A Decade of Dynamics of Residential Location, Car Ownership, Activity, Travel and Land Use in the Seattle Metropolitan Region

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Overview

- Briefly on Triggers
- Data Used
- Multilevel Cluster Models

- Persons within households

- Households over time

- Attitudes vs Longitudinal Travel Behavior
- Next Steps?

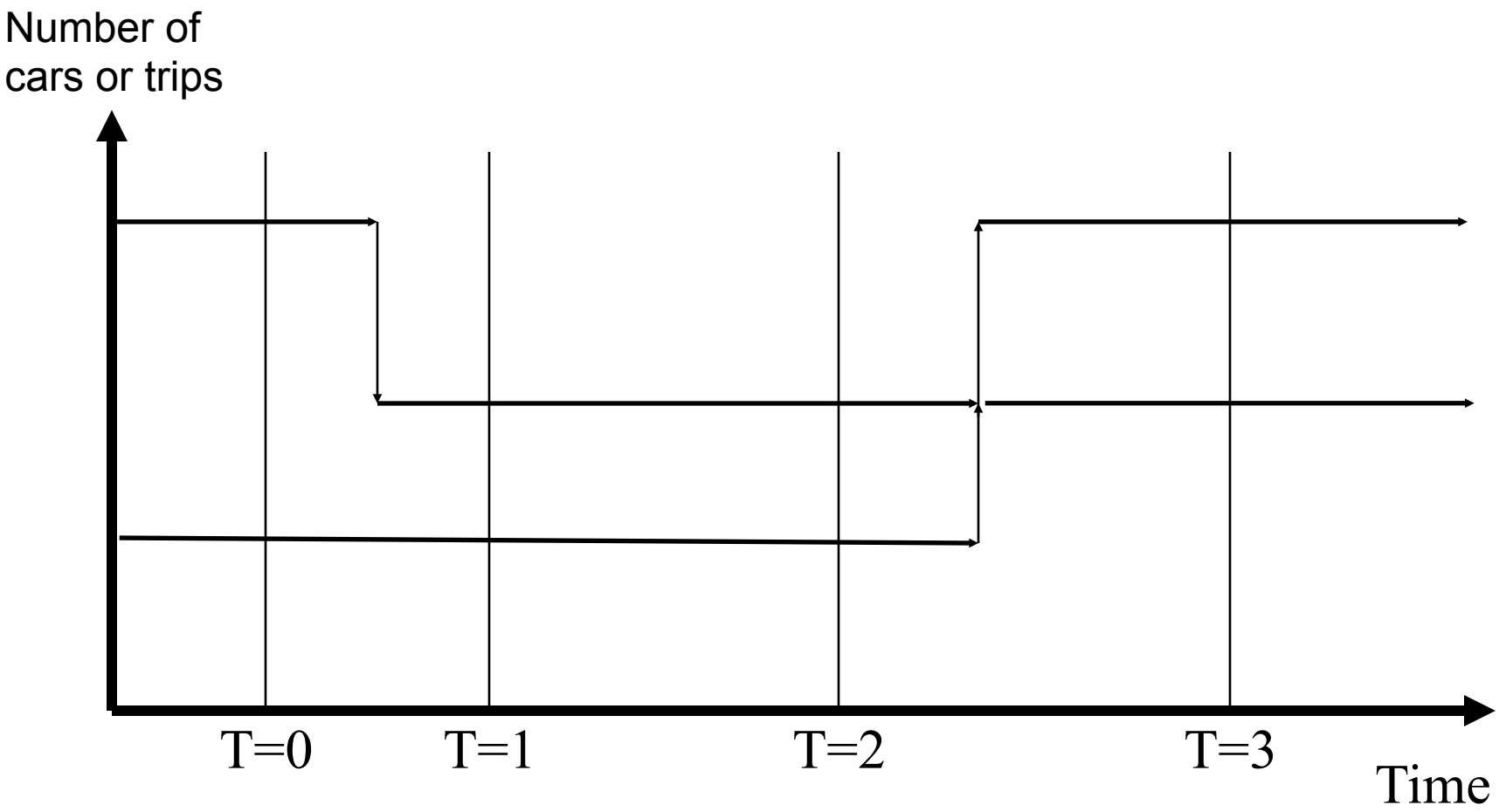
General Motivation of this Research

- We change land use to change behavior (e.g., higher density and diversity of opportunities)
- We change car ownership rules to change behavior (e.g., incentives for hybrid electric cars)
- We extrapolate from cross sectional differences changes over time (e.g., rich and poor) – we know it is wrong!
- We NEED a longitudinal tool to tell us what happens when "things" change inside and outside the household
- We need models that can be used in large scale dynamic activity simulators

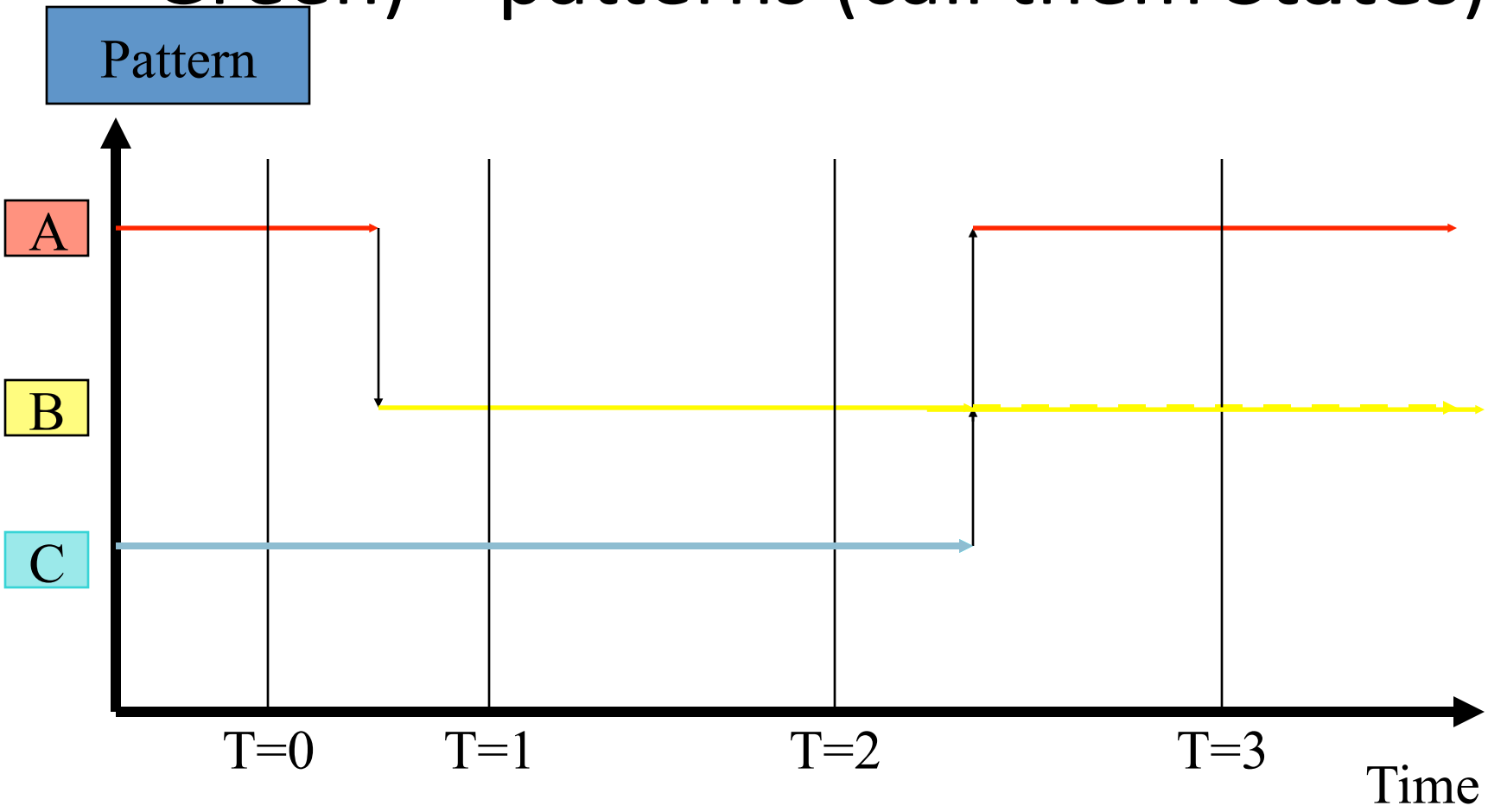
The tool used here

MIXED MARKOV LATENT CLASS & PAST FINDINGS

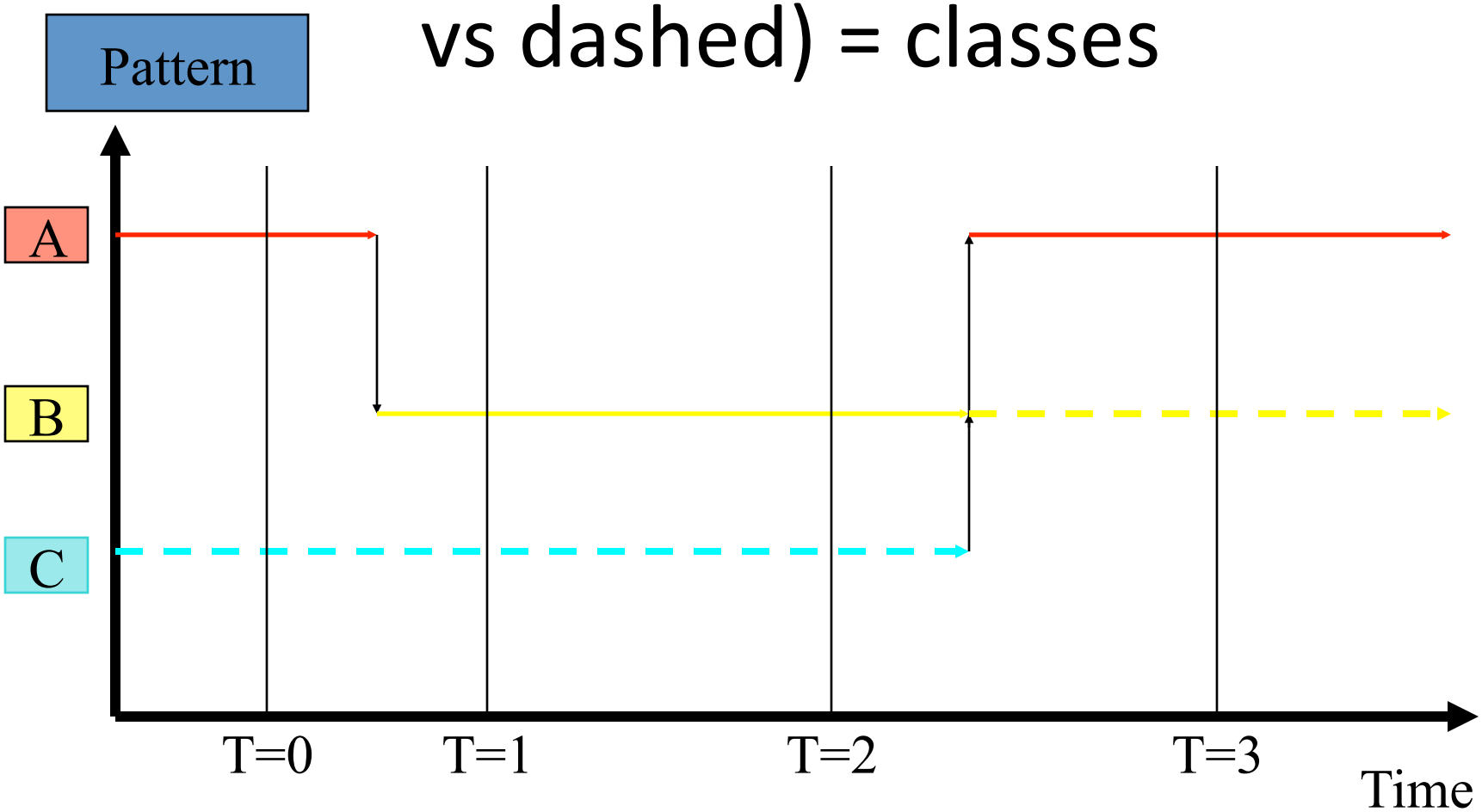
We Observe 2 households



Derive Clusters of Behavior (Red-Yellow-Green) = patterns (call them **States**)



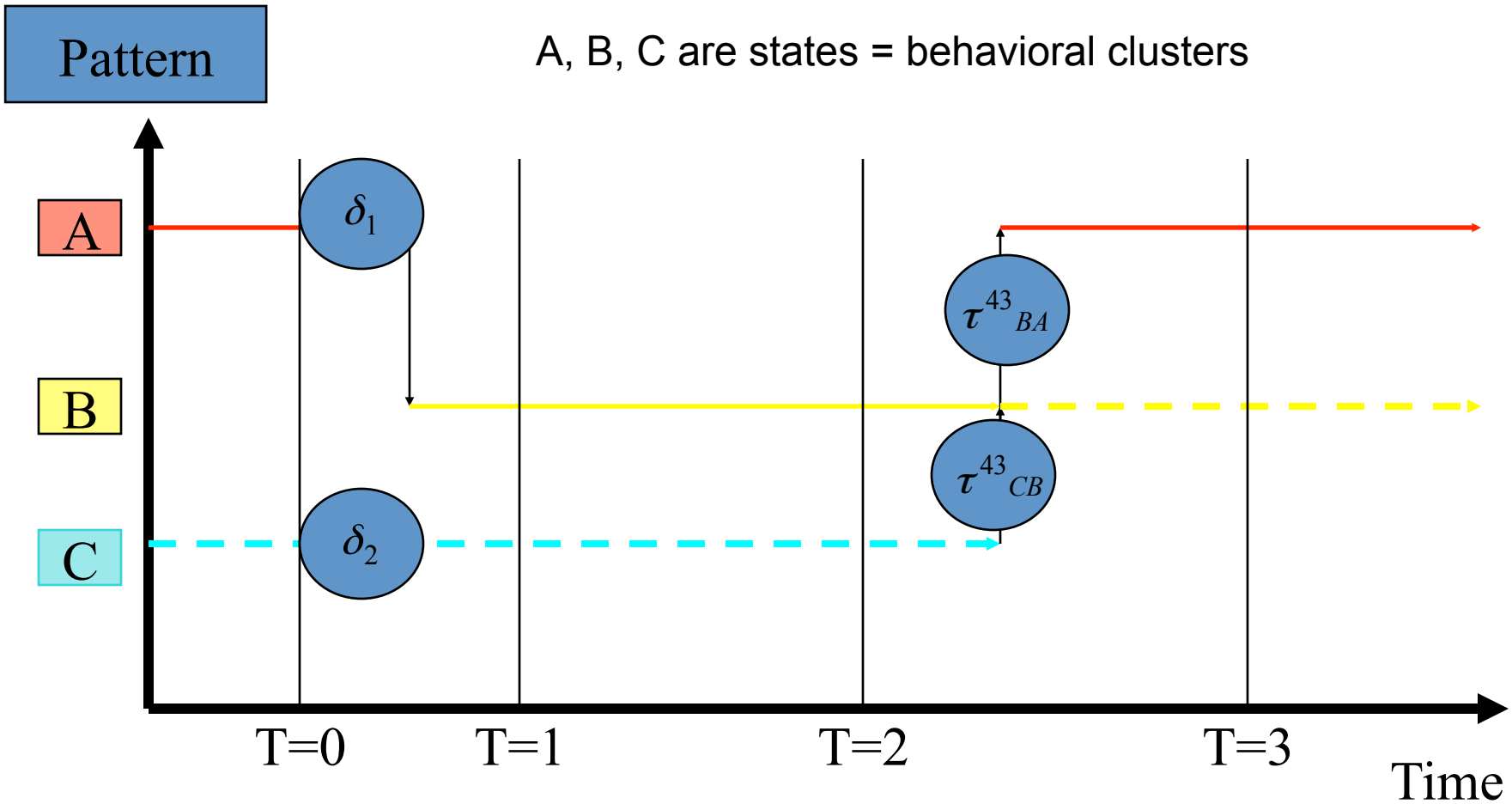
Identify Groups of Households of Different Sequences of Patterns (solid vs dashed) = classes



Solid Line = Household 1

Dashed Line = Household 2

Parameters of Dynamics = switching among patterns by different classes & probabilities of switching



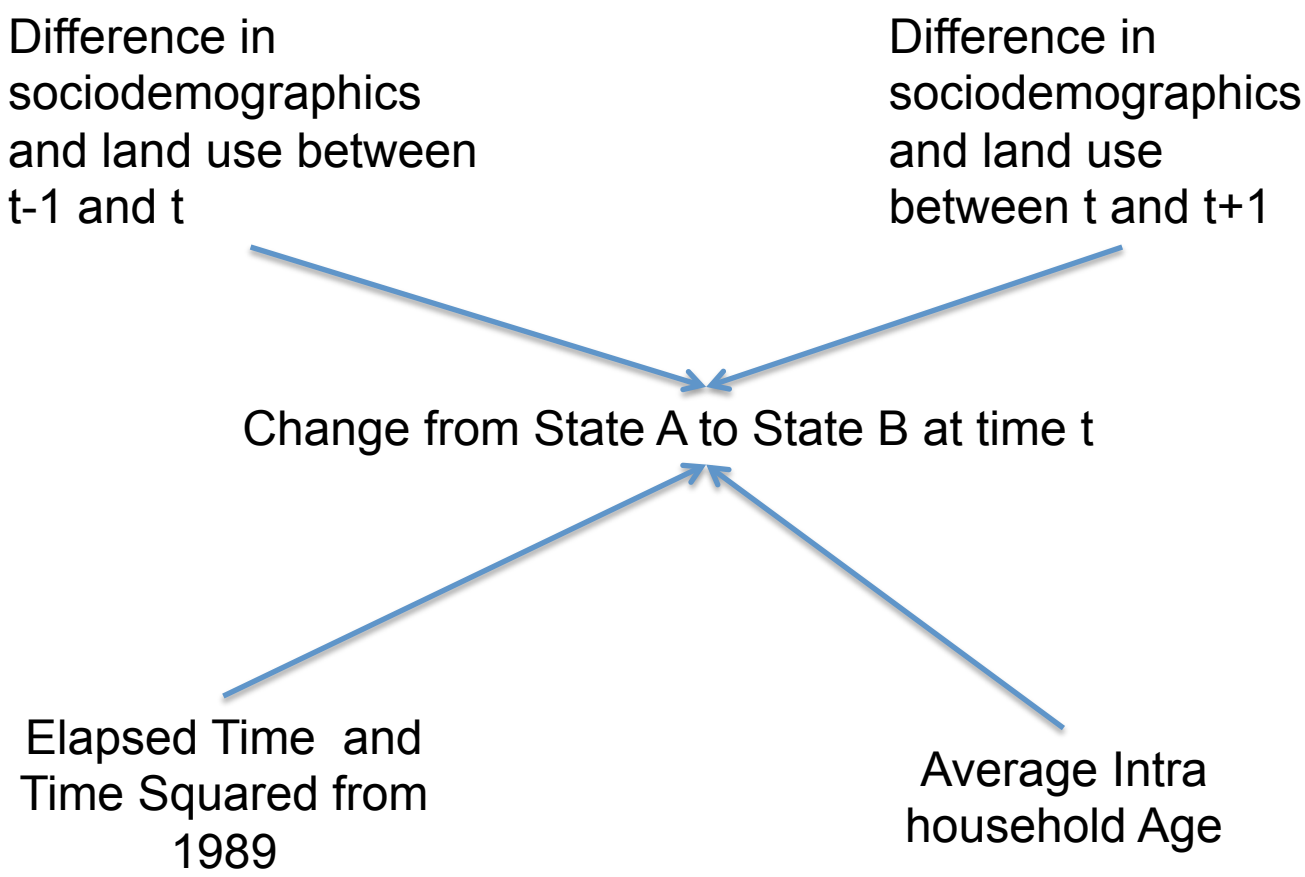
Solid Line = Person 1

Dashed Line = Person 2

MMLC

- includes a multi-category latent variable (w) representing household heterogeneity and its categories called **classes**;
- uses many “dependent” or response variables (y) forming another set of categorical latent variables (x) at 10 time points and its categories are called **states**;
- **transitions** from one state at one time to another state at another time point are estimated using a probability model and they are functions of **triggers**;
- uses and tests the effect of **covariates (Zs)** of many different specifications of the models; and
- is a model-based clustering approach providing probabilistic membership of observations in clusters of **classes,** clusters of **states,** and probabilities of **transitions from state to state over time**.

Transitions



Significant Triggers

(variables that are significant in the transition models)

- Workers (mixed causality)
- Children 6-17 (increase activity)
- Mean Age (aging decreases activity)
- Adults (increase activity)
- Increase in young children no impact

Significant Triggers

(variables that are significant in the transition models)

- Density (Number of Business Establishments and Employees)
  - *Significant but mixed impacts*
  - *We get mixed indications from the 0.5 miles and 2.0-2.5 mile annulus*
- Diversity (Shannon index)
  - *Land use div. increase within 0.5 more likely to stay at same behavior*
  - *Diversity decreases travel*

GOOD BUT NOT ENOUGH!

Specific Questions of the Presentation (bring attitudes in longitudinal models)

- Do people with different attitudes live together?
- Do attitudes early in a person's life persist in its effect in later years?
- Can we identify distinct attitudinal (x-section) and behavioral (over time) groups and study systematic differences among them?

DATA USED

Puget Sound region

- 3.7 million residents
- 4 counties
- 82 cities and towns
- 26 regional growth centers

Source: www.psrc.org

Data

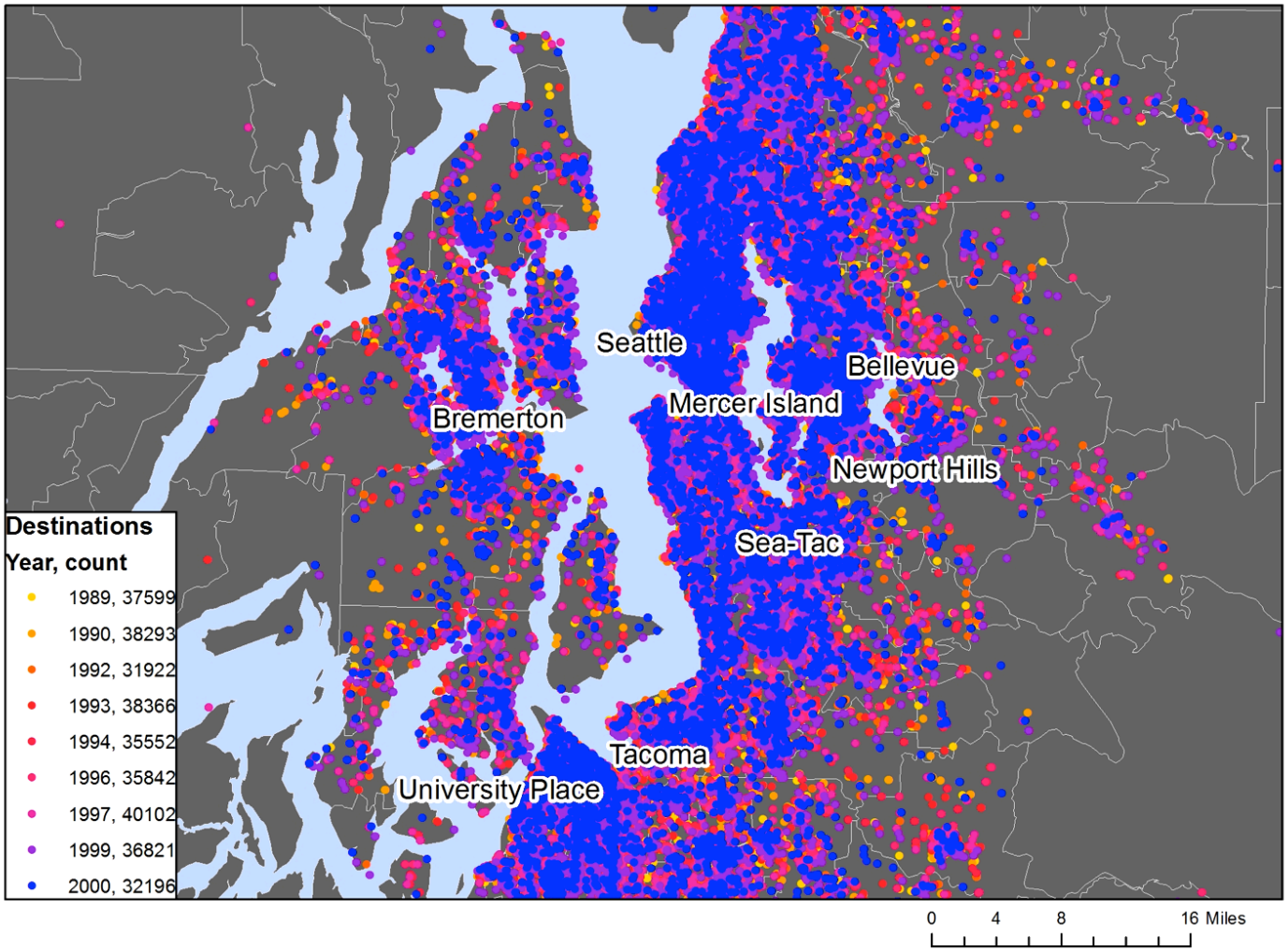
- Puget Sound Transportation Panel, 1989 – 2002
  - Indicators of travel behavior over time
- National Establishments Time Series, 1990 – 2002
  - Indicators of land use over time

Puget Sound Transportation Panel (PSTP)

- The first general-purpose trans. household panel survey in USA
- Administered on the same households and persons within each household repeatedly over time.
- Started in 1989 with irregular intervals – 10 waves to 2002
- Collected
  - Household demographics,
  - Persons' social & economic information,
  - Travel behaviour through two-day travel diary
  - Attitudes about different aspects of trans. system
- Added *Technology Questions* in 1997, 1999, 2000, 2002

Puget Sound Transportation Panel

Destinations span the entire region



Two-part Analysis

- Attitudes about carpooling, transit, and private car use
- 23 attitudinal questions
- 2,472 persons in 1,362 households
- Test homophily (birds of a feather hypothesis)
- Use multilevel cluster analysis to classify people and households jointly

- Behavior over time 1989 - 2002
- 230 households that participated in all ten waves of PSTP
- Use the information about attitudes to explain trajectories of behavior
- Use changes in land use to explain transitions from one type of behavior to another
- Use changes in demographics to explain transitions of behavior from one type to another

ATTITUDE GROUPS (CLUSTERS)

Multi-level Latent Class Clustering (persons in households)

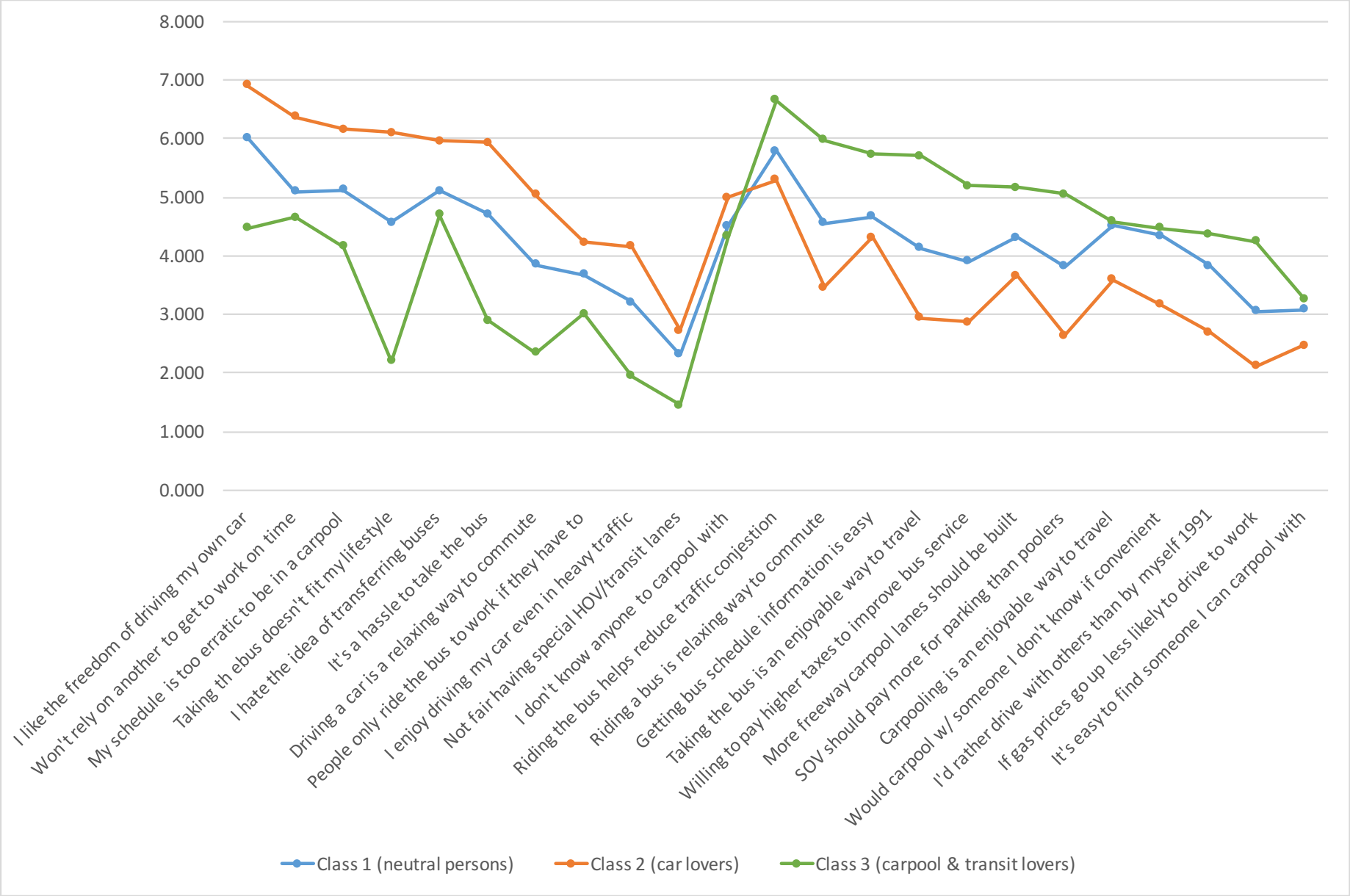
$$f(Y_k) = \sum_{h=1}^{H} P(w_k = h) \prod_{j=1}^{n_k} f\left(Y_{kj} \middle| w_k = h\right)$$

$$f\left(Y_{kj} | w_k = h\right) = \sum_{l=1}^{L} P(x_{kj} = l | w_k = h) \prod_{i=1}^{I} f\left(y_{kji} \middle| x_{kj} = l, w_k = h\right)$$

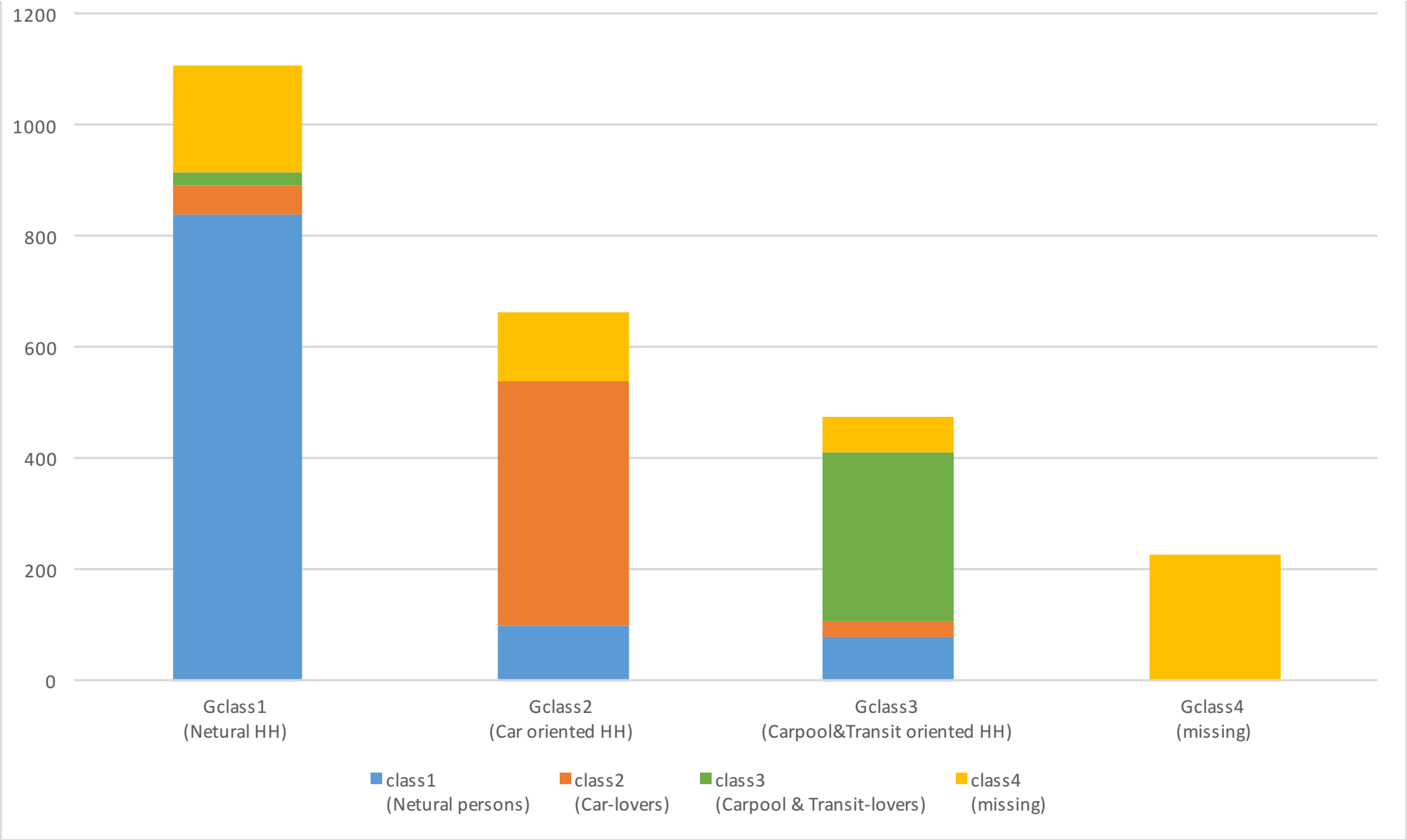
index l (l=1,..., L) is used for the person groups and the index h (h=1,..., H) for the household groups. $f(y_{kji} | x_{kj}=l, w_k=h)$ is the conditional density for variable i of individual j in household k given his/her membership in person-level class l and household level class h.

$P(x_{kj}=l|w_k=h)$ is the probability that individual j of household k belongs to latent class l given that his/her household belongs to latent class h. $P(w_k=h)$ is the probability that household k belongs to latent class h.

1: Very strongly disagree, 2: Strongly disagree, 3: Somewhat disagree, 4: Neutral, 5: Somewhat agree, 6: Strongly agree, 7: Very strongly agree



Person Attitude Groups



Household Attitude Groups and Intra-household Distribution

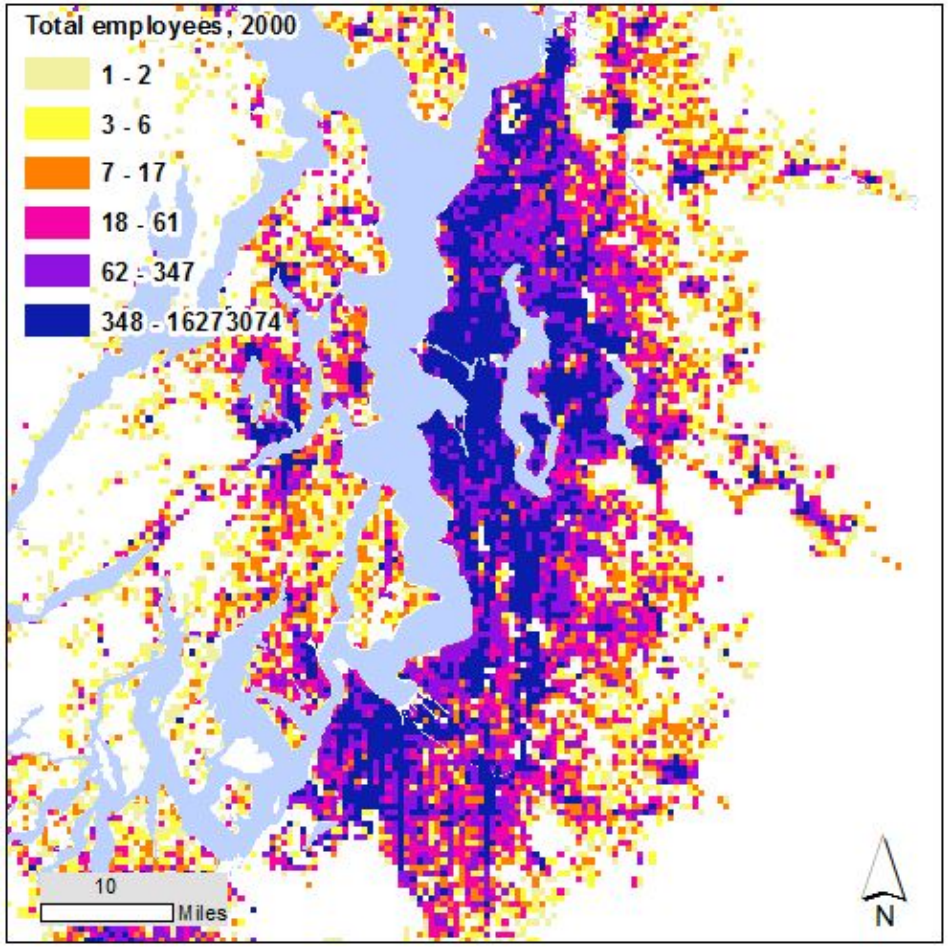
Findings in Part 1 of Analysis

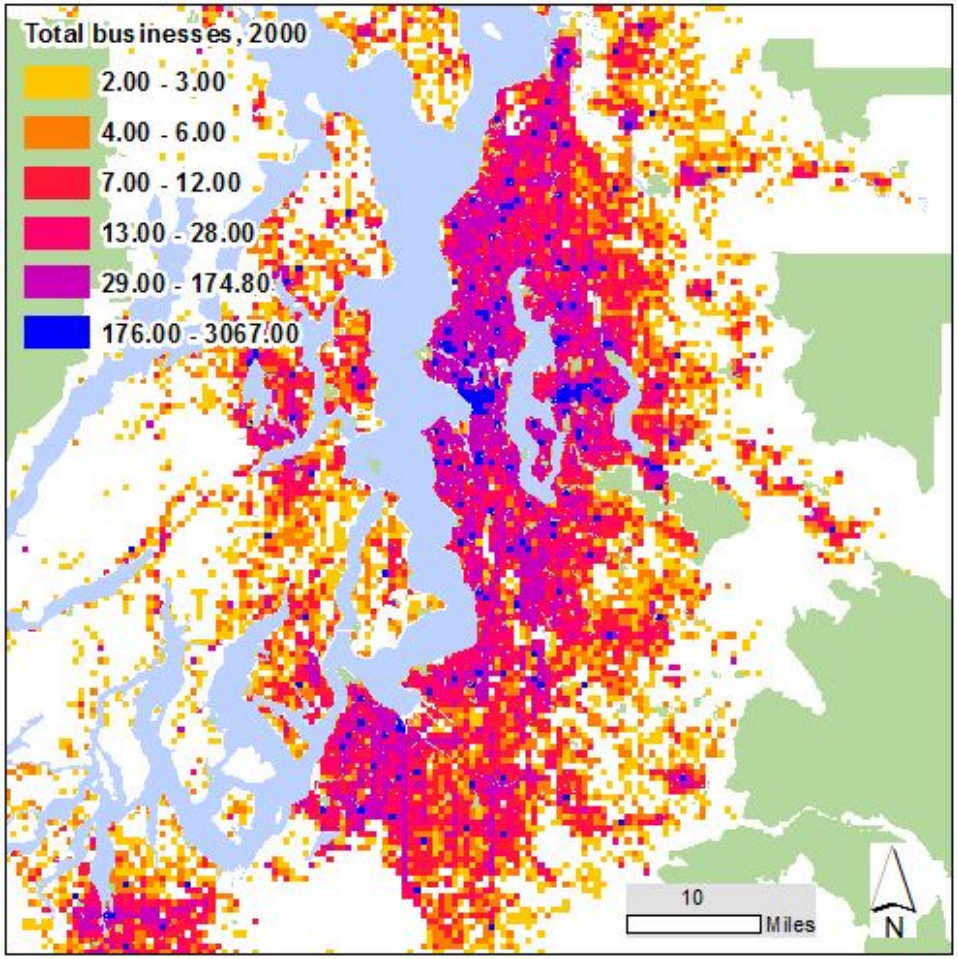
We find mix:

- Car lovers tend to live with car lovers or with neutrals
- Carpool/transit lovers tend to live with carpool/transit lovers, neutrals, but also car lovers
- Lack of strong homophily (reject the bird of a feather hypothesis)

TRAVEL BEHAVIOR

National Establishments Time Series

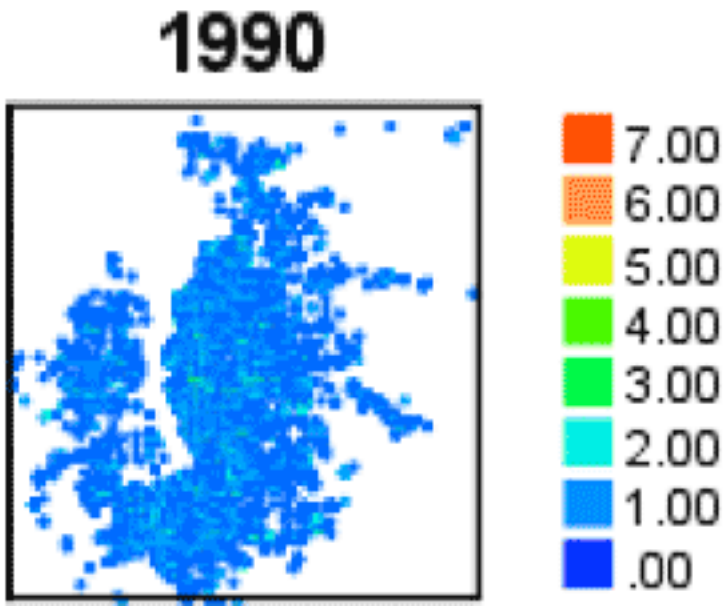


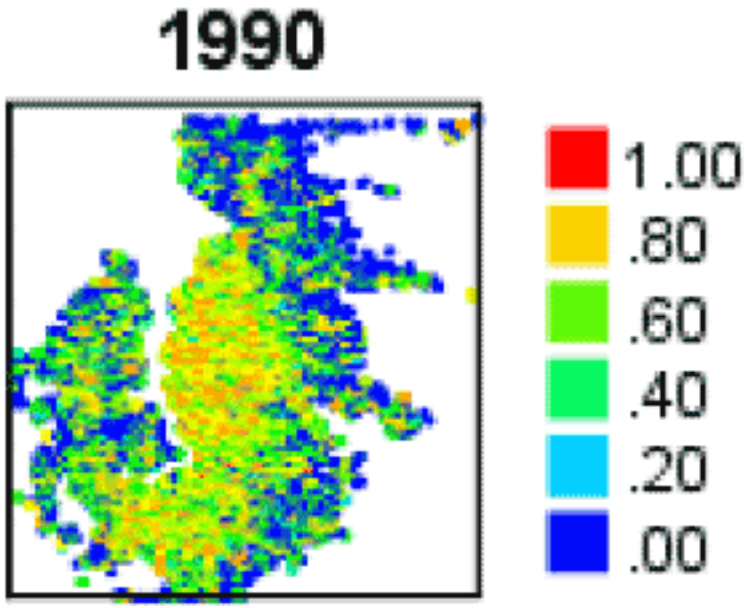


- National Establishments Time Series (1990- 2000+2002)
  - Geocoded establishments, aggregated to 750m^2 grid cell
  - Industry type, no. of employees, total sales

Density and Diversity

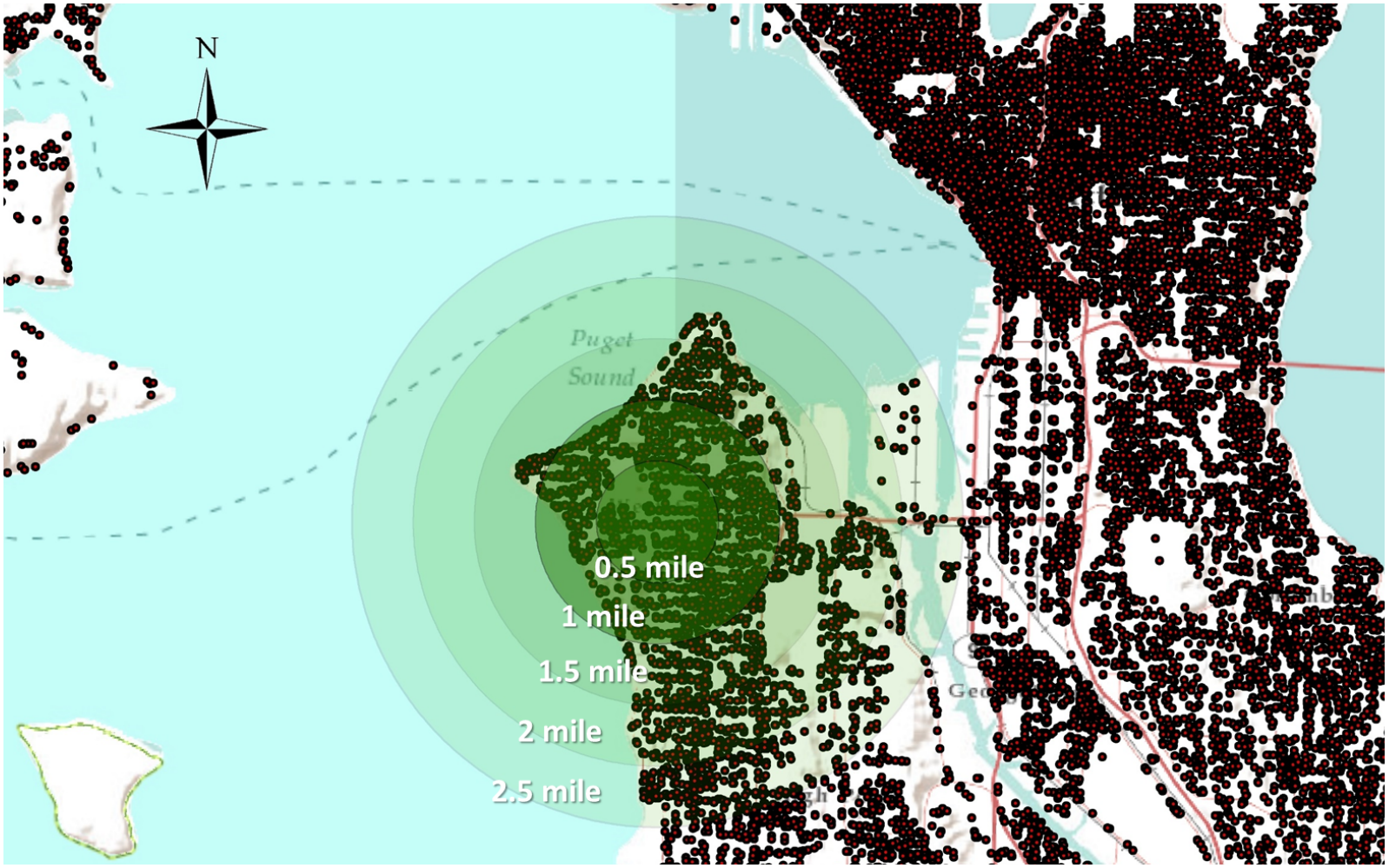
- Density (# of employees)
- Diversity (employees per industry type)



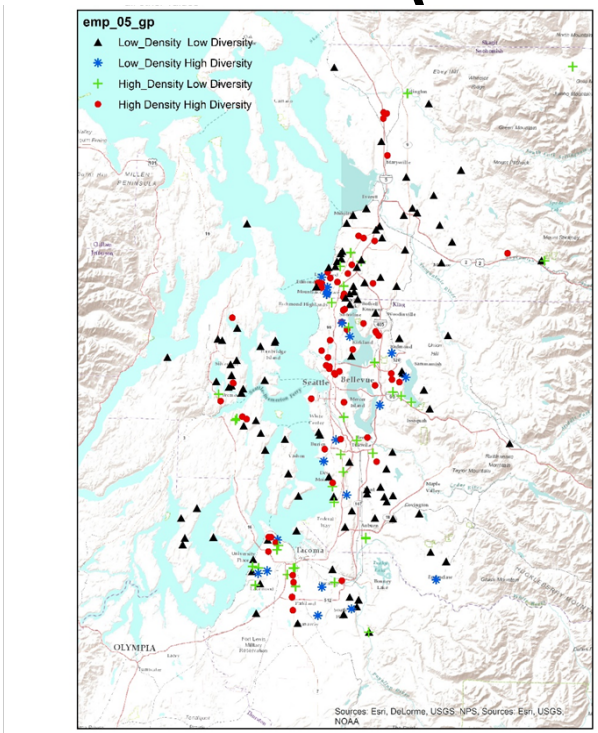


$$H' = -\sum_{i=1}^{R} p_i \, ln p_i$$

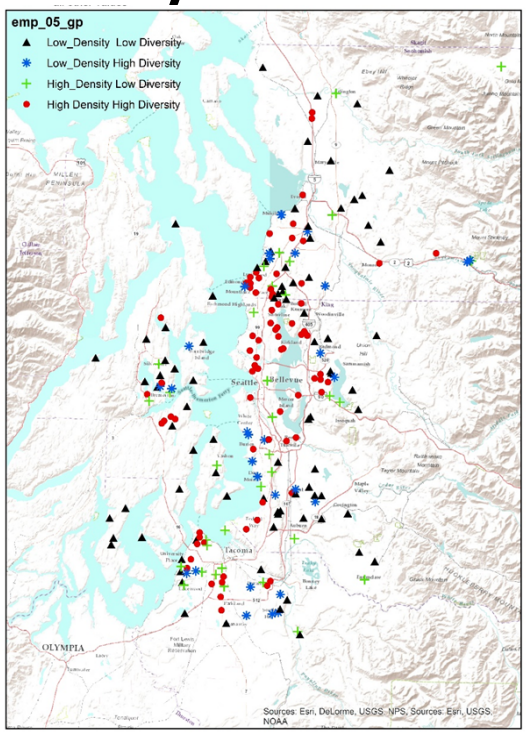
Annuli Surrounding Residences



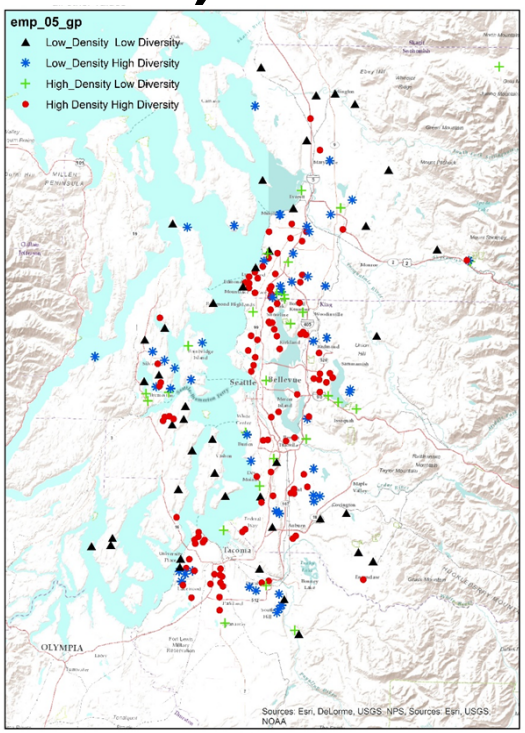
Land use Characteristics Surrounding Home (<0.5 mile) in 1990, 1996, 2002



Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA



Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA



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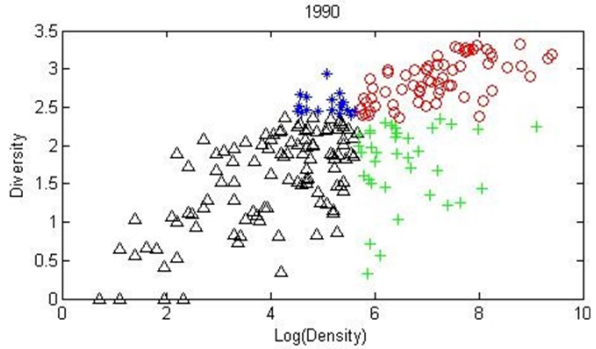
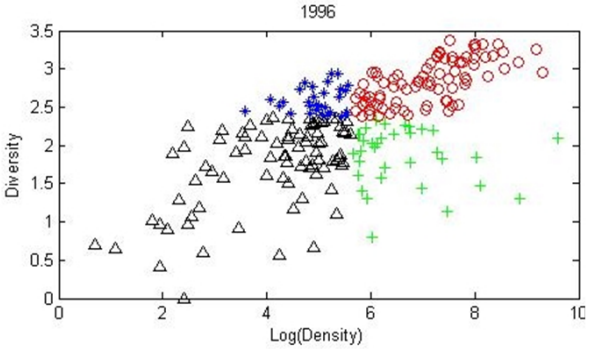
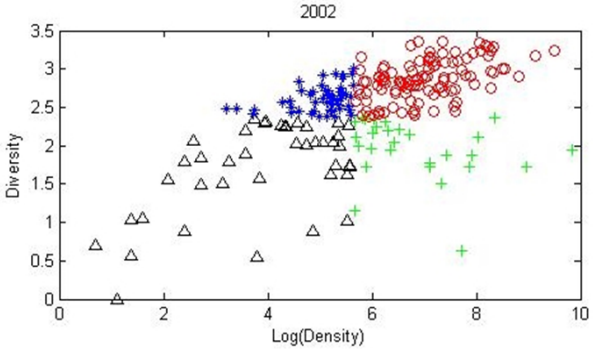
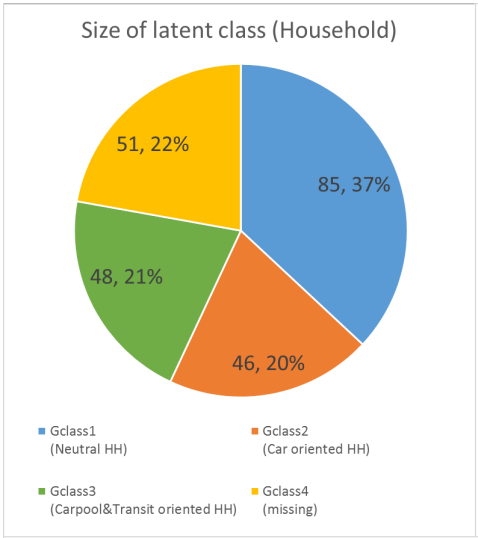


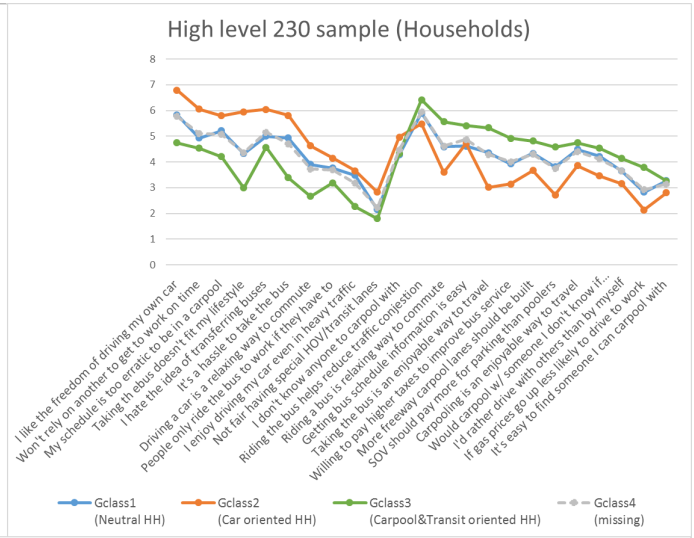


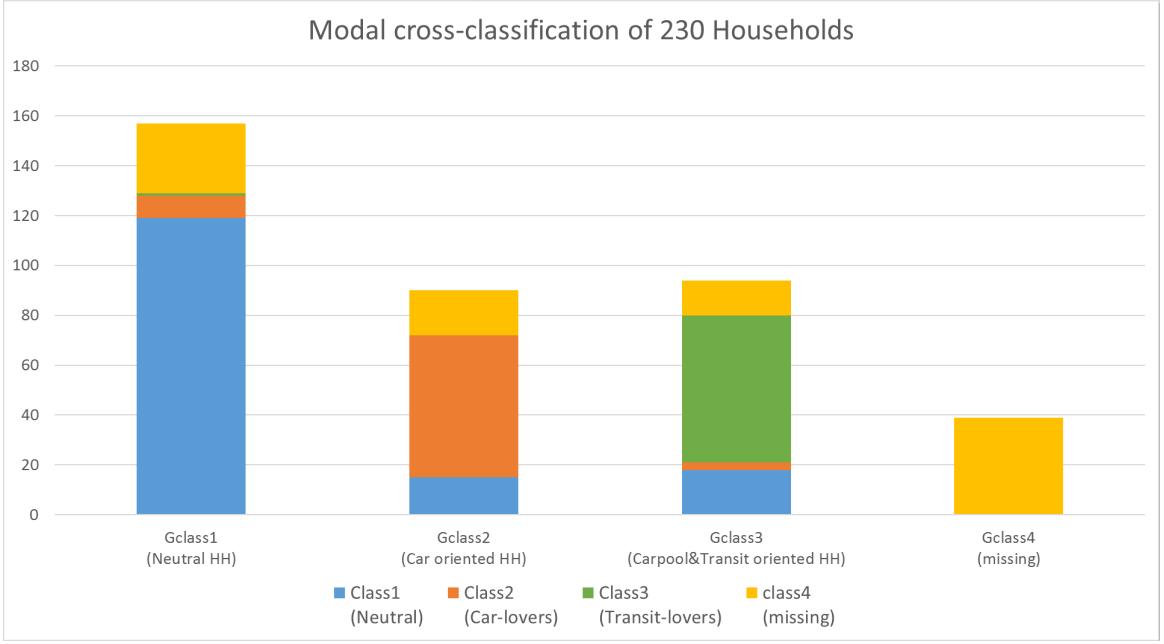


Use the attitude classification from part 1 for both persons and households just to verify if we can see differences in behavior

(my note: skip to 37 if running out of time)

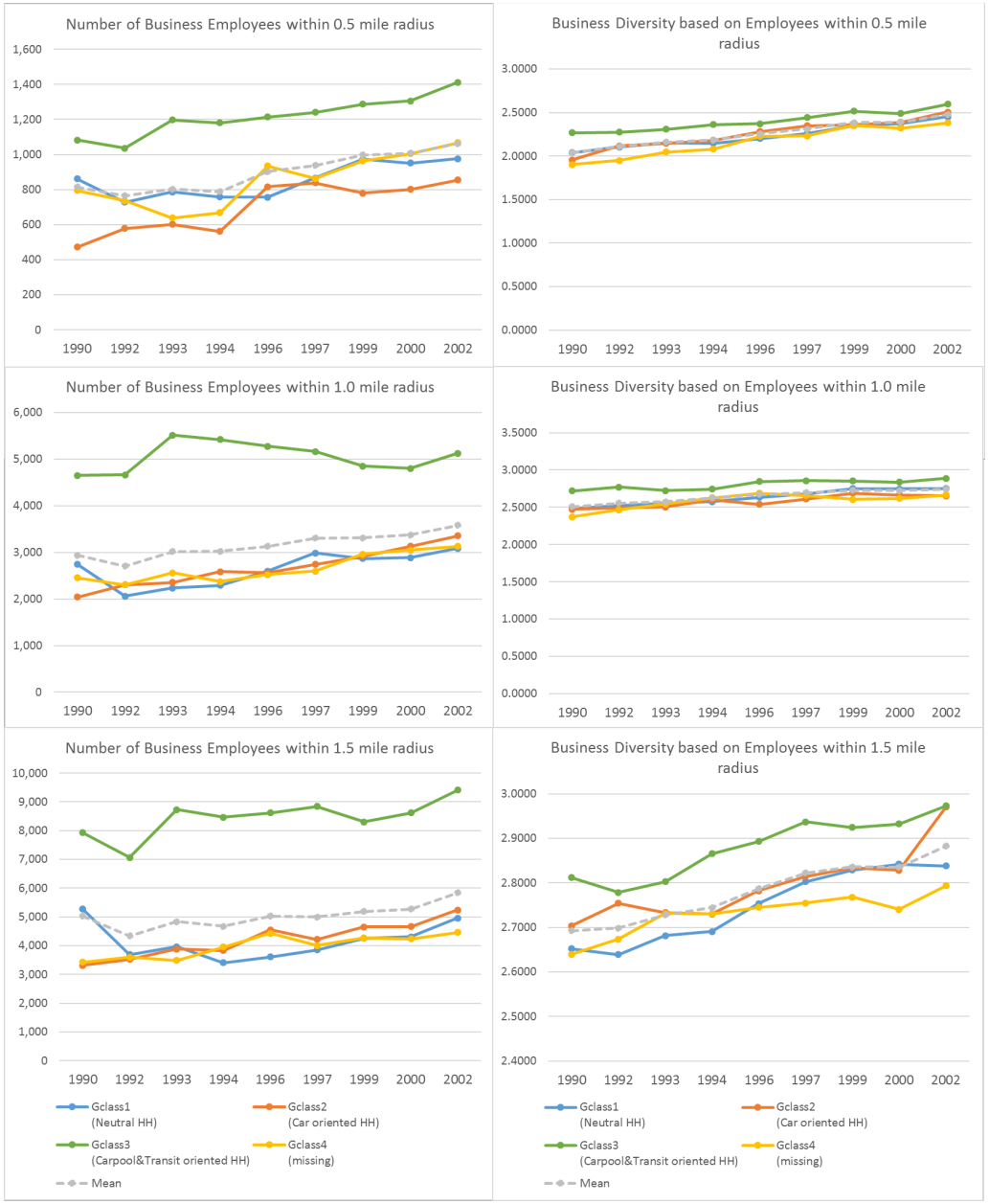


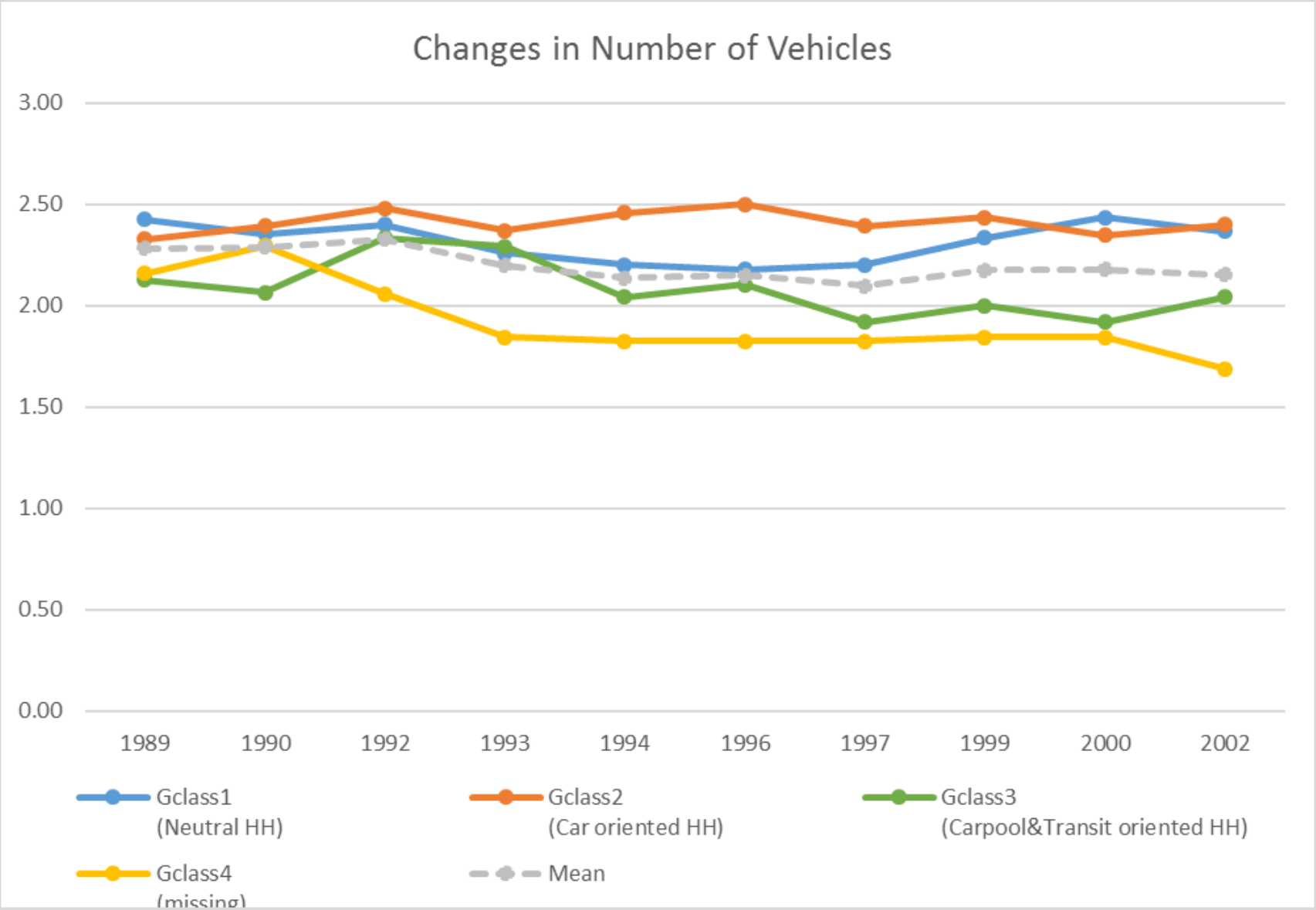


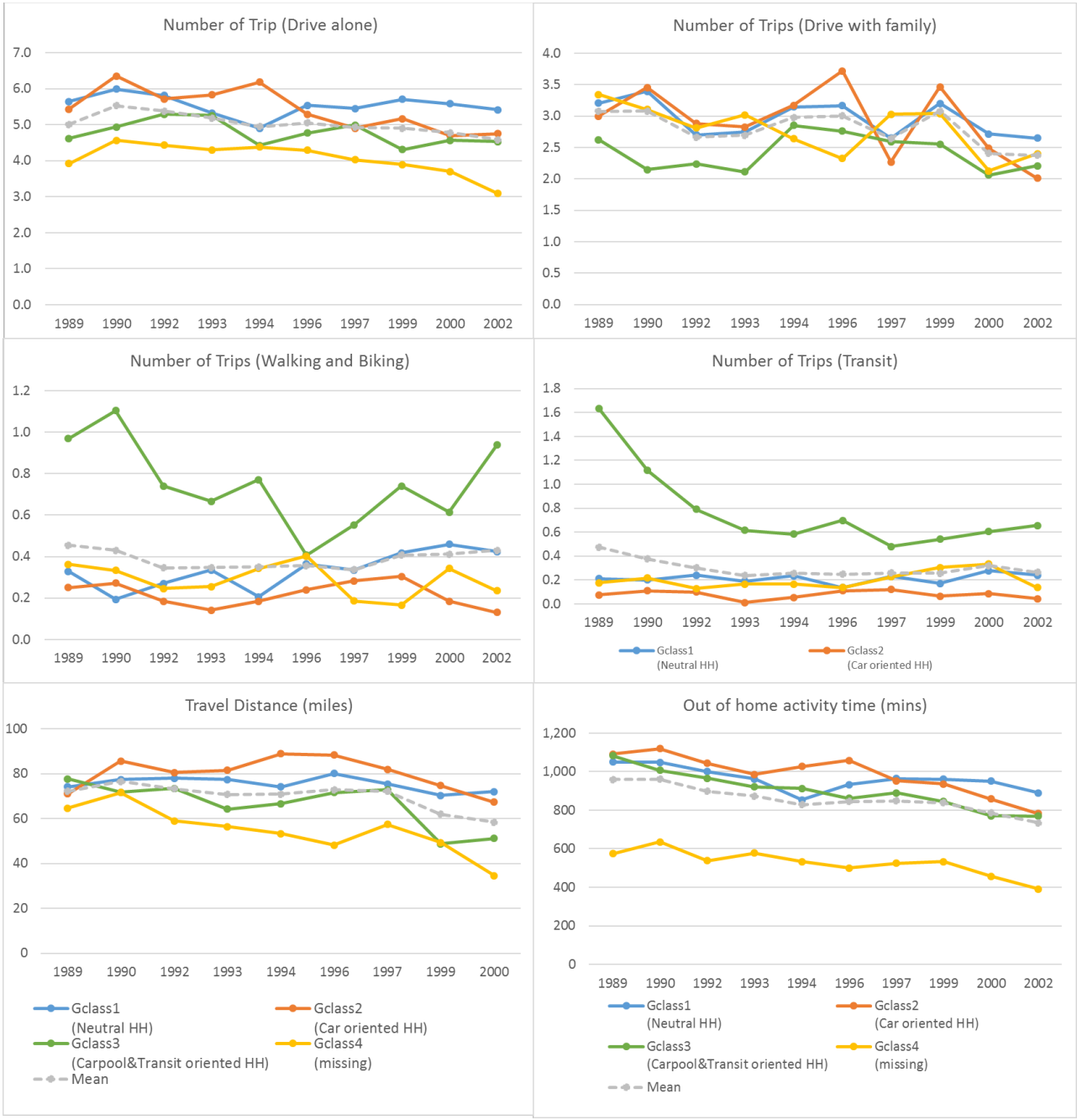


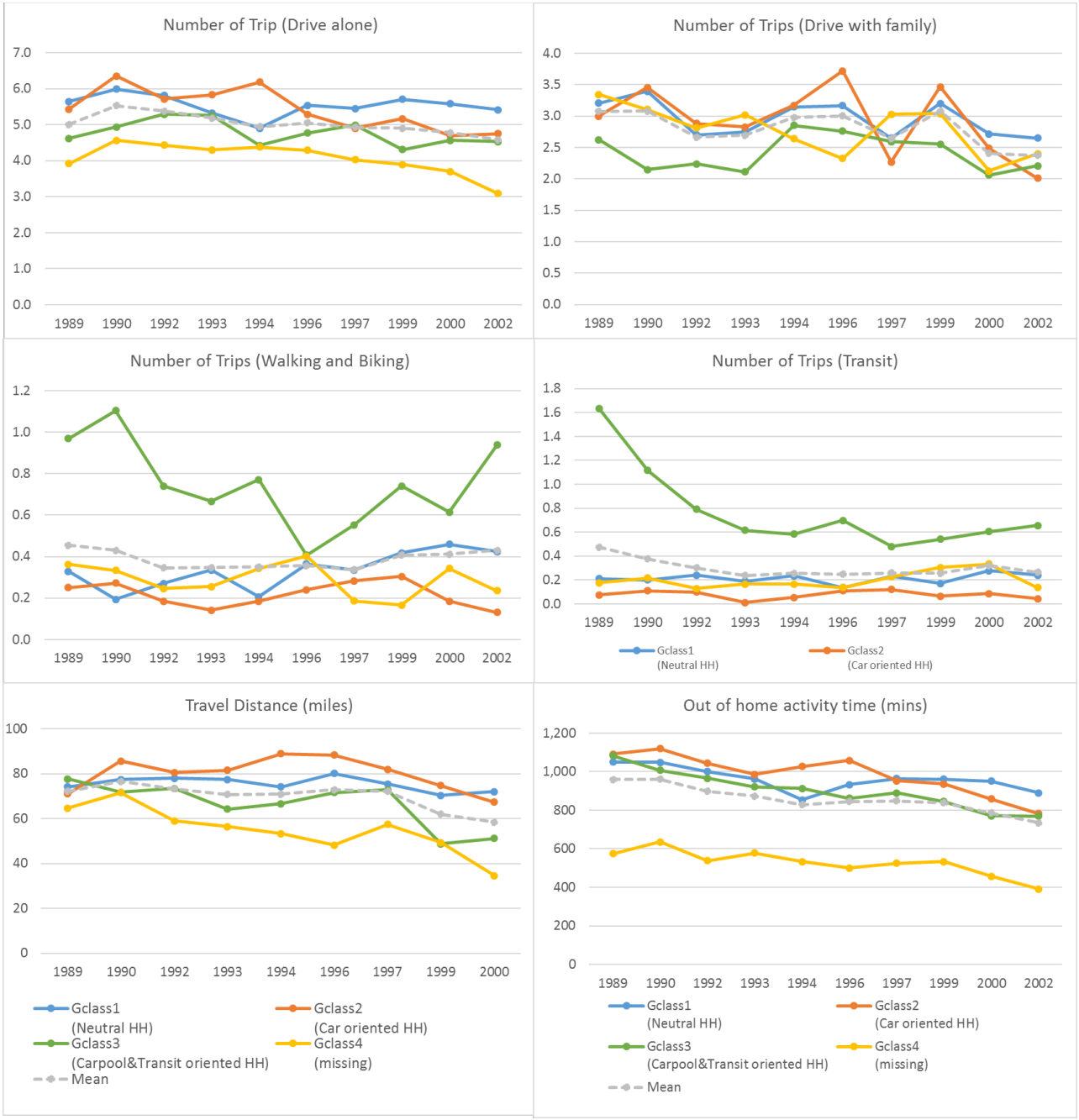
Subset of Households for Whom we have 10 waves of data (1989-2002)

What happens around their homes?




Changes in Number of Vehicles
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1989
1990
1992
1993
1994
1996
1997
1999
2000
2002
Gclass1 (Neutral HH)
Gclass2 (Car oriented HH)
Gclass3 (Carpool&Transit oriented HH)
Gclass4 (missing)
Mean


Number of Trip (Drive alone)
Number of Trips (Drive with family)
Number of Trips (Walking and Biking)
Number of Trips (Transit)
Travel Distance (miles)
Out of home activity time (mins)
1989 1990 1992 1993 1994 1996 1997 1999 2000 2002
Gclass1 (Neutral HH)
Gclass2 (Car oriented HH)
Gclass3 (Carpool&Transit oriented HH)
Gclass4 (missing)
Mean



Consistency of transit lovers and their behavior!

Missing attitudes people are least active (in surveys are also a group that does not participate)

PART 2

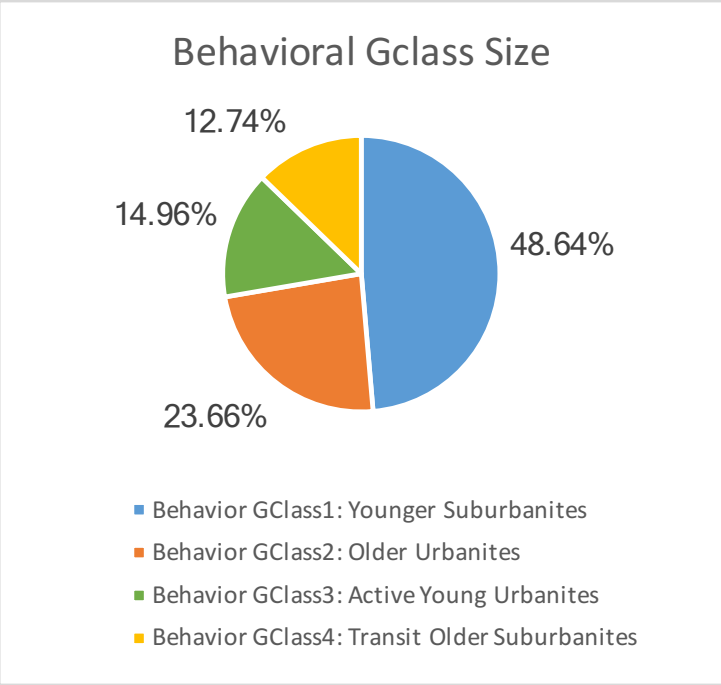
The Multilevel Longitudinal Latent Class Model (time points within persons)

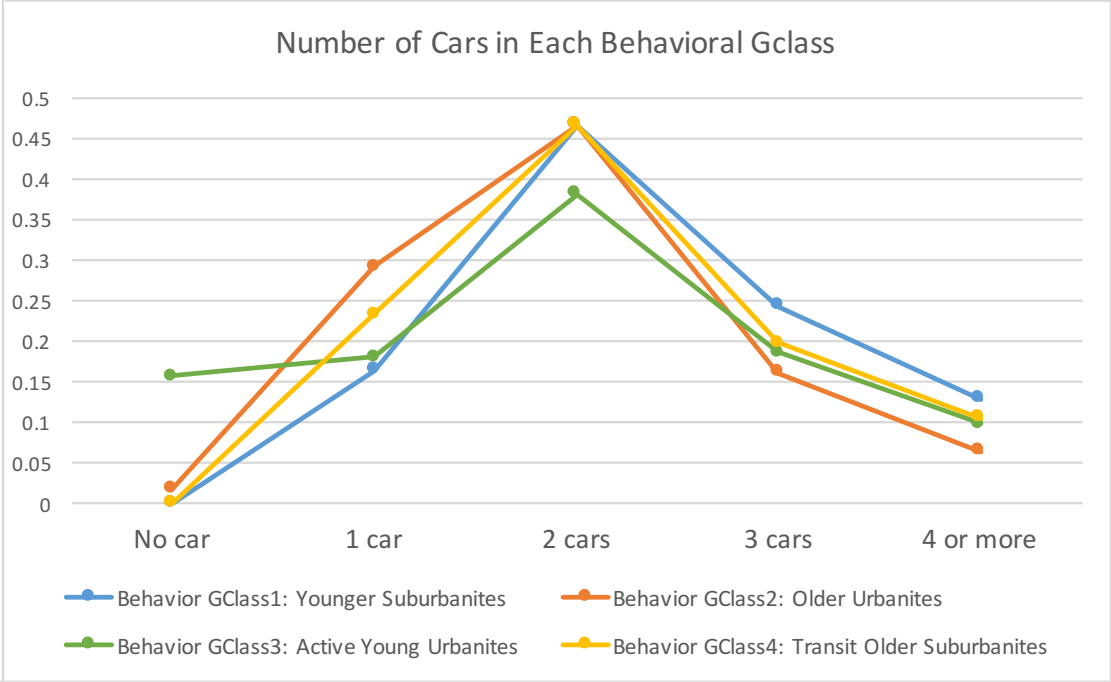
$$f(Y_k) = \sum_{h=1}^{H} P(v_k = h) \prod_{t=1}^{n_k} f(Y_{kt} | v_k = h)$$

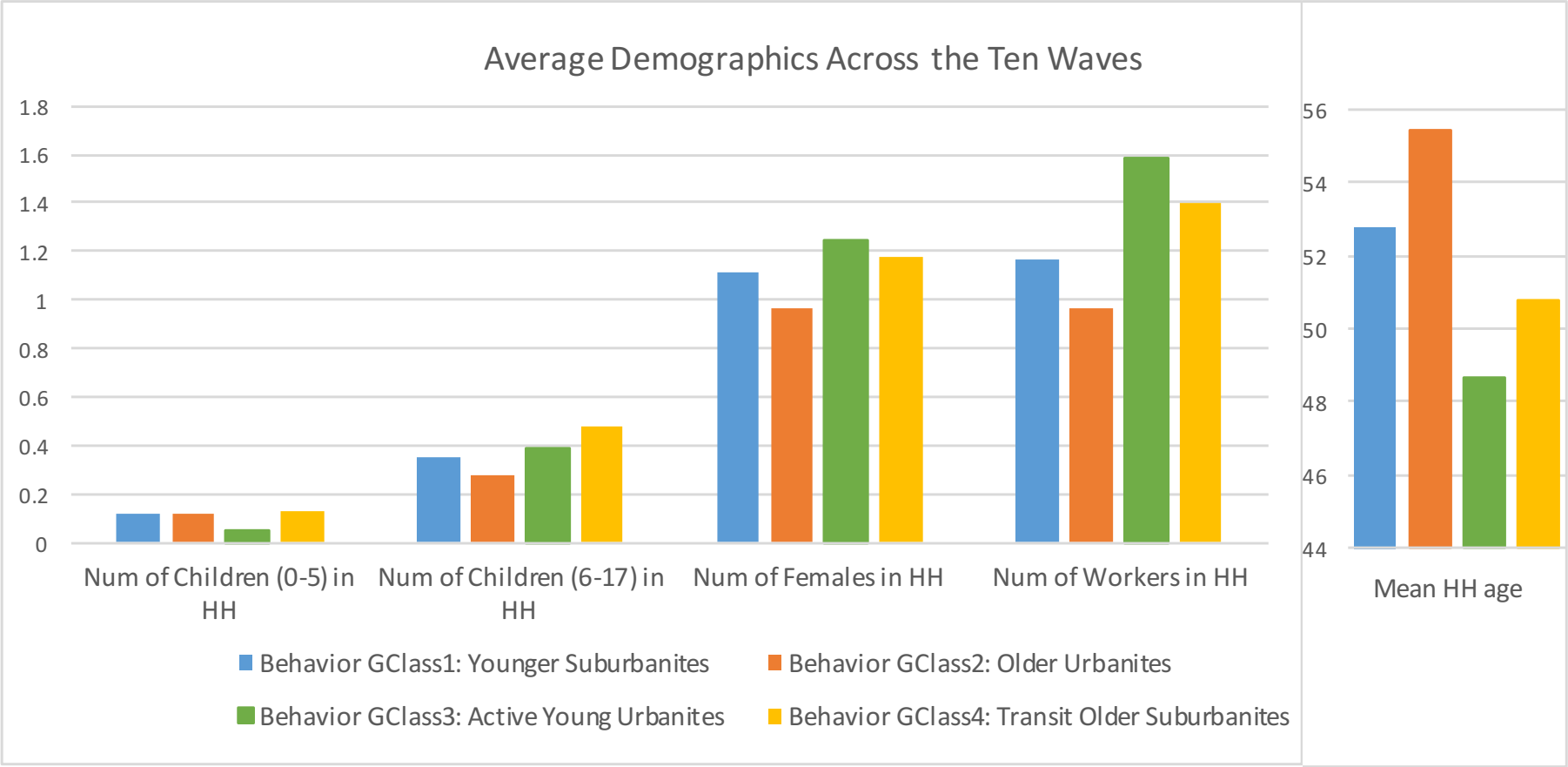
$$f(Y_{kt} | v_k = h) = \sum_{l=1}^{L} P(x_{kt} = l | v_k = h) \prod_{q=1}^{Q} f\left(y_{ktq} \middle| x_{kt} = l, v_k = h\right)$$

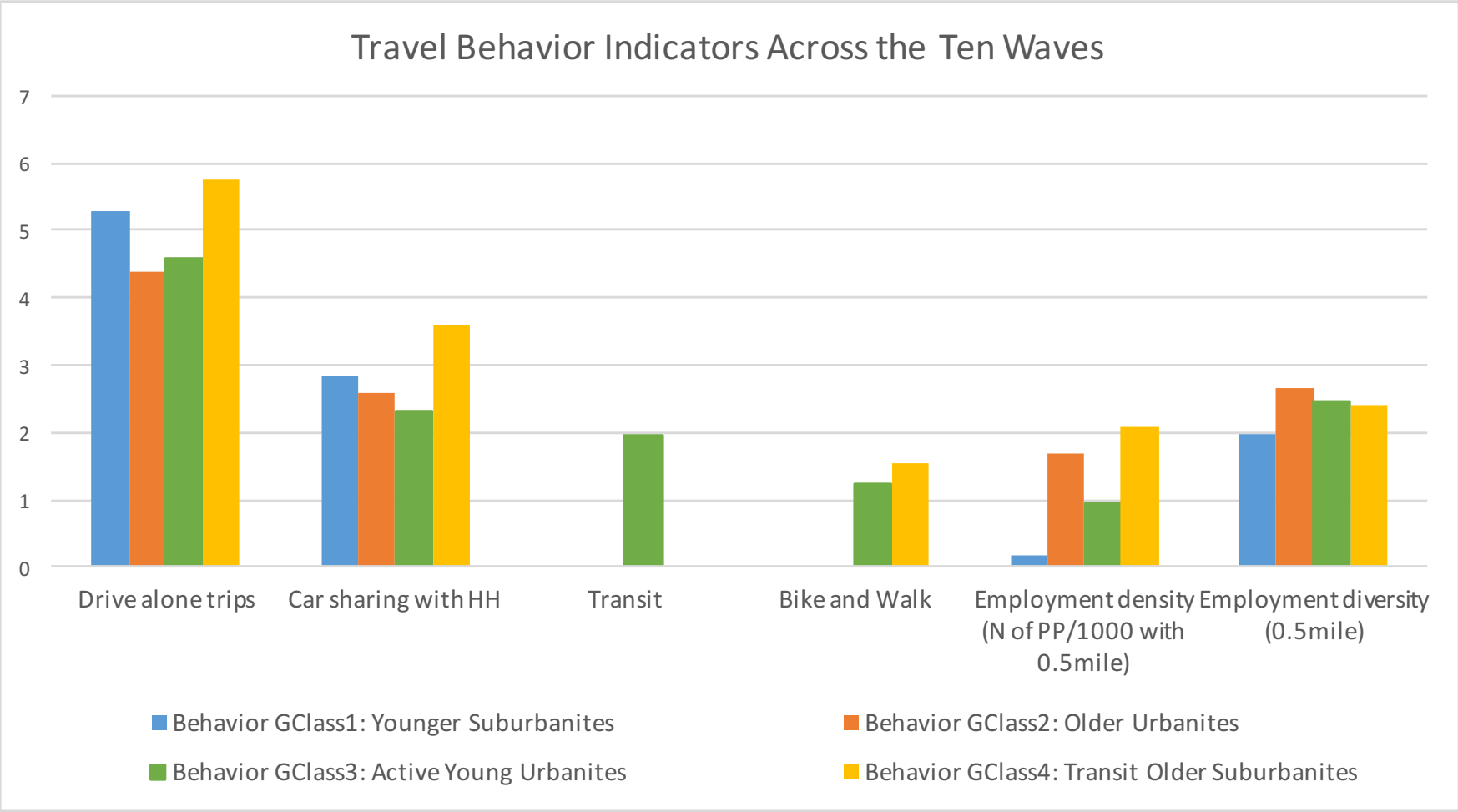
230 households at 10 time points
Groups (latent classes) based on *drive alone trips, car sharing trips, transit trips, bike and walk trips, number of cars, employment density around the household residence, and employment diversity around the household residence*.

Seven variables (q=1,..., 7) and
k for the households (k=1,..,n_k). n_k = 230.
l for the behavioral variables,
t for the 10 time points (Equations 3 and 4). The index k goes from 1 to 230. The sum of all n_k is 2,300 households that provide answers in the 10 waves of the panel.

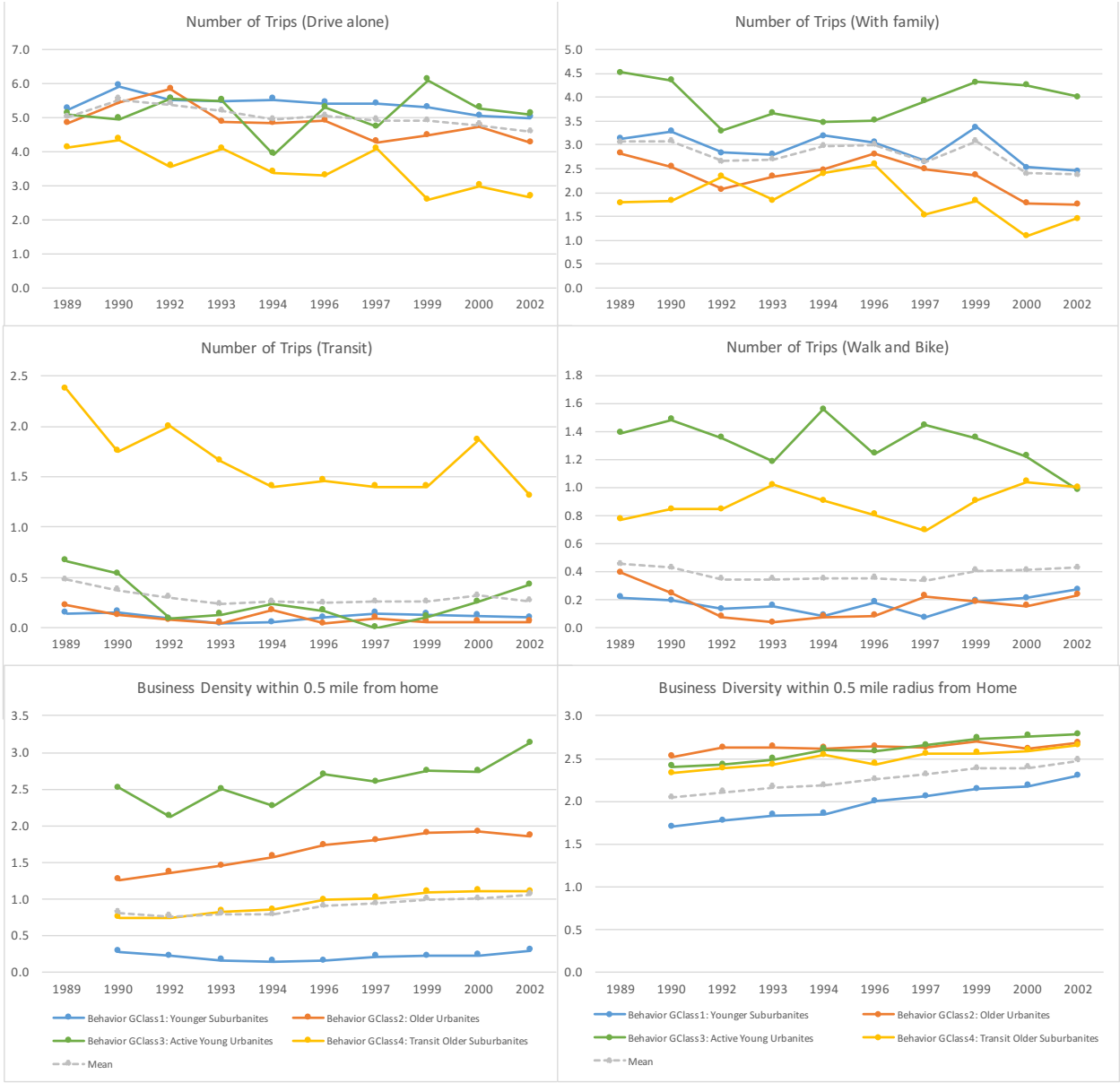

Behavioral Gclass Size
12.74%
14.96%
48.64%
23.66%
Behavior GClass1: Younger Suburbanites
Behavior GClass2: Older Urbanites
Behavior GClass3: Active Young Urbanites
Behavior GClass4: Transit Older Suburbanites


Number of Cars in Each Behavioral Gclass
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
No car
1 car
2 cars
3 cars
4 or more
Behavior GClass1: Younger Suburbanites
Behavior GClass2: Older Urbanites
Behavior GClass3: Active Young Urbanites
Behavior GClass4: Transit Older Suburbanites


Average Demographics Across the Ten Waves
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Num of Children (0-5) in HH
Num of Children (6-17) in HH
Num of Females in HH
Num of Workers in HH
Behavior GClass1: Younger Suburbanites
Behavior GClass2: Older Urbanites
Behavior GClass3: Active Young Urbanites
Behavior GClass4: Transit Older Suburbanites
56
54
52
50
48
46
44
Mean HH age

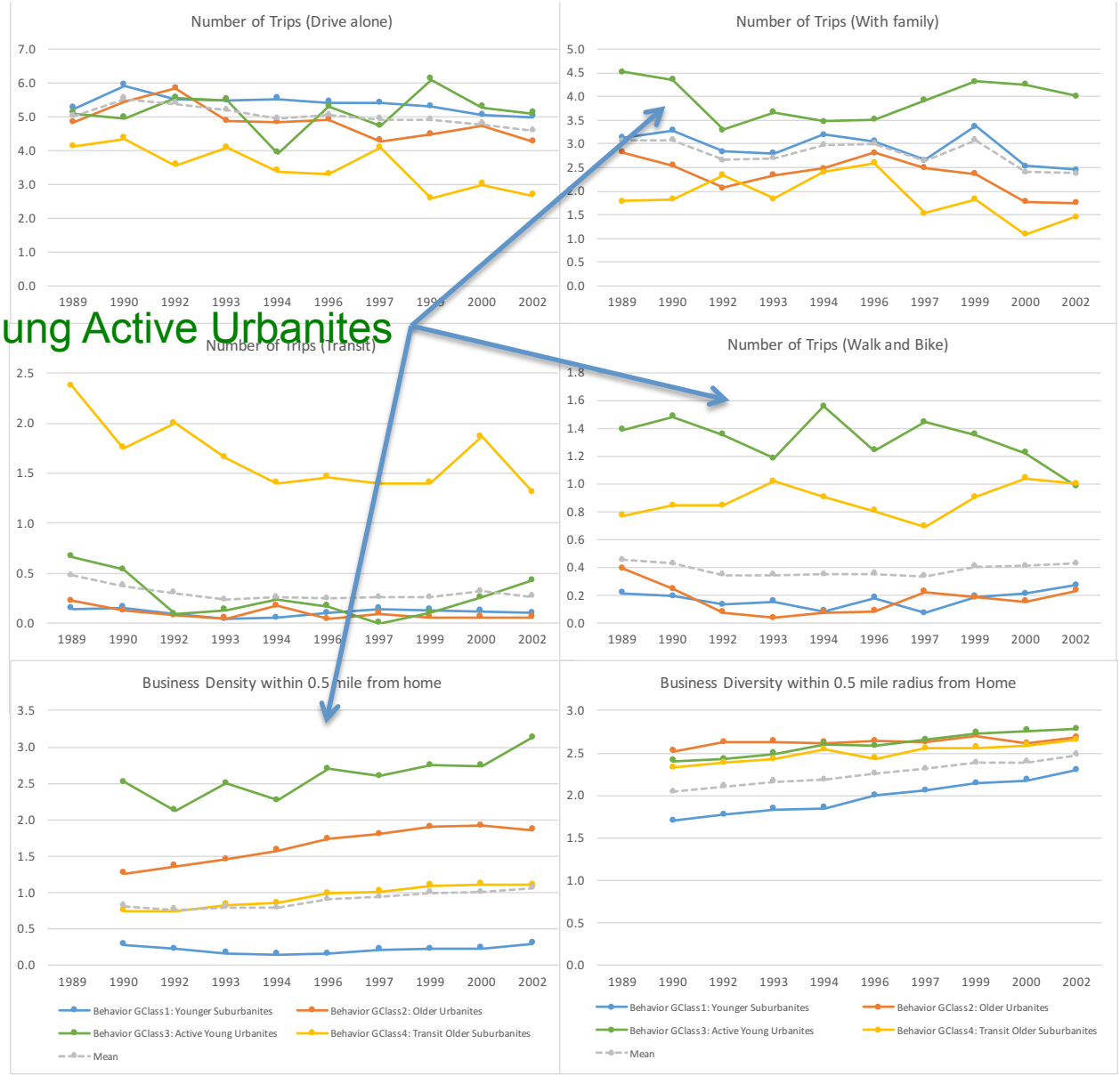

Travel Behavior Indicators Across the Ten Waves
7
6
5
4
3
2
1
0
Drive alone trips
Car sharing with HH
Transit
Bike and Walk
Employment density (N of PP/1000 with 0.5mile)
Employment diversity (0.5mile)
Behavior GClass1: Younger Suburbanites
Behavior GClass2: Older Urbanites
Behavior GClass3: Active Young Urbanites
Behavior GClass4: Transit Older Suburbanites

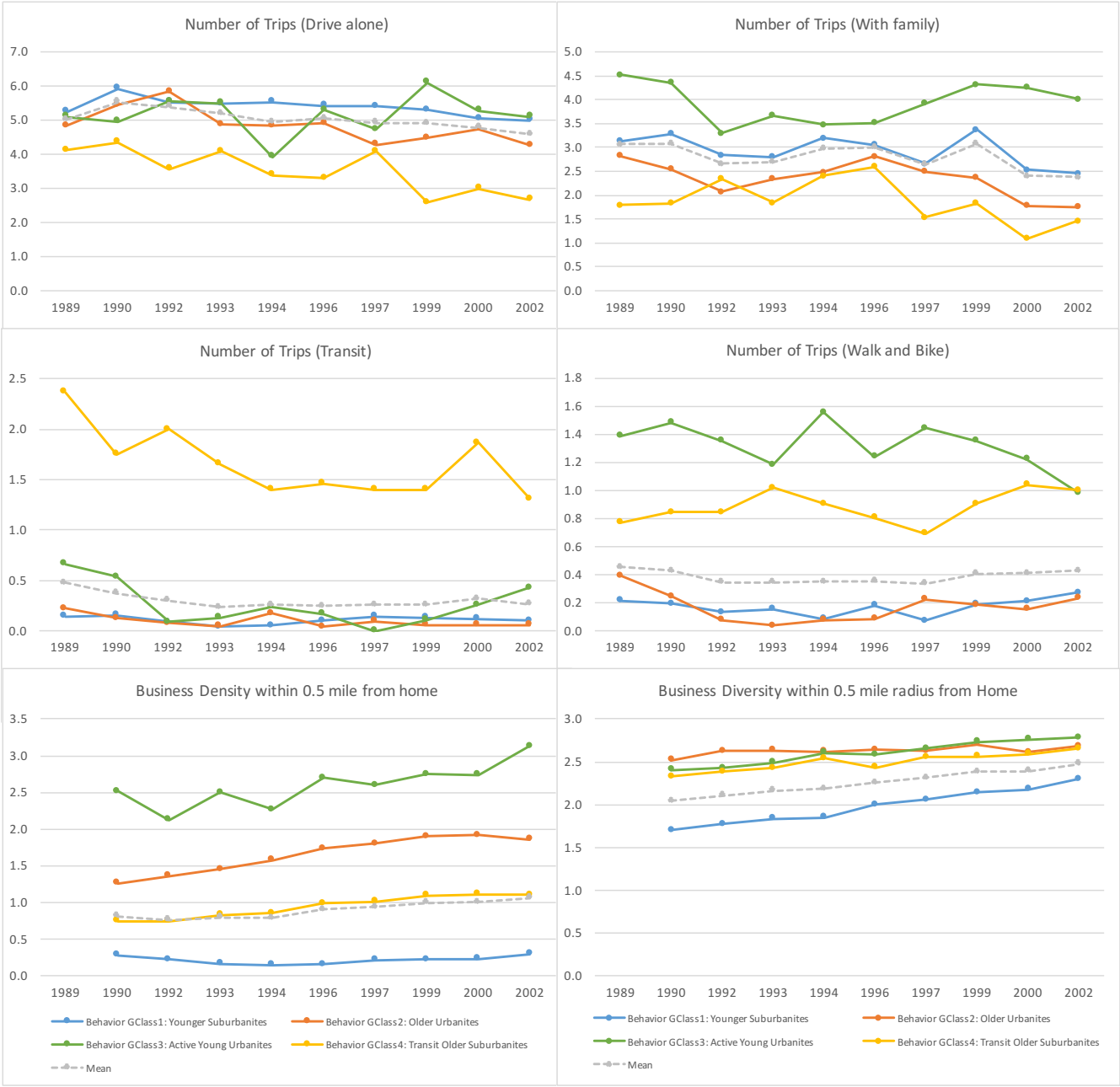
Distinct groups behaviorally over time



Distinct groups behaviorally over time

Green is Young Active Urbanites




Number of Trips (Drive alone)
Number of Trips (With family)
Number of Trips (Transit)
Number of Trips (Walk and Bike)
Business Density within 0.5 mile from home
Business Diversity within 0.5 mile radius from Home
1989 1990 1992 1993 1994 1996 1997 1999 2000 2002
Behavior GClass1: Younger Suburbanites
Behavior GClass2: Older Urbanites
Behavior GClass3: Active Young Urbanites
Behavior GClass4: Transit Older Suburbanites
Mean

Younger suburban dwellers more likely to be neutral (42%), car-oriented (23%) and with missing attitudes (22%).

The transit older suburbanites are car-pool and transit oriented households (65.4%). This is also the behavioral class with the least car driving alone and car sharing with relatives trips.

Chi square: 44.874, df:9, Contingency Coefficient = 0.404			Behavior GClass				Total
			Younger Suburbanites (Blue)	Older Urbanites (Orange)	Active Young Urbanites (Green)	Transit Older Suburbanites (Yellow)	
Attitude GClass	Neutral	Count	53	17	9	6	85
		% within Attitude GClass	62.4%	20.0%	10.6%	7.1%	100.0%
		% within Behavior GClass	42.1%	33.3%	33.3%	23.1%	37.0%
	Car-oriented HH	Count	29	13	4	0	46
		% within Attitude GClass	63.0%	28.3%	8.7%	0.0%	100.0%
		% within Behavior GClass	23.0%	25.5%	14.8%	0.0%	20.0%
	Carpooling& Transit-oriented HH	Count	16	6	9	17	48
		% within Attitude GClass	33.3%	12.5%	18.8%	35.4%	100.0%
		% within Behavior GClass	12.7%	11.8%	33.3%	65.4%	20.9%
	Missing	Count	28	15	5	3	51
		% within Attitude GClass	54.9%	29.4%	9.8%	5.9%	100.0%
		% within Behavior GClass	22.2%	29.4%	18.5%	11.5%	22.2%
Total		Count	126	51	27	26	230
		% within Attitude GClass	54.8%	22.2%	11.7%	11.3%	100.0%
		% within Behavior GClass	100.0%	100.0%	100.0%	100.0%	100.0%

Active young urbanites and suburbunites have a substantial presence of neutral attitudes households (about 33% in both) but the

Young active suburbanites has 33% of their households displaying positive attitudes towards carpooling and transit. These are also the households with the highest number of car sharing with family trips.

Disagreement in terms of attitudes within a household does not equate to different behavior than the households displaying the same within household attitudes

Chi square: 0.118, df:3. Contingency Coefficient = 0.023			Behavior GClass				Total
			Younger Suburbanites (Blue)	Older Urbanites (Orange)	Active Young Urbanites (Green)	Transit Older Suburbanites (Yellow)	
Homophily	All others (missing, disagree)	Count	98	40	21	21	180
		% within Homophily	54.4%	22.2%	11.7%	11.7%	100.0%
		% within Behavior GClass	77.8%	78.4%	77.8%	80.8%	78.3%
	Same Attitude in Household either 1,2,3	Count	28	11	6	5	50
		% within Homophily	56.0%	22.0%	12.0%	10.0%	100.0%
		% within Behavior GClass	22.2%	21.6%	22.2%	19.2%	21.7%
Total		Count	126	51	27	26	230
		% within Homophily	54.8%	22.2%	11.7%	11.3%	100.0%
		% within Behavior GClass	100.0%	100.0%	100.0%	100.0%	100.0%

Specific Questions of the Paper

- Do people with different attitudes live together?
- Yes but lack symmetry
- Do attitudes early in a person's life persist in its effect in later years?
- Yes
- Can we identify distinct attitudinal (x-section) and behavioral (over time) groups and study systematic differences among them?
- Yes but within hh differences don't matter

Related Papers

- Lee J. H. and K.G. Goulias (2017) A Decade of Dynamics of Residential Location, Car Ownership, Activity, Travel and Land Use in the Seattle Metropolitan Region. Paper to be presented at the 22nd International Symposium on Transportation and Traffic Theory, July 2017, Northwestern University, Evanston, IL.

- McBride E., J.H. Lee, A. Lundberg, A.W. Davis. and K. G. Goulias, (2016). Behavioral micro-dynamics of car ownership and travel in the Seattle metropolitan region from 1989 to 2002. *European Journal of Transport and Infrastructure Research,* 16(4), 735-753.

- Lee, J. H., Davis, A. W., & Goulias, K. G., 2015. Triggers of behavioral change. Paper presented at the International Choice Modelling Conference 2015, Austin, May 10-13. GEOTRANS REPORT 2015-05-01.

- Goulias K. G., J.H. Lee, and A.W. Davis (2015) Longitudinal Mixed Markov Latent Class Analysis of the 1989 to 2002 Puget Sound Transportation Panel Data. Paper presentation at the *94th Annual Meeting of the Transportation Research Board, Washington, D.C.,* January 11-15, 2015. Also published as GEOTRANS Report 2014-8-04, Santa Barbara, CA.



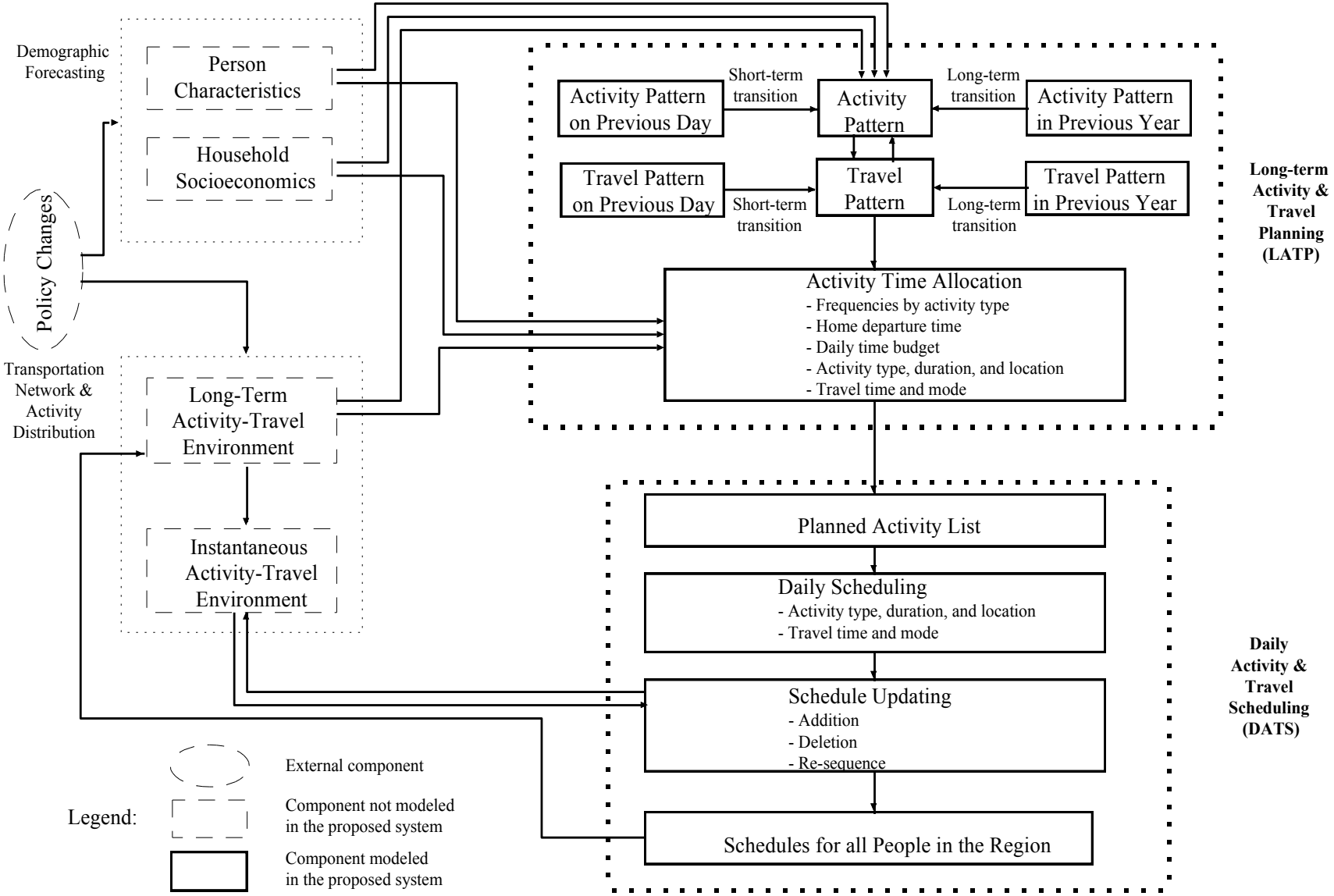
- Many Thanks

&

- Questions?

EXTRA NOTES

The June Ma Model



BEHAVIORAL FRAMEWORK

Principles of Behavioral Dynamics

- **The household and its members in their surrounding environment are in a continuous process of adjustment**
- Examples:
  - Life cycle and turning points in life
  - Day to day scheduling of activities
  - Time allocation among household members and others in the social network (social capital)
  - Activity opportunities and travel time

Source: combination of Oxford 1988 conference, Kitamura 2000 Handbook of Transport Modeling (Eds Hensher&Button)

Principles of Behavioral Dynamics

- **Processes of Adjustment with Lags and Leads**
  - Information awareness and use = short and long lags depending on context
  - Searching for alternatives = length of search is function of behavioral style (optimizing vs satisficing)
  - Experimentation = effort to settle and transaction costs
  - Capability constraints = purchasing and time budgets
  - Institutional constraints = external and internal to household obligations

What are Some Triggers?

- *Physiological alterations* (e.g., hormonal changes that alter physical and social selves)
- *Transitions* (e.g., *age-graded movement* into and out of social roles such as school grades or loss of a parent)
- *Turning points* (e.g., events that cause reorientation of priorities and lasting alterations of a person's developmental trajectory)

What Happens?

- Triggers create barriers or offer new opportunities.
- Lead to changes in roles, self-concepts, lifestyles, worldviews, and dispositions towards other people.
- Impact behavior depending on their timing and duration, the socio-economic characteristics of the individual such as gender and sexual orientation, and ethnic and social class.

Examples of Triggers

- Marriage
- divorce
- building a family and birth of children
- entering a new intimate relationship
- separation
- entering school
- choosing occupation
- engaging in nonoccupational studies
- graduation
- continuing studies
- dropping out of school
- job seeking
- job loss
- retirement
- starting first job
- starting private enterprise/practice
- Change is constant!

- declaring bankruptcy
- moving to another community
- leaving home
- travelling somewhere far away
- moving temporarily to another place
  entering military or community service
- loss due to death of close member
- getting a new apartment
- getting a vacation home
- change in leisure activities and hobbies
- drug use and abuse
- committing crime(s)
- religious engagement
- psychological crises
- own illness
- illness of close member
- accidents

Principles of Behavioral Dynamics

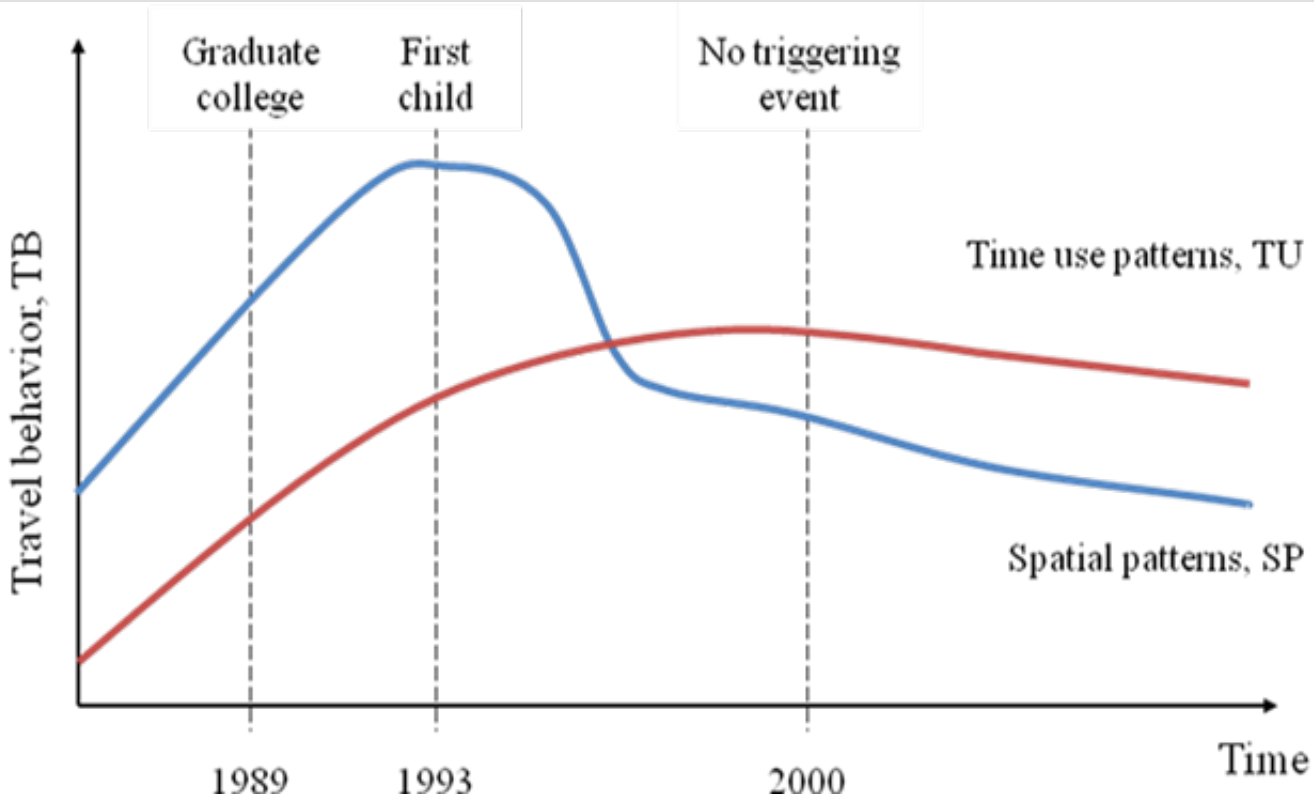
- **Heterogeneity***
  - Differences of lifestyles & roles (observed, unobserved, and unobservable)
  - Differences in types of relationships (observed, unobserved, and unobservable)
  - Differences in sensitivity to changes in the environment surrounding the household (observed, unobserved, and unobservable)

*Note the unobserved heterogeneity effects on illusions of state dependence/habit

Decision Making in Context

- Inertia and "stickiness" of habits = after searching and experimentation households avoid transaction costs
- Thresholds = decisions to change behavioral pattern based on a cost-benefit analysis of breaking habits
- Satisficing = habitual behavior may be at a lower point than optimum
- Properties:
  - Partial (gradual) adjustments possibly observed during search and experimentation
  - Speed of adjustment depends on the decision and context
  - Path dependency in adjustments that depends on knowledge
  - Asymmetry and hysteresis of change (path to increase different than path to decrease – e.g., car ownership and job loss)

Possible Evolution



- Associate changes in behavior to lifecycle turning points
  - Shift in social roles
  - Shift in long-term plans

(Longitudinal)Data to Test Dynamic Hypotheses

- Panel Surveys*
  - Life cycle changes
  - Long vs short term decisions
  - Leads and lags
- Before After Experiments
  - Impose a change
  - Ask questions tailored to decision and context
- Direct tracking
  - GPS family
  - Combinations with panels and experiments

*Note the long research record on panel survey design and countering of panel-specific issues (non-response, attrition, fatigue, conditioning, incomplete change observed)

Data We Use (background)

Approach	Design	No. of Measurements per Sample Unit	Type of Variation Measured		
			Among Sample Units	Within Sample Units	In the Population Over time
Cross-Sectional	One time	One	Yes	No	No
	Repeated	One	Yes	No	Yes
Panel (Longitudinal)	Panel (PSTP)	Two or More	Yes	Yes	Usually No
	Rotating Panel	Two or more	Yes	Yes	Yes

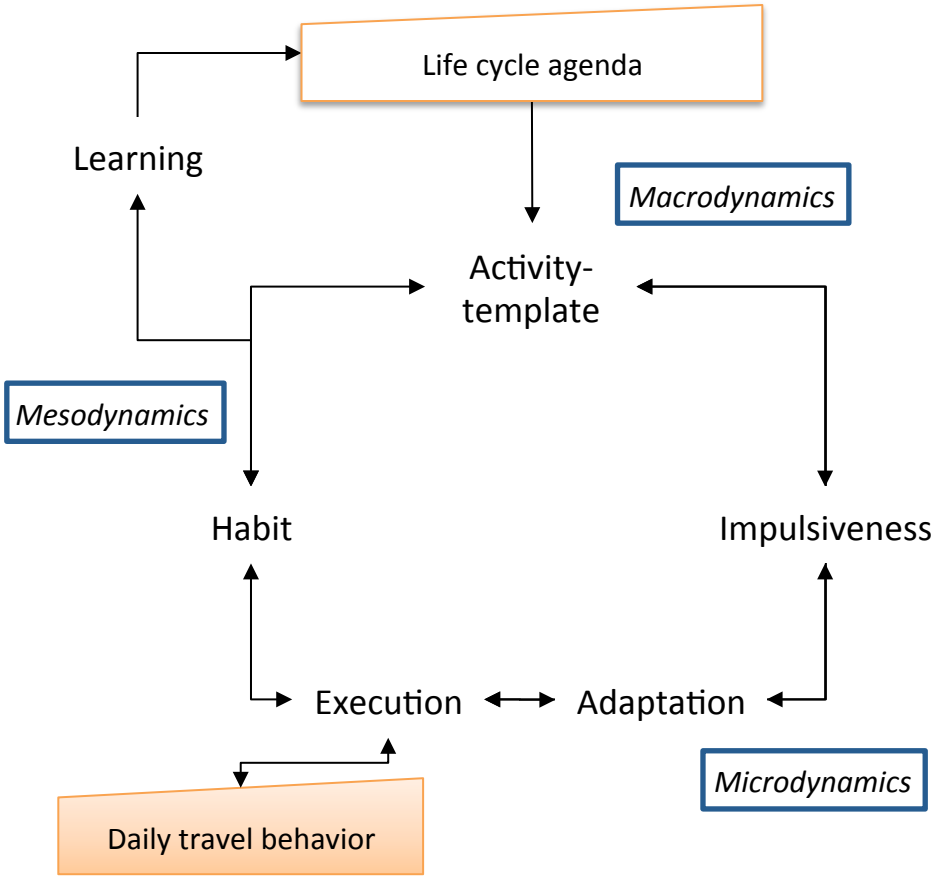
Analytical Tools

- Stochastic Processes
  - Renewal processes
  - Markov renewal processes
  - Markov processes
  - Markov chains
- Discrete time regression models
  - Linear
  - Distributed lags
  - Lagged dependent variables
  - Non-linear models
  - Dynamic models

Note: Structural equations models and computational process models could also be included here – not in RKs review but used by his group and collaborations

Travel behavior dynamics (Pam Dalal Dissertation)

- Behavioral dynamics in activity scheduling
- *Macrodynamics*
  - moving through life cycle stages
- *Mesodynamics*
  - lags and leads in behavioral change
- *Microdynamics*
  - planning for a day



Life course theory

- Over a life course, how does behavioral change manifest over **time**
- Life course theory
  - Stability and change in long-term behavior
- Drivers for behavioral change
  - Turning points
    - Triggers (death, planned retirement)
- Process of behavioral change
  - Habit (lag)
  - Socialization (lead)