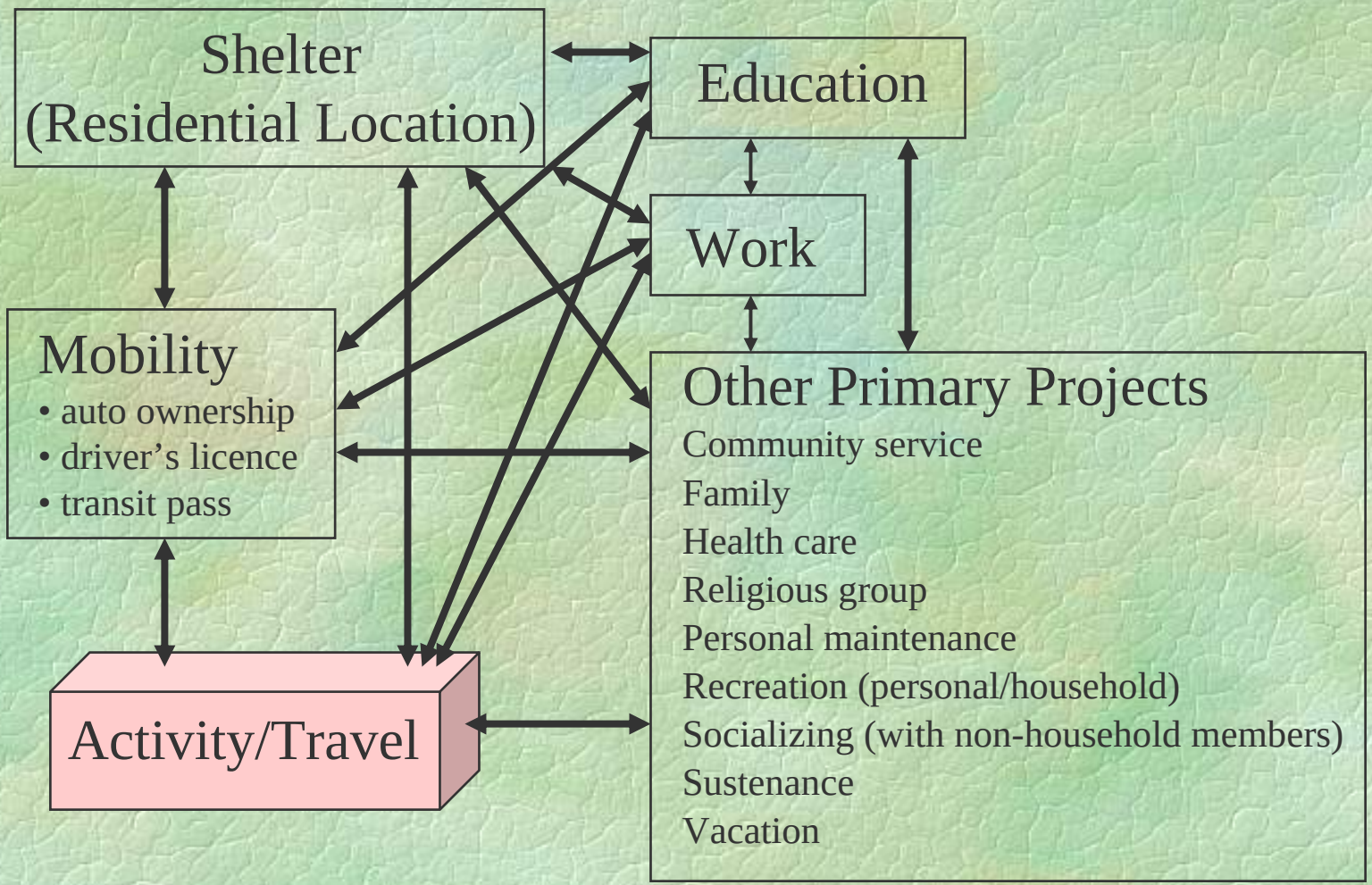
Example, Vehicle Allocation One-Car Household



Activity/Travel Model Current Status & Future Work

- Prototype, simplified 24-hour activity/travel model for the Greater Toronto Area operational
- Continuing to elaborate the 24-hour model
- Looking to expand the model to full week once first-wave Toronto/Quebec City panel data available

Extensions Beyond Activity/Travel

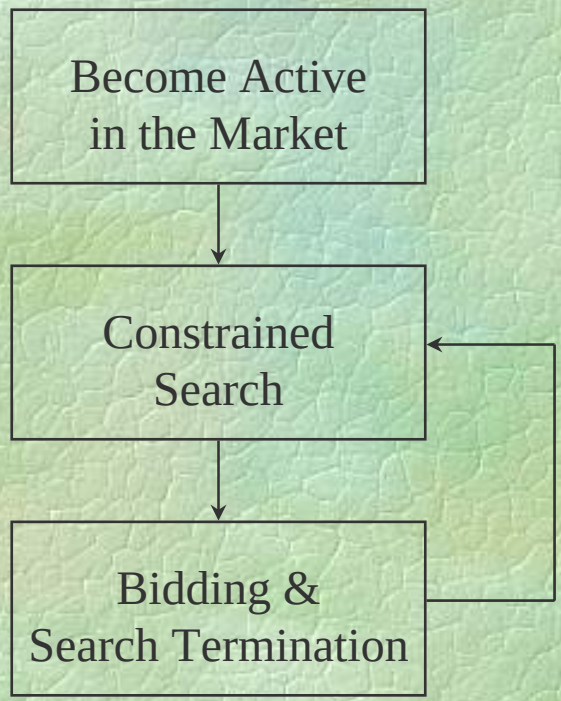


Modeling Markets

Many markets are of interest within ILUTE:

- residential housing market
- commercial real estate market
- land market
- labor market
- markets for goods & services
- personal use vehicle market
- travel markets (persons and goods)

“Generic Model” of Market-Based Decision-Making



Market Representation

Prior work in (Walrasian) market theory provides a rich paradigm for representing interactions between various suppliers and consumers

- supply-demand
- endogenous prices
- preferences/utility

Objective is to extend classic market theory to a microsimulation framework

Limitations of Conventional Market Theory

- money transactions
- aspatial
- homogeneity and single price
- equilibrium and simultaneity
- ambiguity between “long run” and “short run”

Importance of Heterogeneity

- No “average market price” since a “market” is diverse:
  - goods & services
  - actors/agents involved in exchanges
  - location (transport costs, accessibility)
- Can divide market by space and commodity type, but the number of categories approaches/exceeds the number of transactions
- Computationally more efficient and behaviorally more realistic to consider each transaction
- Direct representation of supply and demand
  - individual agents act as a supplier or consumer in each transaction

Parcel

- Bundle of goods, services (or non-market interactions) that can be exchanged between two actors
  - single transaction, not single item
- Described by attributes
  - integer and real numbers
  - category and direction (e.g. buy or sell)
  - quantity or size
  - other attributes in collected data
  - at least one attribute not associated with real data, representing unmeasured diversity

Offer

- A proposal to exchange (buy or sell) a particular Parcel at a particular location
- Parcel + location + price + offerer
- e.g. product descriptions in catalogues, help wanted ads, products on retail shelves, social invitations
- Must always be a supply of outstanding offers
  - simulation moves through time and through agents, with agents making offers and/or accepting offers

Economic Units

- Agents that make or accept offers
- Households and business establishments
  - fixed location and share parcel internally
  - not individuals and firms (not yet)

Expected parcels (potential offers)

- Each Economic Unit has a list of expected parcels
- Are what the Economic Unit expects to achieve (in a time period) and at what price, in an ideal location
  - sales targets, goods inventory, employment positions
  - groceries, services, jobs
- Mechanism for creating expected parcels is probably critical to realistic models
  - can be based on production and consumption functions of Walrasian models
  - can be based on travel surveys

Considered Offers

- Result of a search process for each Expected Parcel
- Small (~20) set of offers of same category but opposite direction
- More realistic and computationally feasible than considering every offer

Search processes

- imitation: agents examine actions of agents that are similar to them in various ways
- spatial search: nearby opportunities are identified, or a search tour is conducted
- repeated behaviour: agents continue patterns of behaviour that are successful (leading to stable trading relationships)
- refinement: once one alternative is identified, small changes are also considered

Outstanding offers

- Changes in the number, price, quality or size of outstanding offers is an indication of changing market conditions
  - e.g. unemployment rates, help wanted indices, advertised prices

Updating of expected parcels based on experience

- When made offers are not accepted (quickly), Expected Parcels made more pessimistic
  - otherwise, Expected Parcels made more optimistic
- Size also adjusted, or Expected Parcel may be duplicated or eliminated
  - to represent supply and demand curves given a fixed number of Economic Units
- Represents changes in lifestyle, expectations, business strategies

Future Work

- Trying to operationalize a housing market model based on these concepts (as well as within the “projects” framework)
- Experimenting with critical components:
  - “expected offers”
  - search processes
  - bid exchanges
  - temporal components
- Continuing elaboration of the conceptual model