CMAP Transit Modernization Model Project: Extending CT-RAMP Transit Modeling Capacity

Overview of completed Phase 1 and

Plan for Phase 2

Focus of the Project

- Existing CMAP CT-RAMP ABM:
  - Advanced microsimulation platform
  - Integrated with CMAP socio-economic & land use data and networks
  - Tested for highway pricing studies
- Enhance and test transit side:
  - Incorporate State-of-the-Art & Practice in transit procedures and mode choice
  - Quantifiable measures of premium transit services
  - Validate against available data on transit ridership

Project Team

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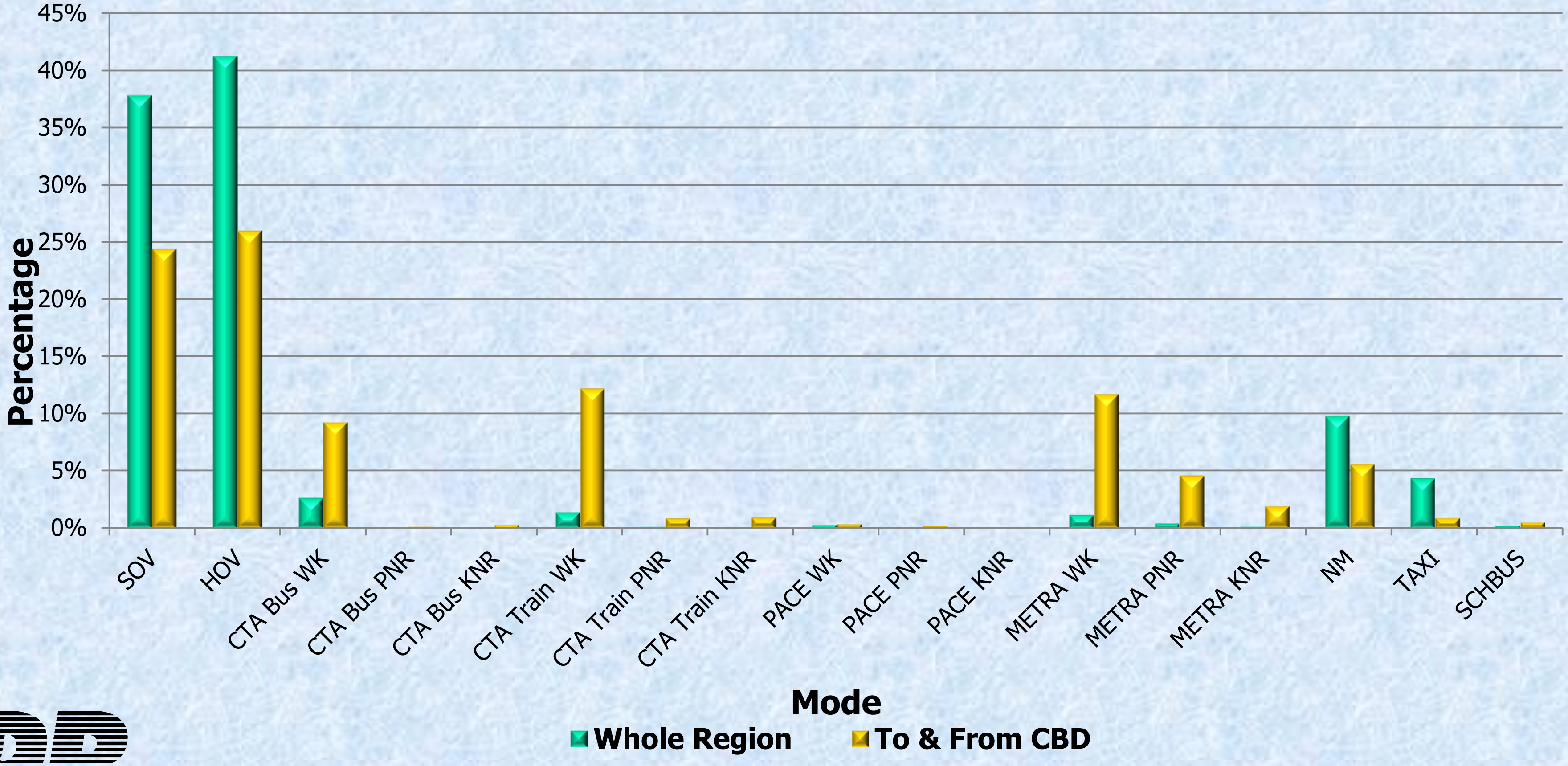
Transit-Rich Chicago Mega-Region (HTS, 2007)



Main Sources of Inspiration

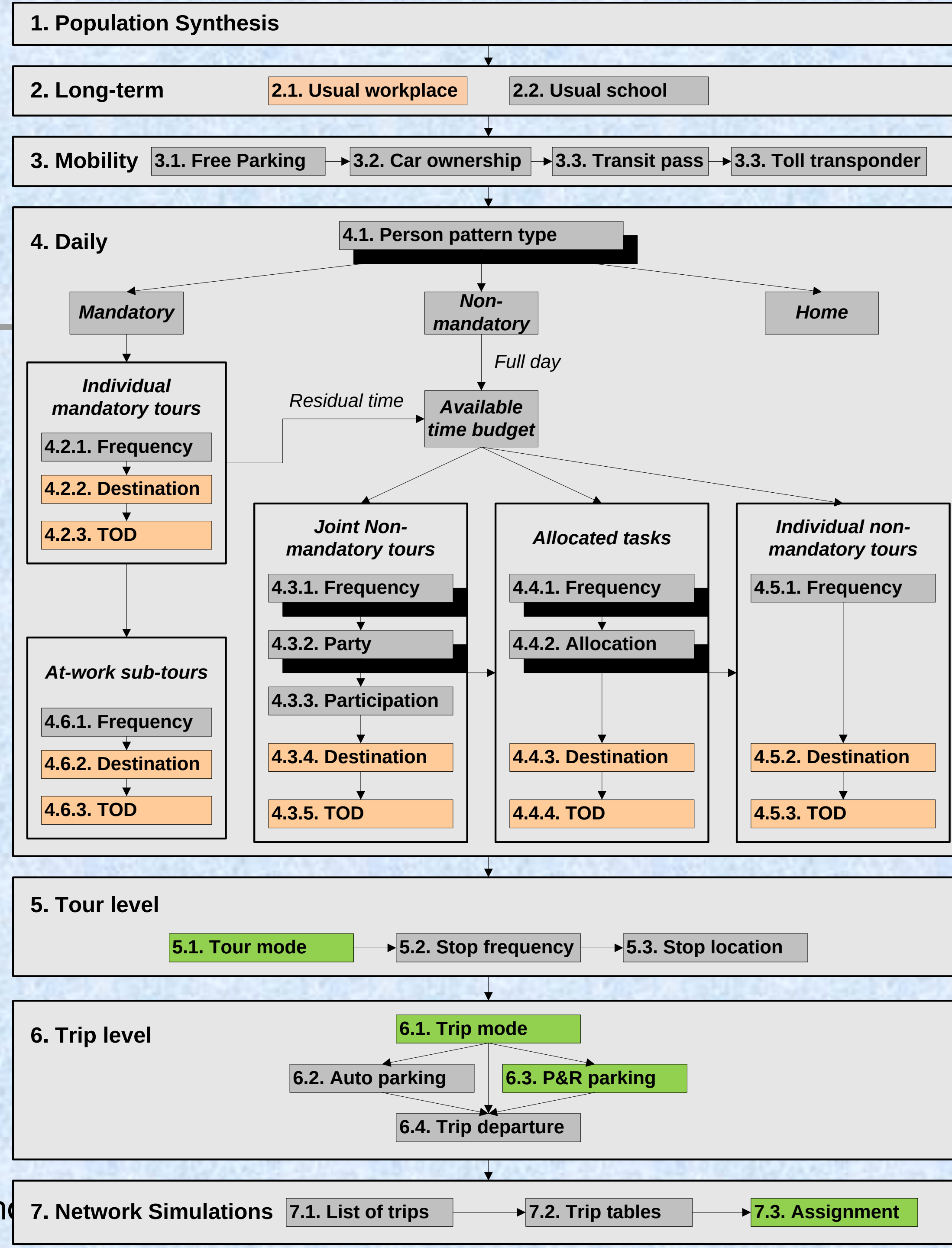
- Enhanced spatial resolution (20,000 MAZs) following SANDAG MAG & SACOG ABM
- TCRP H-37 “Characteristics of Premium Transit Services that Affect Choice of Mode”
- Chicago Area New Starts Model experience
- Portland Metro Study “Understanding & Modeling Transit Preferences”
- LACMTA FTA-Sponsored Study “Incorporation of Transit Capacity Constraints, Crowding and Reliability in Travel Models”

CMAP CT-RAMP

Standard CT-RAMP components

Developed for CMAP Pricing ABM

Developed for CMAP Transit ABM



Main Aspects of Model Improvement

Model Component	Phase 1	Phase 2
Advanced "non-labeled" mode choice	X	X
Transit access / spatial resolution		X
Station characteristics	X	X
In-vehicle parameters	X	X
Capacity constraints		X
Crowding effects		X
Service reliability		X
Transit frequency / wait time	X	X
Fare / cost structures	X	X
Individualized transit path choice		X
Mobility attributes and modality		X

Non-Labeled Mode Approach

- Refer to actual service characteristics and understand traveler perceptions
- Eliminate proliferation of mode-geography-specific constants
- Promoted by FTA
- Essence of TCRP H-37 "Transit Services that Affect Choice of Mode"

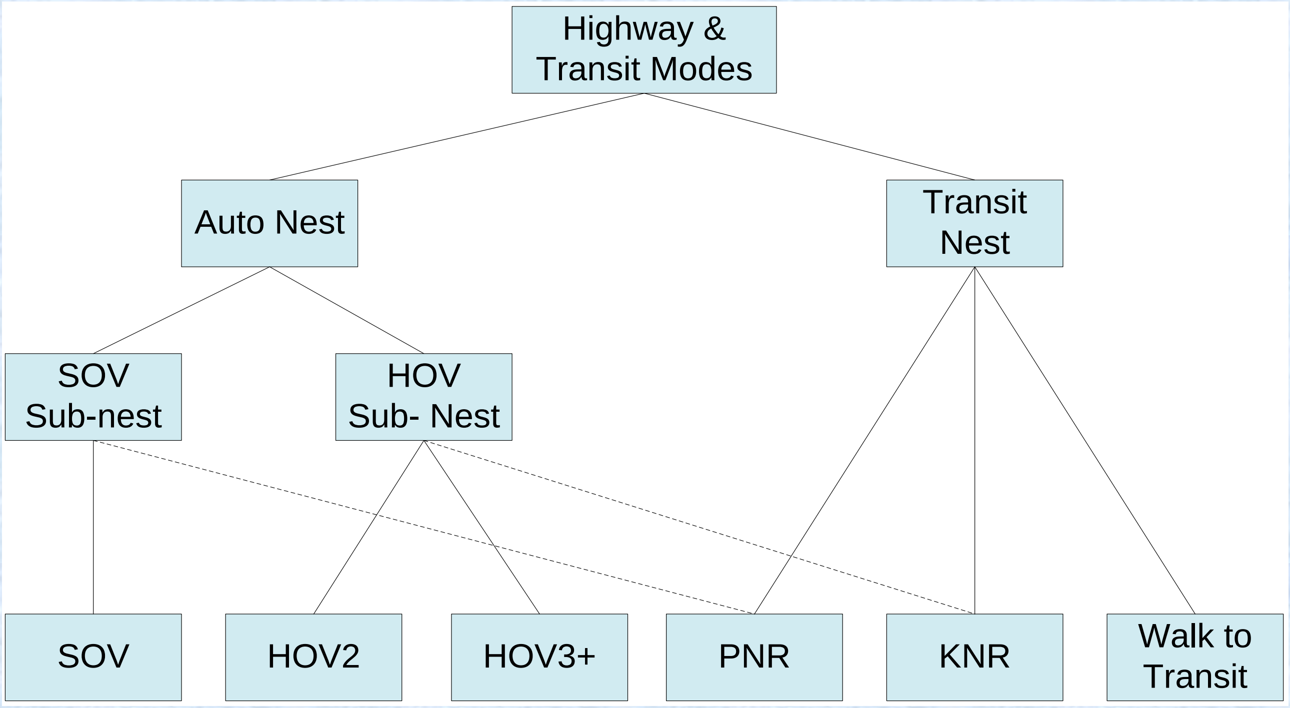
Mode Choice Alternatives

Previous (labeled)	Phase 1	Phase 2
Walk to bus (CTA local bus, Pace local bus, CTA express bus)	**Walk to conventional** transit (CTA local bus, Pace local bus, CTA train)	**Walk to transit** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)
Walk to premium transit (CTA train, Metra commuter rail)	**Walk to premium** transit (CTA express bus, Metra commuter rail)	
Drive to premium transit (CTA train, Metra commuter rail)	**PNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	**PNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)
Drive to bus (CTA local bus, Pace local bus, CTA express bus)	**KNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)	**KNR** (CTA local bus, Pace local bus, CTA express bus, CTA train, Metra commuter rail)

Shift in Transit Modeling Paradigm

- Transit user sees generic transit service where different modes and lines can be used
- Access modes (Walk, PNR, KNR) represent distinctive options
- From proliferation of transit modes to capturing individual path-building rules:
  - Less modes in the mode choice set
  - Path choice sensitive to transit attributes and person characteristics

Cross-Nested Logit (Phase 2)

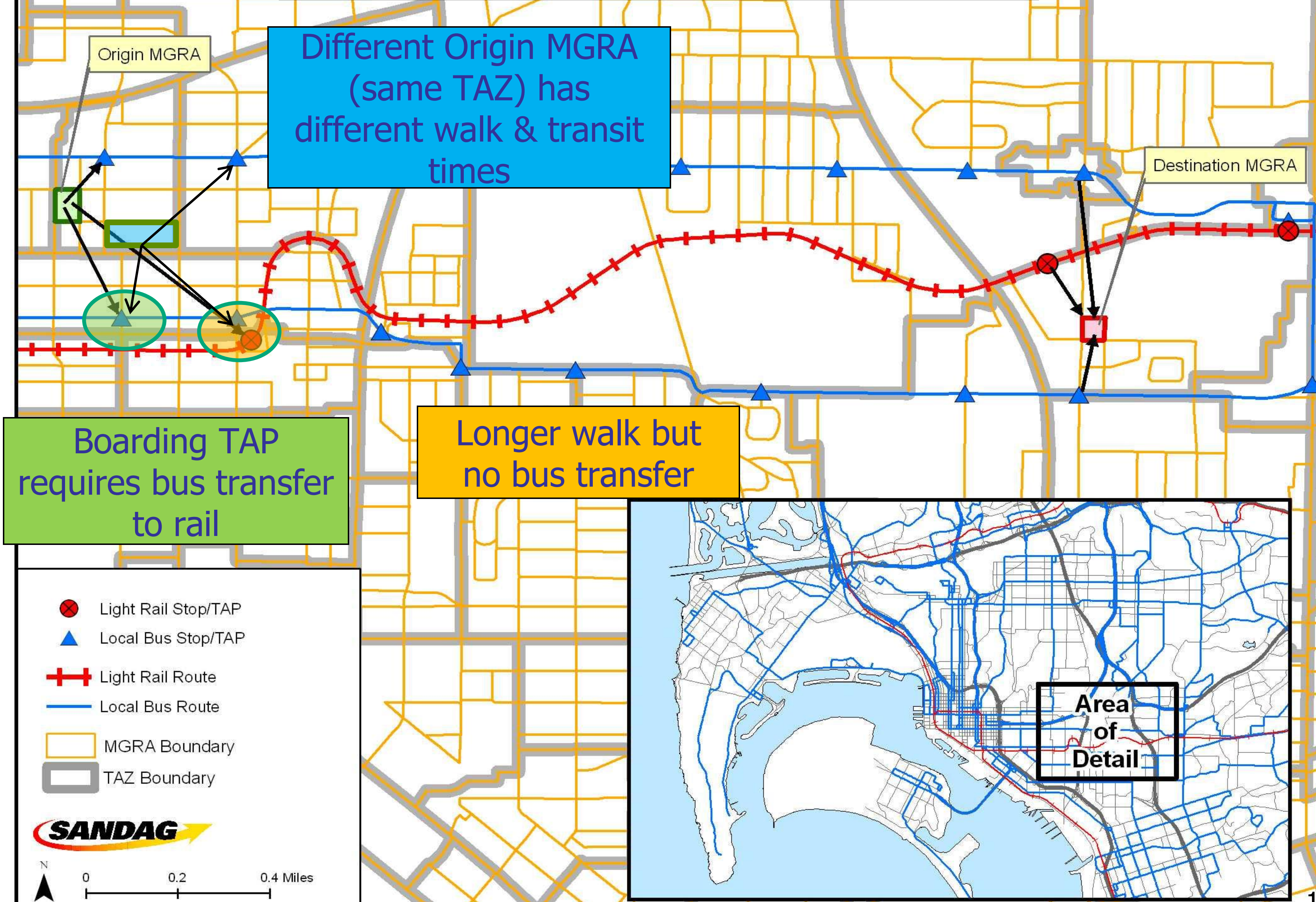


- Partial similarity of HOV and KNR
- Partial similarity of SOV and PNR

Enhanced Spatial Resolution

- 17,000 MAZs nested in 2,000 TAZs:
  - CT-RAMP handles all location choices at MAZ level
  - EMME transit assignment & skimming cannot handle 17,000×17,000 matrices
- Virtual path building:
  - Access and egress time pre-calculated for MAZ-to-station matrices using detailed street network
  - Station-to-station time/cost matrices skimmed
  - MAZ-station-station-MAZ path calculated on the fly

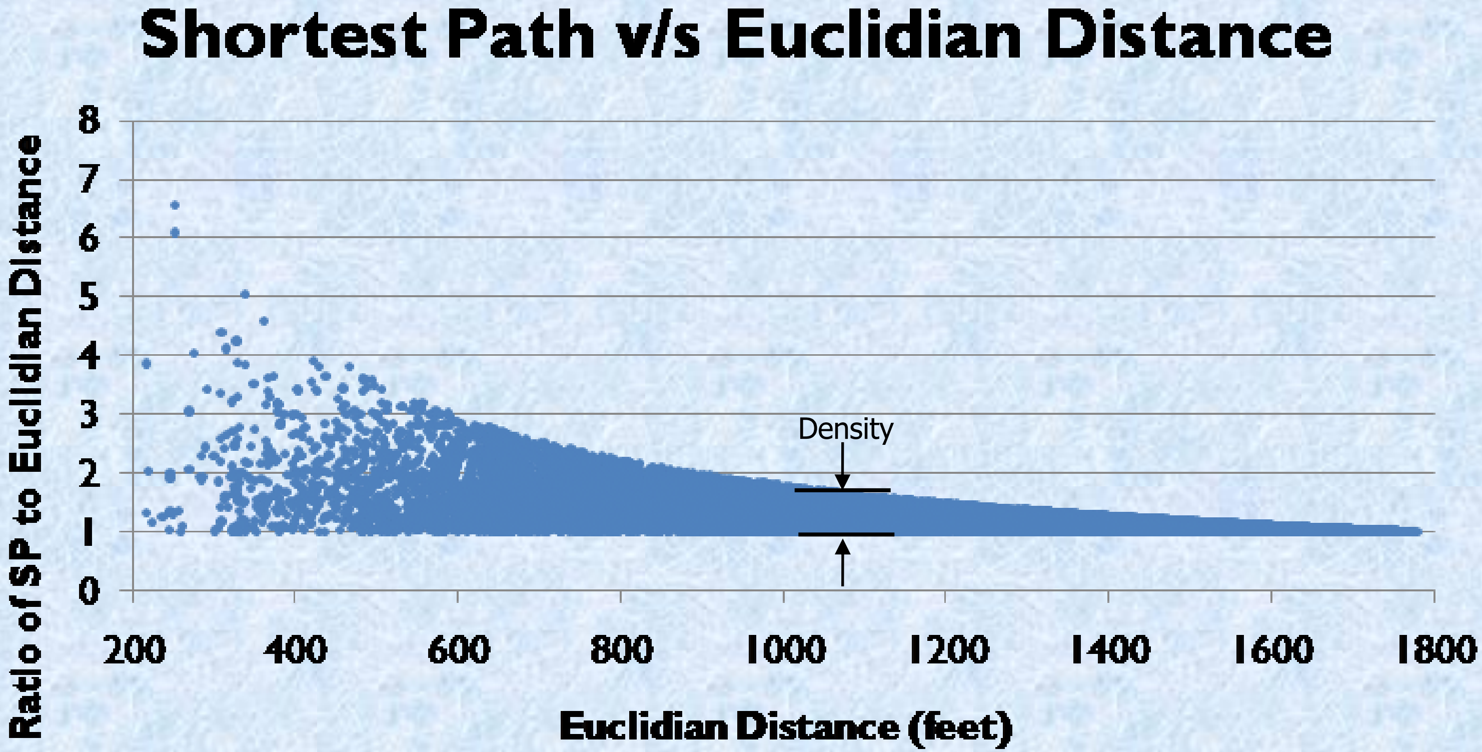
Transit Path-Building



CMAP Data

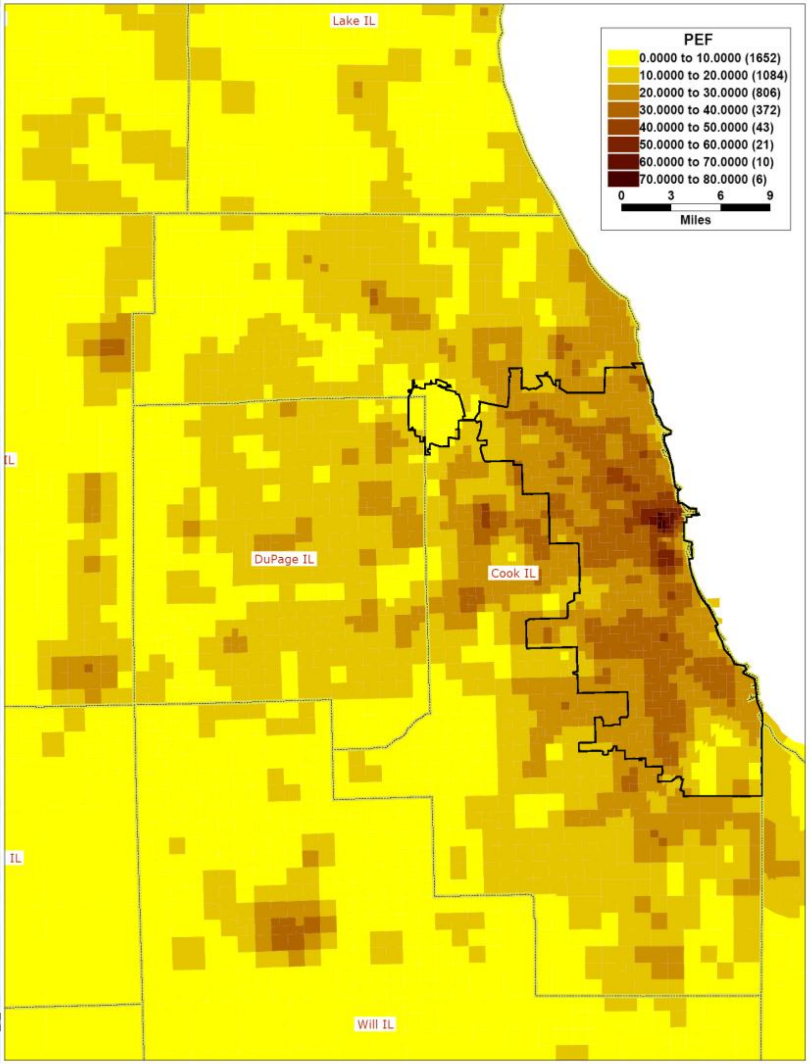
- Chicago has 37,000 total Google transit feed stops
  - Pace – 25,000 stops
  - CTA - 12,000 stops
  - Metra – 240 stops
  - NICTD – 20 stops
- Some duplicates, overlaps
- Collapse stops to reasonable number (<6,000) without losing too much accuracy

Importance of Access Network Details (MAG)



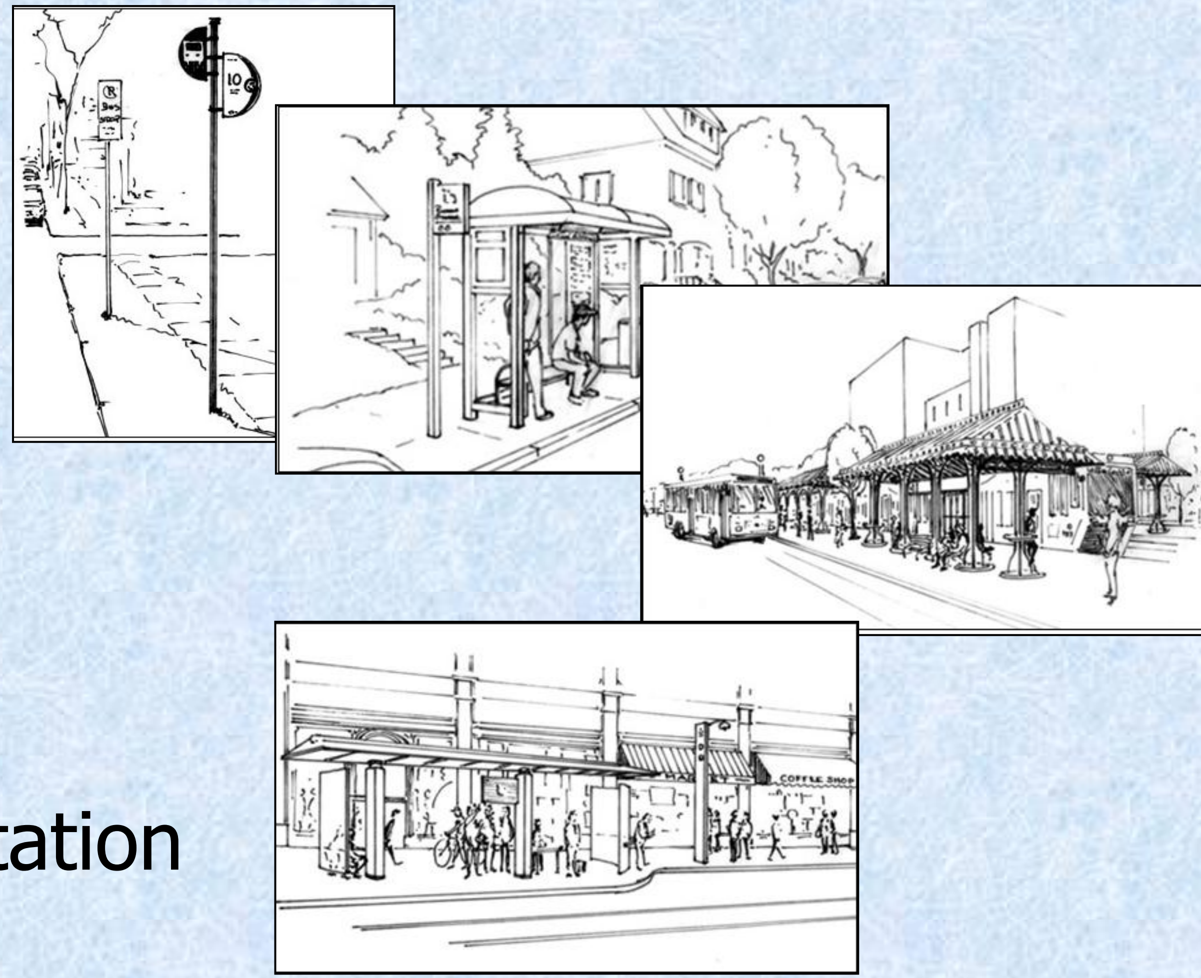
Pedestrian Environment Factor

- Scaled to represent walk time weight:
  - 1.0=best conditions
  - 3.0=worst conditions
- Incorporated in transit path building and mode choice



Classification of Stations

1. Pole
2. Shelter
3. Plaza
4. Station
5. Major station



Parameterization of Stations (Phase 1)

Station Type	Wait convenience factor	Real-time information factor	Boarding / transfer time, min
1=Pole	2.50	0.9	2.0×2.5
2=Shelter	2.25	0.9	2.0×2.5
3=Plaza	2.00	0.9	3.0×2.5
4=Station	1.75	0.9	3.0×2.5
5=Major station	1.75	0.9	4.0×2.5

Parameterization of Stations (Phase 2)

- Estimate all parameters based on observed transit path choices:
  - Individualize by age, income, etc
- Quantify & consider additional variables:
  - Proximity to commercial services
  - Easy of paying (fare policy & media)
  - Easy of boarding (in combination with vehicle type)
  - Cleanliness
  - Security

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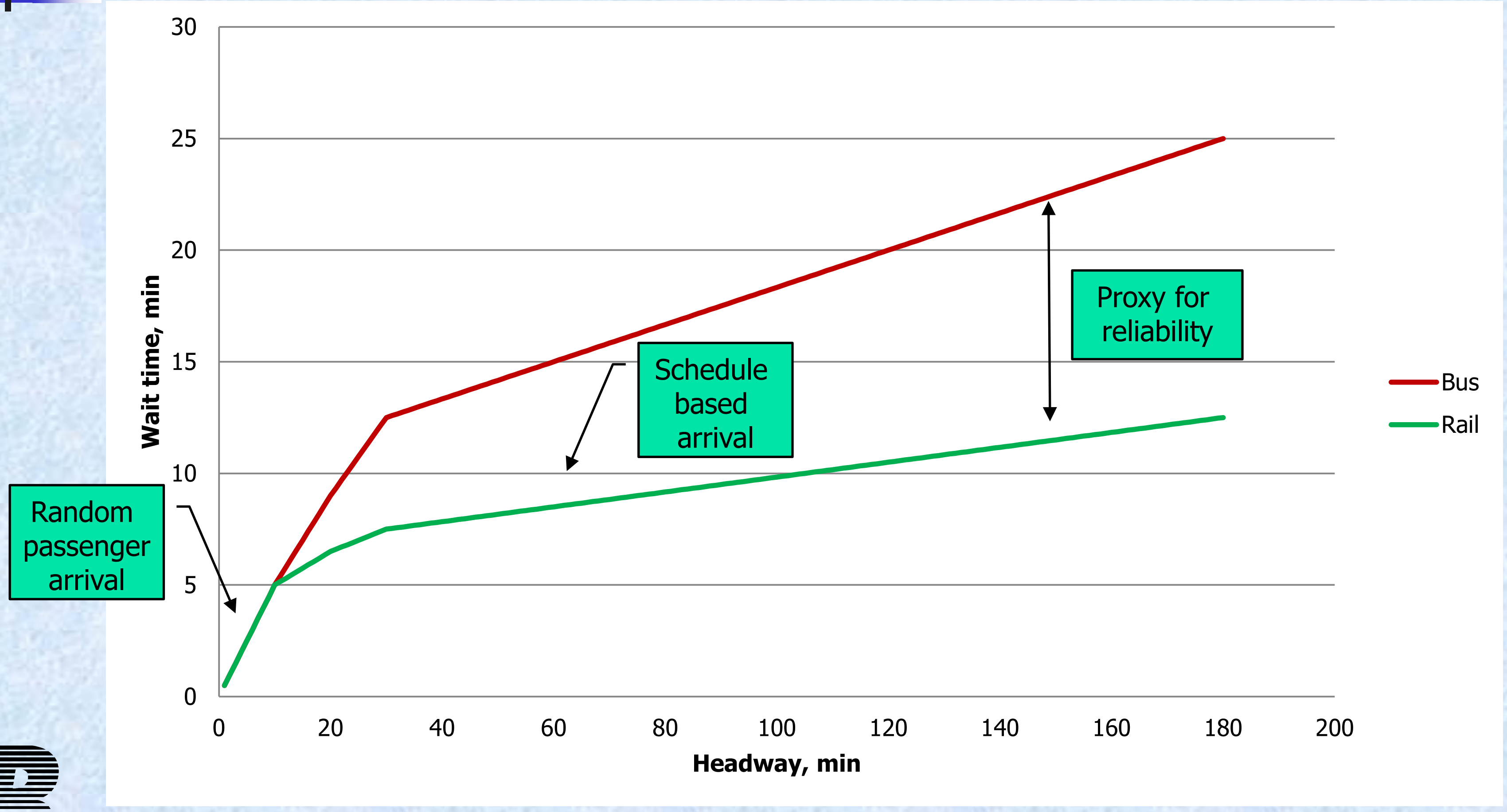
Parameterization of In-Vehicle Conditions (Phase 1)

Vehicle type	In-vehicle time convenience factor
Local bus (BPL)	1.00
Express bus (EQ)	0.95
CTA train (C)	0.90
Metra rail (M)	0.85

Parameterization of In-Vehicle Conditions (Phase 2)

- Estimate all parameters based on observed transit path choices:
  - Individualize by age, income, etc
- Quantify & consider additional variables:
  - Seating comfort
  - Productivity (work, sleep, socialize)
  - Cleanliness
  - On-board amenities
  - Socio-economic compatibility between riders

Wait Time Function (Phase 1)



Model Validation (Phase 1)
Work Tours

		WK CONV		WK PRE		KNR		PNR	
		Survey	Model	Survey	Model	Survey	Model	Survey	Model
Destination Sector	1	172,620	171,630	109,018	112,155	51,723	46,330	25,863	24,865
	2N	21,399	23,860	4,323	2,245	2,109	995	887	560
	2NW	7,562	19,550	840	3,200	849	1,555	76	1,135
	2WNW	8,353	5,245	2,863	675	-	260	-	185
	2W	9,488	11,940	72	1,325	185	880	942	495
	2WSW	6,347	7,990	-	895	56	605	57	260
	2SW	14,090	13,525	218	685	55	965	644	270
	2S	19,759	16,750	5,010	2,605	1,410	1,590	109	695
	3N	2,095	1,915	49	830	1,400	540	113	345
	3NW	1,771	1,800	793	865	45	860	1,044	350
	3WNW	1,189	1,435	2,025	660	160	990	-	325
	3W	88	3,055	634	610	817	1,295	337	520
	3WSW	2,474	2,120	1,367	1,200	1,002	2,070	945	855
	3SW	709	2,005	-	335	-	485	182	145
	3S	885	1,070	-	165	-	985	-	155
	XWI	-	-	-	-	-	35	-	40
	XIL	-	-	-	-	-	-	-	-
	3IN	1,451	85	147	5	44	110	168	30
	XIN	124	-	18	-	-	10	-	10
	4NW	1,659	770	183	390	145	990	-	600
	4N	2,208	1,065	3,625	865	-	580	69	530
	4WNW	347	510	-	50	177	425	-	205
	4W	-	100	-	25	-	160	-	20
	4WSW	-	710	-	35	-	400	-	75
	4SW	-	575	-	30	-	300	-	25
Total		274,620	287,705	131,184	129,850	60,177	63,415	31,437	32,695

Model Validation (Phase 1) Work Tours

		WK CONV		WK PRE		KNR		PNR	
		Survey	Model	Survey	Model	Survey	Model	Survey	Model
Origin Sector	1	34,275	20,655	6,223	2,995	553	1,335	373	310
	2N	86,561	80,245	13,073	19,215	4,088	9,335	3,679	3,695
	2NW	21,083	32,725	4,782	10,745	2,865	2,950	3,796	790
	2WNW	10,878	16,880	4,212	5,385	1,735	1,965	702	115
	2W	18,840	22,315	1,173	4,205	1,306	2,765	3,561	15
	2WSW	15,105	17,605	5,746	7,735	89	2,365	584	215
	2SW	22,877	30,235	2,035	5,565	2,508	4,425	575	430
	2S	50,101	50,890	20,929	38,945	4,979	8,055	4,356	2,560
	3N	1,259	1,275	6,792	1,615	854	515	139	160
	3NW	164	2,125	2,787	1,410	2,847	1,015	279	760
	3WNW	-	410	4,648	1,145	6,715	1,760	142	1,115
	3W	2,546	2,170	4,973	4,860	2,594	2,185	2,199	1,595
	3WSW	1,567	1,505	14,404	10,330	6,464	3,915	5,143	2,755
	3SW	946	3,000	6,396	5,175	3,621	3,435	690	1,740
	3S	1,877	1,540	2,539	3,140	1,611	3,260	1,383	1,500
	XWI	-	-	-	85	-	435	-	895
	XIL	-	-	-	-	-	1,780	-	1,075
	3IN	1,891	115	2,521	430	2,861	3,885	130	4,315
	XIN	197	-	1,603	60	722	770	41	1,660
	4NW	240	550	6,370	1,855	4,820	1,705	263	2,320
	4N	3,867	1,055	7,894	1,875	780	580	611	510
	4WNW	347	640	1,061	490	509	525	1,304	570
	4W	-	85	914	390	760	285	1,485	480
	4WSW	-	925	4,738	935	3,331	965	-	1,105
	4SW	-	760	5,372	1,265	3,564	3,205	-	2,010
Total		274,620	287,705	131,184	129,850	60,177	63,415	31,437	32,695

Model Validation (Phase 1) Non-Work Tours

		WK CONV		WK PRE		KNR		PNR	
		Survey	Model	Survey	Model	Survey	Model	Survey	Model
Destination Sector	1	91,289	101,995	15,630	13,940	8,498	7,445	7,287	7,605
	2N	32,753	40,135	530	1,245	183	465	1,671	1,805
	2NW	9,932	23,205	-	990	-	205	640	1,525
	2WNW	8,277	10,815	-	385	-	190	-	645
	2W	19,172	15,665	-	565	582	300	583	805
	2WSW	10,106	10,875	-	440	-	230	1,160	530
	2SW	16,827	22,000	227	440	394	535	1,492	700
	2S	66,524	43,470	1,537	3,295	425	905	1,272	1,835
	3N	1,809	1,110	52	240	55	55	207	280
	3NW	1,067	910	-	125	-	90	465	225
	3WNW	-	440	-	120	-	75	-	295
	3W	744	1,820	239	260	-	205	59	525
	3WSW	870	1,170	-	365	-	295	756	705
	3SW	1,648	2,270	-	175	-	90	-	310
	3S	1,028	1,390	280	130	97	115	139	165
	XWI	-	-	-	10	-	10	-	20
	XIL	-	-	-	-	-	-	-	-
	3IN	1,702	105	109	20	340	5	424	45
	XIN	235	-	-	5	24	10	-	30
	4NW	5,511	650	683	100	-	195	1,532	510
	4N	942	945	-	240	-	60	-	360
	4WNW	327	350	-	65	71	50	-	220
	4W	218	55	-	15	-	5	-	15
	4WSW	759	880	3,065	40	-	140	98	155
	4SW	762	915	-	40	254	85	1,045	205
Total		272,502	281,170	22,352	23,250	10,921	11,760	18,829	19,515

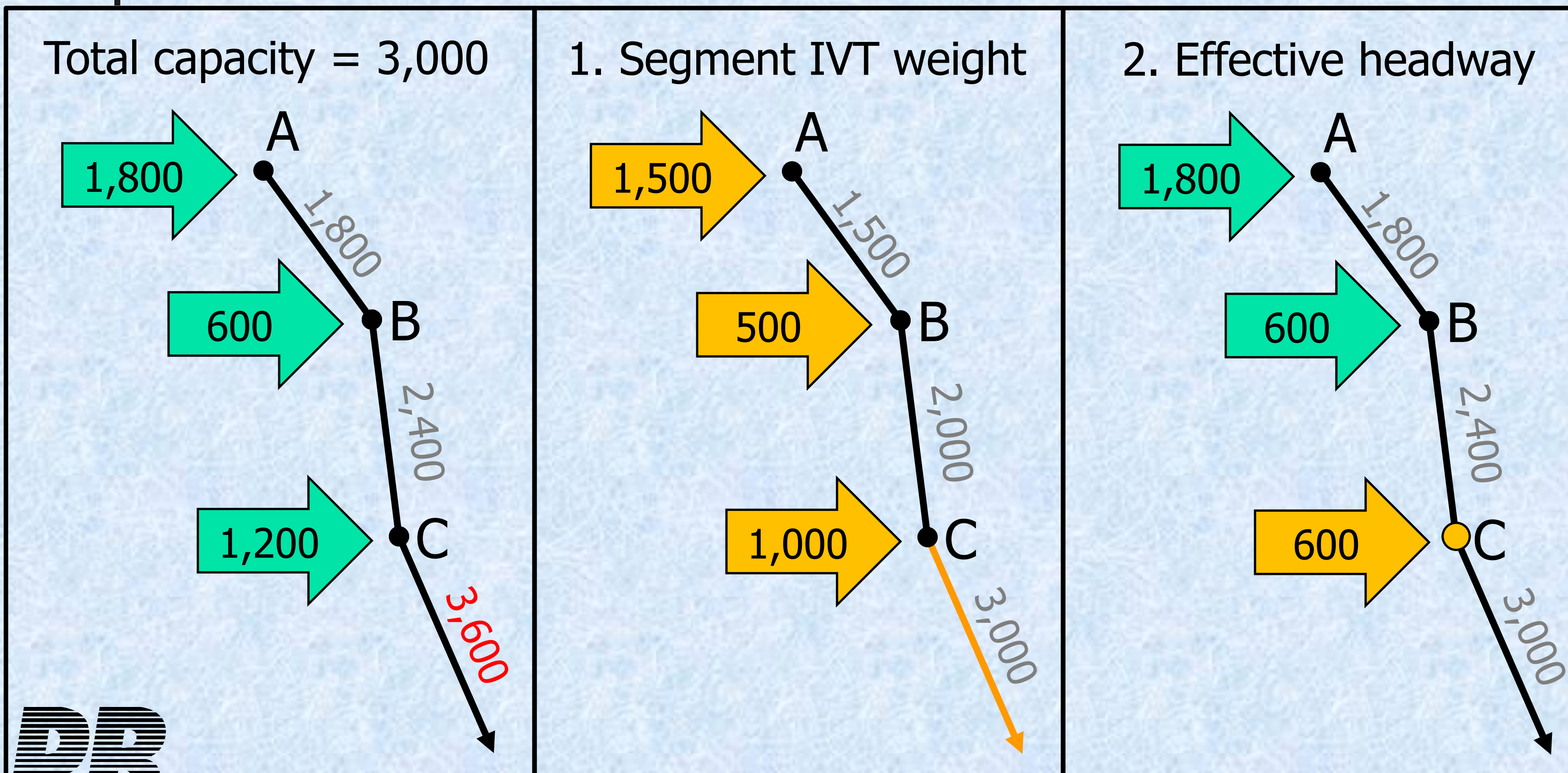
Model Validation (Phase 1) Non-Work Tours

		WK CONV		WK PRE		KNR		PNR	
		Survey	Model	Survey	Model	Survey	Model	Survey	Model
Origin Sector	1	46,718	28,540	1,537	2,010	1,004	1,195	918	145
	2N	42,997	52,045	1,550	1,915	1,327	1,225	2,746	760
	2NW	17,475	30,160	428	1,860	317	600	1,004	345
	2WNW	8,050	19,285	161	1,050	-	670	194	160
	2W	20,670	26,945	-	1,025	194	880	3,037	40
	2WSW	10,334	19,005	584	1,390	199	710	508	190
	2SW	19,889	27,705	44	805	143	915	694	215
	2S	95,047	65,760	3,373	9,030	633	1,945	2,255	1,885
	3N	924	1,120	953	200	55	150	396	125
	3NW	720	995	129	340	29	145	1,006	475
	3WNW	296	315	330	220	207	165	-	490
	3W	643	1,480	1,166	425	171	280	142	345
	3WSW	1,088	1,045	766	575	1,326	290	2,552	700
	3SW	458	1,725	-	325	262	225	-	395
	3S	110	1,155	5,219	250	686	310	594	465
	XWI	-	-	-	95	-	70	-	1,570
	XIL	0	-	-	-	-	555	-	3,120
	3IN	1,708	100	181	95	91	370	74	1,465
	XIN	513	-	32	15	166	155	65	1,595
	4NW	1,767	540	1,284	515	2,728	245	1,285	2,280
	4N	869	1,040	1,007	670	90	95	23	560
	4WNW	327	375	-	150	71	40	-	405
	4W	218	50	-	80	-	30	-	345
	4WSW	378	900	3,065	105	567	190	1,335	625
	4SW	1,305	885	544	105	657	305	-	815
Total		272,502	281,170	22,352	23,250	10,921	11,760	18,829	19,515

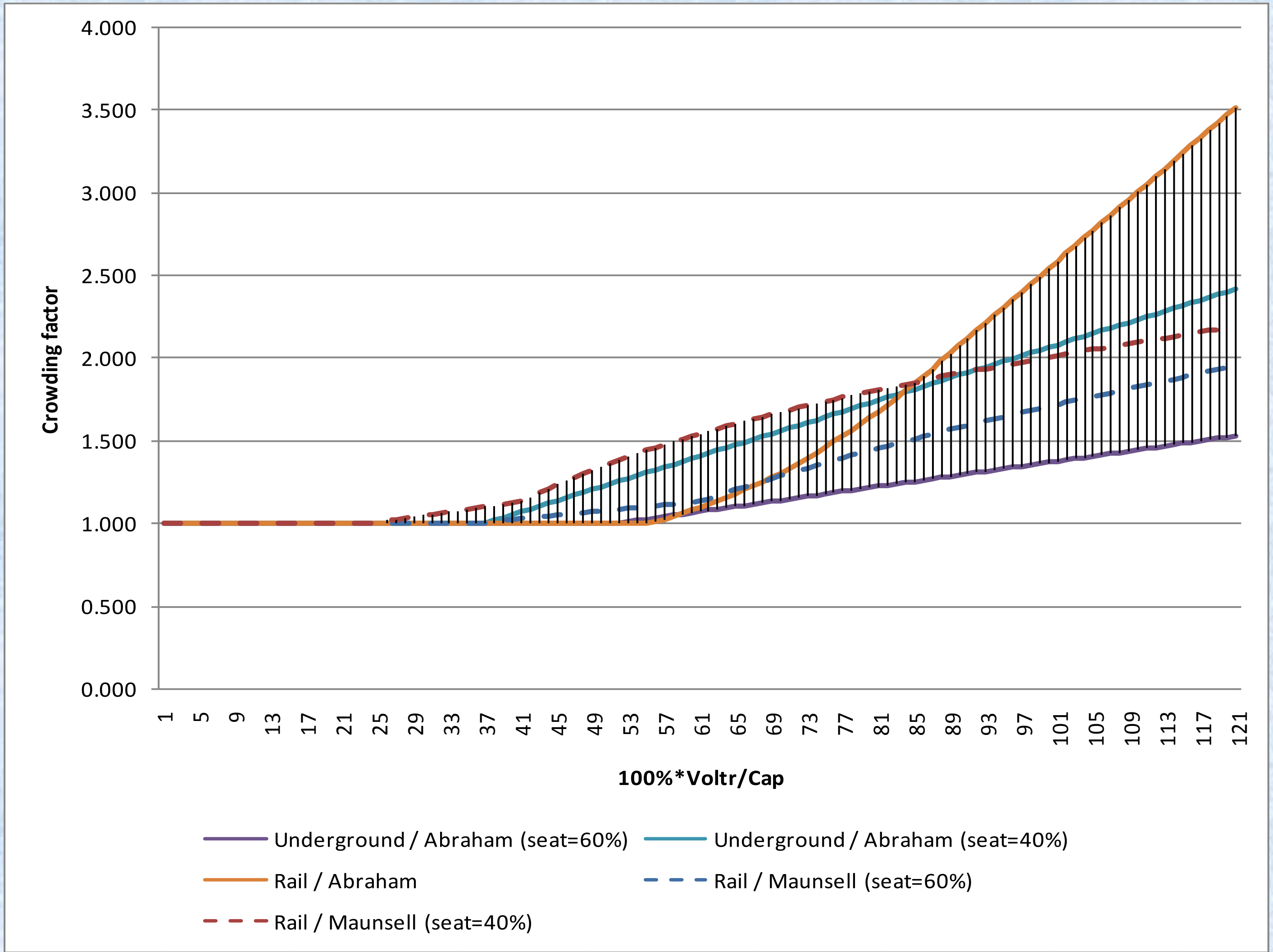
Capacity Constraint & Crowding Effects Intertwined

- Capacity constraint (demand exceeds total capacity)
  - Riders cannot board the vehicle and have to wait for the next one
  - Modeled as effective line-stop-specific headway greater than the actual one
  - Similar to shadow pricing in location choices
- Crowding inconvenience and discomfort (demand exceeds seated capacity):
  - Some riders have to stand
  - Seating passengers experience inconvenience in finding a seat and getting off the vehicle
  - Modeled as perceived weight factor on segment IVT

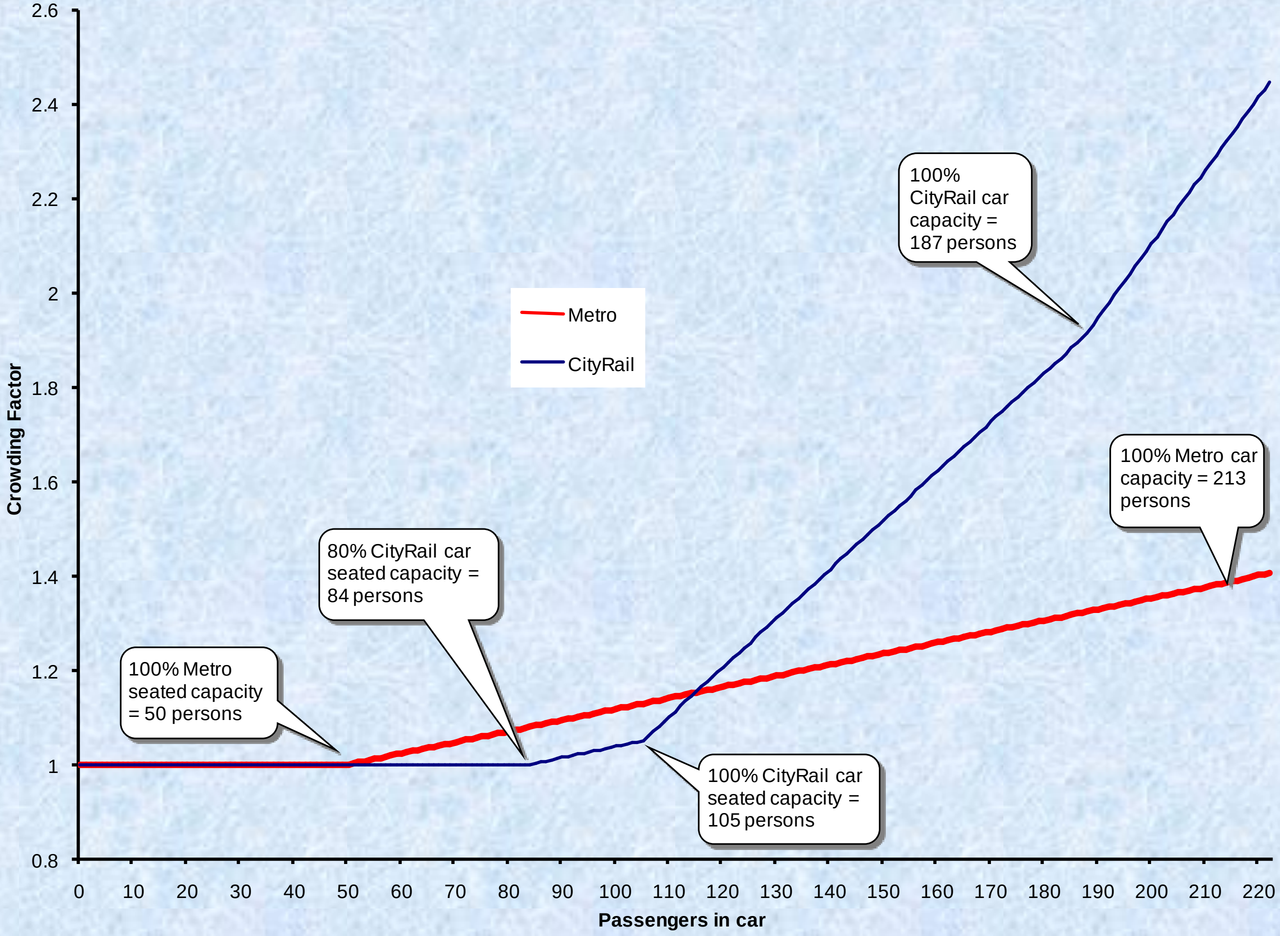
Capacity Constrained at Boarding Nodes and Not by Segments



Crowding Functions for British Rail and London Underground



Crowding Function Applies Incremental Costs as Vehicles Fill Up (Sydney)



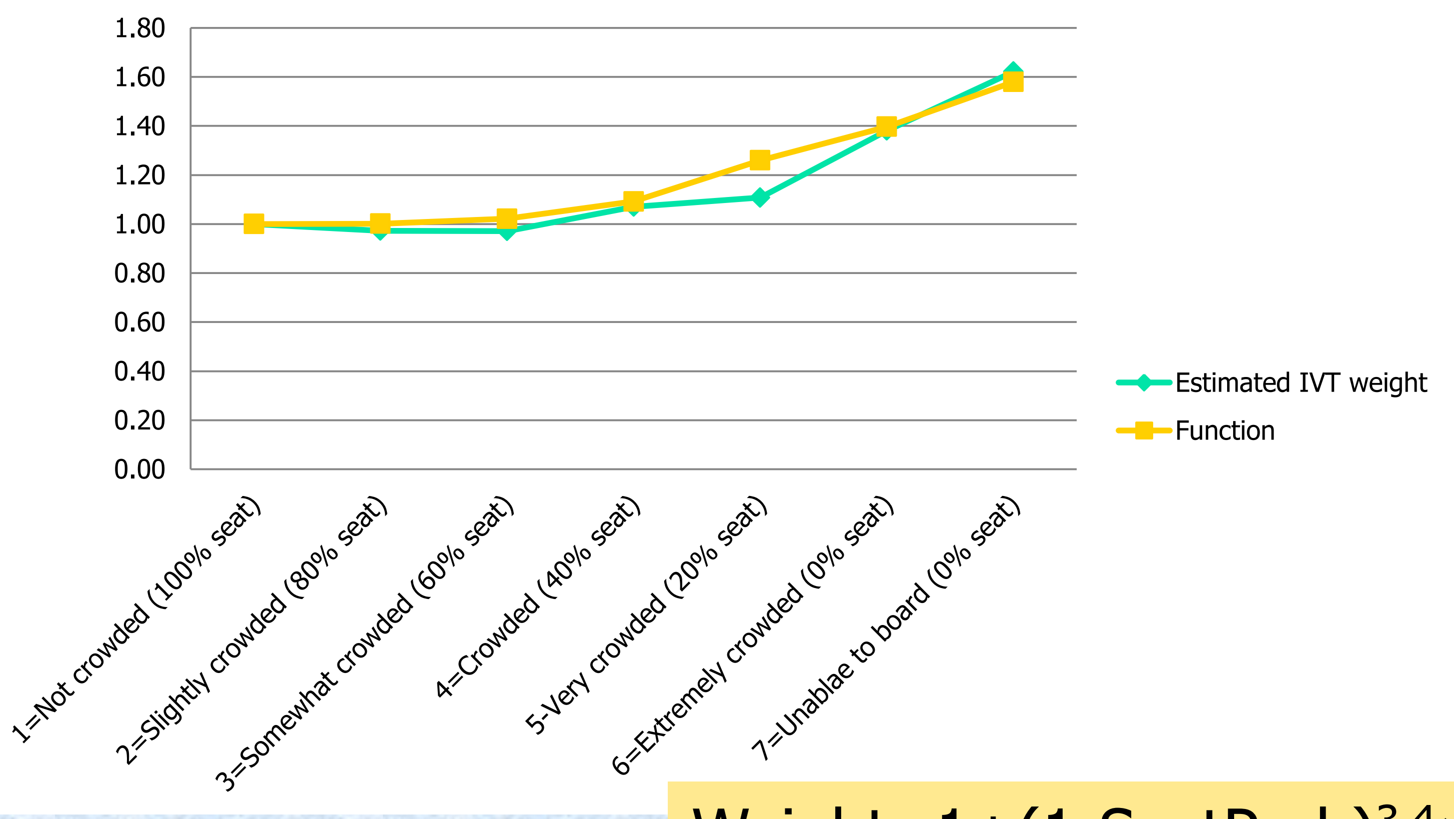
Crowding Effects Summary (LACMTA)

- Hypotheses confirmed:
  - Crowding perceived as extra IVT weight
  - Crowding is more onerous for commuters
  - Crowding more onerous for older riders
  - Crowding perceived differentially by mode
- Hypotheses not confirmed:
  - Crowding more onerous for high incomes
  - Crowding weight grows with trip length

Trip Length Effect

- It might look counter-intuitive that crowding IVT weight does not grow with trip length
- However, even if the weight is constant the resulted crowding penalty does grow with trip length:
  - IVT weight 1.5
  - 10 min in crowded vehicle equivalent to 5 extra min
  - 60 min in crowed vehicle equivalent to 30 extra min
  - Logit models are sensitive to differences, thus trip length would manifest itself in crowding-averse behavior

General Functional Form for Crowding IVT Weight



$$\text{Weight}=1+(1-\text{SeatProb})^{3.4}\times 1.58$$

Transit Reliability Measures

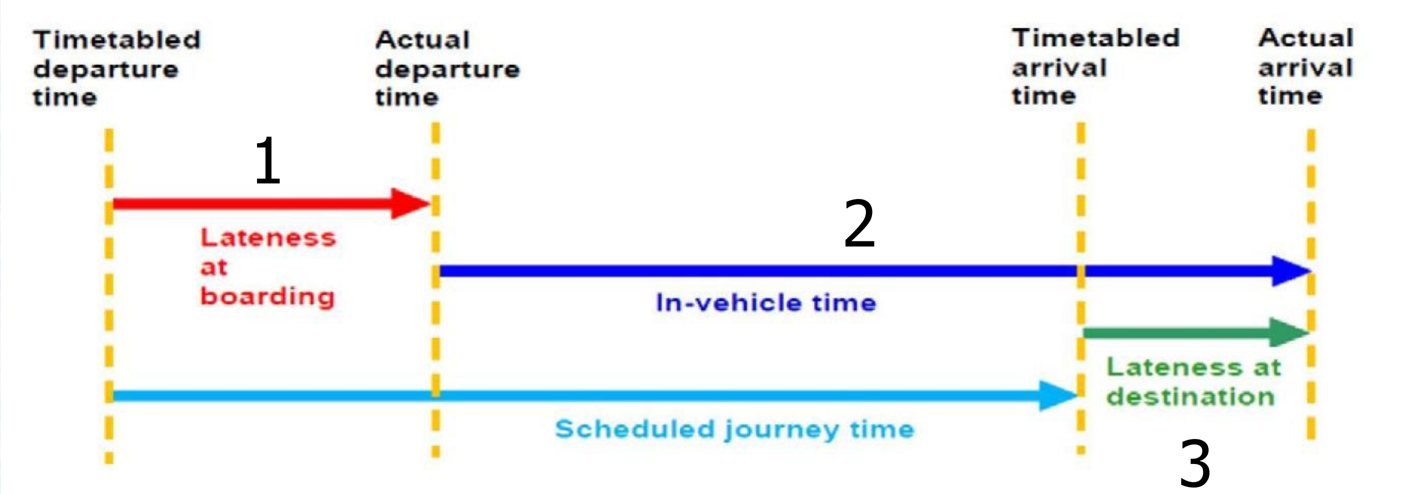


Fig. 3. The time components of a rail journey.

1. Schedule adherence at boarding stop (extra wait time)
2. Impact of congestion (extra IVT)
3. Combined lateness at destination versus planned arrival time (similar to auto)

Reliability Impact: Expected Delay (Linear Formulation)

- Calculated as Amount×Frequency
- Weight vs. non-crowded IVT is 1.76
- Confirms negative perception beyond just extension of IVT

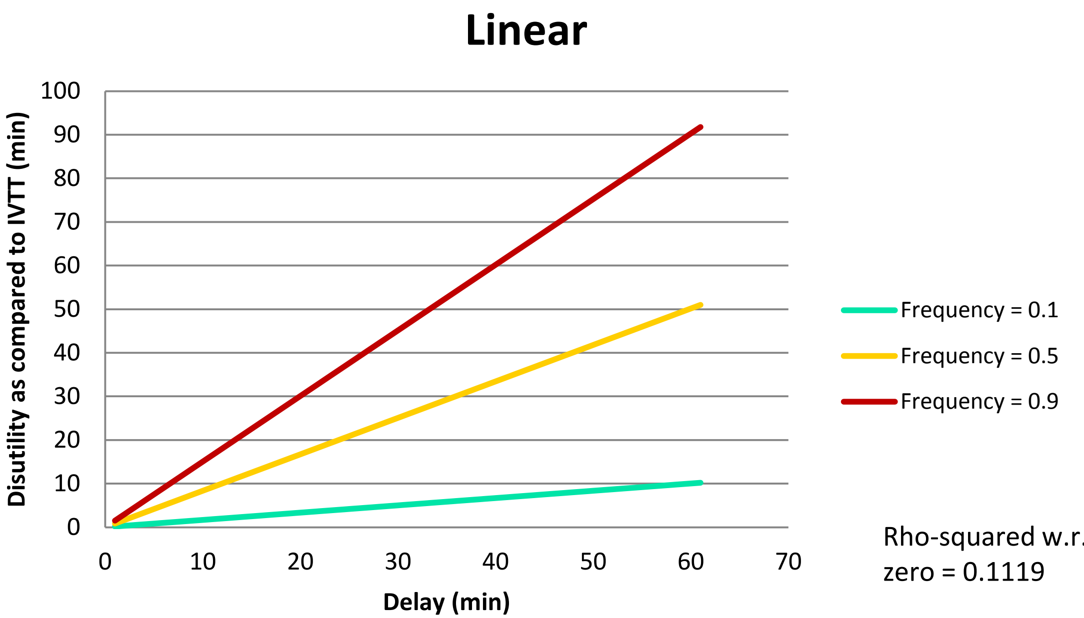
Best Statistical Form

$-0.142 \times Delay \times Freq$ (base linear)

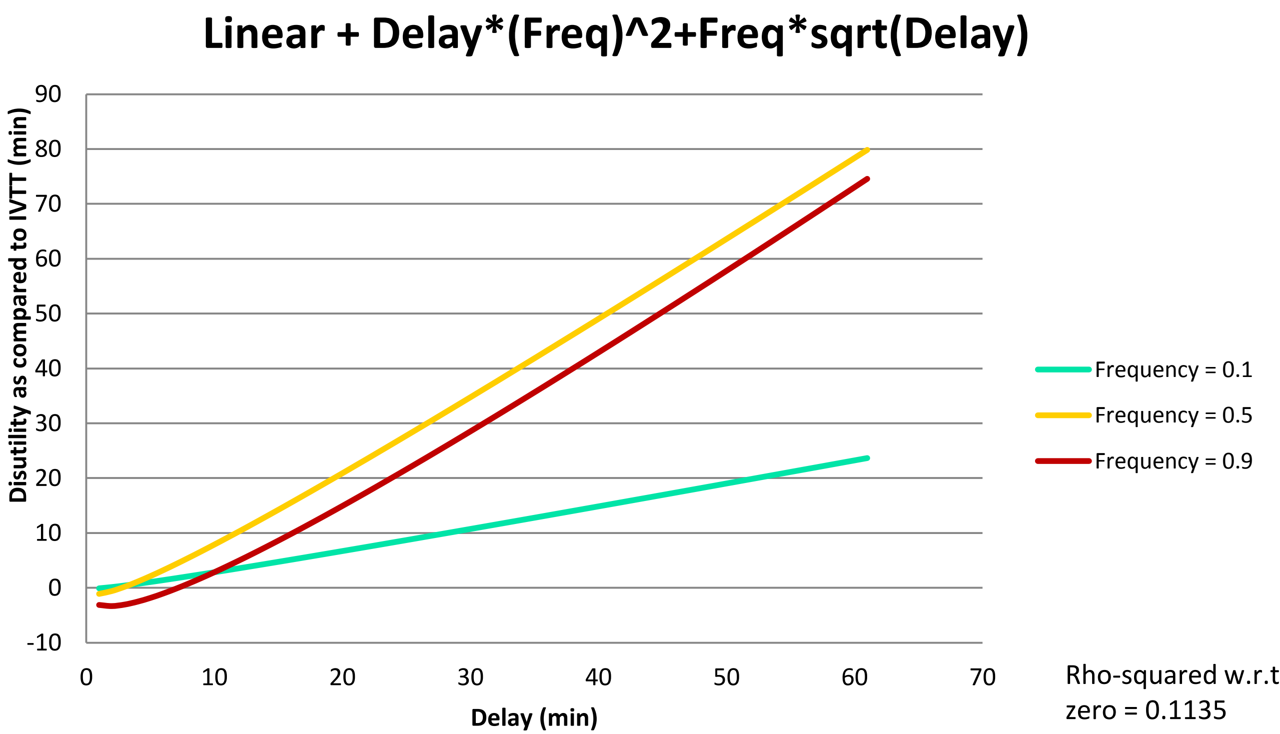
$+0.091 \times Delay \times Freq^2$ (freq convex)

$+0.161 \times Delay^{0.5} \times Freq$ (delay concave)

Amount of Delay Effect



Convexity, discarding very small delays



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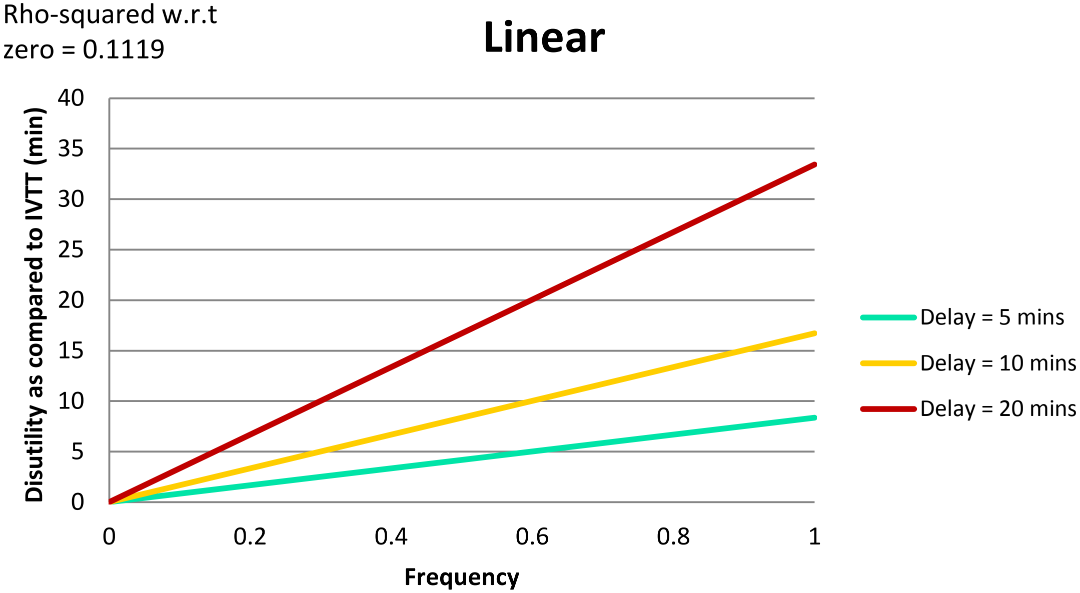
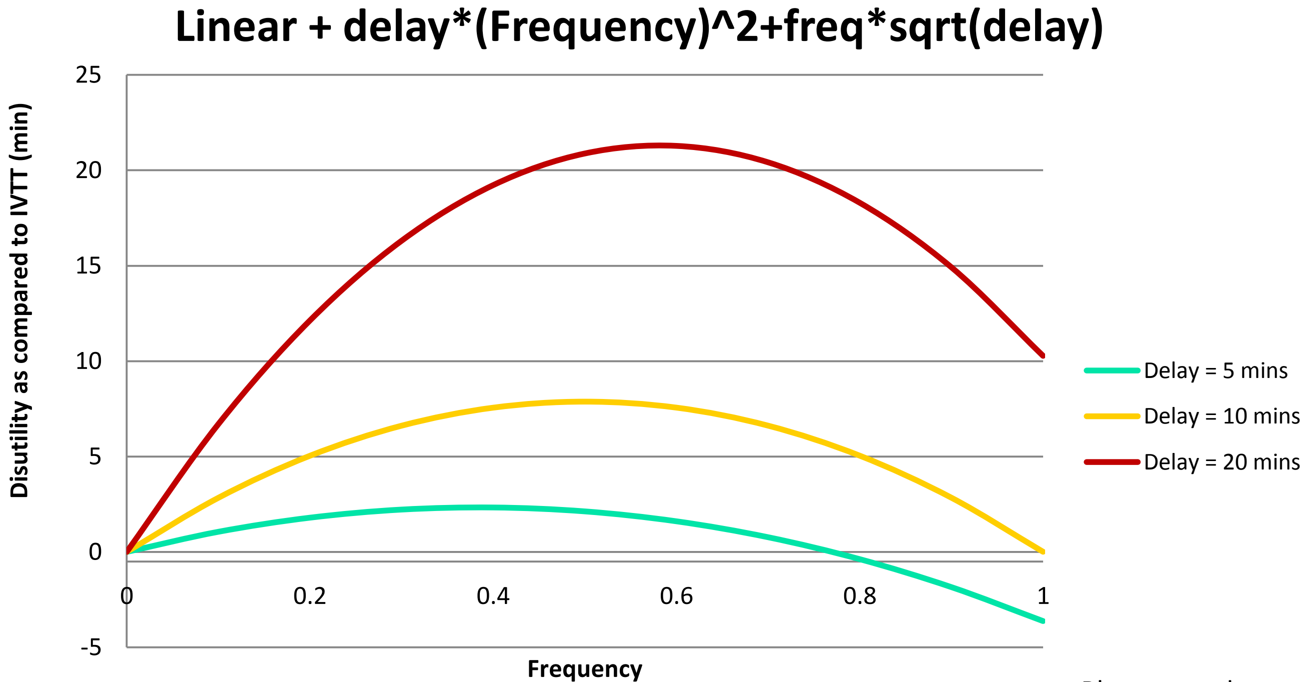
Frequency of Delay Effect

Rho-squared w.r.t zero = 0.1119



Concavity, adaptation

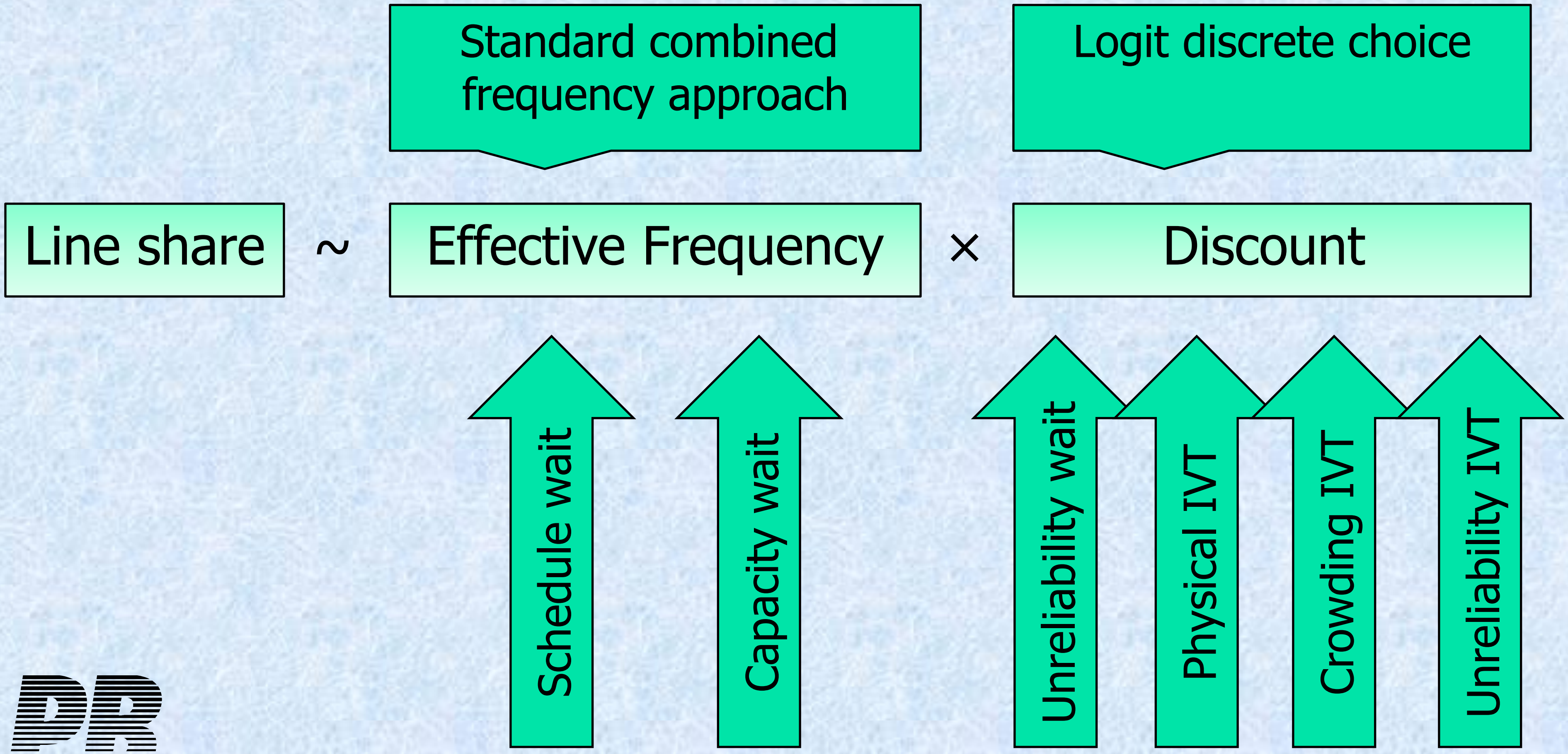


Rho-squared w.r.t zero = 0.1135

Predicting Unreliability in Network Simulation (Phase 2)

- Extra wait time as function of:
  - Transit mode separation
  - Scheduled frequency
  - Accumulated roadway saturation
  - Accumulated transit stop activity
  - Accumulated route length
  - Accumulated number of stops

Passenger Split between Attractive Lines



Extended Transit Assignment with EMME

Flow distribution between lines

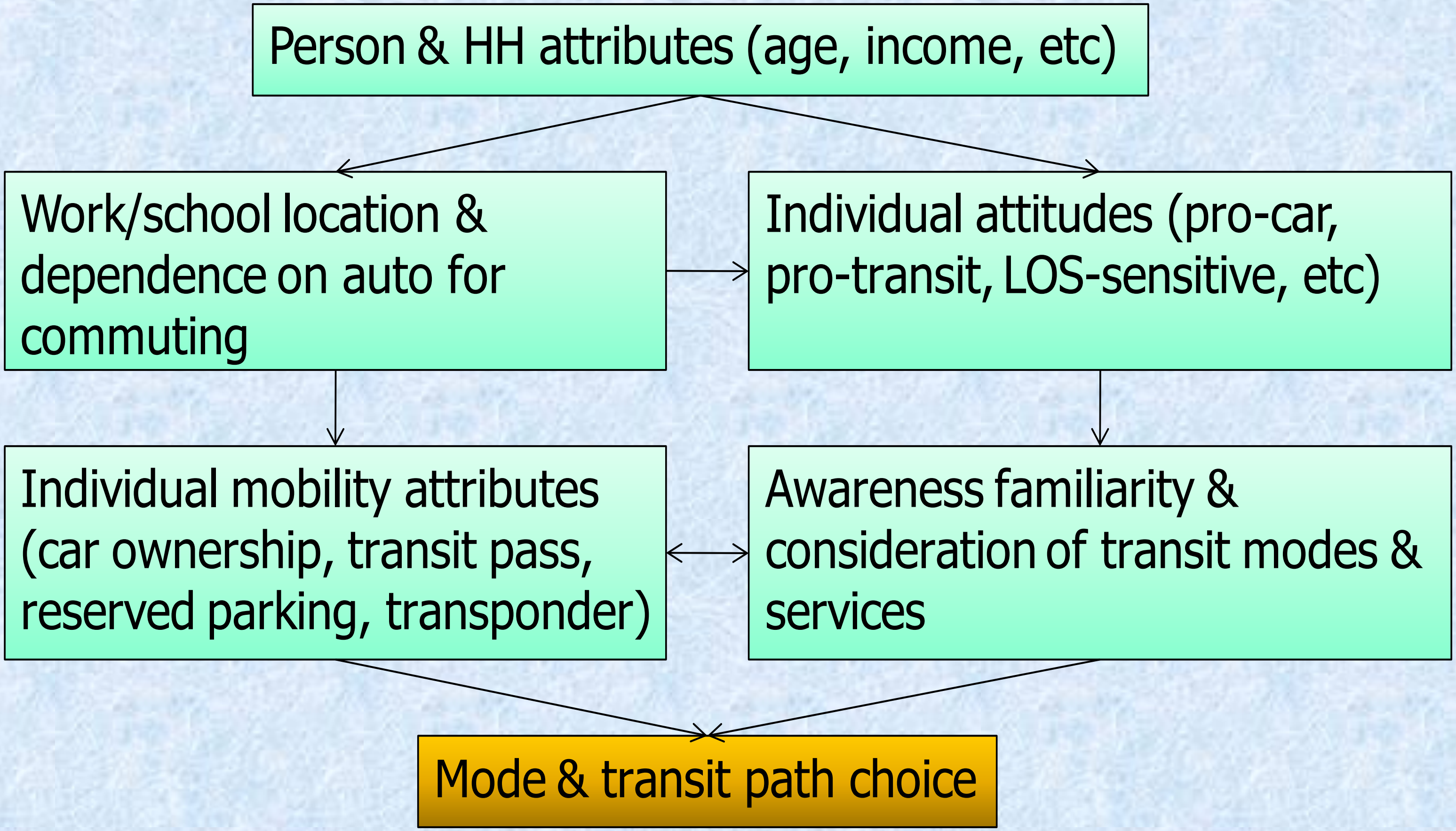
Standard transit assignment

- Optimal strategy: distribute flow in proportion to the frequency of the line, $p_l = f_l / f$
  - where f = sum of the frequency of the attractive lines

Extended transit assignment

- Optimal strategy, or
- Distribute flow in proportion to the frequency and travel time to destination, $p_l = p\_adjust_l * f_l / f$

Incorporation of Attitudes and Awareness in CT-RAMP (Phase 2)



Conclusions

- Microsimulation ABM is flexible platform to incorporate a wide range of transit characteristics
- Promising results for Phase 1
- Challenging program for Phase 2:
  - Finalize measurable transit service attributes
  - Estimate individual path choice preferences
  - Incorporate in operational ABM & transit network procedures