

# **Activity-Based Models in Practice: The Mid-Ohio Regional Planning Commission (MORPC) Model**

Peter Vovsha, *PB Consult, Parsons Brinckerhoff Inc.*



84th TRB Meeting, Washington  
DC, 9-14 January 2005

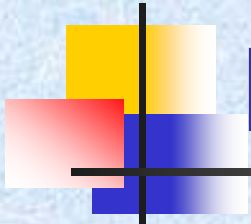


# Project Basics

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# Basic Data

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- Mid-Ohio Regional Planning Commission located in Columbus, OH
- Regional population of 1.4 million (0.6 million HHs)
- 1 day, 24-hours survey of 5,560 HHs, 13,000 person weekdays, NuStats



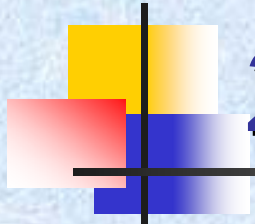


# Basic Features & Sources

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- Already in earlier designs (Portland METRO, SFCTA, NYMTC):
  - **Tour** as unit of modeling
  - **Activity**-based & consistent generation of all tours made during a person-day
  - Stochastic **MCSM** application framework
- Inspirational sources:
  - Research on **intra-household interactions**
  - Concepts of time-use and time-space constraints in combination with duration models (**time windows**)



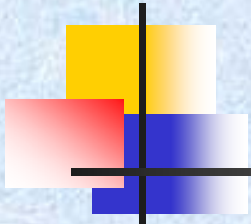


## 2 Advanced Features

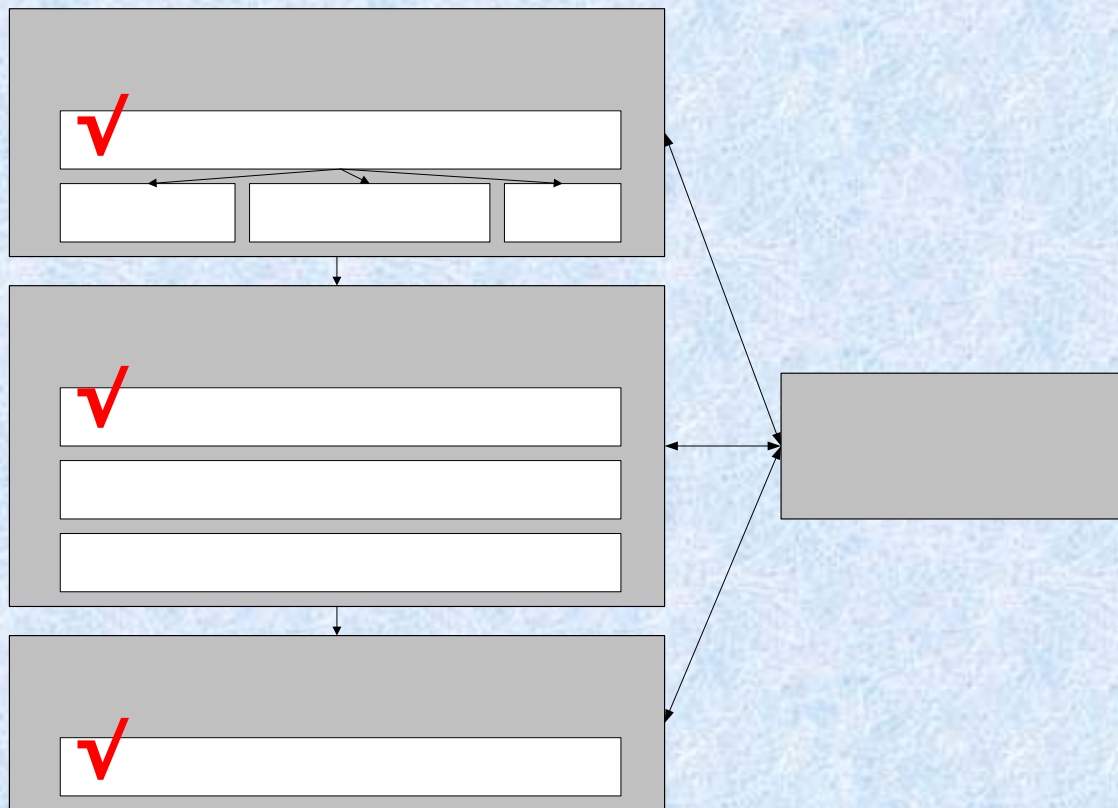
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- Intra-household interactions
- Time windows technique



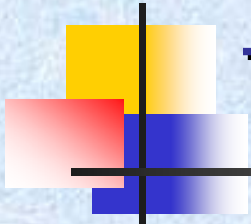


# Intra-Household Interactions



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**Activity Cool**<sup>6</sup>

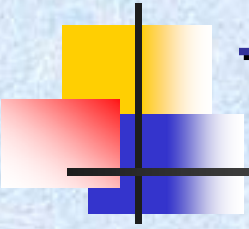


# Time Windows

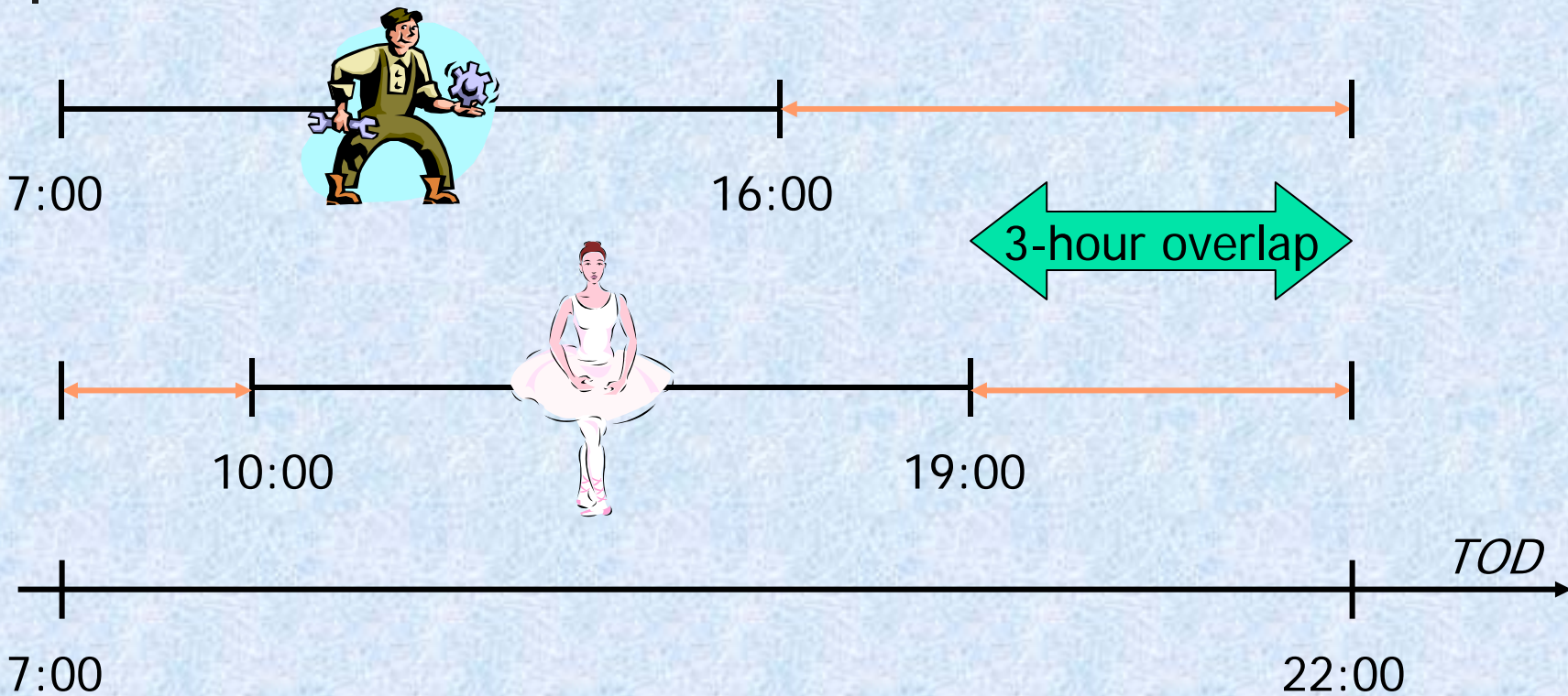
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- Continuous time (1-hour resolution)
- No tour overlaps for the same person (schedule consistency)
- Joint tours are scheduled in available time window overlaps of participants (HH schedule consistency)
- Generation of lower-priority tours is conditional upon residual time window left after higher-priority tours (DAP & schedule intertwined, "time-use")
- Schedule of mandatory tours is conditional upon destination, while destination of non-mandatory tours is conditional upon residual time window ("time-space constraints")





# Time Window Overlaps



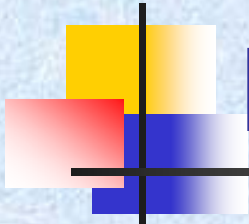


# Model Structure & Components

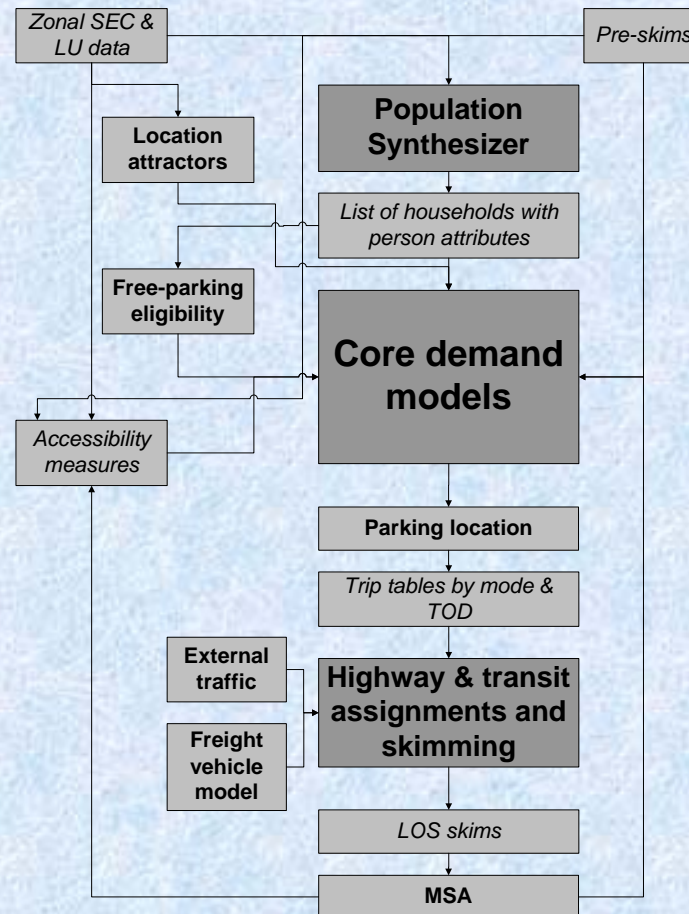
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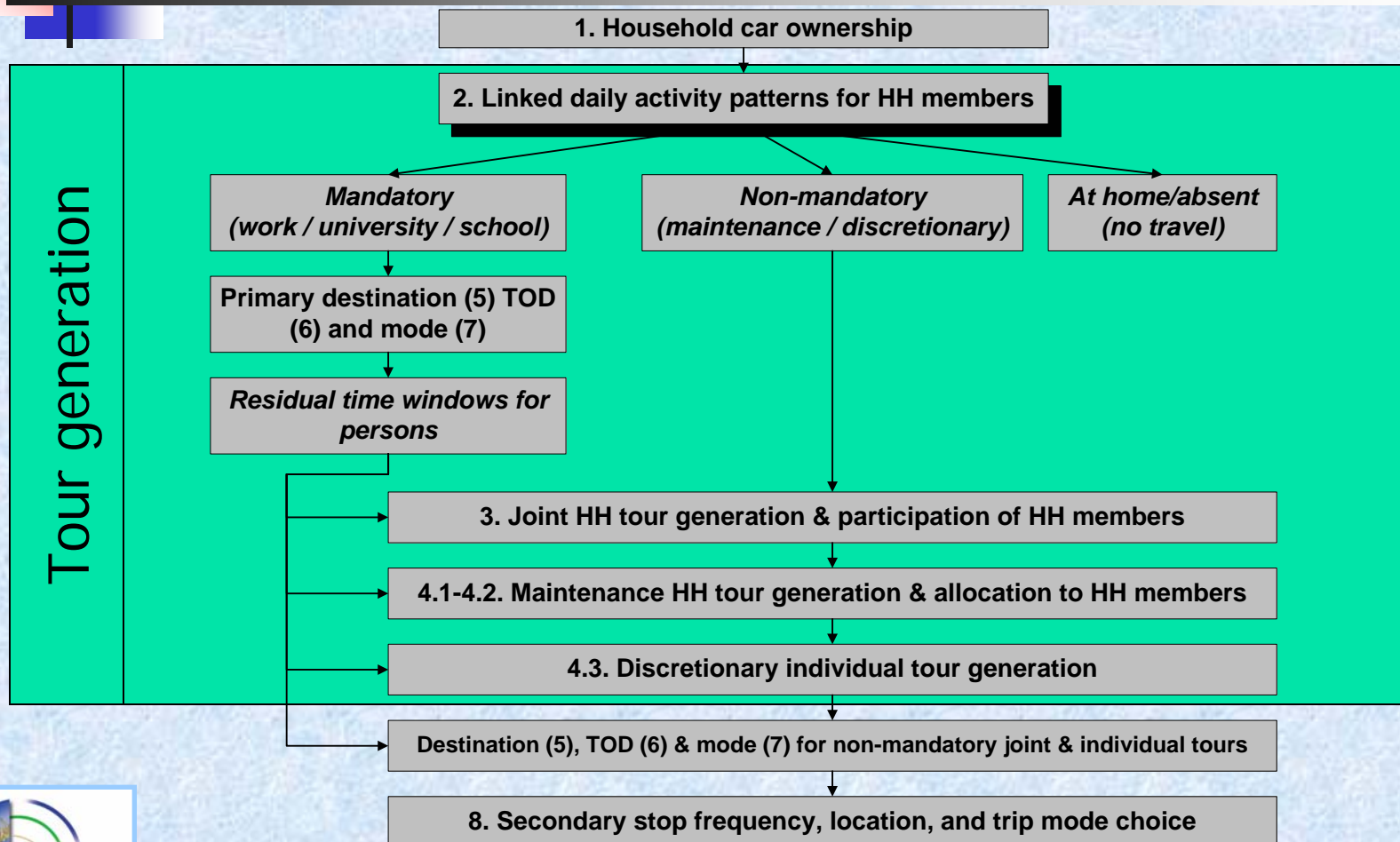
# Model System Structure



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# Core Demand Models

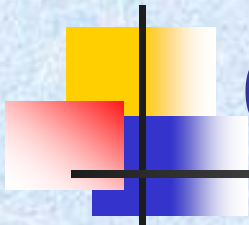




# Correspondence

<i>Level</i>	<i>MORPC model</i>	<i>4-step</i>
Long term	1. Car ownership	Car ownership
Day (tour generation)	2. DAP	Work/school production Non-work production
	3. Joint tours	
	4. Individual tours	
Tour	5. Destination	Distribution
	6. Time of day	Peak factors
	7. Tour mode	Mode
Trip	8. Stops	Distribution, Mode





# Order of Choices

Tour  
Generation

Primary  
Destination,  
Entire-tour  
Mode & TOD

Stop  
Frequency  
& location

Trip mode

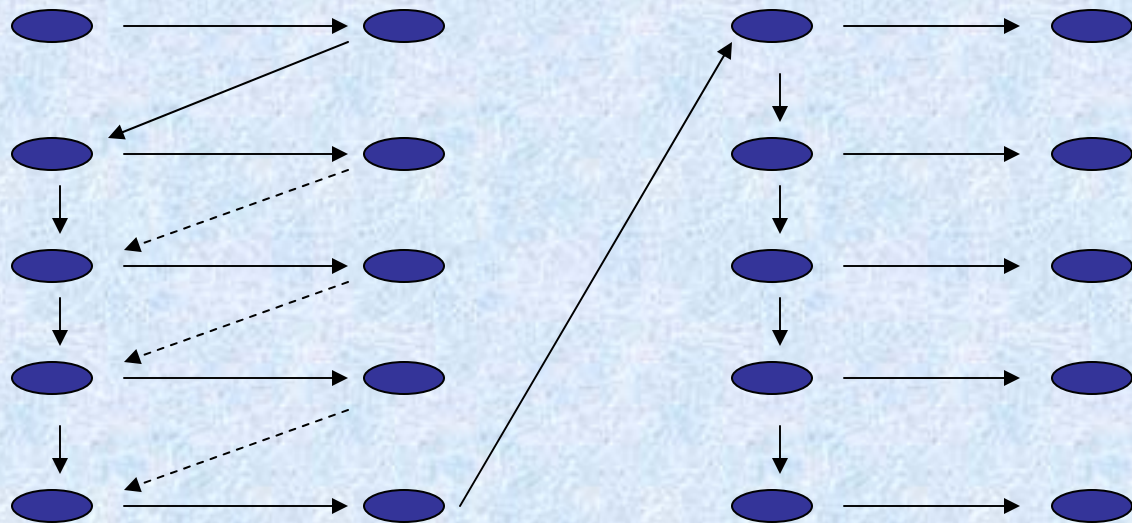
Mandatory

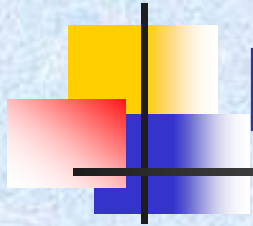
Joint

Allocated

Individual

At work



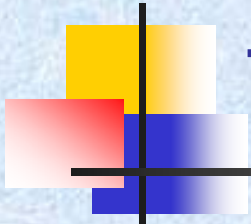


# Benefits of MCSM

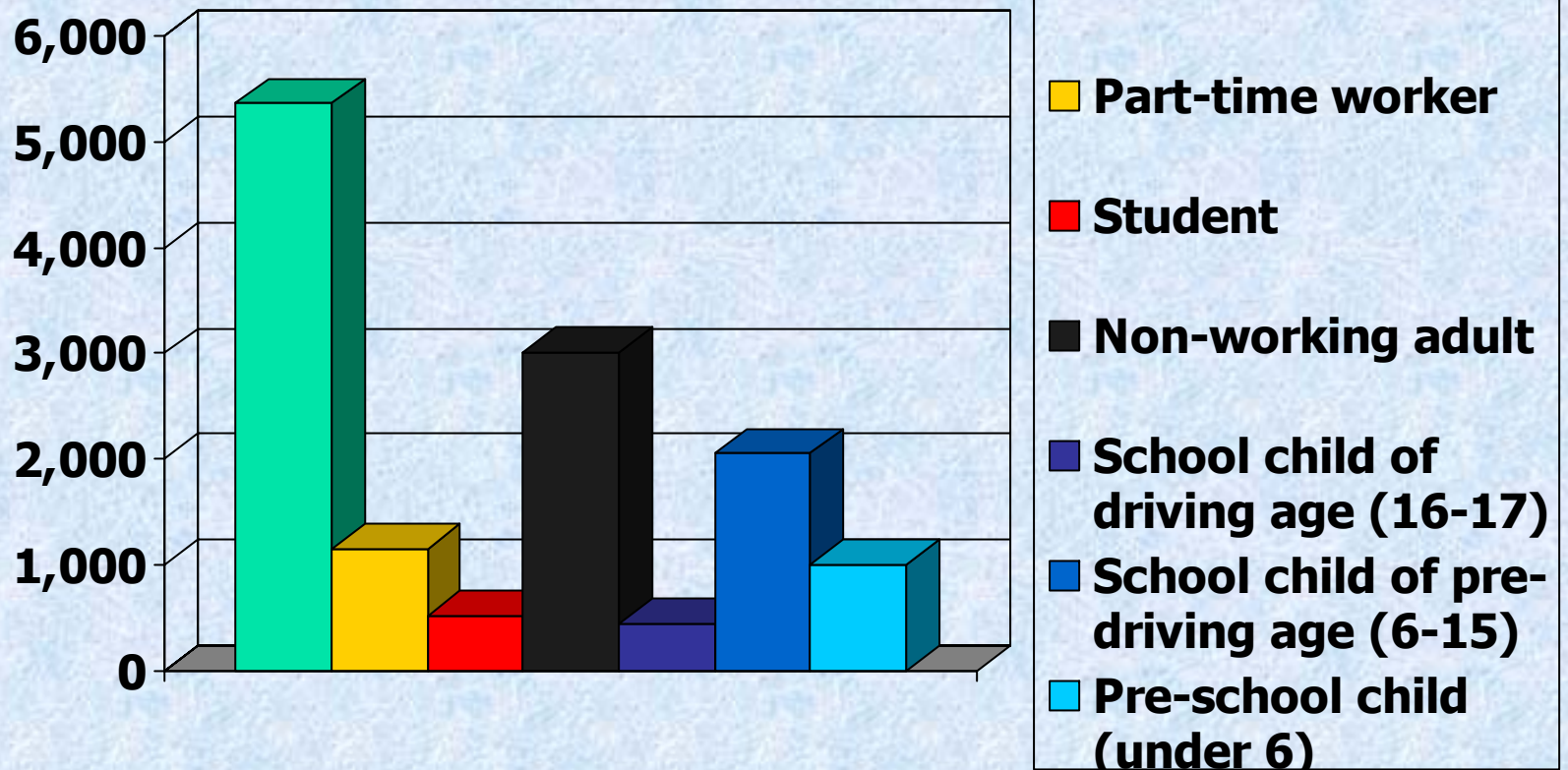
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- Rich set of person and HH variables
- Detailed activity/travel segmentation





# 7 Person Types



# 15 Travel Segments

Purpose	Mandatory Ind	Maintenance		Discretionary		At work Ind
		Joint	Alloc	Joint	Ind	
Work	1.1 (× 3)					1.5
University	2.1					
School	3.1					
Escorting			4.3			
Shopping		5.2	5.3			9.5
Maintenance		6.2	6.3			
Social/recreat				7.2	7.4	
Eating out				8.2	8.4	8.5





# 1. Car Ownership Model

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- HH choice of car-ownership alternative:
  - 0 cars
  - 1 car:
  - 2 cars
  - 3 cars
  - 4+ cars
- Explanatory variables:
  - Relative car sufficiency
  - Accessibility by car, transit, and walk
  - HH income & composition
  - Area type





## 2. Daily Activity Pattern Type

**DAP**

**Mandatory**

At least one out-of-home mandatory activity (tour) and any other activities

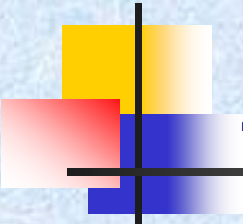
**Non-mandatory**

No mandatory activities; at least one out-of-home non-mandatory activity (tour)

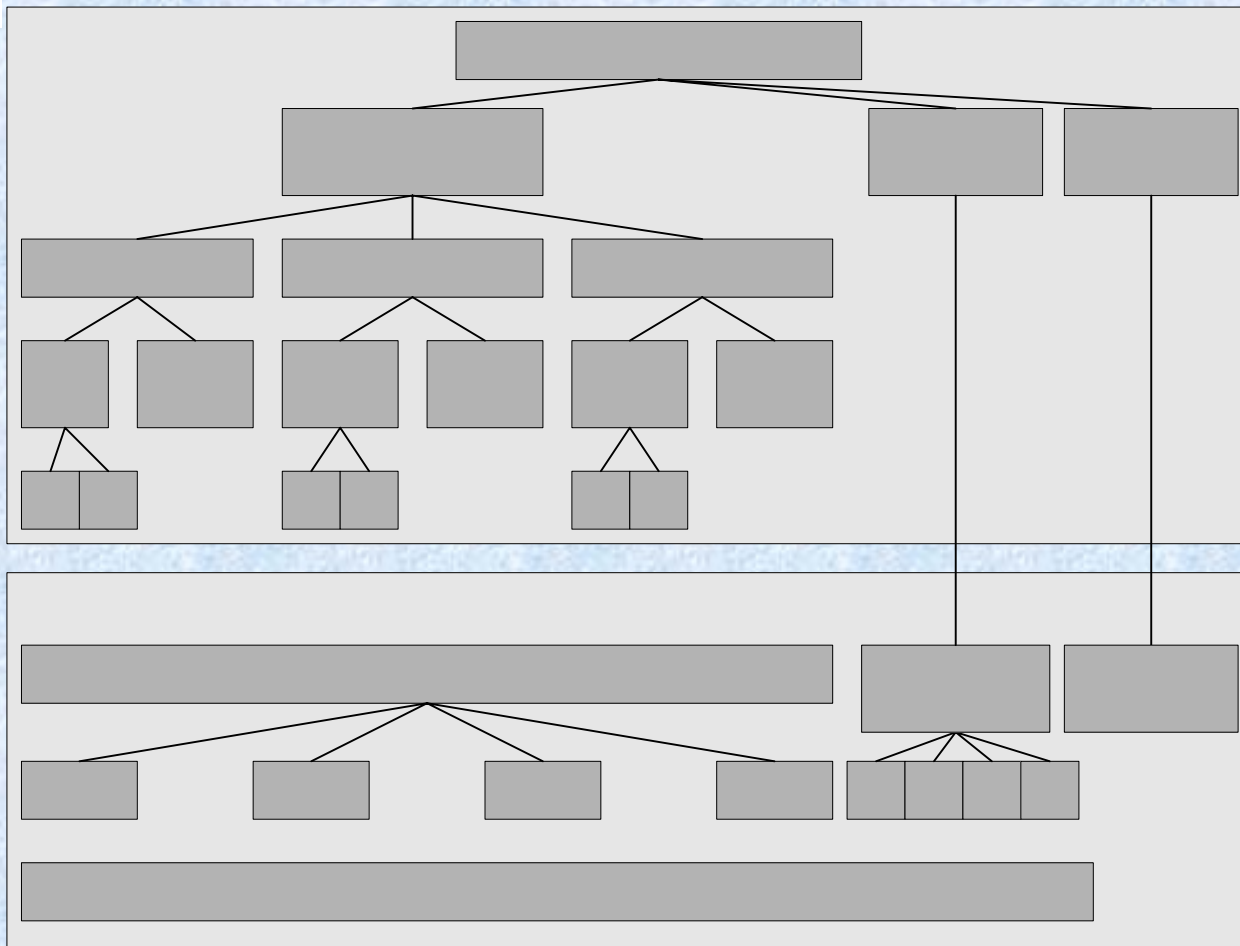
**Home**

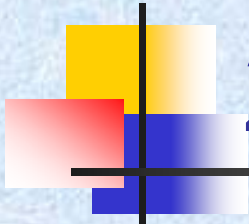
No out-of-home activities (tours) or absence from home/town



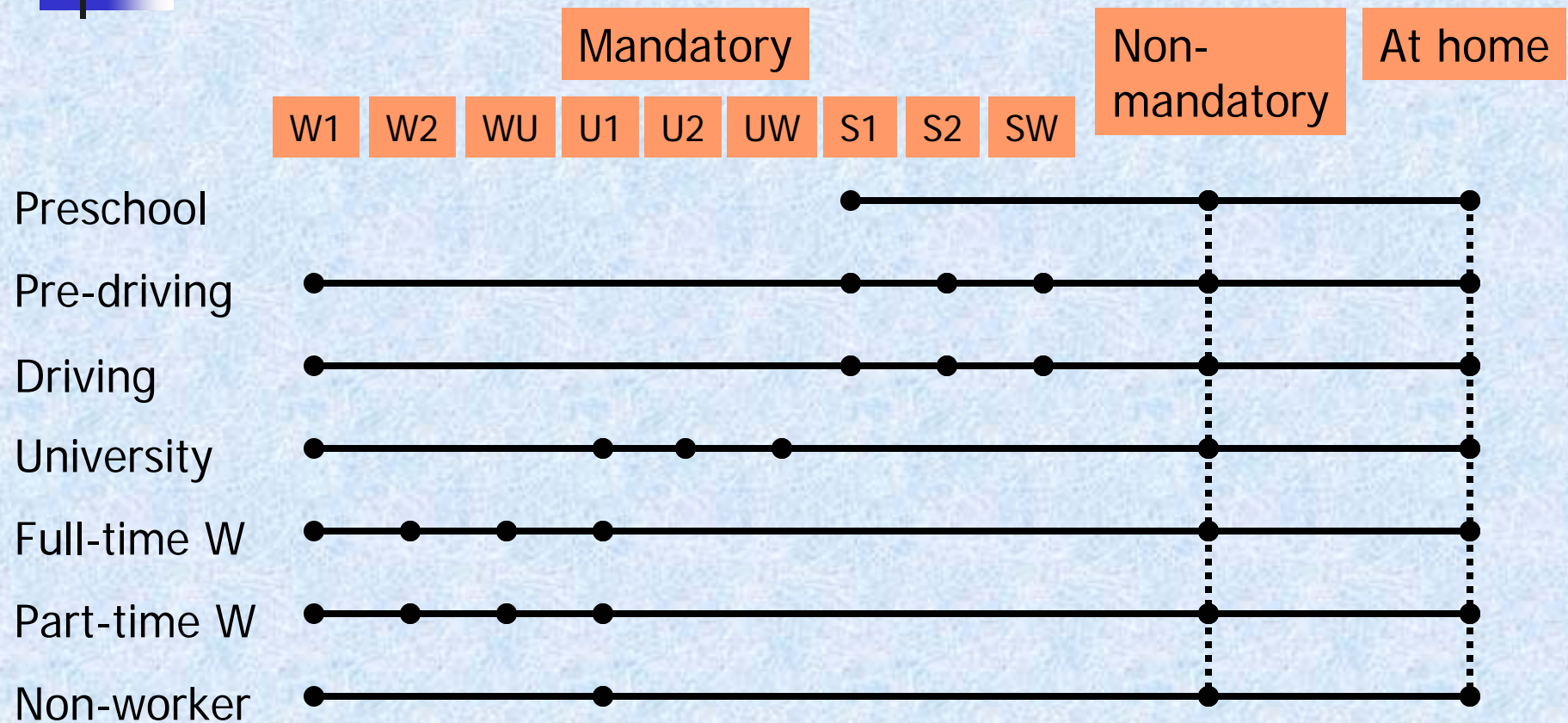


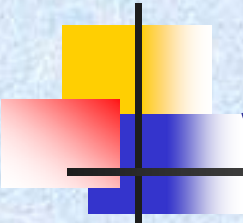
## 2. Daily Activity Pattern Type



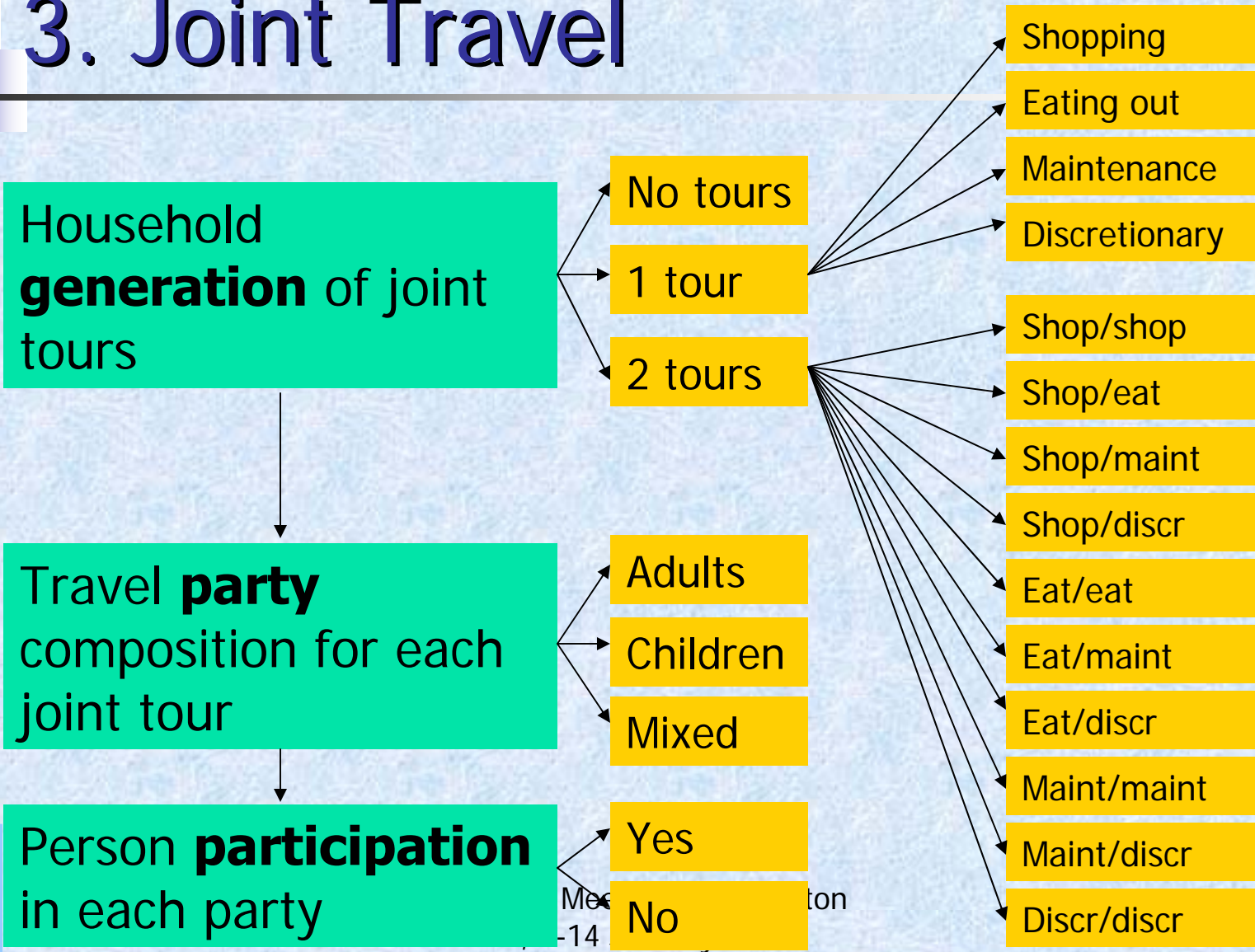


## 2. DAP Type Choice





# 3. Joint Travel





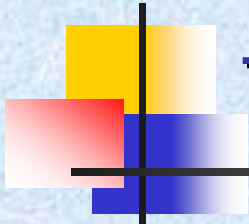
## 3. Importance of Explicit Modeling of Joint Travel

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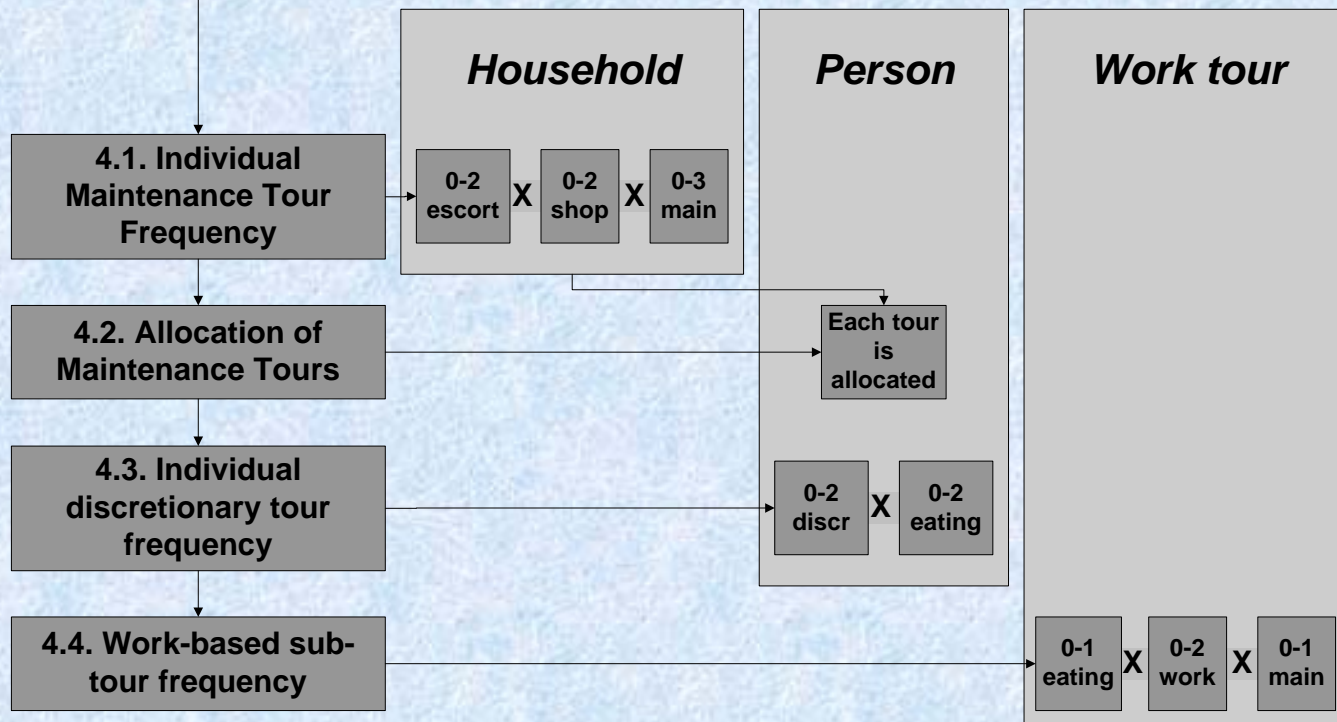
- Significant share in total travel
- Link mode, destination, and TOD choice
- Improve current practice of modeling HOV as **individual mode choice**
- Model High-Occupancy Vehicles (HOV) as joint travel of several HH members based on **shared or synchronized activities**

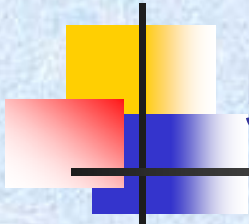


# 4. Individual Non-Mandatory Tours

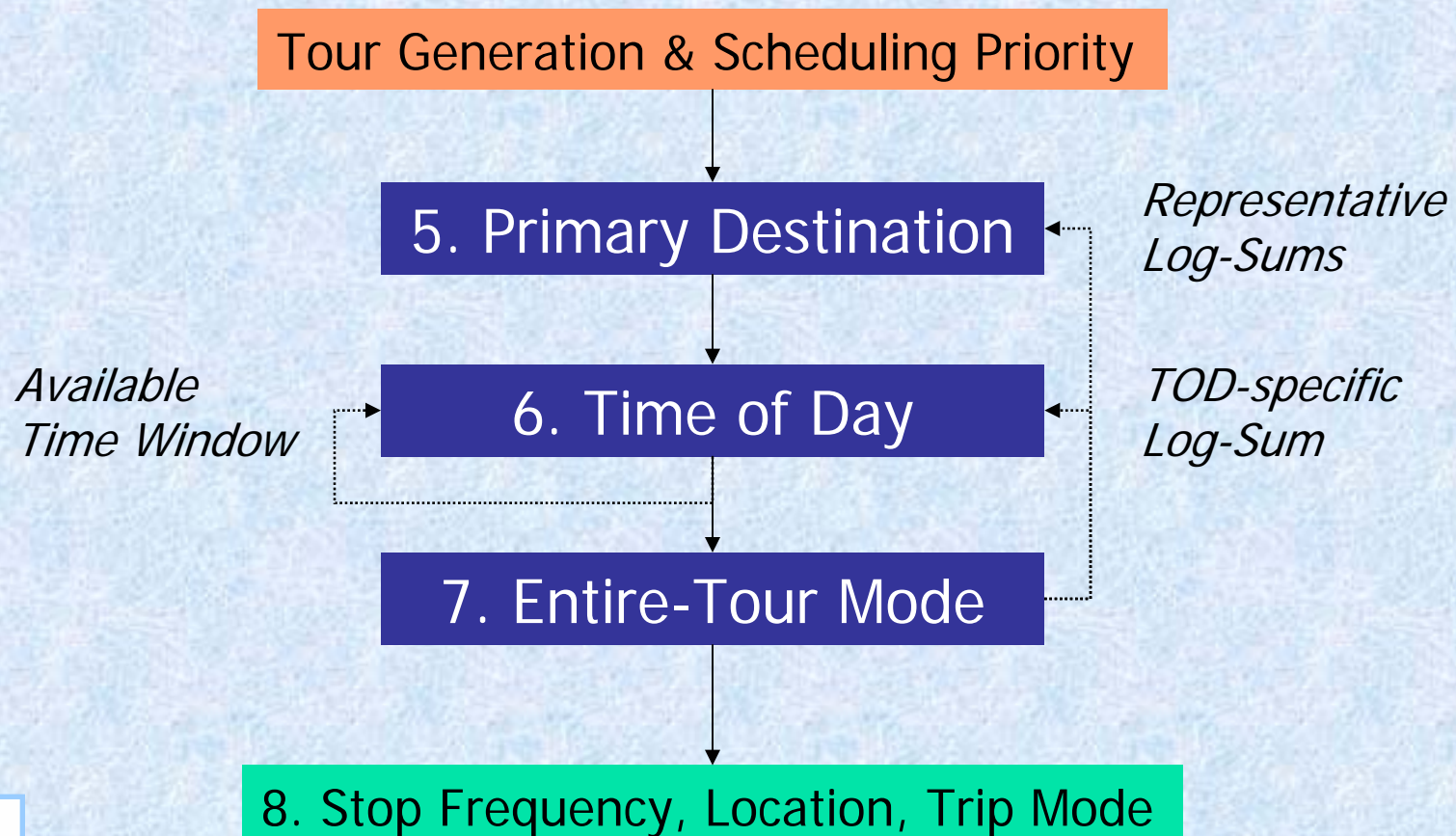


Individual mandatory and joint non-mandatory tours generated by the HH and each person at the previous stages 2-3





## 5-7. Order of Tour-Level Models





## 5. Primary Destination Choice

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- Alternatives:
  - Traffic zones subdivided by short/long walk to transit
- Conditional upon:
  - Travel purpose
  - Income category (for work tours)
  - Joint/individual activity setting
  - Residual time window
  - Person type



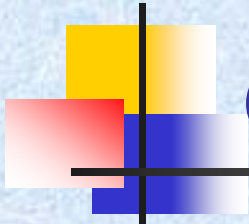


## 6. TOD Choice Model

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- Unit of modeling – travel tour
- Joint choice of:
  - Departure time from home
  - Arrival time back home
  - (Derived) Total duration including activity and travel
- Temporal resolution:
  - 1 hour (from 5:00AM to 23:00PM)
  - Reported time was rounded up to the nearest hour





## 6. TOD Choice

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Work tour to schedule

5

23





## 6. TOD Choice

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Work tour to schedule

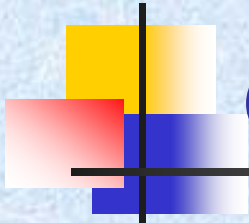
Considerations for  
departure time:

- Office hours (7-10)
- Avoid congestion (10+)
- Give ride to child (7)

5

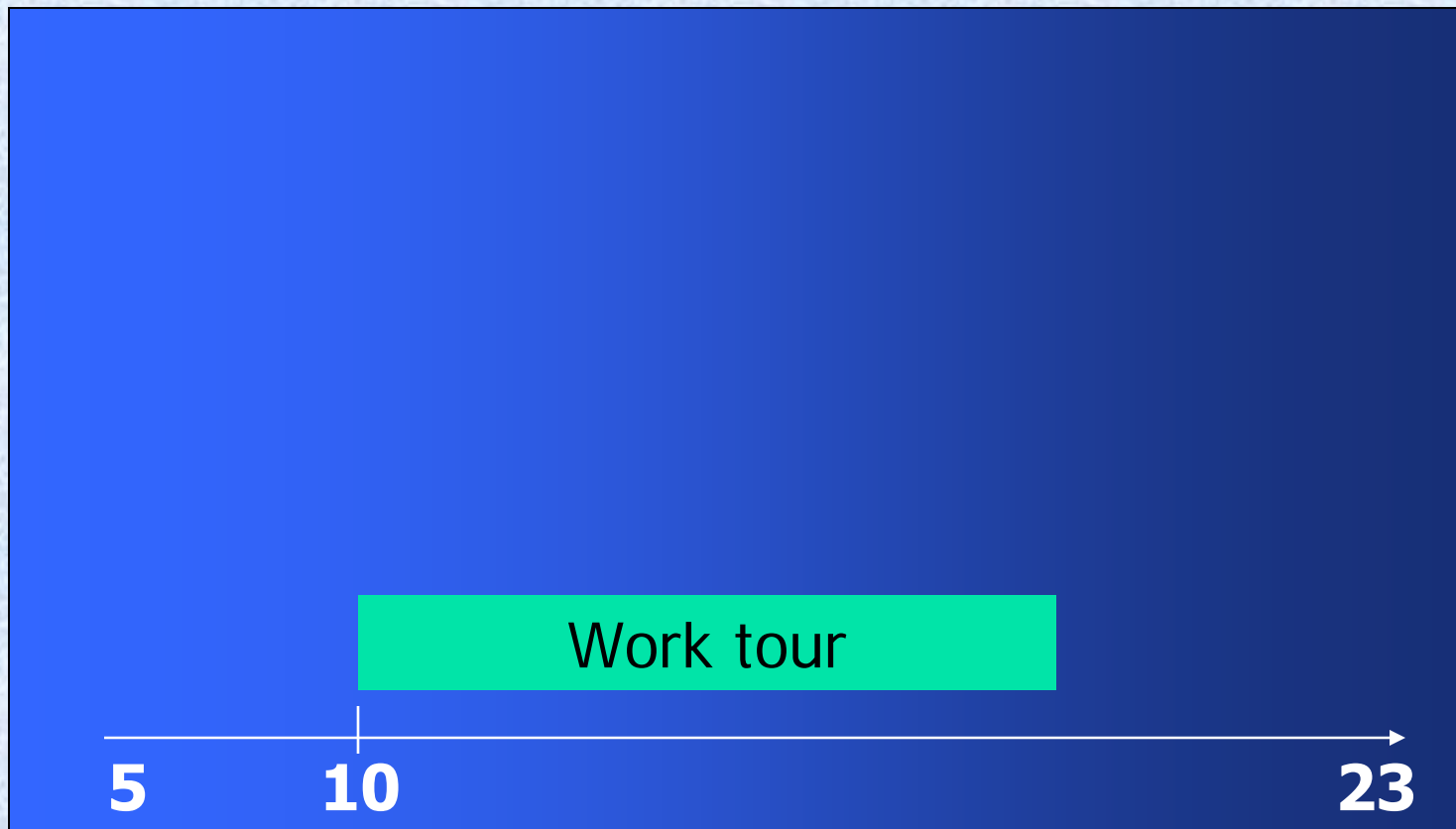
23





## 6. TOD Choice

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## 6. TOD Choice

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Considerations for arrival time:

- Office hours ( $\leq 20$ )
- Avoid congestion ( $< 16$ )
- Tennis before dark ( $< 17$ )



Work tour

5

10

23





## 6. TOD Choice

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Considerations for duration:

- 8 work hours
- Finish presentation on MORPC



Work tour

A horizontal timeline with an arrow pointing to the right. The timeline is marked with the numbers 5, 10, 15, and 23. A green rectangular box labeled 'Work tour' is positioned between the 10 and 15 marks.

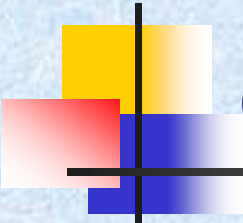
5

10

15

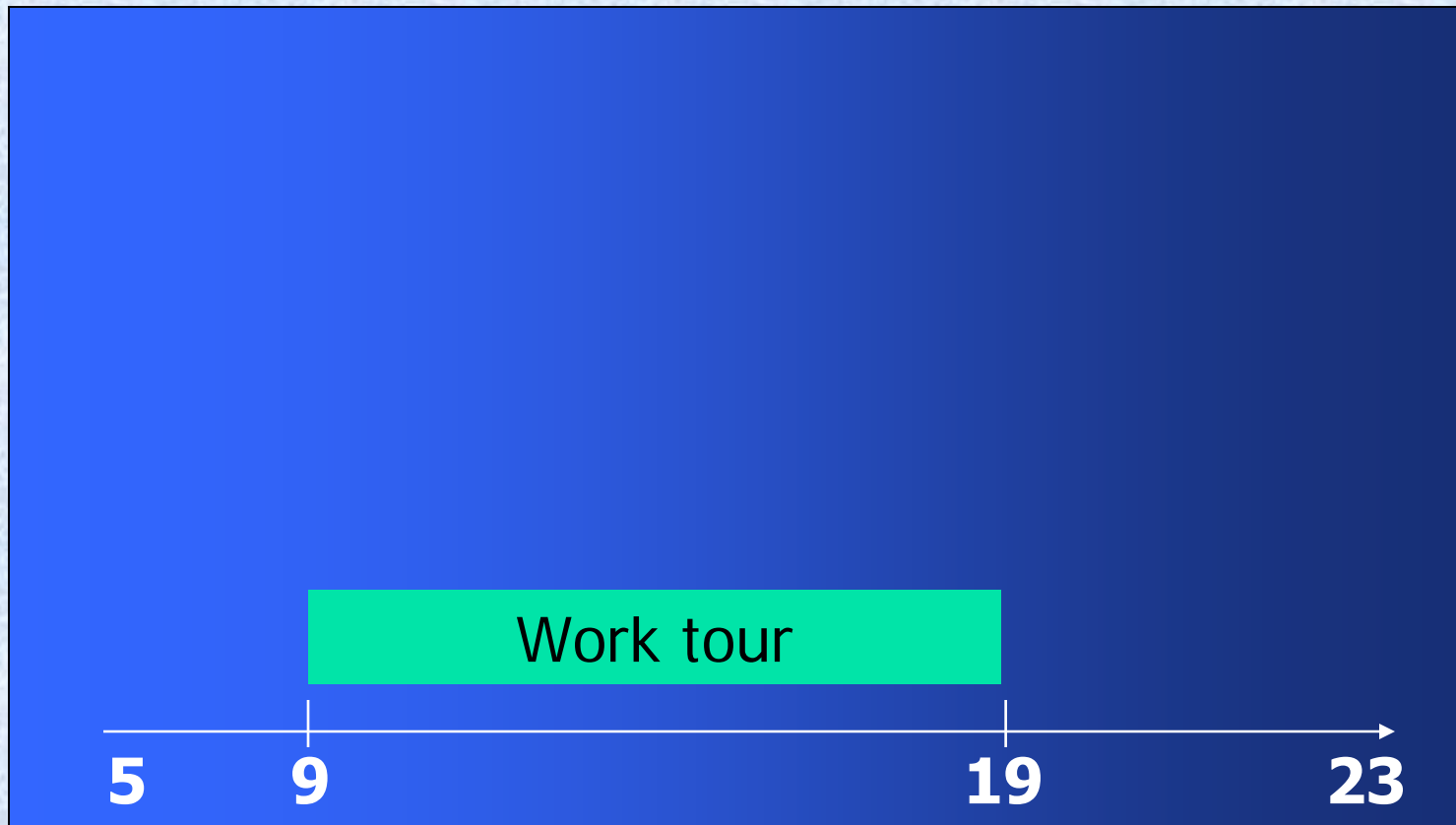
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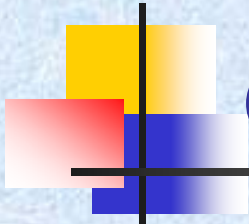




# 6. TOD Choice

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## 6. Time Windows

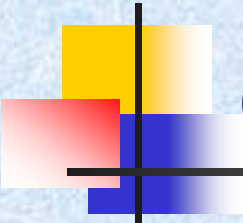
1-Work

*Generate  
mandatory  
tour and  
schedule it*

5

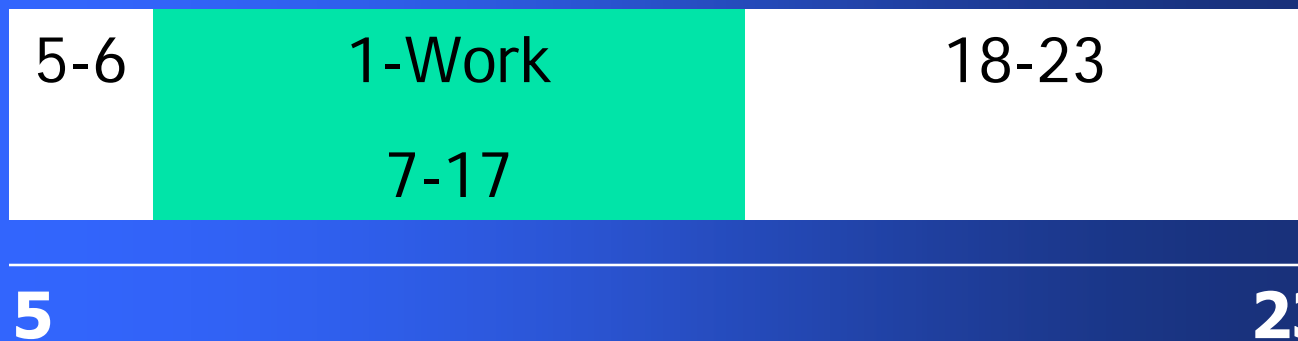
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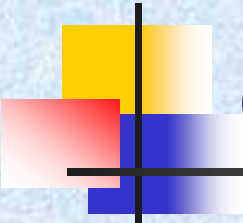




# 6. Time Windows

*Calculate residual time windows*





# 6. Time Windows

2-Discretionary joint

*Generate next activity and schedule it*

5-6

1-Work

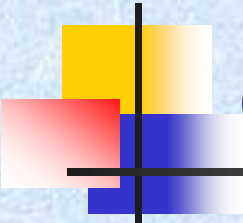
18-23

7-17

5

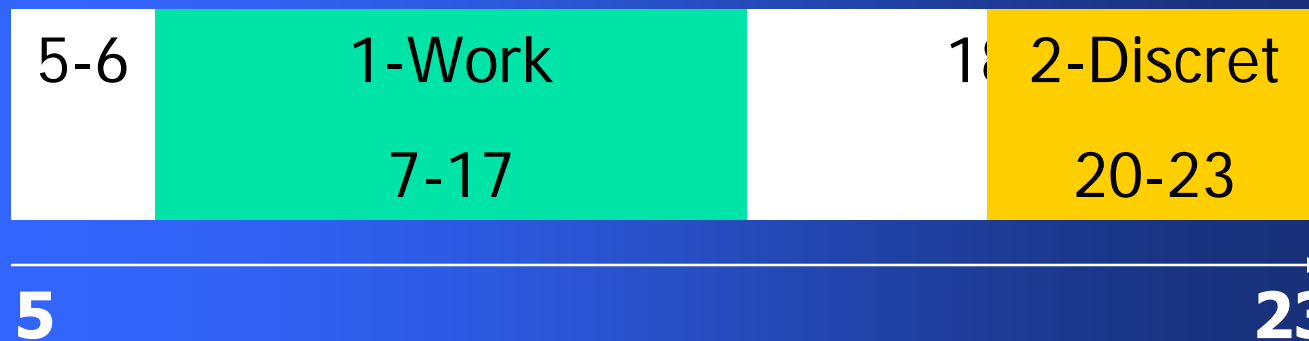
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# 6. Time Windows

*Recalculate residual time windows*

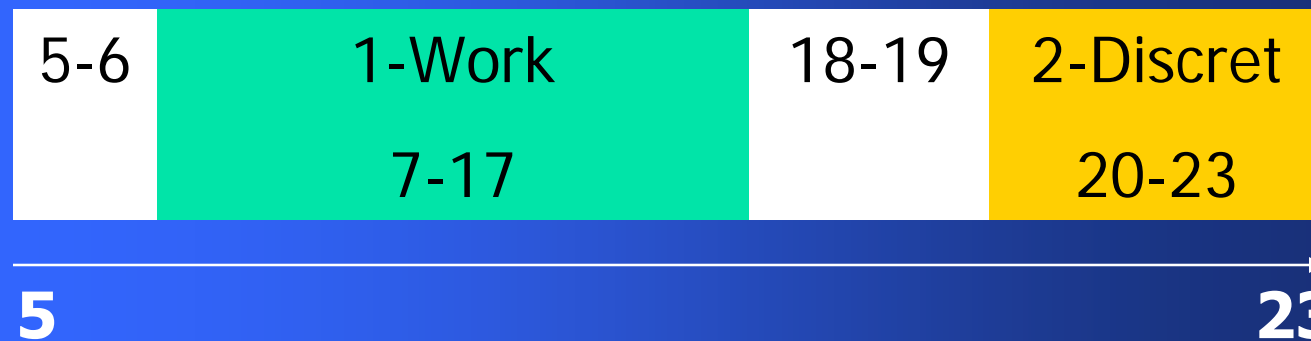




## 6. Time Windows

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*Recalculate residual time windows*



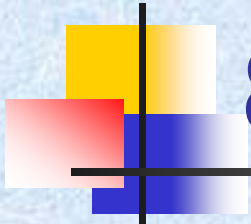


## 7. Entire-Tour Mode

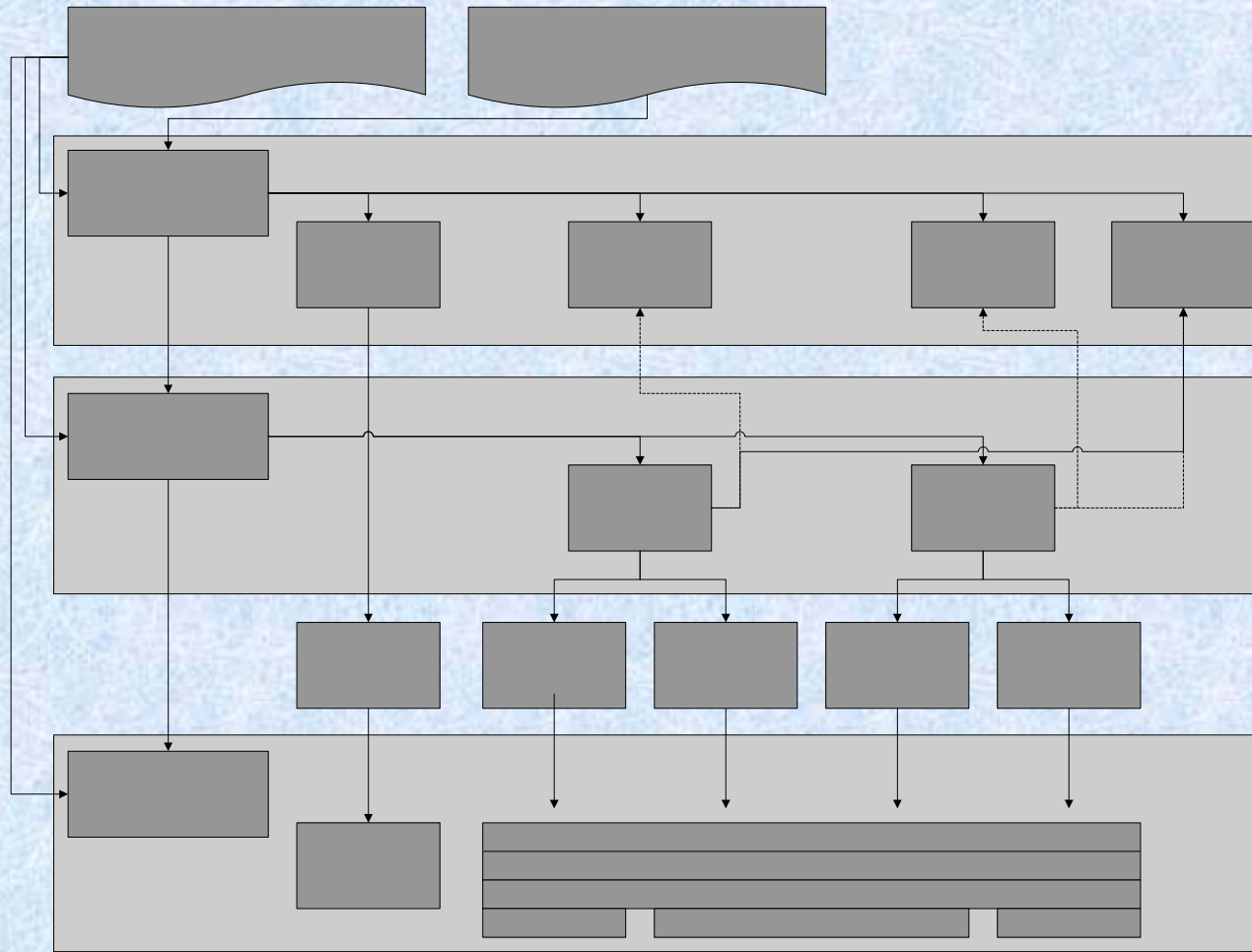
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- Alternatives:
  - SOV (adults and driving-age children)
  - HOV
  - Pure Walk-to-Transit
  - Bi-modal Drive-to-Transit (except for at-work tours)
  - Non-motorized (distance under 3 miles)
  - School bus (for school tours only)
- Conditional upon:
  - Travel purpose and individual/joint setting
  - Primary destination
  - TOD for outbound & inbound half-tours





# 8. Stop Frequency & Location



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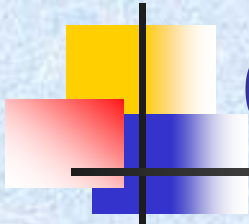


# Programming Implementation

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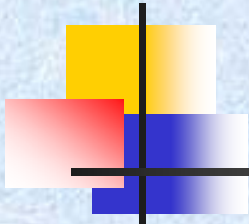


# OOO JAVA Library (CMF)

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- Matrix package:
  - Read/write matrices (EM/2, TransCAD, TP+)
  - Compression of sparse matrices
  - N-dimensional matrix manipulation & balancing
- Discrete choice model package:
  - MNL, NL ...
  - Flexible representation of alternatives
  - Returns probabilities, "crisp" choices, log-sums
- Utility Expression Calculator (UEC):
  - Excel spreadsheet (rows are variables, cols are alternatives)
  - Built-in text parser for math
- Distributed Application Framework (DAF)





# Run Time

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- Two components take 99% of the running time, everything else takes minutes:
  - Location (tour primary destination, stops) choice:
    - $1,800,000 \text{ records} * 6,000 \text{ zones} * 6 \text{ modes} * 100 \text{ variables}$   
= results in 50 hours
  - Multi-class assignment and network skimming procedures:
    - $2,000 \text{ zones} * 2,000 \text{ zones} * 6 \text{ hwy tables} * 4 \text{ TOD}$  = results in 6-12 hours
- Solutions:
  - Pre-sampling of zones
  - Parallel processing



# Calibration Validation & Application

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# Calibration & Validation Steps

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- All core models were estimated based on the HIS and **internally** validated against the surveyed population (5,555 HHs) with very good results
- Then model was applied for base year synthetic population (613,000 HHs) and **externally** validated against traffic counts, transit on-board survey, CTPP tables, and expanded HIS
- External validation has revealed several discrepancies that required **adjustments** (and deviation from the HIS statistics):
  - Make up for under-reported non-mandatory (short, off-peak) activities/trips (VMT regulation)
  - Eliminate relative over-prediction of transit tours in HIS extremely small sub-sample of <200 (Transit regulation by OB)
  - Line up transit share by income groups (CTPP)





# Adjustment Check-List

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1. Car ownership – no adjustment
2. DAP – Licking county (+5%)
3. Joint travel – no adjustment
4. Individual non-mandatory (+10%)
5. Primary destination (minor distance scaling and several CBD K-factors)
6. TOD – no adjustment
7. Tour mode (transit constants)
8. Stop frequency, stop location, and trip mode – no adjustment



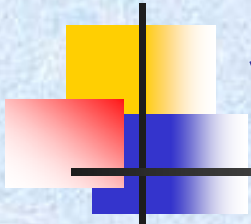


# General Observation

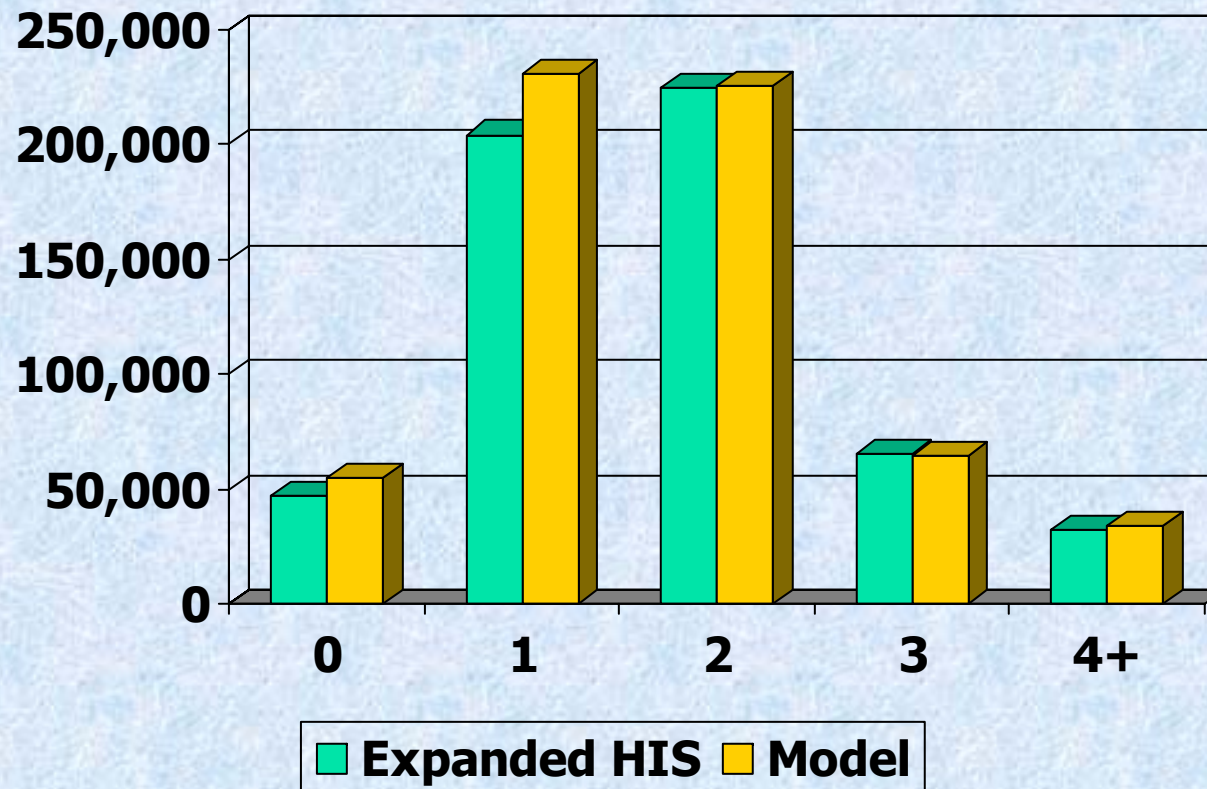
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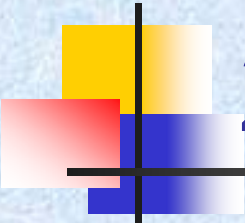
- Activity-based tour-based model is more difficult to calibrate than conventional 4-step model:
  - Everything is interconnected across travel segments and TOD periods
  - Mechanical adjustments of trip tables are meaningless
- However, eventually only a limited number of parameters have to be adjusted:
  - Model structure itself takes care on most logical interdependencies and prevents from illogical adjustments
  - The model “pushes” you to think in conceptual terms and understand travel behavior



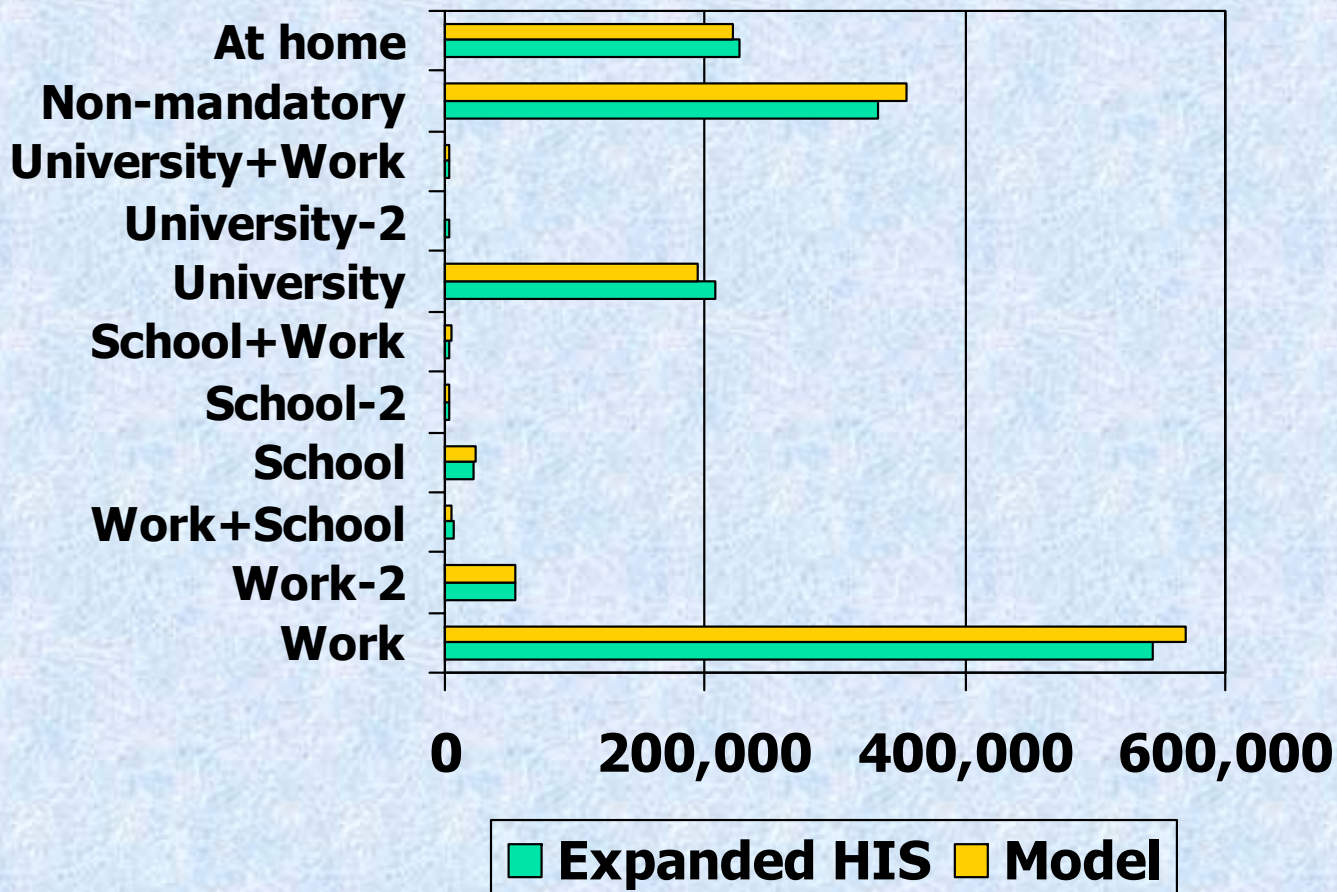


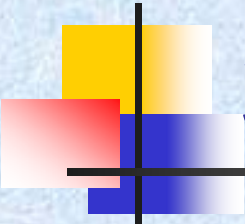
# 1. HH Car Ownership



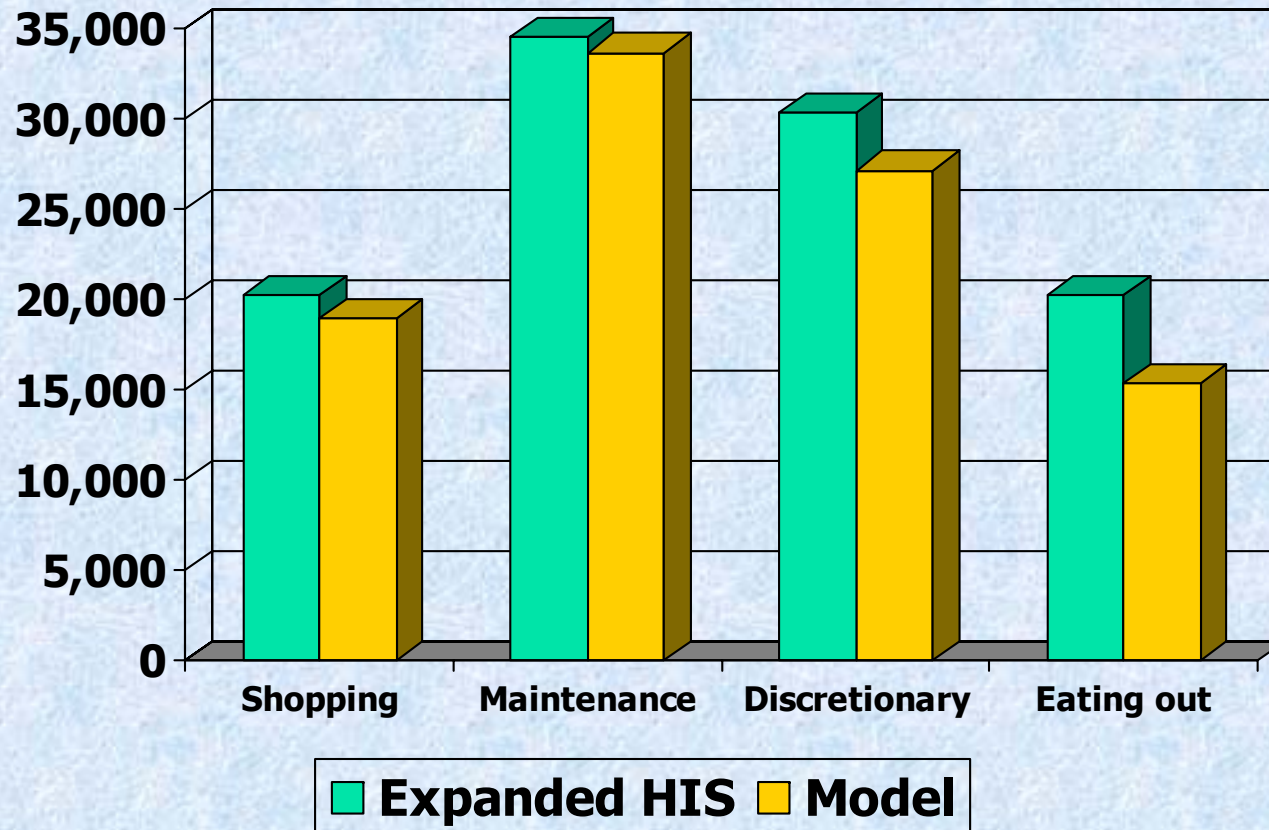


## 2. Daily Activity Pattern

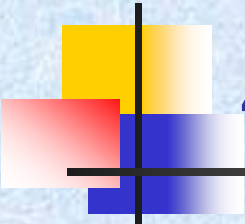




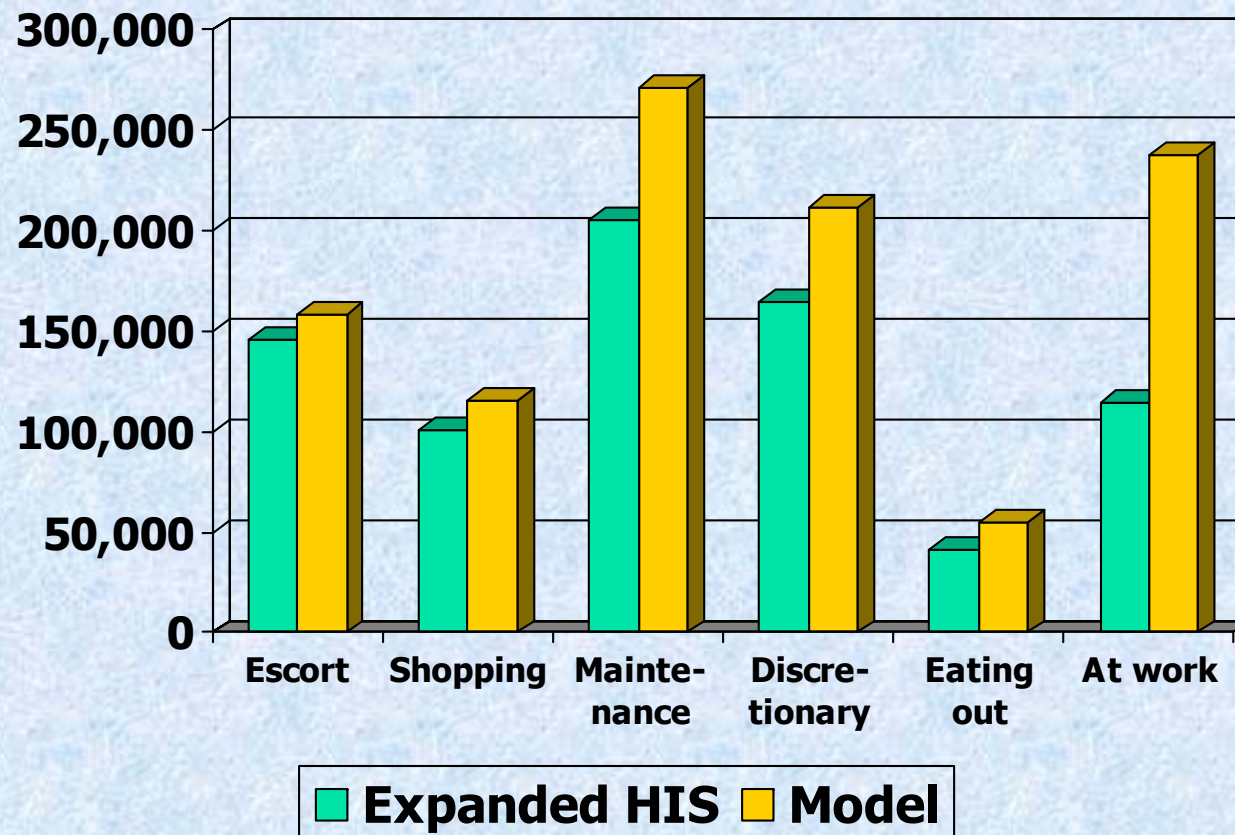
# 3. Joint Tours

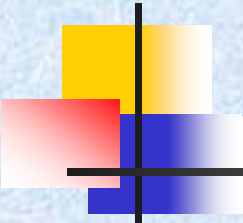


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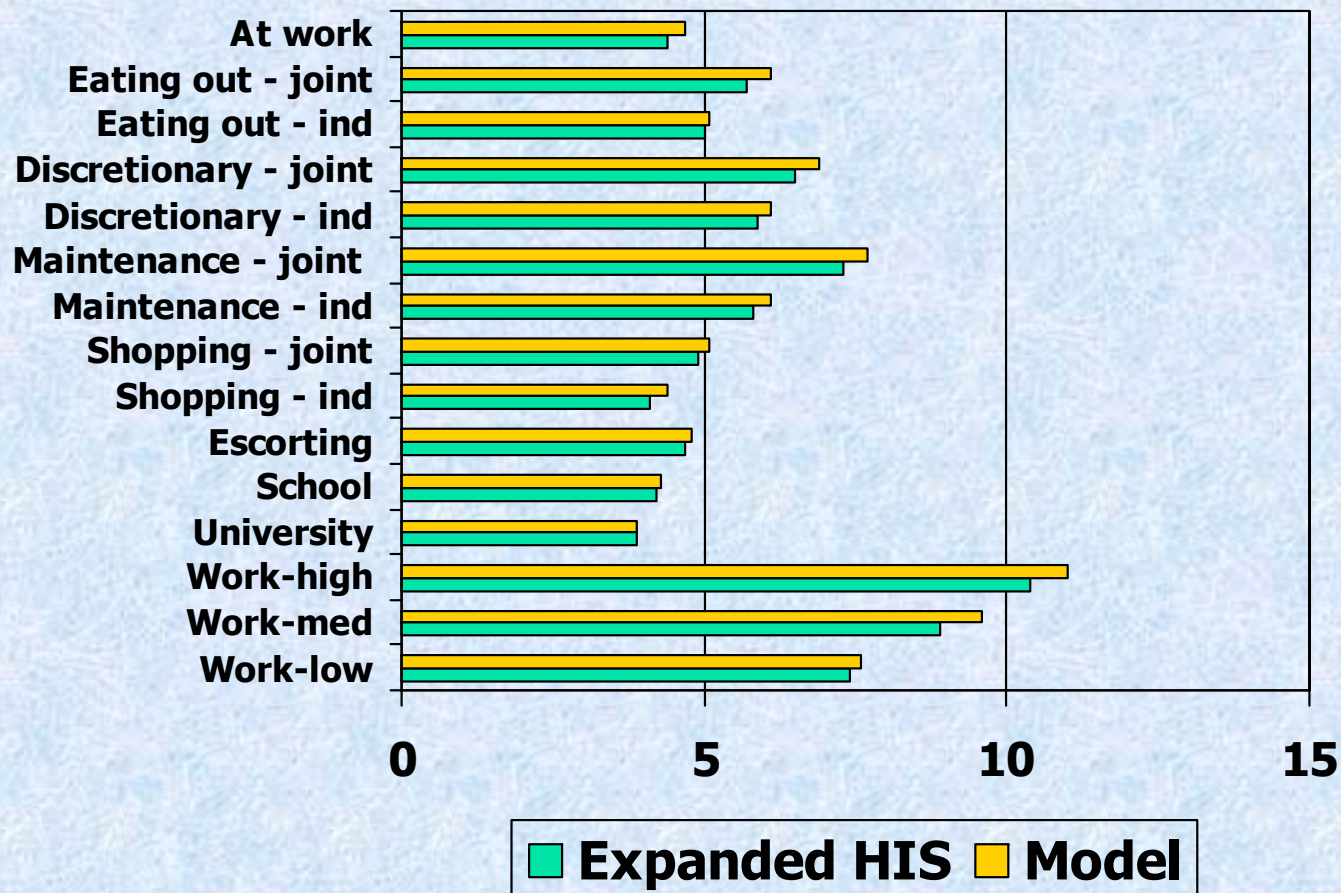


## 4. Individual Non-Mand. Tours

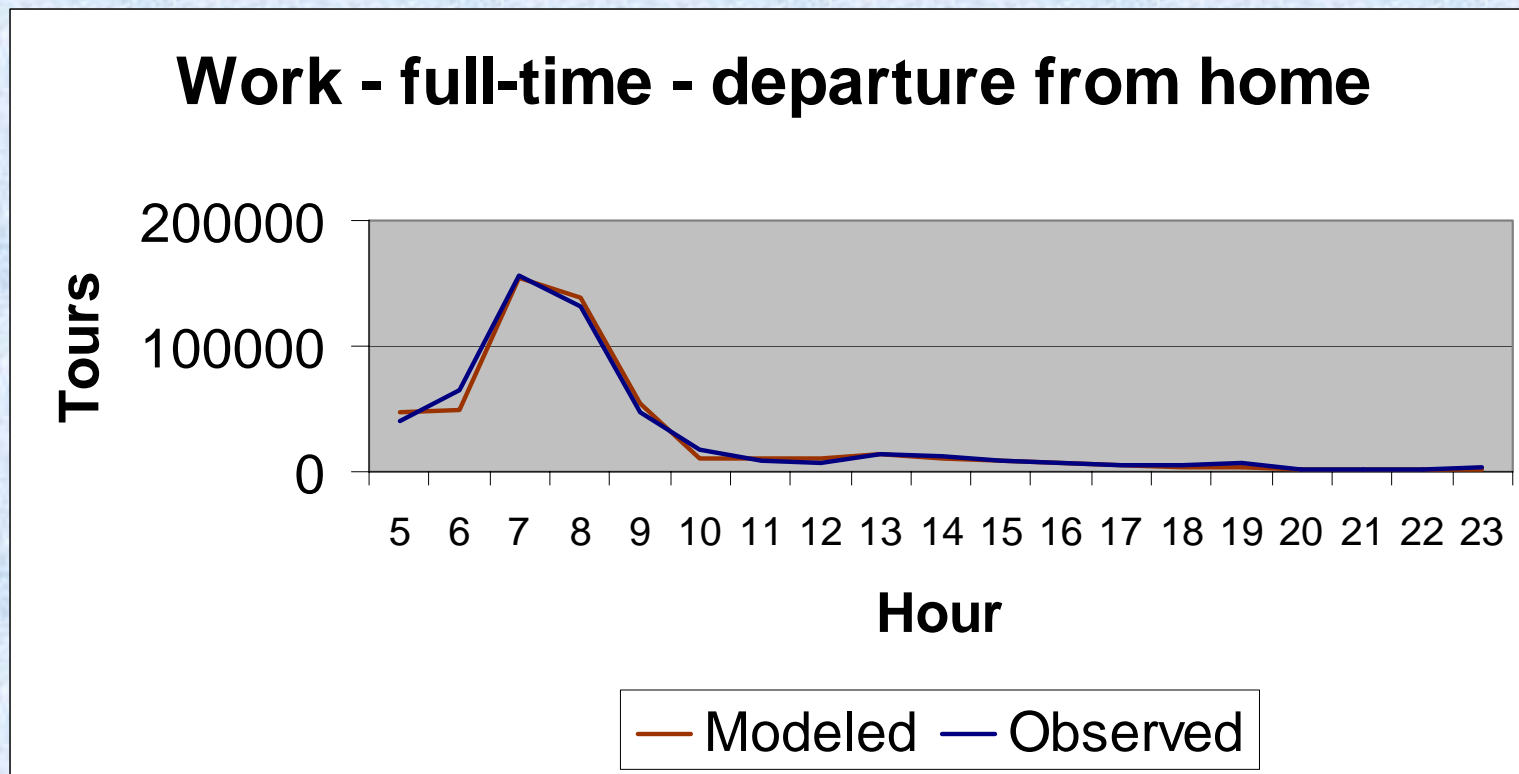


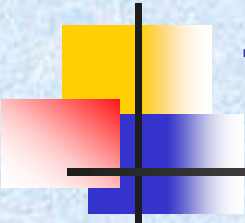


# 5. Destination (Tour Length)

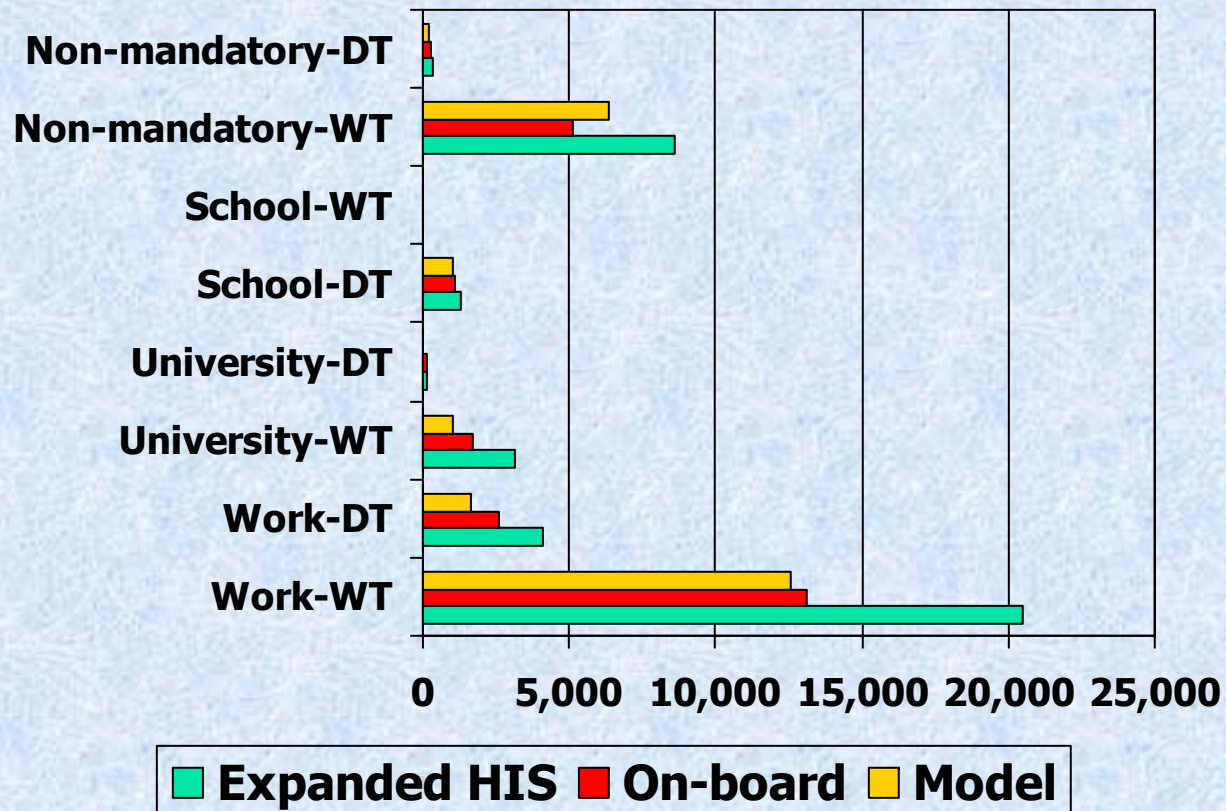


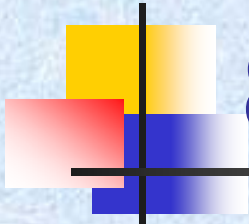
## 6. TOD – Work / Departure





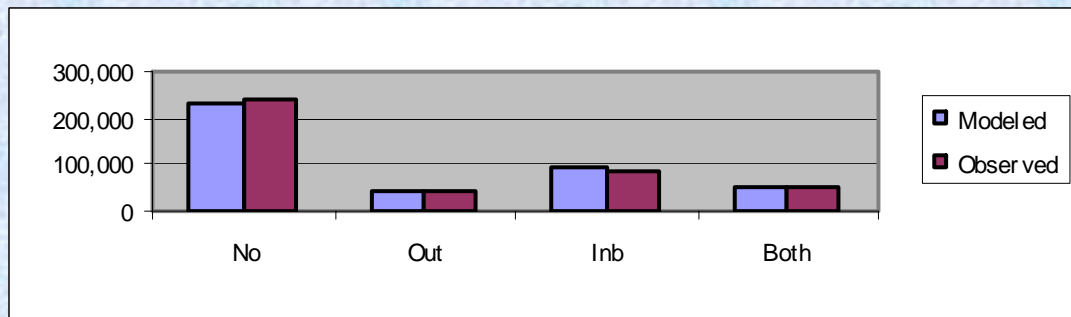
# 7. Tour Mode Choice



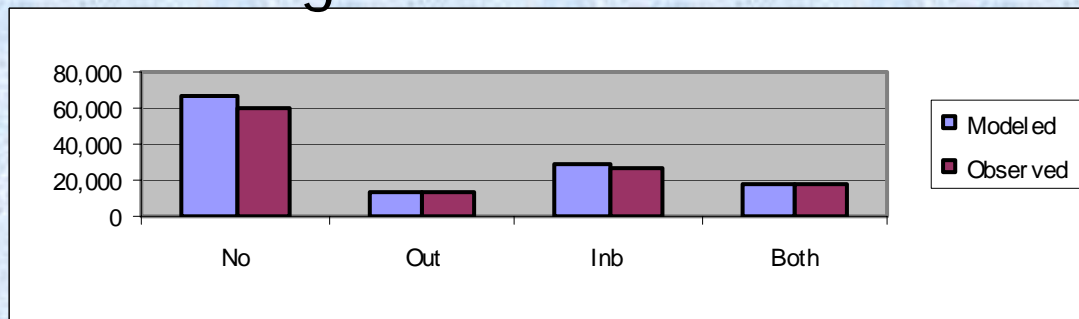


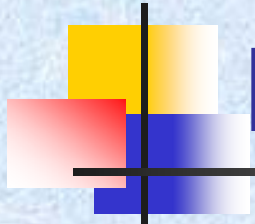
# 8. Stop Frequency

## Work – medium income



## Work – high income



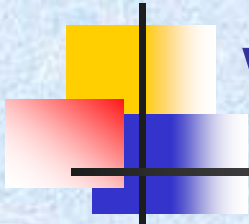


# Highway Validation Criteria

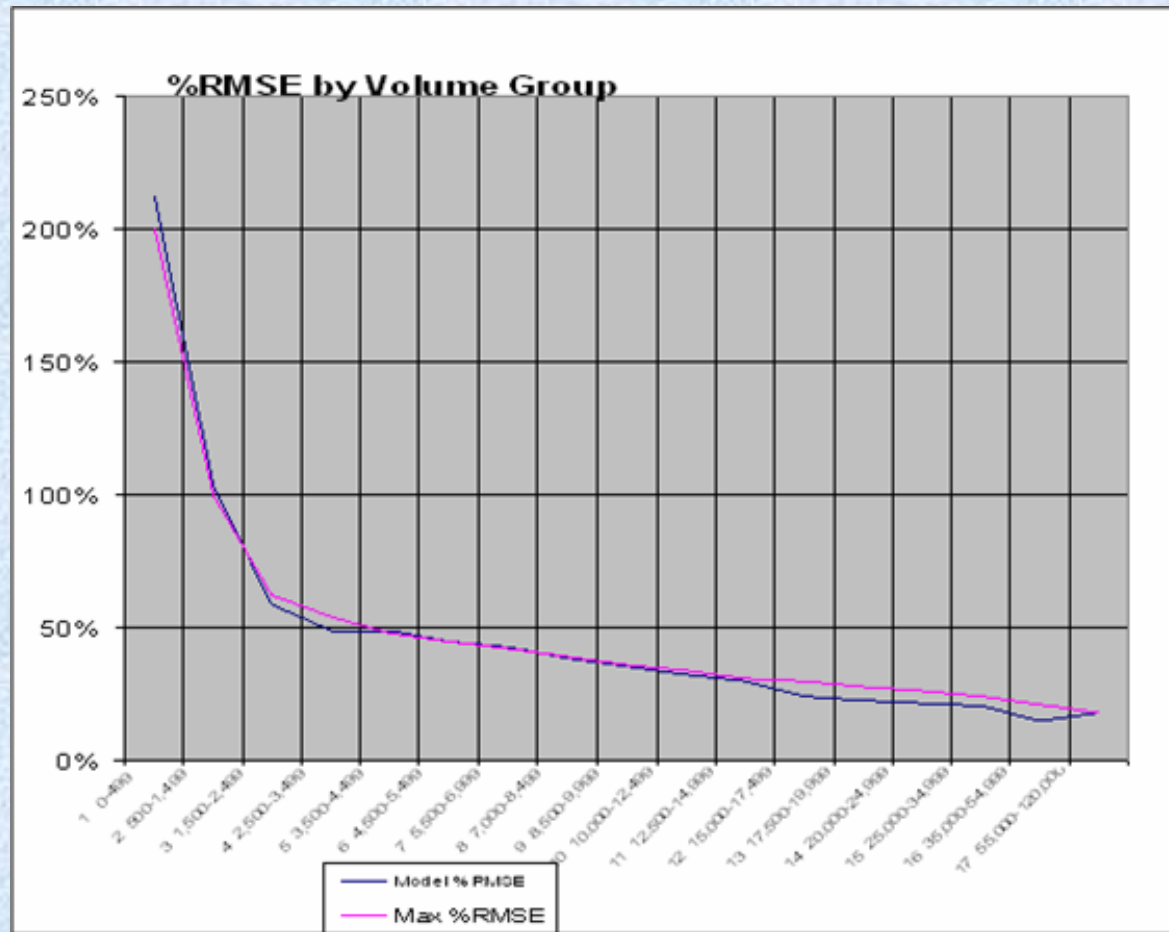
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- ODOT compliant measures
  - Volume Group - %RMSE
  - Facility Group – VMT difference
  - Screenline – volume / count deviance
- Other Geographic aggregations
  - Rings, Sectors, Super Districts

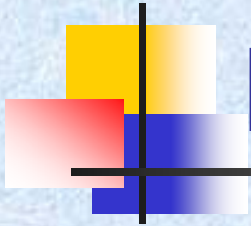




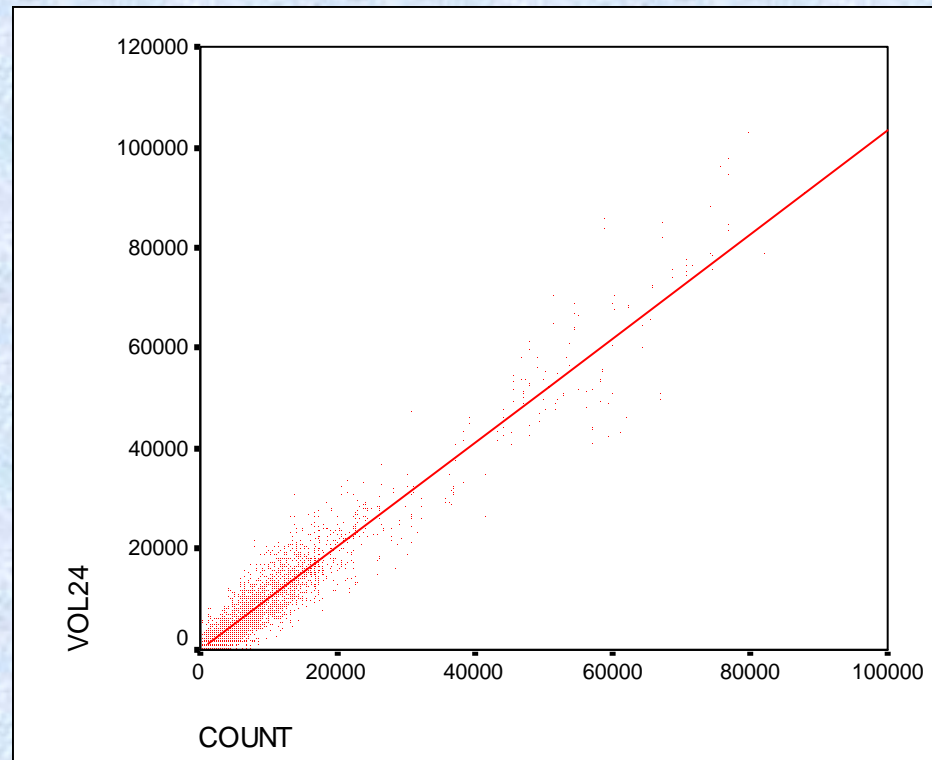
# Volume-Group



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$R=0.96$

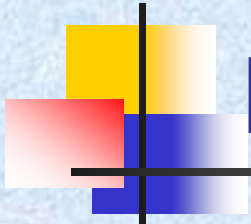


# Followers & Further Improvements

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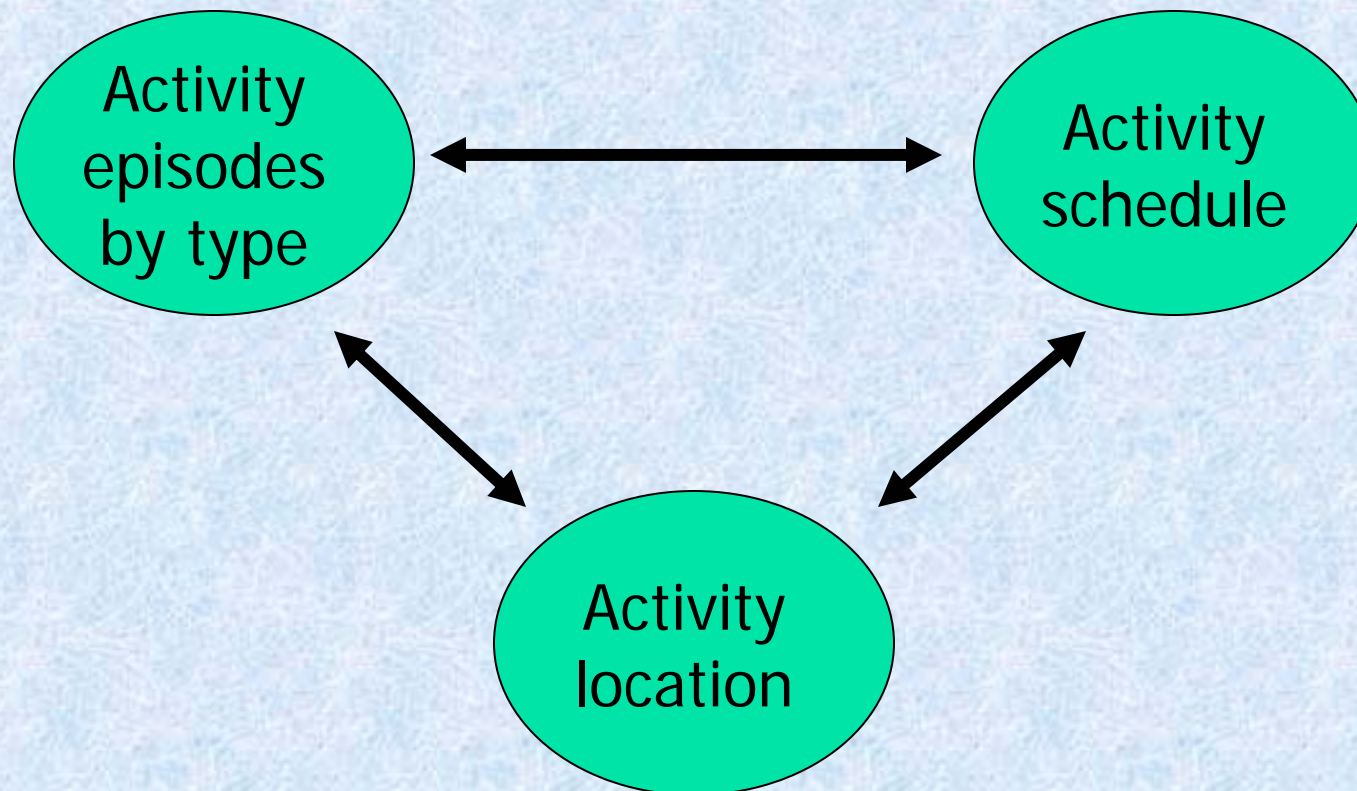
## From MORPC on ...

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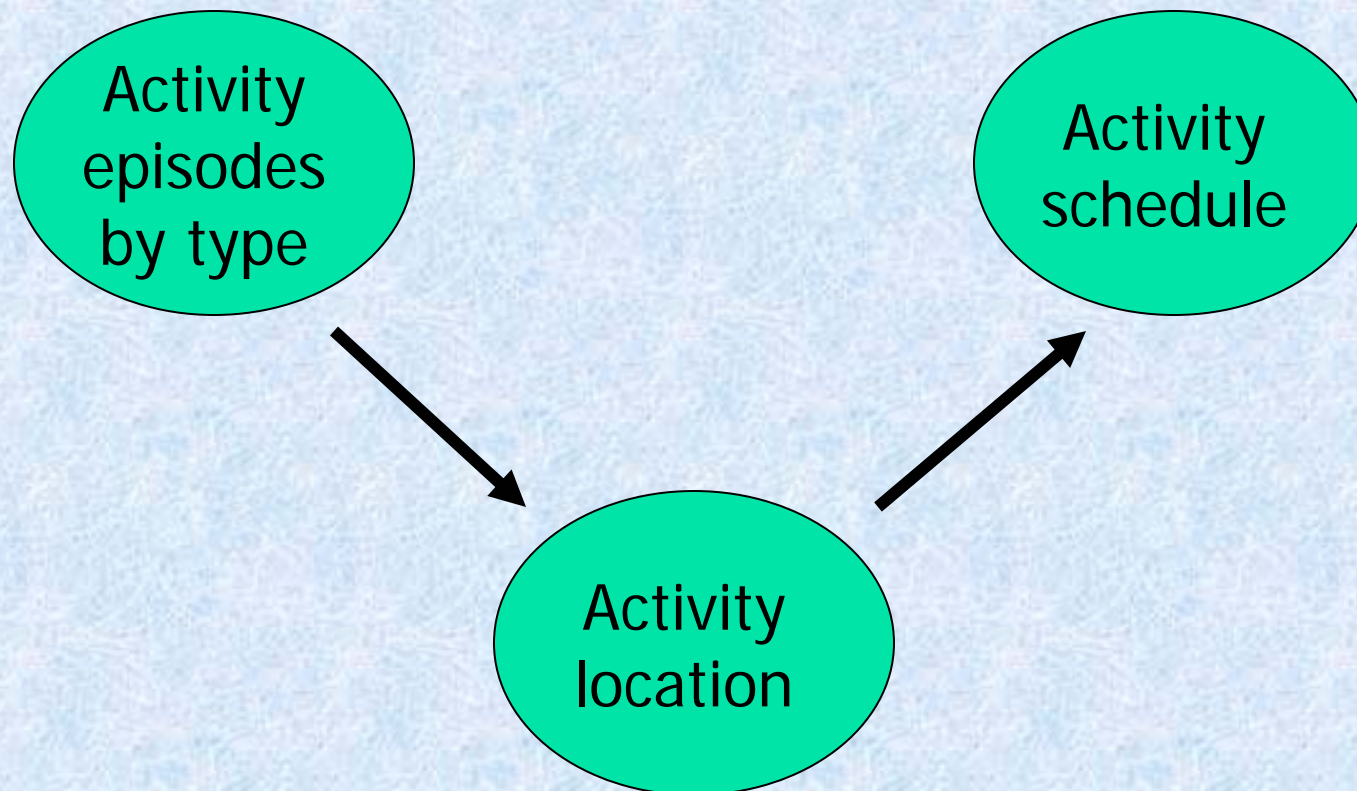
- Open “seed” structure from which future systems are pivoted off
- ARC and DRCOG (vision stage) designs are based on MORPC+
- Grand synthesis with academic research:
  - FAMOS (time-space prisms)
  - CEMDEP (continuous duration models)
  - ILUTE (decision-making process)
  - ALBATROSS (learning & multi-day framework)



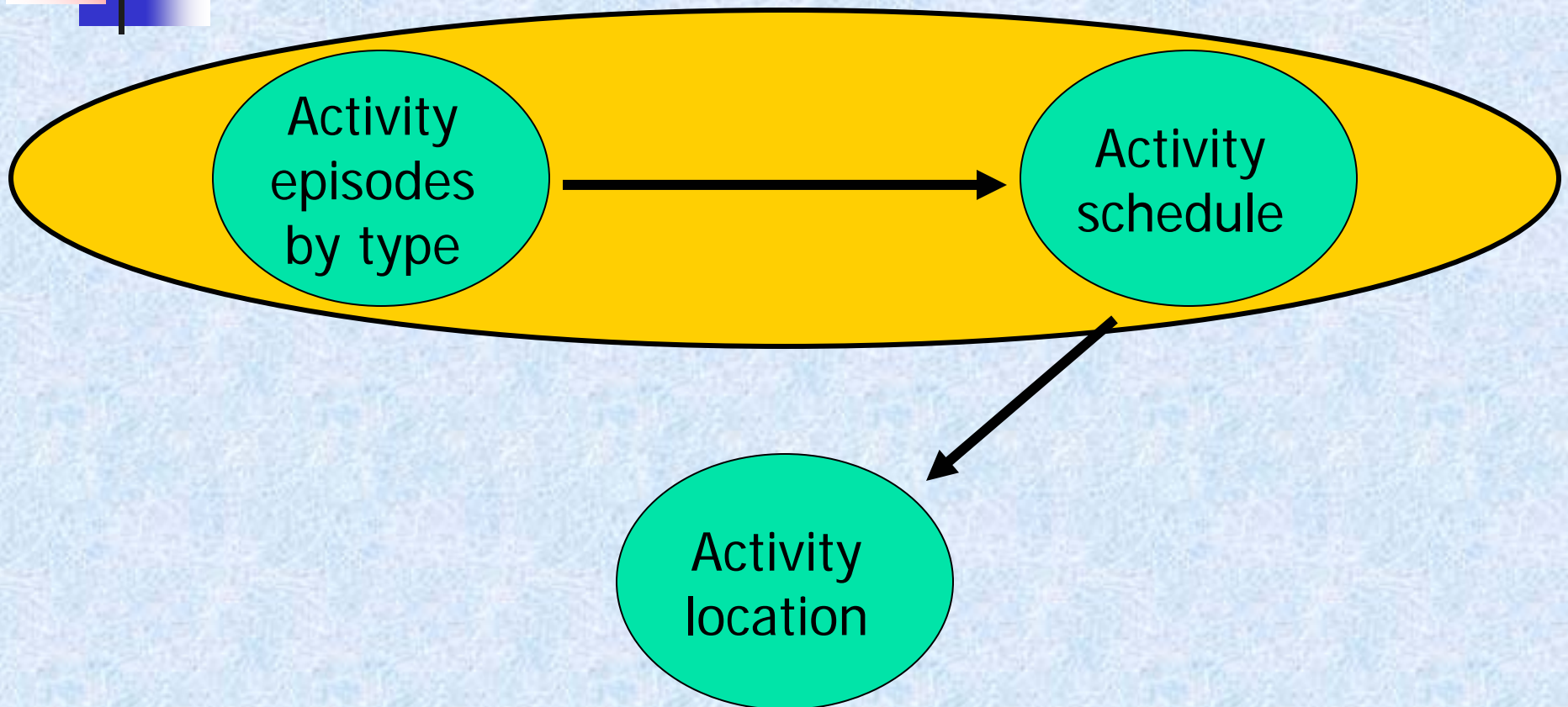
# Better Balance between Dimensions



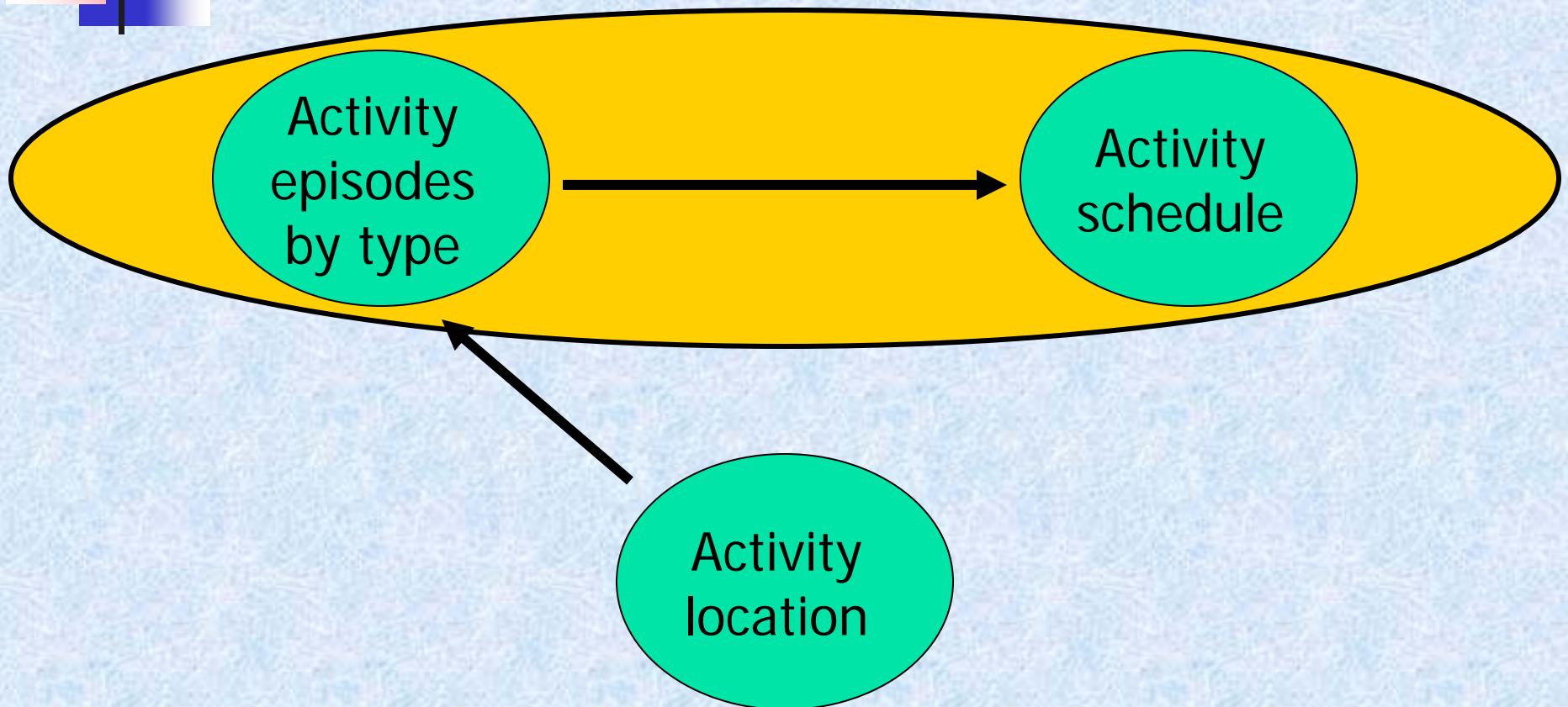
# Better Balance between Dimensions – Applied Models



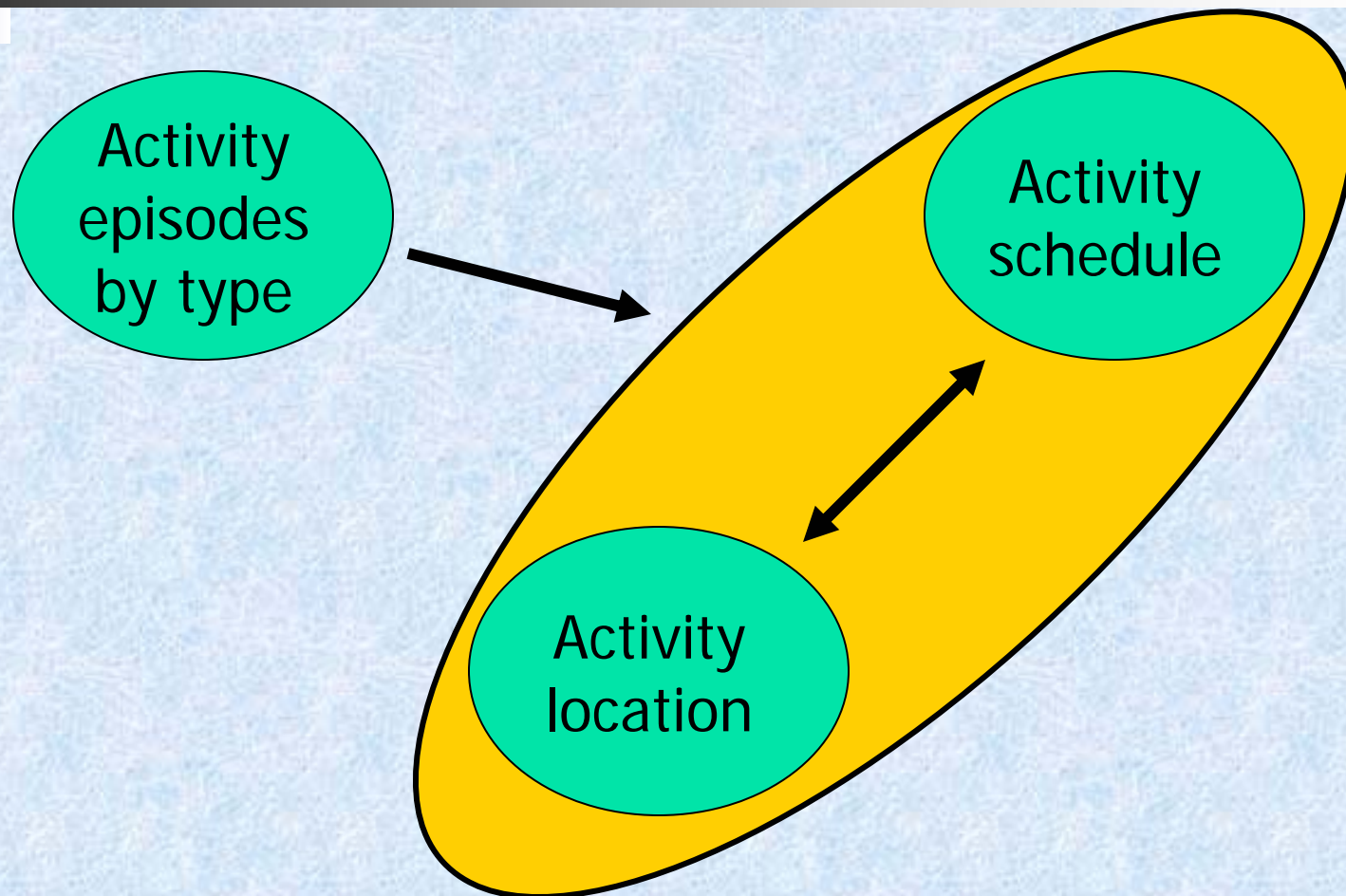
# Better Balance between Dimensions – Activity Research



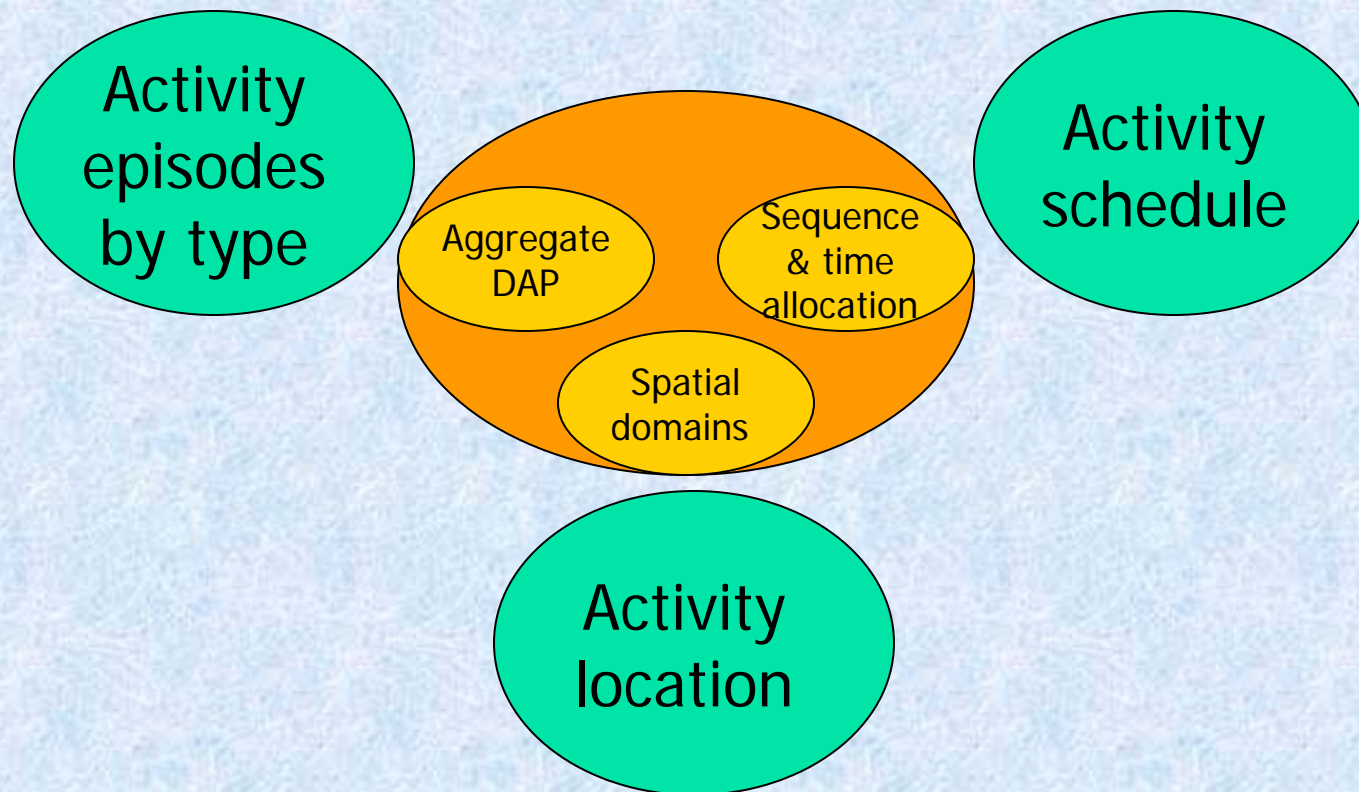
# Better Balance between Dimensions – Activity Research

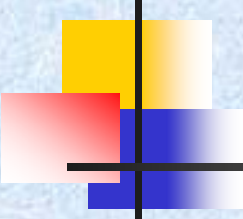


# Better Balance between Dimensions – Time-Space



# Better Balance between Dimensions – Full Integration





# Better Balance between Dimensions – Full Integration

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- Aggregate DAP:
  - Pure mandatory (work/school)
  - Pure non-mandatory travel
  - Mixed
  - Staying at home
- Sequencing and time allocation:
  - Time allocation to mandatory / non-mandatory / home
  - Position of non-mandatory versus mandatory (before / after)
- Spatial domains:
  - Near home
  - Near workplace
  - Usual major shopping / leisure location



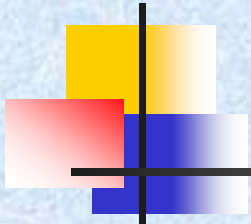


# General Conclusions

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# It Works!

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- We have not found a single principal pitfall or drawback in activity-based models
- Performance is better than of 4-step models
- Conceptual and programming complexity is significantly higher compared to 4-step, but not crucial
- Running times are comparable with decent 4-step models that include all modes and TOD periods



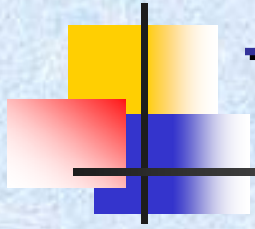


# What Should be Done

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- Travel demand modeling is not a market place – regulations / subsidies are needed
- 50/50 MPO/Feds matching funds for new model development
- Model QC & requirements and more active position of FTA/FHWA/TRB, etc
- Demonstration projects with parallel implementation and comparison of 4-step and activity-based models
- Gradual transition from 4-step to activity-based models





# Thank You for Your Attention!

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# Q?

