Calibration of an Intervening Opportunity Model for Palm Beach County

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Outline

- Mathematical Formulation
- Gravity Model Form
- Calibration Procedures
- Results
- Discussions and Recommendations

Mathematical Formulation

- For any zone *i*, rank all the zones based on the travel time T_{ij} such that $T_{ik} < T_{i,(k+1)}$
- The probability of selecting zone *j* as destination is the joint probability of not choosing zones before *j* and choosing zone *j*.

$$P\left(A_j\right) = \left[1 - P\left(V_{j-1}\right)\right] L A_j$$

where $P(A_j)$ = probability that zone *j* is chosen as destination

A_j = opportunities available in zone *j*

$V(A_{j-1})$ = opportunities available in zones *i* through *j-1*

L = the probability of any opportunity being chosen to satisfy the travel need

Mathematical Formulation (cont.)

- Trip interchange between zones *i* and *j* is

$$T_{ij} = P_i A_j L e^{-LV_{j-1}} = f_i P_i A_j L e^{-LV_{j-1}}$$

where P_j = production from zone *i*

A_j = attractions from zone *j*

f_i = a factor forcing all trips to be distributed

Applying constraint $\sum_j T_{ij} = P_i$

$$f_i = \frac{1}{\sum_k A_{ik} L e^{-LV_{k-1}}}$$

Mathematical Formulation (cont.)

Intervening opportunity model

$$T_{ij} = P_i \left(\frac{A_j e^{-LV_{j-1}}}{\sum_k A_{ik} e^{-LV_{k-1}}} \right)$$

Gravity model

$$F_{ij} = e^{-LV_{j-1}}$$

$$T_{ij} = P_i \left(\frac{A_j F_{ij}}{\sum_k A_{ik} F_{ij}} \right)$$

Calibration Procedure

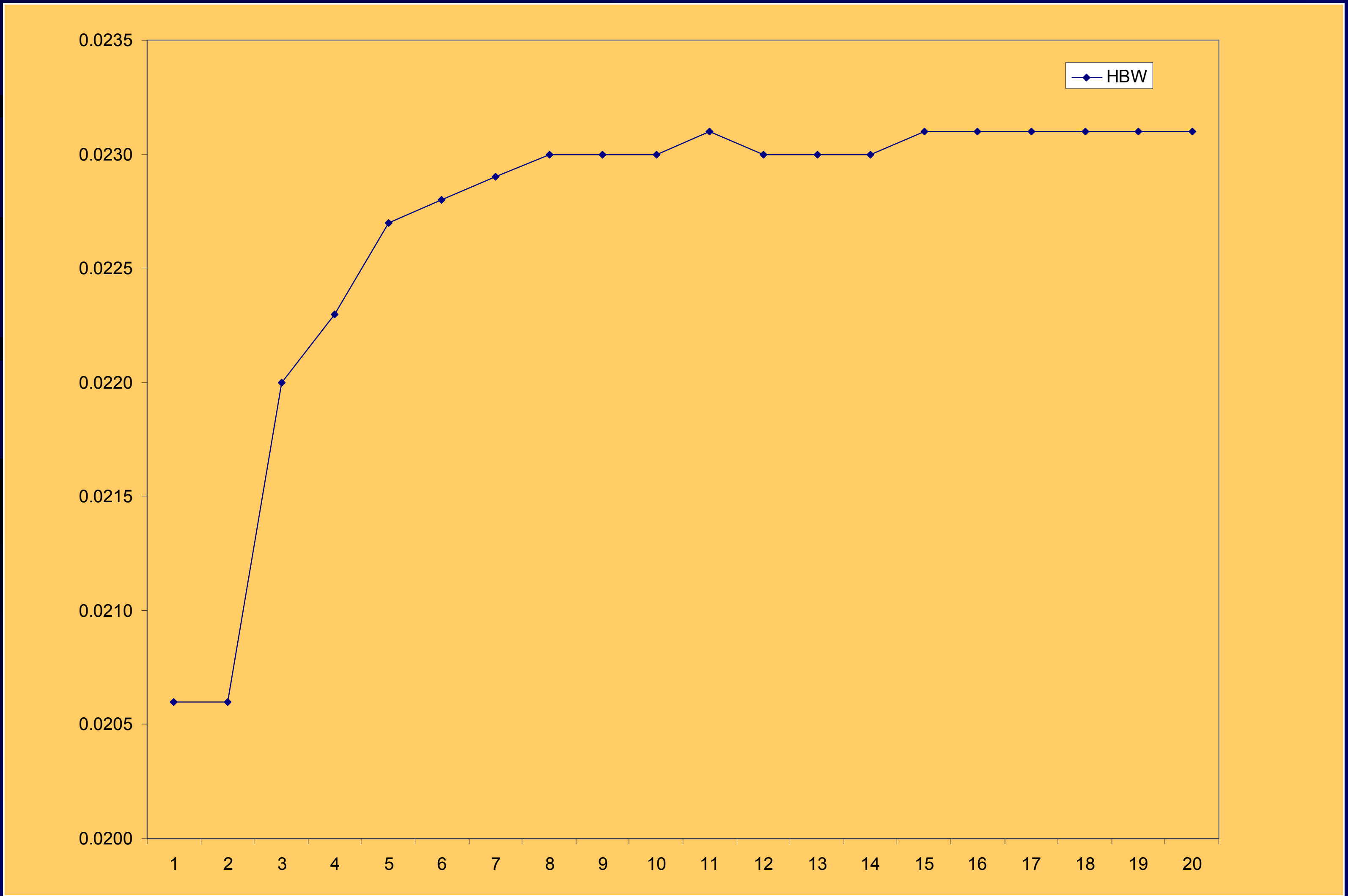
- Run FSUTMS to obtain
  - free-flow travel time impedance skim
  - productions and attractions for HBW, HBS, HBSR, HBO, NHBW, and NHBO purposes
- Construct the opportunity matrices (1172 x 1172) for different trip purposes

matrix cell (*i*, *j*) = cumulative attractions from all zones (ranked by travel impedance from zone *i*) *i* through *j* - *1*,

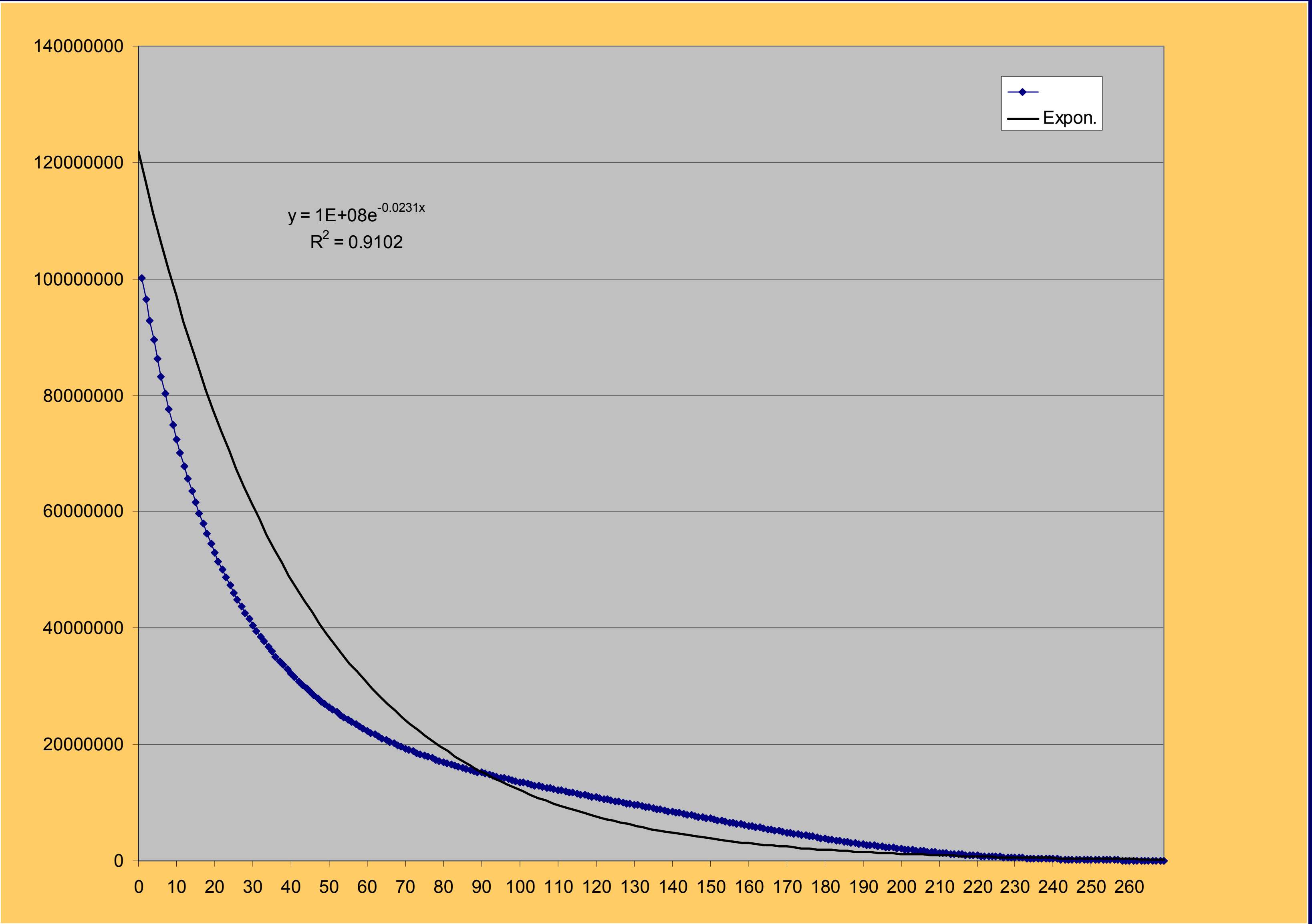
Calibration Procedure (cont.)

- Replace travel time impedance skim by the opportunity matrix for each trip purpose using UPDATE MATRIX command
- Calibrate IOM model and obtain OD matrix
  - replace GT with distribution of opportunities
  - set F FACTOR CLOSURE to 5%
  - set GF in the data specification to 1 for initialization
  - set maximum number of iterations to 20

Convergence of *L*



Friction Factors v.s. Impedance



Intervening Opportunity Model Performance

- Examination of internal trips
  - Average trip length
  - Coincidence factor
  - SRSME
  - Information gain
  - Trip interchanges between districts
  - Intrazonal trips

Average Trip Lengths for Different Trip Purposes

	Average Trip Length in Minutes		
	Surveyed Data	IOM	Gravity Model
HBW	16.71	16.87	16.02
HBS	11.43	13.13	11.29
HBSR	11.51	13.12	10.66
HBO	12.49	13.32	12.45
NHBW	13.08	13.53	11.13
NHBO	11.55	12.42	10.95

Comparison of Shape of Trip Length Distribution Curves

$$\textit{Conincidence} = \sum_{t=1}^{T} \min\left\{ \frac{f^m(t)}{F^m}, \frac{f^o(t)}{F^o} \right\}$$

$$\textit{Total} = \sum_{t=1}^{T} \max\left\{ \frac{f^m(t)}{F^m}, \frac{f^o(t)}{F^o} \right\}$$

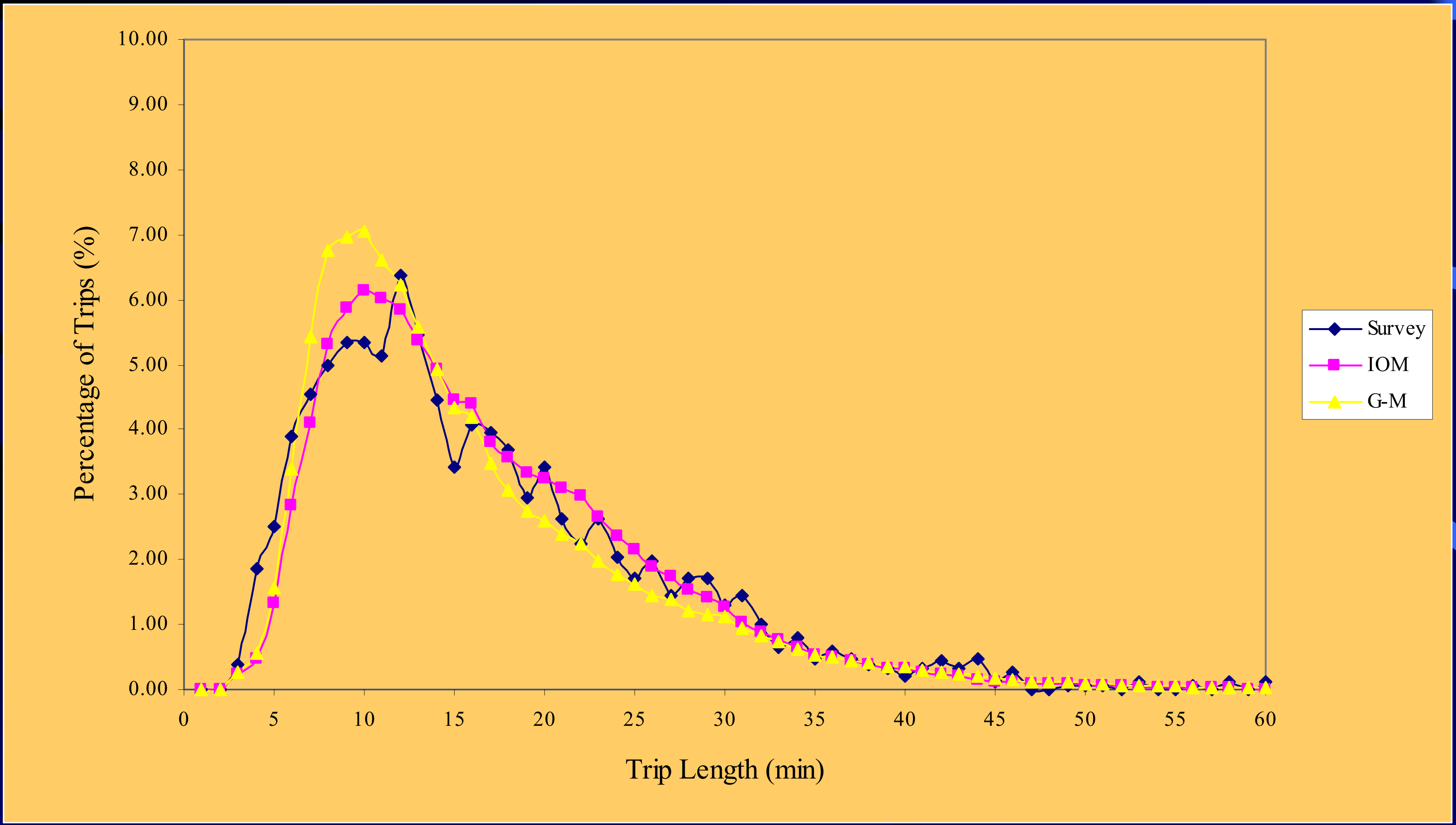
$$\textit{Coincidence ratio} = \frac{\textit{Coincidence}}{\textit{Total}}$$

$f^m(t)$ = frequency of trips at time t from model
$f^o(t)$ = frequency of trips at time t from survey data
$F^m(t)$ = total trips distributed from model
$F^o(t)$ = total trips from survey data

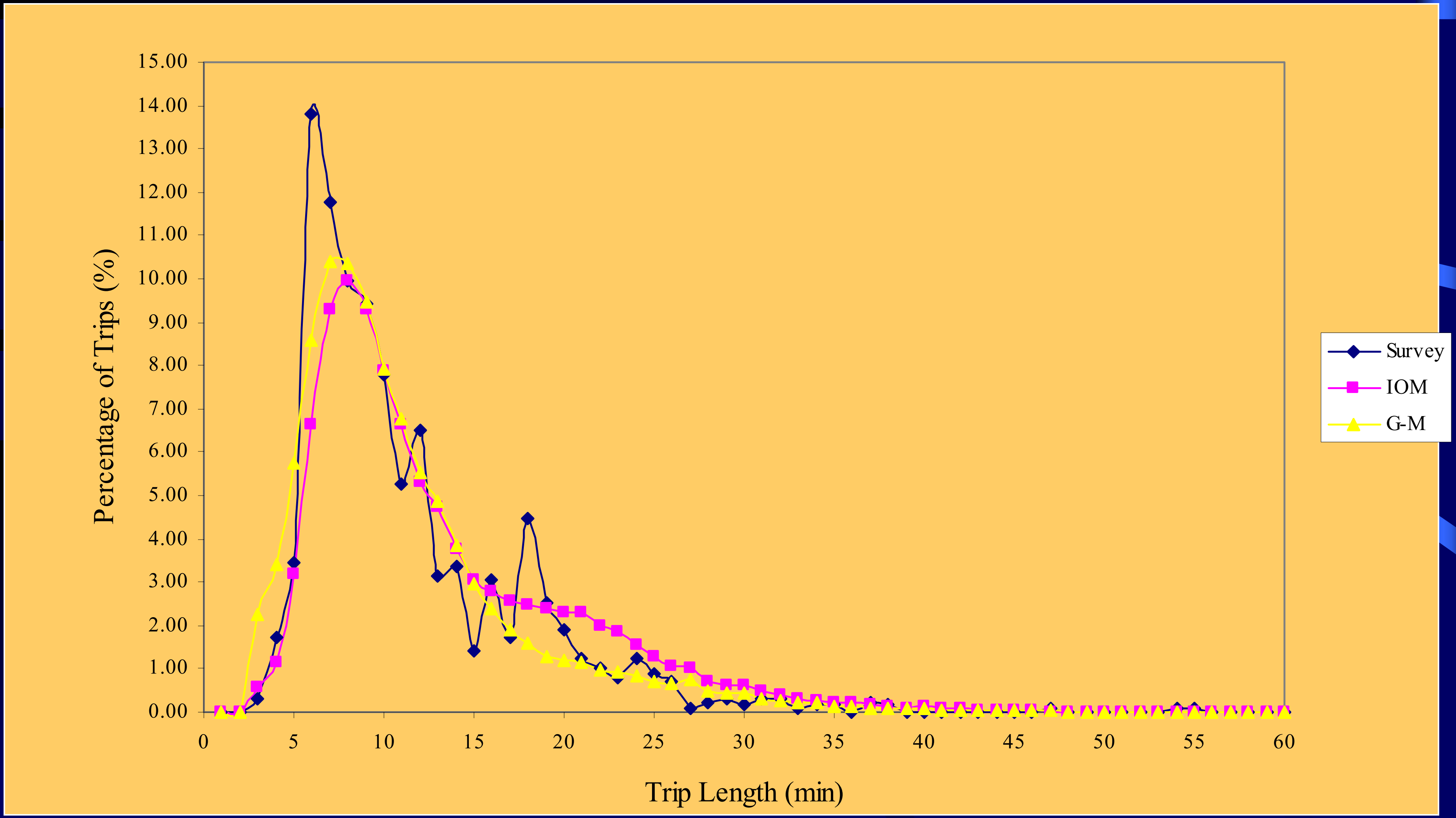
Comparison of Shape of Trip Length Distribution Curves

	Coincidence Ratio	
	IOM	Gravity Model
HBW	0.856	0.816
HBS	0.745	0.751
HBSR	0.682	0.744
HBO	0.832	0.797
NHBW	0.787	0.761
NHBO	0.783	0.780

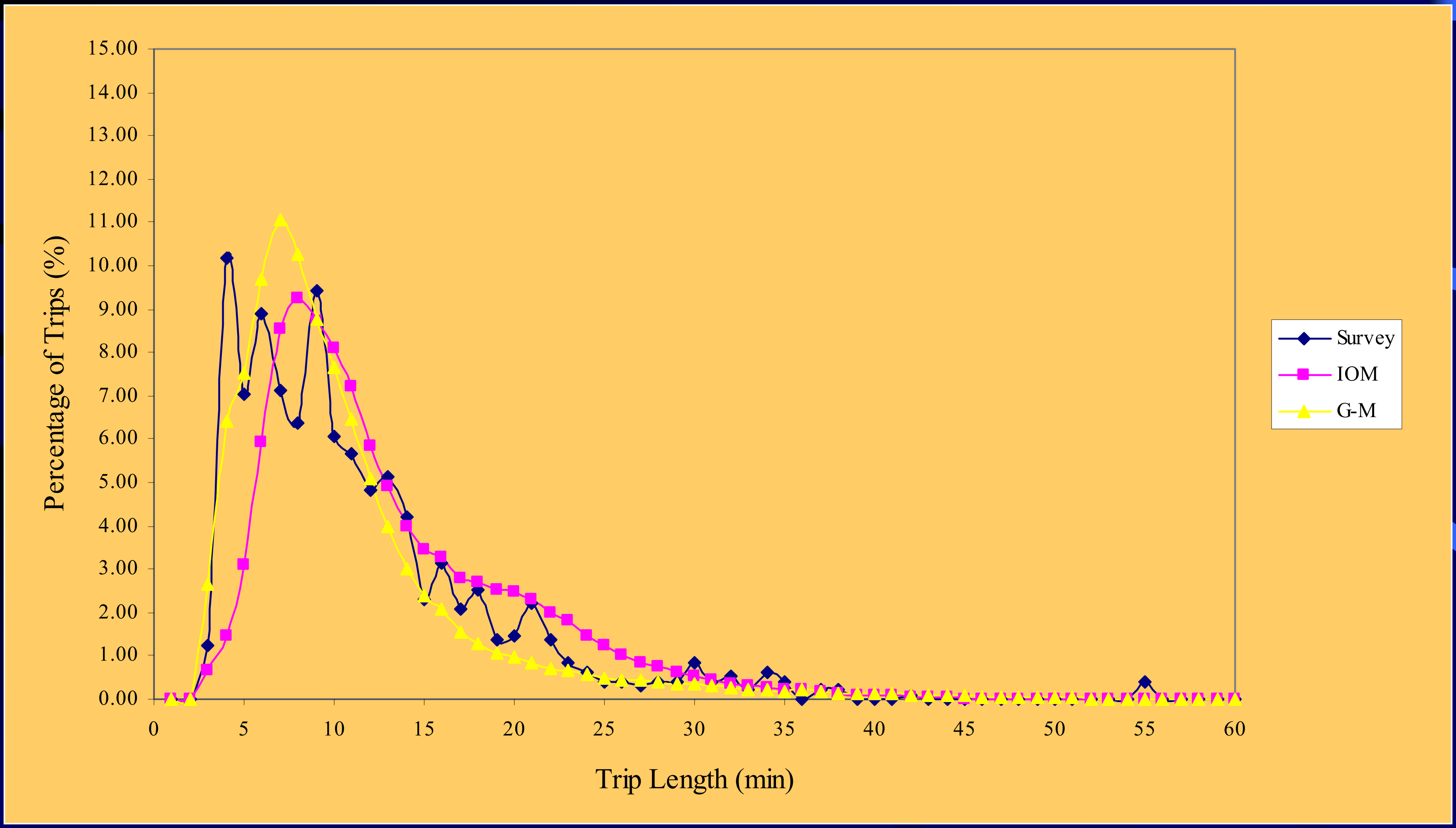
HBW Trip Distributions



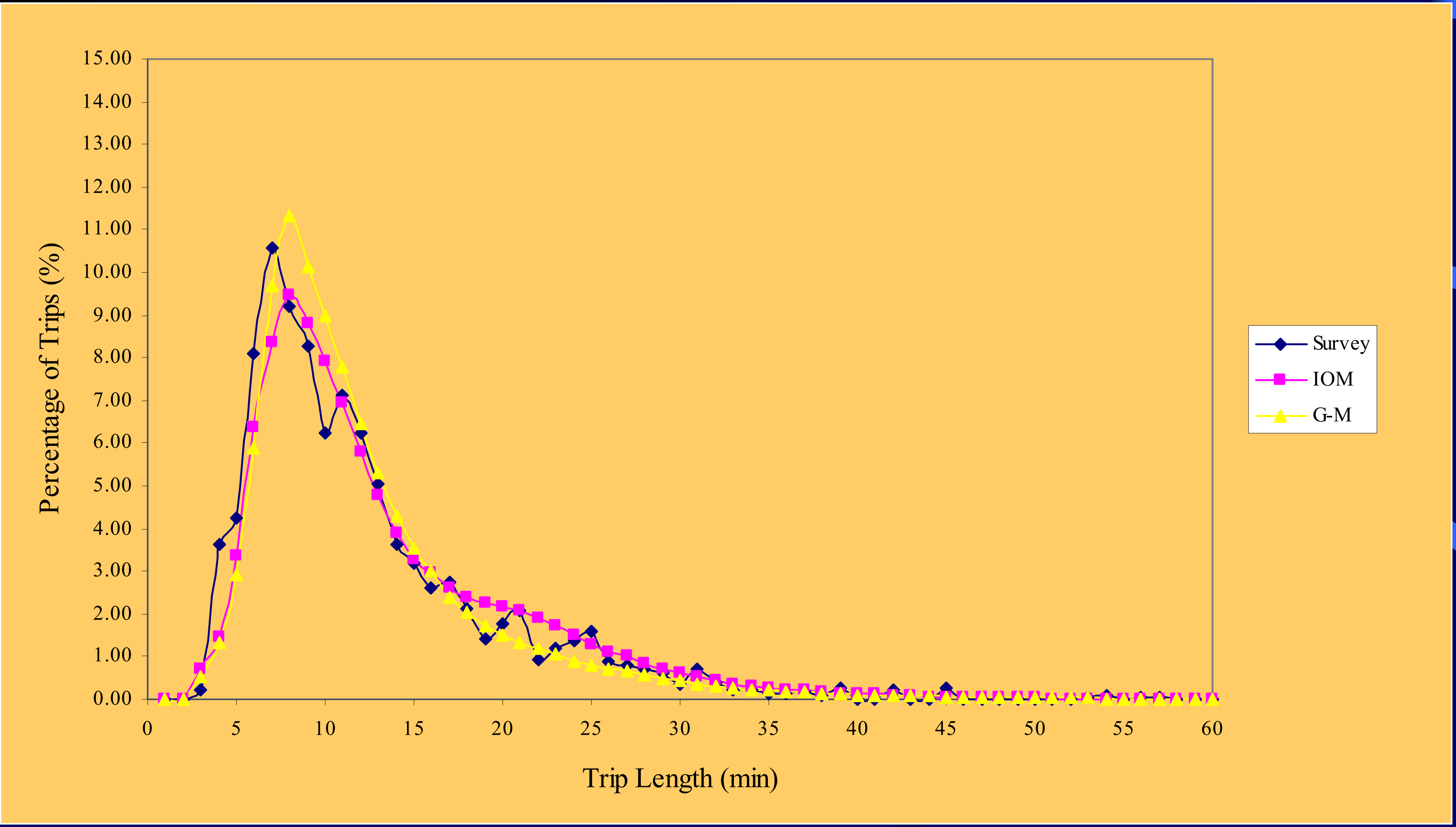
HBS Trip Distributions



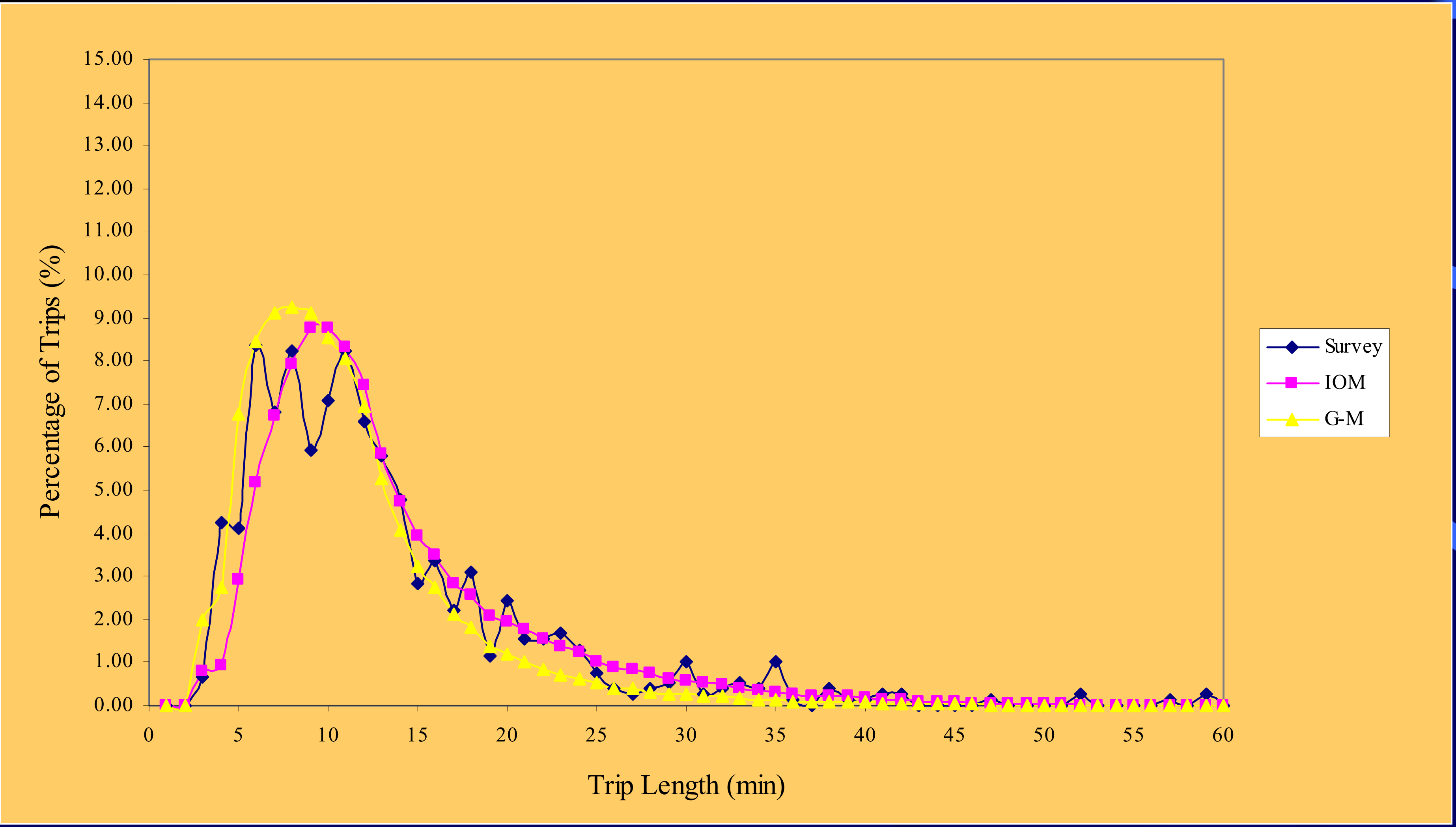
HBSR Trip Distributions



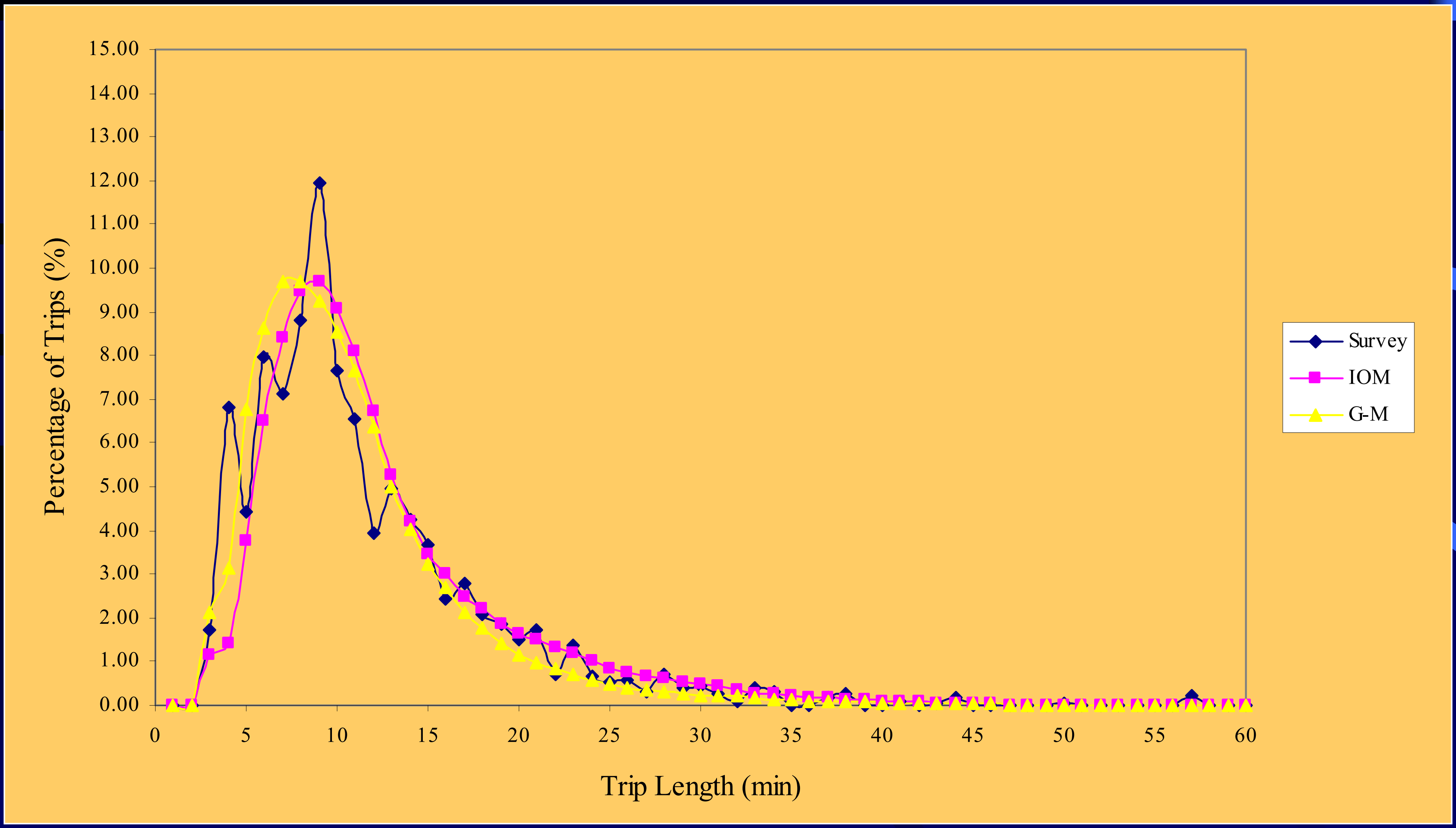
HBO Trip Distributions



NHBW Trip Distributions



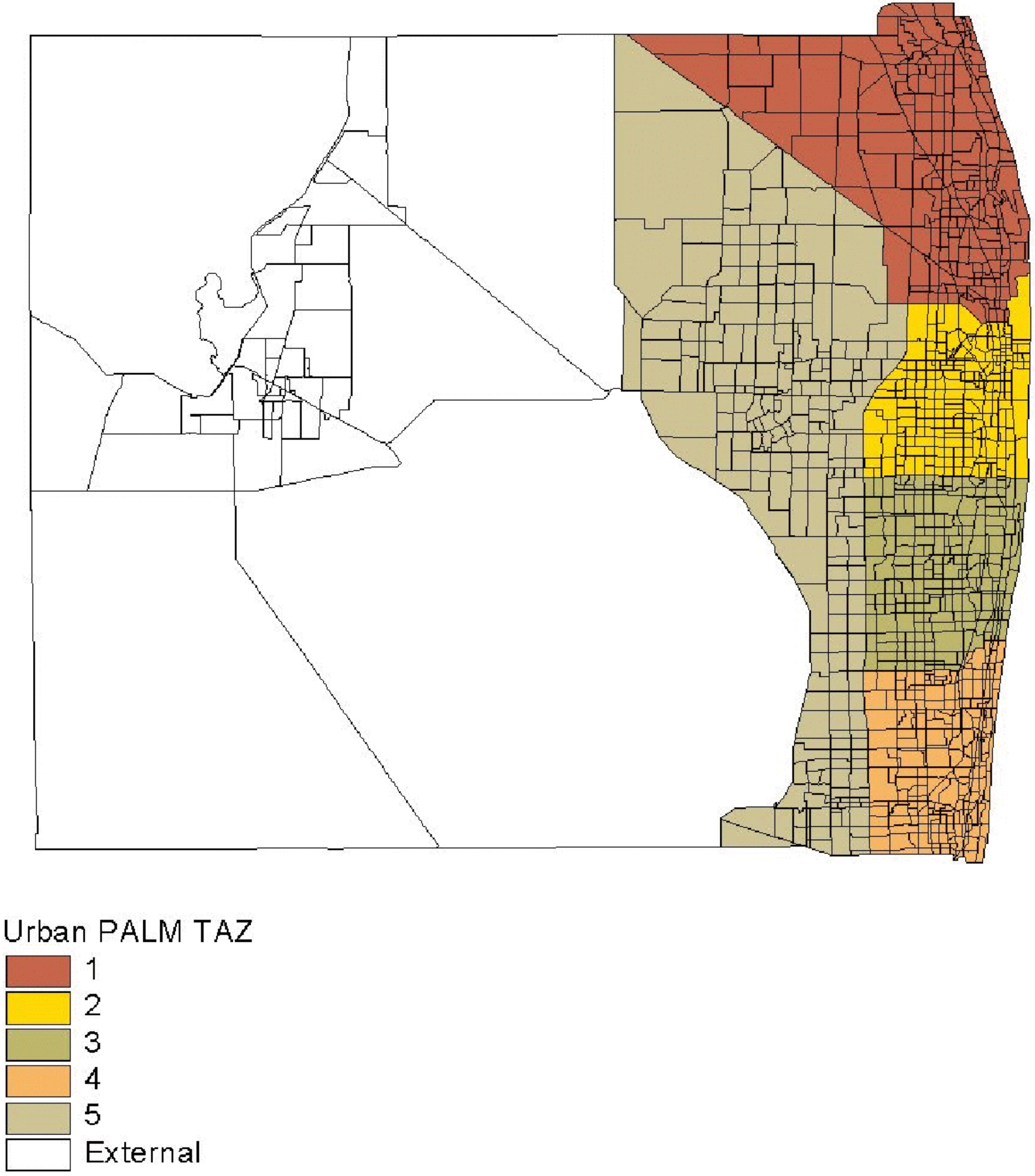
NHBO Trip Distributions



Comparison of Intrazonal Trips

	Surveyed Data			IOM			Gravity Model		
	I-I trips	Intrazonal trips	%	I-I trips	Intrazonal trips	%	I-I trips	Intrazonal trips	%
HBW	1,869	53	2.84	684,678	4,058	0.59	684,744	6,291	0.92
HBS	1,273	41	3.22	599,254	8,152	1.36	600,051	32,445	5.41
HBSR	955	169	17.70	429,206	8,957	2.09	429,482	41,466	9.65
HBO	2,394	159	6.64	841,554	159,45	1.89	842,403	20,381	2.42
NHBW	776	56	7.22	348,261	8,282	2.38	348,305	24,290	6.97
NHBO	1,844	221	11.98	682,165	18,736	2.75	682,199	44,701	6.55

Comparison of Interdistrict Trips



Interdistrict HBW Trips

District		1	2	3	4	5
1	SURV	15.67	5.58	0.48	0.70	0.91
	IOM	14.99	4.29	0.95	0.80	1.67
	GRAV	15.89	4.43	0.60	0.69	1.13
2	SURV	4.94	15.40	2.84	1.77	1.23
	IOM	4.45	11.97	3.09	1.95	1.46
	GRAV	3.76	12.91	2.99	1.71	1.24
3	SURV	2.15	3.27	6.71	6.44	0.64
	IOM	0.85	4.85	7.14	6.65	1.03
	GRAV	1.16	4.61	7.84	5.68	0.99
4	SURV	0.21	0.16	0.70	10.57	1.13
	IOM	0.12	0.69	1.20	11.79	1.02
	GRAV	0.19	0.46	1.19	12.53	0.92
5	SURV	3.27	4.94	1.29	3.65	5.36
	IOM	3.17	4.80	1.56	4.34	5.19
	GRAV	2.60	4.24	1.40	4.68	6.15

Interdistrict HBS Trips

District		1	2	3	4	5
1	SURV	17.05	2.44	0.24	0.16	0.31
	IOM	17.81	2.66	0.68	0.09	0.29
	GRAV	19.38	1.95	0.07	0.06	0.05
2	SURV	1.96	14.06	1.89	0.00	1.26
	IOM	2.66	14.72	2.99	0.96	0.72
	GRAV	1.78	16.90	2.33	0.50	0.43
3	SURV	0.08	1.89	14.38	4.16	0.55
	IOM	0.30	3.32	11.68	5.43	0.65
	GRAV	0.22	2.77	13.99	4.01	0.40
4	SURV	0.31	0.31	0.39	15.08	1.81
	IOM	0.00	0.19	0.87	14.52	0.80
	GRAV	0.01	0.03	0.59	15.45	0.58
5	SURV	0.94	2.99	0.86	2.91	13.98
	IOM	2.40	3.91	1.48	3.33	7.51
	GRAV	2.19	3.59	0.89	3.21	8.62

Interdistrict HBSR Trips

District		1	2	3	4	5
1	SURV	14.76	2.41	0.21	0.52	0.63
	IOM	18.21	3.54	0.89	0.07	0.51
	GRAV	20.21	2.41	0.31	0.21	0.16
2	SURV	1.47	12.25	2.09	0.00	0.73
	IOM	2.85	15.24	4.08	0.70	0.84
	GRAV	1.59	17.88	2.99	0.46	0.45
3	SURV	0.42	1.78	15.39	1.99	0.21
	IOM	0.24	3.51	11.42	4.76	0.58
	GRAV	0.24	2.91	14.01	2.91	0.32
4	SURV	0.00	0.73	1.26	19.58	1.57
	IOM	0.00	0.25	1.41	13.36	1.14
	GRAV	0.03	0.12	0.97	14.99	0.60
5	SURV	0.52	2.20	0.63	3.04	15.60
	IOM	1.46	3.65	1.37	2.54	7.37
	GRAV	1.01	2.93	0.92	2.22	9.16

Interdistrict HBO Trips

District		1	2	3	4	5
1	SURV	17.59	3.63	0.21	0.08	0.13
	IOM	17.55	3.11	0.68	0.30	0.36
	GRAV	18.46	3.00	0.19	0.19	0.13
2	SURV	2.84	11.74	1.92	0.38	0.84
	IOM	2.40	15.26	3.00	1.12	0.68
	GRAV	2.29	15.92	3.00	0.59	0.51
3	SURV	0.29	2.13	14.20	3.13	0.42
	IOM	0.32	3.60	11.12	5.43	0.60
	GRAV	0.30	3.77	11.83	4.72	0.43
4	SURV	0.08	0.84	1.21	16.54	1.59
	IOM	0.00	0.19	0.85	13.20	0.80
	GRAV	0.02	0.08	0.92	13.57	0.79
5	SURV	1.29	2.76	0.84	3.05	12.28
	IOM	2.14	4.31	1.38	3.17	8.43
	GRAV	1.76	3.92	1.12	3.38	9.09

Interdistrict NHBW Trips

District		1	2	3	4	5
1	SURV	17.78	5.67	0.26	0.26	1.03
	IOM	16.26	3.83	0.90	0.44	1.01
	GRAV	18.18	3.35	0.40	0.15	0.38
2	SURV	5.54	19.97	1.55	0.52	1.16
	IOM	3.79	16.55	3.51	0.91	1.68
	GRAV	2.70	18.83	3.26	0.43	1.21
3	SURV	0.52	2.32	8.63	2.45	0.64
	IOM	0.24	2.59	7.56	2.48	0.47
	GRAV	0.15	2.13	9.02	1.66	0.36
4	SURV	0.13	0.90	1.93	18.04	1.93
	IOM	0.24	0.99	2.85	21.27	2.49
	GRAV	0.09	0.34	2.40	23.20	1.79
5	SURV	1.03	1.29	0.52	1.42	4.51
	IOM	1.09	1.75	0.79	1.79	4.52
	GRAV	0.60	1.12	0.56	1.29	6.42

Interdistrict NHBO Trips

District		1	2	3	4	5
1	SURV	17.57	2.66	0.27	0.16	0.49
	IOM	17.46	3.04	0.63	0.24	0.80
	GRAV	18.53	2.94	0.29	0.12	0.35
2	SURV	3.09	15.51	2.71	0.49	1.63
	IOM	3.58	17.38	3.28	0.67	1.59
	GRAV	2.83	18.69	3.17	0.40	1.25
3	SURV	0.43	2.93	12.42	1.57	0.60
	IOM	0.26	3.22	9.82	2.82	0.57
	GRAV	0.26	2.94	10.62	2.22	0.51
4	SURV	0.22	0.65	1.74	18.71	2.01
	IOM	0.10	0.73	2.40	18.85	1.82
	GRAV	0.11	0.35	2.26	19.71	1.52
5	SURV	0.33	1.08	0.60	2.11	10.03
	IOM	0.67	1.78	0.73	1.66	5.88
	GRAV	0.38	1.24	0.55	1.54	7.19

Summary of Interdistrict Trips

	HBW	HBS	HBSR	HBO	NHBW	NHBO
IOM closer	10	9	9	9	11	8
GRAV closer	15	16	15	15	14	16
Tie	0	0	1	1	0	1

Good of Fitness Statistics - SRMSE

$$SRMSE = \frac{\sqrt{\sum_{i=1}^{5}\sum_{j=1}^{5}\frac{(p_{ij} - \hat{p}_{ij})^2}{5^2}}}{\sum_{i=1}^{5}\sum_{j=1}^{5}\frac{{p_{ij}}^2}{5^2}}$$

p_{ij} = estimated percentage of trips interchanging between districts i and j

$\hat{p}_{ij}$ = observed percentage of trips interchanging between districts i and j.

SRMSEs for Two Models

	SRMSE	
	IOM	Gravity Model
HBW	0.0094	0.0091
HBS	0.0158	0.0139
HBSR	0.0258	0.0230
HBO	0.0158	0.0146
NHBW	0.0124	0.0142
NHBO	0.0112	0.0101

Information Gain

$$I = \sum_{i=1}^{5} \sum_{j=1}^{5} p_{ij} \ln \frac{p_{ij}}{\hat{p}_{ij}}$$

	Information Gain	
	IOM	Gravity Model
HBW	51	39
HBS	104	81
HBSR	116	77
HBO	139	116
NHBW	26	38
NHBO	53	31

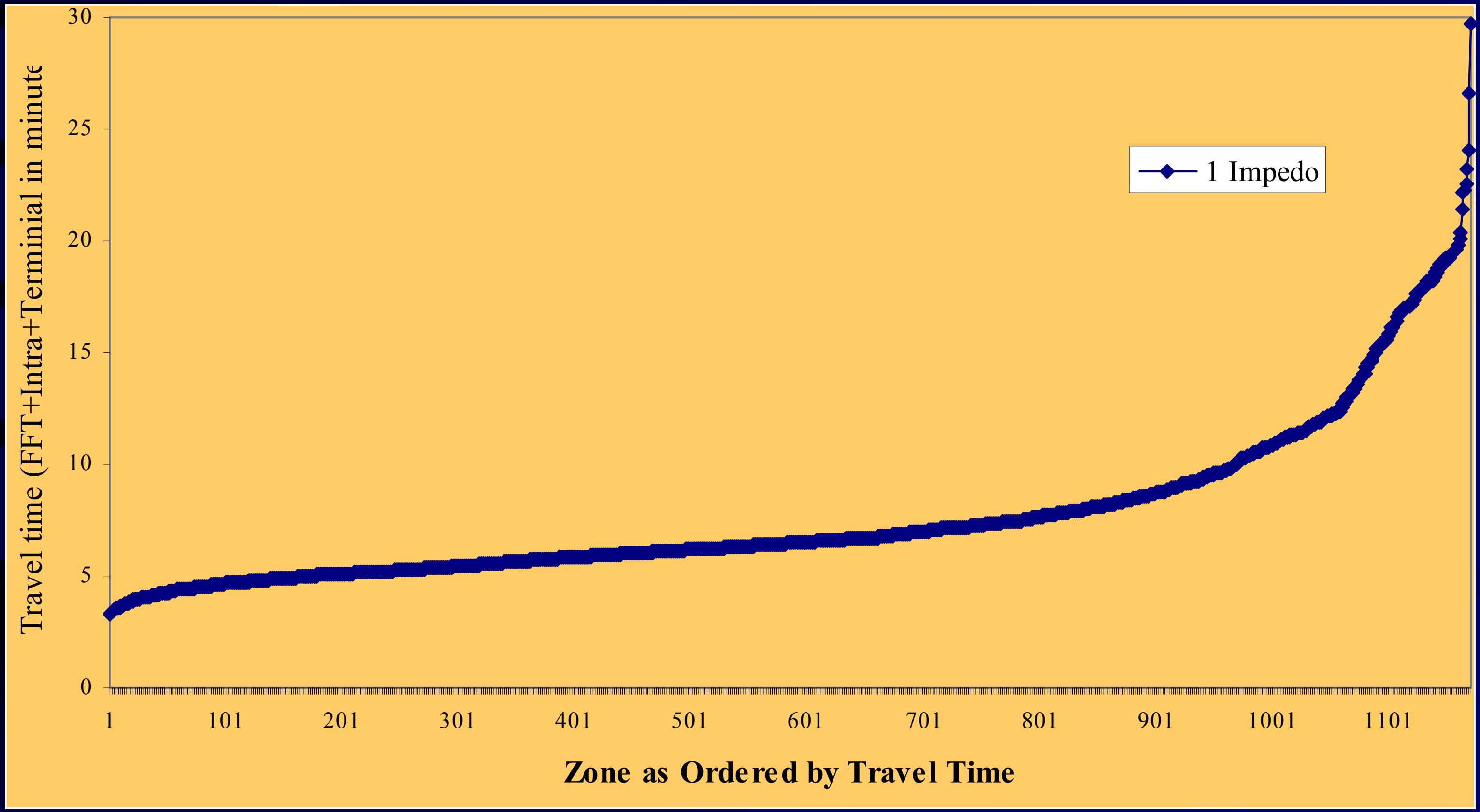
Discussions

- Limit on maximum impedance (327.67)
- Underestimation of Intrazonal trips
- Large cumulative attractions
- Wide range of trip length for any given amount of attraction
- Inaccuracy in calculation of opportunities
- Assumption of *L* being a constant

Limitation on Maximum Impedance

- TRANPLAN allows maximum impedance in summation file to be 327.67
- Maximum accumulative attractions for Palm Beach County reach over 800,000
- Dividing cumulative attractions by a factor of 3,000 results in too many trips grouped for impedance = 1 impedo
- Model insensitive to variations in opportunities within the group
- Model produced a smaller L thus longer trips

Range of Travel Times at 1 Impedo



Underestimation of Intrazonal Trips

- TRANPLAN does not handle zero impedance
- Attractions V_0 set to 1 resulting in grouping intrazonal trips with those from zones with impedance = 1 impedo
- Intrazonal trips calculated as

  $T_{ij}\ .\ P_i A_j L\, exp(-L)$
- Theoretical intrazonal trips should be

  $T_{ij} = P_i A_j L\, exp(-L * 0) = P_i A_j L$
- Intrazonal trips underestimated by at least *exp(-L)*
- *L* is also underestimated

Large Cumulative Attractions

- The gravity model calibration used maximum impedance of 80
- The opportunity model calibration used maximum opportunities of 200
- Various cut-off total attractions experimented
- Model not sensitive to different cut-off's

Wide Range of Trip Length

- For any given amount of attractions, there exists a wide range of trip lengths
- Raise the question if opportunities are a good measure for estimation of trip making

Inaccuracy in Opportunities

- More critical than in gravity model since they are used directly as control measures

Constant *L*

- Can we do better?
- CATS estimated different *L*s for
  - short trips
  - long residential trips, and
  - long nonresidential trips
- Separate trips (after trip purposes) further into short and long trips?

Recommendations

- Modify TRANPLAN
  - Allow specification on the model type: gravity or intervening opportunity models
  - Handle zero impedance cases
  - Relax maximum impedance limit
- Develop or adapt a specialized program for calibrating intervening opportunity models
- Consider separation of short and long trips during calibration
- More studies on attractions