CMAP Advanced Travel Model Cadre

Implementation & Computing Environment for Advanced Travel Model

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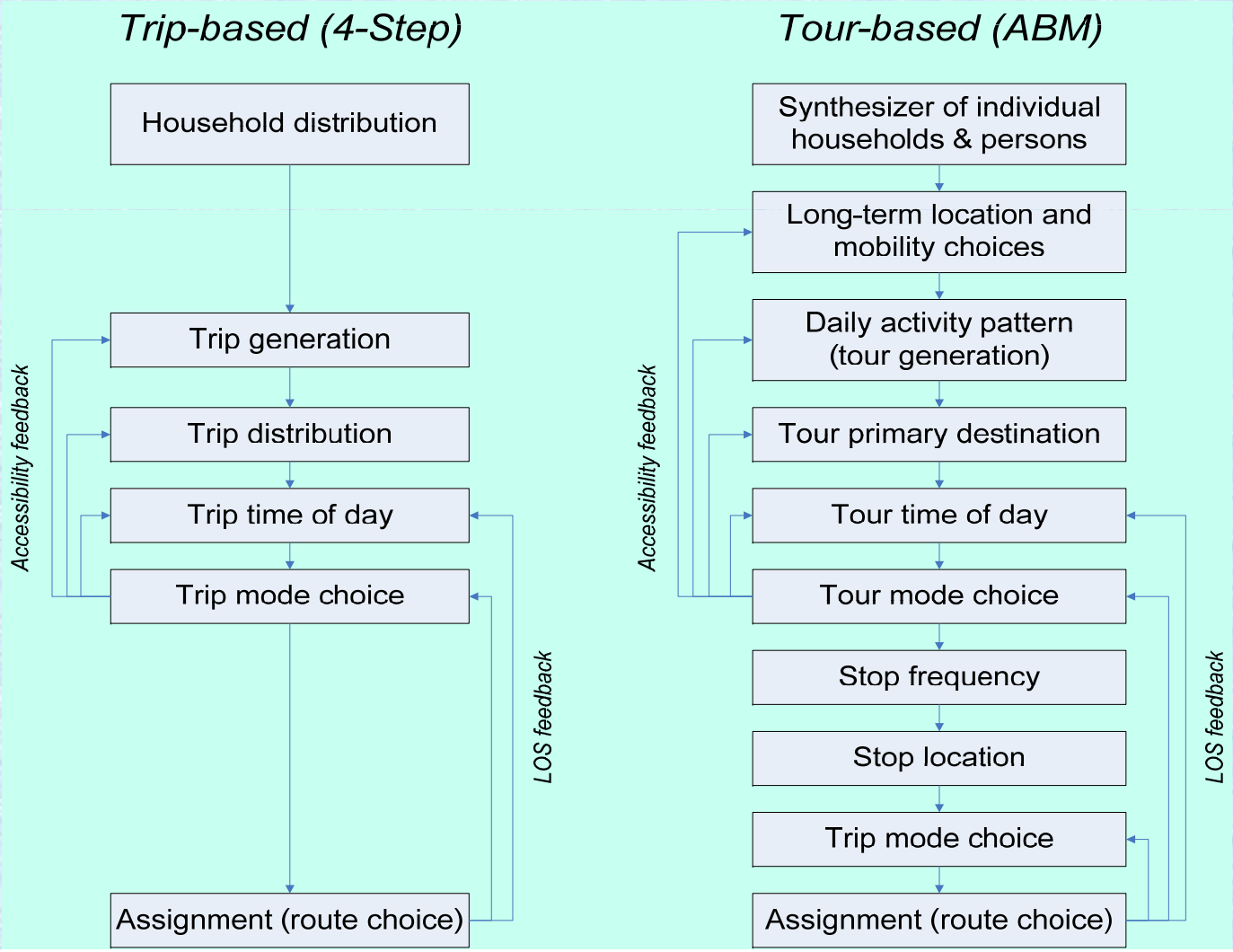
1. Model Features, Algorithms, and Types of Calculations

1.1. Computational Specifics of Advanced ABM Compared to 4-Step

3 Main Features of ABM

- Individual microsimulation:
  - Principally different flow of calculations
  - More parsimonious compared to aggregate
- Tour-based:
  - Adds new dimensions and constraints, specifically for trip distribution and mode choice
- Activity-based:
  - Adds new dimensions and constraints, specifically w.r.t temporal dimension

Typical Model Structures



1.2. Essence and Advantages of Individual Microsimulation

Advantages of Microsimulation

- Savings in calculation and storage of multi-dimensional probability arrays
- Unlimited segmentation of population and travel
- Behaviorally-realistic decision chains and individual time-space constraints
- Realistic variation of individual parameters (like VOT)
- Explicitly modeling variability of travel demand

How Does It Really Work?

- Complexity, data needs, and revolutionary character of ABM are frequently overstated
- In reality, the model structure follows a limited number of simple principles and the model outcome looks like a large HH survey
- Innovative technical features easily understood by 4-step modelers

Operational Implementation

Zonal Socio-Economic Data

TAZ	HHs	HH size	…
1	3	3.3	…
2	200	2.4	…
…	…	…	…

Operational Implementation

List of synthetic households

TAZ	HHs	HH size	…
1	3	3.3	…

Operational Implementation

List of synthetic households

TAZ	HH	HH size	…
1	1	3	…
	2	3	…
	3	4	…

Operational Implementation

List of persons by type

TAZ	HH	HH size	…
1	1	3	…

Operational Implementation

List of persons by type

TAZ	HH	Person	…
1	1	Worker	…
		Non-w	…
		Child	…

Operational Implementation

List of tours by purpose

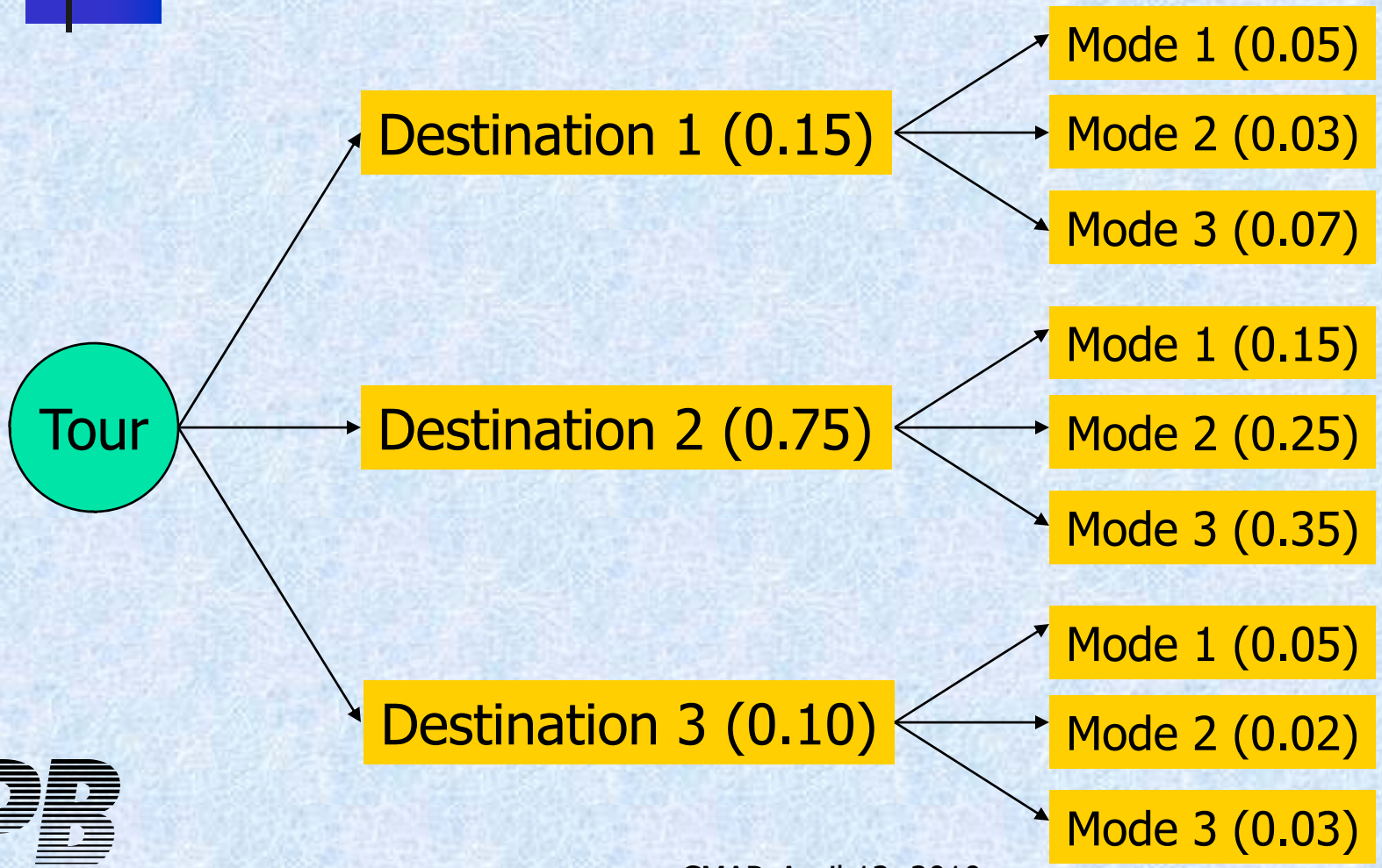
TAZ	HH	Person	Tour
1	1	Worker	Work
			Shop

Operational Implementation

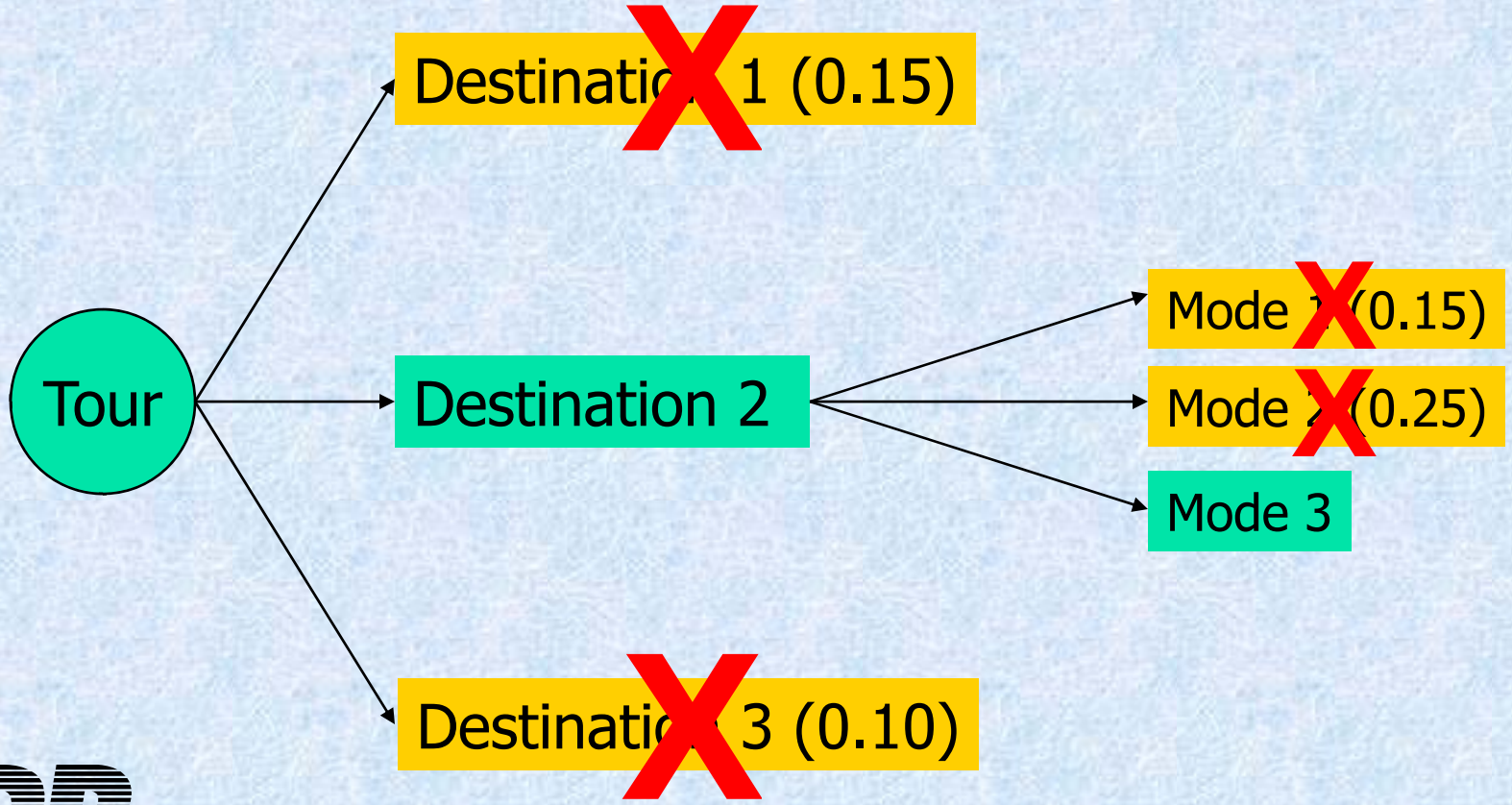
Mode & destination for each tour

TAZ	HH	Person	Tour	Dest	Mode
1	1	Worker	Work	TAZ 10	SOV
			Shop	TAZ 20	WT

Fractional Probability



Microsimulation



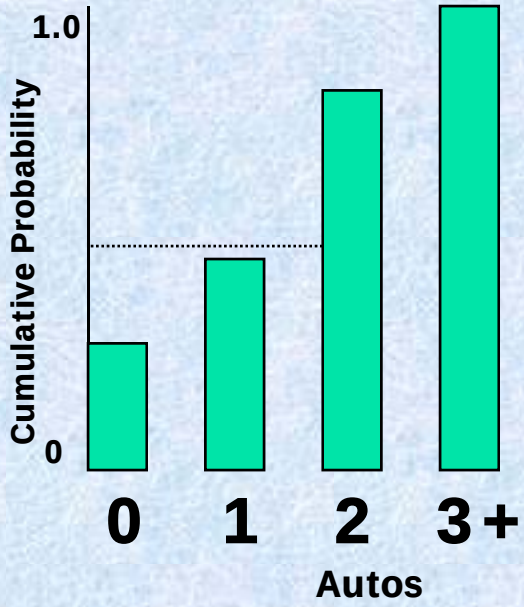
Monte Carlo Simulation Example – Car Ownership

Autos	Utility	Exp(Utility)	Probability	Cumulative Probability
0	0	1.0000	0.0570	0.0570
1	1.7	5.4739	0.3122	0.3692
2	2	7.3891	0.4215	0.7907
3+	1.3	3.6693	0.2093	1.0000
Sum		17.5323	1.0000	

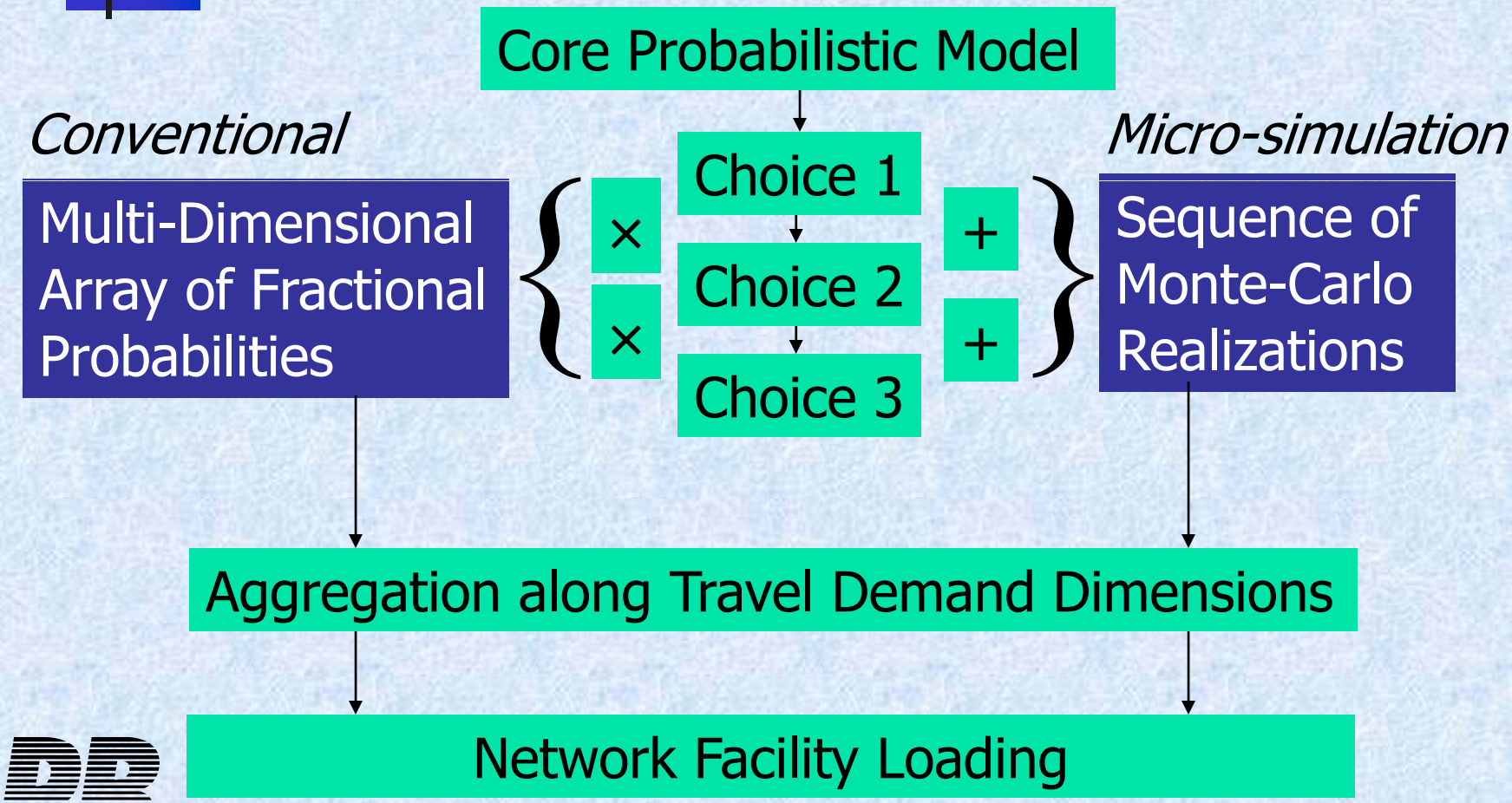
> 0.3897 ?

Random Number Draw = 0.3897

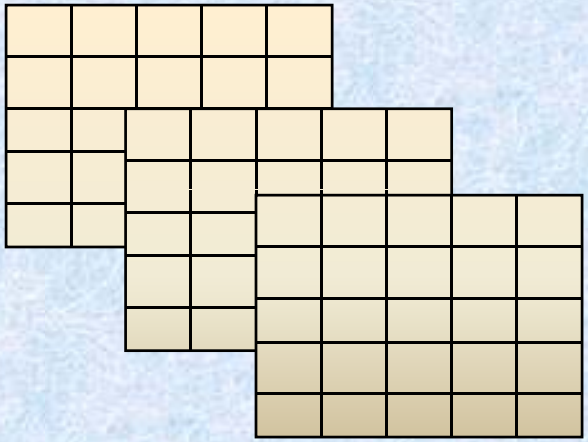
= 2 autos



Essence of Micro-Simulation



Trip-Based Models



- One set of calculations per cell
- Each market segment = new set of trip tables
- **More markets = more calculations**

Micro-simulation

HID	PID	AUT	INC	WRK	GEN	AGE	EMP
1	1	1	3	1	0	24	1
1	2	1	3	0	1	23	0
1	3	1	3	0	1	3	0
2	1	2	4	2	0	32	1
2	2	2	4	2	1	34	1
3	1	3	2	2	0	49	1
3	2	3	2	2	1	47	1
3	3	3	2	2	1	15	0
3	4	3	2	2	0	12	1

- One set of calculations per agent
- Each market segment = new column
- **More markets = no additional calculations**

Person Types

NUMBER	PERSON-TYPE	AGE	WORK STATUS	SCHOOL STATUS
1	Full-time worker	18+	Full-time	None
2	Part-time worker	18+	Part-time	None
3	Non-working adult	18 – 64	Unemployed	None
4	Non-working senior	65+	Unemployed	None
5	College student	18+	Any	College +
6	Driving age student	16-17	Any	Pre-college
7	Non-driving student	6 – 16	None	Pre-college
8	Pre-school	0-5	None	None

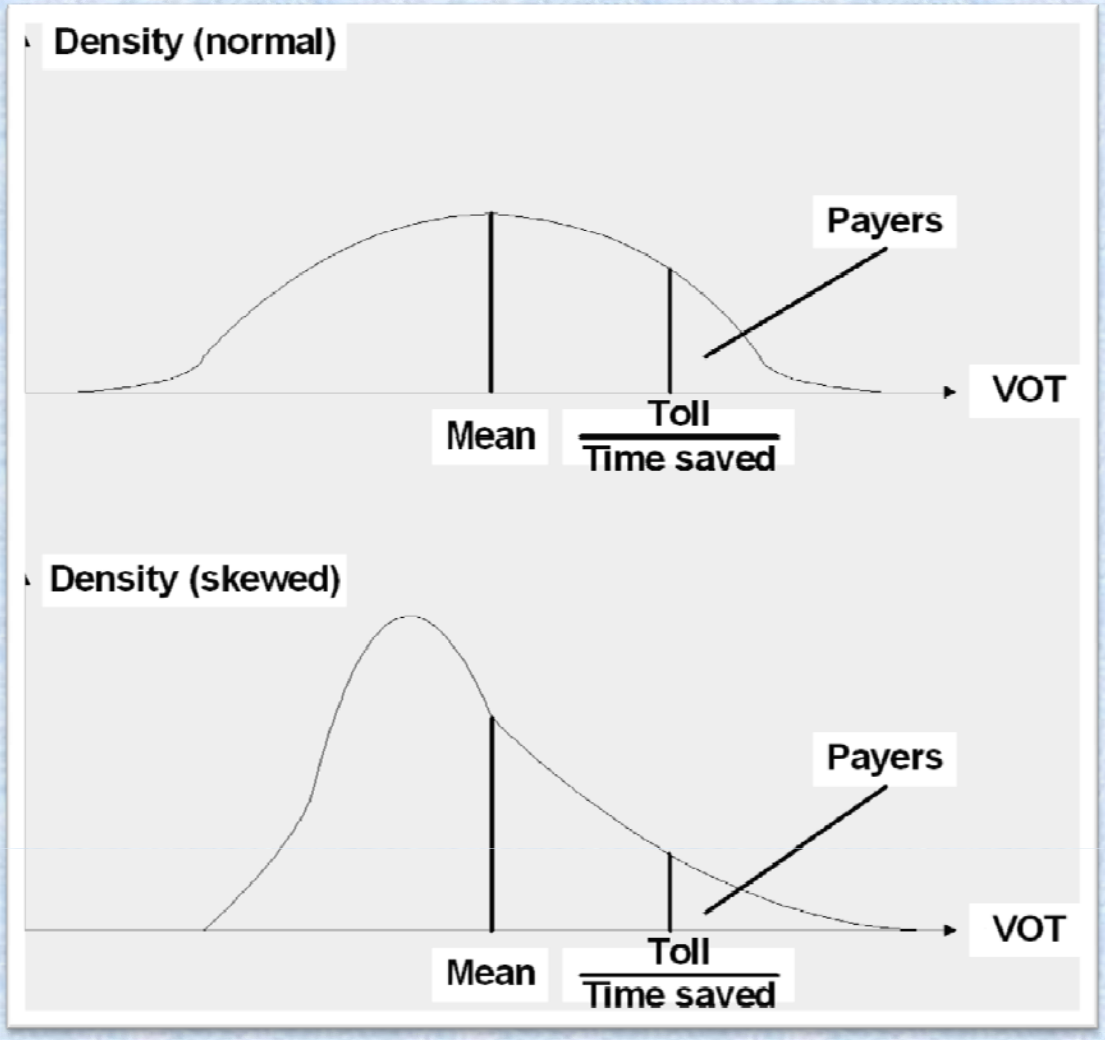
Activity Types

TYPE	PURPOSE	DESCRIPTION	CLASSIFICATION	ELIGIBILITY
1	Work	Working at regular workplace or work-related activities outside the home.	Mandatory	Workers and students
2	University	College +	Mandatory	Age 18+
3	High School	Grades 9-12	Mandatory	Age 14-17
4	Grade School	Grades K-8	Mandatory	Age 5-13
5	Escorting	Pick-up/drop-off passengers (auto trips only).	Maintenance	Age 16+
6	Shopping	Shopping away from home.	Maintenance	5+ (if joint travel, all persons)
7	Other Maintenance	Personal business/services, and medical appointments.	Maintenance	5+ (if joint travel, all persons)
8	Social/Recreational	Recreation, visiting friends/family.	Discretionary	5+ (if joint travel, all persons)
9	Eat Out	Eating outside of home.	Discretionary	5+ (if joint travel, all persons)
10	Other Discretionary	Volunteer work, religious activities.	Discretionary	5+ (if joint travel, all persons)

Individual Parameter Variation

- IPV technique was successfully used for probabilistic VOT (SF) and license plate rationing (NY)
- IPV can be used in a similar way for all types of payment media and individual discounts
- The alternative to IPV is an explicit model segmentation that quickly runs into infeasible number of segments
- IPV requires a microsimulation framework; it can also be applied for network simulations

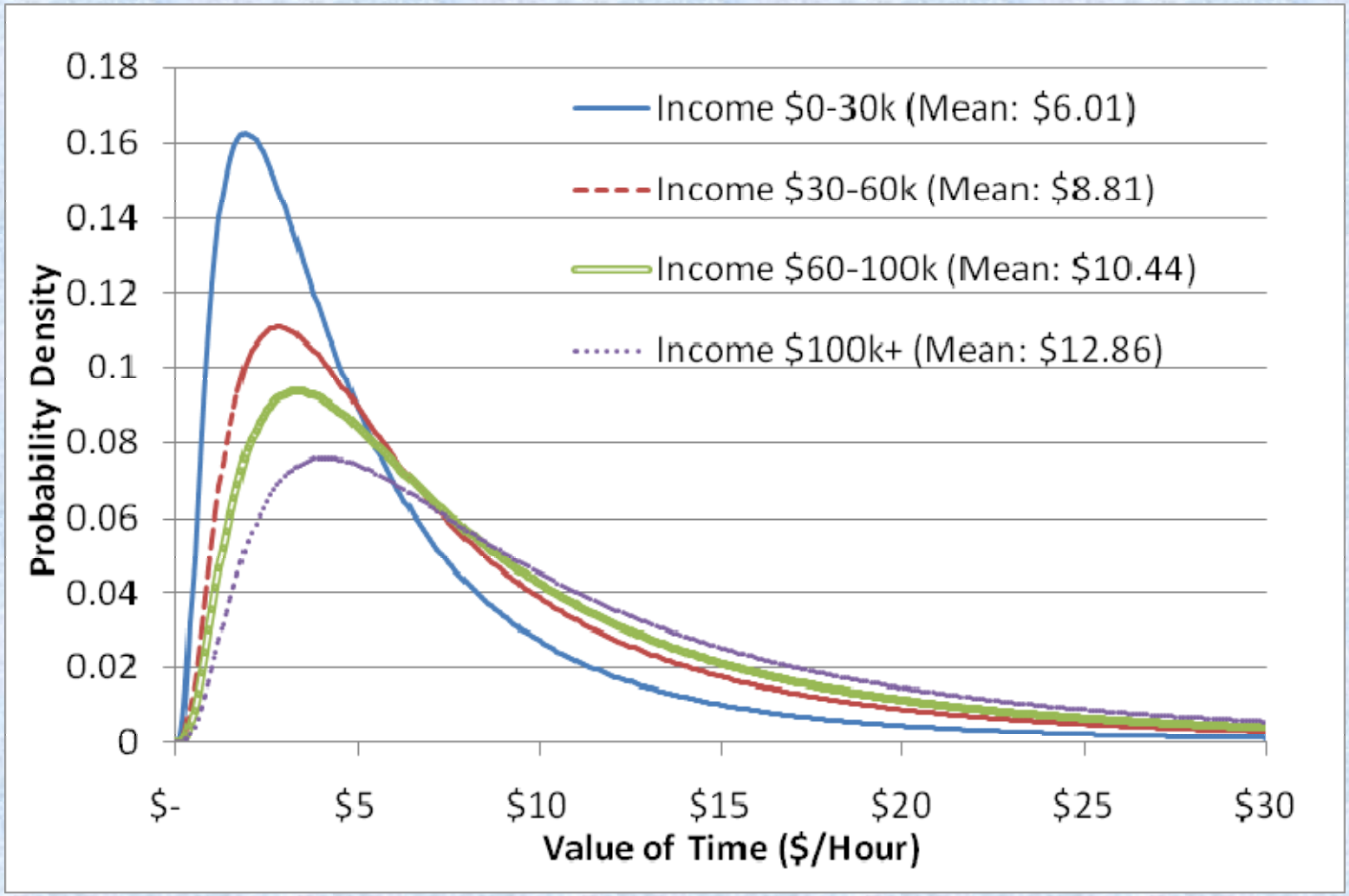
Probabilistic VOT



Probabilistic VOT

- Time and cost coefficients in the mode utility expressions are not fixed for each segment but drawn from the (parameterized) distribution
- Software for choice model estimation (mixed logit) is available
- Implemented and tested in the SFCTA AB model

VOT Distribution



What is License Plate Rationing?






Mon	Tues	Wed	Thur	Fri
✗	✓	✓	✓	✓
✓	✗	✓	✓	✓
✓	✓	✗	✓	✓
✓	✓	✓	✗	✓
✓	✓	✓	✓	✗

Option: License Plate Rationing

- Policy: 20% (or 10%) No-drive to CBD vehicle ban based on last digit of license
- Impact on Travel Choices
  - Destination Choice – No
  - Mode Choice and Stop Location – Yes
- Account for opportunities to reduce impact of ban:
  - Changing the Day of Trip
  - Vehicle availability within Household
- Household Auto availability model
  - Vehicle available for Destinations to CPZ
  - Car Sufficiency revised - # of Autos minus of Workers

License Plate Rationing – 20% Auto Availability Model

Random #'s for tagging

HH#	Wkrs	Autos	Car Suff	a1	a2	a3	a4
1	2	3	1				
2	1	1	0				
3	1	2	1				
4	1	1	0				
5	2	4	2				
6	2	2	0				

License Plate Rationing
Car Availability by Destination

		Not-CPZ		*Random #'s for tagging*				*To CPZ*	
HH#	Wkrs	Autos	Car Suff	a1	a2	a3	a4	Autos	Car Suff
1	2	3	1	0.914	0.190	0.245		2	0
2	1	1	0	0.988				1	1
3	1	2	1	0.246	0.487			2	1
4	1	1	0	0.121				0	-1
5	2	4	2	0.375	0.878	0.165	0.341	3	1
6	2	2	0	0.080	0.660			1	-1

For Tours Not to Restricted Area **For Tours to Restricted Area**

Payment Type / Discounts

- Toll/discount differentiation by payment type:
  - Cash
  - Pass
  - ETC/transponder
- Individual discounts:
  - Area residents
  - Credit-based forms/low-income subsidies
  - Reimbursement of tolls by the employer
  - Free parking provided by the employer

1.3. Tour-Based Techniques and Challenges

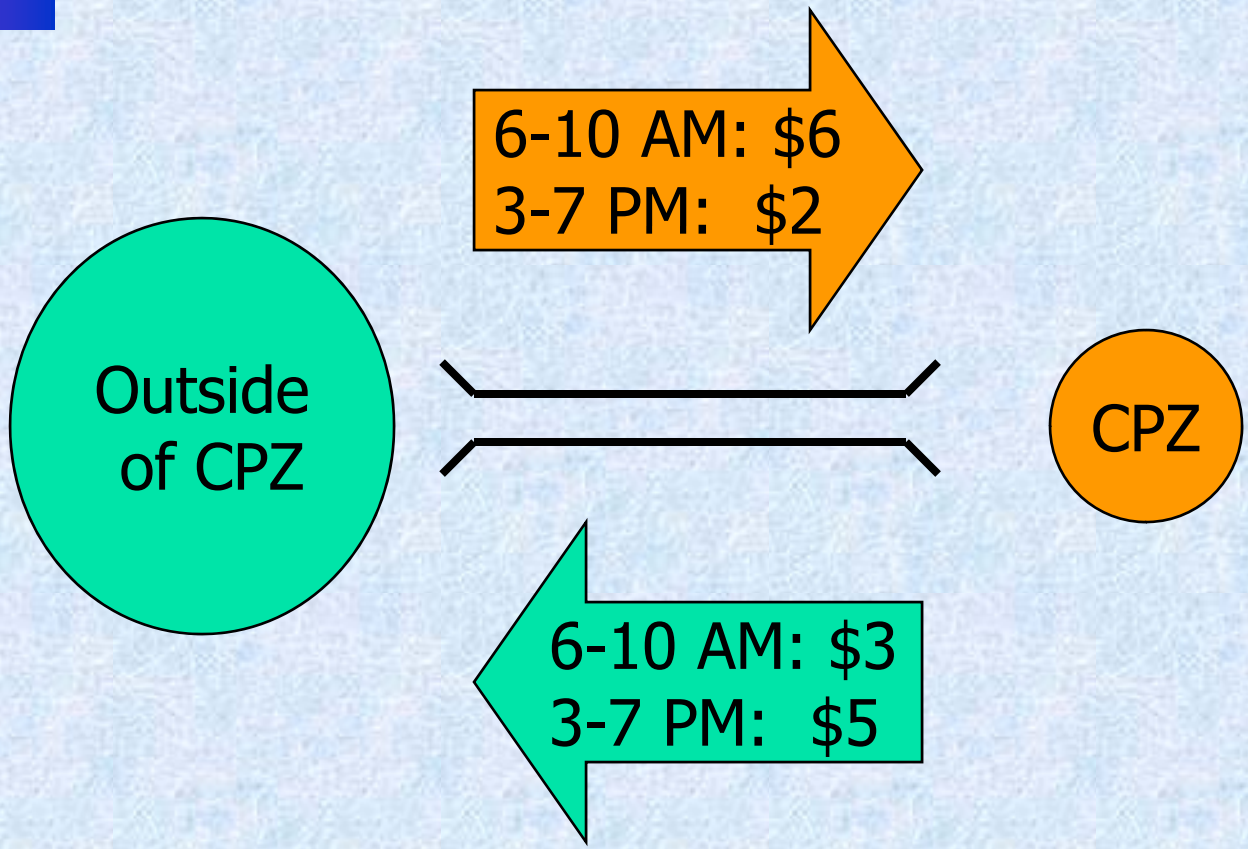
Taking Advantage of

- Tour-based structure:
  - Accounting for tolls in both directions by TOD periods
- Microsimulation of individuals:
  - Probabilistic VOT
  - Payment type / discounts
- Entire-day individual activity pattern:
  - Daily area pricing forms

Accounting for Tolls in Both Directions by TOD

- Scenarios to model:
  - TOD-specific tolls differentiated by directions
- Required model sensitivities:
  - Travelers have to see both tolls that affect:
    - Route choice (independent by directions)
    - Mode choice
    - TOD choice
    - Destination choice

Realistic Example



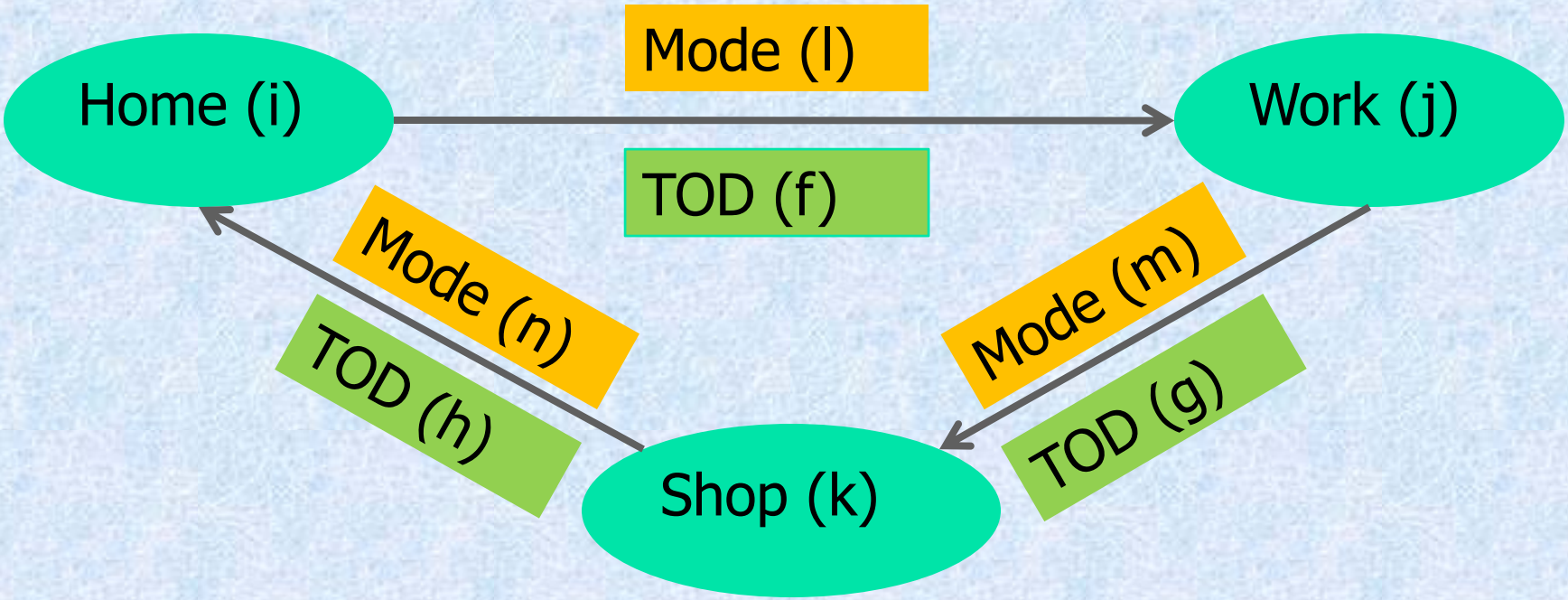
True Tolls Paid by Commuters

Outbound time	Inbound time	Toll, $
Earlier than 6AM	Earlier than 6AM	
Earlier than 6AM	6-10AM ($3)	3
Earlier than 6AM	10AM-3PM	
Earlier than 6AM	3-7PM ($5)	5
Earlier than 6AM	Later then 7PM	
6-10AM ($6)	6-10AM ($3)	9
6-10AM ($6)	10AM-3PM	6
6-10AM ($6)	3-7PM ($5)	11
6-10AM ($6)	Later then 7PM	6
10AM-3PM	10AM-3PM	
10AM-3PM	3-7PM ($5)	5
10AM-3PM	Later then 7PM	
3-7PM ($2)	3-7PM ($5)	7
3-7PM ($2)	Later then 7PM	2
Later then 7PM	Later then 7PM	

Modeling True Tolls & LOS

- With 4-step model:
  - Impossible to ensure any reasonable level of consistency across trip distribution, mode choice, and time of day choice
- With tour-based model:
  - It is still difficult to ensure a full consistency, but a much better job can be done

Dimensionality of Tour



Treatment of Space

- Level of spatial resolution:
  - TAZ (3,000-4,000)
  - MGRA (20,000-30,000)
  - Parcel (1,000,000)
- Calculation of LOS:
  - Predetermined Origin and Destination catchment areas
  - On-fly path building

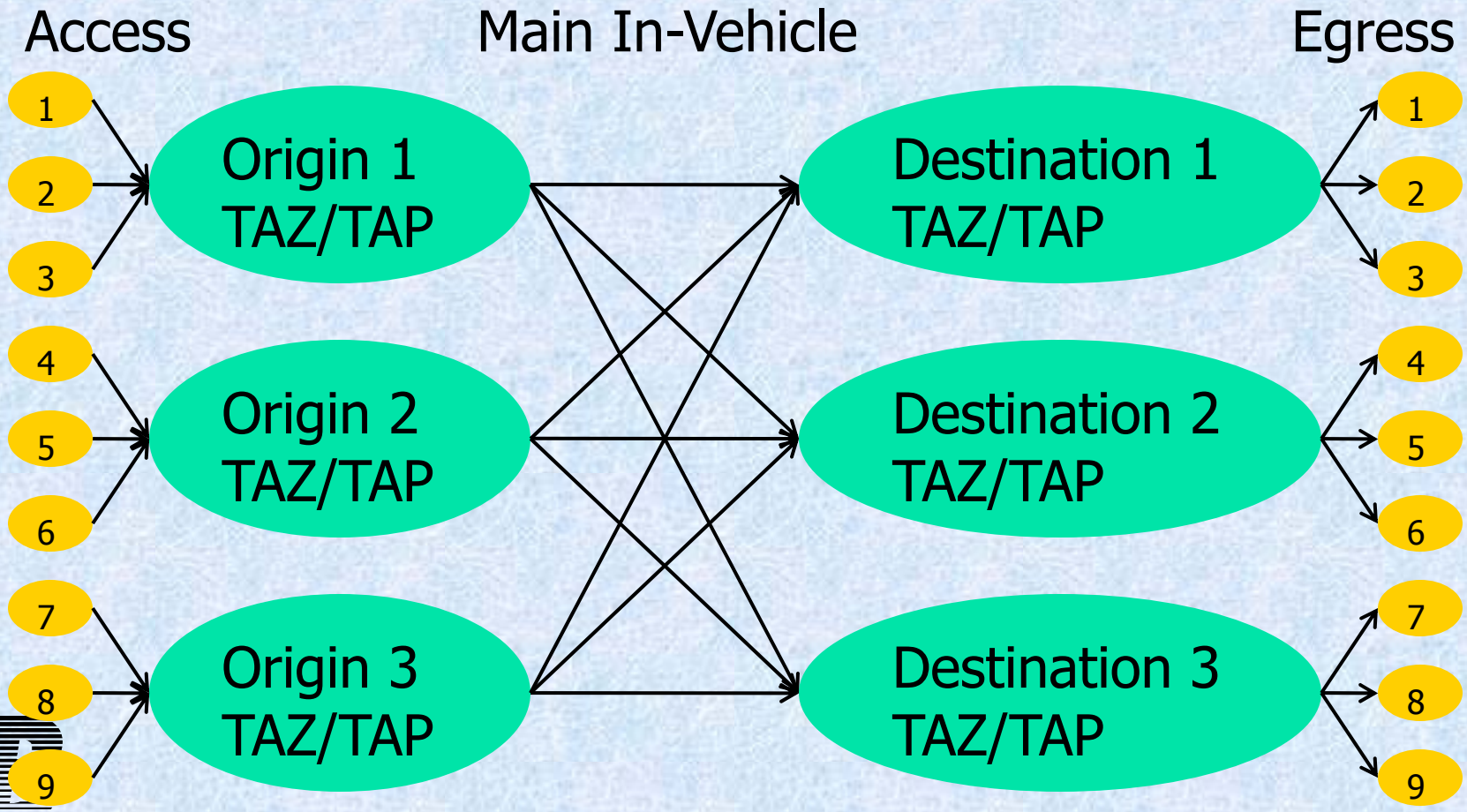
Treatment of Time

- Levels of temporal resolution:
  - TOD periods (4-5)
  - Hour/half-hour (20-40)
  - Fine grain / continuous
- Calculation of LOS:
  - SUE limits to 1 hour
  - Integration with DTA is the long-term avenue

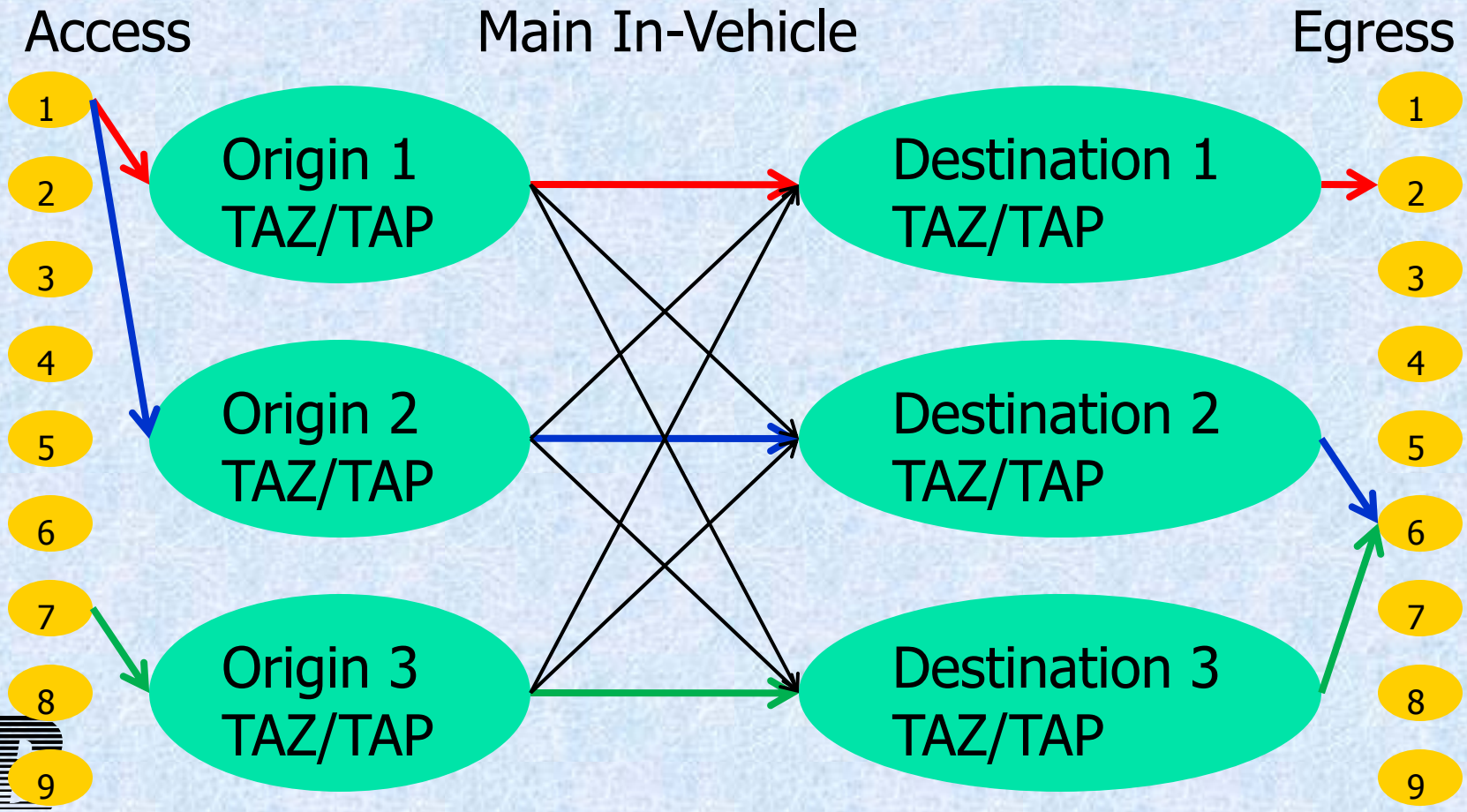
Number of Tour Alternatives

- Even with the crudest resolution:
  - Spatial i×j×k=4,000×4,000×4,000
  - Temporal f×g×h=20×19×18/6=1,140
  - Mode combinations 10×10×10=1,000
  - Combined is practically infinite
- Every alternative utility function requires random access to a large number of LOS matrices

Fine-Grain LOS (1=Pre-fixed)

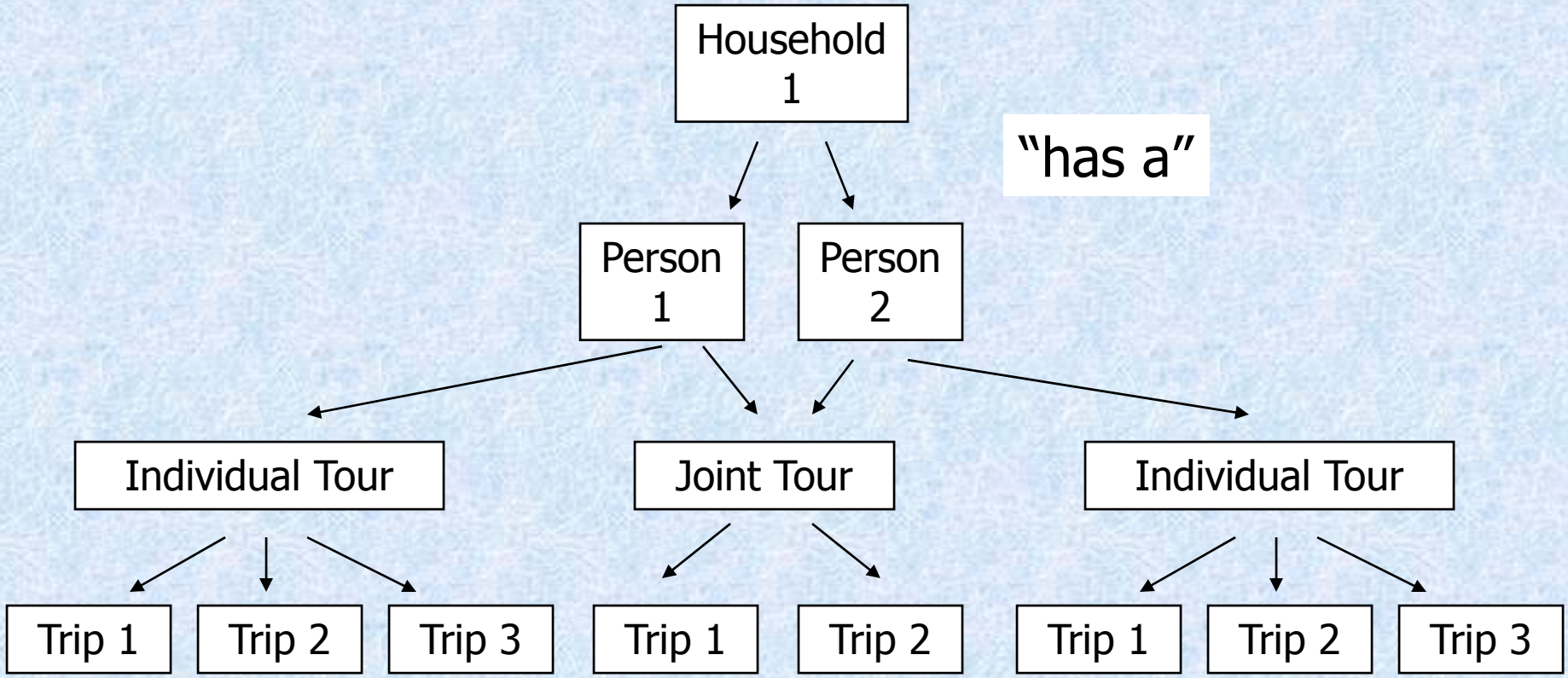


Fine-Grain LOS (2=on Fly)



1.4. Internal Database and Types of Objects

OOP – Composition



1.5. Transportation Network Procedures

Transportation Network Procedures

- ABM like any demand model is integrated with network assignment and skimming procedures
- 2 options:
  - Conventional STA (UE) – short term
  - Advanced DTA w/microsimulation – long term but getting more and more realistic
- All major vendors provide both options:
  - INRO (EMME & Dynameq)
  - Caliper (TransCAD & TransModeller)
  - PTV (Visum & Vissim)
  - Citilabs (Cube Voyager & Avenue)

Different Software Development Paths

- Advanced demand ABMs cannot be implemented using script languages of transportation packages
  - Software is developed by consultants using general-purpose program languages (C, Java)
  - Some vendors like Citilabs are trying to penetrate the market
- Contrary to that, network simulation software has to by bought from the vendor:
  - Commercial packages
  - University Labs (DynaSmart, Dynus-t)

What is Different?

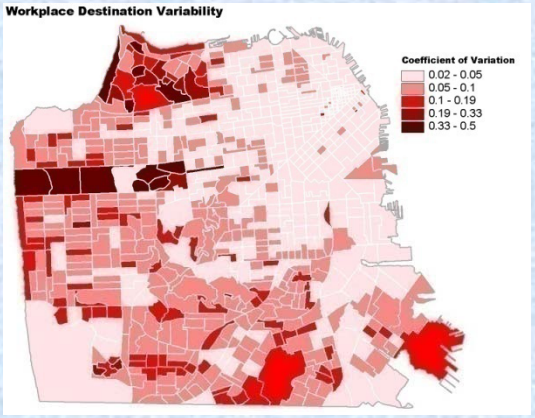
- DTA:
  - Sophisticated but generic algorithm
  - Relatively small number of parameters with recommended default values; no estimation for route choice
  - Calibration relates to network input characteristics (capacity, speed) and demand
- ABM:
  - Less sophisticated but specific algorithm
  - Large number of behavioral choice sub-models and parameters to estimate
  - Calibration relates to model parameters

1.6. Understanding and Managing Microsimulation Model Output

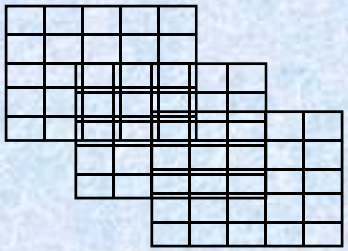
Tour-Based Model Output

Household Data, Person Data, Tour/Trip List

HID	PID	TID	PUR	MOD	SB	SA	OTAZ	DTAZ	S1TAZ	S2TAZ	TLOR	TLDS
1	1	1	2	1	0	1	943	987	0	964	1	3
1	1	2	1	2	1	0	943	731	856	0	3	3
1	2	1	4	1	0	0	943	952	0	0	1	2
1	3	1	2	4	1	1	943	565	698	982	1	2

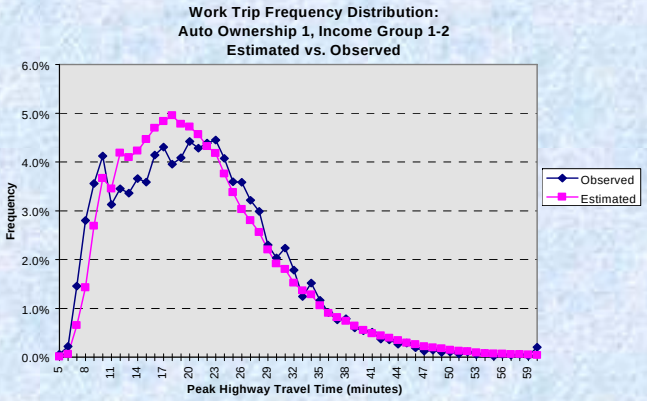


Maps, Graphics



Trip Tables

Assignment

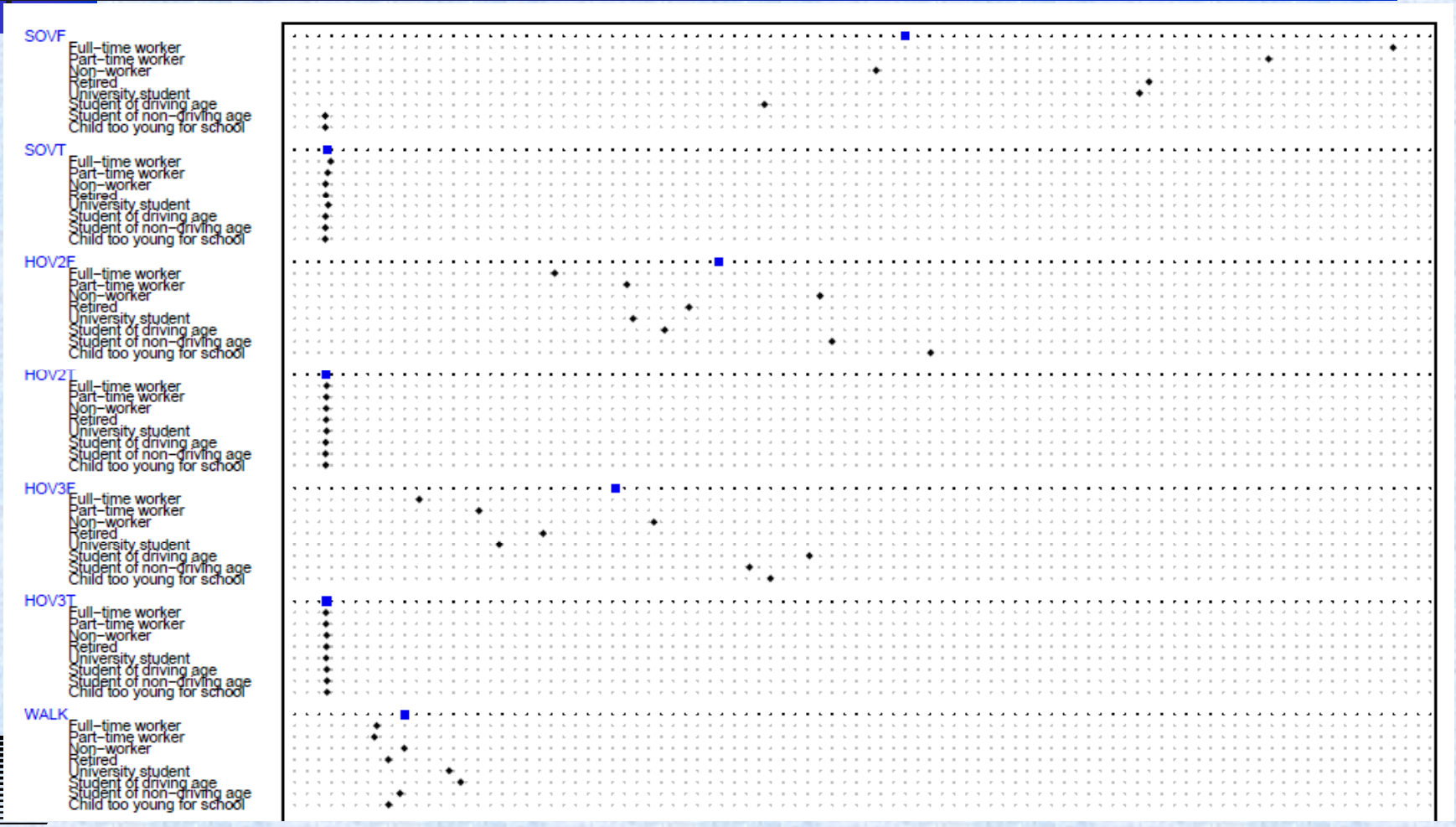


Other Summaries

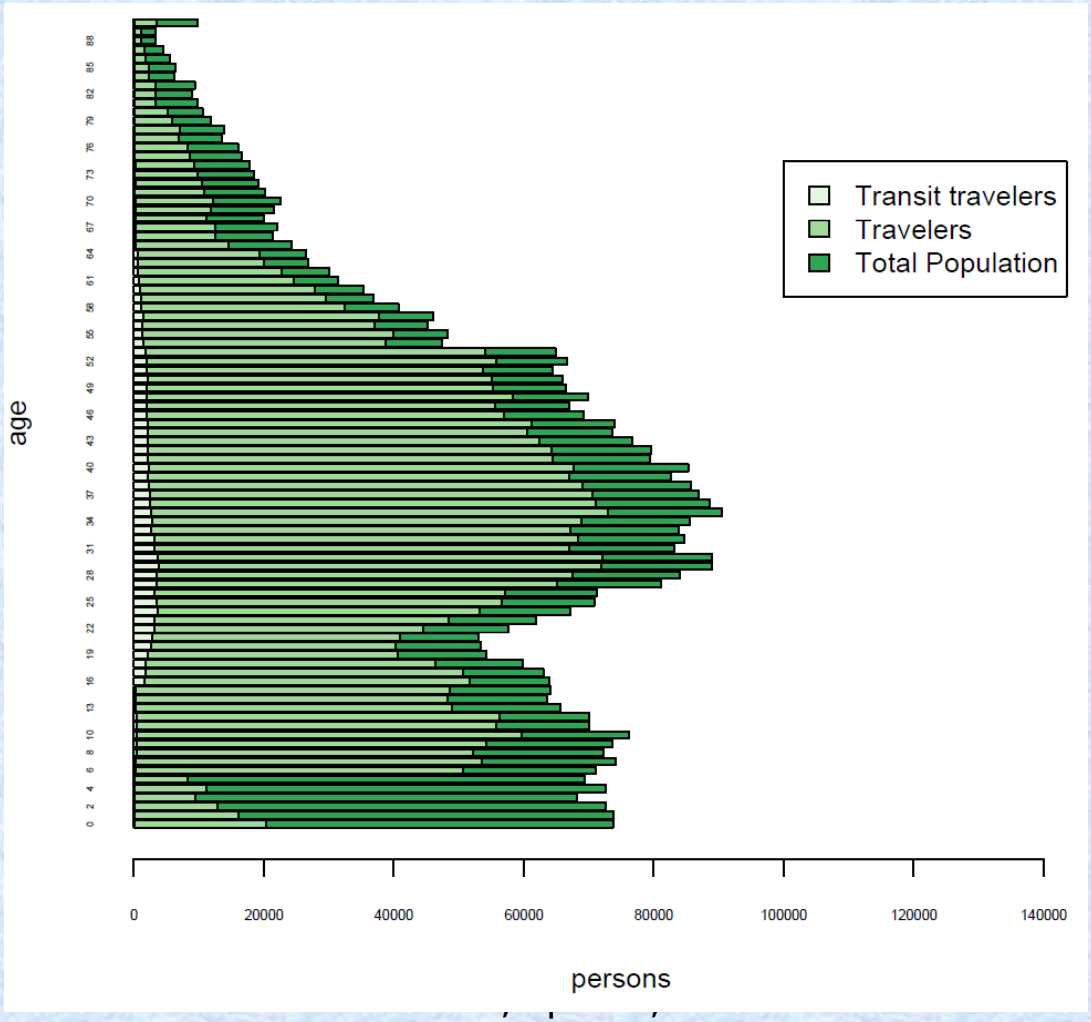
What Sort of Measures/Visuals are Now Possible?

- ABM results in a complete activity diary for all residents
  - A wealth of activity/travel results
  - Just about any custom report/query/visual is now possible
- Scenario testing (ARC examples)
  - 2030 HOV2HOT Scenario
  - 2030 Concept3 Scenario

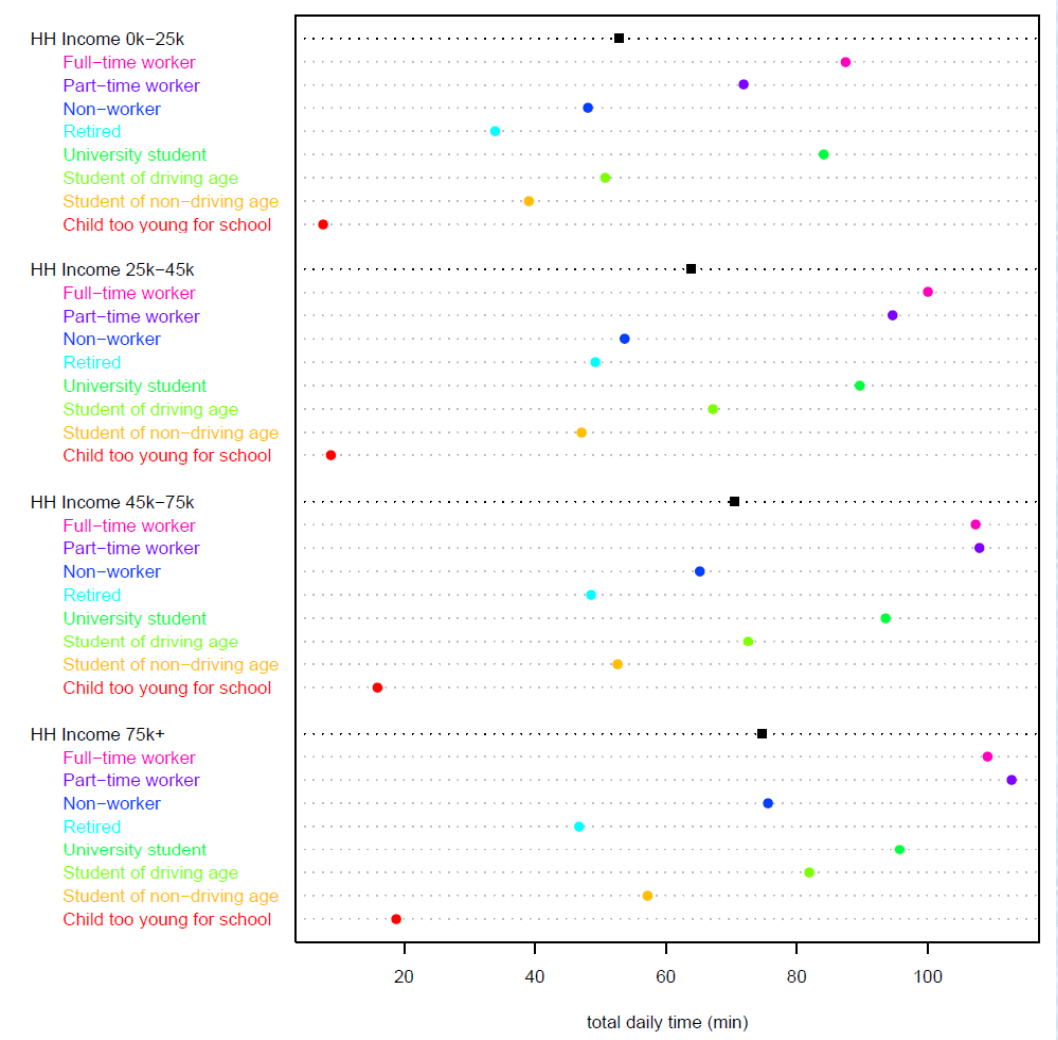
Mode Share by Person Type



Travelers by Age

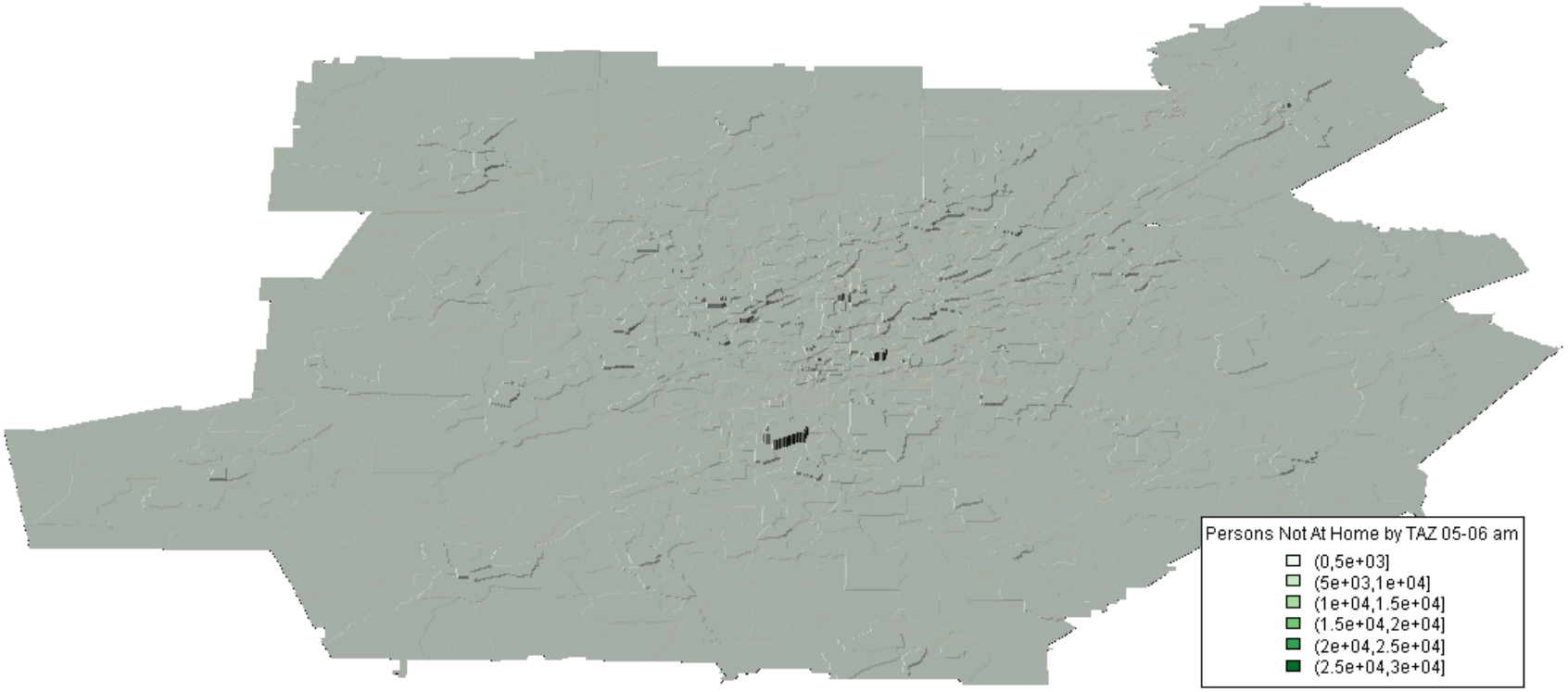


Time Spent Travelling by HH Income and Person Type



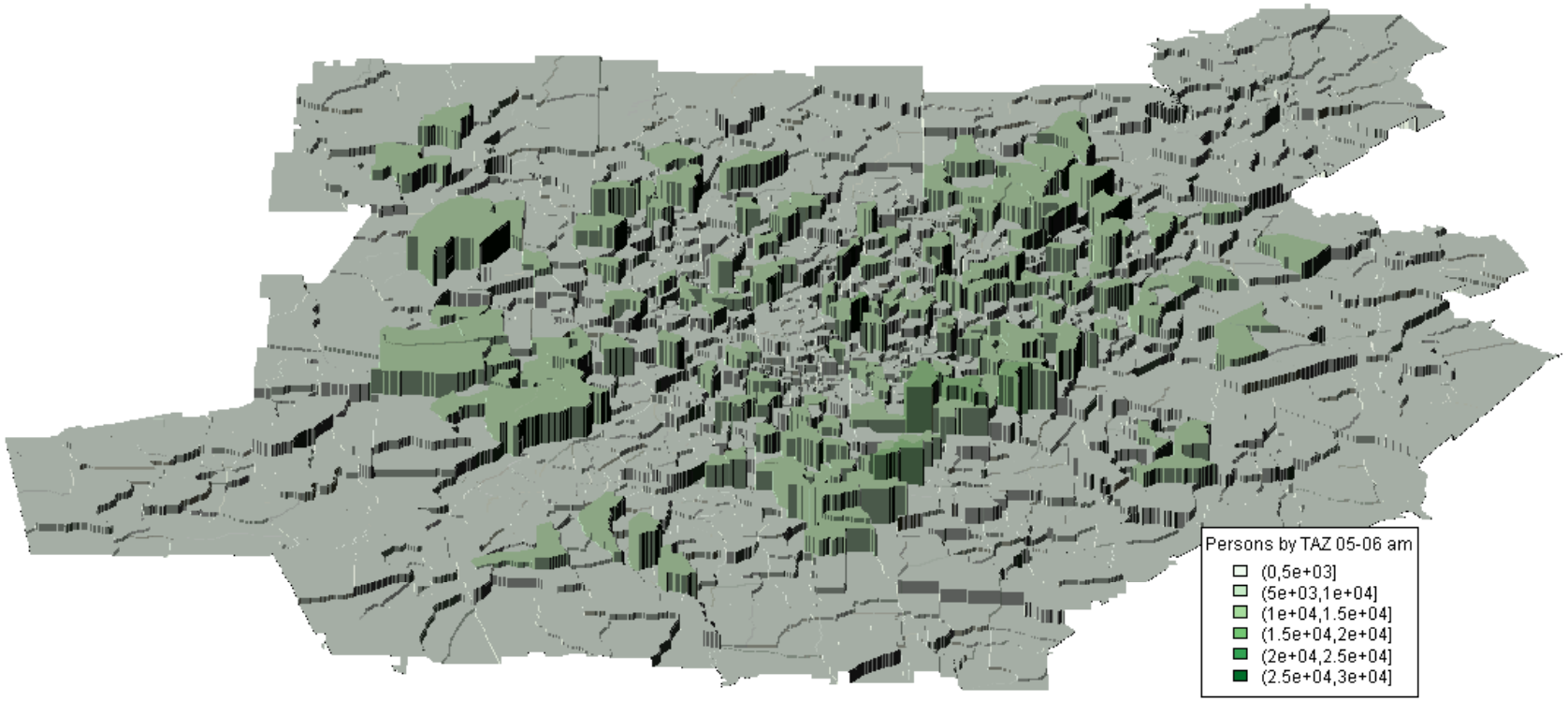


Persons Not At Home By TAZ and Hour

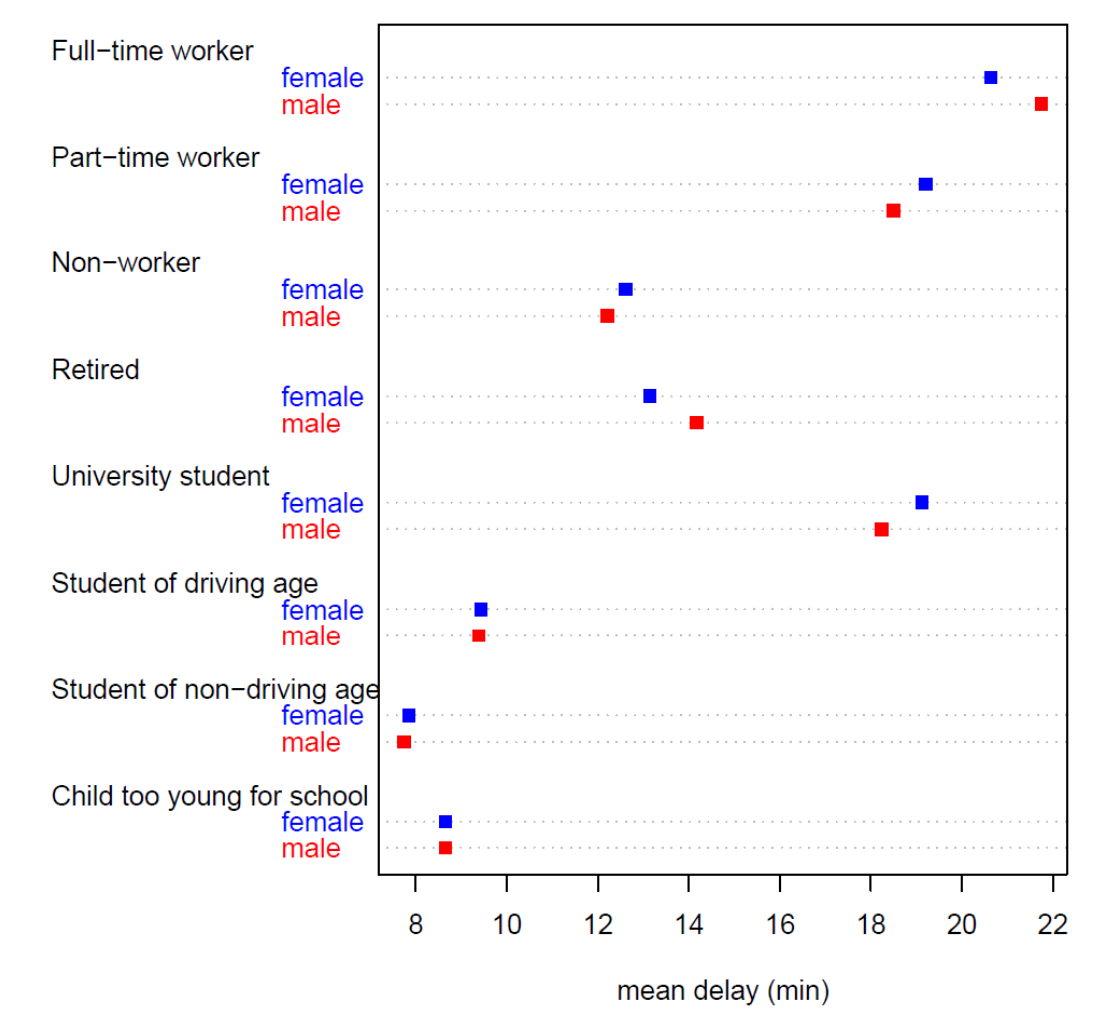




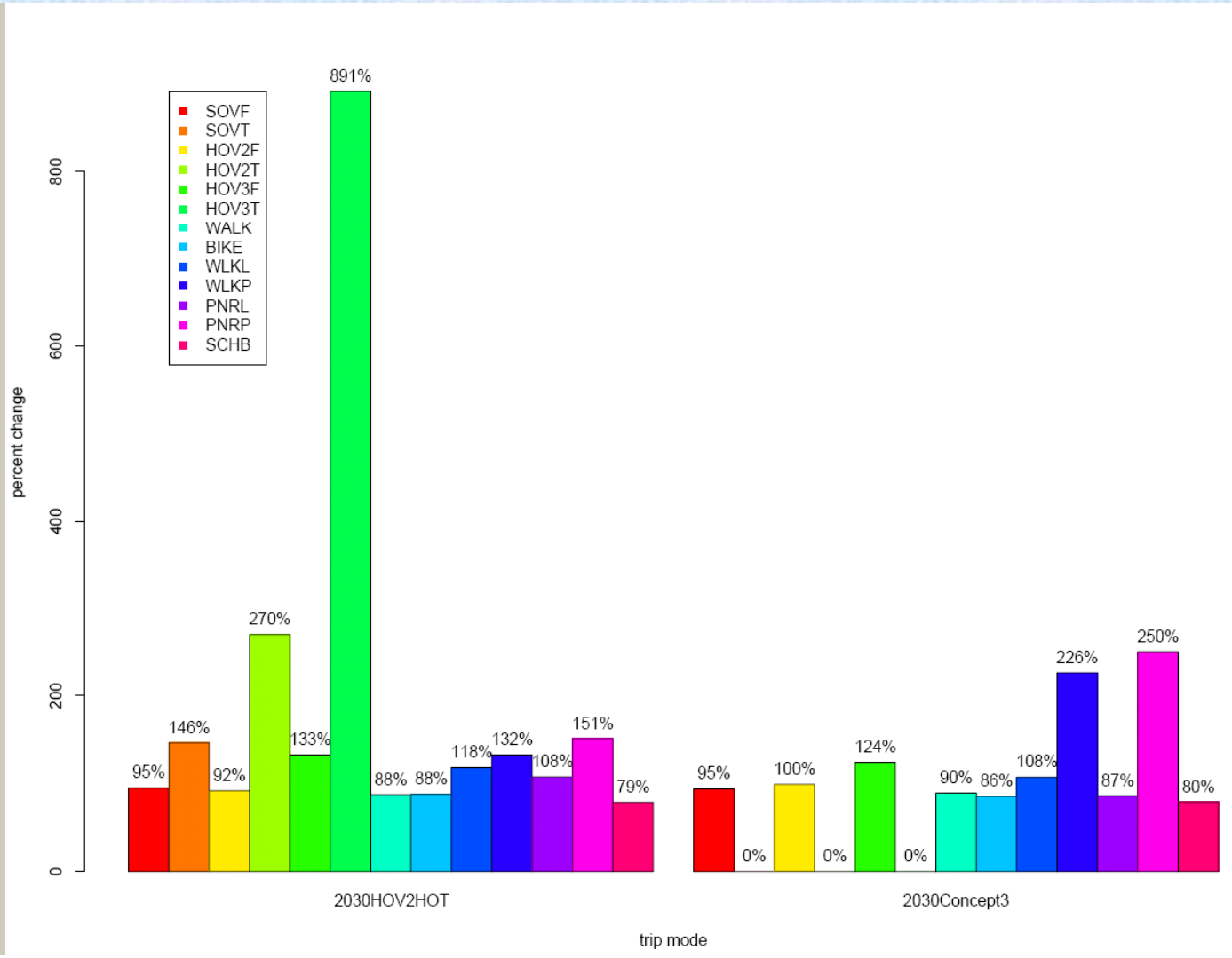

Persons By TAZ and Hour



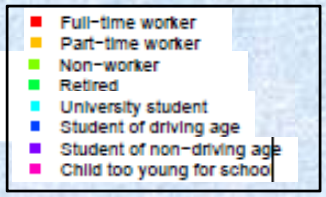
Mean Delay Peak Period Travel

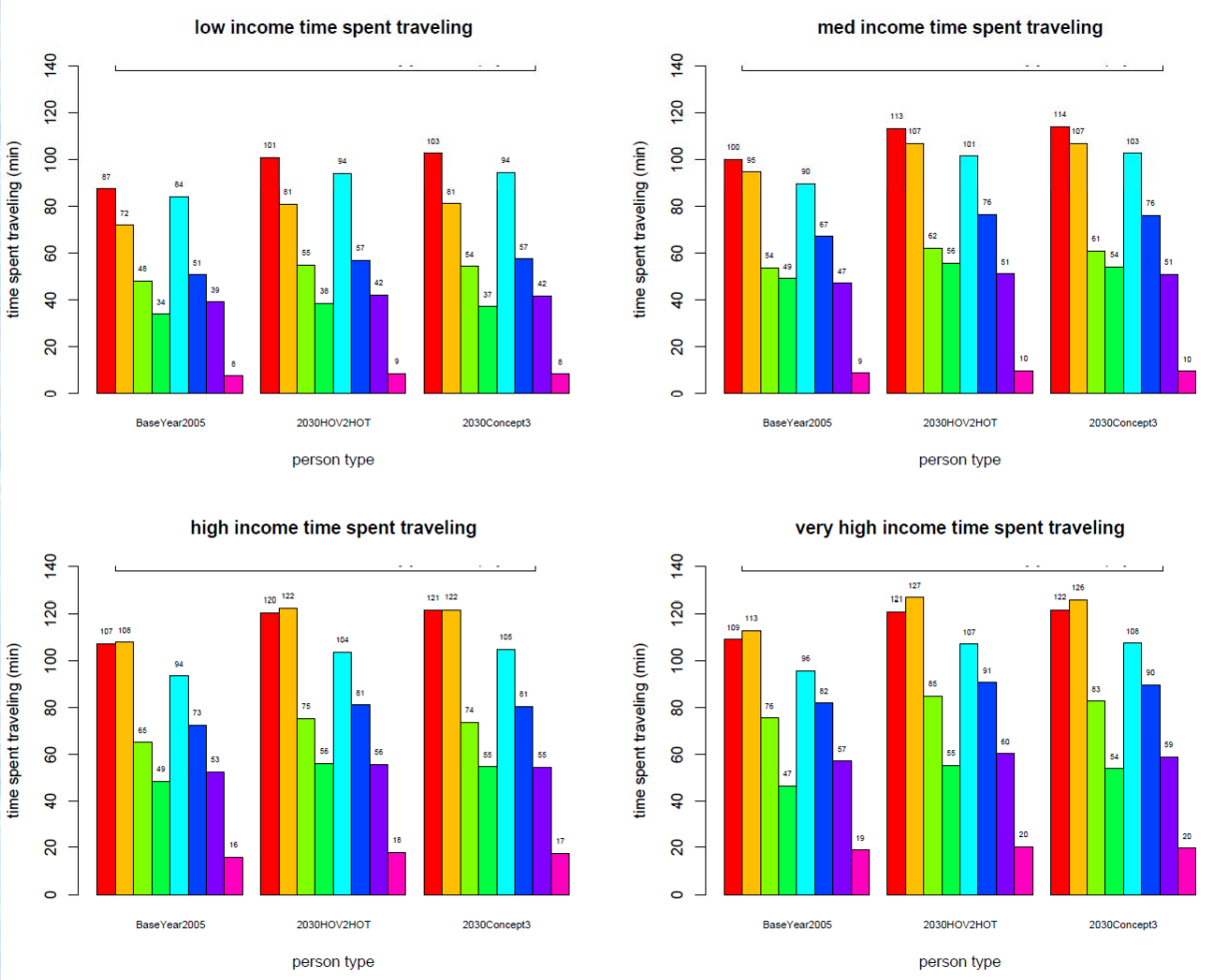


Change in Mode Share Across Scenarios

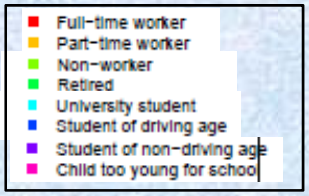


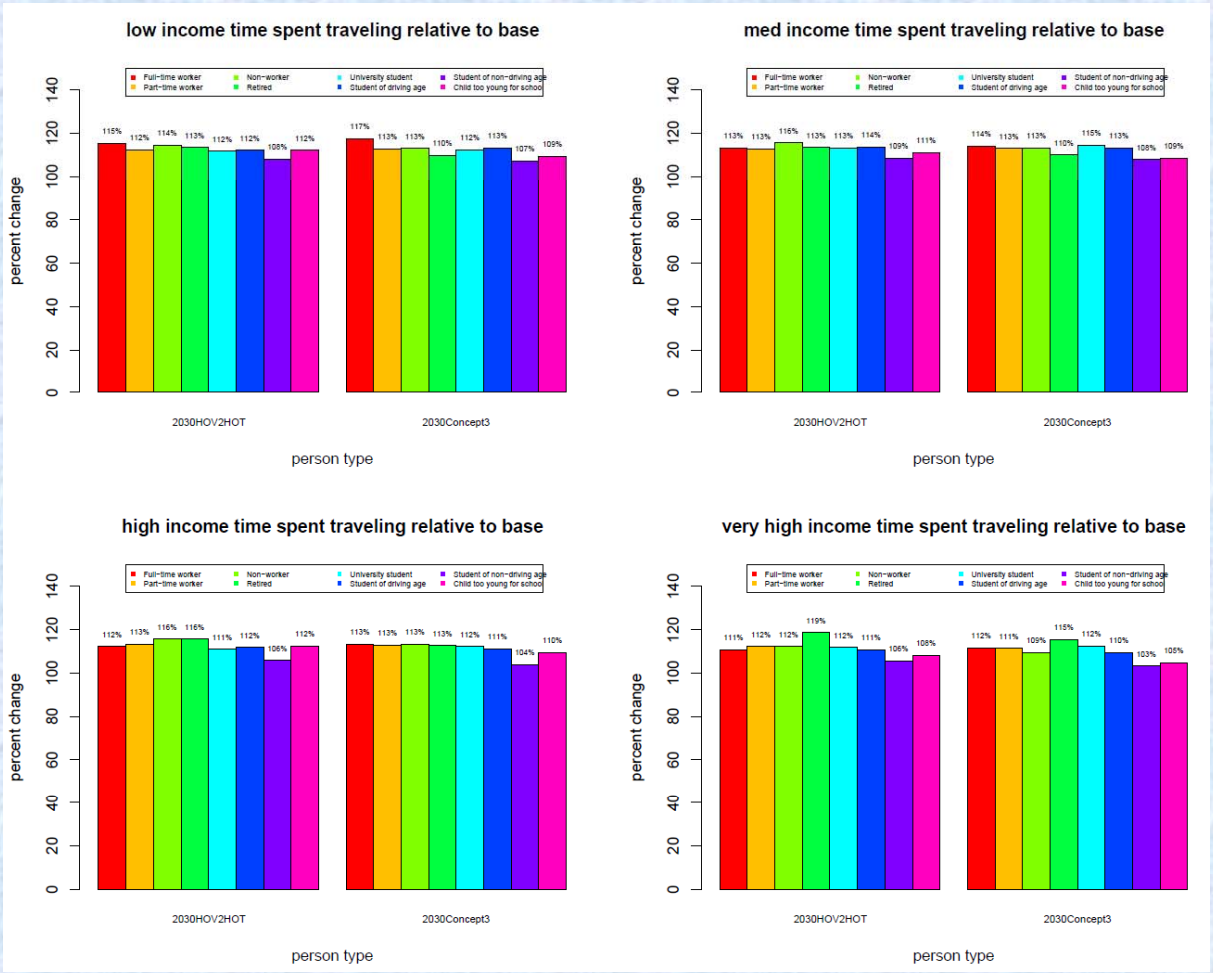
Time Spent Traveling by Income & Person Type





Time Spent Traveling Across Scenarios



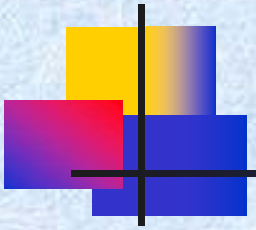


2. Effective Software & Hardware Solutions

2.1. Example of Common Modeling Framework (CMF)

Common Modeling Framework

- A library of tools for building transport and land-use models
- Written in the Java programming language
- Open source (Apache public license)
- Collaborative
- Currently used by over 30 clients



Java Programming Language

- Java is a fully Object-Oriented Programming (OOP) Language
- Java is easy to learn and use
- Java encourages good software design
- Java natively supports multi-threading
- Java is architecture-neutral

CMF Tools – Matrix Package

- Read/write to/from all major software (TransCAD, Cube, Emme, etc)
- Matrix calculations
- Random access (skims in memory, sparse matrices)
- N-dimensional matrix, iterative proportional fitting

CMF Tools – Model Package

- Create and apply discrete choice models
- Flexible in specification of nesting structures
- "Interface" pattern used – any object can be an alternative
- Extensive debugging features

CMF Tools – Model Package

```
/** A simple mode choice model
 *
public class MyModeChoiceModel {

    public runModel(){

        //instantiate modes
        DriveAlone driveAlone = new DriveAlone();
        Transit transit = new Transit();

        //instantiate model
        LogitModel model = new LogitModel;

        //add modes to model
        model.add(driveAlone);
        model.add(transit);

        //calculate utilities
        double logsum = model.getUtility();

        //choose Mode
        Mode chosenMode = (Mode) model.chooseAlternative();
    }
```

LogitModel.add() takes a Mode

getUtility() solves logit model, returns logsum

Uses Monte Carlo to select alternative according to logit probabilities and returns it.

CMF Tools – Calculator Package

- Activity-based models typically utilize many logit choice models, some with many alternatives
- Traditional software relies on hard-coded utility equations
  - Inefficient - Programmer responsible for coding utility equations
  - Inflexible – Requires programmer to change equations and recompile
  - Imperfect – Only one person typically reviews equations, which increases probability of bugs
- Utility Expression Calculator (UEC) developed to overcome these limitations

CMF Tools – Calculator Package

- The UEC is a Java package that reads and interprets an Excel workbook containing a logit model specification and its inputs
- The UEC solves the utility equations for a given decision-maker
- The UEC "opens up" the model specification – anyone can edit the spreadsheets, change inputs & parameters, check that the model is properly specified, etc.

Data Page

Table Data: CSV files of zonal, household, or person data

Table Data						
No	Type	Format	File			
1	zone	csv	%project.directory%/Inputs/retailAccessibility.csv			
Matrix Data						
No	Token	Format	File	Matrix	Group	Index
1	OP_SOV_TIME	http://localhost:6(	%project.directory%/Outputs/SOVFFM05.SKM	time		
2	OP_SOV_DIST	http://localhost:6(	%project.directory%/Outputs/SOVFFM05.SKM	distance		
3	OP_WLKPRE_FWT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	iwait		
4	OP_WLKPRE_XWT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	xwait		
5	OP_WLKPRE_WLK	http://localhost:6(	%project.directory%/Outputs/offpre.skm	walkt		
6	OP_WLKPRE_LOCIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	locivt		
7	OP_WLKPRE_RAILIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	railivt		
8	OP_WLKPRE_XBUSIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	xbusivt		

Matrix Data: Trip tables or level-of-service skims in zone-zone format (TPPLUS, TRANSCAD, EMME2, and/or BINARY formats)

UEC Data Page

Must be consecutively numbered

Path and filename; percents used to pass in global variables set in properties file

Table Data						
No	Type	Format	File			
1	zone	csv	%project.directory%/Inputs/retailAccessibility.csv			
Matrix Data						
No	Token	Format	File	Matrix	Group	Index
1	OP_SOV_TIME	http://localhost:6(	%project.directory%/Outputs/SOVFFM05.SKM	time		
2	OP_SOV_DIST	http://localhost:6(	%project.directory%/Outputs/SOVFFM05.SKM	distance		
3	OP_WLKPRE_FWT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	iwait		
4	OP_WLKPRE_XWT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	xwait		
5	OP_WLKPRE_WLK	http://localhost:6(	%project.directory%/Outputs/offpre.skm	walkt		
6	OP_WLKPRE_LOCIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	locivt		
7	OP_WLKPRE_RAILIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	railivt		
8	OP_WLKPRE_XBUSIVT	http://localhost:6(	%project.directory%/Outputs/offpre.skm	xbusivt		

Matrix tokens are used to refer to the matrix in model specification page

Matrix column indicates which matrix in file to read in – number or string

UEC Dat

Sparse matrices can be grouped for compression:

- Each group is a set of skims, such as “Peak walk-local”
- Each matrix group must have an index matrix, which determines whether the zone-pair is connected or not (typically in-vehicle time for the primary mode is used)

Matrix Data

No	Token	Format	File	Matrix	Group	Index
1	AUTO_TIME	BINARY	%project.directory%outputs/binary/skim_pm_3.binary	1		
2	AUTO_DIST	BINARY	%project.directory%outputs/binary/skim_pm_2.binary	1		
3	ZONE_DIST	BINARY	%project.directory%outputs/skims/StraightLineDistanceCentr	1		
4	WLKBUS_FWT	BINARY	%project.directory%outputs/binary/pmetrnwtw_1.binary	1	1	
5	WLKBUS_XWT	BINARY	%project.directory%outputs/binary/pmetrnwtw_2.binary	1	1	
6	WLKBUS_ACC	BINARY	%project.directory%outputs/binary/pmetrnwtw_3.binary	1	1	
7	WLKBUS_AUX	BINARY	%project.directory%outputs/binary/pmetrnwtw_4.binary	1	1	
8	WLKBUS_EGR	BINARY	%project.directory%outputs/binary/pmetrnwtw_5.binary	1	1	
9	WLKBUS_IVT	BINARY	%project.directory%outputs/binary/pmetrnwtw_6.binary	1	1	1
10	WLKBUS_XIVT	BINARY	%project.directory%outputs/binary/pmetrnwtw_8.binary	1	1	
11	WLKBUS_FAR	BINARY	%project.directory%outputs/binary/pmetrnwtw_11.binary	1	1	
12	WLKBUS_BRD	BINARY	%project.directory%outputs/binary/pmetrnwtw_12.binary	1	1	
13	PNRBUS_FWT	BINARY	%project.directory%outputs/binary/pmtrnwta_1.binary	1	2	
14	PNRBUS_XWT	BINARY	%project.directory%outputs/binary/pmtrnwta_2.binary	1	2	
15	PNRBUS_DRV	BINARY	%project.directory%outputs/binary/pmtrnwta_3.binary	1	2	
16	PNRBUS_AUX	BINARY	%project.directory%outputs/binary/pmtrnwta_4.binary	1	2	
17	PNRBUS_EGR	BINARY	%project.directory%outputs/binary/pmtrnwta_5.binary	1	2	
18	PNRBUS_IVT	BINARY	%project.directory%outputs/binary/pmtrnwta_6.binary	1	2	2
19	PNRBUS_XIVT	BINARY	%project.directory%outputs/binary/pmtrnwta_8.binary	1	2	
20	PNRBUS_FAR	BINARY	%project.directory%outputs/binary/pmtrnwta_11.binary	1	2	
21	PNRBUS_BRD	BINARY	%project.directory%outputs/binary/pmtrnwta_13.binary	1	2	
22	KNRBUS_FWT	BINARY	%project.directory%outputs/binary/pmtrnwtk_1.binary	1	3	
23	KNRBUS_XWT	BINARY	%project.directory%outputs/binary/pmtrnwtk_2.binary	1	3	
24	KNRBUS_DRV	BINARY	%project.directory%outputs/binary/pmtrnwtk_3.binary	1	3	
25	KNRBUS_AUX	BINARY	%project.directory%outputs/binary/pmtrnwtk_4.binary	1	3	
26	KNRBUS_EGR	BINARY	%project.directory%outputs/binary/pmtrnwtk_5.binary	1	3	
27	KNRBUS_IVT	BINARY	%project.directory%outputs/binary/pmtrnwtk_6.binary	1	3	3
28	KNRBUS_XIVT	BINARY	%project.directory%outputs/binary/pmtrnwtk_8.binary	1	3	
29	KNRBUS_FAR	BINARY	%project.directory%outputs/binary/pmtrnwtk_11.binary	1	3	
30	KNRBUS_BRD	BINARY	%project.directory%outputs/binary/pmtrnwtk_13.binary	1	3	

UEC Model – Auto Ownership

A row for each utility term

A column for each alternative (0, 1, 2, and 3+ autos)

Model	3	auto_ownership		Decision-making-unit	h	Alt	4		
No	Token	Description	Filter	Formula for variable	Index	Alt1 0_autos	Alt2 1_auto	Alt3 2_autos	Alt4 3+_autos
1		Alternative-specific constant		1		-5.352	-2.132	0	-0.768
2		Household Size 1		if(@size==1,1,0)		2.613	2.172	0.0	0.000
3		Household Size 2		if(@size==2,1,0)		0.000	0.400	0.0	-0.673
4		Income Group 1		if(@income==1,1,0)		2.878	2.185	0.0	-1.285
5		Income Group 2		if(@income==2,1,0)		1.734	1.731	0.0	-1.061
6		Income Group 3		if(@income==3,1,0)		0.000	1.152	0.0	-1.025
7		Income Group 4		if(@income==4,1,0)		0.000	0.665	0.0	-0.535
8		Worker 0		if(@workers==0,1,0)		1.015	0.000	0.0	0.000
9		Worker 1		if(@workers==1,1,0)		0.000	0.000	0.0	0.000
10		Worker 2		if(@workers==2,1,0)		0.000	-0.934	0.0	0.648
11		Worker 3+		if(@workers==3,1,0)		2.195	0.000	0.0	2.257
12		GVSAD retirement zone		if(GV_SAD_IND==1,1,0)	z	0.000	1.200	0.0	0.000
13		HIRET retirement zone		if(HI_RET_IND==1,1,0)	z	0.000	0.916	0.0	0.000
14		Tot emp w/i 20 min by transit, normalized		trn20w_emp	z	0.014	0.000	0.0	0.000
15		Percent of TAZ w/i 1/3 mile of transit stop		shortWalk	z	0.021	0.010	0.0	0.000

A description for the term

A formula field for computing data items

Coefficients for each term and alternative

UEC Model – Mode Choice

Results of formulas can be stored as tokens, to be used in later formula or filter fields

@ refers to a variable that is computed in memory and given to the UEC in the java code; on-the-fly variable calculations

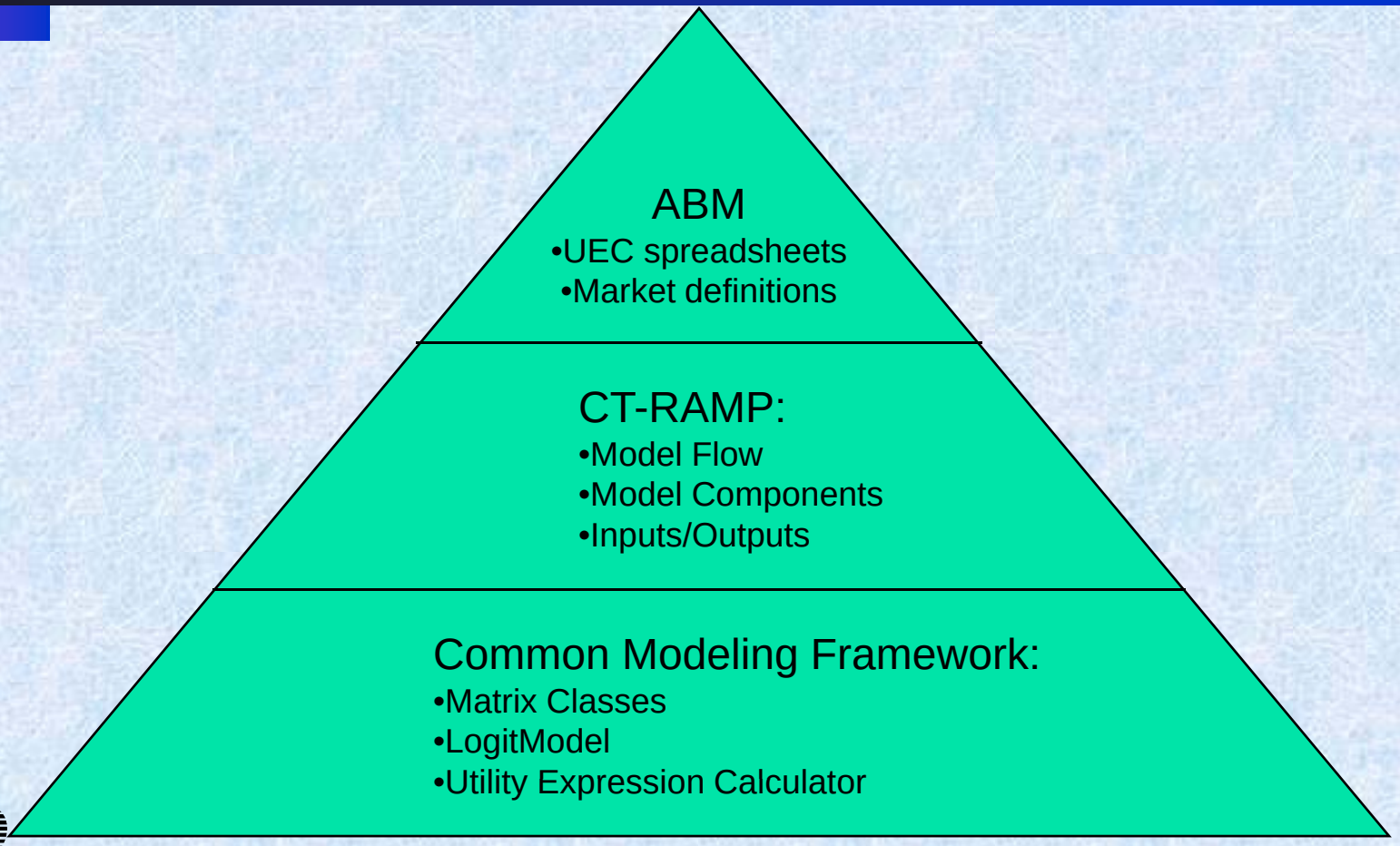
No	Token	Description	Filter	Formula for variable	Index
					DRIVEAL
23	canWalk	Walk to transit is available - walk market		if(@walkMarket<4,1,0)	
24	canDrive	Drive to transit is available - walk market		if(@walkMarket<6,1,0)	
25	canDriveShort	Drive to transit is available -- short walk egress		if(@walkMarket==0, 1, 0) + if(@walkMarket==2, 1	
26	canDriveLong	Drive to transit is available -- long walk egress		if(@walkMarket==1, 1, 0) + if(@walkMarket==3, 1	
27	PNRBusAvailable	PNR to bus is available		if(PNRBUS_IVT/100>0,1,0)*if(PNRBUS_IVT/100<9	do,do
28	KNRBusAvailable	KNR to bus is available		if(KNRBUS_IVT/100>0,1,0)*if(KNRBUS_IVT/100<9	do,do
29	walkModeAvailable	Walk mode available if distance less than 3 miles		if(ZONE_DIST<3,1,0)	do
30	bikeModeAvailable	Bike mode available if distance less than 10 miles		if(ZONE_DIST<10,1,0)	do
31	wBusTotWalkSS	Walk Bus total walk time, short acc - short egr	walkBusAvailable * canWalk	if(@walkMarket==0, min(WLKBUS_ACC/100,shor	do,do,do
32	wBusTotWalkSL	Walk Bus total walk time, short acc - long egr	walkBusAvailable * canWalk	if(@walkMarket==1, min(WLKBUS_ACC/100,shor	do,do,do
33	wBusTotWalkLS	Walk Bus total walk time, long acc - short egr	walkBusAvailable * canWalk	if(@walkMarket==2, min(WLKBUS_ACC/100,long	do,do,do

Filter field: Don't calculate this unless a condition is met

Index field indicates how to index into data read in on data page:
z: zone data
od, do: matrix data
(Indexes set in java code)

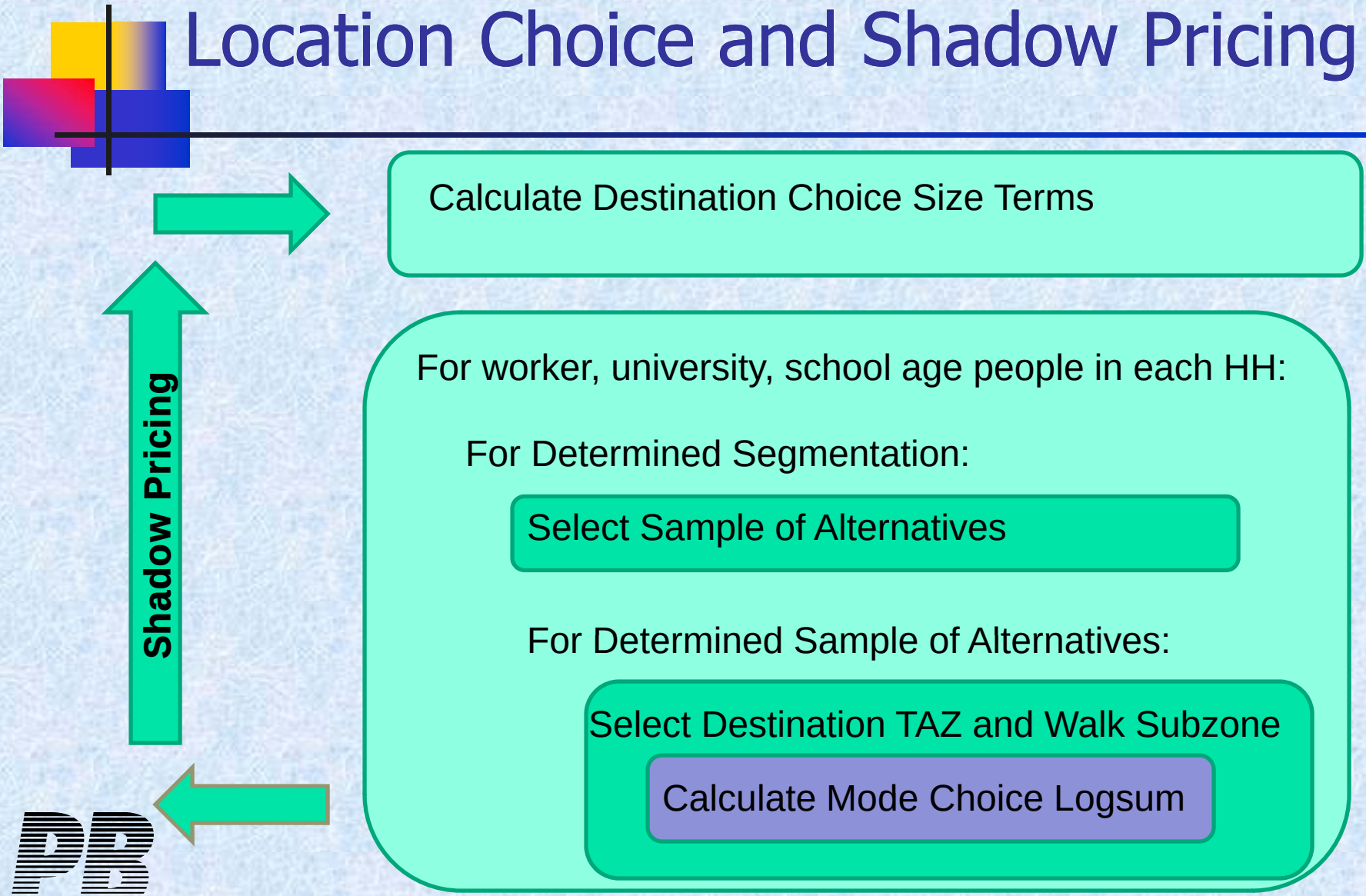
2.2. General Software Architecture

Software Architecture



2.3. Critical Issues & Time-Taking Operations

Location Choice and Shadow Pricing



Shadow Price Adjustments

- Constraining Mechanism to get total tour origins and destinations to match for long term segments
- Size variables adjusted to reflect more/less attractiveness by segment to influence destination choice
- Iterate procedure in previous flowchart until sufficiently constrained
- Calibration determines required number of iterations

Performance

- Two components take 99% of the running time, everything else takes minutes:
  - Location choice
  - Multi-class assignment and network skimming procedures
- Solutions:
  - Parallel processing
  - Pre-sampling of zones
  - Packeting
  - Smart pre-calculation

Packeting

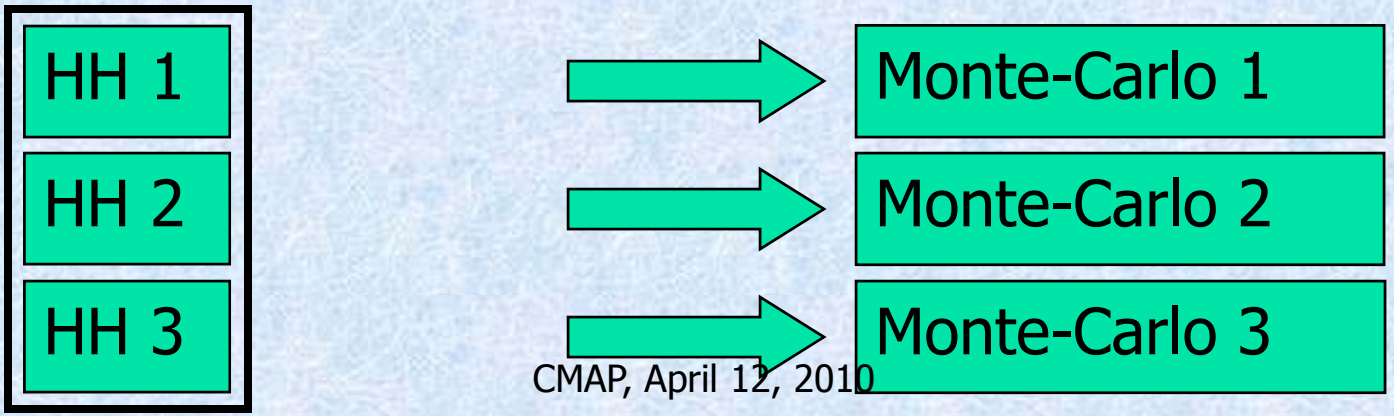
Two stages of choice model application in MCSM:

Choice utility & probability calculation → Monte-Carlo realization

99.99% of runtime

0.01% of runtime

Same TAZ, identical HHs:



Smart Pre-Calculations

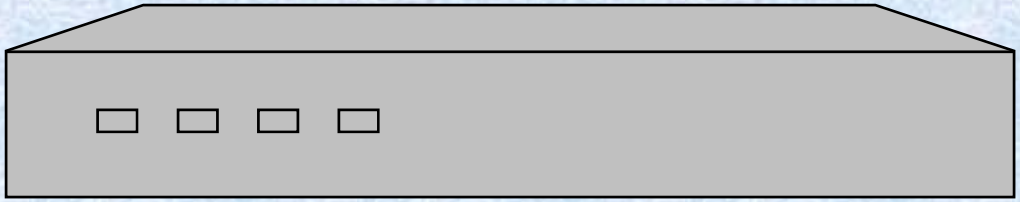
Destination choice utility for 23,000,000 tours × 8,000 zones × Log-sum of 11 modes:

HH part	OD-part	Attr part
23,000,000 × 11 modes	4,000 orig × 4,000 dest × 11 modes × 6 purposes	8,000 dest × 6 purposes

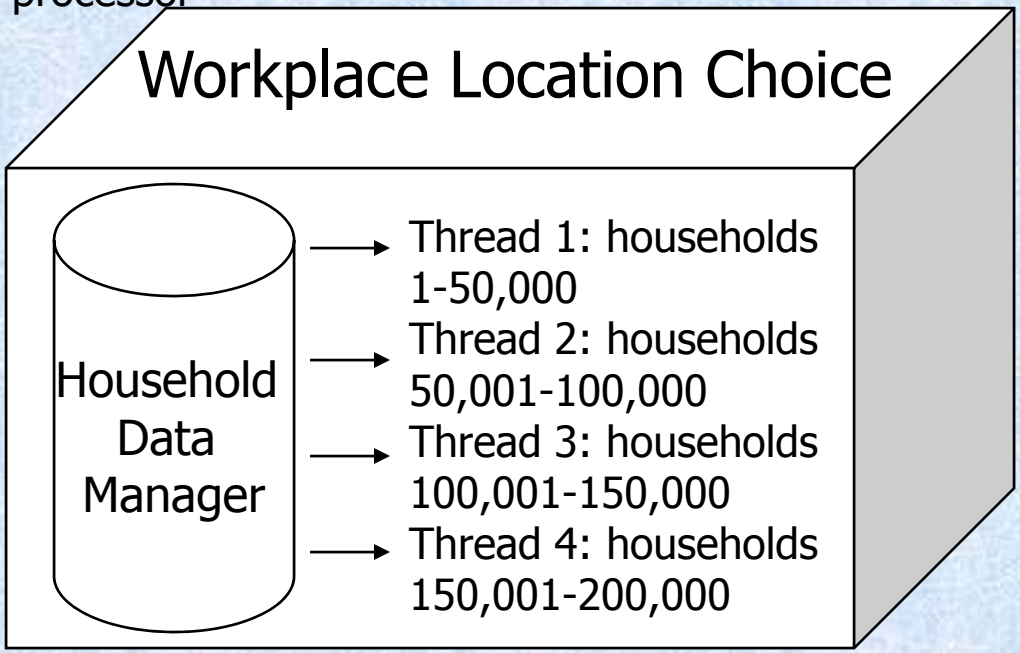
Quick Combination

2.4. Distribution & Threading

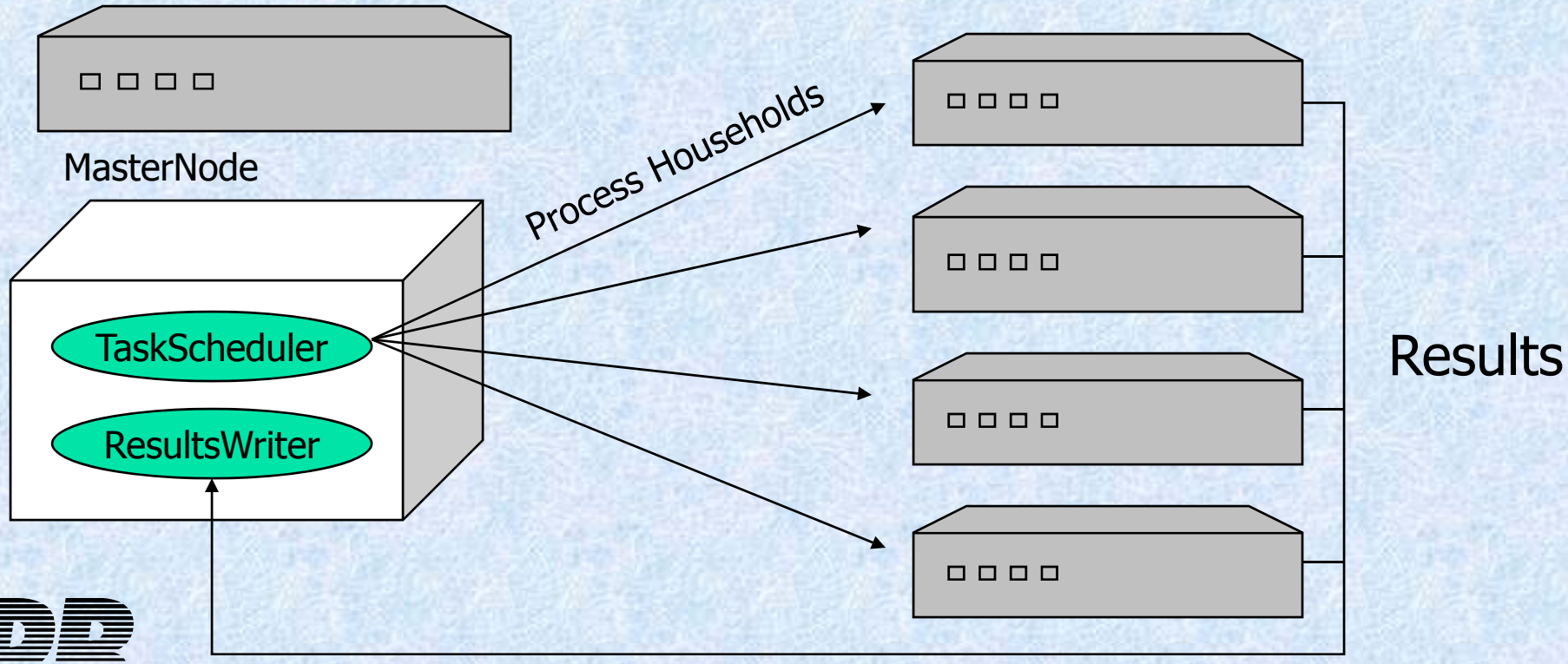
Threading



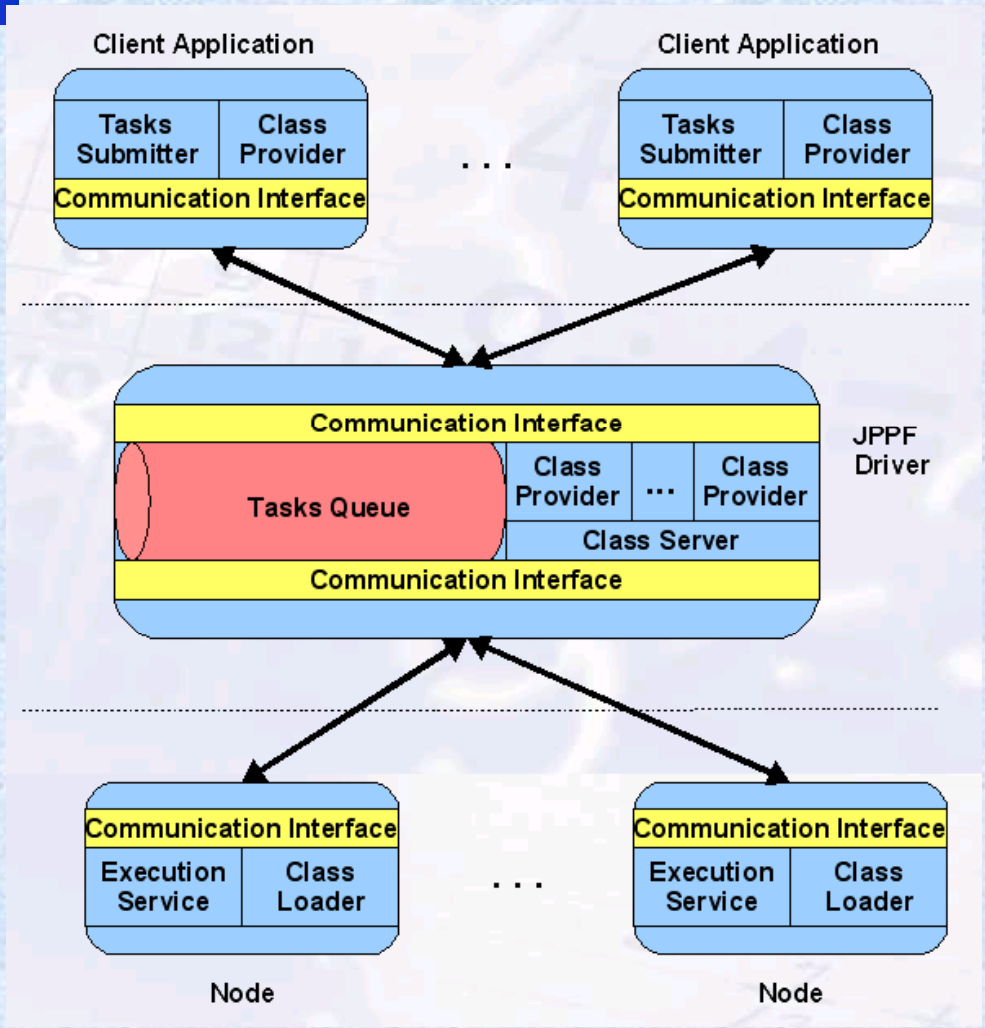
Quad-core Intel Box with 4 GB RAM per processor



Distribution



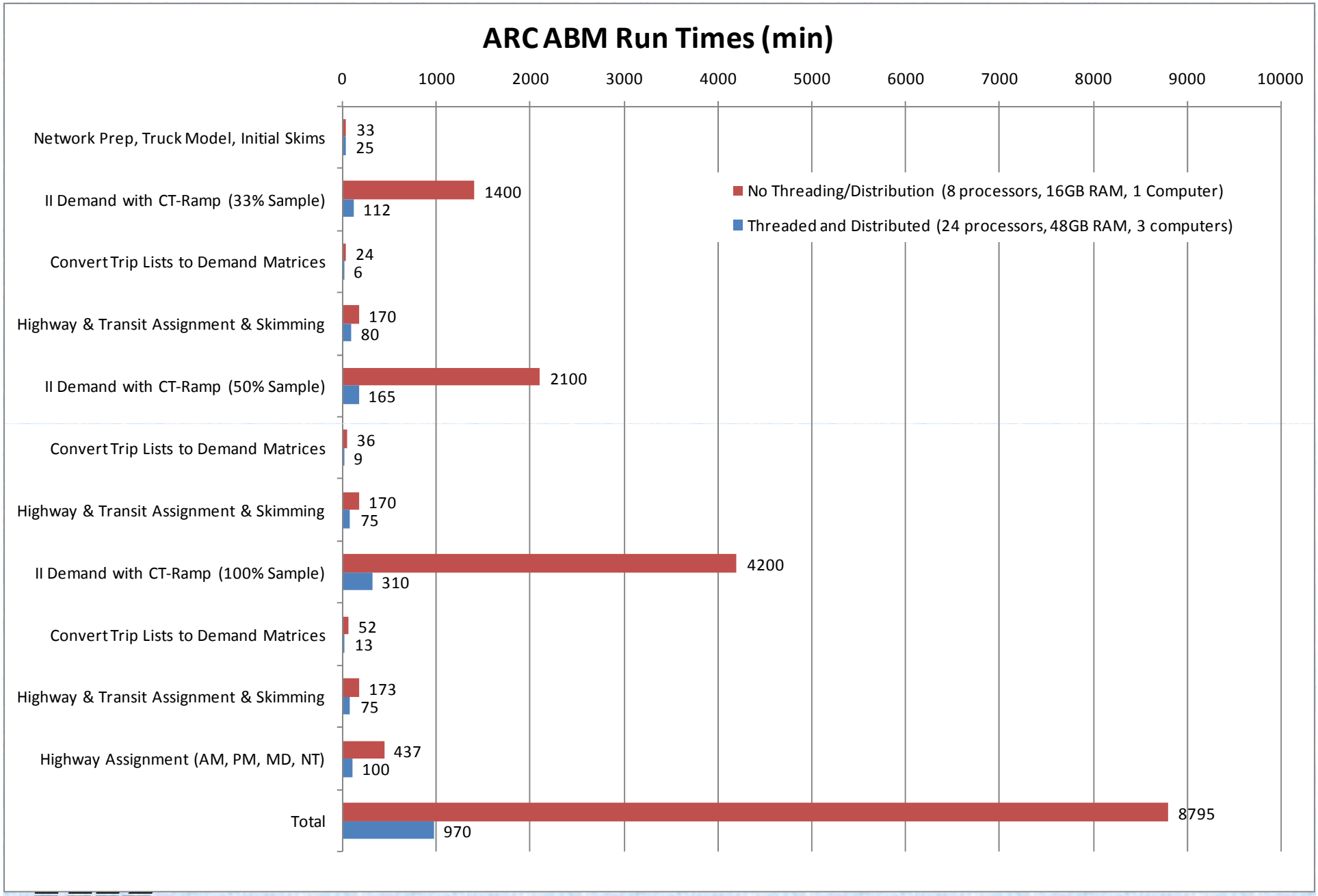
JPPF Framework



2.5. Runtime Statistics

Runtimes

- Model runtime is roughly proportional to population size
- Network skimming and assignment procedures are still proportional to the squared number of TAZs – 50% or more of total model runtime is due to skimming/assignment
- Overnight model runs for large regions possible with threading and distribution
- More hardware = less runtime


ARC ABM Run Times (min)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Network Prep, Truck Model, Initial Skims
33
25
II Demand with CT-Ramp (33% Sample)
1400
112
Convert Trip Lists to Demand Matrices
24
6
Highway & Transit Assignment & Skimming
170
80
II Demand with CT-Ramp (50% Sample)
2100
165
Convert Trip Lists to Demand Matrices
36
9
Highway & Transit Assignment & Skimming
170
75
II Demand with CT-Ramp (100% Sample)
4200
310
Convert Trip Lists to Demand Matrices
52
13
Highway & Transit Assignment & Skimming
173
75
Highway Assignment (AM, PM, MD, NT)
437
100
Total
8795
970
No Threading/Distribution (8 processors, 16GB RAM, 1 Computer)
Threaded and Distributed (24 processors, 48GB RAM, 3 computers)

MORPC ABM Runtimes

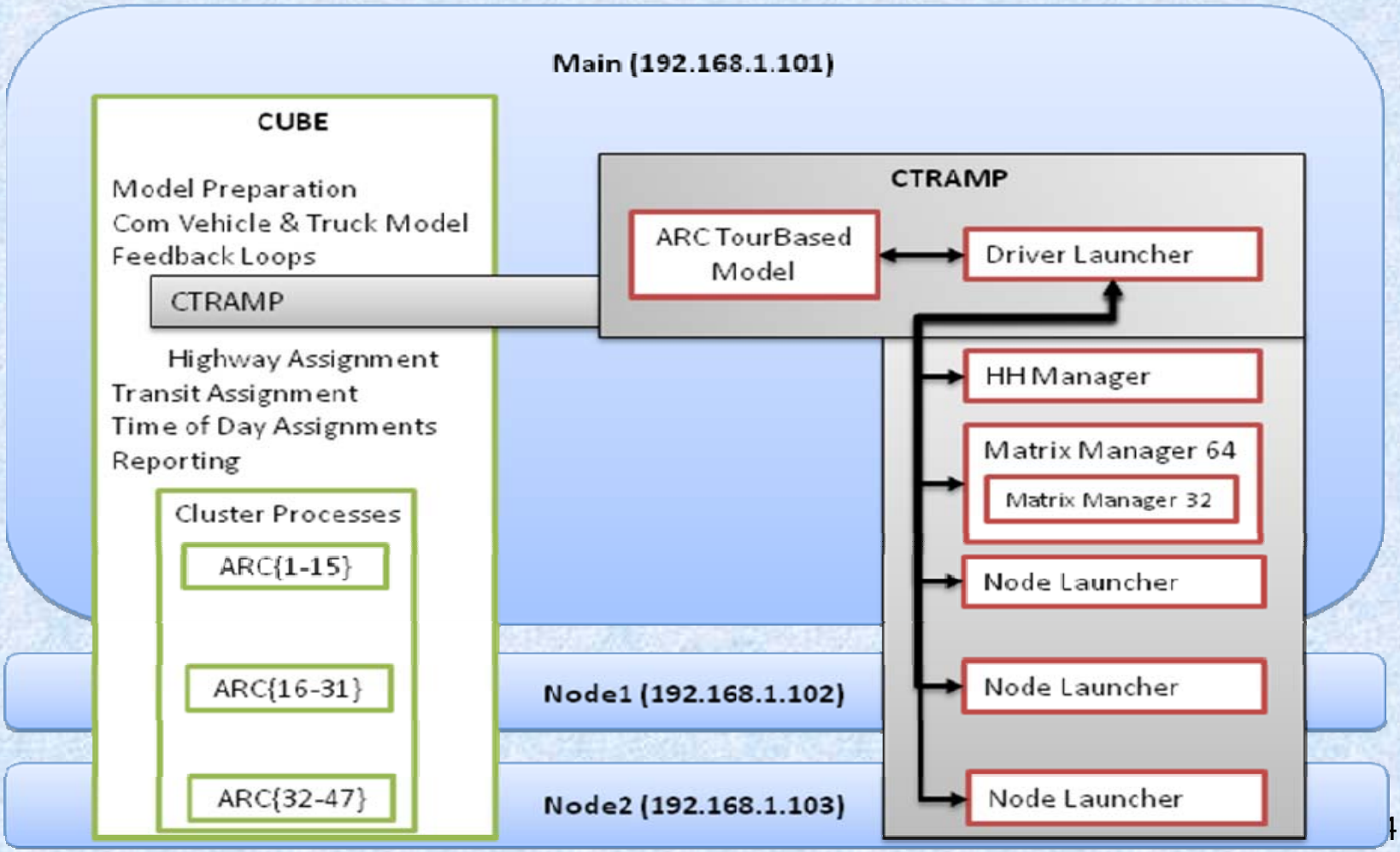
Model components	2000			2000	2030		
	MORPC 3	MORPC 4	COTA	ODOT	MORPC 3	MORPC 4	COTA
Households	610,774	610,774	610,774		872,919	872,919	872,919
Population	1,435,389	1,435,389	1,435,389		1,956,660	1,956,660	1,956,660
Tours	2,074,618	2,073,659	2,075,797		2,997,507	2,997,214	2,996,117
Core Model Total (3 iterations)	35:43	31:20	20:55	10:25	48:35	41:23	26:43
Iteration 1	11:27	10:08	6:51	3:29	16:18	13:28	8:30
Iteration 2	11:26	9:55	6:28	3:28	14:59	12:48	8:06
Iteration 3	12:49	11:16	7:36	3:27	17:17	15:06	10:06
Iter 1 - Population Synthesis	0:02	0:02	0:01	0:01	0:02	0:02	0:01
Iter 1 - Sending Files to Workers	0:20	0:20	0:12	0:39	0:19	0:20	0:14
Iter 1 - Auto Ownership	0:01	0:01	0:00	0:00	0:02	0:02	0:01
Iter 1 - Mandatory Tour Generation	0:53	0:53	0:39	0:29	1:15	1:15	0:39
Iter 1 - Mandatory DTM	4:01	3:14	1:59	0:55	6:07	4:48	2:50
Iter 1 - Joint Tour Generation	0:12	0:12	0:08	0:07	0:14	0:14	0:08
Iter 1 - Joint Tour DTM	0:08	0:06	0:04	0:05	0:08	0:07	0:05
Iter 1 - Individual Tour Generation	0:05	0:05	0:05	0:03	0:07	0:07	0:05
Iter 1 - Individual Tour DTM	0:54	0:41	0:23	0:11	1:15	0:56	0:30
Iter 1 - At-Work Sub-Tour DTM	0:08	0:07	0:06	0:03	0:12	0:10	0:07
Iter 1 - Mandatory Stops Model	0:49	0:38	0:21	0:11	1:14	0:59	0:32
Iter 1 - Joint Stops Model	0:07	0:06	0:04	0:07	0:08	0:07	0:05
Iter 1 - Individual Stops Model	0:54	0:43	0:24	0:14	1:11	0:54	0:31
Iter 1 - At-Work Stops Model	0:06	0:05	0:04	0:05	0:09	0:08	0:05
Iter 1 - Writing Files and Trip Tables	0:13	0:13	0:10	0:12	0:35	0:34	0:26
Iter 1 - External Model +	0:00	0:00	0:00		0:01	0:01	0:01
Iter 1 - Commercial Vehicle +	0:02	0:02	0:01		0:02	0:02	0:01
Iter 1 - IE Trips +	0:00	0:00	0:00		0:00	0:00	0:00
Iter 1 - Highway Assignment - 2 period +	1:08	1:14	1:07		2:03	1:31	1:16
Iter 1 - Highway and Transit Network Skimming +	1:17	1:17	0:53		1:04	1:03	0:44
Iter 3 - Highway Assignment - 4 period +	2:14	2:18	1:51		3:11	3:07	2:19
Iter 3 - Transit Assignment - 2 period +	0:16	0:16	0:10		0:12	0:12	0:07
Core Model	2:59	2:30	1:36	1:09			
		16%	36%	27%			

2.6. Hardware Configurations

ARC ABM Example

- 3 computers:
  - Windows Server 2003 64bit
  - Dual Quad Core Intel Xeon X570 2.93 GHz Processors (8 total)
  - 32 GB of RAM
  - Cube Voyager + 8 seat Cube Cluster license (16 total seats with hyper-threading)
- Hardware+Software≈$30K

ARC ABM System Design



MTC ABM Example

- 4 computers:
  - 16 64-bit processors (2 hyper-threaded quad-core chips);
  - 48 GB RAM;
  - 2 TB hard drive on master; 1 TB hard drive on slaves;
  - Microsoft Windows 2008 Server (64-bit) operating system.
- Hardware cost ≈ $35K

2.7. Staffing & Qualification Requirements

Different Groups

- System analyst / architect:
  - Modification of the model system structure, for example adding an interface between ABM and DTA,
- Programmer:
  - Modifications of the code, for example, adding new transit modes,
- Modeler:
  - Manipulating UEC,
- End user
  - Manipulating input data, networks, and outputs.

Conclusions

- Core demand model runtime is roughly proportional to population size,
- Network skimming and assignment procedures are still proportional to the squared number of TAZs – 50% or more of total model runtime is due to skimming/assignment,
- Overnight model runs for large regions comparable to CMAP possible with threading and distribution.
- The substantial improvements in run times were made possible by a strong supply of computing power and a distributed/threaded implementation.
- More hardware can reduce runtime. The modeling system is built to take advantage of adding additional computers/processes to reduce run times even more.
- Longer term, some other computing technology solutions might prove effective, including possibly cloud computing.